Perugia, Italy July 2-13, 2007

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EARTH: OUR CHANGING PLANET

# IAHS

## INTERNATIONAL ASSOCIATION OF HYDROLOGICAL SCIENCES

## ASSOCIATION SYMPOSIA AND WORKSHOPS

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Compiled by Lucio Ubertini, Piergiorgio Manciola, Stefano Casadei, Salvatore Grimaldi

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EARTH: OUR CHANGING PLANET

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**Abbreviations**

| | |
|---|---|
| **IAG** | International Association of Geodesy |
| **IAGA** | International Association of Geomagnetism and Aeronomy |
| **IAHS** | International Association of Hydrological Sciences |
| **IAMAS** | International Association of Meteorology and Atmospheric Sciences |
| **IAPSO** | International Association for the Physical Sciences of the Oceans |
| **IASPEI** | International Association of Seismology and Physics of the Earth's Interior |
| **IAVCEI** | International Association of Volcanology and Chemistry of the Earth's Interior |
| **CliC** | Climate and Cryosphere |
| **Ev-K2-CNR** | Everest-K2 CNR Committee |
| **GEWEX** | Global Energy and Water Experiment |
| **HKH-FRIEND** | Hindu Kush-Himalayan Flow Regimes from International Experimental and Network Data |
| **IABO** | International Association for Biological Oceanography |
| **IACS** | International Association of Cryospheric Sciences |
| **ICACGP** | International Commission on Atmospheric Chemistry and Global Pollution |
| **ICASVR** | International Commission on Atmosphere-Soil-Vegetation Relations |
| **ICCE** | International Commission on Continental Erosion |
| **ICCL** | International Commission on Climate |
| **ICCLAS** | International Commission on the Coupled Land-Atmosphere System |
| **ICCP** | International Commission on Clouds and Precipitation |
| **ICDM** | International Commission on Dynamic Meteorology |
| **ICGW** | International Commission on Groundwater |
| **ICIMOD** | International Center for Integrated Mountain Development |
| **ICMA** | International Commission on the Middle Atmosphere |
| **ICRS** | International Celestial Reference System |
| **ICSIH** | International Commission on Snow and Ice Hydrology |
| **ICSW** | International Commission on Surface Water |
| **ICT** | International Commission on Trac |
| **ICWQ** | International Commission on Water Quality |
| **ICWRS** | International Commission on Water Resources Systems |
| **IGAC** | International Global Atmospheric Chemistry |
| **IGS** | International Glaciological Society |
| **ILP** | International Lithosphere Program |
| **INQUA** | International Union for Quaternary Research |
| **ION** | International Ocean Network |

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|---|---|
| **IRC** | International Radiation Commission |
| **PUB** | Prediction in Ungauged Basins |
| **SCAR** | Scientific Committee on Antartic Research |
| **SEDI** | Study of the Earth's Deep Interior |
| **SPARC** | Stratospheric Processes and their Role in Climate |
| **UCCS** | Union Commission for the Cryospheric Sciences |
| **UNESCO** | United Nation Educational, Scienti. c and Cultural Organization |
| **UNITAR** | United Nations Institute for Training and Research |
| **WMO** | World Meteorological Organization |

**Session code naming**

The first letter of the session codes indicates whether the session is a Union, a Joint Interassociation or a single Association sponsored event, the second letter indicates the type of event: Symposium (S) or Workshop (W). For Joint events, the second letter indicates the Lead Association (with the abbreviations listed below) and the third indicates whether a session is a Symposium (S) or a Workshop (W). In some cases (namely IAGA, IAHS) Association session codes have an extra codi. cation referring to a speci. c Theme or Division.

| | |
|---|---|
| **U** | UNION |
| **J** | JOINT |
| **G** | IAG |
| **A** | IAGA |
| **H** | IAHS |
| **M** | IAMAS |
| **P** | IAPSO |
| **S** | IASPEI |
| **V** | IAVCEI |

Some examples:

**US**002

is a **U**nion **S**ymposium; **JGW**001 is a **J**oint IA**G** **W**orkshop with IAG as the Lead Association;

**MS**003

is an Association (IA**M**AS) **S**ymposium. **AS III** 020 is an Association (IAG**A**) **S**ymposium sponsored by its **III** Division.

## HS1001 Symposium (3977 - 4014)

**Convener :** Dr. Ward Sanford
**Co-Convener :** Dr. Maurizio Polemio, Dr. Christian Langevin

A New Focus on Groundwater-Seawater Interactions (Sponsors ICGW and IAPSO)

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## HS1002 Symposium (4015 - 4101)

**Convener :** Dr. Corinna Abesser
**Co-Convener :** Prof. Gunnar Nuetzmann, Dr. Thorsten Wagener

A New Focus on Integrated Analysis of Groundwater/Surface-Water Systems: Process Understanding, Conceptualisation and Modelling. (Sponsors ICGW, ICSW and ICCLAS)

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## HS1003 Symposium (4102 - 4171)

**Convener :** Dr. Danny Marks

Hydrology in Mountain Regions: Observations, Processes and Dynamics (Sponsor ICSIH with co-sponsorship of UCCS, ICRS, ICSW, ICCLAS, ICGW, PUB)

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## HS2004 Symposium (4172 - 4249)

**Convener :** Mr. Eva Boegh
**Co-Convener :** Dr. Harald Kunstmann

Quantification and Reduction of Predictive Uncertainty for Sustainable Water Resources Management (Sponsors ICCLAS, IAHS/WMO Working Group on GEWEX , ICWRS, ICRS, IAMAS-ICCL and PUB)

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## HS2005 Symposium (4250 - 4311)

**Convener :** Prof. Bruce Webb

Water Quality and Sediment Behaviour of the Future: Predictions for the 21st Century (Sponsor ICWQ, ICCE, ICGW, PUB and ICT)

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## HS3006 Symposium (4312 - 4376)

**Convener :** Prof. Nick van de Giesen
**Co-Convener :** Prof. Yoshihiro Fukusima

Changes in Water Resources Systems - Methodologies to Maintain Water Security and Ensure Integrated Management (Sponsor ICWRS)

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## HS3007 **Symposium** **(4377 - 4403)**

**Convener :** Dr. Manfred Owe

Remote Sensing for Environmental Monitoring and Change Detection (Sponsor ICRS)

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## HW1001 **Workshop** **(4404 - 4446)**

**Convener :** Prof. John Gibson

Isotope Tracing of Water Balance, Hydrodynamics and Hydrological Processes (Sponsor ICT)

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## HW1002 **Workshop** **(4447 - 4491)**

**Convener :** Prof. Peter Troch

Patterns, thresholds and non-linearities: Towards a new theory of catchment hydrology (Sponsor PUB)

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## HW2003 **Workshop** **(4492 - 4578)**

**Convener :** Prof. Salvatore Grimaldi

Analysis of Variability in Hydrological Data Series

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## HW2004 **Workshop** **(4579 - 4661)**

**Convener :** Dr. Jim Freer, Dr. Erwin Zehe
**Co-Convener :** Dr. Thorsten Wagener

Towards Improved Evaluation of Hydrological Models: The Need to Understand and Characterize Uncertainties in the Modelling Process (Sponsor ICCLAS, PUB)

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## HW2005 Workshop (4662 - 4708)

**Convener :** Prof. Hubert Savenije

From Measurements and Calibration to Understanding and Predictions (Sponsor PUB with the support of ICWRS and ICGW)

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## HW2006 Workshop (4709 - 4755)

**Convener :** Dr. Joerg Dietrich
**Co-Convener :** Dr. Christos Makropoulos

New Avenues for Contemporary Water Resources Management (Sponsor ICWRS)

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## HW3007 Workshop (4756 - 4809)

**Convener :** Prof. Desmond Walling
**Co-Convener :** Mr. Jim Bogen

The Impact of Environmental Change on Sediment Sources and Sediment Delivery (Sponsor ICCE)

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## HW3008 Workshop (4810 - 4840)

**Convener :**
**Co-Convener :** Prof. Mikhail Bolgov, Dr. Hege Hisdal, Dr. Thomas Ternes, Dr. Peter Heininger, Prof. Siegfried Demuth, Dr. Alan Gustard

Changes to Hydrological Extremes and Water Quality (Sponsors ICWQ and ICSW)

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## HW3009 Workshop (4841 - 4847)

**Convener :** Dr. Arthur Askew

Loss of Knowledge (with support of WMO and UNITAR)

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## HW1011 Workshop (4848 - 4896)

**Convener :** Prof. David Holland, Dr. G Hilmar Gudmundsson
**Co-Convener :** Prof. Georg Kaser

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Cryosphere: Observations, processes, and future evolution (UCCS and IGS Workshop hosted by IAHS) (Merges JPSCCS004 and JPSCCS005)

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS1001** **3977 - 4014**

## Symposium
## A New Focus on Groundwater-Seawater Interactions (Sponsors ICGW and IAPSO)

**Convener :** Dr. Ward Sanford
**Co-Convener :** Dr. Maurizio Polemio, Dr. Christian Langevin

In the past, groundwater studies in coastal environments were driven by the need to protect freshwater resources from saltwater intrusion. Recently, a new research focus has evolved to better understand the fluid exchange across the sea floor. This new focus is motivated by the possibility that nutrients or other groundwater pollutants may be contributing substantial chemical inputs to coastal water bodies. The purpose of this symposium is to bring together scientists from the terrestrial and marine sides to establish a dialog and a common understanding of processes that occur at the subterranean boundary between freshwater and seawater. Examples of appropriate topics for this symposium include methods for measuring and modelling saltwater intrusion, submarine groundwater discharge and geochemical reactions within the transition zone.

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**HS1001** **Oral Presentation** **3977**

# Comprehensive evaluations of groundwater/seawater interface and submarine groundwater discharge

***Prof. Makoto Taniguchi***
*Research Division Research Institute for Humanity and Nature IAHS*

Submarine Groundwater Discharge (SGD) is increasingly recognized as an important pathway for water and dissolved material from the land to the ocean. SGD consists not only of terrestrial fresh water, but also of recirculated saline water of marine origin. The quality of SGD at locations along a shore-perpendicular transect depends on the location of the freshwater-saltwater interface. Saltwater-freshwater interfaces have been intensively studied in hydrological sciences for many years, chiefly because saltwater intrusion due to excessive groundwater pumping is a serious problem for water resources in coastal areas. SGD from aquifers on the land into the ocean and seawater intrusion from the ocean into aquifers on land are complementary processes, functioning in opposite direction of flow as a result of the hydraulic gradient across the coastal freshwater-saltwater interface being directed away from shore, or towards shore respectively. In this study, comprehensive study on groundwater/seawater interface and SGD have been made in Sicily (Italy), Perth (Australia), Ubatuba (Brazil), Bangkok (Thailand), Manila (Philippines), Kumamoto (Japan), and Osaka (Japan), by uses of automated seepage meters with conductivity sensors to evaluate SGD and fresh/saline components of SGD continuously, and resistivity measurements to evaluate salinity of the pore water under the seabed and relationship between temporal changes in the location of the saltwater-freshwater interface and SGD compositions. Our measurements show that the processes of SGD differ between the offshore and near shore environments. SGD and Submarine Fresh Groundwater Discharge (SFGD) rates were largest just landward of the saltwater-freshwater interface. SGD variations landward the saltwater-freshwater interface had negative correlations with tidal variations, because of the connections of terrestrial groundwater in the land and the ocean. SGD in the near shore can be explained mainly by connections of terrestrial groundwater, while offshore SGD rate is controlled mostly by oceanic process such as recirculated saline groundwater discharge.

***Keywords:*** sgd, fresh salt water interface, resistivity

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**HS1001** **Oral Presentation** **3978**

# Groundwater-seawater interactions in tsunami affected areas, solutions and applications

***Prof. Evgeny Kontar***
*Experimental Methods Lab P.P.Shirshov Institute of Oceanology IAPSO*

On December 26, 2004 the devastating tsunami waves cause terrible humanitarian disaster affecting thousands of kilometres of coastal belt of the Indian Ocean in SE Asia. Many coastal wetlands get affected by the large inflow of salt seawater and littoral sediment deposits during the tsunami, with longer-term effects including changes in their hydrogeology caused by changes to coastlines and damage to sea-defences. Many water quality and associated problems generated by tsunami and influencing coastal environments are related to past and on-going contamination of terrestrial groundwaters because those groundwaters are now seeping out along shorelines affected by tsunami. For example, chronic inputs of fertilizers and sewage on land over several decades has resulted in higher groundwater nitrogen which, because of slow yet persistent discharge along the coast, eventually results in coastal marine eutrophication. Such inputs contribute to the increased occurrences of coastal hypoxia, nuisance algal blooms, and associated ecosystem consequences, and significantly accelerated by tsunami as well as increasing of magnitude of saltwater intrusion. Tsunami has created an accelerating process of salt water intrusion and fresh water contaminations in affected regions that requires a drastic remediation measures. These measures have to be economically feasible, environmentally sound and socially acceptable. We basically estimated economic, environment and social impacts of tsunami and the feasibility of remediation measures to overcome the damage of the groundwater-seawater interaction systems in tsunami affected areas.

***Keywords:*** groundwater seawater systems, coastal zone processes, tsunami affected areas

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**HS1001** **Oral Presentation** **3979**

# Evaluation of the hydraulic gradient at an island for low-level nuclear waste disposal

***Dr. Prem Attanayake***
*Geotechnical Engineering Bechtel Corporation IAHS*

***Micheal Gene Sholley***

The physiography of small islands makes them candidates for the subsurface disposal of radioactive waste. Placement of waste deep below the offshore is a scenario under which repositories may be considered. One of the key hydrogeological factors influencing the suitability of such a repository is the hydraulic gradient across the island and beneath the offshore area. The hydraulic gradient affects the direction and velocity of ground-water flow, and hence the potential transport of radionuclides. In this study, the hydraulic gradient at a small island off the coast of China was evaluated for the performance assessment of a potential low-level nuclear waste repository. A preliminary assessment of the hydrogeology for the proposed offshore disposal chambers indicated that an unfavourable hydraulic gradient might occur under several scenarios. The following scenarios were analyzed in this evaluation: 1. The potential for a confined aquifer on mainland China to receive recharge at high elevations and for the aquifer to extend beneath the island (located 20 km offshore), resulting in mainland groundwater flow beneath the island; 2. The presence of a freshwater lens overlying saline ground water at the island, or extending from a nearby island; 3. A hypothetical water supply well on the island inducing flow of saline ground water towards the island; 4. A small hydraulic gradient in the saline ground water, toward the freshwater-saline water mixing zone. An evaluation of the potential scenarios indicates that: 1. Absence of a confined aquifer extending from the mainland under the island indicates that a regional hydraulic gradient from the continent through the disposal chambers is not an influencing factor; 2. Calculation of the freshwater lens extent, based on estimated recharge rate and hydraulic conductivity data, and comparison to water quality results, indicates that the freshwater lens would not extend to the offshore disposal chambers; 3. Long-term pumping from the freshwater lens would establish a new freshwater-saline water interface further from the offshore disposal chambers (i.e., closer to the island shoreline, and shallower), and may reduce any hydraulic gradient present at the offshore repository location; 4. A low or negligible hydraulic gradient in the saline water is expected at the proposed repository depth, which is beyond the mixing zone of freshwater and saline water.

***Keywords:*** offshore, groundwater, mixingzone

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**HS1001** **Oral Presentation** **3980**

# Influence of Groundwater Discharge through a Coastal Sandy Barrier in Southern Brazil on Sea Water Metal Chemistry

***Dr. Herb Windom***
*Oceanography Skidaway Institute IAHS*

***Herbert L. Windom, Willard S. Moore, L. Felipe H. Niencheski***

Sandy barriers developed during the Holocene transgressing sea are common features of many coastal regions throughout the world and often restrict the flow of continental runoff to the ocean. One such area is along the Southern coast of Brazil where an ca. 600 km barrier has created the Mirim-Patos Lagoon system, the largest in South America. Because of the limited surface connection of the lagoon system to the ocean, a substantial fraction of the regional freshwater runoff is transported through the permeable sands of the barrier within which freshwater and seawater mix. The resulting fluids which are discharged to the ocean differ significantly in metal concentrations from those of surface freshwater-sea water mixtures, primarily as a result of redox processes. Using radium isotope tracers, the volume of freshwater transport and sea water cycling through this system were estimated. As a result of this process, uranium, molybdenum, cadmium and copper are depleted in adjacent coastal waters whereas iron, manganese and cobalt are enriched.

***Keywords:*** metals, radium, lagoons

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**HS1001** **Oral Presentation** **3981**

# Modelisation de lintrusion marine dans l aquifere cotiere du gabes dans le Sud Tunisien

***Dr. Badiaa Chulli***
*Hydrogologie-Gophysique Centre de Recherches et Technologies des Eaux*

***Badiaa Chulli, Nessim Jebnoun***

Laquifre ctire du Gabs sud fait partir du systme aquifre multicouche de Jeffara Nord. Elle est forme par des sdiment alluvionnaire et dtritiques dage Quaternaire et par des dpt argilo-sabeuses dage Moi-Pliocne. Lvolution pizomtrique est conditionne par la recharge et les prcipitations. La simulation tridimensionnelle de linterface eau douce/eau sale a t labore montrant ainsi que les directions prfrentielles de lintrusion marine se localisent principalement le long de loued Matmata avec une extension latrale de 1100m. Les effets du dme de linterface, dus aux pompages actuels, sont ngligeables. Ce scnario de simulations montre aussi quil ny pas de dplacement significatif de linterface depuis les annes 80. Linterface a commence se deplacer et se stabilise en 1990 montrant que les pompages lamont nont pas une influence significative.

***Keywords:*** pizomtrique, tunisia

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**HS1001** **Oral Presentation** **3982**

# Seasonal Distribution and Flux of Radium Isotopes on the Southeastern U.S. Continental Shelf

***Dr. Willard Moore***
*Geological Sciences University of South Carolina IAHS*

Enrichments of radium isotopes in coastal waters have served as indicators of submarine groundwater discharge (SGD). Because coastal waters exchange with the open ocean on a time scale of weeks to months, seasonal patterns of radium isotope distributions may be used to indicate changes in SGD through the year. Here I report the seasonal distributions of four radium isotopes throughout the water column of the Southeastern U.S. continental shelf. The study area extended from Onslow Bay, NC, to Crescent Beach, FL, encompassing most of the South Atlantic Bight. Activities of the long-lived isotopes were highest off the coast of GA. In the summer these high activities extended throughout the study area; but during spring and winter, they decreased markedly off the coast of SC. The primary source of excess 226Ra and 228Ra (that is activities in excess of open ocean values) is SGD. Because the activities of these isotopes in SGD varies little with season, the lower excess activities off SC imply lower rates of SGD during the spring and winter. The excess inventories and fluxes of 226Ra and 228Ra provide an estimate of the residence time of water on the shelf. These residence times range from 30-60 days with a mean of about 40 days.

***Keywords:*** sgd, radium, atlantic ocean

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**HS1001** **Oral Presentation** **3983**

# Investigations of the brackish karst springs on Croatian Adriatic sea coast

***Prof. Ognjen Bonacci***
*Hydrology Hydrology IAHS*

***Ivana***

Croatian Adriatic coast is karstic area what makes its coastal aquifers open to the sea intrusion deep into the coast. There are many coastal karst springs. Most of them are brackish. Number of these springs become brackish in period of decreased summer discharge, when demand of water is highest due to tourist season. Until now Croatia doesnt face serious problems of the water quality and quantity. But, further increasing development of these areas, resulting with higher water demand and water consumption, threaten to cause shortage of fresh water. Furthermore, it can be expected that irrigation systems, insignificantly developed until now, will cause increase of exploitation of coastal aquifers and moving of contact zone of fresh and sea water further into the coast and toward the surface resulting with brackish water. Consequently, there is increased need for researching water reserves of coastal aquifers and mechanism of their salinisation. Past researches of these springs and results of applied measures contributed to a better understanding of the problem of saline intrusion and can be used as valuable experience upon planning and taking further measures. Paper gives overview of most important coastal karst springs of Croatian Adriatic coast. It presents results of past exploitations of the springs, discovered knowledge about their functioning, taken measures for their desalinization as well as evaluation of these measures. Given overview is carried out for the reason of necessity to evaluate existing and potential coastal water resources regarding their possible exploitation in new increased exploitation conditions. Improved management based on more complex knowledge about fluctuation dynamics of fresh and salt water in vulnerable parts of these aquifers can provide significant increase of drinking water quantities. Finally, guidelines for further investigations and measures are given.

***Keywords:*** karst, brackish, croatia

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**HS1001** **Oral Presentation** **3984**

# Multi-Channel resistivity investigations of the fresh water / salt water interface: a new tool to study an old problem

***Dr. Peter Swarzenski***
*HS1001 HS1001 Sponsors ICGW and IAPSO IAHS*

***Sarah Kruse, Jason Greenwood, Chris Reich***

It has been well established that fresh or brackish ground water can exist far from shore in many coastal and marine environments. For example, almost 30 years ago off north-east Florida, USA, fresh ground water, pressurized by extensive confining units, was observed more than 100km offshore. The often permeable nature of marine sediments and the underlying bedrock provides abundant pathways for submarine ground water discharge. While submarine ground water discharge as a coastal hydrogeologic phenomenon has been widely recognized, only recent advances in both geochemical tracers and geophysical tools have enabled a realistic, systematic quantification of the rates and impact of this coastal ground water discharge. Here we present multichannel electrical resistivity results using both a time-series, stationary cable that has 56 electrodes spaced 2-m apart, as well as a 120m streaming resistivity cable that has 2 current-producing electrodes and 8 potential electrodes spaced 10m apart. As the cable position remains fixed in stationary mode, we can examine in high resolution tidal forcing on the fresh water / salt water interface. Using a boat to conduct streaming resistivity surveys, relatively large datasets can be rapidly acquired in shallow (>1m) waters. We will compare results of the seabed resistivity from various coastal sites using these two approaches and will discuss data processing, reproducibility, precision, and overall effectiveness as a new tool to examine the dynamic nature of the fresh water / salt water interface.

***Keywords:*** electrical resistivity, coastal groundwater discharge, coastal hydrogeology

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**HS1001** **Oral Presentation** **3985**

# Geoelectric and geochemical studies for hydrological characterization of Sagar Island, South 24 Parganas, West Bengal, India

***Dr. Debabrata Das***
*Dept. of Geological Sciences,Jadavpur University, Jadavpur University,INDIA IAHS*

***Debabrata Das***

Integrated geoelectric and geochemical investigation are carried out in the Sagar Island region to assess the prevailing groundwater condition and chemical quality of groundwater. Geologically, the area is constituted of alluvial and marine sediments of quaternary age, which is underlain by the vast thickness of tertiary sediments. It is bordered in the north, west and east by Hooghly , Gabtala and Muriganga river respectively. In the south, lies the Bay of Bengal. Sagar Island with an area of 235 sq.km has a flat topography and no significant variation in elevation from mean sea level (~3m). Landform assemblages like tidal flats, runnels, longshore bars, marshy land, sand dunes and criss-crossing tidal creeks are supportive of estuarine process under which they have been formed. Vertical electrical soundings (VES) in the area of investigation show mostly five layers consisting of topsoil, saline water, brackish water, clay layer and fresh water bearing zones. The VES findings show potential freshwater bearing zone of appreciable thickness at depths from 175.0 m to 220.0 m under confined condition.The surface true resistivity contour map shows the intrusion of saline water in the southern part of Sagar Island at shallower depth level The results of VES studies significantly correspond with the borehole data and a litho-resistivity relationship is established for this area. Chemically the fresh groundwater is Na-HCO3 type with TDS ranging from 465 mg/l to 645 mg/l. Chemically the water is safe for drinking and domestic purposes but unsuitable for irrigation purposes (SAR values range from 4.0 to 13.2) and Na content is significantly higher than what is typically found in groundwater. The seawater contamination (SWC) values for these water samples are significantly low. However one sample , nearest to the sea, is found to exceed marginally (SWC= 0.72) the non-contaminated other water samples (SWC 0.5). The Concentration of arsenic, iron, lead and mercury in the samples are below the recommended limit for drinking water of World Health Organization (WHO).

***Keywords:*** sagarisland, geoelectric, geochemical

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**HS1001** **Oral Presentation** **3986**

# In situ underwater gamma-ray spectrometry as a tool for submarine groundwater discharge studies

***Dr. Pavel Povinec***
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A new technology for in situ investigations of submarine groundwater discharge (SGD) in coastal regions has been recently developed. The technology is based on the utilization of in situ underwater gamma-ray spectrometers for analysis of radon daughter products in water (e.g. 214Bi in the case of 222Rn). In the framework of the joint IAEA-UNESCO project on SGD investigations in coastal zones, the in situ underwater gamma-ray spectrometry of radon daughter products was carried out during the expeditions to Donnalucata (Sicily) and Ubatuba (Brazil). Continuous monitoring of 222Rn in the beach spring at Donnalucata has shown variable 222Rn concentrations in groundwater from 12 kBq m-3 to 19 kBq m-3, depending on the water level during the tide. Significant spatial variations of submarine groundwater discharge were observed in the boat basin in Donnalucata. The average 222Rn concentration in seawater varied from ~0.1 kBq m-3 to 3.7 kBq m-3, showing an anticorrelation dependence on salinity of seawater. The continuous monitoring carried out at the site closest to the coast has revealed a strong anticorrelation dependence of 222Rn concentration on the tide and salinity. The 222Rn concentrations in seawater varied from 2.3 kBq m-3 during high tides to 5 kBq m-3 during low tides. Spatial variations in 222Rn activity concentrations (between 50 and 200 Bq m-3) were observed in Flamengo and Picinguaba bays (Brazilian coast), which were anticorrelated with salinity. The results obtained during the 5 days of continuous monitoring in Flamengo Bay confirmed an anticorrelation between the 222Rn activity concentration in seawater (which varied between 1 and 5kBq m-3) and tide. The observed variations in 222Rn concentrations may be caused by sea level changes, as tide effects induce variations of hydraulic gradient, which increase 222Rn concentrations during decreasing sea level, and opposite, during high tides the 222Rn concentrations are decreasing. Large changes in 222Rn activity concentrations of seawater observed in relatively small areas, which are associated with SGD, document why the isotopic characterisation of coastal waters is important for estimation of groundwater fluxes to the sea.

***Keywords:*** seawater, groundwater, interactions

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**HS1001** **Oral Presentation** **3987**

# Basin wide groundwater flow system study in volcanic low permeability bedrock aquifer including coastal submarine groundwater discharge

***Prof. Jun Shimada***
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***Daisuke Inoue, Sou Satoh, Naohiko Takamoto, Tomoya Sueda***

Quaternary pyroclastic flow deposits are widely distributed in Japan, but their groundwater flow system has not been well understood. Relatively steep morphologic surface with humid temperate hydrological condition of Japan should create active groundwater flow including coastal groundwater discharge. 4.5 km2 mountainous pyroclastic catchments have been selected in Uto peninsula, Kumamoto, Japan for this purpose to reveal the regional groundwater flow system. The major methods are: 1. Precise hydrometric study in the head water catchments relating rainfall-runoff and groundwater recharge process 2. Stable and radioactive isotope hydrological study with the help of groundwater potential measurement using deep observation boreholes of different depths and the Self Potential survey in the study catchments. 3. Self potential survey, resistivity survey, seepage meter measurement, groundwater potential measurement in the observation boreholes has been conducted on and off-shore area during the tidal fluctuation period. 4. Three dimensional groundwater flow simulation and regional water budget study in the study catchments using the observed river water discharge and evapotranspiration rate at different elevations. The major hydrological observation system including 8 river and spring discharge gauging points and 9 different depths boreholes in the study catchments has installed to monitor the hydrolgeologic characteristics of the catchments for 4 years. By the observation and analytic results, it was clarified that topographically driven groundwater flow systems with different flow dynamics and residence times are existing in the study catchments. This hydrologically circulating groundwater flow systems are characterized by the following three types. 1. Local flow system has isotopic seasonal fluctuation, the lowest dissolved ion content with relatively recent precipitation component confirmed by tritium and CFCs content. It exists mostly as the perched groundwater system in the headwater catchments area which is independent from the regional main groundwater body. 2. Regional deep flow system have less seasonal fluctuation of stable isotopes, the highest dissolved ion content with few hundreds year old 14C age. It is relatively less active groundwater flow in the study basin. Coastal SGD is mostly related to this system in these catchments. 3. Intermediate flow system has the medium residence time between the former two systems and flow out as a natural springs in the mid basin area. While the stagnant fresh groundwater system existing under the present sea bed is completely different from those 3 type hydrological circulating groundwater flow systems and is thought to is a kind of residual paleo groundwater recharged during the previous regression era. This has no direct relation to the present SGD in the area.

***Keywords:*** groundwater flow system, coastal submarine groundwater, quaternary pyroclastic flow de

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# Existence of stagnant fresh groundwater in sub-sea formation and diffusion-limited chloride migration at Yatsushiro bay, Japan

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The mechanism of solute transport has become important to better understand the water and mass movement at the coastal area. In this study, we have attempted to evaluate long-term behavior of saline groundwater by analyzing chloride concentration, chlorine isotopic ratio, carbon-14 ages of both groundwater and sediments, and by applying diffusion-sedimentation model at Yatsushiro Bay, southwestern part of Japan. At the studied location, tuff breccia of later Pliocene to early Pleistocene is distributed from 3.8 meters below sea floor (mbsf) to the bottom of the borehole (50 m). Marine clay deposited after the last glacial maximum covers the tuff breccia. Pore waters were extracted from core samples by squeezing method. Chloride concentrations and stable chlorine isotopic ratios were measured on 12 pore water samples. Groundwater with chloride concentrations higher than 16,400 mg/l was found at depths shallower than 1.5 mbsf. Chloride concentration decreases downwards gradually, and it becomes lower than 250 mg/l below 7.7 mbsf,. The stable chlorine isotopic ratio showed minimum value of -1.27 per mil at 5.5mbsf, and those from other depths showed minor fluctuation, from -0.45 per mil to 0.11 per mil. From these results, diffusion is considered to be the dominant process for the transport of chloride. The diffusion-sedimentation model describes both the changes of chloride concentration and chlorine isotopic ratios well. We also measured the apparent groundwater age by carbon 14 method. Obtained apparent groundwater age below intertidal zone is about 100 years while that below sea bottom is about 2000 years. It suggests that groundwater situated below the intertidal zone constitutes a part of present-day groundwater flow system while that below sea bottom is stagnant fresh groundwater. The deposition of marine clay at the location started about 2900 years ago based on the corrected carbon 14 age of organic materials obtained from clay formations. Coincidence between the groundwater age and the age of the start of deposition suggests that the studied area had been a part of freshwater groundwater flow system before the deposition of marine clay, and because of the deposition of low-permeability clay formation, the discharge zone of the fresh groundwater flow system migrated toward the coast and groundwater below clay formation became stagnant fresh groundwater.

***Keywords:*** diffusion limited migration, stable chlorine isotope, groundwater

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# Utilizing a Variable-Density Numerical Model with Flow Dependence on Temperature and Salinity to Guide the Collection of Submarine Groundwater Discharge Data

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Submarine groundwater discharge (SGD) in coastal areas is a topic of increasing concern to marine scientists and managers, primarily because freshwater input can carry nutrients and other contaminants that impact coastal ecosystems. SGD is difficult to computationally quantify, however, because of spatially and temporally varying hydrologic boundary conditions, such as salinity and temperature. Measurement of SGD has been enhanced over the last 10 years as a result of advances in aerial survey techniques that utilize electromagnetic (EM) resistivity and thermal imagery. The question arises as to the best way to optimize collection timing and frequency of EM and thermal imagery data to estimate SGD into the coastal areas. Variable-density groundwater flow models are often used to understand the complex nature of coastal groundwater systems. In this study, a variable-density, transient, cross-sectional model was developed to compute the concentration, temperature, and age of SGD in a situation with a transient simulated saltwater interface. The model contains 1-hour stress periods and simulates an entire year based on inputs from field data collected in southern Florida, including transient recharge, temperature, tidal stage, and salinity. The SEAWAT code simulates variable-density flow driven by changes in salinity. Recently, the code was altered to simulate density-dependent flow caused by changes in temperature and viscosity. This revised code was applied to the cross-sectional model in the current study. Model results indicate that the concentration of fresh groundwater discharging into coastal areas remains relatively constant throughout the year. The temperature of the fresh groundwater and the temperature of the ocean fluctuates seasonally; however, the model results indicate that during the winter, warmer fresh groundwater is discharged into the colder saline ocean. The opposite occurs during the summer, when cooler fresh groundwater is discharged into the warmer saline coastal waters. The simulations also reveal that temperature differences between SGD and the Atlantic Ocean are minimal during the spring and fall. Although EM probably can be used most of the year to estimate SGD, the results indicate that thermal imagery is likely a viable (and possibly preferable) technique for measuring SGD in southern Florida during the summer or winter. This study shows that advances in variable-density numerical modeling can help enhance and guide SGD data collection efforts, and that newly developed features in SEAWAT are applicable to coastal systems for estimating SGD temperature and concentrations.

***Keywords:*** seawat, thermalimagery, electromagneticresistivity

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# Remaining uncertainties in the use of RN-222 as a quantitative tracer of submarine groundwater discharge

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Research performed in many areas over the past decade has shown that radon is an effective tracer of submarine groundwater discharge (SGD) into the coastal zone. The approach works because both fresh and saline groundwaters acquire radon from the subterranean environment and typically display activities that are orders of magnitude greater than those found in coastal seawaters. In addition, radon is conservative, has a half-life on the same order as many coastal processes, and is relatively easy to measure. Improvements in automated monitoring systems have made continuous measurements of radon at environmental concentrations a reality. Estimating groundwater discharges via radon is based on a mass balance approach. Inventories are measured, either as a snapshot or continuously over time (usually over at least one tidal cycle), and these inventories are converted to input fluxes after making allowances for losses due to decay, atmospheric evasion, and net coastal mixing terms. Once a radon mass balance is derived, a groundwater end-member activity is then determined either by direct measurement or by some type of estimation. The groundwater advection rates can then be determined by dividing the radon input fluxby the end-member radon activity. While this approach has worked reasonably well, some uncertainties and unanswered problems still remain. We focus here on these potentially unresolved components of the mass balance: (1) end-member radon is there really only one value? What can we do if groundwater Rn measurements are highly variable? (2) atmospheric evasion do the standard gas exchange equations work under high-energy coastal mixing scenarios ? And (3) mixing losses are there other significant radon losses (e.g., recharge of coastal waters into the aquifer) besides those attributed to mixing with lower-activity waters offshore? We will address these issues using a datasets collected from Dor Beach, Israel and elsewhere.

***Keywords:*** radon, groundwater, discharge

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# Numerical modeling of saltwater freshwater interaction

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Interaction between freshwater and saltwater in coastal aquifers can be simulated using mainly two different approaches; disperse interface approach and sharp interface approach. The sharp interface approach, in conjunction with the assumption of horizontal flow within the aquifer allows the simulation of coastal aquifer systems on spatial and temporal scales. In this study, a finite difference model that simulates freshwater and saltwater flow separated by a sharp interface has been developed to study the saltwater intrusion in coastal aquifers. The main aim of this model is to evaluate the regional as well as global coastal groundwater resources, including the effects of different factors affecting freshwater-saltwater dynamics. The accurate solutions of the coupled, non linear partial differential flow equations require the utilization of a numerical technique. The system of equations is descretized using an implicit finite difference scheme and the descretized equations are solved by the strongly implicit procedure (SIP). The developed model has been used to evaluate the effect of hydro-geological factors on the dynamics of freshwater- saltwater interface. The effect of specific storage, porosity and the hydraulic conductivity were mainly considered here. Parameter estimation process shows that the hydraulic conductivity is the main hydro-geological factor affecting the dynamics of salinity interface. It also shows that the model is very sensitive to groundwater recharge. Higher values of hydraulic conductivity facilitate intrusion of seawater, whereas increased recharge has the opposite. The developed sharp interface model has been then applied to estimate the salinity intrusion in the lower part of the Walawe river basin in the southern coastal aquifer, Sri Lanka. Since storage coefficient and porosity are not much affecting to the change of interface, model was calibrated by adjusting the hydraulic conductivity to match the observed salinity profiles in the southern coastal aquifer. Simulation has been carried out for Sep 2003 to Nov. 2004. The observed long term salinity profile has been compared with the simulation results. It shows that the numerical models can be used to reproduce the salinity profile in the area. The short term variation of the salinity interface according to the changes in groundwater recharge shows that the comparison has been found to be in reasonable agreement. Realistic changes of the salinity profiles can be modeled by matching model behavior with observations over a range of recharge values in study area.

***Keywords:*** salinity intrusion, sharp interface, numerical modeling

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# Regional assessment of groundwater discharge into seas: Present-DAG concept and methods

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Studies of groundwater discharge into the seas and oceans are part of a complex hydrologic-hydrogeologic problem of underground water exchange between land and the sea. Groundwater discharge into the seas is part of groundwater that is being formed in the land and discharged into the seas, excluding the river network. Groundwater flux into the seas is formed in water-saturated coastal rocks, affected by the sea drainage. It occurs constantly everywhere, except in some areas of the Arctic and the Antarctic that are covered with permafrost of great thickness. Submarine discharge into seas and oceans is the least studied element of the present and prospective water and salt balance of the seas. First of all, it is because groundwater inflow is the only water balance component that cannot be measured, and data needed for a well-grounded calculation of a water balance underground component are often missing. Until recently, there was no technique for such calculations. Groundwater discharge into the sea is usually small in comparison with other elements of the water balance (atmospheric precipitation, evaporation, river runoff). Therefore, it is important to determine it directly by hydrogeological methods. These methods of submarine groundwater investigation can be subdivided into two groups: 1) methods based on quantitative analysis of conditions for forming groundwater discharge into the sea within a catchment and primarily coastal areas of the land and 2) methods of marine hydrogeological investigations based on the direct study of the freshwater area of the sea The first group involves the analysis of geologic and hydrogeologic conditions of the sea coastal zone, which include a hydrogeodynamic method for calculating flow discharge (analytically and by modeling), a complex hydro-logic-hydrogeologic method and a method of mean perennial water balance of groundwater recharge areas. The second group includes the methods for prospecting and investigating different anomalies in the sea water or bottom sediments that result from submarine groundwater discharge (anomalies in temperature and sea water composition of the bottom water layer, etc.) These methods permit areas of submarine groundwater discharge to be singled out and quantitatively characterized and in some cases make it possible to calculate the value of ground-water discharge, causing these anomalies. The result of estimating the groundwater discharge to the Capian Sea, Aral Sea, Baltic Sea (from area of the former USSR) as well as to some major lakes (Baikal and Balkhash) are considered.

***Keywords:*** groundwater, submarine discharge, water balance

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# A Simulation of Groundwater Discharge and Nitrate Delivery to the Chesapeake Bay from the Lowermost Delmarva Peninsula, USA

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***Jaon P. Pope***

The Chesapeake Bay was declared an impaired water body under the United States Clean Water Act in 1999. As a result, much work is now being done to study how sediments and nutrients are delivered to the bay, and how these loadings could be reduced in the future. We have developed a groundwater model of the lowermost Delmarva Peninsula that simulates both salt-water intrusion and the delivery of nitrate to the Chesapeake Bay. A flow-path and groundwater-age analysis was performed using the model to estimate the timing of nitrate likely to be delivered to the bay over the next several decades. The simulated mean and median residence times of groundwater in the lowermost peninsula are 30 and 18 years, respectively. Current and future nitrate concentrations in coastal groundwater discharge were simulated based on local data from wells that include both nitrate concentrations and groundwater age. A forecasting analysis indicates that nitrate that has been applied to agricultural regions over the last few decades will continue to discharge into the bay for several decades to come.

***Keywords:*** groundwater discharge, nutrients, groundwater model

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**HS1001** **Oral Presentation** **3994**

# Quantifying groundwater discharge plumes along the Kona Coast of Hawaii using radon and radium isotopes

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Major islands typically exhibit many of the conditions favorable for high submarine groundwater discharges (SGD) to the ocean, including wet tropical climates, poorly developed river systems that would otherwise act to drain the land from precipitation, steep mountainous topography in close proximity to the coastal ocean, and high permeability of the young volcanic rocks. The islands of Hawaii are no exception. In our companion paper, we show that quantitative aerial thermal imaging along the Kona coast of the Big Island of Hawaii reveals plumes of relatively cold groundwater discharging from distinct portals along the coastline. These springs are fed by groundwater flowing down gradient through fractured basalts, porous clinker zones of aa flows, spaces between separate lava flows, and lava tubes associated with pahoehoe flows, all of which provide conduits for groundwater. Many of the plumes represent substantial volumes of groundwater discharge. The goal of the tracer component of this work is to quantify the groundwater fluxes to the coastal ocean from several of these plumes as a means of calibrating the aerial imaging. While both radon and radium isotopes have proven to be effective tools for measuring SGD independently, a combined approach is even more useful. The work presented here uses both radon and radium collectively to assess the fluxes of groundwater to the coastal ocean. We also examine the duration of mixing of the discharged groundwater with the open ocean. Near the coastline, significant tidally-modulated mixing occurs within the terrestrial aquifer as evident from brackish wells and ponds having salinities of around 5. Mass balance modeling of the isotopic data indicates discharges on the order of hundreds to thousands of m3/day with no apparent seasonal variability for the examined plumes. The associated nutrient fluxes from these point-source additions may represent a major fraction of the total flux to the coastal ocean in this area.

***Keywords:*** sgd, hawaii, radon

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# Numerical modeling to determine freshwater/saltwater interface configuration in a low-gradient coastal wetland aquifer

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The classical conceptual model of the salinity interface in a coastal aquifer involves an intruding saltwater wedge at the base of the aquifer with the upper edge of the interface located a short distance offshore and a freshwater discharge face located between the upper edge and the shore. This configuration relies on a sufficient head in the inland area to maintain the freshwater discharge face and an inland water table that lies below land surface. The conditions of a coastal wetland, however, can differ from the standard conceptual model. For example, inland water levels are higher than land surface, and although there is a surface-water flow connection between the wetlands and the offshore waters, coastal wetlands almost always form in protected areas, meaning that an obstruction to surface-water flow, such as a mudbank, shoal, or coastal embankment occurs between the coastal wetlands and the offshore area. This type of surface water creates an atypical ground-water salinity-interface configuration. The coastal wetland in the southern Everglades of Florida has been the subject of many studies to determine existing and historical conditions, trends, and the effects of restoration efforts. The numerical modeling effort by the U.S. Geological Survey in this area involves a coupled hydrodynamic surface-water and ground-water flow model with variable-density salinity transport. The application of this model to Everglades National Park is referred to as Tides and Inflows in the Mangroves of the Everglades (TIME). The application simulates the wetland and offshore tidal stage along with the ground-water heads and salinity in both regimes. Surface-water flow at the coastline is dammed and channelized by a natural coastal embankment. A robust field data-set has been collected for many hydrologic parameters and used for model development and comparison, including airborne electromagnetic surveying to determine the location of the subsurface saltwater interface. The top of this saltwater interface is much further inland than the classical conceptual model. Results of the TIME application, in conjunction with the relevant field data, indicate that three distinct zones can be defined where flux is exchanged between surface water and ground water. The first zone is at the saltwater interface, located several kilometer further inland than in the classical conceptual model, where there is upward flux of ground water to surface water. The second zone of exchange is located near the coastline, where the damming effect of the coastal embankment causes surface water stage to be higher than ground-water head, thereby inducing a downward flux of surface water. Thus, a freshwater lens is formed along the coast. The salinity distribution within the lens, and its size, is subject to seasonal variation. The third zone of exchange occurs immediately offshore, where the ground-water head is higher than tidal stage, inducing an upward flux of ground water to the sea. Thus the complex interface results in three exchange zones rather than the single ground-water discharge face depicted in the classical conceptual model. The implications of this study affect the development and restoration of coastal wetlands and the associated ecology. The location of the saltwater and freshwater marsh can change according to salinity exchange with the shallow ground water. In turn, ground-water salinity is strongly affected by the fluctuations in available fresh surface water upstream. Thus, a change in upstream water deliveries can have a complex effect on the configuration of the saltwater interface, salinity of the shallow ground water, and hence the marsh communities.

***Keywords:*** numerical model, saltwater interface, wetlands

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# Geochemical characterization of salinization process in an anthropized coastal zone

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***Adriano Mayer, Christine Vallet-Coulomb, Olivier Radakovitch, Christelle Claude, Bruno Hamelin***

The general aim of our study is to characterize mass water exchanges between groundwaters and the Adriatic Sea and/or lagoon in the South Lagoon Venice system (Co.Ri.La. program). We are focusing here on the characterization of salinization processes observed in the shallow, partially confined aquifer (0-30m). We used a pre-existing network of 25 piezometers tapping the aquifer. The studied zone is bordered by the Venice Lagoon to the North-East, and by the Adriatic Sea to the South-East. It extends 20 km East to West and 10 km North to South. It is intensively cultivated and the hydrological regime is artificially regulated by a complex network of pumping plants and canals. The canal water is used to irrigate fields during dry seasons. In flood conditions, canals drain phreatic water and the excess water is pumped and rejected into the lagoon. One important particularity of the area is that the ground level, and consequently the water table, lies below sea level (respectively up to -2m and up to -4m, at 5 km from the coast). We conduct a multi-element study (major and trace elements, stable water isotopes, radioactive isotopes) to characterise the hydrodynamic processes occurring between the different water reservoirs in this coastal zone. Our results show that the groundwater salinization (135 mS/cm) is due to the intrusion of marine type water (lagoon and/or seawater). However, the groundwater does not reach the high levels of salinity that could be expected in such a low-lying area, and the saltwater intrusion appears relatively limited in space. The equilibrium between fresh and sea water expected in this coastal zone seems to be perturbed compared to a classical transition zone. Two factors may explain this trend : input of lagoon water with salinity lower than seawater (2055 mS/cm) and/or the presence of artificial canals separating this area from the lagoon and from the sea. We propose to use geochemical tracers in order to analyse the factors controlling the subterranean mixing between fresh and marine waters in this context.

***Keywords:*** salinization, anthropization, lagoon

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# A Numerical Analysis of the Influence of Tidal Fluctuations on Contaminant Loads to the Ocean

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Contaminant transport models require extensive computational resources that can result in lengthy runtimes, especially for those simulations that deal with seawater intrusion and tidal variation. To simplify contaminant transport simulation, most coastal aquifer studies neglect variable density and tidal cycles. These studies have demonstrated that sea water density and tidal change have little consequence on the numerical prediction of migration paths and does not affect noticeably the overall migration rate of the plume before it reaches the seawater interface (Zhang et al., 2001). However, it is necessary to investigate the influence of tidal variation on contaminant transport in cases where the contaminants reach the seawater/freshwater interface and discharge into the ocean. Transport simulations that neglected and incorporated tidal effects were compared. Active cells in a cross-sectional numerical model were assigned properties similar to those of a coastal aquifer located in eastern Italy. The 7.5 m by 500 m model domain is located within a coastal refinery property, and the underlying aquifer contains high levels of Methyl Tertiary Butyl Ether (MTBE). To analyze the influence of tidal variation on contaminant behavior and rate of mass flux toward the sea, simulations were performed using with a constant ocean stage and dispersivity. Equivalent simulations were conducted using three different dispersivity values also considering the effects of a pumping well on coastward contaminant mass flux. Ocean tides do not substantially affect the natural discharge of MTBE because contaminant mass flux does not differ by more than 2% between simulations. However, mass flux rates diverge when a pumping well is activated to withdraw ground-water contaminants. In this case, ignoring tidal effects results in a 10% error in calculated mass flux and overestimates solute mass discharge into the ocean. Greater dispersivity values induce larger errors when ignoring tidal effects. For example, contaminant mass flux for a 2-year simulation period that ignores tidal change is about 10% greater when dispersivity is 16 m. The difference in contaminant mass flux decreases to 7% when dispersivity is 5 m. Simulations also were developed in which dispersivity is not uniformly constant, varying only near the seawater/freshwater interface. Results show that the different distribution of calculated concentrations in the transient simulation with tidal effects can be replaced by calculated concentrations from the steady-state model if dispersivity is increased about 120% near the seawater/freshwater interface of the steady-state model. Therefore, it may be possible to replace tidal effects with a change in the dispersivity value when calibrating a model. Thus, when tidal effects are neglected, the error that occurs in the estimation of concentration near the ocean is a function of dispersivity in correspondence to the transition zone; this error may or may not be acceptable based of the scale of the problem being studied. Zhang, Q., Volker, R.E., and Lockington, D.A. 2001, Influence of seaward boundary condition on contaminant transport in unconfined coastal aquifers, Journal of Contaminant Hydrology, (49) 201-215. U.S. Geological Survey, Florida Integrated Science Center Ft. Lauderdale, FL, USA 33315 D.I.I.A.R., Polytechnic of Milan, 20133 Milan, Italy

***Keywords:*** tidal variation, contaminant transport, density

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# Groundwater contributions to the nutrient dynamics at shallow inter- and sub- tidal areas adjacent to a mega city, Bangkok.

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Both groundwater and Chao Phraya river are major agents to supply nutrients and organic matter into the Gulf of Thailand. With the development of the city and population increase, however, lowered groundwater level at Bangkok city due to over-drawing suggests decreases of groundwater flux and associated nutrients supplies into the sea. In this study, we investigated nutrients dynamics at intertidal bed adjacent to Bangkok city with multiple physical and chemical approaches. As reported in previous study, simple multiplication of nutrient concentrations in porewater and upward fluxes measured by automated seepage meter seemed to show substantial contribution of groundwater-derived nutrients into the coastal area. However, time-series resistivity monitoring under the seabed did not show any symptom of groundwater fluxes from the sediment. The oscillation of upward fluxes corresponded with tidal range and the strength of wave-derived currents, suggesting that tidal pumping could be major agent to cause such upward fluxes. Furthermore, d15N and d18O values in NO3- and NO2- slightly existed at the upper sediment also indicated that these components were not from groundwater, but river-derived ones and subsequent denitrification of them. On the other hand, high gradation of NH4+ and PO43- concentrations between the upper layer of sediments and overlying water indicated that diffusive fluxes also contributed to the nutrients supplies from the sediment. Along the coastal line adjacent to Bangkok city, therefore, it turned out that river water was important agent to bring terrestrial nutrients including particulate organic matter after all, and specific components, NH4+ and PO43- mineralized in anoxic condition, were pushed back to the overlying water mainly by tidal pump and diffusion.

***Keywords:*** automated seepage meter, resistivity under the seabed, stable isotopes in nitrate

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# Temporal changes in submarine fluxes of groundwater, Dor Bay, Northern Israel

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Dor Bay is located in the Carmel coastal plain, 30 km south of Haifa. In this area, Holocene sands cover N-S oriented calcaranitic sandstone ridges (locally known as 'Kurkar'). The two units are often separated by a confining clayey unit. In the bay, the Kurkar is exposed in half of the area, while in other half, it is covered by sands of variable thickness. Groundwater discharge into the bay was measured three times within four months (March to July 2006) using both continuous radon measurements by RAD7 and seepage meters. The Rn-calculated average advection rates were pretty similar during the three campaigns, between 11.1 and 12.9 cm/d. The water discharging from the seepage meters are saline (15-20 ppt) and contain between 100-235 dpm/l, which is about half the activity found in the Kurkar but is significantly larger than the activity found in groundwater in the sand. Therefore, we assume that the discharging water is a mixture of Kurkar fresh groundwater with recycled seawater (in relative proportions of about 50:50). Seepage meter results, all deployed on sand covered seafloor, were slightly lower than the Rn-calculated values during the May campaign (10.6 cm/d, average of 4 meters), while very low in July (3.1 cm/d, 6 meters) and considerably higher in March (18 and 50 cm/d in two different sites). It is suggested that in July, hydraulic gradients in the sand were lower than in May and March (both due to falling of onland hydraulic heads and to a higher average sea level), thus the discharge from sand-covered areas was inhibited, and discharge was limited to the Kurkar-covered areas. During May (after the rainy month of April 2006), with a relatively low sea level, gradients were high and discharge was more even across the bay. In March, following the main part of the rainy season and after the storms brought seawater way up onshore (as was reflected in a layer of saline groundwater on top of fresh water up to 40 m from shoreline), the discharge from the sands was enhanced, though was very heterogeneous. This was not reflected in the radon-calculated fluxes, since (1) in more than half of the area, the Kurkar is directly discharging to the water column and (2) in those sand-covered areas, the Kurkar-derived water were more diluted by the sand derived groundwater (reflected by relatively low radon activities in seepage meter water in March).

***Keywords:*** sgd, radon, seepage meters

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# Estimation of nutrient inputs through submarine groundwater discharge to Ariake Bay in Kyushu Island, Japan

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The ecosystem and aquatic environment for human activities and fisheries in semi-enclosed bays as well as coastal areas have been deteriorated in the recent past. This study focuses on environmental reclamation of Ariake bay, which is semi-enclosed inner bay located in the west of Kyushu Inland, Japan, as having such problems. Although the government has been implementing several measures to improve the ecosystem and aquatic environment, significant recovery has not yet been achieved in the bay. One of the reasons for the deteriorated situation is considered to be an increase in the nutrient due to fertilizers and wastewater through continuous surface water and groundwater discharge from the residential and agricultural area in Ariake bay catchment. In recent studies, it is revealed that nutrient discharge through submarine groundwater discharge (SGD) is not negligible as compared to river discharge. Nutrient discharge plays a significant role in nutrient cycle and primary productivity in the coastal ocean. In Ariake bay, however, there is little quantified information of nutrient source as SGD. A detail investigation for estimating the amount of SGD and nutrient flux is indispensable for better understanding of the role of SGD and its anthropogenic or natural perturbations. This paper takes a first step for estimating nutrient inputs through SGD to the coast of Saga region of Ariake bay by the measurement using seepage mater. As a result, it was shown that SGD rate ranged from 0.01 to 20.52m/s. Water quality analyses indicated that SGD water is classified into semi-sodium bicarbonate type similar to the neighboring shallow groundwater. Geochemical tracer using hydrogen and oxygen stable isotope ratio (D18O) indicated that SGD would be formed by the infiltrated rainwater at piedmont surface of low altitudes. The results also suggest that SGD through locally developed crack in offshore submarine aquiclude from shallow confined aquifer consisted of pervious rock (basalt) and aquiclude (pyroclastic fall) with shorter residence time. It was revealed that reduction reaction for SGD proceeded up to denitrification since nitrate and ORP in SGD were slightly lower than those of neighboring shallow groundwater and significant manganese and iron were not detected. SGD associated nutrient loads (N, P, SiO2) were estimated at 1.40g/(m2day), 0.07g/(m2day), and 52.78g/(m2day), respectively. The results of the present study demonstrated that SGD found in the area would be a significant source of nutrient to the coastal sea area in Ariake bay.

***Keywords:*** submarinegroundwaterdischarge, nutrientinputs, reductionreaction

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**HS1001** **Oral Presentation** **4001**

# El Nio-Southern Oscillation determines the salinity of the freshwater lens under a coral atoll in the Pacific Ocean

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The freshwater resources of coral atolls occur mainly as lenses floating on salt water underneath the islands. The size and shape of the freshwater lenses are determined by the subterranean geology, and the groundwater recharge rate, as well as the density difference. The mixing of these miscible fluids is a density-driven process largely determined by tidal fluctuations, vertical longitudinal dispersivity and recharge rate. Besides saltwater intrusion as a result of upconing, the salinity of water pumped from the lens is determined by the motion of the position of the freshwater-saltwater interface. The seasonality of this motion has recently been shown to potentially have an important impact on the chemical loading of coastal waters (Michael et al. (2005). In the South Pacific, rainfall exhibits seasonal as well as interannual variability related to the El Nio-Southern Oscillation (ENSO). We used electric conductivity measurements from pumped wells on the raised coral atoll of Tongatapu (175 12′W 21 08′S, Kingdom of Tonga) to show a moderate ENSO control on the temporal fluctuation of the pumped freshwater salinity (van der Velde et al., 2006). We used a transfer-function model to describe the convolution of the variations in rain with the variations in the reciprocal of electric conductivity. A log-normal probability density function was chosen for the transfer function to reflect the transport and mixing of the percolating water. The use of a transfer function allows us to describe the whole system and the processes occurring in this system in a relatively simple way. Our system is a porous medium through which the infiltrated water moves and it includes the soil, the limestone, and the saturated limestone aquifer to a depth of about 1 to 2 m below the water table. The processes in this system include the infiltration of rain water in the soil, the downward movement of this water through the vadose zone, and the subsequent mixing of the drainage water into the freshwater lens. Good agreement was obtained between the temporal pattern of the simulation and the measured variations in the inverse of EC. We obtained a R-squared of 0.71 (P value: 0.0000) for averaged measured and simulated variations in EC, the peak of the transfer function occurred at 4 months. The electric conductivity of the lens after a particularly intense rainfall event when 336 mm fall in just two days that triggered rapid discrete infiltration through the soil and limestone was not captured by the transfer function model. This may relate to the occurrence of a fast preferential flow paths as often observed within karstic limestone formations. Recharge after rapid discrete infiltration can occur days after rainfall, especially with high reported saturated hydraulic conductivities of the overlying soil. The 4-month time lag may then relate to diffuse infiltration through the vadose zone. However, as recharge lifts the water table, the freshwater-saltwater interface moves deeper and seaward influencing the salinity of pumped water, and the lag time in this motion may be critical to pumped water salinity. The salinity dynamics depended on low or increased rainfall recharge during respectively dry El Nio periods or wet La Nia events. ENSO events cause a large variation around the mean salinity and determine the relative salinity over the time-scale of several years, while a smaller variation is introduced by seasonal rainfall. The Southern Oscillation Index (SOI) was used to predict freshwater salinity with a lag time of 10 months. The SOI then explains 27% of the variation in modelled EC (P value: 0.0000). This predictive capability of SOI for water salinity may be beneficial for practical planning by water manager in similar environments. Michael, H.A., Mulligan, A.E. and Harvey, C.F. 2005. Seasonal Oscillations in water exchange between aquifers and the coastal ocean. Nature 436, 1145-1148. Van der Velde, M. Javaux, M., Vanclooster, M.

and Clothier, B.E. 2006. El Nio-Southern Oscillation determines the salinity of the freshwater lens under a coral atoll in the Pacific Ocean. Geophysical Research Letter, in press.

***Keywords:*** hydrogeology, climate variability, islands

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**HS1001** **Oral Presentation** **4002**

# Nutrient dynamics with interaction of groundwater and seawater in a beach slope of steep Island, Seto Inland Sea, Western Japan.

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Previous studies had reported the important role of groundwater to the nutrient discharge, especially phosphorus and silica, using observations and model estimations. On the other hand, nitrate elimination in coastal groundwater or mixed water of groundwater and seawater under the tidal flat had been confirmed by other studies. The dynamics of seawater and groundwater interaction has been making clear in recent years. However, the nutrient dynamics with the interactions has not been made enough clear. To clarify the nutrient dynamics in a tidal flat, it is necessary to confirm the semidiurnal and seasonal variation in nutrient concentrations with water dynamics. The objective of this research is to confirm nutrient dynamics in a tidal flat with the interaction of groundwater and seawater. As we focused on the semidiurnal and seasonal variation, the intensive observations for the 12 hours were conducted in four seasons. The observation beach slope is located on a steep island, Seto Inland Sea, western Japan. The elevation of mountaintop is about 500m asl. The island is covered by about 50% of orange groves and 50% of forest. Large amount of nitrogen fertilizer is applied in orange groves (2400kg/ha/year). The basement rock is composed of granite. To observe the nutrient dynamics, we installed 20 piezometers with various depths at 7 plots on the observation line with about 80m. Measurements of water level and water collections were carried out at 2 hours interval. Chemical components were analyzed in a laboratory, using ion chromatography, spectrophotometer, and DOC/DN analyzer. Based on the natural chloride tracer balance, the observation tidal flat was determined as mixing zone of groundwater with seawater. Nitrate concentration declined from about 10 mgL-1 to 0 mgL-1 with groundwater flow from the hillslope area covered by the orange plantation to the beach slope. On the other hand, the nitrate concentration in the seawater was 0.4 mgL-1. These results suggest the reduction process of nitrate originated in both groundwater and seawater in the groundwater-seawater mixing zone. It means the nitrate load of groundwater to the sea was negligible. However, nitrate content of underground water at the offshore area was higher than that of seawater. The chloride concentration and redox potential of these water were same as seawater. Based on the piezometric potential, the volume of recirculated seawater at the offshore was estimated to be similar to groundwater discharge at the beach slope. These suggest the nitrogen mineralization of organic compounds under the oxidative condition at the offshore and large nitrate flux with recirculated process. In addition, phosphorus and silica were also produced at the offshore as well as transport from a land area. We confirmed also seasonal variation in nutrient dynamics such as a little bit of decline of mineralization with decreasing of temperature and nitrate discharge with large groundwater flux.

***Keywords:*** nutrientdynamics, recirculated seawater, redoxpotential

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**HS1001** **Oral Presentation** **4003**

# Chemical and isotopic characteristics in stagnant water isolated at coastal area

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The Taiheiyo Coal Mine had been mining from land toward undersea floor for approximate 86 years since 1920. The mining area facing the Pacific Ocean was extended to maximum 8.5 kms off seashore and 700 m depth below sea level. According mining records, mining tunnels was excavated along the Harutori coal-bearing formation in the Palaeogene period and the inside tunnel has kept very dry and there is little seepage water from tunnel wall and floor except water-drops from the ceiling. But, as the formation, which is rich in natural gas and the pressured high saline water, is underlying below the coal formation, some bores were drilled from the tunnel floor toward the underlying Cretaceous formation to prevent gas explosion and a flood. Flowing water from bores stops within a few months or years after drilling, and dries up. The chemical and isotopic characteristics in flowing saline water are different from that in the present seawater overlying above the undersea mine. We found three different types of water in the coal mine. One is freshwater, which flows from land area and is occupied in the shallow mining area of 150 m depth. Second is saline water with chloride concentration ranging 5000~22000 mg/L, which was found in water-drops from the tunnel ceiling at the entire undersea mining area and has the altered chemical properties from the present seawater. Third is estimated fossil seawater, which is high saline water from flowing bores and has homogeneous chemical and isotopic properties (eg. Cl-: 12500 ~ 13700 mg/L, Na+: 3610 ~ 4290 mg/L, Ca2+: 3930 ~ 4280 mg/L, D: -19.7~ -28.0 , 18O: -4.4 ~ -5.2 , 36Cl/Cl: (7.9 ~ 10.8)~10-15). Its residence time is estimated over 2 million years from the secular equilibrium ratio of 36Cl/Cl. We found the boundary between freshwater and saline water at 200 m depth below sea level in the mining tunnel. However, judging from chemical and isotopic characteristics, the present sweater is not contributed to formation of the interface of freshwater. The interface of the present sweater is estimated to locate in the shallow area where the mining tunnel was not encountered. On the other hand, the fossil sweater was found from deep spa well drilled at the inland area located in 10 km north of the coal mine. Consequently, the high saline water stored in the Cretaceous formation has been isolated from the groundwater-seawater interaction for at least more than 2 million years despite located in the costal area.

***Keywords:*** ground seawater interaction, fossil seawater, chemical characteristics

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**HS1001** **Oral Presentation** **4004**

# Indicators and quality classification applied to groundwater management in coastal aquifers. two case studies: Mar del Plata, Argentina and Puglia, Italy

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The use of indicators has been recently called for designed to be used in environmental and ecologic monitoring and in the general assessment of environmental sustainability at a local, national and international scale. Environmental indicators are variables with a social meaning attached to that of their own scientific entity and whose aim is to briefly describe the interests and preoccupations of the society with regard to the environmental evolution and coherently participate in decision-making processes. Indicators help answer the four following basic questions. What is going on in the environment (conditions and trends)? What is the reason for this (causes, relationships between human influences and natural processes)? What makes it significant (economic, ecologic and health effects)? What is being done regarding this (planning and political implications)? There is a wide range of environmental indicators, most of them are addressed to decision-makers and designed to assess: 1) environmental PRESSURE caused by human activity; 2) evaluated environmental conditions or STATE; 3) anthropic RESPONSE to correct undesirable situations. Groundwater is affected by two types of degradation risks: quality and quantity degradation. It represents a special case for indicators due to the speed with which it changes and its origin (natural and anthropic); thus particular consideration is given to those that better depict the way ecosystems and human beings health is being affected. In order to define the coastal environmental processes related to groundwater resources, some indicators addressed to decision-makers and quality classification are proposed and discussed in relation to two different types of coastal aquifers located in different countries: the porous aquifer of Mar del Plata (Argentina) and the Salentine karstic aquifer (Italy). The use of indicators in the characterization of the strategies management in different coastal aquifers is shown considering two test cases, a porous aquifer located in Argentina and a karstic aquifer located in Italy. The results show this approach could help to reach a consensus to propose a methodology to qualify the water environmental quality and establish groundwater exploitation criteria.

***Keywords:*** coastal aquifer, management, environmental sustainability

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**HS1001** **Oral Presentation** **4005**

# Seawater intrusion in the coastal aquifer of Wadi Ham, UAE

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A transport model was developed to simulate the seawater intrusion into to the aquifer system along the Kalbha and Fujairah coast of the United Arab Emirates. The flow model was used to simulate the salinity level of the groundwater of Wadi Ham aquifer and its variation in time and space from January 1994 to March 2005. Data regarding bulk density, species parameters and dispersion were evaluated and introduced to the model. The initial groundwater concentration level in the aquifer was developed by the available historical data of some locations in the study domain during the 1994 and 1995. A 20 m of longitudinal dispersivity for each transport grid cell was considered. The ratio of horizontal to longitudinal dispersivity of the layer was 0.1 and the ratio of vertical to longitudinal dispersivity of the layer 0.01. A molecular diffusion coefficient of 0.1 m2/s was considered for the layer. The area covering the coast of Gulf of Oman in the study domain was taken as a constant concentration boundary with an average salinity (TDS) value of 35000mg/lit. An artificial recharge experiment was conducted in the field to assess the infiltration rates and the feasibility of this technique to mitigate the seawater intrusion problem. The results of the simulation indicated that the seawater intrusion is affected by the dry and wet conditions. During the dry years, the velocity vectors are directed from the Gulf of Oman to the aquifer causing sever intrusion problem. During the aquifer wet years where rainfall is relatively high and groundwater recharge is encountered from the ponding area

***Keywords:*** seawater intrusion, numerical molding, mitigation

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**HS1001** **Oral Presentation** **4006**

# The importance of shallow confining units to submarine groundwater flow

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The variable density of fresh and saline groundwater in coastal aquifers makes such systems complex, compared with either fully fresh or fully saline flow systems. Recent and ongoing studies along the Atlantic coast of the U.S. have shown that this complexity is further complicated by the heterogeneity of submarine sediments. Various field investigations have delineated submarine confining units that commonly create semi-confined offshore aquifers that are recharged by unconfined onshore flow systems. The boundary between the confined and unconfined portions of the aquifers is often at or near the shoreline. Submarine confining units generally originate as fine-grained estuarine deposits laid down in low-energy coastal embayments or back-barrier lagoons, or in similar non-marine settings such as fresh coastal ponds and freshwater marshes. These deposits are usually either Holocene in age (<10 ka), or date to the last interglacial, especially Marine Isotope Stage 5e (~117-130 ka) when global sea level was up to six meters higher than modern sea level. Submarine confining units that can be regionally extensive also originate in three special types of depositional environments that are restricted to latitudinal zones. In the tropics, mangrove peats buried during the Holocene sea level transgression often serve as submarine confining units. In mid-latitudes, submerged and buried peats deposited in salt marshes and cypress or cedar swamps are common. At higher latitudes, fine-grained glaciomarine sediments deposited in pro-glacial lakes or isostatically depressed coastal embayments are widespread. The net effect of the presence of these shallow confining units is that fresh groundwater from land often flows much farther offshore before mixing with saline water or discharging than would normally be expected. Fully fresh groundwater has been detected within a few meters of the seafloor beneath these sorts of confining units by sampling and geophysical surveys at sites up to 2 km from shore. In settings where onshore groundwater has been impacted by pollutants such as excess nitrate from wastewater and fertilizer, the presence of such confining units is critical to understanding how and where the pollutants will be discharged into coastal waters, and what remedial measures might be appropriate. Alternatively, these confining units may also protect fresh groundwater supplies from saltwater intrusion into shallow domestic wells used for drinking water by coastal residents. Such situations would call for the protection of submarine confining units from breaching by dredging and other marine construction.

***Keywords:*** groundwater, seawater, confining layer

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**HS1001** **Oral Presentation** **4007**

# Possibilities of geophysical survey of spatial and temporal groundwater contamination variations, salt/water intrusion and subsurface pollution determination and monitoring in the coastal zone

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Subsurface discharge of fresh water from coastal aquifers, called submarine groundwater discharge (SGD), has been recognized as an important component of the hydrological cycle. One of the more important challenges facing natural resource managers today is how to identify, measure and monitor the cumulative impacts of land use decisions across space and time. Understanding the multi-variable dimensions of groundwater management can be improved through the application of innovative information technologies (application of neural networks to data analysis, optimization, pattern recognition, image identification, et cetera) and using new generation of non-invasive techniques for subsurface exploration (petroleum, mineral, geothermal and groundwater exploration). MARSES TDEM operative monitoring system has abilities and advantages which are defined by its multifunctional methodological application, that could be used as an operative system for water search tasks (ground water table), definition of waste level, monitoring changes in subsurface horizons, etc. Also this system could be applied to solve long-term tasks for nature subsurface ecosystem monitoring, subsurface horizons, soil salinity level, salinity gradeand ground water level measurements. All these parameters can be used to track seasonal and climatic changes in selected area. The distinctive difference between proposed regional monitoring system and other sounding systems is measurement of soil's humidity along all the depth down to ground water level. It is not possible to detect these subsurface horizon humidity parameters by other monitoring means, such as: observation wells, ground digs, etc. The project aims at obtaining a fundamental understanding of the physical and chemical processes taking place at a dynamic fresh/seawater interface through carrying out detailed studies at a small-scale study site in a coastal area. This should provide a conceptual framework for understanding the effect of these processes at a larger scale and over longer periods of time. A fundamental understanding of the processes involved is presently not available. Insight into the controlling processes, development and testing of a coupled variable-density flow, multispecies transport, and reaction code will increase the possibilities for sustainable management of coastal aquifers.

***Keywords:*** groundwater, seawater, monitoring

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**HS1001** **Poster presentation** **4008**

# Impact of Water Divertion Project on Ground Water Environment of Xiamen Island

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Drastically influenced by human activities, the water quality of the Middle Lake of Xiamen island has been seriously polluted. In order to alleviate water pollution of the lake, two projects have been carried out--- water divertion project from east to west and water divertion project from west to east. As a result, sea water is transferred to the lake and thus divides Xiamen island into two parts. It has caused great environmental problems, the most important one of which is the impact on the ground water environment of the whole island. Since 2002 when it was carried out, water divertion from east to west project has not improved water quality of the lake. Will the other project improve water quality without causing extra problems? Will it decrease sea water invasion, groundwater-seawater interaction, and nutriment reciprocation between freshwater bodies and sea water as well? And since sea water and fresh water are mutual-active, will it cause eutrophication of sea water? By adopting the flexible Finite Element Method (FEM), we set up a conceptual model, and analyze groundwater flow and sea water transportation with a mathematical model. The conclusions are: first, in annual average precipitation years, sea water invasion will persist in one year after the project is finished, and sea water level will be close to adjacent place on the lakeside. As a result, there may be, in low water years, reverse supply of sea water to lake water through groundwater flow, which will cause salinity rise, water quality decline, and deterioration of drinking water sources of some areas. Second, even in high water years, nutrient reciprocation between freshwater bodies and sea water will be not enough for eutrophication of sea water.

***Keywords:*** water divertion projection, sea water invasion, eutrophication

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**HS1001** **Poster presentation** **4009**

# Seasonal changes on horizontal and vertical distribution of groundwater in coastal zone and its relative to submarine groundwater discharge, Ise Bay, Japan

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A rice fields are one of the most typical land use in the Monsoon Asia. Also, the rice fields are widely distributed over the coastal zone of Ise Bay, so water areas expand during irrigation season comparing with non irrigation season. The recharge rate from surface water to groundwater is larger than the non irrigation season. This suggests that nutrient flux or groundwater discharge rate have seasonal changes in the coastal zone where is located at groundwater discharge area. This study is presented as follows: 1) seasonal changes of horizontal and vertical distribution of fresh water and salt water, 2) relationship between the seasonal changes of these and submarine groundwater discharge (SGD). Monitoring wells which had the depth of 5m, 10m, 20m, and 30m were excavated at the two sites in tidal zone. Each well site has different geology; one is thick alluvium where the past river channel gravel layer exists in the deep layer, another is thin alluvium where anticline exists. Conductivitytemperaturedepth (CTD) sensor was installed in each well and continuous measurement of electric conductivity, water temperature, and water level were made at 15-min intervals from December 1st 2005. Hourly measurement of resistivity among onshore to offshore was made from low tide to next low tide during the spring tide from February 2006. Groundwater sample collections were made at these wells for major ions and stable isotopes (oxygen18 and deuterium) analyses. The results of the continuous measurement of groundwater level and electric conductivity and the chemical analyses, fresh water aquifer existed at the deep layer and salt water existed at shallow layer in the thick alluvium site, besides, fresh water existed shallow layer in the thin alluvium site. In the thick alluvium site, water level and water quality of Fresh water layer didnt show seasonal change clearly. Cl ion concentration of Shallow salt water was diluted by irrigated water and rain water during irrigation season. In the thin alluvium, water level and water quality of shallow water changed sharply by rain water and tidal changes. Cl ion concentration of deep salt water was diluted by irrigated water during irrigation season. The result of measurement of resistivity, SGD was well shown during irrigation season comparing with non irrigation season in both sites. SGD existed at near the shore line during irrigation season. However, during non irrigation season, SGD existed slightly in low tide. The distributions of resistivity for a cross section were corresponded with the fresh water and salt water profiles in both well sites. It was made cleared that groundwater flow system in the inland area relates SGD in the sea floor. They concluded that seasonal changes of groundwater-seawater interaction were controlled by geology and recharged water and some tidal conditions.

***Keywords:*** seasonal changes, irrigated water, sgd

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**HS1001** **Poster presentation** **4010**

# Effect of a sinkhole perforation in a coastal confined aquifer on submarine groundwater discharge

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In order to explore the effect on the freshwater-seawater transition zone of karst features that penetrate the confining layer of an offshore, partially confined aquifer, we constructed a 3-dimensional slab model using the SUTRA (Saturated-Unsaturated TRAnsport) variable-density groundwater flow model. We ran a parameter sensitivity analysis, testing the effects of recharge rates, the permeabilities of the aquifer and confining layer, and the thickness of the confining layer. In all of our simulations, less than 20% of the freshwater recharge for the entire model exits through the sinkhole. In most cases, recirculated seawater accounts for 10%-30% of the total outflow across both the sinkhole and diffuse flow face. Increasing recharge to the model moves the transition zone seaward but does not affect its general shape. Changing the permeability ratio between the aquifer and the confining layer influences the configuration of the freshwater wedge the most, lengthening the wedge as the confining layer permeability decreases and increasing the fraction of total discharge exiting through the sinkhole. When this permeability ratio is low (about 1 to 30), the sinkhole lies seaward of the transition zone and acts as a recharge feature for the recirculating seawater. A cone of saline water appears at the seaward edge of the sinkhole when the sinkhole discharges water. In most cases, however, the water discharged is 95% freshwater. Although the sinkholes influence is mostly local, its presence would be enough to complicate estimates of submarine groundwater discharge.

***Keywords:*** sinkhole, spring, submarine

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**HS1001** **Poster presentation** **4011**

# Submarine groundwater discharge under extreme rainfall events

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Submarine groundwater discharge (SGD) is one of main processes which transfers the contaminants and nutrients from the inland to the sea, therefore has significant effect on the estuary environment and ecosystem. Being difficult to notice its existence and the effect on estuary environment visibly, scientific interest to the SGD had not occurred until recently. Even though numerous researches have been performed to identify SGD for several years, many parts still exist that cannot explain scientifically. Especially recent studies of SGD mainly focus on the effect of dynamic oceanic conditions such as tide, wave, and current and show the insufficiency in reflecting dynamic hydrologic condition of the inland. Michael et al. (2005) shows the impact of seasonal oscillation of inland recharge rate with sign curved shape to the SGD flux, but such a gradual change of recharge rate is not enough to represent the actual hydrologic condition such as storm or heavy rainfall. So in this study, we focus on the localized heavy rain effect and the unusual increase or decrease of recharge rate on SGD. Numerical modeling and laboratory experimental test are performed. A two dimensional vertical section of an unconfined coastal aquifer is constructed considering variably saturated flow system. Then, various cases of Neumann type boundary condition which consider the temporal change of precipitation rate are assigned to the domain and the time-varying SGD flux rate is calculated at each case. Numerical code FEFLOW (Diersch, 2005) is used for solving coupled equations of density-dependent flow and solute transport. Laboratory test is also used to characterize the impact of recharge rate variation to SGD. A sand tank representing the coastal aquifer was made and outflux was measured with the recharge rate and saturation ratio in the unsaturated zone. The results demonstrate the calculated SGD flux with time-varying recharge rate shows a quite different pattern from the one with constant recharge rate. Different types of the recharge correspond to the unique pattern of SGD as a function of time. Modeling result indicates that sudden rise of precipitation rate makes both fresh water flux and seawater outflux to the ocean increase while makes seawater influx through the seafloor decrease after the specific event. The intensity of recharge rate also plays an important role in the hydrograph of SGD. The magnitude of precipitation affects the saturation ratio and relative permeability, thus changes the velocity of percolated water. This phenomenon leads to the different buffering effect of recharge to the aquifer and causes various time lags between rainfall event and SGD. The result tells that not only the change of oceanic condition but also the change of precipitation rate should be considered to quantify SGD flux to the ocean in transient condition.

***Keywords:*** sgd, heavy rainfall, feflow

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**HS1001** **Poster presentation** **4012**

# Three-dimensional numerical simulation of density-dependent groundwater flow and salt transport due to groundwater pumping in a heterogeneous and true anisotropic coastal aquifer system

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The aquifer system is located on the western coast of Republic of Korea and is composed of Quaternary alluvial layers underlain by Precambrian gneiss and Cretaceous quartz monzonite, rhyolitic tuff, Kyokpori Formation (conglomerate, sandstone, and shale), and rhyolite with a major fault. Such geologic media and fault do not only have irregular thicknesses and boundaries but also contain bedding planes and joints of various orientations. Thus the aquifer system is hydrogeologically heterogeneous and true anisotropic. Groundwater has been pumped indiscreetly from the overlying alluvial layers and even from the underlying bedrocks for various agricultural activities. As a result, extensive groundwater depletion and salinization have occurred under seawater intrusion, and the sustainability of coastal groundwater resource has become a significant issue in the area and even in its surrounding areas. In order to protect coastal groundwater resource from seawater intrusion under groundwater pumping in such a heterogeneous and true anisotropic aquifer system, a series of three-dimensional numerical simulations of density-dependent groundwater flow and salt transport is necessary and thus performed using a multidimensional hydrodynamic dispersion numerical model, which is named COFAT3D. In the numerical simulations, hydrogeological heterogeneity and true anisotropy within the whole aquifer system are considered and implemented as they are observed and measured in the field. The numerical simulation results show that such hydrogeological heterogeneity and true anisotropy have significant effects on the spatial distributions and temporal changes of density-dependent groundwater flow and salt transport. Therefore it may be concluded that hydrogeological heterogeneity and true anisotropy cannot always be ignored if they are observed in actual aquifer systems, and thus they must be properly considered when more rigorous and reasonable predictions of long-term density-dependent groundwater flow and salt transport induced by groundwater pumping are to be obtained for the optimal management of coastal groundwater resource.

***Keywords:*** heterogeneity, true anisotropy, seawater intrusion

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**HS1001** **Poster presentation** **4013**

# Investigation of submarine groundwater discharge using several methods in the inter-tidal zone

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Recognition of the importance of submarine groundwater discharge (SGD) is increasing for the studies on water and dissolved material transports from land to the ocean. SGD research using several methods has been done to understand the processes of SGD. Seepage meter method, resistivity method, piezometer method and measurement of temperature on the seabed have been applied for this study. Study site is located in the coastal zone of Osaka bay, Japan. The length of the inter-tidal zone in the study area is 150m. The average of tidal change of Osaka bay ranges from 1 to 1.5m. In this site, 5 seepage meters and 7 piezometers were installed to evaluate the variation of SGD due to tidal change. Resistivity values under the seabed were also measured to estimate the distributions of freshwater and salt water. As the results, it is clarified that submarine groundwater discharge decrease with the distance from the coast. However, SGD rates were highest in the location near the coast line of low tide. Piezometer method revealed the direction of groundwater flow in the coastal zone. According to this result, seawater recharge was found near the coast line of high tide in inter-tidal zone. In addition to this, groundwater discharge was found, especially in the points near the coast line of low tide. This result agrees with the results of seepage meter method. Spatial and time variations of freshwater and salt water were confirmed by resistivity measurements of pore water under the seabed. This result also supports results of seepage meter and piezometer methods. As the conclusion of this study, the processes and flow paths of SGD were evaluated from the field data with several different methods.

***Keywords:*** submarinegroundwaterdischarg, inter tidalzone, seepagemeter

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**HS1001** **Poster presentation** **4014**

# Driving While Under The Influence: Pumping-driven Interfacial Circulation Under The Influence of Regional Groundwater Flow

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Submarine groundwater discharge occurs as terrestrial fresh-groundwater driven by ambient regional gradients and through wave-, tide- and current-driven interfacial pumping of ocean water through shallow sediments. Little is known, if any, on how these two types of flow systems interact. Is there pumping-driven interfacial exchange in coastal areas, or even continental shelves, under the influence of regional fresh groundwater discharge? What happens when one dominates over the other or when regional groundwater flow is actually from the ocean and into coastal aquifers? We provide some answers and investigate the complex dynamics of such systems at the meter scale via multiphysics numerical modeling. We investigate the interaction between turbulent water column flow, current-dune topography driven flow in underlying permeable sediments, and ambient groundwater discharge (AGD) of deep groundwater within the sediments, using coupled numerical simulations. AGD, whether towards or away from the water column, reduces the spatial extent of the current-topography driven interfacial exchange zone (IEZ) within the sediments and may prevent its development when the turbulent flow cannot induce sufficient pressure gradients along the sediment-water interface (SWI) to overpower AGD. A Morgan-Mercer-Flodin-type model describes how the presence and size of the IEZ depends on water column Reynolds number (Re) and AGD, while the IEZ flux dependence is described by a power model. The mean residence time (MRT) of water flowing through the IEZ is large at low Re, when the IEZ is of limited spatial extent, and decreases at higher Re when the IEZ is more extensive. AGD decreases the MRT. Although the metrics for interfacial exchange (size, flux and MRT) look similar between gaining and losing conditions, the geometry of the IEZ is different. Under gaining conditions, the IEZ is centered around the bottom-pressure maximum at the stoss face of dunes, near where the eddy in the water column reattaches. Deep groundwater discharges near the bottom-pressure minimum which is at the crest. Under losing conditions, the IEZ forms around the pressure minimum at the crest. Water infiltrating from the water column near the bottom-pressure maximum along the stoss face infiltrates deeper into the sediments and does not return to the SWI. Our previous models ignore density-driven flow, future modeling studies will consider variable density flow.

***Keywords:*** groundwater, ocean, interaction

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**HS1002** **4015 - 4101**

## Symposium
## A New Focus on Integrated Analysis of Groundwater/Surface-Water Systems: Process Understanding, Conceptualisation and Modelling. (Sponsors ICGW, ICSW and ICCLAS)

**Convener :** Dr. Corinna Abesser
**Co-Convener :** Prof. Gunnar Nuetzmann, Dr. Thorsten Wagener

A comprehensive understanding of the transport of water and chemicals between surface water and groundwater and the affects this has on biological processes is essential to improve management of surface and groundwater resources and to protect the functionality of the associated ecosystems. Here, surface-water is defined broadly to include rivers, lakes, and water fluxes related to precipitation, snow and ice that affect ground-water recharge and discharge. Factors of importance include climate and weather, geologic setting, fluvial geomorphology, terrestrial vegetation, glaciation, flow and transport through the unsaturated and saturated subsurface and human impacts. Historically, policy makers, scientific investigators and water resources managers have considered surface-water and groundwater as separate, essentially unconnected components of the watershed. However, today we appreciate the fact that hydrologic exchange is critical for the maintenance of biodiversity and the ecological functions of both rivers and groundwater. Data, computer capabilities, computer programs, and expertise have finally advanced far enough that the artificial barriers are being removed and integrated approaches are being used to better understand entire hydrologic systems. This advance is badly needed as these systems have already been severely altered and increasingly face over-exploitation and contamination. Moreover, in many areas of the world large sums are being devoted to stream restoration while the ecological consequences and potential benefits of these measures are hardly considered in the light of surface/groundwater exchange and hence not designed to improve the ecological connectivity of these systems. This symposium will bring together scientists to advance integrated analysis of groundwater/surface-water systems. Physical, chemical, biological, and ecological contributions focused on ground-water/surface-water interactions are welcome, including innovative field investigations, new methods of data collection and use, new process conceptualisations, and new methods of simulating integrated systems. We also welcome contributions on water resource management strategies for mitigating exploitation impacts.

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**HS1002** **Oral Presentation** **4015**

# Natural Attenuation Potential of Downwelling Streams for perfluorochemicals and other Emerging Contaminants

***Dr. Eduard Hoehn***
*Water Resources & Drinking Water Eawag IAHS*

IUGG Assembly/IAHS Symposium A New Focus on Integrated Analysis of Groundwater/Surface-Water Systems: Process Understanding, Conceptualization and Modelling, Perugia, Italia, July 9-13, 2007 Natural Attenuation Potential of Downwelling Streams for perfluorochemicals and other Emerging Contaminants Eduard Hoehn1), Megan Plumlee2), Martin Reinhard2), Alice Ringer3), and Hossein Ashktorab3) 1) Eawag, Swiss Federal Institute for Water Science & Technology, CH-8600 Dbendorf, Switzerland; <hoehn@eawag.ch> 2) Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305, U.S.A. 3) Water Use Efficiency Unit, Santa Clara Valley Water District, San Jos, CA 95118, U.S.A. Stream augmentation with tertiary treated municipal wastewateri..e., recycled wateris increasingly considered as an ecologically beneficial way of water reuse, especially in water-starved regions of Mediterranean climate. We are currently planning the augmentation of Upper Silver Creek, (USC; San Jose, California) which feeds into Coyote Creek (CC), with recycled water (RW) for Summer 2007. There is concern that emerging contaminants, i.e. unregulated but biologically active organic compounds potentially present in RW, will impact the aquatic environment and the underlying groundwater. There is currently insufficient data to predict the behavior and the fate of these compounds during river and surface water transport, which is necessary for a regulation with standards. Many streams lose water to permeable river-bed and aquifer materials, referred to as the hyporheic zone. The objectives of this project are to investigate on a possible natural attenuation potential of selected organic water contaminants of wastewater origin in USC, and the extent of an exchange of water between USC and hyporheic groundwater. Concern is raised that emerging contaminants of a conservative behavior that are present in RW could lead to groundwater contamination due to downwelling USC water. Conservative contaminants are those that do not undergo significant attenuation processes (sorption, biodegradation) onto surfaces of river-bed materials. The project is a follow-up of an earlier study of a larger scale, executed at the Santa Ana River in Southern California. The earlier study indicated river transport and infiltration as effective treatment steps for polishing many emerging contaminants. Similar results are reported from Swiss studies, where highly treated wastewater effluents with emerging contaminants (pharmaceuticals and flame retardants) are released into rivers that flow over floodplains consisting of permeable alluvial gravel and sand. Such aquifers are recharged from rivers and are widely used to supply drinking water. The study foresees augmenting the USC with between 0.014 and 0.028 m3/sec RW from the San Jose treatment plant (average base flow rate of USC is approximately 0.03 m3/sec). The RW has been shown to contain traces of perfluorochemicals (at concentrations of up to 0.4 g/L, N-nitrosodimethylamine, and organophosphates. The reach of interest of USC and CC is of a length of about 3000 m, and a test site for hyporheic flow is located in a riparian forest, down to about 300 m from the injection point at the pump station for RW. At the test site, USC flows on alluvial fan deposits and some loss of recycled water into the subsurface can be expected. Below the alluvial fan lies partly well-permeable flood plain aquifer material, the ground water of which is used for the supply of drinking water. The catchment of USC consists to a considerable extent of ultramafic rocks (serpentinites). Preliminary analyses indicated that the total mineralization of USC water is similar to that of RW, but the fraction of some of the major constituents is different in the two waters. In the creek water (without augmentation), PFCs were consistently found in concentrations of up to about 0.1 g/L, and organophosphates and a plasticizer of up to 0.2 g/L. By 2007, the results of groundwater analyses will be discussed.

***Keywords:*** hyporheic zone, emerging contaminants, solute transport

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**HS1002** **Oral Presentation** **4016**

# Small-scale water- and nutrient-exchange between lowland River Spree (Germany) and neighbouring groundwater

***Dr. Joerg Lewandowski***

***Gunnar Ntzmann***

Water- and nutrient-exchange between surface water and groundwater affect the water quality of both water bodies and, thus, are important for their management. To find out more about the involved exchange processes we used a site surrounded by the current river bed and an old branch of the lowland River Spree, a 6th order river, near Freienbrink, north-eastern Germany. Water levels and temperature in River Spree, in its old branch and in 12 groundwater wells of a 300 m long transect were collected automatically with data loggers in order to model groundwater recharge and water exchange between surface water and groundwater. Bi-weekly phosphate, nitrate, ammonium, sulphate, dissolved iron and chloride were determined in the wells to investigate nutrient exchange. Additionally, in the hyporheic interstitial pore water samplers with a spatial resolution of 1 cm and novel flow microsensors with a resolution of 100 µm were used to study the exchange processes. Performance of the methods and limitations are critically discussed. We observed high spatial and temporal variabilities of concentration. Exchange pattern between surface water and groundwater is much more complex than previously thought. Infiltration and exfiltration of the surface water into the groundwater alternate depending on precipitation and water level fluctuations of the River Spree. Surprisingly high phosphate concentrations in the groundwater (more than 1000 µg PO4-P/L) are probably due to peat mineralization of relictant layers in the soil or cattle breeding on the study site. Long-term data also indicate that phosphorus concentrations of the River Spree increase in this section of the river. We assume that this is caused by infiltration of phosphorus rich groundwater.

***Keywords:*** river groundwater exchange, nutrients

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**HS1002** **Oral Presentation** **4017**

# Interaction between groundwater and surface water transferred from Yellow River

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***Fadong Li, Xianfang Song, Akihiko Kondoh, Guoying Pan, Yintao Lu***

The Yellow River to Weihe River water transfer (YWWT) project in Henan Province, China was launched thirty years ago in order to meet the water demand for agricultural irrigation and local development of society and economy, and to increase the runoff of Weihe River which passes through the Xinxiang, a main city of Henan Province. The YWWT project transports water from south to north and converges into Weihe River at east of Xinxiang. Around the outskirt of Xinxiang city, agricultural irrigation consumes more than 70 percent of the total water supply. Increasing water demands associated with rapid urban and industrial development have led to overexploitation of both surface and the groundwater resources. Consequently, the environment of interaction between groundwater and surface water transferred from Yellow River had also been changed extremely. In order to release the changed relationship between surface water and groundwater, water samples along the YWWT project which located around the outskirt of Xinxiang city were taken for electrical conductivity(EC), hydrochemistry and stable isotopic analysis to determine the hydrologic effects of the project on water environment and surface-groundwater interaction. The field survey and the geochemical analyses of the groundwater samples indicate that the local groundwater system can be divided into three zones (south, middle, and north) along the transferred canal. The surface water sampled from canal is 1 and 2 per mil more depleted in delta18O than most of the water in middle zone and in north zone respectively. From the south transferred canal to the outlet intersected with Weihe River, the EC and SO4 in groundwater increase significantly. The results show that the transferred water is interacting with the local groundwater system, especially, in south zone of the region. Moreover, The results imply that the transferred water from Yellow River is remitting the salinization of local groundwater system. As groundwater flows along the canal from the recharge zone in south to the middle zone in center and discharge zone in north, chemical patterns evolve in the order: Ca-HCO3 >Na-Mg-SO4 > Na-SO4. In addition, the stable isotopic ratios of surface water and groundwater provide a mechanism to assess the potential for future degradation of groundwater system around Xinxiang city. These data provide information relevant to the constructing south-to-north water transfer (SNWT) project in China for its groundwater quality management and protection.

***Keywords:*** surfacewater, groundwater, interaction

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**HS1002** **Oral Presentation** **4018**

# Hydrological droughts: role of aquifer-stream interaction

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***Lena M. Tallaksen***

Drought is a sustained and regionally extensive occurrence of below average natural water availability, and can thus be characterized as a deviation from normal conditions. It occurs in all hydroclimatological regions, although frequency and severity vary. Droughts start with a precipitation deficit over a large area and for an extensive period of time (meteorological drought). The deficit propagates through the terrestrial part of the hydrological cycle and may give rise to hydrological droughts (groundwater and streamflow droughts). A thorough knowledge of drought generation is required for proper management of groundwater and surface water resources that respects biodiversity and ecological functions of both groundwater and surface water. It is even more pressing because global change is likely to increase frequency and severity of droughts. This first part of the paper describes how soil and aquifer processes, i.e. subsurface water flow and storage, determine the development of streamflow droughts. Drought events are derived using the threshold level method and characterized in terms of duration and deficit volume (severity) of the event. The response of aquifers with different properties (quickly and slowly responding) to meteorological droughts is explored. Results are provided for two climates, i.e. a temperate, humid climate (Noor catchment, Belgium/Netherlands) and a semi-arid climate (Upper-Guadiana, Spain). The modeling results confirm the catchment control in modifying the drought signal, from a series of short duration drought in rainfall through fewer and longer droughts in groundwater and streamflow. This applies both to the quickly and the slowly responding aquifers. The longest duration of streamflow droughts is found for slowly responding aquifers and semi-arid conditions. The second part of the paper describes the interaction between surface water systems on groundwater in lowland areas and the effect it has on the generation of groundwater and streamflow droughts. This is illustrated through modeling studies of catchments with different properties, including a sandy aquifer, a dense drainage network and controlled surface water levels in the East Netherlands. The results demonstrate that water management measures that raise surface water level result in less severe groundwater droughts, but in more frequent and severe streamflow droughts. Some projected measures will lead to 40-50% longer streamflow droughts and 60-70% higher streamflow deficits dependent on the catchment properties. The paper concludes with research needs necessary to advance our understanding of aquifer-stream interaction on drought generation.

***Keywords:*** drought, propagation, modeling

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**HS1002** **Oral Presentation** **4019**

# Effect of forest stand succession from conifer trees to broad-leaved evergreen trees on infiltration/percolation and groundwater recharge processes

***Prof. Tadashi Tanaka***
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In a warm-temperate region, the climax of forest stand is affected mainly by the air temperature. So, if the possible global warming will occur, the species of forest stand climax will change and the succession will progress. Under the climatic condition like Japan, it is predicted that the global warming may cause the succession from conifer trees to broad-leaved evergreen trees, and the latter forest area would expand in near future. On the other hand, the succession of forest stand could cause the change of forest water balance. Our former results indicate that the succession from Japanese red pine (Pinus densiflora Sieb. et Zucc.) to evergreen oak (Quercus myrsinaefolia Blum) causes the change of water balance component in the forest: there was a substantial increase in stemflow and a substantial decrease in interception, comparing the results of forest water balance during a 17-year period for which 75 % of Japanese red pine had been removed by the succession. These changes of water balance components due to the succession are also expected to affect infiltration/percolation and groundwater recharge processes. The study was conducted at Japanese red pine forest, of which the succession proceeds about half stage to the climax, within the Terrestrial Environment Research Center (TERC), University of Tsukuba, Japan. The observation site was instrumented intensively for monitoring the spatial and temporal variability of inputs on forest floor and its influence on potential distribution in both unsaturated and saturated zones. Field evidence concerning infiltration and percolation phenomena underneath the different species of forest stands provides us an important nature of water distribution within the unsaturated zone due to its different amount of input onto the soil surface and different water uptake depths by different stand species. Field data obtained by intensive observation also indicate that the stemflow is significantly more effective than throughfall as a source of concentrated inputs in infiltration/ percolation and groundwater recharge processes. Furthermore, the results of observation suggest that the succession from conifer trees to broad-leaved evergreen trees, of which succession is predicted to occur in near future less than 100 years later according to the global warming, will affect strongly the groundwater recharge process depending on changes of forest structure and the differences of root form and its distribution pattern between stand species. This means that the succession of forest stands due to the global warming may be a crucial matter for considering hydrological and ecological responses in a catchment in near future. The results presented here also imply that it is necessary to design more intensive instrumentations for monitoring spatial and temporal variability of water movement in both unsaturated and saturated zones to make clarify the interaction between groundwater/surface-water systems in a future work.

***Keywords:*** succession, forest stand, groundwater recharge process

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**HS1002** **Oral Presentation** **4020**

# Coupled modeling of groundwater and surface water for renaturation planning in the National Park Lower Odra

***Prof. Stefan Kaden***
*IAHS*

The National Park Lower Odra is located along the Odra river at the border between Germany and Poland. For the park a series of measures have been planned to improve the natural water system. Major parts of the region are controlled polder areas (inundation areas), which are flooded during the winter season. The planned measures include the prolongation of flooded periods for ecological reasons and the construction of a natural like river course parallel with the Odra River through the polder area. Because in the study region surface water and groundwater are closely interrelated, the planned measures cause a number of conflicts, e. g. related to agriculture and biotopes due to changing groundwater tables. In order to analyze the impacts of the planned measures and to optimize those, WASY has been asked to develop and apply a coupled groundwater - surface water model system. For that purpose the WASY groundwater simulation system FEFLOW has been coupled with the DHI hydrodynamic simulation system MIKE11. With the recently developed IFM-Tool (FEFLOW Interface Manager) it is now possible to model the interaction surface water groundwater effectively. For the coupling of FEFLOW and MIKE 11 the module IfmMIKE11 has been developed. Water levels of MIKE11 are imported to the boundary conditions of FEFLOW and discharges along the branches being calculated by FEFLOW are exported to the MIKE11 calculation points. A big advantage of the module is the fact that the assignment of the FEFLOW boundary points to the MIKE11 calculation points can be realised fully automatically. By use of observation point groups and reference distributions (both are options inside FEFLOW) this can be optimised. Further more, a comfortable GUI enables the user to check the assignment being made as well as to observe the interaction while simulating. In the presentation the coupled model for the National Park Lower Odra will be explained and examples of its use for conflict analysis (urban areas, biotopes, agriculture, flood protection, water quality etc.) and planning of the water system in the park are given.

***Keywords:*** coupled modeling, innundation areas

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**HS1002** **Oral Presentation** **4021**

# Interaction between near-surface groundwater and water in drain ditches in lowland areas

***Dr. Britta Schmalz***
*HS1002 HS1002 IAHS*

The aim of our project is to detect nutrient entry pathways and to develop a methodology to model water quality efficiently in a complex hydrologic lowland catchment. In a nested approach we examine three catchment areas which cover different scales: a) Treene catchment 517 km, b) Kielstau catchment 50 km, c) drained section of Kielstau catchment 0.15 km. The investigation areas are located in Northern Germany as a part of a lowland area with low hydraulic gradients and near-surface groundwater. Sandy, loamy and peat soils are characteristic for the catchment. Land use is dominated by agriculture, pasture and forest. Various river regulations and drainage changed the natural water balance. For an assessment of water balance and quality we analyzed data from own measuring campaigns since 04/2005 and from German authorities. Ecohydrological models with the river basin scale model SWAT (Soil and Water Assessment Tool, ARNOLD et al. 1998) were compiled for the Treene and Kielstau catchments. Because of problems at calibrating and validating discharge dynamics in the models a better understanding of the transport processes was required. Therefore we selected a section of the Kielstau catchment where various ditches drain a pasture area. Various gauges in the ditches and in the river Kielstau and groundwater tubes near the ditches were installed to measure water levels and quality in a high spatial and temporal resolution. The measurement results submit different reaction behaviour of the water levels between the various drain ditches and also in comparism to the river Kielstau. In relation to the groundwater levels the flow directions and the interaction between groundwater and stream water was analyzed. Especially under lowland conditions a high interaction and changing flow directions are generally visible and can be confirmed with this analysis. Water quality analyses support the water level investigations and reveal the same conclusion. Furthermore chemical reactions and dilution in ditch profiles or nutrient entry pathways into the ditches can be observed and identified like subsurface drainage. Using this detailed investigations flow and transport processes can be derived. The nested approach assists to improve the process understanding for ecohydrological model approaches by using data of different scales. The presented approach provides a possibility to conduct analyses of watersheds in terms of the European Water framework directive (EU 2000), which sets up an examination of river catchments as spatial units and of interactions between water bodies and their environment.

***Keywords:*** lowland catchments, ecohydrological models, eu wfd

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**HS1002** **Oral Presentation** **4022**

# The role of alluvial valley deposits in groundwater surface water exchange in a Chalk River, Southern England, UK

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***Paul Shand, Daren Gooddy, Denis Peach***

The Chalk aquifer and Chalk rivers of southern England provide a significant water resource, but are most important for their role in sustaining surface water ecosystems and their associated diverse flora and fauna. River flows are mostly sustained by groundwater discharge from the Chalk aquifer which contributes as much as 80-95% of total flow. Many Chalk rivers have been impacted by point-source and diffuse pollution from agriculture and other anthropogenic sources. However, little knowledge is available on how pollutants are transported to the river and significant uncertainties exist in our understanding of the interaction between river and groundwater systems. However, such knowledge is important to establish potential pathways of pollutant inputs to the river-system and to understand and quantify the likely response-time between a pollutant entering the system and its subsequent emergence in the surface-waters. In particular, the role of alluvial valley deposits needs to be considered as they may present pathways of preferential flow through the catchment that will further complicate the pattern of surface water-groundwater exchange. In order to better understand the processes of surface water groundwater exchange in chalk catchments, a detailed study was carried out in the Lambourn catchment in Berkshire, south east England. Monthly monitoring of the river and groundwater levels together with the water chemistry has highlighted a large degree of heterogeneity at the river corridor scale. The data suggest an irregular connection between the river, the alluvial deposits (gravels and sands) and the chalk aquifer at the monitoring site, and also imply that enhanced connectivity must exist upstream of the site as indicated by the presence of a river component in both, the alluvial and the Chalk groundwaters. The groundwaters in the alluvial gravels represent a mixture of river water and deeper (Chalk) groundwaters, but simple two-component mixing can not describe the data and additional processes are required to explain the hydrogeochemistry in the alluvial deposits. The alluvial gravel deposits provide an important lateral flow pathway for pollutant transport along the river valley corridor, the river being only part of the story of how water moves in the river corridor.

***Keywords:*** chalk, river corridor, hydrochemistry

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**HS1002** **Oral Presentation** **4023**

# Watershed analysis of spatially and temporally varying nitrate transport as a result of agricultural inputs

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***Margaret E.A. Scott***

An important step in developing a watershed scale surface water and groundwater quality model is the determination of spatially and temporally varying agricultural contaminant loadings. Management of a watershed requires the determination of the effect of agricultural practices on long-term groundwater quality and to identify locations within the watershed that are at a higher risk of contamination. This study focuses on the transport of nitrate through the root zone as a result of agricultural inputs with attenuation due to biodegradation. The driving force for transport is spatially and temporally varying groundwater recharge that is a function of land use/land cover, soil and meteorological inputs. The Grand River Watershed is one of the largest watersheds in southwestern Ontario with an area of approximately 7000 square kilometers. Ninety percent of the watershed is classified as rural, and 80 percent of the watershed population relies on groundwater as their source of drinking water. Fertilizer sources are determined from Statistics Canadas Agricultural Census and include livestock manure and a popular commercial fertilizer, urea. Accounting for different application rates based on farm best management practices yields 60,066 unique land parcels of which 22,809 are classified as croplands where manure and inorganic fertilizers are directly applied. The transport for the croplands is simulated over a 14-year period to investigate the impact of seasonal applications of nitrate fertilizers and farm best management practices on the concentration leaching from the root zone to the water table. Based on land use/land cover maps, ArcView GIS is used to define the location of fertilizer applications within the watershed and to spatially visualize data and analyze results. The large quantity of input data is stored and managed using a relational database management system. Nitrogen transformations and ammonium and nitrate uptake by plants and transport through the soil column are simulated on a daily basis. Nitrogen transformations within the soil column were simplified using parameters that were obtained from literature or could be calculated from readily available soil information for the Grand River Watershed. Spatially and seasonally averaged results for the 14 year period indicate that nitrate leaching through the root zone does not exceed the maximum contaminant level (MCL) of 10 mg/l nitrate. However, in 1992, over 12 percent of the watershed area in crops exceeded the MCL during the winter season. The characteristically well drained soils of the central region of the watershed are more susceptible to groundwater contamination following autumn manure-N applications, as no crop-growth is present to remove excess nitrogen from the system. Therefore, farm best management practices do not ensure that groundwater contamination will not occur. Municipalities can utilize this model as a management tool to determine the extent of contamination and delineate site sensitive locations, such as well-head protection zones. Other applications of this model include risk assessments of contaminant migration due to climate change predictions, varying fertilizer application practices, modifications in crop management and changes in land use. The impact of climate change on recharge has been investigated.

***Keywords:*** nitrate transport, agriculture, watershed model

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**HS1002** **Oral Presentation** **4024**

# Transient peat properties and peatland pond interactions in the sub-humid western boreal plains, Canada

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***Kevin J. Devito, Stephen Kaufman, Jonathan S. Price, Uldis Silins, Carl Mendoza***

In the Canadian Western Boreal Plain (WBP), wetlands (ponds and peatlands) comprise up to 50 % of the landscape, and represent unique habitat where summer precipitation is often outpaced by evapotranspiration and hillslope groundwater position does not follow topography. In this sub-humid WBP, groundwater fluxes and stores in riparian peatlands influence pond water levels and root zone moisture sources for forested uplands. To accurately describe the transport and retention properties of water in peat, it is important to consider peat subsidence. This paper quantifies the amount and effect of season subsidence in a riparian peatland in the Utikuma Lake region in North-Central Alberta, Canada. Results demonstrate that the deep, and poorly decomposed, peat deposits in the WBP are resistant to compression, and that thick (and persistent) ground frost hinders pore collapse (compression) above the water table until late summer when the ground has thawed. Even then compression is still limited to the top 50 cm and is not well related to changes in peatland water table or pond water level. Thus, the water balance of these ponds and riparian areas appear to be less sensitive to peat-volume changes than it is to the persistence of a substantial frost layer well into the snowfree period.

***Keywords:*** peat, subsidence, wetland

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**HS1002** **Oral Presentation** **4025**

# Modelling nitrate export from lowland catchment systems the role of seasonal factors and hydrologic controls

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***Joris Spindler, Michael Rode***

Field data from the study catchment Schaugraben (NE-Germany, Saxony-Anhalt) revealed a nitrate loss in the order of 50% of the soil input and strong seasonal fluctuations of in-stream nitrate concentrations, with highest concentrations (up to 35 mg/l NO3-N) in winter and lowest in summer (nitrate free), correlating well with other seasonal variables such as temperature and discharge. The objective of our modelling approach was to identify the most important factors controlling nitrate export from a lowland catchment. We developed a distributed catchment scale model, based on the combined application of a soil nitrogen model (mRISK-N) and a reactive groundwater model (MODFLOW and RT3D) to study the interaction of nitrate transport and reactive processes with spatial and geochemical catchment characteristics. Additionally we carried out numerical experiments to study the effect of seasonal changes of the hydrologic system on nitrate export. Based on the groundwater models MODFLOW and MT3DMS a two-dimensional groundwater model was set up representing a simplified catchment with a main and a tributary drain channel and two land use classes, grassland (between main and tributary channel) and agriculture (beyond tributary channel). A steady-state simulation, based on average groundwater recharge and nitrate loads, was compared with a transient simulation based on monthly lysimeter data. Groundwater denitrification was considered in a simplified reaction approach, assuming no denitrification (conservative transport) as well as first-order decay of nitrate based on half-life times of 2, 1 and 0.5 years. The catchment scale model gave insight into the effect of the spatial distribution of source areas and the role of reactive processes in affecting nitrate export from the system. The position of source areas in relation to the stream system was an important factor controlling nitrate export. The results of the transient simulations showed that seasonal changes of the flow system are a possible mechanism explaining dynamics of in-stream nitrate concentrations at the catchment outlet. The connection of nitrate-rich groundwater via tributary channels to the main channel increased both, discharge and nitrate export. Sinking groundwater level disconnected nitrate rich areas from the main channel reducing total discharge and nitrate export. Assuming denitrification affected the concentration levels but did not change general concentration dynamics. The quantitative effect of this hydrological mechanism may be different in individual catchments depending on the stream and channel configuration and proportion of land use types. Temperature dependent denitrification processes or plant uptake may be superimposed to the hydrological mechanism, amplifying seasonal concentration changes.

***Keywords:*** groundwater dynamics, nitrate, seapage

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**HS1002** **Oral Presentation** **4026**

# Groundwater flow systems in South Pare Mountains, Tanzania

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***Robert Kirya Mutiibwa, Jan Willem Foppen, Stefan Uhlenbrook, Hubert Savenije***

In recent years, population growth on the hill slopes of the semi-arid South Pare Mountains in Northeast Tanzania has increased water usage. Water availability is directly dependent on the groundwater/ surface water interaction, which in itself is dependent on the hydrogeology of the catchment. In order to better understand the hydrogeology of the area, a groundwater flow systems analysis was carried out for two adjacent meso-scale catchments (Makanya and Mbaga; both around 300 km2). Extensive geological mapping and spring sampling were carried out. Some 300 water samples were collected from inside and around the catchment and analysed for all major cations and anions, including dissolved silica. Due to a combination of the dipping and faulting of the geological units, a substantial amount of water is draining out of the Makanya catchment into the Mbaga catchment. In the elevated parts of the catchments, springs contributing to base flow were found in old rockslides, consisting of weathered parent rocks. Water quality in these parts was mainly determined by silicate weathering, with concentrations generally increasing with decreasing altitude. In the lower parts of the catchments, several springs contained high amounts of sodium, chloride and sulphate and did not compare with water quality found uphill. It can be concluded that two distinct flow systems exist in the catchment: a local system, defined by the limited thickness of the weathered material and landslides, and a regional flow system that was most likely controlled by regional faulting. This case study demonstrates how hydrochemical methods can be used to analyse groundwater flow systems.

***Keywords:*** hydrochemical, groundwater, flowsystems

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**HS1002** **Oral Presentation** **4027**

# Comprehensive physics-based hydrologic-response modeling: examining the impact of a forest road

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***Brian Ebel, Keith Loague***

Recent advances in the fields of geomorpholgy and ecology have highlighted the importance of understanding near-surface hydrologic processes. Particular emphasis is currently being placed on characterizing and quantifying fluxes between surface and subsurface waters. More that 35 years ago Freeze and Harlan proposed a blueprint for a comprehensive physics-based hydrologic-response model, based upon numerical solution to the coupled partial differential equations describing movement of water on the surface and within the variably-saturated subsurface. The Integrated Hydrology Model (InHM), a full realization of the Freeze and Harlan blueprint, was designed to quantitatively estimate, in a fully-coupled approach, 3D variably-saturated flow and solute transport in porous media, 3D variably-saturated flow and solute transport in macropores, and 2D flow and solute/sediment transport over the land surface and in open channels. InHMs first-order coupling facilitates detailed examination of interactions that are not obvious, thereby advancing our understanding of the non-intuitive interplay between processes that are not mutually exclusive. One example of anthropogenic influence on near-surface hydrologic response processes are forest roads, which introduce near-surface permeability contrasts and change the topography at the road-cut. Forest roads are known to cause an increased likelihood of overland flow, seepage, and slope instability. This study uses InHM to examine the hydrologic impact of a forest road on the C3 Catchment within the H.J. Andrews Experimental Forest (Oregon, USA). The C3 data set includes enough information to parameterize and evaluate InHM for continuous hydrologic-response simulations over a 43 day period. InHM simulations were conducted in both 3D and 2D for the C3 catchment. The results from the 3D InHM simulations compare well with the C3 observations of runoff and total head. Concept development analyses include assessments of spatially and temporally variable soil-water contents, subsurface pore pressures, surface water depths, and groundwater-surface water interactions. The 3D simulations show that (i) discharge is dominated by subsurface stormflow exfiltrating from the roadcut, (ii) Horton overland flow occurs only on the road during high intensity rainfall, (iii) positive pore pressures develop within the hollow at the soil/bedrock interface, and (iv) subsurface flow in the saturated zone converges to the axis of the hollow. Simulation results also highlight the importance of transient versus steady-state simulation, 3D versus 1D/2D boundary-value problem characterization, continuous versus event-based simulation, and some problems inherent to rigorous assessment of model performance.

***Keywords:*** hydrologic response, modeling, forest road

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# An Integrated Systems Model for Conjunctive Water Use, Angas-Bremer Prescribed Wells Area, South Australia

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The Angas-Bremer irrigators have learnt about conjunctive water use the hard way. This premier wine-grape region in South Australia, near the mouth of the Murray, has learnt the perils of over-exploitation of groundwater resources and the vagaries of reliance on surface waters, but continues to grow as an irrigated region, with a ten-fold increase in area under vines over the past 20 years. Even so, concerns over future expansion and unsustainable use of water resources have driven a number of recent initiatives trying to understand aspects of the complex interaction between surface and ground water supplies and, in particular, the effects this has on salinity of these resources and the potential for irrigation-induced salinisation of the region. Expansion of the floodplain for irrigated agriculture (particularly lucerne) was accelerated in the 1950s by groundwater extraction leading to severe depletion of a deep aquifer and near-surface salinisation and mounding of a shallow one. Regulation and development of surface water supplies (pipelines from an adjacent lake) combined with an increase in vines and decrease in lucerne reduced dependence on groundwater as well as overall water consumption. Restoration of sustainable water resource conditions, however, requires impetus from flood events, emphasising the importance of floods in the health of the environment and sustainability of the resources. Increasing numbers of farm dams in the upper catchment are thought to be threatening this important process, while reduced flow in the Murray, which is the main feeder for the lake, threatens this major surface water supply. An integrated systems model is being developed that combines groundwater modelling, airborne geophysics interpretations, soils mapping, digital elevation models, climate assessment and socio-economic evaluations to assess drivers and levers and provide what if? scenario testing capability for the resources managers. Crucial to this is an understanding of surface-groundwater interaction and a combination of airborne and ground electromagnetic surveying, coupled with airborne radiometrics and on-ground soil investigations, has provided a framework, while chemistry and isotopes have been used to assess partitioning between surface waters, shallow and deep aquifers, and assess the role and rates of recharge and transfer within the system. The systems model will be constructed using the TIME (The Invisible Modelling Environment) framework, facilitating a shorter development and testing cycle, greater ease of use, and eventually delivery through the World Wide Web which will allow for the widest possible user base both in technical experience and spatial scale. Constraints can be imposed on scenarios to test the system response to market and social drivers and environmental threats to water supplies and important wetlands and red gum stands. Thus, a multi-disciplinary team is required with significant input from local and regional resource managers to generate realistic frameworks in which to impose potential threats and to assess the bounds of the systems response.

***Keywords:*** integrated systems model, conjunctive water use, airborne geophysics

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# Protection against flooding and nature restoration in the Demer Valley

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The Demer between Diest and Werchter is a typical example of a Belgian river manipulated to meet different needs of the inhabitants of the valley. Historically, the river was calibrated for shipping purposes, and to provide the necessary capacity to accommodate peak discharges. However, rectification, deepening, the construction of embankments, resulted in the loss of the relationship between the river and its natural flood plane. The lower water levels in the river resulted in a decline of groundwater levels in the valley, while seepage and groundwater dependent habitats were pushed back to the edge of the valley. Moreover, recent floodings show that the embankments provide no efficient protection, as several built-up areas remain inundated, while several large natural flood planes are not flooded at all. As the river lost its function as a waterway, the authorities decided to combine protection against flooding with restoration of the wetland nature of the valley, but keeping in view of the today?s claims of agriculture, forestry, industry, and town and country planning. As both surface and groundwater were identified as steering variables, much work was devoted to their complex dynamic interaction. This presentation/paper is focused on the corresponding study. Detailed surface and groundwater modelling was used to describe the flooding and the surface and groundwater flow in the valley. Both steady state and transient models were calibrated using flow and head data available throughout the valley. The coupling between the models allowed to investigate the effect of surface water levels on the ground water levels throughout the seasons, and to calculate relevant groundwater levels for the prediction of different nature types. The calibrated models were used for the evaluation of effects of scenarios consisting of a group of measures on both protection against flooding and perspectives for nature restoration. The scenarios include the involvement of the natural flood plane in protection against flooding by removing and relocating the embankments, the reconnection of once cut-off relict meanders, the restoration of the original, shallower and narrower bedding morphology, together with the restoration of historical monuments such as water mills. These measures also aim to reinstate higher stages during base flow conditions. Where necessary, the construction of safety dikes alongside houses was considered for protection against flooding. The scenarios were optimised in order to obtain the best possible hydrological conditions for nature development against the requirement of protection against flooding, and keeping in view the claims of the concerned sectors. The most feasible scenario is now subject of a detailed design project for a shortly upcoming realization.

***Keywords:*** flood protection, nature restoration, river management

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# Groundwater and surface water interactions: past achievements and future challenges

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As a result of hot and arid climatic conditions throughout most of the interior of Australia, evapotranspiration far exceeds precipitation. This has resulted in the accumulation and concentration of cyclic salts in the environment. The relatively low topographic relief of the continent combined with low rainfall and inland draining groundwater systems means that salts cannot be flushed from our rivers and groundwaters at the same rate that it has accumulated. This build up of salinity is the major environmental problem facing Australia today. Salinisation of large portions of the Australian continent has been accelerated by the large-scale replacement of native vegetation with shallow rooted crops. This has increased both groundwater recharge and saline groundwater discharge to rivers. This presents exciting new research challenges, not only in the arid zone, but also in fractured rock hydrogeology where salt accumulates. Research over the past few decades has been driven by the paradigm that a change in recharge rates has increased the advective driving head, which has resulted in an increase in salt loads to the river. This recharge-centric view of salt loads to rivers, although making a large contribution to understanding groundwater surface water interactions in Australia, has in large neglected to examine two important mechanisms that have the potential to impact upon salt discharge to the river, namely: (1) Groundwater discharge processes directly to the river. This is important because discharge represents the ultimate terminus of the groundwater flow system as well as the location where salt enters the river, and; (2) The potential role that density driven flow may have on groundwater flow dynamics. Whilst numerous authors have examined groundwater discharge behaviour into rivers, the influence of density differences between a fresh river and saline groundwater, which often exit, are typically not discussed. An in-stream coring and sampling investigation along the River Murray in South Australia has enabled for the first time the collection of groundwater samples beneath the river bed. The results of this investigation surprisingly revealed extremely high concentrations of groundwater salinity (> 50, 000 ppm) at depths of less than 1 m below the river-sediment interface. These salinities (in some locations) are higher than those observed in adjacent floodplain groundwater wells. These results raise a number of intriguing questions. What is the origin of salt beneath the riverbed? What is the fate and mobilization of this stored salt? How stable is the saline-fresh water interface ? Does or will this high salinity groundwater breach into the river and if so, what impacts will this have on salt loads to the river? Understanding groundwater-surface water interactions in heterogeneous fractured rock catchments presents exciting challenges for future research. Traditional hydrological models of transient stream flow response assume that stream flow hydrographs are, in general, controlled by surface runoff, shallow interflow in the weathered soil zone (regolith) and deeper groundwater baseflow. It is typically assumed that (i) the rising limb and peak in a storm event hydrograph is controlled by quickflow - a shallow fast interflow response controlled by flow within the regolith/soil zone as well as by substantial overland runoff and that (ii) the delayed

***Keywords:*** australia

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# Towards a better conceptual understanding of groundwater surface water interactions in fractured rock catchments

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The relationship between land clearance and increasing salinity in rivers is well established in Australia. Increases in salinity are related to the replacement of native vegetation by shallow rooting crops allowing increased recharge. This has caused mobilisation of salt stored in the shallow regolith and/or increased groundwater discharge. However, the impacts on flow pathways in fractured rock catchments are poorly understood. Hydrochemical comparisons were made between rivers in cleared (Cygnet River) and pristine catchments (Rocky River) overlying fractured rock aquifers on Kangaroo Island, which forms an extension of the Mt Lofty Ranges in South Australia, in order to assess differences in water chemistry and sources of water at different times of the year. A range of tracers was used including major and trace elements, 222Rn, d2H, d18O, 87Sr/86Sr and CFCs. The rivers in the cleared Cygnet catchment had high SEC (1120-59000 S cm-1), although this was spatially variable. The samples in the lower Cygnet catchment showed a greater increase in salinity and enrichment in d2H and d18O during the drier summer months, whilst high 222Rn concentrations in the headwaters and several tributaries indicated significant groundwater inputs to the river. 87Sr/86Sr ratios showed that much of the Sr is not derived from rainfall, and a non-marine source is significant. The Rocky River catchment is a pristine wilderness catchment, supporting native flora and fauna, including platypus in fresh water pools. Stream water salinity was remarkably low (SEC 300-600 S cm-1). Although the lower reaches of the river dried up in summer, the middle-upper reaches flowed all year round and the small change in d2H and d18O indicated little evaporation. Relatively high 222Rn concentrations around the Platypus pools suggest that this is an important area of groundwater discharge. 87Sr/86Sr data showed three sources of Sr: marine (from rainfall); silicate weathering of Pre-Cambrian metasediments, and Pleistocene calc-arenite. Although no groundwater wells exist, there is a significant storage of salt storage in the soils (Cl up to at least ca. 7000 mg L-1). A number of streams in the Cygnet and Rocky catchments were sampled prior to and following a large storm in June 2005. The responses of the two catchments were very different: in the larger Cygnet catchment, the flow response was more rapid and overland flow was important. This is likely to reflect changes in by-pass flow mechanisms through the soil and regolith in cleared land. The fresh waters in the Rocky River indicate rapid bypass flow through the salt store to the water table indicating a contribution to stream flow from deeper flow paths than previously postulated. The changes in river hydrochemistry and tracer data following the storm could not be explained by a simple dilution with rainfall and show that a range of processes and sources must contribute to streamflow generation in these catchments. The results of this study will be of fundamental importance to many aspects of fractured rock catchment scale water resource management issues including salt loads to streams, assessment of groundwater dependent ecosystem water requirements and dependencies and conjunctive groundwater-surface water management.

***Keywords:*** fractured

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# Mechanisms of saline groundwater discharge into the River Murray Australia

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Understanding the interaction between surface water and groundwater is important for the effective management of water resources. While variable density flow has been studied intensely in a number of settings, the influence of variable density flow on the discharge behaviour of saline groundwater into fresh rivers is generally neglected when calculating salt loads into a river. Field investigations along the River Murray in South Australia showed that fresh river water is generally directly underlain by high salinity groundwater. The aim of this study was to test whether or not and to what extent variable density flow can suppress discharge of saline groundwater directly underneath a fresh river. The mixed convection ratio M, as a measure of the dominance of either advection or density driven flow, was explored and a matrix of numerical simulations with variable hydraulic and density gradients developed for this purpose. Vertical salt breakthrough into the stream only occurs in the advection dominated cases (M<1), where the flow direction points towards the river. When the flow is driven by the density difference between the two fluids (M>1), no vertical breakthrough of mass occurs into the river. The saltwater-freshwater interface occurs at greater depths, the larger the density difference between the two fluids. The absolute amount of salt discharged is a function of hydraulic and concentration gradients between the two fluids and the hydraulic conductivity of the riverbed. The salt flux into the stream only increases with increasing concentration until the mixed convection ratio reaches a value of 1, and later becomes zero as the flow direction reverses or stagnates in the density dominated cases. Therefore, a simple density invariant approach to estimate the vertical salt flux into a stream is inadequate when large density differences exist between surface and groundwater. Field data, including hydraulic, hydrochemical and isotopic data obtained from beneath the River Murray in South Australia are used to better define and constrain the developed conceptual model.

***Keywords:*** salinity, river murray, australia

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# Colloid Facilitated Transport of Phosphorus through Agricultural Soil

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Expanding our understanding of the mechanisms by which contaminants are transported through the subsurface environment is essential for improving the management of water resources and protecting their associated ecosystems. Research into colloid facilitated transport of phosphorus through preferential flow pathways within the soil has the potential to enhance our appreciation of the possible risks posed to water quality by diffuse agricultural sources of phosphorus pollution. This is especially important in the light of the widespread use of land spreading as a means of sewage sludge disposal. While field scale monitoring was used to give some insight into the degree of phosphorus losses following sewage sludge application, laboratory based, physical modelling was used to explore the subsurface mechanisms involved in phosphorus transfer. Rainfall simulation experiments carried out on a series of large (60cm deep x 40cm diameter), intact soil cores and intact soil blocks (50cm3), were designed to allow investigation into the importance of the different size fractions and flow routes involved in subsurface transport of phosphorus. Particular emphasis was placed on discerning the significance the colloidal size fraction on phosphorus transport and assessing the potential for preferential flow pathways to act as routes for rapid transport of phosphorus to receiving waters.

***Keywords:*** colloid, phosphorus, soil

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# Coupling of surface water management and groundwater dynamics for mining pit lakes

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*IAHS*

***Uwe Grnewald, Kai Mazur***

The main tasks of Integrated Water Resources Management (IWRM) are the provision of water in sufficient quantity and quality, the conservation or recreation of functioning ecological systems, and the protection of society from damages or hazards caused by water. This means IWRM has to bring in line the location, quantity, quality, date, and probability of the water yield with the location, quantity, quality, date, and probability of water demand, using a minimum of funds. Economic, political and social forces as well as hydrological, ecological and climatic conditions have to be accounted for in this task. Especially in regions with mining activities the availability of surface water can be affected by groundwater drawdown due to these mining activities. In order to manage the available surface water resources in a sustainable way also groundwater dynamics have to be regarded in mining areas. In the lusatian mining area, located in Germany, large scale lignite mining was conducted for more than 100 years, leaving large mining pits to be filled with surface water and groundwater. Since the inflowing groundwater leads to extremely low pH-values and other water quality problems, the mining pits are planned to be filled by surface water preferably. However, due to unreliable and low surface water availability the implementation of the filling process, which will take 15 years approximately, requires a systematic planning. Therefore, a water management model using stochastic inflow series was used to account for lack of knowledge about actual future surface water availability. Functional chains between surface water and groundwater derived from a groundwater simulation model were included in the water management model. To enable the simulation of water management scenarios the functional chains derived from the groundwater simulation model had to be simplified to a certain extend, while the most important feedbacks can be reproduced. The direct inclusion of functional chains between surface water and groundwater enables the simultaneous calculation of effects caused by surface water management and corresponding groundwater dynamics. Results of the coupling will be presented and problems and their resolution will be discussed.

***Keywords:*** surface groundwater coupling, iwrm, miningareas

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# Weathering and geochemical processes controlling the geochemistry of surface, sub-surface and mine water in the upper catchment of Damodar River Basin, India

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The water bodies are continuously subjected to a dynamic state of change with respect to lithological characteristics and geo-climatic condition. This dynamic balance in the aquatic system is upset by human activities, resulting in pollution. Mining is one of the major activities causing water pollution. Damage to quality and quantity of surface water and ground water due to dumping of overburden (OB) and spoils or spreading of OB through rolling and washing may cause the chemical pollution. Damodar River Basin is known for its coal deposition and commonly refereed as the storehouse of Indian coal. Damodar River originates from the Khamerpet Hill, near Palamu and flows through the cities Ramgarh, Bokaro, Dhanbad, Asansol, Durgapur, Bardwan and Hawrah, before ultimately joining the lower Ganga (Hooghly estuary) at Shayampur. The upper catchments of the Damodar River basin are actively associated with mining activities for more than a century. More than 500 coalmines including famous Jharia coalfield, which produce prime coking coal, are located in the basin area. Besides, active open cast and undergrounds mine, there are number of abundant coalmines and associated dormant overburden dumps. The presence of active and abundant coal mines, overburden dumps, thermal power plants, coal washeries, coking coal plants and other coal based industries including refractories, steel, fertilizer and cement plants poses serious threats to the quality of available water resource of the area. In the present study, detail investigation of water chemistry of surface, subsurface and mine water of the upper catchment of Daomodar River basin has been carried out to know the source of the dissolved components of waters, geochemical factors controlling the water composition and the suitability of water for domestic, agricultural and industrial uses. The analytical results show that Ca, Mg, and HCO3 dominate the chemical composition of the water chemistry. However, in the mine water and water samples collected from mining areas having high concentration of sulphate and it replace the dominance of bicarbonate in the anionic abundance. Water chemistry of the study area strongly reflects the dominance of continental weathering aided by anthropogenic activities. Higher concentration of SO4, Cl and TDS in some samples indicates mining and anthropogenic impact on water quality. The high contribution of (Ca+Mg) to the total cations, relatively high (Na+K)/TZ+ ratio and low equivalent ratio of (Ca+Mg)/(Na+K) suggests combined influence of carbonate and silicate weathering. The higher value of C-ratio for most of the surface and subsurface water signify that carbonic acid weathering is the major proton producer in these waters. However, the low C-ratio for the mine water (average 0.22) and the waters collected near the coal mining areas suggests that either sulphide oxidation and/or coupled reactions (involving both carbonic acid weathering and sulphide oxidation) control the solute acquisition processes in the mining areas. It is observed that the quality of the ground water is suitable for domestic uses with some exception. The calculated values of SAR, RSC and sodium percentage indicate good to permissible quality of water for irrigation uses. However, the high salinity, %Na, Mg-hazard, and RSC values at certain sites restrict its suitability for agricultural purposes.

***Keywords:*** weathering, geochemistry, damodar

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# Optimisation of nature development scenarios for the integrated nature reserve of the Hemmepolder (Belgium)

***Dr. Roeland Adams***

***Eric Degand, Roeland Adams, Maurice Hoffmann, Florimond De Smedt, Hannah Van Nieuwenhuyze, Jean-Louis Herrier***

The Hemmepolder is situated between the dune belt of the Belgian coast and the estuary of the IJzer. The polders orgin goes back to the 14th century when people gained land from the tidal creeks by constructing dikes along the estuary. Recently, a naval basis in the estuary has been dismantled. Since then tidal mudflats and salt marshes develop again. As possibilities to develop nature along the Belgian coast are limited, the depoldering of the neighbouring Hemmepolder offers a unique opportunity to create an integrated coastal nature reserve, including different coastal environments such as the shore, the dunes and the estuary, with its mud and salt marshes, and by including the polder also part of the former creek system. Surface and groundwater modelling was used in order to determine the hydrological conditions, such as groundwater levels, inundation frequency and duration, for three totally different development scenarios: - the restoration of freshwater humid grasslands by non brackish rewetting of the polder - brackish grasslands development by controlled inlet of seawater - allowing free tidal action in order to create mud and salt marshes Nature potential and ecological benefits were predicted for these conditions. The measures needed to create the required hydrological conditions for the development of these nature types were derived from and optimised using the groundwater and hydraulic modelling. This allowed on its turn a reliable cost estimate. The nature benefits have been confronted with the effects on soil and groundwater in a multi-criterion analysis. The salinization of the groundwater, which contributes to the development of wet brackish grasslands and mud and salt marshes, is a threat to the fresh water lenses developed in the surrounding dunes. A density dependent groundwater flow model was used to study the development of a new salt-fresh water interface and to evaluate the consequences on the present groundwater extraction. The study demonstrates that for each scenario the optimisation using the mathematical models comes up with a cost-efficient solution (relative to the other variants within the scenario) with high nature benefits. Comparing however among the three main scenarios, it becomes extremely difficult to decide for one or the other scenario: nature benefits are obviously higher for the scenario with highest degree of salinization, the environmental consequences on the other hand weigh on the nature benefits.

***Keywords:*** nature development

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# Integrated simulations of the long term impact of hydropower development on river-flow groundwater interactions in the danubian flood plain

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The paper focuses on the understanding of the interactions between surface water and groundwater and their impact on the soil-water-plant system of floodplain areas of a reach of the Danube below Bratislava, Slovakia, which is subject to anthropogenic pressure due to hydropower generation. The alluvial area under the impact of the system consists of agricultural land, huge groundwater resources and unique forested flood plain ecosystems directly connected to discharge regime of the river and the groundwater regime. The changes in these regimes primarily depend on the operating rules of the hydraulic, energetic and hydro-ecological structures, on hydraulic properties of the studied river reach with its flood plains and that of the diversion channel. The possibilities of using analytical approaches to estimate the long term changes of these regimes are limited to rather simple scenarios. It was therefore necessary to develop adequate process conceptualizations and a methodology to simulate the operation of the system for a long period with a detailed time step using mathematical models. The impact of the alternative operation rules of a diversion type hydro- power station on the runoff regime of the reach of the Danube and the groundwater regime of the large left bank aquifer connected to the river has been studied and modelled. A multilinear flow routing model based on the state space representation of the Kalinin-Miljukov cascade was used together with a conceptual mathematical model of the power station to simulate eight decades of operation of the system using historical daily flow data for alternative operating rules. Simulated time series served as a dynamic boundary condition for groundwater regime modelling using a 2D finite element model to simulate the changes in the groundwater levels, which in turn were used as a boundary condition for the soil water plant system. For comparison the predicted uninfluenced hydrological conditions were modelled, too. The long term effects of the system operation on groundwater and surface water interactions have been studied and evaluated, the soil-water-plant system of adjacent areas and of the behaviour of aquatic ecosystems was also studied. Possibilities stream restoration in the floods plains, hydro-ecological consequences and potential benefits of diverse engineering measures were considered in the light of surface/groundwater exchange.

***Keywords:*** hydropower, simulation model, flood plain

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# Analysis of nutrient losses and associated data and parameter uncertainties in soil and surface water systems on catchment scale

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Quantification of the contribution of diffuse nutrient losses caused by agricultural activities is not well understood and not well defined. The EU Water Framework Directive demands the implementation of measures in order to reach the defined targets for water bodies. Models can be very helpful in defining the sources of nutrient pollution and the magnitude of relevant pathways. The NL-Cat modelling system has been developed to enable the assessment of the relation between agricultural land use and surface water quality at the catchment scale in a mechanistic way. The modelling system comprises of specialised modules for spatial discretisation, data processing, and process simulation. It has been widely recognized that risk assessment is a crucial part of the water management process. ncertainties in the quantification tools can be addressed, but a constraint for quantification is that uncertainty aspects are often complicated to deal with. The modelling system has been applied to the Regge catchment in the Eastern part of the Netherlands. The objective of this case study is to predict surface water concentrations and its associated uncertainty due to variability in parameters and input data. The propagation of a number of data and parameter uncertainties in the integrated model for soil and surface water has been analysed. Uncertainties with respect to land use data, fertilizer and manure application rates and meteorological variation affects the variability of the results most. The uncertainty associated with nitrogen concentrations reduces with the reduction of future N-surpluses. However, the uncertainty asscociated with phosphorus concentrations increases in time despite the reduction of P-surpluses.

***Keywords:*** modelling, catchment, uncertainty

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# Investigating the role of groundwater surface water exchange flows and streambed characteristics for natural attenuation of nitrogen species within the hyporheic zone of two UK streams

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Interactions between groundwater and surface water can affect the floodplain water balance as well as the stream discharge dynamics. As water passes through the hyporheic zone, exchange fluxes between groundwater and surface water control the advective transport of nutrients and pollutants and thus effect also its dispersive migration and spatial pattern of concentrations within the sediment. Within the hyporheic zone redox sensitive elements may be subject to natural attenuation. This study investigates the impact of physical riverbed conditions on the dynamic fluxes across the groundwater surface water interface as well as on transport and metabolism of nitrogen species. The investigation focus on several reaches of two UK rivers: the River Leith, Cumbria and the River Tern, Shropshire. The complex spatial pattern of physical riverbed characteristics were examined by 42 sediment cores which were taken during base flow conditions in summer 2006 along characteristic pool-riffle sequences and cross sections including mid stream islands and sandbanks. Eighty seven piezometers were installed in arrays at several transects and cross sections. Pressure head differences between the piezometers of different depths and the river have been recorded in order to observe the temporal and spatial dynamics of exchange fluxes along the groundwater - surface waters interface. In order to investigate the impact of physical riverbed conditions on the temporal and spatial pattern of redox sensitive nitrogen species within the hyporheic zone the sediment cores have been analysed for nitrate and ammonia concentrations in 5 cm steps. Stream water and pore water sampled in the piezometers have been analysed for nitrogen species at 4 dates corresponding with the hydraulic head observations. Additionally three nested arrays of 50 shallow sediment cores along characteristic features as mud banks and bare or reed covered islands were analysed for their nitrate and ammonia concentrations in order to quantify the potential effect of these geomorphic structures. The analyses of the hydraulic head gradients between the piezometers and the river detected complex spatial pattern and some significant temporal dynamics of fluxes along the groundwater surface water interface. Generally the groundwater is contributing to the river with variable intensities but also stream reaches which are gaining and loosing groundwater at opposite sites of a cross section could be found. The results of the chemical analyses detect that pore water nitrate concentrations are related to the physical streambed characteristics and the resulting intensities of exchange fluxes and flow directions as well as to the chemical conditions of the sediment material. The vertical distribution of nitrate within the analysed profiles is mainly characterised by a decrease of nitrate concentrations with depth. High concentrations of up to 8 mg/l could be found in shallow top gravel layers on top of in-situ sandstone, low concentrations in some organic rich and peat layers. Low nitrate concentrations within the sediment strongly corresponds with the amount of organic carbon as a reductive agent and the existence of anoxic conditions which promote denitrification. Within pools generally higher nitrate concentrations than in riffles were detected. The typical longitudinal pattern of a pool - riffle pool sequence was characterised by high nitrate concentrations in the pools, low nitrate concentrations in the beginning of a riffle (which we attribute to natural attenuation processes) and a subsequent increase towards the end of the riffle.

***Keywords:*** hyporheic zone, natural attenuation, nitrate

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# Why would a subsurface drained catchment export less or more water above a threshold flow rate?

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*ICCLAS Towards Improved Evaluation of Hydrological Model IAHS*

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Subsurface drained soils cover large areas in agricultural lands of North-western Europe and North America. Hydrology of these catchments is dominated by the response of subsurface systems. By lowering the shallow water table, drain pipes increase the dynamic storage capacity of water in soil and limit overland flow. However, during high runoff events, water table may reach soil surface and flow be limited in the buried network attaining its maximum capacity. Additionally, the actual flow regimes at the junction between drain collector outlets and collector ditches play a role in the overall ability of water to be exported. Our study intends to analyse the interactions between these three processes. A flow duration curve was derived using 40 years of recorded flow data on the artificially drained Mlarchez catchment (7 km2 in France). It shows an obvious inflexion point, which deserves interpretation. For that purpose, both subsurface flow rates and ground water elevation were monitored. Flow rates were measured in a pipe at the outlet of an all-drained 80 ha sub-catchment during 3 years. Water table elevation and soil water pressure heads were monitored at midpoint between drains and used as calibration and validation data for modelling purposes. The physically based model HYDRUS-2D has then been used to derive soil saturation probability occurrences. The flow duration curve threshold at the catchment scale can apparently be linked with either/both the occurrence of ponding conditions due to soil saturation at the plot scale or/and the hydraulic limitation associated to the buried drainage network. Ponded water is probably forced to eventually infiltrate because of both the lack of surface water network in the sub-catchment, and the ability of water to infiltrate above the drain. Observed peak flow retardation can be explained by this re-infiltration process, itself probably limited by the hydraulic maximum capacity of the buried network.

***Keywords:*** drainage, saturation surface runoff, hydrological threshold

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# Closing the catchment-scale water balance: a case study

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One of the still unsolved problems of Rainfall-Runoff (RR) modelling is that of the accounting for underground, discrete or diffuse (non-point source) gains or losses which affect the catchment-scale water balance. Once we have closed hydrologic textbooks and their nicely simplified diagrams, we have to face the fact that surface catchments lying on a continuous impervious horizon are the exception rather than the rule. In the same time, hydrogeologists encounter the greatest difficulties to estimate recharge, which is an essential boundary condition of groundwater systems, and often become angry at the few conceptual surface models they have to use for that task and that are not really designed for it. On this topic, Beven [2001] argued that we cannot currently close the water balance by measurement. Traditionally, there was no direct way of measuring actual evapotranspiration, so errors in the long term measured water balances tended to be assigned to the evapotranspiration term, despite the fact that we know that rainfall inputs, discharge outputs and changes of storage are not always accurately measured. [. . . ] There is still no way of checking whether the catchment is indeed watertight. The continuity equation is the most fundamental law in hydrology, but as a hypothesis it would appear that we cannot currently verify it at the catchment scale. The aim of this communication is to present a unique case of karstic catchment, the Touvre (Charente, France), where we can test the validity of estimates of catchment leakages: this spring is fed by the losses of three rivers, which are themselves gaged before and after they reach the karst. This setting is exceptional in that it allows confronting simulations of karstic losses with actual spring discharge measurements, and thus to validate (or at least evaluate) estimates of karstic losses from surface catchments. Of course the success obtained here should not be interpreted as a definitive demonstration of the validity of the intercatchment groundwater flow estimates provided by the model we used (the daily GR4J model, see Perrin, 2003). Many more of similar cases would be needed, but at least this study recalls the importance of the rainfall-runoff information as a way to estimate groundwater recharge, not only its fraction in annual water balance but also its dynamics. References Beven, K. J. (2001), On hypothesis testing in hydrology, Hydrological Processes, 15, 1655 1657. Perrin, C., C. Michel, and V. Andrassian (2003), Improvement of a parsimonious model for streamflow simulation, Journal of Hydrology, 279, 275289.

***Keywords:*** leakingcatchments, karsticlosses

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# Determination of groundwater fluxes via sensing and simulation of hydraulic head and streambed temperatures in lowland rivers

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In this research the aim is to better understand, simulate and visualize fundamental exchange processes in river ecosystems. The presented work is part of a multidisciplinary project, which includes contributions of engineers, hydrologists, ecologists and biologists. The introduction of innovative, but cost effective field investigations lead to a better perception of the diverse physical and biological processes in margins and inundation areas of water courses and how their interactions determine the exchange of water, dissolved compounds and particulate matter. Several of these processes occur simultaneously, thus the investigations should lead to net rates of exchange between the different parts. Moreover it is necessary to sample data, which fulfill the requirements of modern, data intensive simulation techniques. Field data collection was conducted by sampling temperature data of the riverbed by two different means, firstly by measurement of riverbed temperature profiles at different locations along a river stretch, and secondly by installing nests of piezometers in the riverbed and equipping them with dataloggers. At two different study sites, located in Belgium and Poland, several experiments have been conducted. Respectively, the Aa and Biebrza River represent low land rivers, which are characterized by a small slope and a sandy or peat riverbed. For the rivers a combination of longitudinal and cross-sectional stream bed temperature profiles have been used on a bi-monthly basis. The data set gained in this survey by a T(emperature) stick covers up to 2.5 years for both locations. The measurements are performed with a simple hand-held instrument, which is pushed into the sediment of the riverbed, measuring several temperature points up to about 80-100cm depth. A streambed temperature survey does not lead directly to an estimation of groundwater flux, thermal conductivity of the water and soil matrix is necessary as well. Once obtained, e.g. from literature, a high resolution survey on a local scale is relatively easy to perform. The groundwater fluxes hence where calculated on basis of an analytical equation (Arriaga et al. 2006) and solved with the help of Microsoft Excel or different MATLAB routines. To display the different interaction processes surface, groundwater and eco- biochemical models have been developed, integrated and tested. GIS is used for an appropriate data management, while the generalized modeling platform FEMME, serves as a tool for integrating the different models such as MODFLOW, HecRas, WetSpa, WetSpass, etc. In this research regional groundwater and transport models are used to constrain and provide boundary conditions for smaller local models. As the regional model is able to solve the most common questions on the exchange, the local model should describe the transport and biochemical transformation processes occurring in the hyporheic zone, between groundwater and surface water. Based on data collected from other aspects of the project, a comparison was made of the results gained from streambed temperature measurements with methods like seepage meter measurements, pore-water profiles of chlorides or mass- balance calculations for the stream reach.

***Keywords:*** streambed temperatures, hyporheic exchange, groundwater flux

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**HS1002** **Oral Presentation** **4043**

# A conceptual framework for modelling surface water groundwater interactions in Australian catchments

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The combined effects of water scarcity, population growth, and the need to provide water to meet environmental demands have consolidated the need for a conjunctive management system for water resources, which accounts for stream aquifer interactions and address common problems such as double accounting. The eWater Cooperative Research Centre has commissioned a project that aims to estimate exchange fluxes between groundwater and surface-water for lowland rivers and how these may change with groundwater and surface water management. This capacity will be delivered as software models within the Catchment Modelling Toolkit framework (http://www.toolkit.net.au/cgi-bin/WebObjects/toolkit). Those models will mainly address issues related to double accounting and groundwater dependent ecosystems. In this paper, we present a conceptual framework for those modelling tools, the processes that they handle and at what level of complexity, and the spatial and temporal scales at which they operate. We propose three frameworks for modelling surface water groundwater interactions that are applicable in the most common landscape setting in Australia. Firstly, the 2Csalt model, which is a catchment scale model based on the concept of disaggregating the catchment into surface and groundwater response units where the latter is split into a hill slope and an alluvial bucket; the model estimates the surface and sub-surface flow components to the stream. Secondly, we propose a lumped groundwater-bucket model that operates at a stream reach scale (of the order of tens of kilometres) and links to existing river models to better account for groundwater interactions; this is a low-complexity approach that spatially lumps groundwater surface water interactions to a scale compatible with the node spacing of the river model. Groundwater fluxes into the groundwater-bucket may be obtained from 2Csalt or other modelling techniques; groundwater response functions are used to incorporate the effects of far-field effects such as pumping. And thirdly, a more complex model that operates on a smaller scale (a sub-set of the river bucket) is proposed to explicitly model surface water groundwater interaction processes including bank storage, evapotranspiration, depletion due to pumping, over-bank flooding, and their interactions. The latter modelling approach may feed into ecological response models, which are currently being developed within the eWater Cooperative Research Centre.

***Keywords:*** groundwater surfacewater, modelling, conjunctive management

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# Towards A Common Conceptual Framework for Integrated Modeling of Surface-water/Groundwater Systems in Arid and Semi-Arid Regions

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The reliability of water supply in arid and semi-arid regions is highly sensitive to climate variability and change. As the demand for water continues to increase due to economic and population growth, integrated planning and management of surface- and groundwater resources under climate uncertainties becomes increasingly critical in order to achieve sustainability of water resources in a river basin. However, although integrated surface-/groundwater modeling has started to emerge, most evaluations remain centered on either groundwater systems (e.g., aquifers) or surface-water systems (e.g., watersheds) only. This is partially (if not primarily) due to the lack of a common conceptual framework that encompasses both surface- and ground water systems and their exchange of water with the overlying atmosphere. The Center of Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) has been developing multi-resolution integrated modeling systems for the south-western US, which link surface-water systems to groundwater systems and social-economic factors within the Rio Grande and San Pedro river basins. This paper describes the development of a common conceptual framework that aims at enabling integration and comparative evaluation of these multi-resolution modeling systems. Based on the hydrologic landscape (HL) concept, Geographic Information System (GIS) tools and multivariate statistical analysis techniques are used to identify the major HL units in the two river basins, using quantitative information on climate, land surface form, land use, and geology. Characteristics of these HL units enable the identification of dominant surface- and groundwater processes in the hydrological systems. This conceptual framework will continue to evolve to include other aspects such human behavior and socio-economics. Eventually, when pre-defined scenarios are applied to the integrated models, this framework will facilitate assessing the scenario results by providing insights on how the hydrologic systems behave under different future climate and socio-economic scenarios.

***Keywords:*** conceptualization, hydrologic landscapes, integrated modeling

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**HS1002** **Oral Presentation** **4045**

# Towards integrated assessment of groundwater-surface water exchange in mountain headwater streams: physical, chemical and ecological interactions at different spatial and temporal scales

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Over the past 10 years it has become apparent that montane catchments have complex groundwater surface water (GW-SW) systems which exert a profound influence on the hydrology, water quality and ecology of headwater streams and rivers. Abundant groundwater is found in a diverse range of geological settings including fractures systems in hard rock units, as well as various glacial and fluvio-glacial drifts. This is in marked contrast to previous assumptions that such streams were essentially surface-water dominated. This paper will report from over 10 years of investigations in the 31km2 Girnock experimental catchment in the Cairngorm mountains, Scotland which have moved towards an integrated multi-scale perspective on GW-SW interactions. These have shown that the characteristics of upland GW-SW systems can be understood as a nested hierarchy of spatial scales ranging from the catchment, sub-catchment, reach and point scale. Different techniques have been used to investigate these: Fine resolution spatial sampling of springs and streams guided by GIS-based watershed analysis - used tracers (such as stable isotopes and rare earth elements) to elucidate catchment and sub-catchment scale systems, whilst traditional wells, piezometry, together with geochemical and thermal tracing were used at the reach and point scales. These showed that groundwater accounted for around 30% of annual streamflow at the 31km2 catchment scale, but this ranged between 20 50% in individual sub-catchments depending upon the distribution solid and drift geology. At the reach scale, areas of groundwater upwelling were found to be relatively localized, again depending upon solid and drift geology. These patterns of GW-SW exchange have been shown to have a strong influence on ecological processes in river channels. For example, the study catchment is an important salmon spawning stream and many of the most popular spawning locations lie in areas of groundwater upwelling. These locations tend to relate to valley constrictions where alluvial sediments accumulate which, together with local hydraulic conditions, create suitable spawning habitat. However, the survival of salmon eggs in these areas, which are laid at depths of up to 30cm in river gravels can be low (with 100% mortality). This appears to be the result of long-residence time, de-oxygenated groundwater dominating the hyporhic zone along such reaches where GW-SW exchange can be intense. Continuous groundwater head and water quality monitoring in these reaches of the river have shown that patterns of GW-SW interactions exhibit marked temporal variation both intra- and inter-annually. These reflect the degree to which the riparian GW-SW exchange is driven by highly connected sub-surface drainage systems in the adjacent hillslopes and thus depend upon prevailing and antecedent climatic conditions. Such findings have clear implications for catchment management which seeks to maintain the integrity of GW-SW systems.

***Keywords:*** groundwater, surfacewater, hyporheic

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# Altering surface-groundwater interactions through catchment land use change and its implications for environmental flows

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In arid and semi-arid regions, where atmospheric demand is high and recharge to groundwater and rivers is relatively small, a small change in catchment land use can have a major effect on recharge to groundwater and streamflow. This is particularly important in dry periods where streamflows are low and may be entirely sustained by groundwater and unsaturated flows from the surrounding hillslopes. South Africa has a long history of research into the impacts of commercial afforestation on catchment hydrology. These and related studies have highlighted that in arid and semi-arid regions, unsaturated soil moisture is the major source of water for transpiration of vegetation. In recent years, an increasing focus on the flow requirements of the aquatic environment has resulted in a need to better understand the generation of low flows and thus, the interaction between surface and groundwater and the role of developments which may include changes in catchment land use. In this context, low flows are considered those flows which are generated from the movement of water in unsaturated form down the hillslopes of a catchment to the river, flows which are derived from localised shallow water tables and flow which is derived from the

***Keywords:*** afforestation, lowflows, riparian

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**HS1002** **Oral Presentation** **4047**

# Integrated Hydrologic Modeling: A Semi-Discrete Strategy

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In this paper we develop and demonstrate a strategy for the synthesis of multi-state, multi-scale distributed hydrologic models using the integral representation of the underlying physical process equations and state variables. Our interest is in devising a concise representation of watershed or river basin hydrodynamics, which allows interactions among major physical processes operating simultaneously, but with the flexibility to add or eliminate states/processes/constitutive relations depending on the objective of the numerical experiment or purpose of the scientific or operational application. The approach is based on the semi-discrete finite-volume method (FVM) which represents the system of coupled partial differential equations (e.g. groundwater-surface water, overland flow-infiltration, etc.) in integral form as a system of ordinary differential equations. Domain discretization is fundamental to the approach and an unstructured triangular irregular network (e.g. Delaunay triangles) is generated with constraints (geometric, and parametric) using open-source GIS tools. A local prismatic control volume is formed by vertical projection of the Delauney triangles forming each layer of the model. Given a set of constraints (e.g. river network support, watershed boundary, altitude zones, ecological regions, hydraulic properties, climate zones, etc), an optimal grid is generated. River volume elements are also prismatic, with trapezoidal or rectangular cross-section, and are generated along edges of river triangles. The local control volume contains all equations to be solved and is referred to as the model kernel. The global ODE system is assembled by combining all local ODE systems throughout the domain and then solved by a state-of-the-art parallel ODE solver. A research program has been built as an implementation of the above theory under the open-source framework, including a GIS tools. This effort is part of the Chesapeake Bay Community Modeling Program. From a scientific perspective, we are implementing the integrated strategy to address questions of integrated river basin response and feedbacks to climate variability, groundwater controls on evapotranspiration rates, hydroclimatic phase-plane behavior over complex terrain, and the enslaving principal for optimal system dimensionality.

***Keywords:*** integration, surface water, groundwater

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# Understanding Complex Processes in Groundwater-Surface Water Systems using High-fidelity Multiphysics Models and High-Resolution Data

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Groundwater and surface water interactions at all scales are inevitably tied to those occurring along the sediment-water interface (SWI). The relatively small spatial and short temporal scales at which complex and strongly coupled processes along the SWI take place necessitate robust and high-fidelity integrative modeling methods and novel measurement techniques. We present results of multiphysics modeling studies that consider coupled turbulent surface water flow, groundwater flow, solute and heat transport along SWIs leading towards process-level holistic understanding. Robust two-dimensional turbulent flow simulations accurately predict flow in channels with bedforms. The pressure distribution along the SWI from the turbulent flow solution externally forces and provides the boundary condition for our groundwater flow models. This scheme allows mechanistic examination of current-topography (bedform) driven hyporheic exchange and development of predictive equations that can be applied in natural settings. Furthermore, heat transport models for the sediments provide explanations for typically observed temperature distributions that are seldom directly tied to causal models. Residence time distribution (RTD) analysis is conducted via simulation of solute transport through the sediments. We discuss how simulated RTDs driven by bedforms may be responsible for basin scale stream chemistry behavior. Studies along SWIs require specialized instrumentation that allows for broad yet detailed measurements. We use thermal infrared imagery using ground-based cameras to monitor in-stream temperature with centimeter to sub-centimeter resolution. The results show how different roughness elements, physical (bars) and biological (wood and periphyton), contribute to thermal heterogeneity of fluvial systems. Thermal images taken at baseflow and stormflow conditions indicate dynamic thermal heterogeneity. We will explore how these dynamic surface temperature distributions may be affecting subsurface temperature distributions using our multiphysics modeling approach.

***Keywords:*** modeling, sediments, hyporheic

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# Modelling the hydrological balance of an amazonian floodplain lake: indirect quantification of groundwater/surface-water exchange

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The floodplains of the Amazon basin influence the hydrology and fluxes of suspended solids and solutes on multiple scales. Our study focused on the floodplain of Lago Grande de Curua (bidos, Brazil), a 4000 km2 segment of floodplain and local upland catchment representative of the lower Amazon. Based on in situ and satellite data acquired from 1997 through 2003, we calculated the exchanges of water between the floodplain and the river and determined the temporal dynamics of lake water derived from river flooding, rainfall, runoff, and exchange with groundwater annually for six years. The Amazon River dominated the inputs of water to the lake year-round, accounting about 53% of the annual total; rainfall and runoff accounted for about 10% and 8%, respectively, while seepage from the groundwater system and local upland catchment accounted for 22%. The hydrologic residence time of the lake was about 2.6 months, and the floodplain made a net contribution of water to the river. The exported volume varied between 2.1 and 4.4 km3 depending on the year and represented about one third of the maximal storage reached each year.

***Keywords:*** river floodplain interactions, amazonbasin, hydrologic residence time

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**HS1002** **Oral Presentation** **4050**

# The role and the particularities of groundwater recharge and baseflow in integrated regional models

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Integrated water resources management is often concerned with problems on the river catchment scale: The evaluation of the effects of global climate change, of changes in agriculture, demography, or in the water supply structure. The impacts of such changes affect all compartments of the hydrological cycle. This requires integrated approaches of analysis and modelling. Important processes that connect the groundwater and the surface system (soil, unsaturated zone, surface waters) are groundwater recharge and baseflow (groundwater discharge). A closer look at these apparently well defined terms reveals that the description and quantification of these processes depend on a number of factors. Both recharge and baseflow depend on the scale, the context of modelling, the model concepts and on the specific conditions of the investigated area, including climate, topography, hydrogeology and others. In RIVERTWIN (EC, www.rivertwin.org) an integrated water resources management system was developed for three river basins: The Neckar in Germany, the Oum in Benin, and the Chirchik in Uzbekistan. With a focus on the Neckar basin the models which are used to represent the groundwater (MODFLOW) and the surface water system (HBV) in MOSDEW are introduced. HBV is used to calculate discharge and groundwater recharge used as a boundary condition in MODFLOW. MODFLOW in turn simulates groundwater levels and baseflow which is handed over to HBV. It is shown, that an individual calibration of the models yields relatively good results, if he HBV model is calibrated using measured discharge and MODFLOW is calibrated mainly against groundwater levels. However if coupled together in the way described before it proves that the results get worse with respect to the results of the individual models. The reasons for this are the different conceptual descriptions and modelling approaches of the processes in both models. Traditionally, recharge is not an important output of hydrological models and baseflow usually receives not too much attention by groundwater modellers. Integration necessarily changes this attitude. Even if coupled model result might, from a strictly disciplinary view point, be worse that results of stand alone models, model coupling is beneficial. Here we will show, that an integrated approach provides more information than the single models: Not only does it provide more than one measurable quantity for model calibration, it also gives us the chance for an indirect check on usually internal state variables, the model structure and the conceptual base of the model. This can help to reduce model uncertainty which is always present. Coupled modelling is a valuable exercise because it forces us to describe the water cycle in a holistic, scale and context specific, consistent way that acknowledges both the groundwater and the surface water system.

***Keywords:*** groundwater recharge, baseflow, model integration

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# Effect of surface and groundwater interaction on nitrate reduction process in a small alluvial fan catchment, Western Japan

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Nitrate (NO3-) is a widespread pollutant derived from human activities such as agricultural practice. Previous studies have shown the occurrence of nitrate attenuation in groundwater by denitrification that is microbial reduction of NO3- to N2 in reductive condition with sufficient organic compound. Most of them are reported about groundwater in the riparian wetlands (Hill et al., 2000; Bhlke et al., 2002), floodplain (Fustec et al., 1991; Tesoriero et al., 2000), alluvial fan (Hinkle et al., 2001) or coastal area (Howard, 1985; Uchiyama et al., 2000) with gentle topographic gradient. These areas are characterized by transition zone between the surface water and the groundwater with low velocity. On the other hand, Japanese river catchments are generally characterized by steep river and alluvial fan composed with coarse grain sediment, and groundwater velocity is high. However, the effect of interaction between surface water and groundwater on the nitrate attenuation process is little known in such region with steep gradient. This study is aimed to clarify the effect of surface and groundwater interaction on the nitrate attenuation process in a steep, small alluvial fan catchment. The study area is located on the small island within the Seto Inland Sea, southern Japan. Total area of study catchment is 44ha underlain by granite with more than 40% is covered by orange groves. It is characterized by relatively steep topographic gradient with about 1/4 and alluvial fan deposits in the midstream and the downstream area. Consequently, river water recharges groundwater in the alluvial fan area. There are no sewage lines in the study catchment and as a result domestic wastewater is discharged directly to the river and drainage systems. Groundwater samples were collected at 10 dug wells with 2~5m depths and 6 pumping boreholes with 20m~30m depths located in the midstream and the downstream area of the two study catchments from October 2002 to April 2005 at every 2 months. Also river water, precipitation, spring, tap water and domestic wastewater sample were collected. All water samples were analyzed for chemical (HCO3-, NO3-, SO42-, DOC and TP) and isotopic (18O in water and 15N in aqueous NO3-) components in the laboratory. Groundwater flows from the mountainside to the ocean side in the study catchment (Saito et al., 2005). In the deeper groundwater, NO3--N concentrations decreased along groundwater flow about 25mg L-1 in 400m. On the other hand, it decreased about 30mg L-1 with the distance of 50m in the shallower groundwater. The variations of δ15N suggest the isotope enrichment caused by the denitrification process in the groundwater of the downstream area. The results of δ18O imply the mixing of domestic wastewater with high concentration of DOC to the shallower groundwater. Based on these results, it is suggested that mixing with domestic wastewater leads to supply of organic carbon compounds to the shallower groundwater and consequently increase in denitrification process. The results of other catchment were also similar to former results. These results revealed the important role of interaction between surface water and groundwater in the alluvial fan on nitrate reduction in the coastal area.

***Keywords:*** river groundwater interaction, nitrate reduction, alluvial fan catchment

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# Modelling water exchanges between channel networks and soil domains

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Modelling water exchanges at the interface between a complex channel network and the surrounding soil domain is important for understanding many hydrologic, geologic, and biologic processes such as surface/subsurface runoff generation, landslides/debris flow initiation, and aquatic habitat development. Approaches capable of treating these processes in an integrated manner are needed for many water resource applications. A detailed description of water fluxes at the land surface can be provided by coupling a three-dimensional Richards equation for variably saturated subsurface flow, with a one- or two-dimensional approximation of the Saint-Venant equations for overland and/or channel flow. The rate and direction of these exchange fluxes depend on spatial and temporal distribution of rainfall, and on topographic and hydraulic characteristics of land surface. Although a numerically clean coupling between surface and subsurface flow models can be obtained by adopting a two-dimensional sheet flow representation for surface flow, in nature surface water generally propagates along a complex network of rivulets and channels. This justifies then a special effort for an accurate conceptualization of water exchanges between a channel network and the surrounding soil domain. In this study, the planar and relief configuration of the rivulet/channel network is determined explicitly from grid-based digital elevation model data using detailed algorithms for the determination of single or multiple drainage directions. Rivulet and channel geometry is characterized by combining the concepts of at-a-station and downstream hydraulic geometry and by using relevant physiographic features such as upslope area and slope to allow parameter estimations. Surface runoff is propagated through the channel network using a diffusion wave conceptualization based on the Muskingum-Cunge method with variable parameters, which is capable of incorporating the channel network characteristics obtained from terrain analysis and from the application of the hydraulic geometry concept. Flow characteristics are combined with terrain data to provide accurate estimates of water depth at the land surface for use as boundary conditions of the soil domain. The exchange flux between the land surface and the subsurface and the hydraulic head at the surface are handled via a boundary conditions switching between Neumann type (atmosphere-controlled soil wetting or drying processes) and Dirichlet type (soil-limited processes). Numerical experiments are carried out to evaluate the sensitivity of response variables to model parameters affecting the exchange of water at the interface between rivulets/channels and soil domain under different geomorphic and climatic settings. These numerical experiments aim to assess: (1) the relevance of using single or multiple drainage direction algorithms, (2) the sensitivity to channel network geometry parameters, and (3) the relative role of channel flow resistance coefficients and soil conductivity. Illustrative test cases considering simple synthetic drainage systems and complex real catchments are presented.

***Keywords:*** surface subsurface hydrology, rivulet channel networks, variably saturated soils

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# A new subsurface flow formulation incorporating subgrid spatial variability of topography and groundwater recharge

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An adequate representation of subsurface flow processes is very important for land surface modeling at large spatial scales. At a regional scale, for example, the amount of annual averaged subsurface flow is an important component of the water budget used to manage water resources. However, the understanding of impacts of subgrid spatial variability on subsurface flow processes at the large spatial scales is very limited. Most land surface models use simple parameterizations to estimate the subsurface flow where groundwater discharge is related to a lumped soil moisture state, while some models incorporate the effects of landscape and lateral flow partially into the subsurface flow calculation using the framework of TOPMODEL. In this study, we present a new subsurface flow formulation that considers subgrid spatial variability of topography and groundwater recharge. This new formulation is quite generalized and it includes several popular subsurface flow formulations as its special cases. Furthermore, with this new subsurface flow formulation, groundwater recharge rate can be estimated based on observed streamflow, groundwater table, and topography, which provides an alternative way to efficiently access the groundwater recharge process that is critically important in the study of surface water and groundwater interactions.

***Keywords:*** subsurfaceflow, variability, recharge

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# A simplified model for estimating surface runoff hydrographs at watershed scale

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In this paper, we develop and test a simplified model for generating surface runoff over small basins with spatial variation of both rainfall rate and saturated hydraulic conductivity. The model is able to represent the effects of local variation in infiltration, as well as the run-on effect that controls infiltration of excess water from saturated upstream areas. The effective rainfall excess is routed over planes and channels to the basin outlet using a simplified solution of the kinematic wave approximation. Model results are compared to averaged hydrographs from numerically-intensive Monte Carlo simulations for observed and design rainfall events and soil patterns typical of Central Italy. The simplified model is found to yield satisfactory results with a relatively small computational effort.

***Keywords:*** surface runoff, infiltration, modelling

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# Quantifying groundwaters role

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Groenvlei is a small freshwater coastal lake known for its diverse bird life and is one of the best venues for large mouth black bass angling. It is one of a series of 5 brackish coastal lakes along the Southern Cape coast of South Africa, but is the only one disconnected from the sea. Urban development in and around the nearby town of Sedgefield potentially poses a threat to Groenvlei. Abstraction of groundwater for water supply purposes could impact the volume of groundwater discharged into the lake, while sewage disposal could compromise water quality. Little is known about the hydraulic functioning of the Groenvlei. Using information gleaned elsewhere regarding the role of groundwater in sustaining a shallow coastal lake and data measured on site, the role of groundwater in sustaining Groenvlei was quantified. Both groundwater level and chemistry data support the interpretation that the lake is both influent and effluent in character. Analysis of climatic data, monitored water level data of Groenvlei and groundwater data suggests the length of the inflow boundary is 6 170 m while the length of the outflow boundary is 3 450 m. Proposed groundwater use adjacent to the lake could lower the level of Groenvlei by 26 mm and is thus unlikely to significantly impact the hydrological or ecological functioning of the system. As much of South Africa is underlain by fractured hard-rock aquifers, the primary aquifer setting in which Groenvlei is located is somewhat unique. However, the outcome of the study facilitates a better understanding of surface groundwater interaction in general, and may assist in developing knowledge of the role of groundwater in sustaining the unique and ecologically important St Lucia wetlands located on the Zululand Coastal Aquifer on the eastern seaboard of South Africa.

***Keywords:*** surface groundwater, darcy s law, water balance

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**HS1002** **Oral Presentation** **4056**

# Groundwater-river interaction in the context of inter-basin transfer

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***Surin Worakijthamrong***

This study is focused on the problems of coupled groundwater-river interaction in the context of inter-basin transfers. The United Kingdom, along with many other countries, has considered the development of water resources schemes which transfer water from regions of plenty to regions of deficit. The transfer of water from the River Severn to the River Thames and the South-East of England has been considered for the last 100 years with major studies being completed in the 1970?s and 80?s by the UK Water Resources Board and its successor body the Central Water Planning Unit (CWPU). The primary problems to be resolved are the real-time forecasting and control of the transfer scheme and the understanding of the groundwater-river interaction issues. This study describes some of the experimental results of the 1970?s in the context of the modelling capability of the present. day, in particular the problems associated with the presence of large gravel floodplains where up to 40% of a man-made release can be temporarily stored during the passage of a transfer release. This paper describes operational experiments carried out by the CWPU in the 1970?s and more recent modelling in terms of understanding the fundamental processes involved in the context of inter-basin transfer. The mathematical modelling utilises elements of MODFLOW and extends its general interests to the behaviour of natural flood waves where interaction with floodplain deposits are also an important factor. The study focuses on operational data obtained from the River Tees and the River Severn during specific river transfer experiments conducted by the CWPU in 1975 and 1976 and the extensive modelling of the groundwater river interaction problem using modern mathematics.

***Keywords:*** interbasin transfer, groundwater interaction

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**HS1002** **Oral Presentation** **4057**

# Development of an integrated surface water-groundwater model for wetland restoration and habitat evaluation in a Southwest Florida basin using MIKE SHE/MIKE 11

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***Joseph D. Hughes, Maria C. Loinaz, Ananta Nath***

The Picayune Strand Restoration Project, a component of the US Congresss plan for restoration of Americas Everglades, aims to restore the hydrology of approximately 246 square kilometers of drained wetland areas in Southwest Florida. The restoration of the Picayune Strand is important because of its location and connectivity to critical preserved areas that serve as wildlife habitat and also the headwaters of the Ten Thousand Islands estuary. The excessive drainage of this area led to severe ecological impacts such as: reduction of groundwater levels, increased freshwater loads to critical estuaries, invasion by exotic vegetation, increased fire frequency, and loss of wildlife habitat connectivity. The proposed restoration project consists of converting existing canals to natural wetland areas using a combination of distribution canals, pump stations, canal backfilling, and road degradation. An integrated surface water and groundwater model for the area has been developed by the application of the MIKE SHE/MIKE 11 modeling system to evaluate the response of the watershed to the proposed restoration plan under a variety of hydrologic conditions. Earlier configurations of the model for the area were updated with newly acquired topographic and aquifer data and include a more detailed representation of the channel hydrography and water control structures. The model has been calibrated to dry, wet, and average conditions and is capable of producing simulated results that correlate well with observed surface water stage and aquifer water levels. Model calibration has also been verified using higher resolution rainfall data during the hurricane season of 1995 and 1999. The calibrated model was applied to evaluate system responses to the proposed restoration plan. Model results indicate that the plan will restore the historical flowways in Picayune Strand with desired hydroperiods for wetland functions, and without adverse impact to the agricultural and urban areas adjacent to the project. The timing, magnitude, and duration of freshwater discharges to critical estuaries located downstream of the project area will be more similar to historical discharges as a result of the proposed restoration activities.

***Keywords:*** integrated hydrology, florida everglades, wetlands restoration

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**HS1002** **Oral Presentation** **4058**

# Prospecting for freshwater: hydro-meteo-bio-geo- physical controls of surface water-groundwater interactions

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Natural watersheds are characterized by high spatial heterogeneity that reflects interactions among the climatic, topographic, geomorphological and biophysical characteristics of the landscape. The representation of spatial variability and associated nonlinear scale effects in hydrologic models remains a challenge both from the observational and from the modeling point of view. The focus of this presentation is on the relationship between the space-time organization of precipitation and the spatial variability of hydrogeology and recharge areas, soils, vegetation, and landform, and how this in turn is reflected on the hydrological function of river basins from extreme events to the availability and sustainability of freshwater stocks. End-to-end interpretive modeling studies of the hydroclimatological regimes of selected rivers basins in the tropics and at mid-latitudes will be used to demonstrate the fundamental linkages between the physiography of rainfall and recharge on the one hand, and hydrological non-stationarity in space and time including soil-water-vegetation interactions, surface-subsurface interactions, and runoff production. Model results show that climate and especially rainfall control water availability, whereas vegetation and surface water-groundwater interactions regulate access and sustainability. These are consistent with the expectation of highly nonlinear river-basin systems where non-stationarity emerges from the interactions among the spatially variable landscape and the temporally variable climate forcing. Specifically, we will examine three key implications of our findings: 1) the utility of hydrologic models for predictive studies hinges on the quality of the precipitation forcing, especially in regions of complex terrain where the space-time characteristics of rainfall combine with those of the landscape to establish highly nonlinear hydrologic regimes; 2) vegetation behaves as the hydrostat of humid landscapes and controls land-atmosphere feedbacks; and 3) surface-subsurface interactions provide an impedance matching service to the hydrological cycle that determines both long-term access to groundwater storage (slow time-scales) and short-term access to soil moisture and runoff (fast time-scales). Finally, at a time when the policy paradigm in water resources management has shifted toward an integrated view of land-water management and the water cycle (a land-use decision is a water decision, Falkenmark 2001), it is proposed that the notion of freshwater prospecting in that it entails a dynamical, and thus adaptive view of the water cycle is more consistent with the state-of-the-science than that of the traditional practice of water resources assessment which implies a static view of the hydrologic cycle

***Keywords:*** hydroclimatological model, river basin system, nonlinear scale

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**HS1002** **Oral Presentation** **4059**

# Hyporheic sediments as refugial zone for benthic invertebrates.

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Increase in sediment colmation and in clogging intensity is currently observed in relation to human activities. It may alter hydrological and biological exchanges through the hyporheic zone and especially modify the ability of hyporheic interstices to provide refugial space for benthic invertebrates. The use of sediment interstices by benthic invertebrates as a refuge during disturbance periods and role of the hyporheic zone in resilience processes are not genuinely demonstrated. In consideration since the seventies (hyporheic refuge hypothesis, Clifford 1966, Williams & Hynes 1974), the question remains still unsolved with divergent results (e.g., Palmer et al., 1991 vs Dole-Olivier et al, 1996). Why such a long time devoted to such an apparently simple question? By synthesizing the current knowledge and available data on this topic, this work splits the question into its deive and quantitative aspects, points out the relation with environmental heterogeneity (hydrological patterns) and tackles the effect of scales. It also evidenciates gaps in knowledge and proposes several working hypotheses to set future research into a common framework. Final target is to emphasize and develop research towards a streams methodology to assess the quality of alluvial sediments, not only in terms of anthropisation but also in terms of intensity of exchanges with surface stream and ability to ensure life and rapid recovery after stress periods. In the situation of global climate change, that will modify the frequency of extreme hydrological events, critical periods for stream organisms would also increase both in intensity and duration. Within this context, it is of paramount importance to provide tools for identifying and delineating functional zones along stream corridors, being of great interest for the overall stream life. In this approach, ecologists strongly need to combine skills originated from researchers in geosciences such as geomorphology, hydrogeology and hydraulics.

***Keywords:*** hyporheic, stream sediment, benthos

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**HS1002** **Oral Presentation** **4060**

# Identification and significance of sulfonamides (p-TSA, o-TSA, BSA) in the Berlin water cycle

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The drinking water production of Berlin relies on induced bank filtration from a broad-scale, lake-type surface water system. Because the surface water contains treated sewage, wastewater residues are present in the surface water and reach the groundwater via bank filtration. Hence, persistant organic pollutants may potentially reach the drinking water wells. An analytical method was developed to detect the three sulfonamides para-toluenesulfonamide (p-TSA), ortho-toluenesulfonamide (o-TSA) and benzenesulfonamide (BSA) in environmental water samples at concentrations down to 0.02 µg/L using liquid chromatography coupled to tandem mass spectrometry (HPLC-MS/MS). Wastewater, surface water, groundwater and drinking water samples from Berlin were analysed for all three compounds which appear to be ubiquitously present in the aquatic environment of Berlin. P-TSA was found in high concentrations in the wastewater (< 0.02 to 50.8 µg/L) and in groundwater below a former sewage farm (< 0.02 µg/L to 41 µg/L), and in lower concentrations in the surface water (< 0.02 to 1.15 µg/L) and drinking water (< 0.02 to 0.27µg/L). O-TSA and BSA were detected in considerably lower concentrations. The occurance and fate of the sulfonamides during bank filtration was investigated at an observation well transect in flow direction between a lake and a production well. The study showes that p-TSA is a persistant sewage indicator and not completely eliminated during bank filtration.

***Keywords:*** sulfonamides, berlin, water cycle

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**HS1002** **Oral Presentation** **4061**

# Surface Water – Groundwater Interaction and Vegetation Response: Synthesis of Observation and Modelling

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***Marius-Viktor Birsan, Laura Foglia, Peter Molnar, Paolo Perona, Paolo Burlando***

The natural dynamics of many floodplains is endangered by strong anthropogenic influence of the hydrological system, both in the surface and in the groundwater component. Streamflow regulation due to hydropower, groundwater abstraction, and river engineering works affecting the exchange of water between river and aquifer are the main contributing factors in this respect. The long-term impacts on floodplain ecosystems are to a large extent still unknown, but decisions related to river conservation and restoration must be taken anyway. To this purpose, we developed an integrated modelling system of the water fluxes throughout the entire watershed, especially focusing on the river-aquifer exchange, which allows the investigation of the long-term evolution of floodplain systems. The modelling system was developed within the context of the MaVal project (www.maval.ethz.ch), which concentrates on alpine floodplain environments. The alpine watershed of the Maggia Valley (Switzerland) is characterised by a braided river system with an ecologically valuable floodplain. Strong and fast interaction between surface water and groundwater occurs due to the high permeability of the alluvial deposits, thus leading to a considerable impact of the existent streamflow regulation also on groundwater dynamics. Long time series of runoff, measurements of groundwater variations since the 1970s and the delineation of vegetation classes from aerial photography from the last 70 years in combination with recent geobotanical field observations allowed us to investigate the interaction between surface water, groundwater and vegetation in the past, both under pre-dam and post-dam conditions. Substantial changes in vegetation distribution and development were found as result of streamflow regulation superimposed to natural processes. This led to the development of a transient coupled modelling system to simulate the behaviour of the river aquifer system, using a 2D approach for the surface water, and a quasi 3D approach for the groundwater modelling. The entire modelling system includes also a watershed model acting as boundary condition for the coupled surface water-groundwater model. The spatially and temporally explicit inundation and depth to groundwater patterns so generated form the basis for a stochastic model of the vegetation dynamics, which mimics the response of the floodplain vegetation system to streamflow and groundwater variability. Space-time distributed scenarios of hydraulic and hydrological variables of ecological importance, such as inundation depth, period length and frequency, variation in depth-to-groundwater, are presented, together with the most important effects of streamflow regulation on the river-aquifer exchange. The results provide additionally an insight into the dominating water stress scenarios, which can impact the dynamics of river corridor vegetation. The study aims at showing the importance of combining observation and modelling tools to anticipate changes that may occur to natural floodplain systems as a result of streamflow regulation. The modelling system is indeed meant to be a tool for further studies to develop optimal strategies fulfilling both the requirements of hydropower production and preserving ecological integrity of the floodplain. The tool is fairly general and could be applied also in other river environments or for restoration projects.

***Keywords:*** river groundwater interactio, vegetation dynamics

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**HS1002** **Poster presentation** **4062**

# Effect of surface water infiltration on groundwater fluoride concentration close to an irrigation tank in Polonnaruwa District in Sri Lanka

***Mr. Ashvin Wickramasooriya***
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Fluoride in small quantities promotes dental health, and is essential for growth of bones and is an essential element for the human body. So fluoride is an essential element for the human body yet in excess may cause dental fluorosis. Many health problems may arise either through deficiency or excess of fluoride. Drinking water is the main source of fluoride required by humans. Thus understanding the geochemistry and behavior of fluoride in surface water and groundwater is vital for human health. This is significant for Sri Lanka as the majority of the population does not have modern pipe-bone water systems especially in the rural areas. They depend entirely on dug and deep hand pump wells, rivers and channels for their domestic water requirements. A problem of growing concern is the excessive concentrations of fluoride found in many dug wells and water supply bore holes in the low plains of the dry zone, notably in the Anuradhapura and Polonnaruwa districts. The fluoride concentration in many of these wells exceeds 1.5 mg/l and poses a health hazard to consumers. In these areas, wide prevalence of dental fluorosis is found specially among children of school going age. The slow rate of groundwater movement and high evapo-transpiration in the low plains of the dry zone tend to increase the fluoride concentration. Within the areas of high fluoride bearing groundwater, it is still possible to find certain areas specially close to irrigation tanks, with considerably low fluoride concentrations with regard to drinking water standards. Surface water containing low fluoride concentrations from the irrigation tanks could be a major governing factor for this situation. The possible effects of surface water infiltration on groundwater fluoride concentrations was studied in Polonnaruwa district, in a small village situated below the major irrigation tank; Parakrama Samudraya. The behavioral patterns of the groundwater table and groundwater fluoride content revealed that the concentration in groundwater of the area is controlled by the infiltration of the surface water from the tank and the irrigation channel. It was found that the fluoride in groundwater is low in the vicinity of the surface water bodies especially down-slope. Fluoride concentration increases in the direction of groundwater flow and away from the surface water bodies within the area of influence of the surface water. On account of the widely spread surface water irrigation network in Polonnaruwa district, it could be expected that the low fluoride areas close to irrigation tanks and channels are a result of infiltration and dilution of fluoride content by the surface water.

***Keywords:*** infiltration, fluoride, surfacewater

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**HS1002** **Poster presentation** **4063**

# Efficiency of post-harvest, autumn irrigation in the upper reaches of the Yellow River, China

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This paper describes a complicated process that has been shown by the authors to be an example of groundwater/surface-water interactions in irrigated fields. In the upper reaches of the Yellow River, a great quantity of water is irrigated after harvest in late autumn, when the discharge of the Yellow River is rather large, so that part of the irrigation water remain in a soil profile until next spring of little rain and is used for crop generation and development. Winters in this region are so severe cold that the soil layers from the surface to a depth of more than one meter freeze in the irrigated fields. From late autumn of 2004 to spring of 2005, the overwinter water loss due to evaporation at an irrigated field in the upper Yellow River valley was evaluated. We estimated that the field was irrigated by impounding more than 230 mm of water after harvest in late autumn, but only 19 mm remained in the upper 100 cm of soil when corn was planted at the end of April. At that time the depth to a water table was 1.73 m and 0.27 m shallower than that before the autumn irrigation. Although precipitation of about 40 mm occurred during the period, about 170 mm was lost by evaporation and more than 80 mm percolated into the water table when the irrigation was practiced. On the other hand, about 80 mm moved upward by capillary action into the root zone from the water table in spring and early summer of little rain. We confirmed that some part of the irrigated water that was percolated into the water table moved up into the frozen layer and passed the winter in it, and moved down into the water table again when the layer was thawed in early spring. Consequently, about 100 mm out of the irrigation water of more than 230 mm was utilized for growing corn in this field; that is, the efficiency of post-harvest irrigation on a field basis was estimated to be smaller than 0.43.

***Keywords:*** autumnirrigation, yellowriver

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**HS1002** **Poster presentation** **4064**

# Optimization of land use for sustainable groundwater quality

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***Nolz Reinhard, Aus Der Schmitten Volker***

Groundwater contamination is a serious problem. In many plains of Austria, groundwater is used as a major source of drinking water. Nitrate concentrations in these groundwaters have increased dramatically during the last decades. Agriculture in particular, due to excessive application of fertilizers, is identified as a significant contributor to the diffuse groundwater contamination. Hence, in intensively used agricultural areas like the Grazer Feld, the risk of groundwater pollution by nitrogen is very high. There is an increasing awareness of the impacts of fertilization and irrigation as well as of crop rotation and tillage operations on groundwater contamination, and the protection of water resources has now become a high priority. In this study, Environmental Policy Integrated Climate (EPIC), which is a physically based model for continuous simulation, combined with Desktop-GIS is used to estimate effects of land use on groundwater resources. The research area, the Grazer Feld, is a large flat valley in the southeastern part of the Styrian Alps. The typical soil of the area is a brown meadow soil overlying fluvio-glacial sediments. The average temperature of the area is 9.8C, the average annual rainfall is 830mm. The total agricultural research area is about 4400 ha, 90% of which are intensively used and the rest is grassland. Referring to an existing actual crop-growing database of the cultivated area, typical crop rotations were generated. The most commonly grown crop is maize (app. 50%), which is cultivated in crop rotation and in monoculture, as well as pumpkin (app. 20%). Different species of small grains (i.e. winter barley, winter wheat) rank third (app. 16%) continued by soybean, potato, field pea etc. As a first step, the simulation of the actual state was carried out. Crop rotation and tillage operations of the last decade were used to simulate percolation and nitrogen leaching as well as crop yields. The results were then used to verify and calibrate the model by comparison with field measurements. Subsequently, different scenarios of alternative land uses (e.g., crop rotation, tillage operation) were simulated to find crop rotations and tillage operations, which lead to a sustainable groundwater quality concerning nitrate.

***Keywords:*** groundwater contamination, simulation, epic gis

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**HS1002** **Poster presentation** **4065**

# Variabilite spatiale des flux internes dune nappe libre surexploitee par mesure de gradients thermiques et geochimiques (Kairouan, Tunisie)

***Dr. Badiaa Chulli***
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***Badiaa Chulli, Favreau Guillaume, Nessim Jebnoun, O Monique***

Laquifre libre de la plaine de Kairouan constitue le plus important rservoir aquifre de la Tunisie centrale. Dans cette rgion climat mditerranen aux prcipitations irrgulires, cette ressource en eau souterraine est depuis de nombreuses annes surexploite, avec une chute pluri-dcamtrique des niveaux statiques. Une gestion long terme de cette ressource en eau partage implique une modlisation des flux hydrique base sur une connaissance fine des processus, quils soient externes (recharge/dcharge) ou internes (3D) laquifre. Jusqu prsent, les mthodes gochimiques et hydrodynamiques appliques pour contraindre le bilan de la nappe ont permis de mettre en vidence des phnomnes de recharge localiss (oued, barrage), avec plus large chelle des flux latraux (2D) dominants. Les gradients thermiques mesurs montrent en majorit des valeurs positives avec la profondeur, en moyenne plus faible (+0.018C/m) que le gradient gothermique local (+0,029C/m). Ceci tmoigne de flux composante verticale descendante, dintensits variables. A lamont de la plaine, plusieurs gradients ngatifs tmoignent de flux ascendants deaux relativement plus fraches. En accord avec linterprtation isotopique effectue de manire indpendante, ces gradients inverses tmoignent dune recharge artificielle par les barrages situs lamont.

***Keywords:*** hydrodynamique, geochimique, kairouan

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**HS1002** **Poster presentation** **4066**

# Assessment of Interaction between Groundwater and the Teganuma Lake, Chiba, Japan

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***Yasuo Sakura, Akihiko Kondo***

Water quality in the Teganuma Lake, Chiba, Japan was once the worst one in Japan for more than twenty years. It was found that area for residents and industry expanded rapidly in the study area since 1970s. Water quality in the Teganuma Lake deteriorated rapidly from 1975, and recorded the highest COD value of 27 mg/L in 1979. Although it gradually began to improve after that, annual average COD rose to 24 in 1995 before dropping back to 14 in 2000. In order to make clear the interaction between groundwater and lake, as well as its effects on regional water quality and quantity, authors focused their attentions on the following aspects in this paper based on the field works in the basin including the Teganuma Lake. (1) To study the changes of water quantity and quality of groundwater and lake water in past 20 years; (2) To assess the remediation effect of lake-side trees on nitrates in groundwater; and (3) To understand comprehensively relation between groundwater and lake water. Field surveys were conducted in two periods from 1983 to 1984, and from 2004 to 2006. The hydraulic potentials were measured at piezometers. Water samples were taken from piezometers, spring and the lake. During field surveying, pH, electrical conductivity, temperature, DO and redox potential of water were measured in situ. Water samples were analyzed in the laboratory at Chiba University. The major ions such as NO3-, Cl-, SO42- Na+, K+, Ca2+ and Mg2+ were measured by ion chromatography (LC-10A, Shimadzu). The concentration of HCO3- was measured by titration. Groundwater in the study area flows toward the lake year around, which means that the lake is not only recharged by rivers that run into, but also by groundwater surrounding of the lake. Because of much better quality than the rivers, groundwater has very high potential to improve the lake environment. However, it was found that many spring disappeared and less groundwater flowed into the lake in past 30 years, because of the decrease of infiltration area by urbanization on one hand and the increase of pumping on the other hand. Human activities also have strong affects on the water chemistry in the study area. Authors have paid their attentions not only on the changes of water quality in past 20 years, but also the variations of nitrate concentrations of groundwater before and after it flowed through the tress that make a buffer zone to protect the fertilizers from groundwater into the lake. Finally, the chemical characteristics of groundwater and lake were discussed by considering interaction between them. It was concluded that integrated groundwater recover and water development management are urgent tasks in the study area.

***Keywords:*** groundwater, lake, interaction

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**HS1002** **Poster presentation** **4067**

# The method to estimate the root-zone soil moisture from gravelsand mulch in the semiarid loess region of northwest China

***Dr. Haishen Lv***
*Department of Applied Mathematics Hohai University IAHS*

In the semiarid loess region of northwest China, the use of gravel and sand as mulch has been an indigenous farming technique for crop production for over 300 years. However, systematic studies concerning the effects of surface gravelsand (mixed gravel and sand) covers on soil and water conservation are scarce. Based on previous studies, this study investigates the method to estimate the root-zone soil moisture from gravelsand mulch in the semiarid loess region of northwest China. The system consists of an initialization phase, which provides gravel-sand mulch surface and root-zone moisture contents as initial values for the dynamic phase of a soil water balance model. The initial value of gravel-sand mulch surface moisture can be a measured value. The gravel-sand mulch surface moisture value for a given day is in turn used to derive the initial value of the root-zone moisture for the same day. This can be obtained from an empirical relationship. The two-layer soil dynamic model requires as input daily rainfall, evapotranspiration, and some soil physical parameters-soil moisture at field capacity, wilting point and a pseudodiffusivity coefficient. The first layer represents the gravel-sand mulch surface, taken as 0-10 cm, and the second represents the root-zone, taken as 40-50 cm, for both sites. The model has been run in 2003. The dynamic model, which offers a good balance between accurate description of the processes and minimum input of data, proved capable of simulating both gravelsand mulch surface and root-zone moisture content. Keywords: ; Surface moisture; root-zone soil moisture; Semiarid; NW China

***Keywords:*** gravel sand mulch surface, surface moisture, root zone soil moisture

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**HS1002** **Poster presentation** **4068**

# Hysteresis in the Soil Hydraulic Properties under Field Scale

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In the study of soil hydrology, it is important to study hysteresis in the Soil Hydraulic Properties, soil water retention curve and unsaturated soil hydraulic conductivity. In order to describe the hysteretic behaviour of a particular soil, many wetting and drying experiments have to be performed, because the water-retention function may change with each drying and wetting process. Therefore a theory is needed to estimate the water-retention function for any drying and wetting loop based on the envelope of main drying and wetting curved. In this paper, we put forward a method to estimate boundary wetting curve and the boundary drying curve under field scale. Our study is based on the model of van Genuchten. Using our method, we estimated wetting curve and dry curve in a experiment site in west-north of China. The validity of the model is established for a number of test problems by comparing numerical results with the observational results. The results show our method is fast and significant.

***Keywords:*** wetting curve, drying curve, field scale

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**HS1002** **Poster presentation** **4069**

# Numerical analysis of one-dimensional unsaturated flow in layered soils

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In the semiarid loess region of northwest China, the use of gravel and sand as mulch has been an indigenous farming technique for crop production for over 300 years. However, systematic studies concerning the effects of surface gravelsand (mixed gravel and sand) covers on soil and water conservation are scarce. Based on previous studies, this study deals with numerical solutions to the Richards equation to simulate one-dimensional unsaturated flow of layered soil profiles (the gravel-sand mulch surface and root-zone). The equation is expressed in the maxed form and a mass-lumped linear finite elements scheme are used for discretization of the mixed form of the Richards equation. A finite-difference algorithm is developed for accurately estimating the values of the hydraulic conductivity between two neighboring nodes positioned in different soil layers, often referred to as the interlayer hydraulic conductivity. The validity of the model is established for a number of test problems by comparing numerical results with the observational results. The results show a significant reduction in relative errors when using the proposed model.

***Keywords:*** layered soil profiles, unsaturated flow, richards equation

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**HS1002** **Poster presentation** **4070**

# Characteristics of geochemistry and stable isotopes in groundwater and Surface-Water in the Pearl River Delta, China

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***Tang Changyuan, Chen Jianyao, Sakura Yasuo***

Located between 11130E116E and 2130N2340N in south China, the Pearl River Delta (PRD) is an alluvial plain covering approximately 26,820 km2, and one of the most developing regions even in Asia. The PRD is an open-ended V-shaped estuary system. The Pearl River is the third largest river in China after the Yangtze River and the Yellow River. Lots of groundwater and surface-water is used on agriculture, industry and cities. However, the PRD is facing serious water problems in both quantity and quality with its rapid urbanization in last decade. Plenty of domestic sewage and industrial effluents from cities discharge into the river and groundwater. As the result, an environmental impact (falling of water table and groundwater pollution) on the ambient environment has become inevitable. To clarify the source of groundwater and surface-water and evaluate pollution effected by human activities, hydrological field surveying was carried out thrice in March and July 2005 and June 2006. The samples (groundwater and river water) were brought back to Hydroehmistry Laboratory, Chiba for analyzing the contents of major ions ( K+ , Na+ , Ca2+ , Mg2+ , NH4+、Cl- , SO42- , HCO3- , NO3- ) and stable isotopes (18O, D and 15N). Based on hydraulic head distribution, the shallow groundwater is expected to move to the southern East River and/or the western or northern North River. The down stream of East River is mainly from groundwater supplied by rainfall of Xiangtou Mountain and Luofu Mountain areas. It implies that part of river water is supplied by groundwater. The δ18O and δD compositions show that modern rainfall is a dominant component for shallow groundwater. And the variations of δ18O and δD values show that groundwater has the same change with precipitation due to the effect of latitude and elevation. The linear relationship between NO3- and NH4+ is: [NH4+]= 0.0226[NO3-], except some points polluted by domestic sewage. Ammonium ion (NH4+) is the most serious pollutant causing eutrophication of aqueous environments. High NH4+ concentrations are found in the new town without suitable facility for treatment of sewage water. Finally, the risk of groundwater pollution during the urbanization in PRD has been discussed. The spatial distribution of nitrate concentration in this area was found related to septic tank, groundwater flow, water-use and length of periods for wastewater irrigation.

***Keywords:*** stable isotope, human activities, water quality

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**HS1002** **Poster presentation** **4071**

# Investigation of Unsaturated Hydraulic Conductivity and Groundwater Recharge by a Soil Moisture Model

***Dr. Xi Chen***

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Estimation of precipitation recharge is very important for regional water resources evaluation because it is a primary source of groundwater resources and is very useful for reasonable groundwater exploitation. In this study, the methods of zero flux plane (ZFP) of soil moisture potential and fixed flux plane (FFP) were used to determine the precipitation recharge amount by using the observation data of the Hanwang Hydrological Experiment Station in Xuzhou, Jiangsu Province. Further estimation based on combing ZFP with FFP was proved to be more accurate than that from ZFP and FFP, respectively. A numerical model for simulating soil moisture content based on Richard equation was used to estimate the precipitation recharge. In the simulation, the key parameter of the unsaturated-zone conductivity was determined from the relationship between the conductivity and soil moisture content which is developed by FFP using the observation data of the Hanwang Hydrological Experiment Station. Other parameters were calibrated by comparing soil moisture contents between the observation and the simulation. The model was further validated by comparing the model calculated precipitation recharge and the lysimeter observation at the Hanwang Hydrological Experiment Station. The validation results demonstrated that the model is able to accurately estimate the precipitation amount.

***Keywords:*** hydraulic conductivity, groundwater recharge, soil moisture model

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**HS1002** **Poster presentation** **4072**

# Using neural networks for simulating groundwater/surface water interaction in hydrological yield modelling

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***Rainier Dennis***

The Department of Water Affairs and Forestry have identified water-stressed catchments, where Water Availability Studies are initiated in preparation for eventual legally defendable compulsory licensing. These studies will quantify and evaluate water availability in the stressed catchments, as prerequisite to the development of water allocation plans and schedules, and will require methodology and surface water system model improvements to enable efficient, effective and more accurate assessment of surface resource capabilities, as well as determining the availability and method of surface water allocation, taking into account conjunctive use. In the past surface hydrological studies assumed that the impact of groundwater abstraction on surface water (mainly baseflow) was implicitly accounted for in the calibration process or that the interaction is negligible in the context of the large catchments. The Directorate: Water Resource Planning Systems is in the process of reviewing methodologies, best suited for South African conditions, for implementing groundwater/surface-water interaction improvements in the surface water systems models. Using neural networks to simulate this interaction has been listed as a possible solution and using various groundwater/surface water interaction methods in testing the applicability of neural networks will be the focus of this research. Various methods of groundwater/surface water interaction are being evaluated to determine their applicability to South African groundwater conditions. Favourable methods will then be converted into neural networks with typical input parameters such as rainfall and abstraction. The hidden layer could contain nodes that simulate parameters such as hydraulic conductivity, storativity, hydraulic gradient and the area of discharge. Output files will include time series of the contribution of groundwater to the baseflow component of river flow. Case studies with suitable data and information will be used to train and test the different methods using the neural network. As a result of the heterogeneous nature of South African geology and therefore hydrogeology it is proposed that zones are identified, within the case study areas, which could typically respond as a homogeneous unit when viewed on a catchment scale. Training of the neural network and testing of the simulation of the groundwater/surface water interaction will then be done for each of the homogeneous hydrogeological units.

***Keywords:*** neural network, modelling, groundwater/surface water inte

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**HS1002** **Poster presentation** **4073**

# Investigation of the applicability of various groundwater/ surface water interaction methodologies in South African fractured rock environment

***Dr. Ingrid Dennis***
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***Chris Moseki***

The South African National Water Law recognises the interdependency of all the components of the hydrological cycle and that it should be managed as a single resource. Sustainability, equity and efficiency are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources in South Africa. These principles recognise: the basic human needs of present and future generations, the need to protect water resources, the need to protect aquatic ecosystems, the need to share some water resources with other countries, the need to promote social and economic development through the use of water, and the need to establish suitable institutions in order to achieve the above-mentioned principles Understanding and quantifying groundwater/surface water interactions, especially for authorisation and allocation purposes, is a key issue in achieving the above-mentioned principles. This paper discusses various groundwater/surface water interaction methodologies and the application thereof in three different case studies. The pros and cons of each methodology will be highlighted, with regard to the accuracy of the method. The best suited methodology for specific conditions will be identified.

***Keywords:*** sustainability, basichumanneeds, aquaticecosystems

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**HS1002** **Poster presentation** **4074**

# Surface-ground water relationships and integrated numerical modelling of runoff formation on a small basin scale

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During storm and snowmelt, groundwater has proved to be a dominant runoff component in many regions and under different climatic conditions. The new, integrated methodical approach of runoff formation process that will be presented, and which is based on variable surface/ground water relationships aims on the analytical quantification of surface-near water gains and subsurface soil and ground water losses on a small basin scale. For this purpose, origin, age and pathways as derived from application of environmental isotopes and artificial tracers for those water fluxes, that cause channel inflow and hence generate flood hydrographs, are required in high resolution. Numerical treatment of hydrological and hydraulic data using coupled FEFLOW and MIKE11 software packages intends to simulate the appertaining flood hydrographs with sufficient accuracy. The new approach is applied on the Lange Bramke basin, Harz Mountains, Germany (area of 0.76 km, altitude of 540-700 m a.m.s.l., forested by 90% Norwegian spruce), where overland flow is negligible. The unsaturated zone USZ (soil and upper weathered and fractured/fissured bedrock) is non-layered, thus interflow is almost zero. Accordingly, even during flood events channel flow originates predominantly from ground water of the saturated zone SZ which is made of fractured Lower Devonian sandstone, quartzite and slates. UZ and SZ are short-cut by distinct preferential flow paths, which enable fast percolation of the infiltration water that was traced with dyes, and hence permanent ground water recharge throughout the year. Major cross-faults play an important role for ground water transfer towards channels with flow speeds of more than 10 m/h, but which explain only minor portion of total flux. The simulated flood hydrographs for real events are the result of successive work steps of pre-processing and modelling with FEFLOW and MIKE11 which will be discussed in detail: (1) Developing a structural geological basin model by considering fracture zones in particular; (2) Identifying hydrogeological parameters by considering tracer experiments; (3) Simulating groundwater flow with FEFLOW by using discrete fracture elements (1D) and rock elements (3D); (4) Developing a simple channel model; (5) Using an interface manager to couple the groundwater model FEFLOW with the hydrodynamic channel model MIKE11; (6) Computing channel flow for discrete channel sections by using groundwater inflow rates from FEFLOW and the 3rd kind Cauchy type boundary condition. As a result, simulated and measured discharges of Lange Bramke river course agree quite well, i.e. groundwater is by far the dominant source. Differences can be attributed to minor portions of direct (surface-near) flow components and to errors in identifying hydraulic parameters. The advantage of this physically-based numerical pilot study is that it will allow for a regionalization of the runoff formation process in Palezoic central European highlands with scarce data. This meets the requirements for Prediction in Ungauged Basins (PUB). However, further tracer experiments are needed to improve the model calibration, and a stochastic fracture network model for the transfer and regionalisation of results.

***Keywords:*** runoff generation, groundwater flow, fractured rock aquifers

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**HS1002** **Poster presentation** **4075**

# Murzuq Basin in Libya: towards a more sustainable groundwater management

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Murzuq basin is one of the five major groundwater systems in Libya, all of which are considered to be relatively independent of one another. The Murzuq represents a tectonic basin of about 400,000 k m2 area with gentle dips towards the basin centre. In the basin, sediments of Cambrian to upper Cretaceous age predominate. Murzuq basin sits far from coastal areas; it is therefore unlikely that there will be problems of saltwater intrusion. However, groundwater in Murzuq basin is fossil water and with little or no recharge expected because of the aridity of the catchment, the aquifers are vulnerable to over-exploitation and significantly depressed water table and piezometric surface. For example from a previous study of Murzuq basin, it has emerged that in the last three decades, remarkable lowering of groundwater levels has occurred as a consequence of extensive irrigation water abstraction. This, together with the very low water use efficiency in the irrigation schemes served by the aquifers, means that the existing aquifer management practices in the Murzuq are not sustainable. To understand the long-term prospects of the Murzuq, a MODFLOW mathematical model was designed, calibrated and validated and used to simulate the hydraulic conditions within the basin for various farming scenarios in the future. Later, an optimisation model was coupled with the simulation model via a management model to develop optimum irrigation water pumping regimes for the basin. The results showed that if existing farming practices within the basin continue, then no further significant depression of the piezometric surface would take place; however, changes in farming practices such as through increasing the land area under cultivation or substituting more water intensive crops will result in further depression of the piezometric surface. A major finding of the optimisation was that the current pumping schedule is wasteful of water as a number of wells could be shut down and the irrigation water demands will still be met. The paper will present details of these results and proffer advice on how the study could be used to better manage water resources within the basin to make it more sustainable.

***Keywords:*** murzuq, libya, groundwater

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**HS1002** **Poster presentation** **4076**

# Investigating of infiltration losses for an arid basin

***Dr. Abdullah Al-Wagdani***
*Department of Hydrology Associate professor*

INVESTIGATING OF INFILTRATION LOSSES FOR AN ARID BASIN Abdullah S. Al-Wagdani 1, Mohamed El-Sherbini 2 1. Department of Hydrology, KAAU, P.O. Box 80208, Jeddah, Saudi Arabia 2. Department of Civil Engineering, Cairo University, Cairo, Egypt. In this study infiltration rate was measured using double ring infiltometer for Namman basin in the western region of Saudi Arabia. The area of the basin and its tributaries was about 650 square kilometers. The measurements were conducted at eighteen sites and there locations were spatially distributed over the basin drainage area. The results of the field infiltration measurements were compared to linear, Kostaikov and Philip's equations for cumulative infiltration depth and infiltration rate. The results of the comparison and the applicability of these equations to arid basins were discussed. .

***Keywords:*** infiltration, arid basins

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**HS1002** **Poster presentation** **4077**

# Understanding an ungauged river-lagoons system under degradation processes

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Capivara River drains a coastal watershed in the northeast border of Brazil. It comprises a rain-groundwater fed system formed by a predominance of lagoons linked by deeper channels. Even in its headwaters several wetlands integrate the landscape either feeding the river and channels or being flooded by its high waters. That 206 km2 area has an impressive aesthetic value and forms an invaluable diverse ecosystem. Pressure and damages has been imposed to that watershed by human activities. Mining and deforestation has caused erosion and channel sedimentation; human settlements have contributed with sewage disposal; and petrochemical industry has polluted some areas by liquid effluents and smoke. Even with those sources of negative impacts, parts of the ecosystem have been resilient and present some biological integrity. Even though the importance of the environmental benefits has been recognized by public administrators, nothing has been done to improve understand, to recover damaged areas and to prevent against further harms. No hydrological data and investigation have been conducted so far. A research project is currently under way by the Group of Ecohydrological Studies of UFBA, basically devoted to collect primary hidrometeorological and groundwater data and to start studies about the behavior of that water system. However difficulties for traditional gauge stations implementation have been an issue. Amount of available funds, difficult to access some areas and safety reasons have impeded more effective data collection. The circulation patterns in the lagoons caused by diffuse channels and by fixed and floating macrophytes (islands) are also a challenge. This way remote sensing should be useful to constrain the uncertainties in this poorly gauged river basin. However satellite images, aerial photography and radar data, if available, are still high-cost in developing countries. Electro-resistivity survey has been conducted by a collaborative team and must be of importance to understand the aquifer and its relationships with surface water. Linking the sparse information collected in a more traditional way and geophysical survey is part of an effort to overcome difficulties and even the lack of remote sensing data, which we expect to be temporary. First field observations and geomorphologic assessment have showed a complex system integrating wetlands, streams and lagoons fed and maintained by groundwater of excellent quality, but highly sensitive to environmental changes.

***Keywords:*** wetlands, data collection, ground surface interactions

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**HS1002** **Poster presentation** **4078**

# Analysis of contaminant and thermal stream loadings in a fully-integrated surface/subsurface modeling framework

***Mrs. Andrea Brookfield***
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***Edward Sudicky, Young-Jin Park***

Over the past several years, increased attention has been directed towards understanding flow, contaminant and thermal transport exchange processes occurring at the interface between surface water and groundwater, particularly in the vicinity of riparian zones in the riverine valleys and within the hyporheic zone. In this paper, we will examine these processes in the context of the HydroGeoSphere model, a recently developed surface/subsurface control-volume finite element model. HydroGeoSphere is a fully-coupled 3D model that can simulate water flow, evapotranspiration, snow accumulation and melt and advective-dispersive heat and solute transport over the 2D land surface as well as flow and transport processes in the 3D subsurface under variably-saturated conditions. Full coupling of the surface and subsurface flow regimes is accomplished implicitly by simultaneously solving one system of non-linear discrete equations describing flow and transport in both flow regimes, as well as the water, heat and solute exchange fluxes between continua. The model capabilities and main features are demonstrated with several high-resolution 3D numerical simulations to examine the effect of contaminant and thermal loadings, including land-use change, on surface and groundwater quality. It is also demonstrated that the streambed thermal regime can vary markedly both spatially and temporally depending on the intensity of the groundwater discharge/recharge patterns along and across the streambed. The development and application of a comprehensive model is fundamental to the development of sound management and policy strategies for the protection of the environment, for both human and natural ecosystem functioning. A fully-integrated framework utilizing physically-based, watershed-scale modeling tools enables the quantitative assessment of the capacity and the limits of water resource systems, the evaluation of impacts of anthropogenic activities on water quality, and the definition of the conditions needed to maintain a balance between consumptive water use and the needs of natural habitats to maintain aquatic and wetland resources.

***Keywords:*** contaminant, thermal, modeling

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**HS1002** **Poster presentation** **4079**

# Project management to ensure sustainability of multivillage surface source based water supply system- a case study for Bidar district of Karnataka state, Sourh India

***Prof. Hanumana Hally Kambada Rangappa Ramaraju***
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Development and management of water supply systems forms the integral part of overall developmental strategy of the country. It is an irony that despite continuous investment on developmental works, the rural parts of India and some states faces shortage of water for drinking and other consumption needs. Ground water which meets drinking water to 90 percent of rural population get depleted year by year with unscientific management and large scale drawles. The situation in Karnataka State is not different than rest of the country, and the state is classified as water stressed and its 43 taluks out of 175 are considered as critical for ground water. The ground water drawl has increased with increase in number of wells from 2.62 lakhs to 5.63 lakhs from 1971 to 1994 resulting to decline on water table by more than 7 meters between 1978 and 1993 and with more than 20 meters of decline in a few locations. Each year in the State around 50,000 to 60,000 bore wells are drilled including 8000 to 9000 bore wells for meeting drinking water. Such concentrated drilling of bore wells coupled with erratic distribution of rainfall has resulted to faster depletion and drying up of many wells indicating the urgent need of comprehensive approach to manage the water situation to ensure its sustainability. Karnataka state is pioneer in establishment of rural water supply system and has made varied techno-managerial efforts to provide potable water to all habitations. State is capacitating the community to own and manage water supply systems to ensure the sustainability in service level, financial viability and to meet the demand of community in future. This study is an effort to articulate comprehensive approach to draw drinking water supply for future and to over come the quality and quantity linked problems. The study is taken up for Bidar district of Karnataka state, South India, which has quality and quantity linked problems in ground water.

***Keywords:*** communityinvolvementlithology, habitations, sustainability

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**HS1002** **Poster presentation** **4080**

# Human impact on groundwater flow and quality in the Seoul City, deduced by multiple isotopes (dD, T, d18O, d34S, and 87Sr/86Sr)

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***Alain Laraque, Jean Loup Guyot, Francis Sondag, Cristelle Lagane***

In order to evaluate the influence of human activity on the flow system and quality of groundwater in the Seoul City, dD, T, d18O, d34S, and 87Sr/86Sr were determined for representative 14 groundwater samples and four river water samples for comparison, which were collected over a wide area of the city. On the basis of groundwater level, dD, T, and d18O data, groundwater of the Seoul City is suggested to be flowed from surrounding area to central part of the city where subway tunnel pumping are concentrated. Corresponding to this frame, groundwater tends to change in its ion balance from Ca-Cl+SO4 type to Ca-HCO3 type toward central part of the city. The d34S value of sulfate (SO42-) in groundwater tends to decrease (+16.3 permil to +4.3 permil) with increasing of concentrations of SO42-, nitrogen (as NO3-), and potassium (K+), and this can be attributed to the contribution of man-made materials such as fertilizers. In addition, it was indicated from the d34S, SO42-, NO3-, and K+ mappings that the influence of human activity is accumulated basically from surrounding to central part of the city. On the other hand, the 87Sr/86Sr value of the groundwater varied (0.7133 to 0.7506) in accordance with its host rocks with different origin, and moreover, it became clear with combined analysis of 87Sr/86Sr value and elements data that bivalent cations such as calcium (Ca2+) were largely derived from geological materials. As a consequence, it could be pointed out from our work that discharged materials due to human activity were carried along flow system controlled by subway tunnel pumping toward central urbanized area contributing to the water quality change of the Seoul City.

***Keywords:*** groundwater, isotopes, human activity

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**HS1002** **Poster presentation** **4081**

# Optimal design for sustainable groundwater supply based on intrinsic vulnerability

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Nowadays, sustainability is a significant topic in utilization and protection of available groundwater resources. In this study, optimal pumping strategy for the sustainable groundwater management in rural region, susceptible to contaminations from fertilizer and/or livestock excretion, is determined on the basis of intrinsic groundwater vulnerability assessment. The vulnerability of groundwater to contamination is described probabilistically using adjoint-derived backward transport equation. The backward transport equation calculates the location probability density function (pdf) and the travel time probability density function. The location pdf represents the most likely location in the domain for contaminant particles to reach the well in concern and the travel time pdf describes the most likely time for particles to reach the well. With both the location and travel time pdfs, it is possible to make an expected concentration at a well. Since the backward equations are used in this process, the expected concentration of contaminant at a well can be made with only a single simulation of transport, which would require numerous simulations with forward simulation. This feature makes the method efficient to apply when the information of known or potential contamination sources are insufficient and imprecise in comparison with the detection information. Genetic algorithm (GA) that searches the global optimum is used to achieve the optimal pumping strategy in a region where the groundwater vulnerability to certain contaminant is assessed by the backward equation. The pumping strategy involves obtaining the optimal pumping rates that are able not only to supply sufficient amount of the groundwater resources, but also to protect the groundwater from the contamination by keeping the location pdfs in the domain below a prespecified probability. It also controls the fertilizer loading that can cause the contamination at the wells located at the vicinity of the contamination sources by calculating the maximum permissible fertilizer mass lowering the expected concentrations at the wells below the water quality standard. The results present that a novel methodology suggested in this study is considerably efficient in resolving the sustainable groundwater management problem in the rural regions where may have a difficulty in prediction of the contamination due to insufficiency of information about the contamination sources.

***Keywords:*** groundwater, management, vulnerability

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**HS1002** **Poster presentation** **4082**

# Prediction of water table variation due to intermittently applied transient recharge to a sloping aquifer

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***A. Manglik, P. Banerjee***

Irrigation is applied intermittently in many parts of the arid and semi-arid regions to increase the production of food grains. In regions having water table at shallower depth, recharging of aquifer due to return flow from irrigation leads to the growth of water table near to the ground surface. This causes problems like water logging, soil salinity etc. These problems can be alleviated or at least minimized to a certain extent by the implementation of proper drainage schemes for which a better understanding of the spatio-temporal variation of the water table in response to intermittently applied recharge is very essential. The rate of recharge is known to vary with time due to several factors such as dispersion and swelling of the soil particles, displacement of entrapped air from soil pores, and sediment and biological clogging of the soils pores In this paper a mathematical model is presented to predict the variation of the water table due to intermittently applied transient recharge to a sloping aquifer which is subjected to drainage along two parallel ditches. The rate of recharge is approximated by a number of linear elements of different lengths and slopes. The advantage of this scheme of recharge approximation is that any type of variation in the recharge rate for any number of cycles of recharge can be approximated with the help of the required number of linear elements of different lengths and slopes depending on the nature of variation in the recharge rates. This reduces uncertainty in the approximation of recharge rates which in turn reduces uncertainty in the of water table variations. Application of this model for the prediction of water table fluctuations is demonstrated with the help of a numerical example.

***Keywords:*** transient recharge, aquifer, water table

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**HS1002** **Poster presentation** **4083**

# Modelling as an investigation tool in water resources integrated analysis

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***Bonomi Tullia***

A three-dimensional model of an aquifer system in a regional framework has been developed in order to apply a numerical code to simulate the groundwater flow. The choice of a modelling approach offers many advantages as the possibility of taking into account the interactions between surface water bodies and the aquifer, the influence of climate change on the water table levels and, consequently, on the water level in streams and rivers. The adopted methodology represents a new approach that combines a great quantity of data, managed with ease by means of database, fast and powerful computers and software able to reproduce a sophisticated and detailed 3D hydrogeological model. The final step concerns the simulation of the groundwater flow directions and piezometric levels for different values of the parameters of the hydrologic water balance. This represent an investigation tool of how the water balance changes would affect the aquifer and hence develop an optimization scenario in terms of water resources planning and management. The study area is represented by a shallow aquifer in an outwash plain in the Piedmont Region; the fluvial and glacio-fluvial aquifer materials are highly heterogeneous with the presence of low permeable lenses at different depths. The quality of the aquifer is thoroughly compromised by pollutants such as nitrate and fertilizer all over the area. The presence of a close rivers and streams net, in hydraulic connection with the water table, plays an important role in the hydrologic cycle, as well as wetlands and springs located in the northeastern part of the studied area. Its therefore strictly necessary to know the flow field dynamic to determine the directions along which the interaction between surface water and groundwater develop and estimate the volumes involved in the water balance. The calibration of the model by field measurements has been carried out in order to validate the model and further use it for predictions; both head and flow target have been implied, represented by water table values and streamflow rates observed respectively in correspondence of two regional monitoring nets. A reasonable degree of accordance between observed and simulated values has been gained.

***Keywords:*** modelling approach, regional framework, aquifer parameterization

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**HS1002** **Poster presentation** **4084**

# Integrated analysis of water resources for the ground water management in the Province of Cremona (Northern Italy)

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In order to support the environmental policy of the Province of Cremona, in particular the release of permissions of new water well drillings, a mathematical model of the aquifer system has been developed. The area is delimited by Adda, Oglio and Po rivers and its extension is about 2500 square kilometers. The model will improve the analysis of the hydrological balance in this complex system, where ground water strongly interacts with the network of surface water and its evolution depends on the aquifer recharge due to irrigation and rain water. In particular the hydrological balance requires a quantitative evaluation of several terms: (1) aquifer recharge from infiltration of rain and irrigation water and from channel losses; (2) drainage from depression springs and from the terraces that delimit the fluvial valleys; (3) river-aquifer interactions; (4) water extraction for industrial and agricultural purposes; (5) water extraction for drinking purposes. The aquifer system is characterized by a dual circulation system: (a) shallow ground water flow in a very permeable phreatic aquifer; (b) deep ground water flow in semi-confined aquifers where fluxes are smaller, induced by water exctractions from public wells, and which are fed by the phreatic aquifer mainly through aquitard windows. The mathematical model developed for this application uses two submodels in cascade: (1) a model of the irrigation system to estimate aquifer recharge on the basis of the soil use, the crop characteristics and the meteorological data and (2) a conservative finite-differences ground water flow model to describe the ground water dynamics.

***Keywords:*** ground water modeling, irrigation and drainage, water resources management

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**HS1002** **Poster presentation** **4085**

# Mathematical modelling of the surface and ground water system as a tool in a land consolidation project in Zondereigen (Belgium)

***Dr. Roeland Adams***

***Eric Degand, Filip Debrabandere, Perry De Louw, Roeland Adams, Ype Van Der Velde***

Zondereigen is the name of a little village in the north of Belgium near the Dutch border. To meet the expectations of modern agriculture, land consolidation was decided around the village by the Flemish authorities. The land consolidation committee decided to use mathematical modelling of the surface en groundwater system to determine the most favourable hydrological conditions for both agriculture and nature. The project area is sandy and drained by the Noordermark and the Gels Loopke streams. The upstream area is an infiltration area, while seepage in the valley and downstream part of the catchment is drained by a system of ditches As both surface and groundwater are identified as steering variables of the hydrology and water management of the area, much work was devoted to their complex dynamic interaction. This presentation is focussing on the corresponding modelling study. Detailed surface and groundwater modelling was used to describe the surface and groundwater flow in the project area. Both steady state and transient models were calibrated using monitored flow and head data. The models were coupled and used to evaluate the effects of different management scenarios to improve the understanding of how the water system responds. A first set of scenarios was dedicated to the study of the effect of suppressing some of the ditches and damming up other ones. These scenarios were first modelled with the ground water model. Their results were used to review the calibration of the hydrological model injected into the hydrodynamic surface water model. The results of the latter model were finally used as a boundary condition for the groundwater model. The second set of scenarios was used to investigate the effects of changes to the two major streams, namely the Noordermark and Gels Loopke. One scenario tested the effect of raising the streambed of the Noordermark. Another investigated the introduction of weirs in the Noordermark every 200 m. The changes in the water system were introduced in the surface water model, in order to calculate the new stages, which were on its turn used as a boundary condition for the groundwater model, which was used to calculate the effect on the groundwater table. The scenario analysis contributed greatly to the drafting of the global land consolidation plan in which agriculture and nature development could together profit from the best possible hydrological conditions. Therefore the Noordermark en Gels Loopke will have to be relocated, several ditches have to be filled in, while new ones will have to be trenched.

***Keywords:*** nature development, land consolidation, water management

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**HS1002** **Poster presentation** **4086**

# Effects of agricultural activities on groundwater nitrate contamination in a yellow river irrigated region

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Agricultural activities induced increase of nitrate loading in groundwater is a worldwide problem. The Yellow River irrigated regions play an important role in food production of China. In these regions, the groundwater table is always sallow buried varying from 1-2 m to ~10 m in depth because of the effective recharge from surface irrigation. This indicates that there is less water shortage in the Yellow River irrigated regions comparing to other places in North China Plain, where the groundwater table falling addresses the most concerned water shortage. Therefore, the water balance in irrigated region and surface water-groundwater-soil water-atmospheric water inter-exchange/transformation, so called 4-water transformation, is a main topic in agricultural water management during the last 2-3decades. However, accompanying obvious food production increase, which relies to a large extent on the increasing application of chemical fertilizer, is groundwater contamination. This is severer in surface water irrigated regions. In this study, we conducted a field survey on the groundwater level and nitrate concentration in Weishan Irrigation District, located at the lower reach of Yellow River. The field survey is carried out in different seasons in 2005. The survey includes observation of groundwater level, pH, electrical conductivity, nitrate concentration, land use pattern, yield, and fertilization intensity in the study area. Regular groundwater sampling and quality analysis is carried out at a comprehensive eco-hydrological experimental site to investigate the seasonal dynamic change of groundwater quantity and quality. Based on the survey, this paper will address the impacts of agricultural activities on groundwater nitrate pollution in the Yellow River irrigated region. In the study area, agricultural land use patterns are dependent on the land and water conditions. Besides wheat-maize rotation, the most popular cultivation pattern, other patterns with high production/income, such as greenhouse vegetables, watermelon-cotton, and etc., are also widely adopted. N-fertilizer is excessive applied for all land use patterns with the annual amount ranging from 500 to 1420 kg N ha-1. The nitrate loading in groundwater has large seasonal variation mainly caused by agricultural activities. Even in the best water quality season, 4 of 27 samples were checked out the nitrate loading exceeds drinking standard, and the maximum nitrate concentration in well water amounts to 100 mg NO3- L-1. The shallow groundwater over the study area is susceptible to be contaminated.

***Keywords:*** nitrateleaching, irrigation, yellowriver

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**HS1002** **Poster presentation** **4087**

# A DEM-Based Residual Kriging Model for Estimating Groundwater Levels within a Large-Scale Domain - A Study for the Fuyang River Basin

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Understanding the movement and change of groundwater is a basis of the effective groundwater resources management, wherein the information about spatial distribution of groundwater levels is indispensable. Geostatistical methods like kriging has been widely used to estimate groundwater levels based on observation wells. The errors are inevitably introduced through the interpolation process so that how to increase the accuracy and accuracy based on limited well data has become an urgent issue for estimating groundwater levels, especially for a large area. This study developed an integrated DEM-based residual kriging (DEM-RK) model for estimating groundwater levels within a large-scale domain. The model can yield more physically plausible estimates of groundwater levels in a large-scale domain than those currently in use by effectively utilizing well data and considering the influences of terrain morphology on the groundwater flow. The model was then applied to the Fuyang River Basin, a 5000 km2 study area, in the North China for estimating the regional groundwater levels and flow. The Kolmogorov-Smirnov (K-S) test was employed to prove that the DEM information could markedly facilitate the residuals to approach a normal distribution, which ensures a satisfied estimate accuracy. For demonstrating the advantages of the proposed DEM-based trend surface, three types of trend surface using both simple and quadratic equations were developed to estimate groundwater levels. Based on the verification points, the average error (ME), the average absolute error (MAE), and the square root of the quadratic multiply error (RSME), for each trend surface equation were compared. The DEM-based trend surface equations were discovered with the highest accuracy. The results indicated that quadratic equation could more effectively present the trend surface than simple one with a higher correlation coefficient. However, for a large-scale estimation domain with limited well data, the simple equation for DEM-based trend surface showed more feasible with a better accuracy than the quadratic one. Further research on improving trend surface simulation to more effectively reflect system complexities would be desired.

***Keywords:*** groundwater levels, large scale domains, residual kriging

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**HS1002** **Poster presentation** **4088**

# Quantifying surface water/groundwater interaction along regional rivers in Flanders (Belgium).

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Surface water/groundwater interactions have already been discussed fairly frequent. This study applies available methodologies and techniques to three gauged river basins (Dender, Grote Nete and Meuse) in order to define the relation between surface water and groundwater. Furthermore, an attempt has been made to extrapolate the described relations to similar ungauged riversystems in Flanders. To represent the variability of Flemish rivers, the three basins, selected for this study, differ in their hydro-geological composition. The river Dender is dammed by weirs and flows through a loamy to sandy-loamy valley, while the Grote Nete is partially tidal and its valley consists mainly out of sandy to sandy-loamy soils. Finally, the river Meuse, which is the largest of the three, is a free flowing gravel bed river. This study shows that in the Dender, interaction between groundwater and surface water is minimal. This is most likely caused by the damming of the river. In the Grote Nete, groundwater is influenced by the tides on the river. However, to what extend this is the case, is still under research and will be fully presented at the assembly. The study also indicates that the interaction between surface water and groundwater in the Meuse is considerable. This could be due to the canal, which was dug on the flanks of the valley of the Meuse, parallel with the river. This might supply the additional volume of water to the groundwater-system and consequently to the river. The relation between surface water and groundwater in ungauged riversystems will also be addressed at the General Assemby.

***Keywords:*** groundwater, surface water exchange, belgium

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**HS1002** **Poster presentation** **4089**

# prediction of groundwater discharge in groundwater dependent wetlands

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Water exchange and related nutrient fluxes occur from the underlying groundwater to the wetland surface water in groundwater dependent wetlands. Consequently, groundwater discharge has a crucial influence on the ecosystem in groundwater dependent wetlands. Quantification and delineation of groundwater discharge is, thus, of paramount importance for the development and protection of groundwater dependent wetlands. However, it is often the most difficult to quantify the groundwater component with measurement techniques due to the complexity of interactions between groundwater and wetland surface water. For this reason, much attention has been paid, of late, to numerical modeling for prediction of groundwater flow in wetland environments. This study aims (1) to quantify the groundwater discharge in groundwater dependent wetlands by using a numerical code, and (2) to assess the impact of groundwater discharge to wetland water environments under various hydrological conditions. Numerical investigations are performed in consideration of hydrogeological conditions of groundwater dependent wetlands such as seasonal fluctuations of wetland water level and groundwater table due to seasonal changes in rainfall, vegetation in the surrounding of wetlands, and topography of surrounding area. Results demonstrate that simulated groundwater discharge is influenced by seasonal rainfall changes, and the surrounding vegetation and topography control the recharge to groundwater table. Simulation results indicate that groundwater discharge may have a significant impact on the overall wetland surface water environments though it occupies relatively small amount of the total wetland water. This study is limited to analyzing hydrogeological factors related to wetlands, but little consideration is made for eco-hydrological factors such as water and nutrient uptakes by wetland plants from groundwater. Further research attempts should be made to integrate wetland ecohydrology into wetland flow system modeling for comprehensive study.

***Keywords:*** groundwater dependent wetland, groundwater discharge, ecosystem

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**HS1002** **Poster presentation** **4090**

# Monitoring for the mitigation of rural diffuse pollution

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It is increasingly recognised that it is necessary to take an holistic approach to catchment management and that, in order to identify and tackle issues of diffuse pollution, any monitoring programme has to encompass both surface and groundwater. It is important to have accurate characterisation of surface and ground waters in catchments due to the forthcoming Water Framework Directive, which demands that all water bodies must meet good ecological status. In Scotland one of the factors which would prevent water bodies meeting good ecological status is rural diffuse pollution and therefore, SEPA, as the main regulatory body for water quality has devised a monitoring tool, the Diffuse Pollution Screening Tool, which has been used to identify catchments which are at risk of not meeting good ecological status due to pressures from diffuse agricultural pollution. In a selection of these catchments, it is hoped to carry out monitoring of surface and groundwaters so as to characterise accurately the source of any pollutants. Monitor farms are to be chosen in these priority catchments, where a series of measures will be implemented in an attempt to reduce diffuse pollution. Results from monitoring before and after the implementation of such measures will assess their relative effectiveness. The first of a series of catchments selected for monitoring and the implementation of measures is the Lunan Water, Angus, a catchment where intensive agriculture is the main land use with arable, root crop and fruit farming being the main crops grown. In the upper reaches of the catchment there is a loch system in which the eutrophic status is believed to be sustained by inputs of nutrient rich groundwater, while in the lower reaches, because of the agriculture, threats to water quality come mainly from surface runoff of sediment and nutrients. Water resources are also at threat due to abstraction for irrigation in the lower reaches. It is hoped that, through monitoring both surface and groundwaters, main sources of diffuse pollution to both surface and ground waters will be able to be identified and reduced or completely prevented by the implementation of revised and improved farming practices.

***Keywords:*** diffuse pollution, ground water, surface water

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**HS1002** **Poster presentation** **4091**

# Comparative study on multi-branch river runoff forecasting method

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In the runoff forecastingCthe prediction on multi-branch river is much more difficult and complicated than that does not have branches. And the more branches, the more difficult and complicated to predict. But many areas with significant control reach, or areas where economy is more developed, are all on the multi-branch rivers. Today, making proper use of water resource is becoming more and more important. So improving the precision of multi-branch river runoff forecasting to meet the request of the operation and management of reservoir, is an urgent subject to be solved. In the recent several years, various mathematic techniques have been widely applied to runoff forecasting. Like fuzzy mathematics, stochastic model, regression analysis in the early researches, and now artificial neural network model has become a new focus. These methods have their own superiority and insufficiency on various aspects, such as the establishment and solution of model, forecast accuracy, applied effectCsuitable condition and so on .This paper attempts to do some research on three kinds of models with different influence factors. The methods to be discussed include multivariate linear regression analysis model, water balance model and 3-layers BP neural network model. In multivariate linear regression analysis, it carries on correlation analysis to select predicting factors tentatively; then sieves the predicting factors out according to the result of calculation; finally sets up the optimum multivariate linear regression model. Water balance model is founded on the basis of water balance equation, obtains the output variables by the input variables. Because some input variables are unknown, the model ascertains them through establishing response relation between the unknown terms and the known variables. The BP network model readjusts weight value continually through training the sample repeatedly, causes the network to restrain, thus forms the function mapping of input - output. The application of three models to the watershed of Tarim indicates that the discharge hydrograph simulated and predicted are satisfying. Although the effects of some other factors are considered, the forecast accuracy will not be improved obviously. Above all, through analyzing the structures, parameters and forecast precisions of these models, artificial neural network model is better as compared with other two. In the end, this article puts forward some proposals about how to strengthen the predict abilities of multi-branch runoff forecasting methods.

***Keywords:*** runoff forecasting, multivariate linear regression, artificial neural network mode

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**HS1002** **Poster presentation** **4092**

# Features of formation of a slope flow caused by interaction of non-uniform surface stream and seepage

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The decision of various engineering problems of hydraulics of open streams requires quantitative definition of morphological and hydromechanic design parameters of a local surface slope flow. In many cases the quantitative estimation of the dominating factor causing formation of the mechanism of interaction between surface runoff and self-washed canal also is necessary. For example, for forecasting erosive stability of soils the establishment of energetic characteristics of cooperating surface stream and seepage is necessary, and for definition of optimum distances between intercepting canals, the value of the water flow and morphological parameters of the formed surface runoff, responding to the maintenance of probable maximal reduction of ecological balance of a geomorphologic landscape has major importance. The forced export of surface runoff from the areas in many respects depends on concrete hydro-geological, soil and other natural and relief conditions. Usually, in design model the flat stream which specific water flow is considered depends on an atmospheric precipitation. Water permeability inflow seepage of effective cross-section of a stream is determined by coordinates which in turn represent function of time parameter. Because of multifactor process of formation of a surface runoff, the problem in most cases is examined by ignoring of permeability of bottom canal layer, i.e. the problem is solved just for the water-proof basis. However, well-known, that capacity and parameters of hydromorphology are mainly redistributed, not only through the intensity of an atmospheric precipitation, but in most cases from permeability of a bottom canal layer. Formation of a surface runoff during the storm atmospheric precipitation in tropical zones where the bottom canal layer is presented by coarse-grained sediments serves bright example for this. In this connection, it is expedient to take into account non-stationary state of infiltration water absorption in a zone of suspended water (aeration), which determines all design parameters of non-stationary open stream. During designing of check catch water and intercepting canals it is accepted, that movement of a stream is non-uniform, that certainly does not correspond to a reality and therefore, it is necessary to take into account non-uniformity of movement of mutually influencing surface runoff and seepage. According to it, it is necessary to take into account variability of seepage velocity reflected in the variability of the pressure gradient along a way of stream movement. On the basis of these preconditions the design model is developed, allowing to determine the depth in optional section. It will enable to receive the equation of curve for free surface with the accuracy, satisfying engineering requirements of the decision of practical problems, using the method of iteration of gradual approximation. Simultaneously with it, section parameters are established, and considered physicomechanical and strength and deformation characteristics meet noneroding conditions.

***Keywords:*** runoff, seepage, nonerosion

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**HS1002** **Poster presentation** **4093**

# Intrusion of surface water with contaminant into deep groundwater on intensive urbanization area, Bangkok, Thailand

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The most of mega-cities in the world have been developed in Asia, and the most of them are located on the coastal area. These growing Asian mega-cities have severe pollution problems in coastal area as well as urban area. In addition, groundwater has been pumped up intensively on the urban area. Consequently, groundwater potential has been decreased, and land subsidence occurred. The large changes of groundwater condition also have accelerated the contaminant intrusion from the surface to the groundwater. To prevent the diffusion of contaminant under the ground of urban area, it is necessary to consider the interaction of surface water and groundwater with including relationship of deep and shallow groundwater. However, these processes have not been confirmed in detail. The objective of our research is to confirm the intrusion of surface water with contaminant into deep groundwater on intensive urbanization area. The research area is located around Bangkok in Thailand. The population of Bangkok is about 8 millions. Bangkok metropolitan city is located on a delta of Chao Phraya River, and faced Gulf of Thailand. The Delta is composed of Holocene marine clay with about 30m thicknesses and Pleistocene sediment with the depth of about 300m. The main aquifers are divided into 4 to 6 layers, surface (SG), second with a depth of about 100m (PD), third with about 150m (NL), forth with about 200m (NB), fifth with 300m, sixth with 400m. We measured the water level at boreholes with multi-depths (100m to 200m) in 2004 and 2006. In addition, we collected more than 50 water samples. Dissolved chemical component and stable isotope (D and 18O) of water samples were analyzed by ion chromatography, ICP spectrometer, and mass spectrometer, respectively. Most of groundwater potentials in some aquifers at same sites indicated downward groundwater flow with the hydraulic gradient of 0.01 to 0.1 in the urban area, except for the northern suburban area. As a topographic gradient is extremely low (0.0001 to 0.001) in the urban area, it is obvious that the downward flow is dominant rather than the lateral flow. However, Sanford and Buapeng (1996) indicated the upward deep groundwater flow with long residence time, using 14C analysis and numerical simulation. These differences mean the radical change of groundwater flow with intensive pumping for last 15 years. The 18O of deep groundwater on the northern suburban area was low, compared with shallow groundwater and surface water. On the other hand, that was high on the urban area. These results suggest that downward gradient caused surface water intrusion into deep groundwater. In addition, Mn concentration in deep groundwater was extremely high under the urban area. This suggests also the contaminant intrusion and storage in deep groundwater. These results imply that we have to recognize the possibility of contaminant transport with deep groundwater discharge after recovery of its potential in the future.

***Keywords:*** contaminant, intrusion, urbanization

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**HS1002** **Poster presentation** **4094**

# Long term and spatial variations in nutrient discharge with considering the interaction of river and groundwater in watersheds of 1km2 to 1000km2, western Japan

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Previous studies had clarified that the direct interaction of surface and subsurface water, that is hyporheic effect, causes various chemical changes and that has great impacts on material cycle in a watershed. However, the application of hyporheic effects to large watershed has not been enough examined. Therefore it is necessary to evaluate the effect of the interaction in various catchment scales on mass transport and to integrate the results to apply the interaction to a much larger basin. In addition, in a viewpoint of a nutrients discharge to the ocean, it is important to confirm factors controlling the long-term variation as well as to consider the interaction in a large basin. But there are few researches that evaluated a long-term variation in discharge including artificial impacts. In this study, it aimed to confirm the nutrients discharge with considering the interaction of river and groundwater in a different scale. In addition, it purposes to evaluate its long-term variations considering influences of human activities. The study watershed is Ashida River, which is the first-grade river flowing into the Seto Inland Sea. The problem of eutrophication has not been solved yet. In Ashida River watershed, we confirmed the long-term variation using the data of runoff and water quality for last 3 decades from Ministry of Land, Infrastructure and Transport etc. Then we analyzed these data by the nutrient balance model for the effect of the natural interaction and human activity such as the change of land use and population on the variation of nutrient discharge. Results estimated by a nutrients balance model indicates that the TN flux in a unit area tended to decrease with expanding of watershed area, especially the expansion of one order in area caused the increase of two order in nitrate reduction. This result suggests that the workable area of the hyporeic effect increases with the expansion of watershed area. In addition, nitrate flux variation suggests to be largely attributed to population growth but agriculture area. As for TP and SiO2, an obvious hyporeic effect was not confirmed in any scale. However, it was estimated that TP flux by groundwater was equals to that by river in the delta area. This groundwater is also recharged by the river water on the upstream area. That is, it was suggested that TP flux increased by the interaction in the delta. On the other hand, the SiO2 variation in the river indicated that the discharge decreased by the trapping effect of the dam constructed on the midstream area in 90's.

***Keywords:*** nutrients discharge, long term variation, hyporheic effect

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**HS1002** **Poster presentation** **4095**

# The effect of irrigation channel network on surface and groundwater connections in the lower valley of the Cachapoal River in Chile

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***Diego Rivera, Eduardo Holzapfel***

The effect of irrigation channel network and irrigation systems on the hydrology of an irrigated valley is analyzed. The study area is the Peumo Valley, located 100 kilometer South of Santiago. This valley has geomorphologic and infrastructure characteristics that increases the interaction between surface and groundwater. Due to the lack of hydrology data on the valley, the methodology of this study consisted on a continuous feedback between monitoring and modeling. Monitoring focuses on the establishment of a network to evaluate groundwater levels and quality, measurement of flow rates and water quality on irrigation channels, and evaluations of flood pathways after severe storm events. A groundwater model was develop to study the effect of channel network on groundwater and a superficial water model was use to study the groundwater recharge distribution. This interaction produces a stability of groundwater level along the different seasons of the year. During the winter season, irrigation channels behave like rainwater collector system and do not allow the infiltration of rainwater in the lower areas of the valley; in the irrigation season, infiltrated water from the channel recharge the aquifer raising the groundwater level. Hydrology of the valley is affected by irrigation; for this reason is important to understand how irrigation channel lining can affect the water balance on the valley and it agricultural productivity potential.

***Keywords:*** irrigation channels, groundwater surface water, interaction

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**HS1002** **Poster presentation** **4096**

# A conceptual approximation to model the coupled groundwater-surface water system in the lower valley of the Cachapoal River IN Chile

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The effect of irrigation channel network and irrigation systems on the hydrology of an irrigated valley is analyzed. The study area is the Peumo Valley, located 100 kilometer South of Santiago. This valley has geomorphologic and infrastructure characteristics that increases the interaction between surface and groundwater. The analysis has been carrying out using a methodology based on a continuous feedback between monitoring and modeling. Monitoring focuses on the establishment of a network to evaluate groundwater levels and quality, measurement of flow rates and water quality on irrigation channels, and evaluations of flood pathways after severe storm events. In this document we present a conceptual approximation to model the coupled groundwater-surface water system, based on the use of the finite volume method to obtain a numerical solution of Richards equation, programmed in Matlab. The numerical solution can be applied on a three-dimensional domain where the soil can have variable saturation degree (saturated and non-saturated). An initial solution is obtained for a two-dimensional plane, then a second solution is obtained for an orthogonal two-dimensional plane; after that, a weighted interpolation is use to obtain the solution for the three-dimensional domain. Superficial flow like: irrigation channels, drainage channels, ponds and rivers are introduce in the numerical model as time-variable boundary conditions. This conceptual framework includes the analysis of field-measured data and modeling-generated data, considering that uncertain is associated either to monitoring as well as modeling. In this way, both set of data (monitoring and modeling) are improved. For that reason, this methodology differs from the classical model calibration, where the model is forced to fit the field-measured data. Actually the methodology is been applied in the lower Cachapoal Valley and the results indicated that is potentially utilizable to study groundwater-surface water interaction in many other cases.

***Keywords:*** irrigation channels, groundwater, surface water interaction

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**HS1002** **Poster presentation** **4097**

# Analysis of potential impacts of water resources developments on the hydrology of Okavango delta, Botswana.

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***Kalaote Kalaote***

In Setting up the integrated hydrologic model for Okavango Delta, the worlds largest Ramsar that is located in Botswana, the hydrology of the delta and the source basin upstream as it is and as it may possibly be due to potential water resources developments and climate change, among others, has been analyzed. This paper, therefore, presents derivation of simplified scenarios and their potential impacts on the hydrology of the delta using the integrated hydrologic model. The overall water balance is used relating rainfall, evapotranspiration, upstream inflow, downstream outflow and surface and sub-surface storage changes. The flooded area, which, appears to be the most sensitive parameter to water resources developments showing the impact of declining inflows, revealing delays in the timing of the upstream flood wave and individual rainstorms is studied. Potential dams in Angola, with a combined storage approximately equal to the annual delta inflow are studied. Upstream irrigation in Namibia and especially in Angola has the potential of reducing the lower envelope of flooding by close to 50 % in dry years. Present and possible future surface and ground water abstractions appears to have insignificant impact on the upper envelope of flooding while projected climate change appears to have the most severe impact, reducing both the inflows from upstream and rainfall over the delta (lower and upper envelopes of flooding are reduced) and increasing temperature and the rate of evapotranspiration.

***Keywords:*** envelope flooding, lower envelope flooding, upper envelope flooding

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**HS1002** **Poster presentation** **4098**

# Development of a hyporheic zone typology for water framework directive water bodies within England and Wales

***Dr. Tracey Goodwin***

The Hyporheic Zone (HZ) can be defined as the water-saturated transitional zone between surface water and groundwater. As such, the role of the HZ within processes of pollutant migration and transformation within river corridors is of increasing interest, in particular, the significance of water exchange and pollutant attenuation processes occurring at the groundwater - surface water interface. Understanding these processes, and their spatial and temporal variations, is a pre-requisite for meeting the challenges posed by the Water Framework Directive (WFD) which emphasises a more integrated approach to catchment management thus it is of importance to The Environment Agency, the regulatory authority of England and Wales. The main objective of this research was to develop a typology of the HZs found within WFD-defined surface water-bodies (SWBs) within England and Wales. The typology was split into two tiers; the first uses information derived from national datasets, the second then uses locally sourced data to validate and increase the spatial definition of the typology. The development of the tier 1 methodology is the focus of the research presented here and is based on four parameter axes; Fine Sediment Depth; Sediment Permeability; Sub-surface Permeability; and Geo-chemistry. The resulting HZ type ascribed to any water-body is defined by low, medium or high categories of each of the above axes derived using available national datasets including: WFD water-body catchments and river network; the1;50,000 Centre for Ecology and Hydrology (CEH) river network, 1:50,000 British Geology Survey bedrock and drift geology digital maps; Low Flows 2000 regional runoff models; 50m CEH DTM; 1km2 Land Cover Map 2000 and Hydrology of Soil Types digital maps. Initial validation of the typology was completed using data from the River Habitat Survey and field data from the River Severn. In the first instance it is envisaged that the typology will be used by the Environment Agency to identify those water bodies that are most likely to have significant potential for pollutant attenuation at the ground water surface water interface, and to direct actions (e.g. land-use change) in the most effective and proportionate manner

***Keywords:*** hyporheic zone, goundwater surface waterinter, water framework directive

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**HS1002** **Poster presentation** **4099**

# Estimate of balance elements for an exploited aquifer by methods of mathematical modelling (an example of Privolgski Artesian Basin)

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***Tatjana N. Saevets, Tatjana I. Vechkanova***

Groundwater, as any dynamic system, is characterized by variability of their parameters as a result of changes in natural conditions and human pressures. Operative management of natural resources for large regions by decision makers presupposes the presence of actual assessment of groundwater state for the region, as well as possible variants of scenarios concerning groundwater development (depending on different levels of human impact). The most comprehensible tool to support the groundwater management is creation of regional mathematical models, which give possibilities to reflect the impacts both from natural factors and human pressures. The main purpose of such models is to protect groundwater resources from overexploitation and contamination. The possibility of realization of such approach is illustrated by an example. The model has been created for hydrogeological sub-region, which is a part of the Privolgski artesian basin. This region has been chosen as the less favorable both in natural and anthropogenic conditions, with numerous groundwater users (present and future). The purpose of the regional modeling was to define the parameters that govern the formation of the groundwater resource within above-mentioned hydrogeological unit. Beside this, the optimization of the water-supply system has been proposed. For the creation of the mathematical model, digital maps have been used (scale 1: 1 000 000 and 1: 200 000), as well as data from the State groundwater monitoring. The model reflects the multi-layered structure of the groundwater system. The two main aquifers are divided by a thick aquiclude. The groundwater use has been set on the model taking into account both operating and future well-fields. The total need of groundwater for 20 towns and villages is assessed as more than 1000 m3/d. Besides different variants have been considered for situation of the new well-field for water supply of the town of Volgograd (the need of groundwater is assessed as 200 000 m3/d). The obtained results are as follows: ˜ A new well-field is proposed for water supply of the town of Volgograd (for the assessed need); ˜ Limitations of the groundwater withdrawal are set up for the whole area, taking into account operating well-fields, as well as the prospective need of water supply (the need of groundwater is assessed as 335 500 m3/d); ˜ The water balance of the territory is defined for different years, including input from streams; ˜ For the center of any well-field, groundwater levels are estimated for the period up to 2050. The analysis of components of water balance for the developed aquifers has shown that some restrictions in groundwater withdrawal are necessary for protection of groundwater from overexploitation.

***Keywords:*** ground surface water, flows modelling

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**HS1002** **Poster presentation** **4100**

# The hyporheic network: a new knowledge transfer network on groundwater-surface water interactions and hyporheic zone processes

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The Hyporheic Network is a new Knowledge Transfer network that focuses on groundwater surface water interactions and hyporheic zone processes. It aims to improve dissemination of research on this important topic from the research community to science end-users, and to aid its use in regulatory, management and policy decision-making processes. It will provide a forum for presentation and discussion of new research, and it will also allow the users of researchers to directly communicate their priorities for future research to the academic community. The specific objectives and opportunities for the Hyporheic Network are to: 1. establish and maintain a forum on groundwater / surface water (GW-SW) interactions and hyporheic zone processes that will attract and actively engage scientists and science end-users, including researchers from a wide range of scientific disciplines; 2. promote and disseminate research on GW-SW interactions and hyporheic processes to end-user communities through a series of workshops and symposia, and by a web-based portal; 3. prepare and publish a manual on GW-SW interactions and the hyporheic zone, focussing on environmental management of hyporheic chemistry, ecology (including microbial ecology) and flow. The manual will synthesise cutting-edge science into a text focussed on the needs of river managers; 4.stimulate novel research proposals that address priority end-user problems by building new cross-disciplinary research teams; 5. identify emerging research and provide a forum for scientists to interact with policy makers at UK and EU level, in order to influence future policy and legislative development; 6. encourage discussion and collaboration between young and more experienced researchers, including the active participation of young researchers, including PhD students, by supporting their attendance at network meetings. The Hyporheic Network runs for 3 years from January 2007, and will comprise a series of workshops and seminars at which multidisciplinary research, policy issues and management challenges will be discussed. It is UK based, however, the network will provide real-time webcasts of the main workshops to reach an international audience. The network will produce a range of outputs, including the website, workshop proceedings, a Hyporheic Manual for river managers that synthesises the relevant science on hydrology, geochemistry, ecology, geomorphology, etc., and journal papers. We aim to submit a number of new research proposals that address the priority science and management questions, and that develops into an active community of multidisciplinary researchers, and engaged science end-users. We invite anyone who is interested in this subject (either in research or by application of the science) to join the network and participate in the workshops. Further details can be found at the Hyporheic Network website: www.hyporheic.net

***Keywords:*** hyporheic, groundwater surface water int, knowledge transfer

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**HS1002** **Poster presentation** **4101**

# Study on the potential water resource change under climate change in source of Yalong River watershed, China

***Dr. Shiqiang Zhang***
*CAREERI Chinese academic of Sciences*

***Ye Baisheng***

The source of Yalong River watershed, one of the water supplying regions of the First Phase of the Western Route of South-to-North Water Transfer Project (S2NTP), is geographically located at the southeast of the Qinghai-Tibetan Plateau, where the altitude is high and observed hydrological data is poor, where the glacier, snow and frozen soil play very import roles in the hydrology process. The potential change of water resource in the supplying region is very important to the project, especially for the ungauged upstream areas. A monthly-scale, spatial-distributed hydrological model with consideration of glaciers, snow cover and permafrost were developed on the basis of GIS analyses. Some of parameters of the model were directly determined by observed meteorological data and Remote Sensing data, others were calibrated and validated using the observed discharge data of the downstream gauge station, Ganzi. The Nash-Sutcliffe coefficient exceeded 0.8 of the Ganzi either during the calibrated or validation period, Comparisons of simulated results with the short-term observations at the auxiliary station, Wenbo, which observed after 1992, suggests that the simulation is successful, and then the discharge serials of the Wenbo station were constructed. The sensitivity of the model and the uncertainty of the constructed discharge series of Wenbo station were discussed further. The climate change scenarios, which include two schemes of climate change, A2 and B2, in 2030, 2050, 2070, 2100, were chosen. The potential changes of water resource in the study area were estimated by the monthly hydrological model and the potential climate change scenarios. The results suggest that the upstream station is more sensitive to climate change in all scenarios than that of Ganzi station where the increasing of glacier melt under higher air temperature compensates the decreasing of discharge due to increasing of evaporation. The discharge of two stations has nearly the same gradually decreasing trend from 2030 to 2100 under the potential climate scenarios either in A2 or B2 Scheme. However, the discharge of 2 stations will increase from 2070 to 2100 while under A2 scheme.

***Keywords:*** ungauged, hydrology, change

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**HS1003** **4102 - 4171**

## Symposium
## Hydrology in Mountain Regions: Observations, Processes and Dynamics (Sponsor ICSIH with co-sponsorship of UCCS, ICRS, ICSW, ICCLAS, ICGW, PUB)

**Convener :** Dr. Danny Marks

The storage and modulated release of water from seasonal snowpacks and perennial ice are major components of hydrological systems in many mountainous regions of the world. In these regions, snow cover and ice are critical component of the annual water cycle, controlling soil moisture, streamflow and the development and stability of terrestrial and aquatic ecosystems. Heavy rainfall is another input to many mountain systems, resulting in water excess and mountains operating as the Water Towers of the world. This water is crucial to downstream areas, many of which are arid or semi-arid and subject to drought. Detailed understanding of snowpack dynamics coupled with the ability to adequately model intra-basin hydrologic processes is necessary to test hypotheses concerning runoff, biogeochemistry and climatic interactions. The relative contribution of glacial ice versus seasonal snow to mountain runoff also remains relatively unknown in many regions. Monsoons are important to other regions and require better understanding. Prediction in ungauged mountain basins will require improved understanding of such runoff generation processes and their dynamics at appropriate scales. The objective of this symposium is to promote the advancement in understanding of the dynamics of a broad range of physical and chemical hydrological processes, measurements and models in mountainous regions. It will address a broad range of topics that are important to understanding hydrology in mountains. Of interest are oral and poster presentations on all aspects of hydrology in mountains, with an emphasis on the following specific topics: * Novel measurement and monitoring techniques and instruments * Investigations into physical properties of snowmelt, rainfall delivery, infiltration and runoff generation: linking microscale properties to macroscale processes * Modelling in vegetated and complex terrain * Remote sensing of mountain states and fluxes * Prediction of runoff with minimal calibration in mountain headwaters catchments.

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**HS1003** **Oral Presentation** **4102**

# The probleme of determine extreme discharges-the case study of Zagreb Mountain In Croatia

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***Mr.sc. Ksenija Cesarec, Marija Beraković***

The City of Zagreb, the capital of Croatia, is situated on the slopes of the Zagreb Mountain (1033 m asl). Seventeen watercourses flow down in Zagreb in which were noticed very small discharges ( a few liters per second) as well relative high discharges ( 60 m3/s) at the time of concentration of several hours. In this paper briefly is described the present state, the measuring of rainfall and discharges, the evaluation of extreme discharges, the protection of the city from terrential floods as well as the effect of the protection measures. In the paper are presented data and analyzes for two creeks before and after construction of reservoirs, and in the concluding part there are some suggestions for improvement of the measurements and operating reservoirs.

***Keywords:*** measurements, rainfall, discharges

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**HS1003** **Oral Presentation** **4103**

# Remote quality control of on-line measurements for hydrological investigations

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***Christian Kollmitzer, Paul Skritek, Dietmar Pindeus***

Early warning systems and networks for quality control of water supplies with the target to supply the population also in future with high quality drinking water became more and more important. Reasons for that are global changes in ecosystems, increasing conflicts of land-use and modifications of the legal framework. Also the sustainable protection of important drinking water resources as a significant task of water resources management is usually based on on-line measurements. In all these applications the supervision of the quality of the measurements ought to be a great challenge. In this paper two complete different possibilities to check the data quality of measurements are presented in an exemplary fashion with two different parameters. The water-level is one of the most important parameter to calculate the discharge of springs, which is indispensable for all hydrogeological investigations. At present we develop a system, which transmits via Low Earth Orbit (LEO) Satellites measurements in real-time from the measuring site and pictures from staff gauges or bank reinforcements to a Central Monitoring Station. By the means of digital image processing and pattern identification from these pictures control-values are generated. Both, the pictures and the generated control-values are provided with a time flag and stored to a database. While the measured values from a pressure probe are transmitted for instance every 15 minutes, the pictures for the control measurement are transmitted with a longer time interval or on demand or caused by a trigger event. These control values can be compared now with the measured values. If a deviation appears, you can handle this within a quality management tool. With the LEO-Satellite communication also remote configuration or queries for new pictures and measurements can be sent to the measuring site. The electrical conductivity is also a very important parameter for hydrogeological investigations, because it is easy to measure and you can receive an impression of the aquifer dynamics. Despite of new technologies these sensors are sensitive against contamination and sinter. By the means of a purpose-built measuring system and algorithm simultaneously to the conductivity also the situation of current and voltage at a four electrode conductivity cell is recorded. From this, after an appropriate measurement processing, a new quality parameter is generated and enables us to evaluate the situation of contamination at the electrodes. The thresholds of this new quality parameter for accurate conductivity measurements are also known. In combination with real-time LEO-Satellite communication an efficient quality assurance and maintenance of measuring sites can be organized. In a similar way it is possible to supervise pH-electrodes and ion-selective sensors.

***Keywords:*** quality management, on line measurements, leo satellite communication

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**HS1003** **Oral Presentation** **4104**

# Predicting runoff from mountain headwater catchments and its socio-economic implications in Jammu Province of India

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The mountain headwater region of Chenab river in Jammu Province of Jammu and Kashmir state of India, has an area of 18971 km2, with altitude varying from 300m to 5000m above mean sea level. Almost whole of the region is mountainous and has the problems of isolation, fragility, marginality and resource heterogeneity. The geological and geomorphic processes have made the region inherently unstable and prone to soil erosion, landslides and resource degradation. The region can conveniently be divided into three zones namely; the middle or lesser Himalayas, the Siwaliks and the outer plains. The formation of rivers in western Himalayas was not consequent upon the physical features or the relief of the region as many of the Himalayan rivers are older than the mountains they traverse. During the slow process of mountain formation by the folding, the old rivers kept very much to their older tracks. The Chenab river has its origin in the glaciers of the middle Himalayas. The region, due to its biophysical features, has strong potential for poverty promoting processes. The region is rich in natural resources and has high potential if these resources are judiciously and carefully exploited. The culture of the people of the headwater region has developed through centuries of isolation and compulsions of the survival strategies. Due to fast increase in population, there is considerable pressure on limited arable land and other natural resources. On an average, the literacy per cent in the headwater region is 54.4% with wide variation in literacy per cent among males( 73.6 ) and females ( 28.2 ). The crop yields are poor, averaging about 1575 kg ha-1 in food grains, due to low accessibility to good quality inputs because of lack of communication. Development of agriculture with modern technologies, particularly horticulture, for food security as well as other enterprises like household enterprises, tourism industry and basic infrastructure for subsidiary source of income, can transform the region to an extremely better place for living. Unabated deforestation has caused land and environmental degradation. Rains are concentrated to July and August and high intensity rainfall generates huge runoff, carrying with it heavy sediment load down the slopes and to the river channel. The water is clearly the major factor in socio-economic recovery and development in the region. Though the region has enough water resources, yet it has complex natural and man made problems that constraints exploitation and proper development of its enormous potential. The vegetation suffers from various ecological stresses such as erosion, drought, grazing, air pollution, logging and deforestation. Considering that slope, rainfall, soil texture, vegetation and soil saturation are the major factors in runoff generation, a mathematical model, based on these parameters, has been proposed to make prediction of runoff from ungauged catchments. This would help in estimating sediment loads being transported from mountain areas to the rivers and in-situ rainwater retention to recharge groundwater as well as making predictions of runoff generation..

***Keywords:*** runoff predictions, mountain headwater region, socio economic implications

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**HS1003** **Oral Presentation** **4105**

# Snow conditions in mountains and climate change a global view

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***Dr. Lucas Menzel***

An advantage of continental and global scale hydrological models is their ability to compare the hydrological characteristics of typical landscape units (such as mountains) in different climate zones. The spatial extent and resolution of these type of models is well adapted for the use of climate scenarios from General Circulation Models (GCMs), thus enabling a hydrological impact analysis for the climate sensitive mountain regions of the world. On the large scale however, climate and hydrological data for model calibration and validation are limited. This is especially true for mountain regions. Therefore, detailed and data demanding approaches to simulate snow dynamics in mountains can not be incorporated in large scale hydrological models. Thus, ways have to be found to model snow dynamics with robust and simple approaches which require only few data but which are able to reproduce the snow related processes as well as possible. The global water model WaterGAP (Water Global Assessment and Prognosis) has been applied to simulate the impact of snow conditions on hydrological characteristics of rivers draining mountains and their forelands. Climate scenarios were used to investigate the impact of climate change on the future snow extent in mountains and to identify the respective consequences for river discharge. In WaterGAP, temperature, precipitation and land-cover information are considered for the simulation of snow accumulation and melt. Snow melt is modelled based on a simple degree-day-approach. Further improvement of the representation of snow cover heterogeneities in mountains was achieved from detailed, subscale elevation data. The model has been used to simulate global snow cover extent and duration as well as discharge hydrographs of snow dominated river basins in mountains. Model results have been validated with observed discharge and satellite data. For a comparative analysis, a number of river basins in mountains or with mountain headwaters have been selected from different regions of the earth. The results show that WaterGAP is generally applicable to mountain regions, delivering satisfactory results regarding the reproduction of river discharge. However, there are significant differences in the modelling efficiency of discharge in the selected river basins. The model is also able to reproduce the snow cover extent quite well. The quality of these results increases with increasing accuracy of the climate input data and decreasing terrain heterogeneity. Effects of changes in snow cover extent of mountainous regions as a consequence of climate change are shown. Furthermore, the snow cover duration of major mountain areas worldwide and possible changes due to climate change are presented. Possible consequences for the regional hydrology with special focus on climate sensitive areas are discussed. It can be concluded that WaterGAP with its relatively simple description of snow accumulation and melt is an appropriate tool to represent a global view on the hydrological characteristics of mountains and to evaluate the impact of climate change on mountain hydrology.

***Keywords:*** climate change, global scale, snow

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**HS1003** **Oral Presentation** **4106**

# The rainfall and runoff characteristics in Cherrapunji (Meghalaya, India) area.

***Dr. Soja Roman***
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The environment of the southern scarp of the Meghalaya Upland (India) with globally highest rainfall has been extensively degraded. The upper soil cover is denuded. The regolith is restricted to small patches. The tropical jungle is preserved on steep canyon sides upto 1000 m deep. The secondary vegetation has character grassland. The mean annual rainfall for 148 years in Cherrapunji reaches 11371 mm. The highest annual rainfall 23663 mm was recorded 1974. The highest daily rainfall on 16 June 1995 exceeded 1563 mm and in two days 2493 mm. In the Cherrapunji area three automatic pluviometer (SEBA, Germany) were installed. A very distinct daily course of rainfall is observed. The convectional precipitation of 20-100 mm order start usually 2-3 hours after sunset and continue during 1-2 hours. The continuous rainfalls mainly of frontal character follow during 10-20 hours and their totals fluctuate between 200-800 mm. The detail structure (intensities for 1, 5, 10, 60 min.) of rainfall will be presented. The environmental condition rainfall intensities and duration facilitate accelerated runoff and soil erosion. On the bare rocks the overland flow starts after 2-5 mm of rains. The highest calculated specific run-off exceed every year 100 m*-3*s*km-2. Therefore in the rocky channels over plateau the bedload is missing. The higher suspended load is connected with open coal mines and limestone quarries. In the deep canyons are transported blocks upto 16 m in diameter. Among the erosional factors the very low pH of precipitation below 4.0 pH must be taken into consideration.

***Keywords:*** cherrapunji, monsoon, rainfall ranoff

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**HS1003** **Oral Presentation** **4107**

# Effect of precipition and mulching measures on soil moisture movement

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***Fadong Li, Xianfang Song, Mengyu Liu***

Lack of water resources and non-sustainability for agriculture in North China Plain (NCP) were paid more attention to. Therefore, it is very important to study on hydrological processes in this region. Soil moisture is valuable to plant growth, food production, vegetation distribution. Taihang mountain region has important impact on hydrological processes in adjacent NCP. However, as one of essential aspects of hydrological cycle, soil water in Taihang mountain region mainly concentrated on variation law of soil water and effect of mulch on content of soil moisture. The study on response of soil moisture variation to precipitation and mulching measures is poor. The objective of this study is to analyze response of soil moisture variation to precipitation and mulching measures by experiment in runoff plot, and to discuss the soil water movement in changed environment. The experiment was conducted from May to October in 2003 at Taihang Mountain Ecological Station Catchment, Chinese Academy of Science (114a1550E, 37a5244N , altitude 550 m above sea level ) , lied around 50 km southwest of Shijiazhuang, capital city of Hebei Province, China. Area of three plots is 3m1.5m4.5m2. There are three treatments such as nomulching; straw-mulching and stone-mulching. Vegetation grew naturally after mulching to investigate effect of above three treatments under natural condition on precipitation and infiltration, and to analyze the movement of surface and upper layer moisture after farmers cultivate or ecological engineering. Response of soil moisture to precipitation and mulching measures was investigated based on the continuous observation information in plots with no-mulching, straw-mulching and granule-mulching. The results show that individual rainfall event is difficult to infiltrate into up to 30 cm depth from surface during the dry season ,especially when soil moisture is lower than 20 % at 30 cm depth. As for the responsive time, at 30 cm, it is the shortest in granule-mulching plot, followed by straw-mulching plot and longest in no-mulching plot. At 60 cm, shortest responsive time is observed in straw-mulching plot and longest in no-mulching. At 100 cm, soil moisture increases first in granule-mulching plot and 10-h delay takes place in straw-mulching plot compared with that of straw-mulching and its the slowest in no-mulching. The soil moisture at 30 cm depth in nomulching plot is 0113 and 0107 cm3Pcm3 lower than those of granule- and straw-mulching. It indicates the mulching measure is good for the storage of soil moisture. Although infiltration ability at 60 cm is more powerful in straw-mulching plot than that in granule-mulching plot, the latters ability of water conservation is better than the formers.

***Keywords:*** soil moisture, mulching, taihang mountain

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**HS1003** **Oral Presentation** **4108**

# Rainfall variability along the Southern Flank of the Bambouto Mountain (West-Cameroon)

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Rainfall is a major component of the water cycle and as any natural phenomenon, it is subject to great variations that need to be taken into account in resource (water and land) management. This paper presents the rainfall variability along the southern flank of the Bambouto mountain, where elevations range from 800 m to 2740 m a.s.l. Crop and livestock production are very intense here. Data were collected from raingauges installed in the corresponding watershed, while spatial variability was estimated through daily recorded data. Monthly and annual data were used to draw isohyets via the triangle method, with linear interpolation between observation points. Results show that rainfall is highly variable in the slope. Daily rainfall depths range from 0.1 mm to 120 mm. Mean yearly rainfall is 1918.1 mm. The relation between rainfall depth and elevation is not significant. Rainfall amount does not have a linear relationship with altitude. Dschang is characterised by abnormally high rainfall. Following a North-South direction, rainfall decrease varies between 20 mm/km to 40 mm/km in a distance gradient in the Melang-Loung-Djuttitsa axis. From this axis, the gradient reverses, as rainfall increases rapidly from about 90 mm/km to 130 mm/km in the distance gradient towards the Mltan mountain. The existence of the relatively dry zone within the hillside seems to be due to two air masses. The first is cold and very wet which moves from the Mamf basin to the summit zone where it starts to dry as it flows towards Melang and Loung where temperature increases. The second comes from the south to south-east monsoon which is also impoverished during the ascension from the lower to the mean zone. It is also likely that a third air mass from the dry harmattan is involved depending on the position of the ITCZ. In summary, the variability of rainfall in the slope is due to the effects of relief, the distance from the sea and the exposure to wind.

***Keywords:*** rainfall, variability, isohyets

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**HS1003** **Oral Presentation** **4109**

# Study on the distributed evaporative model under consideration the effects of topography

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*HS1003 none IAHS*

***Baohong Lu, Zhenchun Hao***

There are quite differences in ground temperature, soil moisture, and vegetations, as well as its coverage between sunward and apheliotropic sides in rolling terrain because the topographic undulations results in diverse solar radiation receiving and evaporation processes. The topographic variability of sub-grid in the most of the developed distributed hydrological models is always neglected so that the sub-grid is only considered as a plane to estimate evaporation capacity. In fact, the land surface gradient and exposures in any computational cell exists obvious differences. Each cell receives different solar radiations leads to diverse evaporations and spatial variations of soil moisture. To solve the issue mentioned above, a new distributed hydrological model was built using USGS GTOPO30 DEM data and 1day computational step. Generally, direct solar radiation is the main source of cells energy. The impact of cells topography on direct solar radiation in the study was disassembled into 4 coefficients (C1, C2, , C4) where C1 and C3 respectively represent the variations of the solar radiation across cells section through longitudinal and latitudinal gradient, and C2, C4 severally reflect the changes of cells actual land surface in the direction of longitudinal and latitudinal gradient. Each coefficient is quantitatively analyzed in terms of the solar zenith angle and cells geometric features of the slope and its exposure. The total effects (Marked C0) of cells slope and its exposure on the daily gross solar radiation can be expresses as 4 coefficients scalar product. The coefficient C0 combined effects of cells topography is used to replace the net solar radiation term in original Penman-Monteith equation (FAO Irrigation and drainage paper 56) for evaporation estimation in the study. Dong-wan sub-basin (2636 km2) of Yellow River as a study region to analyze the sensitivity of the solar radiation adjust coefficient C0, and to examine the spatial-temporal distributions of the coefficient C0, ground temperature, and net radiation, as well as evaporation capacity, the results shown the coefficient C0 quickly increases with latitude and gradient. In the main land of China, there is 70% land area with slope above 5 and latitude above N 45. All these regions have to employ the proposed adjust coefficient C0 to compute cells evaporation capacity. Obviously, the proposed model can be widely used to directly estimate evaporation capacity for each cell in insufficient observatory region, especially in drought and semi-drought area, or in tundra. As a result, the built model expands application region, and improves forecast accuracy of the distributed hydrological model.

***Keywords:*** distributed hydrologic model, slope exposure, evaporation capacity

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**HS1003** **Oral Presentation** **4110**

# Effects of wind on rainfall-topography relationship in mountainous regions of Northern Nigeria

***Mr. Olu Onafeso***

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The relationship between rainfall and topography are investigated in the mountain regions of northern Nigeria in West Africa using GOES derived satellite data of a 1 by 1 grid spatial resolution. The findings show that the Dependence Line on Topographic Elevation (DLTE) of rainfall distribution reflect a linear rainfall-elevation relationship with a correlation coefficient of 0.9013 and most of the mountainous locations differing from the regional average rainfall (RAR) with a 100-500 mm range. The effects of wind on the distribution of rainfall were also considered to shed more light on the mechanism of the rainfall topography relationships. The results indicates a definite positive but differing correlations between the mean daily rainfall amount and mean daily wind speed at heights 10m, 50m and 100m for the entire region. The monthly characteristics of wind direction across the region was also examined to confirm the effect of the two predominant winds, i.e. the dry Saharan continental air and the moist Maritime air, and the results show a good reflection of the seasonal variation of rainfall amounts characteristic with the migratory pattern of the Inter-Tropical Discontinuity (ITD).

***Keywords:*** rainfall, topography, windspeed

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**HS1003** **Oral Presentation** **4111**

# Groundwater Flow Modeling of Perched Karstic Aquifers and Springs and its Implication for Determining Precipitation-Recharge Relationship

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***Menachem Weiss***

The carbonate rocks at the Judea and Samaria Mountains, Israel, are composed of thick bedded karstic limestone and dolomite, and thin marl formations. Groundwater accumulates preferentially on top of the relatively impermeable marl layers and creates perched aquifers. The karstic character of the carbonate rocks, in conjunction with the marly aquitards, causes diversion of groundwater flow to discrete springs. These perched-karstic springs are common across the Israeli mountain landscape and some have discharges on the order of 100,000 m3 per year. Using detailed topographic and geologic maps, we estimated the recharge areas of various springs (at a scale of 1-5 square kilometers). For many of the springs, there is an extensive database, tens of years long, of spring discharge (hydrographs). Detailed records of daily precipitation are also available from meteorological stations adjacent to the springs. In this study, we developed numerical groundwater flow models, using the finite-difference MODFLOW code. The models accurately simulate the groundwater flow field within the perched-karstic subaquifers, as well as the spring hydrographs. The models account for the two separate flow domains, matrix and karstic conduits; the latter being simulated by using the drain package within MODFLOW. The perched nature of the aquifer was simulated in a way that the upper sections of the modeled domain oscillate between saturated and unsaturated conditions. The leakage from the perched aquifer through the lower aquitard into the deeper aquifer was simulated by assuming atmospheric pressure lower boundary conditions. During the calibration process, the following parameters were estimated: (1) the horizontal hydraulic conductivity within the upper, perched aquifer layer; (2) the vertical leakance between the upper, perched aquifer layer, and the lower regional aquifer layer; (3) the storage coefficient in the upper, perched aquifer layer; (4) the karst conduit conductivity and the appropriate spatial geometry within the upper, perched aquifer; and (5) the recharge. Although precipitation can be quantitatively well-defined, the conversion from precipitation to subsurface recharge values is very vague and many hydrologists are constantly dealing with this problem. Using the numerical models and the long-tern precipitation and discharge records, we were able to calculate the transient behavior of recharge, leakage and spring discharge. Preliminary results from such numerical modeling calibration efforts show that peak spring discharges cannot be replicated by using a simple percentage of the observed transient precipitation data. However, by considering the assumed changes in evapotranspiration rates in unusually wet or dry years, the model can be reasonably calibrated. Thereby, a new hydrometeorological model (a Precipitation-Recharge function) that accounts not only for normal years but also for exceptionally wet and dry years was quantified. The new model circumvents the problem of overestimating recharge in relatively dry years and underestimating recharge in relatively wet years. To date, four springs have been analyzed: 1. Ein Al Matwi near Ariel at the Samaria Mountains. The recharge area is 2.0 km2 and the average yearly discharge is 100,000 m3. 2. Ein Delbah near Dura at the Judea Mountains. The recharge area is 0.6 km2 and the average yearly discharge is 36,000 m3. 3. Ein Chaniya at the southwestern part of Jerusalem. The recharge area is 2.6 km2 and the average yearly discharge is 110,000 m3. 4. Ein Harrashah near Ramallah at the Samaria Mountains. The recharge area is 1.4 km2 and the average yearly discharge is 80,000 m3. The first 3 springs are located at the contact between the Aminadav Formation (karstic limestone perched aquifer) on top and the Moza Formation (relatively impermeable marl aquiclude) below. The fourth spring is located at the contact between the Kfira Formation aquifer and the Qatana Formation aquitard. Because of the

different geological settings, the modeling efforts have also allowed us to better understand the spatial variations of the hydrological parameters.

***Keywords:*** modeling, perched aquifer, recharhe

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**HS1003** **Oral Presentation** **4112**

# Validation and interpretation of spatial soil-water modelling in the tropical subcatchments of Mae Chaem basin

***Dr. Sukanya Vongtanaboon***
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The characteristics and implications of spatial soil moisture variation and the occurrence of saturation excess runoff in catchments are significant for understanding the behaviour of the catchments and for land management. The purposes of this research are to represent the spatial distribution of soil moisture samples from the field surveys corresponding to different moisture statuses by geostatistical modelling, to test the applicability of TOPMODEL for runoff simulations in the tropical mountain basin and to validate the topographic index of TOPMODEL with the spatial patterns of soil moisture data from field measurements The distribution of water content in space at the soil surface has been investigated on the small subcatchments of Mae Chaem Basin from two field surveys corresponding to different moisture statuses. The soil properties in a large number of points within the subbasin and a detailed characterization of the spatial soil variability are also determined. For each survey, more than 250 positions of soil moisture spaced 20 m apart are collected along the axes parallel to the greatest slope for analysis of soil moisture spatial variability. Time Domain Reflectometry (TDR) probe is used to measure the average soil moisture to determine soil moisture conditions for rainfall-riverflow modelling. A geostatistical analysis is then performed to examine the soil moisture for spatial characteristics. Topographic model (TOPMODEL) is applied to the hydrological behaviour and seasonal contributing area responses in these adjacent small tropical catchments. Model simulations are run at a daily time step and the spatial resolution of the distributed model simulations is 5 m.

***Keywords:*** soil water modelling, tropical catchment

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**HS1003** **Oral Presentation** **4113**

# Development of integrated hydrological menu in the ARCGIS environment by using visual basic for applications and ARCOBJECTS

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The water resources constituted always and constitute these days the necessary condition for the existence of the life, but also for the development of all kind of activity. The Community Framework directive 2000/60/EC constitutes the most modern legislative approach in the securement of a single way of approach of the rational management of water resources in a level of river flow basin and imparts particular emphasis in the geographic component for the establishment of institutions of management in level of flow basin and the growth of administrative drawings. The geographic Systems of Information (GIS) have enjoyed in the past few years internationally an extensive use in applications of environmental management and more specifically in water systems, as reaching conclusions does not depend only on the attributes and the informational characteristics but mainly on their territorial dimension and their geographic distribution. The swift growth of science of computers facilitates the applications of Hydrology, while the use of modern technology of G.I.S allows the territorial analysis of flow basin. The nature of water resources and their territorial variability make the G.I.S. a useful tool to the Management of Water Resources in level of flow basin; that is why the past few years many models connected with G.I.S. have been developed. The present work aims to the growth of application G.I.S.. in a level of river or torrent flow basin in the graphic environment of ArcGIS. With the use of Visual Basic for Applications and ArcObjects an integrated menu was shaped constituted from three parts (projection, elaborations and analyses), of which in the individual parts the new innovative GIS-Tools was placed, which manage the parameters of flow basins with speed and precision and contribute to the more rational management of flow basins providing integrated knowledge of the environment of torrent flow basins and constitute precious adviser in the process of decision-making. Thus GIS-Tools were developed, which create automated thematic maps, determine with precision and speed the geomorphologic characteristics, the environment and the type of torrent and determine the coefficient of flow, the biggest expected water-supply, discharge of a concrete cross-section, water balance, degradation and sediment discharge. The GIS tools, which were developed, provide information as much to the level of individual flow basins as to the total of flow basins of research areas. The knowledge of torrent behaviour as well as of the expected consequences in a region helps us, the specialised manager on issues of water resources on the process of decision-making for the suitable system of arrangement that should be followed, for the adjustment of a water discharge of torrent currents and the dissuasion of their damage-causing activity contributing effectively to the effacement of similar phenomena.

***Keywords:*** gis tools, arcobjects, watershedmanagement

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# A distributed water-heat coupled (DWHC) model for mountainous watershed of an inland river basin in Northwest China (I): model structure and equations

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Quantify the hydrological processes in the field and using numerical models, in the cold regions where the most large rivers acquire their headstreams in China, and the glacier, permafrost and snow cover have degraded largely in the recent 50 years, under global warming, is very necessary, especially in an arid inland river basin, where the main water resources come from mountainous watershed. However, frozen ground effects to water cycle was little considered in the distributed hydrological models for a watershed in large scale. Took the Heihe mountainous watershed with an area of 10,009km2, as an example, the authors designed a distributed heat-water coupled (DWHC) model, deriving some methods from SHAW and COUP. The DWHC model includes meteorological variable interception model, vegetation interception model, snow and glacier melting model, soil water-heat coupled model, evpotransporation model, runoff generation model, infiltration model and flow concentration model. With 1km DEM grids and in daily scale, the DWHC model describes the basic hydrological processes in the research watershed, with 3~5 soil layers accounting to 18 soil types, 9 vegetation types and 11 land use types, according to the field measurements, remote sensing data and research results in the literature. The model can estimate the water and heat factors in the soil continuously, by solving the continuous equation for heat and water flow using numerical methods and some empirical formula, according to the freezing states of soil. However, the model is still has some conceptual parameters, and need to be improved in the future. In this paper, only the model structure and basic equations are described, while the model calibration results using data measured at the meteorological stations and outputs from MM5 model, will be discussed in the next papers.

***Keywords:*** frozensoil, soiltemperature, soilwatertension

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**HS1003** **Oral Presentation** **4115**

# Hydro meteorological networking for Afghanistan-a case study

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Afghanistan is a semi arid land locked country with an approximate area of 6,55,000 square kilometre out of which, about 75% of its land surface is mountainous and extends about 1300 km from southwest to northeast and about 600 km from northwest to southeast. The climate of the country is continental in the nature, with cold winters and hot summers. Most part of the country possesses semi-arid or arid climatic condition with low amount of precipitation with a high variability between years. Over 80% of the countrys water resources have their origin in the Hindu Kush mountain ranges at altitude above 2000 m. These areas function as the natural storage of water in the form of snow during winter and that is the primary source of stream flow in all major rivers in spring and summer. The volume of water received in these areas is estimated to be about 1,50,000 M cum in compare to 30,000 M cum over the rest of country. The country is characterized by a rugged mountainous landscape, large rangeland and desert areas, limited arable land and scare water resources though there are five major river system exists. The rainfall increases from west to east and vegetation ranges from desert in the south and west, to steppers and dry land in the centre and north, to coniferous forest in the humid mountain along the Pakistan borders. In most part of the country water available for agriculture is likely to be subject to considerable annual variation affecting both rain fed and irrigated agriculture. The need is to capture the maximum amount of available water i.e. increasing water capital and making the best possible use of this natural resource. At present, the data and information on water resources in entire country date back up to more than two decades. The lack of actual baseline figures make the planning of any water resources project be a hydroelectric power, water supply or irrigation difficult, if not impossible. Keeping in view of these, an attempt has been made to prepare and implement the hydro meteorological networking of the country. Needless to mention that in a mountain area like Afghanistan, a relatively dense observation network is required to assess the variability of water resources. The authors recognize that a key component of the effective operation of any water control structure is the measurement and processing of hydrological data. The foundation of all the hydrologic, hydraulic and operational modeling and decision support software package is quality data. The quality of data collected can be improved by the use of better acquisition methods and equipments, well designed networks, redundancy and maintenance schedules, and modern quality control applications. By this paper, the basic need, criteria and implementation strategies of hydro meteorological networking are formulated and exhibited for a landlocked and environmentally fragile country.

***Keywords:*** hydro meteorology, waterresources, variability

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# Sediment yield in a Brazilian Northeast semiarid experimental plot

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This paper aims to analyze sediment erosion processes associated with storms which occurred between march/19 and april/19/2006 on an experimental plot located in an semiarid Ecologic Station, Serra Negra do Norte-RN, northeastern Brazil. Rainfall and runoff rates were obtained by automatic measurement and storage systems. Plot dimensions were 5m x 50m, plot gradient was 4%, desert grassland vegetation and gravelly sand-silt litholic soil. Four rainstorm events were simulated by a kinematics wave equation model. Model parameters were associated with Horton infiltration function (fo, fc, e) and Manning resistance coefficient (n). For each run, calibration of parameters criteria was the adjustment between observed and calculated peak discharges. The parameters of Horton function, obtained in the field by constant-head infiltration experiments, were used as reference. Model simulations allowed estimating Manning resistance coefficients for each run. Furthermore, plot sediment yield monitored data allowed to obtain an empirical relationship between sediment yield rate and maximum storm intensity. Sediment yield size distribution data showed a tendency of bulk size to increase as a function of time, which seems to be associated with a decrease in sediment availability.

***Keywords:*** manningcoefficient, semiarid, experimentalplot

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**HS1003** **Oral Presentation** **4117**

# Hydrology of Native and Invaded Tropical Montane Cloud Forest in Hawaii

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Tropical montane cloud forests (TMCF) in Hawaii and in other tropical areas are hydrologically and ecologically important. They are often major sources of hydrologic input to headwater streams and groundwater systems because of high rainfall, direct input of intercepted cloud water, and low transpiration rates due to frequent canopy wetting, high humidity, frequent cloud cover. Until recently, most TMCF have remained remote from most human settlement and agricultural development, making them valuable refugia for the remaining intact native terrestrial plant and animal ecosystems in the tropics. However, increasing pressure to clear forest, invasion of alien tree species, and global warming now threaten to impact the hydrological services these forests provide and to damage their ecological integrity. Alien tree invasion in Hawaiis forests has completely altered forests at lower elevations in Hawaii. Several of Hawaiis worst invasive trees are now encroaching into the middle elevations, where persistent orographic lift creates a fog zone. Much speculation has been made about the hydrological effects of replacing Hawaiis native forest tree species with alien trees, but until now no measurements have been made to allow these assertions to be confirmed or refuted. Two towers equipped with eddy covariance and other micrometeorological instrumentation were constructed, one within native Metrosideros polymorpha forest and the other at a site heavily invaded by Psidium cattleianum, in the cloud forest zone of Hawaii Volcanoes National Park. Measurements of stand-level ET, tree transpiration (using sapflow techniques), throughfall, stemflow, and soil moisture are underway to quantify the canopy water balance and to estimate the direct deposition of cloud water at each site. Based on preliminary analysis of the stand-level measurements, mean monthly stand level ET for the native site ranges from 1.69 (March 2005) to 3.43 (July 2005) mm per day. These rates are slightly lower than expected for this site, and much lower than rates recently found at forest sites on other tropical islands. During the first four months of simultaneous observations at the two sites (March-June 2006), ET at the invaded site was similar to or higher than the native site, averaging 35% higher. The evaporative fraction (the ratio of latent energy flux to net radiation) was clearly higher at the invaded sites during all four months, averaging 43% higher. Measurements of sapflow, throughfall, and stemflow have recently begun at both sites and will provide urgently needed data to assess the impacts of alien tree invasion in Hawaiis TMCF.

***Keywords:*** cloud forests, species invasion, eddy covariance

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**HS1003** **Oral Presentation** **4118**

# An optimized grid dataset of mean monthly and annual runoff for Switzerland: coupling modeled data with robust information derived from observations

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The aim of this applied research project was to establish a high-resolution, reliable data set, relatively simple in the application and yielding satisfactorily accurate estimates of the mean annual and mean monthly runoff at any place in Switzerland, above all at ungauged sites. The challenge consisted not at least in the hydrologically heterogeneous conditions in the mountainous environment. None of the currently existing data sets in Switzerland could meet all these criteria. The idea was therefore to couple two different information sources, each bringing in its respective strengths and limitations. On the one hand, quasi the point of departure, we took the output of a modeling-experiment for Switzerland. The used hydrological model considers explicitly the relevant hydrological processes. The model has the potential to yield the temporal hydrological dynamics with a high spatial resolution (it provides a grid with a 500 m raster). In short, the strong point of this simulation is to provide information with fine patterns in space and time. The shortcoming however is the limited reliability when it comes to estimation accuracy, which was proven also by a validation analysis. This is where the second information source comes into play. The latter represents a data set with a coarse spatial resolution of reliable runoff data. More specifically, it is a hydrographically structuring of Switzerland into so-called medium-scale catchments (100 to 250 km2) for which annual runoff data have been derived from direct observations and checked for plausibility with the water balance equations. After accurate transformations necessary to align the two data sets (harmonizing the underlying period mean runoff representative for the period 1981-2000 and breaking down the second data set into monthly runoff values), the actual coupling of the two information sources is relatively simple: Taking the second data set as reliable, we modified the original modeled raster data in such a way, that they fulfill the balance equation for the single medium-scale catchments. After an introduction of the original data sets and the aim of the project, we will present the coupling methodology in detail. The results of this optimized data set will then be discussed. Finally the improvement of the estimation accuracy with the gained data set has been examined with a validation analysis and will be demonstrated, giving special attention to the alpine regions.

***Keywords:*** mean runoff, optimized grid dataset, switzerland

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**HS1003** **Oral Presentation** **4119**

# Application of a fully-coupled integrated hydrologic model to analysis of water budget in mountainous forest and agricultural rice field in Korea

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Generally, stream hydrographs and subsurface hydraulic heads are influenced by the various factors; geomorphology, surface conditions, infiltration, intermediate flow, base flow and so forth. Geomorphology is one the most influential factors among the referred factors, especially in mountainous area. In Asian region, rice fields cover the very wide region. Actually, rice fields are typically located in plain area. But in South Korea, 70% of total area is highly mountainous. Therefore, most of rice fields are distributed on valleys in mountainous area, except in south-western part of Korea. Total discharge from rice fields is highly related to the human activities and rainfall intensity. When it rains with high intensity, the bank around the rice field should be open. And after rain stops, the bank should be rebuilt to reserve the water in the rice field. In addition, irrigation activities in rice field can make some influence on the natural water circulation process. Trapping water in rice fields can make some influence on the infiltration and evapotranspiration, and opening the bank can make the great influence on the stream discharge rate during intensive raining periods. We try to investigate the stream flow hydrograph in rice field. We try to analyze the sensitivity of irrigation activities with a fully-coupled, integrated numerical model of surface and subsurface flow and transport (Hydrogeosphere). From the partial results of our investigation, we can found that if we did not considered the human irrigation activities we cannot explain the variation of discharge rate even in mountainous area.

***Keywords:*** gwsw interaction, numerical simulation, rice field

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**HS1003** **Oral Presentation** **4120**

# Model estimation of stemflow contribution during rainfall-runoff process in a mountainous forested area.

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Stemflow is very important as a point source input of precipitation and tree solutes to the ground in a mountainous forested area. However, their hydrological contribution has not been much studied because of its quantitatively less contribution per unit canopy projection area when compared to throughfall. In the densely forested area with relatively high rainfall, some recent studies pointed out that stemflow has a significant influence on runoff generation, soil erosion, groundwater recharge, soil solution chemistry, and the distribution of understory vegetation and epiphytes (Levia and Frost, 2003). It is known that there exist clear differences of isotopic composition and water chemistries in the gross rainfall, throughfall, and stemflow, even in a rainfall event. In order to evaluate the stemflow contribution for the infiltration into a forest soil and groundwater, the precise isotopic observation of rainfall and river discharge water during rainfall-runoff process has been conducted in a densely forested headwater catchment of Kahoku experimental forest (KHEW: 33o08N, 133o43E) , Kyusyu island, Japan, since June, 2004. This site has been established to monitor the major hydro-meteorological components including amount of rainfall, river discharge and evapo-transpiration flux measurements from 1992 and the basic hydrological characteristics of the discharge basin is well known. Water samples of gross rainfall, throughfall, stemflow, and riverwater were collected every hour using automatic water sampler. These samples were analyzed for deuterium and oxygen stable isotopes, inorganic water chemistry, and dissolved Silica. As Ikawa et al. (2005) reported that dissolved Silica is an effective tracer for hydrograph separation in this catchment, the hydrograph separation has been done for all rainfall events during the study periods. The water height of throughfall, stemflow, and interception loss per unit area during each rainfall event was estimated using calculation method described in Ikawa et al. (2005). With these factors, the stemflow contribution to rainfall-runoff process was quantitatively evaluated. To validify the above stemflow contribution during the rainfall-runoff process, catchments scale tank model was proposed by using stemflow and throughfall as an input, and an isotopic fluctuation of river water during rainfall event was calculated by this model to compare with the observed isotopic fluctuation in the river water. The results show clear evidence of the stemflow contribution during the rainfall-runoff process in the densely forest of warm humid area. In the IUGG 2007, we will explain more precisely about the quantitative evaluation method and result of stemflow contribution during rainfall-runoff process by using chemical isotopic data and tank model.

***Keywords:*** stemflow, tank model, rainfal runoff process

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**HS1003** **Oral Presentation** **4121**

# Melting glaciers and reducing stream flow: Himalayan paradox

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***J T Gergan***

The IPCC 2001 suggests that the glacier fed stream runoff is likely to increase initially owing to the water release from long term storage in the glaciers due to warming and decline sharply thereafter. Present study suggest that the phenomena of enhanced glacier melting increasing the river flow is not universally true and many regions of the Himalaya are already experiencing the anticipated reduced water availability from snow and glaciers. In this paper we demonstrates that the characteristics high flow regimes of glacier fed streams are determined by the precipitation characteristics and the low flow regimes are dominated by the glacier contributions as hydrology of glaciated catchments in the Himalaya is influenced by the winter snow precipitation and summer monsoon. Hydrological processes associated with such a paradoxical behaviour of Himalayan glacier basins have been explained by six years of experimental runoff data from three altitudes in the Din Gad stream which originates from the Dokriani glacier, Ganga basin. Din Gad stream experienced 57% runoff decline from 1998 to 2004 at the discharge station established at 2530 ma.s.l., irrespective of the variations in the glacier discharge. Analyses of monsoon and winter precipitation clearly indicate that the decline was resulted from the changes experienced by the winter snow regime in recent years. As a result of declining contributions from snow covered areas of the catchment, glacier melt water component in the stream runoff increased two fold during these period, sustaining the stream flow from falling to much lower level. This study emphasis that the regional characterisation of role of cryospheric changes on river flows is imperative, before drawing up a adative strategies for the future.

***Keywords:*** himalayanglaicers, climatechange, dokrainiglacier

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# Interrelation of surface and groundwater runoff in mountainous catchment of Studeny Brook

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Hydrological data gained by final monitoring objects can give the assistance by characterization of hydrological conditions in the places, where objects of regular monitoring network are missing. Temporary final monitoring objects for surface and groundwater measurement were built in the mountainous catchment of Studeny brook in the High Tatra Mountains and observed during one hydrological year. The time interval of thirty minutes was selected for data recording of surface and groundwater levels, temperatures and electric conductivities. As a result, interrelations of surface and groundwater runoff could be assessed using basic statistical data evaluation, simple analyses of time series, cross correlation methods, simple and multiple regression models. Time series analysis showed the most synchronic pattern of surface and groundwater electric conductivity values. Another visible feature was the more smoothed course of groundwater temperatures in comparison with the surface stream temperature. The time shift between pairs of variables was estimated using cross correlation methods. The lag of approximately 1.3 days (32 hours) was proved between groundwater levels and stream discharges. In the end, interrelations of all observed variables were assessed using correlation matrix, simple and multiple regression models.

***Keywords:*** runoff, groundwater, interrelation

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**HS1003** **Oral Presentation** **4123**

# Ground Water Flow Patterns of Glacial Moraine Features in an Alpine Environment

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Field research from a number of mountain sites has shown that much of the water from rain and melting ice and snow infiltrates into the ground before it reaches surface water bodies. Recent studies suggest that depositional features such as talus slopes and moraines may play a dominant role in the storage of spring melt water and the contribution to alpine streams and lakes during both peak and base flow periods. However, the nature of ground water flow and storage in these types of features is not well understood. Thus, in this study we investigate an area at the edge of a moraine where ground water discharges to an alpine stream. The moraine is part of an interconnected moraine-talus field in the Lake OHara Research Basin in the Canadian Rockies. Stream flow hydrographs and a subsurface tracer test suggest that the discharging ground water is sourced by a large proportion of the moraine-talus field, and that at least some of the ground water flow is rapid. The chemistry of discharging ground water varied substantially over a 25-m section, with no single location providing a consistently representative sample. However, end-member mixing analysis suggests the discharge area is a mixing zone for two ground water end members and that the relative contribution of the two members varies throughout the summer. This analysis suggests that ground water sourced from different areas is flowing in isolated flow paths. A two-dimensional geophysical survey using electrical resistivity imaging was conducted across the edge of the moraine to investigate the subsurface geology. The results suggest that a system of partially-connected bedrock channels is underlying the moraine material and likely controlling the ground water flow in this area. In addition, the fact that ground water temperatures remained essentially constant at less than 2 degrees Celsius throughout the summer suggests there is likely buried ice within the moraine-talus field that may also act to separate ground water flow paths.

***Keywords:*** groundwater, end member mixing analysis, electrical resistivity

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**HS1003** **Oral Presentation** **4124**

# Ecohydrology of high altitude mountain wetlands: case study of Ladakh

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High altitude mountain wetlands are recognized as fragile and are increasingly threatened by anthropogenic activities. These wetlands in the Ladakh region are confined to Changthang region of Tibetian Plateau. These wetlands represent oases of productivity in otherwise arid steppe environment and thus have significant conservation values, particularly in avifaunal and floral diversity. These lakes and wetlands attract a large number of tourists. One of the characteristics of tourism in this area is high degree of seasonality, which tends to concentrate and enhance its adverse impact on environment. These months are also the peak period of the biological activity and breeding season for most of the fauna. This adversely affects the breeding success of wetland birds, which need frequent monitoring. Given an increased probability of adverse affect on wildlife populations in many places in the TransHimalayan region, in the event of any catastrophic disturbance or habitat degradation and motivation, the information generated through this study would help in conserving the ecosystem. The lake hydrology which plays very important role in the wetland ecosystem is under severe stress. The qualitatative parameters, though have not changed since it was first measured by Hutchinson in August, 1932 elucidated from the fact that major parameters such as dissolved oxygen, PH and Chlorides in July, 2006 remained 9m, 7.4 mg/L, 9 26 mg/L and 10.5m, 7.57 mg/L, 8.85, 9 26 mg/L respectively. The increase in the runoff from the glaciers have drastically increased over the decade leading to the rise in the lake level by 6meters on the western shore and 4.5 meters in the eastern shore. On the anthropogenic front market forces and undue intervention by similar activities have played significant role in changing the socio-economic conditions of the villages. The rising number of the Pasmina Goat beyond sustainable limits is putting immense pressure on the agriculture and rangelands can be considered a case in point. On one hand this self sustained village is largely becoming dependent on the supplies from town, the influx of tourist have rose to more than 100 times over the decade. The study seeks to investigate the major issues affecting the wetland ecosystem and life around it and suggests use of proper monitoring tools to mitigate and check further degradation. In the light of above issues, wetlands monitoring provides specific information on the characteristics and functioning of environmental variables in space and time so that the decision makers can take ameliorative measures. The present study is also based on the fields experiences in the Changthang wildlife sanctuary. The objective of the paper is to bring out critical ecohdrological issues and suggests use of proper monitoring tools to mitigate further degradation.

***Keywords:*** wetlands, highaltitude, ecohydrology

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**HS1003** **Oral Presentation** **4125**

# Canopy and forest floor interception and transpiration measurements in a mountainous beech forest in Luxembourg

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Evaporation from interception and transpiration are important processes in the water balance of a forest. They determine to a large extent the amount of water which is available in the soil moisture and hence runoff. Both interception and transpiration strongly depend on vegetation cover. Therefore both processes are intensively measured in an experimental plot in a beech forest in Luxembourg. Interception is generally considered to consist mainly of canopy interception, which is most oftenly measured. Generally canopy interception is determined by subtracting the measured throughfall and stemflow from the open field precipitation. Besides canopy interception, we also measured forest floor interception. Interception from the forest floor appears to be a significant flux (e.g. 35% of the throughfall measured in November 2004) and hence can not be neglected. A special device has been developed for measuring forest floor interception. It consists of a permeable upper basin which is filled with forest floor and a watertight lower basin. Both basins are weighed continuously with strain gauges. The amount of water that drains into the lower basin is considered to be infiltration. This water replenishes the soil moisture, where it can be used for transpiration. The transpiration is estimated by sapflow measurements (thermal dissipation method). From the results it can be concluded that interception and transpiration strongly reduce the amount of water that can percolate to the ground water. Especially the amount of forest floor interception is significant and is at least in the same order of magnitude as canopy interception depending on the season.

***Keywords:*** interception, evaporation, experiments

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**HS1003** **Oral Presentation** **4126**

# Stable isotope tracers of shallow groundwater recharge dynamics and mixing within an Icelandic sandur, Skeiarrsandur

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Stable isotope (oxygen, deuterium) tracers have been used to investigate the interaction of different components of the hydrological system and the temporal and spatial distribution of different sources of recharge within a proglacial outwash plain aquifer at Skeiarrsandur, SE Iceland. The shallow groundwater system at Skeiarrsandur is highly responsive to changes in recharge making this an ideal situation to investigate both recharge and flow phenomena within a proglacial environment. There are two principal and isotopically-distinct sources of groundwater recharge on Skeiarrsandur: glacier/ice melt and local precipitation. The oxygen isotope and deuterium composition of precipitation is highly variable between precipitation events and an end-member for direct summer precipitation across Skeiarrsandur is established from a weighted mean of summer precipitation compositions from field seasons in 2000 and 2001. The oxygen isotope and deuterium composition of shallow groundwater generally lies between the end-member compositions of ice melt and local precipitation recharge. Groundwater samples lie close to the Global Meteoric Water Line showing that there is little modification to the isotope signature from evaporation. The shallow groundwater typically becomes isotopically heavier with decreasing depth and distance from the glacier margin. Depth-specific sampling of groundwater identified differences in the vertical stratification of stable isotope composition between areas of different recharge source and vertical flow regime. Limited vertical variation in oxygen isotope composition with depth exists where there is a single recharge source or discharging flow regime. The greatest vertical stratification where the groundwater is increasingly isotopically negative with depth is recorded in an area of horizontal flow paths where limited mixing occurs. The vertical stratification at this site is reduced in winter where there is greater homogenisation in oxygen isotope composition with depth possibly due to cryogenic turnover processes associated with repeated freezing and thawing cycles. Shallow groundwater adjacent to an enclosed moraine basin lake is isotopically enriched relative to average summer rainfall and shows a clear evaporative trend indicating recharge from the evaporated lake water. A simple binary mixing model is used to determine the proportions of different recharge sources in groundwater. Proportions of different recharge sources and the evolution of the isotope composition of shallow groundwater are controlled by: 1) proximity to the spatially restricted recharge sources (ice melt, surface water bodies), 2) depth of groundwater, 3) vertical flow patterns, 4) recharge dynamics in response to local precipitation events, 5) connection to localised flow systems and 6) seasonal mixing processes. Investigation of the dynamics of hydrological connections between shallow groundwater and surface water bodies has implications for the calculation of solute fluxes from the proglacial sandur and the determination of controls on the biodiversity of aquatic ecosystems in glacial outwash environments.

***Keywords:*** isotopes, recharge, sandur

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**HS1003** **Oral Presentation** **4127**

# Investigating the rainfall-runoff response of a small forested mountain catchment in the seasonally humid tropics using a modelling approach

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***Keith Richards***

The rainfall-runoff response behaviour of mountainous catchments in areas of the humid tropics experiencing a highly seasonal rainfall pattern is not fully understood, partly because of the limited hydrological data. Heavy seasonal rainfall in these headwater catchments often results in flash floods that cause serious damage further downstream. This paper uses a modelling approach to consider the rainfall-runoff response behaviour of a small forested catchment (0.74 km2) located in the mountainous region of Mae Chaem, Chiang Mai, Northwest Thailand. The aim is to investigate catchment hydrological behaviour and issues to consider (i.e. model calibration and simulation) when models are used for practical hydrological applications in these regions. The hydrological models chosen as investigative tools to examine rainfall-runoff response in this catchment had to be parsimonious because of the lack of hydrological data. Three models were tested. The IHACRES model (Identification of unit Hydrographs and Component flows from Rainfall, Evaporation and Streamflow data) and the Data-based Mechanistic (DBM) model are both transfer function models with a slightly different modelling approach. The IHACRES model structure is pre-defined in terms of the relationship between soil moisture conditions and the production of excess rainfall. The DBM model, by contrast, does not have a pre-defined model structure but infers the appropriate structure from the rainfall and discharge data. The third model is TOPMODEL, which was chosen given the steep topography of the study catchment, which suggests that topography and subsurface flows may be dominant. The DBM model was first tested to identify the nature of non-linearity of hydrological response and how it varies over the course of the monsoon season. Subsequently, the IHACRES model and TOPMODEL were tested to see if the processes encapsulated in the model structure reflect rainfall-runoff processes operating in the catchment. All three models were calibrated on different periods chosen from the wet monsoon season, representing different hydrological conditions. Model simulations were performed on the remaining dataset. The results showed that significant variability existed within the monsoon season indicating highly dynamic conditions. As a result, the model calibration period has to be chosen carefully as simulation results are affected by the choice of the calibration period. It cannot be guaranteed that the calibrated parameters derived for one monsoon season will result in successful simulation in another. In addition, TOPMODEL failed to capture the hydrological response behaviour of this catchment in terms of both peak flow estimation and recession behaviour. Similar problems were faced by other Thai researchers and point to the possibility that the current TOPMODEL assumptions, such as the exponential decline in hydraulic conductivity and the conceptualisation of the unsaturated zone used in the version of TOPMODEL adopted, are not suitable for the study catchment. These modelling results show that rainfall-runoff processes in small mountain catchments in the monsoonal humid tropics are highly variable temporally, and do not always share the characteristics of temperate regions.

***Keywords:*** runoff response, seasonal rainfall, tropics

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**HS1003** **Oral Presentation** **4128**

# Real time simulation of the inflow discharge for regulated reservoirs using distributed hydrological model with continuous soil moisture account

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In recent years sophisticated continuous deterministic hydrologic models including complex land surface sub-models have been developed for simulation and forecasting soil water dynamic and river discharge for drought and flood period. In this framework a distributed hydrological model is then presented to simulate continuous inflow discharge into regulated Alpine lakes for an operative real time management system; processes like snow melt, soil water balance, surface and subsurface flow routing are considered. To avoid complex parameterization for soil water balance module, that is often difficult to quantify, especially in presence of dense vegetation, an extension of the well known SCS-CN method for the continuous simulation is developed and discussed. The model has been tested comparing simulation results at hourly time scale with observed inflow data at Maggiore Lake in Italy for a 5 years period (2000-2004). This work is part of the TwoLe-A project, founded by Fondazione Cariplo, for the development of real time management of the water resource of the lake Maggiore

***Keywords:*** distributed model, soil moisture account, real time simulation

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# Continuous record of seasonal snowpack by two methods in a small Pyrenean basin

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In a small Pyrenean basin (33 ha, at 2060 m a.s.l), during the autumn-winter (2005-2006) and the spring (2006), the depth of snow (and its water equivalent) were continuously (every hour) recorded by two methods: a) an ultrasonic device for the distance between the sensor and the surface of snow (and thus the depth of snow); and b) a snow pillow measuring the pressure of snow (and then its water equivalent). The relationship between the values of both methods was very high, at a daily span, during the different periods of snow accumulation (lasting ca 135 days, between October 2005 and March 2006), and melting (going on for only 35 days, in April-May 2006). This year the maximum depth of snow was low (1.3 m), as compared with the average of the last ten years (1.8 m).

***Keywords:*** snow depth, swe, pyrenees

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# Application of HEC-HMS Model to Improve the Operation of Yuvacik Dam Reservoir in Turkey

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Yuvacik dam reservoir is one of the most important arteries supplying water to the city of Kocaeli, which is located in the southeastern part of Marmara region in Turkey, since 1999. Although considered to be a large dam, the spillway is being operated every year, especially during the spring months as large quantities of water come from the basin due to high rainfall and snowmelt. In this respect, the operation of the reservoir becomes an important task as critical decisions have to be made on the right time with limitations due to the discharging canal. For this purpose, atmospheric-hydrologic model integration and application studies came about to provide an improved decision support system for the operation and management of Yuvacik dam reservoir. In the present study, HEC-HMS version 3.0.1, including the snow module, released by US Army Corps of Engineers, Hydrologic Engineering Center (USACE-HEC) in April 2006, is applied to Yuvacik basin with snow component in a semi-distributed manner. Snow monitoring system was scarce and precipitation measurements were restricted to a limited area within a relatively small relief in the basin until recently. Therefore, new Automatic Weather Operating Stations (AWOS) were installed to different locations and altitudes in Yuvacik basin to collect representative meteorological data including snow depth. Snow course studies were also conducted to measure snow water equivalent values nearby AWOS locations. The recent and past data were processed and used to calibrate and validate the model in each subbasin for the period between 2001-2006. The model studies were carried out in daily time steps and for different seasons of a year (during ablation, melting and rain on snow periods) and the model results were evaluated in terms of different statistical criteria. After the calibration/validation of HEC-HMS model parameters, 1-day ahead Numerical Weather Prediction (NWP) data from Mesoscale Model 5 (MM5) are used as input to HEC-HMS model in order to predict the runoff to the dam reservoir from each subbasin. Early results of this atmospheric-hydrologic model integration are evaluated in terms of shape, volume and peak discharges and presented in the study to show if it can be used as a decision support tool in the optimum operation and management of Yuvacik dam reservoir.

***Keywords:*** hec hms, atmospheric hydrologic model, turkey

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**HS1003** **Oral Presentation** **4131**

# Modeling Time-series Wind Fields over Mountainous Terrain

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In headwater mountain catchments wind frequently is the dominant process controlling snow distribution. In the western United States, where more than 75% of the annual precipitation falls as wintertime snow, distinct patterns of vegetation, soils, and associated hydrologic response develop around characteristic wind-driven snow distributions that are generally repeated every year. Distributed snow models, presently capable of capturing these heterogeneities, require time-series of distributed wind data at compatible scales. Mass and energy balance 3-D wind flow models come with an unfeasible computational cost for production of time-series data while the resolutions of GCM wind fields render drifts and scour zones as subpixel features. This study starts with wind data from a unique set of monitoring sites located across a gradient of exposures within the 0.36 km2 Reynolds Mountain East (RME) headwater catchment in southwestern Idaho, USA to examine the efficacy of a basic wind speed model based on topography and vegetation. After a one-year calibration period, an optimal relationship between a sheltering index derived from upwind topography and vegetation cover, and hourly averaged wind speeds was developed. The developed relationship was tested and validated in successive years. Using the results from RME and additional observations from 10 lower elevation sites, hourly-observed wind speeds were detrended, relative to shelter, to develop elevation based lapse rates. The lapse rates and shelter/wind relationship were then used to predict wind speeds at all observation sites representing an area of approximately 60 km2 with a range in elevations of 1500 2170 masl. It was found that reasonable predictions of wind speed across this heterogeneous landscape capturing both large-scale elevation trends and small-scale topographic variability could be achieved in a computationally efficient manner.

***Keywords:*** wind, distribution, snow

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# Mapping the upper soil layers saturated hydraulic conductivity in mesoscale alpine basins: a methodology and its applications

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The upper soil saturated hydraulic conductivity Ks is a key soil property affecting a number of surface processes. Particularly in alpine basins and during heavy rainfall events, it plays an important role in the separation between quick or overland flow and lateral flow. To provide an experimentally based quantitative Ks map can be very important with the aim of applying physical based rainfall/runoff models at the prediction of flood events. On the other hand, due to its high space variability, frequently spanning orders of magnitude, and to the cost of field and laboratory experiments activities, it is often difficult to produce a physically sound quantitative map over a whole basin at the mesoscale (few hundreds to few thousand square kilometers). Here an experimental methodology, based on the use of the single ring infiltrometer and on the falling head laboratory permeameter, is proposed and the data, obtained after several wide field and laboratory campaigns, are compared and discussed. The hypothesis, that the soil response to a rainfall event is largely influenced by its pedogenesis, which e.g. affects its layering, structure and grain size distribution, and by its landcover, was introduced. With such an hypothesis, a preliminary qualitative map of the infiltration classes of the investigated basin can be provided by a cross-tabulation of a lithologic and a landCover map. The homogeneous areas can be therefore sampled on the basis of a representativeness criteria. At the experimental points the conductivity at saturation is determined for the surface and some subsurface layers, down to the depth of about 50 cm, when possible. A value of the hydraulic conductivity at saturation is finally provided for each infiltration class. Also the investigation of the Ks profile across the upper soil layers provides information useful to simulate soil moisture dynamics after long imbibition. As in fact the upper soil layers are often characterised by a reduction of the saturated hydraulic conductivity with increasing depth, the soil begins to show the effects of the decrease of Ks only after that the lower layers moisture has been reached by the imbibition front. An analytical solution of soil infiltration in a gradually stratified soil is also presented. As a result of wide field and laboratory experimental campaigns, this methodology was applied to obtain the surface saturated hydraulic conductivity maps of three Alpine basins, respectively characterised by metamorphic rocks (the Toce River basin at Candoglia, 1532 km, in the Eastern Italian Alps; here 146 experimental sites were selected), by significant intrusive formations (the Oglio River basin at Costa Volpino, 1446 km, in the Central Italian Alps; 100 sites) and by mainly sedimentary rocks (the Mella River basin at Stocchetta, 312 km, Central Italian Alps; 120 sites). The experimental analysis moreover shows, for the hydraulic conductivity at saturation, an average exponential decay factor of about 0.19 m for the Toce River basin and 0.12 m for the Mella River basin respectively.

***Keywords:*** infiltration, conductivity, soil properties

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# Analysis of Maximum Precipitations Frequency in North Karun Basin using Gumbel's Mixed Model

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The north part of the Basin of Karun River with an area of 23400 Kilometer squire is one of the vast Basins in Iran. With regard to the developing plan in agriculture, industry and electric power in Iran, the behavior of this river has vitally important. The floods with high discharge during last years caused a lot of damages in the foundation of the basin. The floods event in this area is highly related to the behavior of precipitations. Therefore managing on this basin needs special study on the behaviors of precipitation. This paper with regard to the extreme value distribution, namely the Gumbel mixed model constructed from Gumbel marginal distribution is employed to analyze the joint distribution of correlated storm peak (maximum rainfall intensity) and amount .Based on its marginal distributions, the joint distribution, the conditional probability distribution, and the associated return periods can be deduced. Parameters of the bivariate distribution, model are estimated based on its marginal distributions by the method of moments (MM).The usefulness of the model is demonstrated by using it to represent multivariate probable maximum precipitation events at the north Karun basin meteorological stations (Armand, Barez , Marghak and pol Shalo ) in Iran.

***Keywords:*** probablemaximumprecipitatio, gumbelmixeddistribution, periodreturncondition

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**HS1003** **Oral Presentation** **4134**

# Mountain Villages Threatened By Flash Floods. A GIS based prediction

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The last 1-2 decades were, in Romania as well as all over the world, marked by the increase of the frequency and aggressiveness of flash floods, characterized by historical extremes, sometimes corresponding to some return periods of 50-100 years. In the mountain area the specifically ant erosion techniques, targeted to shut down torrents and reduce flash floods, have quickly overrun their estimated lifespan. Moreover, the huge deforestations in the last years have increased the discharge parameters, the retention and the infiltration being significantly reduced; hence an increasing precipitation volume at yearly maximum rainfall creates the surface runoff as flash floods. In the last years extremely damaging flash floods have occurred, including events where lives were lost, in the mountain area where never since then such hazards have occurred. Thus, the present study estimates the actual parameters of the maximal discharge in the Carpathian belt and the risk of those to generate flash floods that would menace the settlements below. The increasing aggressivity of torrential runoff may be a consequence of possible recent climate changes, but as well a consequence of the anthrop cal irrational modifications of the land use in the mountain area. For this purpose we proceeded to estimate probabilistically the heavy rainfall and the obtained parameters were implemented as GIS functions. The DEM and the land use layer were then actualized, in order to deduce the parameters involved in the process of formation and evolution of flash floods. Because the study targets very small basins, slopes and inter-basin territories, the reductional method was used. In the calculus we have used the parameters interpolated through GIS. Thus the maximal discharge with its exceeding probabilities were computed, values that served to quantify the risk involved. Moreover, possible paths of flash floods were identified, obtaining maps of areas with several degrees of vulnerability and exceptional flash floods risk, susceptible to affect some rural settlements in the mountain area.

***Keywords:*** villages, flash flood, gis

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# Towards minimal calibration of process-based rainfall runoff models in mountainous watersheds integrating tracer data into geomorphic instantaneous unit hydrographs

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The Geomorphological Instantaneous Unit Hydrograph (GIUH) approach was applied for rainfall-runoff modelling in a 30km2 montane headwater catchment in the Scottish Highlands. Modelling was based on flow path length distributions derived from a DTM. The model was applied in two ways; a single hillslope response based on the DTM alone, and a two-hillslope response, which incorporated the distribution of saturated areas based on field-based observation and GIS based soil maps. This was to test the hypothesis that incorporation of process-information would enhance the model performance in such complex terrain. The model was applied with limited multiple event calibration to produce a group of parameter sets, which, although not well-defined, could be applied to a spectrum of events with contrasting characteristics and antecedent conditions. Gran alkalinity was used as a conservative tracer (soft data) to provide an additional objective function for assessing model performance. The models captured the hydrological response dynamics of the catchment reasonably well and this was corroborated by feasible predictions of stream water chemistry. In general, the single hillslope approach produced the best individual model performance statistics, though the two-hillslope approach provided a better range of models, which bracketed the storm hydrograph response more convincingly. There was a tendency to over predict the rising limb of the hydrograph, underestimate large storm event peaks and anticipate the hydrograph recession too rapidly. Most of these limitations could be explained by the simplistic assumptions embedded within the GIUH approach. Nevertheless, the study suggested that the approach has considerable potential for prediction of hydrological response in ungauged montane headwater basins.

***Keywords:*** tracers, giuh, modelling

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# The role of groundwater in an alpine catchment: Lake Ohara, Yoho National Park, Canada

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***Masaki Hayashi***

The Canadian Rocky Mountains are the source of many major rivers in Canada. Snow and glacier melt are the primary contributors to these rivers, with 70% of the mean annual discharge occurring during the high-flow period of May through August. Recent climate warming and variability has resulted in concern about potential changes in water supply downstream of mountain sources. In order to predict the response of mountain rivers to climate change it is important to conduct field studies in small watersheds, which will allow us to understand the physical processes and improve their parameterization in hydrological models. As such, a comprehensive hydrological study was initiated at Lake OHara, Yoho National Park, in 2004. A lake water balance study conducted during 2004-2005 indicates that groundwater inflow is 30-70% of total inflow to Lake OHara, suggesting that groundwater flow and storage may play a larger role in alpine watersheds than previously thought. Therefore, an improved understanding of groundwater parameters in alpine hydrologic response units, including talus and moraine, may be required to produce effective model simulations. This paper presents the results of streamflow simulations in the Opabin sub-basin of Lake OHara, using existing hydrologic models for cold regions. Field data were used as inputs to the model, including spatially-distributed snow-water-equivalent, precipitation, glacial melt and soil moisture conditions. Meteorological data were obtained from an automatic weather station on-site. The objective was to discern whether or not there is a lag between the simulated stream hydrograph and the observed stream hydrograph, when the model is run without calibration. It is hypothesized that the presence of such a lag is a result of storage and release of melt water from groundwater reservoirs. Additionally, comparison of hydrologic inputs (snow and glacial melt, summer precipitation) and outputs (surface water discharge and evapotranspiration) provides an indication of potential groundwater recharge. Future field and modeling efforts will involve characterizing groundwater parameters in alpine hydrologic response units for inclusion in a physically-based distributed model of the watershed.

***Keywords:*** groundwater, snowmelt, alpine

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**HS1003** **Oral Presentation** **4137**

# An integrated approach to characterization and numerical analysis for mountainous regions

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***Taehee Kim, Hyoun-Tae Hwang, Edward A. Sudicky, Yongje Kim***

Hydrology in mountainous regions is, in general, difficult to characterize because of limited accessibility and the lack of data. It is also complicated to analyze due to the highly nonlinear nature of the physical processes in the system such as surface water flow on steep surface slopes, percolation through thick unsaturated zones, and the interactive infiltration/exfiltration between surface and subsurface. A fully-integrated and physically-based model of surface and subsurface flow and transport was applied to two well-defined, intensively characterized mountainous catchments in Korea. In order to understand physical hydrologic processes in mountainous terrains, three-dimensional high resolution numerical models were constructed for these catchments and then the models ability to reproduce the existing surface/subsurface hydrologic measurements was tested under steady and transient conditions. The physically-based 3D model has the capability to simulate a multitude of processes including stream generation with 2D overland flow, infiltration and exfiltration over the land surface, 3D variably-saturated percolation and groundwater flow in the subsurface, and the temporal and spatial variation of saturation dependent evapotranspiration. Results show that the appropriate consideration of evapotranspiration along with the effects of agricultural drainage/irrigation was essential for understanding the water cycle in such areas. From the results, it is concluded that a fully-integrated characterization and numerical analysis are necessary to delineate and reasonably predict hydrologic behavior in mountainous systems.

***Keywords:*** integrated approach, hydrology, subface subsurface

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**HS1003** **Oral Presentation** **4138**

# Simulating Flood Process in the Mountainous basin with Physically-based Distributed Hydrologic Model

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Mountainous basin is usually ungaged or data-poor basin, thus makes its flood process simulation/prediction difficult with lumped hydrological model which requires enough observed historical data including meteorological forcing data and hydrological data. Physically-based distributed hydrologic model is an emerging model which derives model parameter physically from the terrain characteristics that can be observed with remote sensing technologies, thus has the potential to be applied to flood simulation/prediction in the ungaged or data-poor basin. Zengjiang basin is a headwater basin in the southern China that is a data-poor small mountainous basin with a drainage area of 102km2. The climate in the basin is humid with an annual average precipitation of 1900mm. The basin is frequently affected by floods, but as there is only 2 years observed hydrological data, it is difficult to calibrate a lumped model for the flood simulation/prediction. In this study, a Physically-based distributed hydrologic model for flood simulation/prediction for Zengjiang basin was presented that includes Basin Digitization, Precipitation preparation, Evapotranspiration, Runoff Production and Runoff Routing. The model was set up with data that could be acquired publicly, and five flood events were selected from the recently observed data for parameter deriving and model validation. A procedure for deriving the less sensitive parameters directly from the terrain data and the sensitive parameters through a trial-and-error method aided by GIS techniques is presented. The reference value regions for the less sensitive parameters are proposed first, and their values are then derived. Two flood events are used to validate the values of the model parameters, and three other flood events are used to validate the model performance. It is found that the model simulates the flood peak flow well.

***Keywords:*** flood simulation prediction, hydrological model, data poor basin

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**HS1003** **Oral Presentation** **4139**

# Influence of climate change on El Yeso reservoir in Santiago, Chile

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The impact of climate change on the availability of the water resources in the El Yeso reservoir, located in the Andes Mountains in Chile near the capital city, was assessed on monthly basis. This assessment was achieved through a downscaling of the weather impacted variables of a general climate model (GCM), the application of these variables into a hydrological model to simulate the inflow of the reservoir and the water balance in the reservoir with the changed inflow calculated with the climate change scenario variables. The data downscaling was done through SDSM 3.1, a program with a statistic-stochastic approach. The selected GCM was selected in order to analyse with HadCM3, A2 and B2 scenarios. The hydrological model selected was Sacramento, with a coupled snow model (based in Snow-17). The comparison between the current and changed condition of the reservoir inflow, the reservoir volume variations and the snow accumulation were used to assess the climate change impacts. Comparing current inflow with the scenario projections, an overestimation of a low discharge and an increasing probability of exceedance for a lower discharged was detected. The result of the volume balance analysis was that the water availability was not under risk considering the discharge impacted by climate change. The increase observed in the probability of exceedance of the climate change impacted reservoir inflows in the period from 1980-2005 can be explained by the lower variability of the mean yearly temperature in the scenarios A2 and B2 compared to the observed values. This leads to more snowmelt and more runoff during low flow periods because it rains in areas which are usually covered by snow. In the period from 2006-2054, the additional discharge augment is caused by the local increase of precipitation in this period, even with the general trend of this variable to decrease.

***Keywords:*** climate change, downscaling, snow influenced basin

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**HS1003** **Oral Presentation** **4140**

# Factors controlling ground-water recharge in the mountaineous hard-rock Aravalli terrain

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Recharge is one of the key hydrological parameters for assessment, budgeting, management, and modelling of ground-water resource. To have a measure of ground-water recharge, it is necessary to obtain precise information on the factors governing infiltration and loss from the ground-water system. In hard-rocks, the accumulation and flow of ground water is a function of various hydrological, hydrogeological, and hydrometeorological parameters. The deformative forces and the different earth processes depending upon the nature and composition of the rock, produce characteristic structural, morphologic, and topographic features, which influence and control the accumulation, storage, and movement of ground water. Identification and accurate evaluation of various parameters influencing ground-water recharge is a challenging task, and in mountaineous region the challenge is enormous. The present study focused in the Aravalli terrain of India covering ~ 25,000 km2 area in between N2330' - N2618' and E7224' - E7436'. Evaluation of individual and combined influence of hydrogeological and non-geological parameters on ground-water recharge was set as the main objective, and linear multiple-regression was chosen as the technique. Ground-water recharge is manifested by seasonal fluctuations of ground-water level, and is used as the dependent variable in the regression analysis. Standardised partial regression coefficients have been used as a scale for relative influence and as a tool for sensitivity analysis. The multiple-regression established that frequency of deficient rainfall is the most important recharge-controlling parameter with largest standardised partial regression coefficient. This eventually infers that ground-water recharge is most sensitive to deficient-rainfall frequency. Depth, elevation, vegetation, lineament buffer, and density of lineament count and lineament-intersection are found to be other parameters significantly influencing seasonal water-level fluctuations. With accumulation of temporal data, the mean value of water-table fluctuation varies, and with the variation of the responsive parameter, the partial regression-coefficients of the regressors also vary. Therefore, confidence interval of regression coefficients have been be used in the present study to check model uncertainty.

***Keywords:*** hard rock, aravalli, ground water recharge

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# Water exchange between a stream and peat aquifer in the Canadian Rocky Mountains

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Stream banks transiently store overbank floodwaters, which attenuate flood peaks and contribute baseflow during dry periods. Knowledge of bank storage dynamics is critical in determining soil moisture availability for riparian plants, recharge to shallow aquifers, and rates of soil biogeochemical cycling. Exchange of water between the stream and stream banks is controlled by the stage of the stream, the duration of a particular stage, the hydraulic conductivity of the stream-aquifer system, and aquifer porosity. Beaver dams, which are ubiquitous in North American streams increase stream stage for extended periods of time. This likely affects water exchange between streams and near-stream aquifers. The objective of this study is therefore to quantify spatial and temporal variations in water exchange between a stream and near-stream aquifer, and to determine the effects of in-channel beaver dams on this exchange. Water levels were measured in a network of 228 standpipes and mini-piezometers in the Sibbald Lake Research Basin, a catchment located in the foothills of the Canadian Rocky Mountains, during the summer of 2006. Hydraulic gradients between the stream and near-stream peat aquifer were higher above two beaver dams than along reaches without dams. The enhanced movement of water into the near-stream peat aquifer above the beaver dams was facilitated by the reduced stream velocity and higher stream stage, which presumably increased hydraulic residence time and stream hydraulic radius. These results suggest the need to integrate biological phenomena into conceptual models of bank storage dynamics.

***Keywords:*** bank storage, beaver, water levels

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# A study of the energy balance and melt water production on Juncal Norte Glacier, Central Chile

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Results from a recent glacio-meteorological experiment on the Juncal Norte glacier, central Chile, are presented. In the Central Andes of Chile melt water is a crucial resource that provides drinking water, water for agriculture and for industrial uses. There is also increasing competition for water use and allocation, as water demands from mining and industry are rising. Assessing water availability in this region and its relation with climatic variations is therefore crucial. The Dry Central Andes are characterised by a climatic setting different from that of the Alps and the subtropical Andes of Bolivia and Peru. Summers are very dry and stable, with precipitation close to zero and low relative humidity. Solar radiation is very intense, and plays a key role in the energy balance of snow covers and glaciers. The main aim of this study is to investigate the glacier-climate interaction and processes of runoff generation in this area. During the ablation season 2005/2006, an extensive field campaign was conducted on the Juncal Norte glacier. Melt rates across the glacier, runoff at the snout, meteorological variables over and near the glacier, GPS data and glacier topography were recorded over the entire ablation season. Using this extensive and accurate data set, the energy balance of the glacier and spatial melt rates are simulated for the entire melt season, and from this runoff is modelled. Simulated melt water production is compared with hourly runoff measured at the glacier snout using a combination of radar and salt dilution measurements. Runoff from the glacier is related to that observed at the standard network of discharge stations. In a second step, the performance of an enhanced temperature index model is also assessed against the performance of the energy balance model, because the former requires less input data and is therefore more suitable for application in areas where data, both for input and validation of the model, are sparse. Its ability to reproduce melt at different temporal scales is related to the distribution of the components of the energy balance at these latitudes.

***Keywords:*** melt modelling, glacier, runoff

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**HS1003** **Oral Presentation** **4143**

# The importance of snow-melt as a source of groundwater recharge - multi-parameter correlation of an exceptionally warm winter season with a subsequent severe hydrologic drought

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Snow-melt causes a concentrated release of melt-water and therefore is not only an important process of runoff generation in snow-melt may also represent a major source of groundwater recharge. A long-term monitoring of the stable isotope and chemical composition in spring flow, runoff and groundwater at the meso-scale Dreisam catchment (Black Forrest, Germany) indicates that the serious hydrologic drought in summer of 2003 was preceded by deviations from the hydrologic regime that started already in the exceptionally warm winter and spring season 2002/2003. The lack of intense groundwater recharge from snow-melt due to a winter season that was warmer than average was found to be the most likely cause for the observed deviations in hydrologic and isotopic regimes of several springs. These observations were confirmed by long term groundwater water table measurements in the Dreisam catchment suggesting that spring snow-melt is the major source of groundwater recharge for the alluvial aquifer of the Dreisam river (Zartener Becken). An intense stable isotope measurement campaign during the winter/spring season 2005/2006 was set up to investigate and quantify the role of snow-melt for the replenishment of aquifers in the Dreisam catchment. The depth of the snow-pack, water equivalents and isotopic composition were measured along several altitude profiles. The possible end members rainfall, pre-event runoff and baseflow were sampled and analyzed for stable isotopes. During 4 snow-melt events in 2006 discharge, temperature, electric conductivity and the isotopic composition (oxygen-18) were monitored at two springs (Zipfeldobel, Zaengerlehof), three nested sub-catchments with gauging stations (Zastler 17,8 sqm; Brugga, 39,8 sqm; Dreisam, 257 sqm) in 3 hour intervals. These measurements were combined with hourly ground water level readings at 10 boreholes in the adjoining alluvial aquifer of the Dreisam. Based on end-member mixing analysis event and pre-event discharge could be distinguished at all stations, event discharge being further sub-divided into rainfall and snow-melt components. The calculations show a scale-dependent and event-dependent percentage of snow-melt contributions to runoff. While pre-event components dominate runoff in all stations (52 to 82 percent), the event components contained between 6 and 18 percent of snow-melt and 11 and 30 percent of event-rainfall. In all stations the isotopic composition of base-flow changed significantly towards more depleted values during the observation period. This trend results from major groundwater recharge caused by the snow-melt events. The observed deviation is higher in the upper and smaller catchments (Zastler, Oberried) and less pronounced at the lower gauging stations (Ebent). The groundwater level and temperature data correlate strongly with snow-melt events. The results of this investigation confirm that until now the impact of snow-melt on the groundwater regime was underestimated in this catchment. In the future, climate changes resulting in modified accumulation and melting regimes of snow-pack may induce non-linear impacts on groundwater recharge as in the season 2002/2003.

***Keywords:*** snow melt, recharge, isotopes

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# Characterization of structures at an alpine slope for hydrological modeling on different scales

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***Falk Lindenmaier, Jrgen Ihringer, Erwin Zehe***

In general, hydrological active structures are considered responsible for fast preferential flow and transport. In mountainous regions, high relief gradients are a additional factor driving fast hydrological processes. In this contribution we present a conceptual approach for the representation of preferential structures which constrain the dynamics in a mountainous hydrological system. Our investigations conducted at an Alpine slope system (Heumoes slope, ~1 km, 400 m relief gradient), being part of the Ebnit river catchment (~50 km; located near Bregenz, Vorarlberg, Austria), focus on the observation of 'fast' processes, i.e. infiltration, surface and subsurface lateral flow, by combining field data gathering, conceptual and physical based modeling on local to catchment scales. The spatial pattern of these interacting processes is determined by dominating heterogeneities, i.e. preferential pathways like shrinking cracks and strata in the fine-grained slope body. Interestingly, dynamics on the slope scale highly correlate with the overall run-off dynamics in Ebnit River. Field observations covering small parts of different hydrotopes identified on Heumoes slope include a soil moisture measuring cluster on a pastured area and a multiple tracer test in steep forested terrain. Especially tracer tests with surface application provide a means to characterize the integrated response of a subsystem. From these exemplary observations, we developed a concept to represent the spatially variable structures and process parameters. The concepts found are transferred to the hillslope scale using a geostatistical upscaling approach and, in turn, are applied to enhance the physically based hydrological modeling of Heumoes slope, which provides a general means to enhance our understanding of how these processes interact with preferential structures across various spatial and temporal scales. Additionally, similar upscaling techniques provide a means to conclude from the processes and dynamics on the hillslope scale to the runoff generation processes on the catchment scale, which is supported by the results of rainfall-runoff modeling for the Ebnit River catchment.

***Keywords:*** upscaling, process based model, preferential flow

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# Impact of glacier recession on runoff from Alpine basins since the Little Ice Age

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During periods of climatic warming coupled with declining glacier extent, annual runoff from glacierised basins might be expected to be greater than precipitation inputs, and increase with enhanced melting and destocking of water stored as ice. However, higher annual total discharges resulting from warmer summers can not continue indefinitely, as glacier mass losses translate into declining glacier-covered areas and hence reducing runoff. Ultimately, runoff will decline to a level commensurate with contemporary precipitation as glaciers disappear. Records of discharge in rivers draining basins with between ice-free and 70% glacierisation, in the upper Rhone catchment in the Swiss Alps, for the period 1894 through 2004 have been analysed with a view both to assessing overall trends in discharge with climatic warming in basins of varying percentage basin glacierisation through three epochs of warming (in the 1920s, 1940s and the 1990/2000s) and to assessing the impact of sustained reduction of glacier mass on runoff. Precipitation and air temperature records from several meteorological stations in the region have also been analysed in order to identify fluctuations in climatic conditions to which meltwater runoff has responded. Annual total discharges from more highly-glacierised basins varied in the range -40% to +30% of period means, reflecting secular variations of both summer energy inputs for melting and winter snow accumulation. Discharge in the 1940s was lower than at the beginning of the twentieth century, but exceeded flows in the 1990/2000s, despite warmer summers during the second period. Mean annual total precipitation for the twentieth century was regularly exceeded in the cool 1970s, but declined through the late 1980s -2000s. In basins with little or no ice-cover, discharge increased up to the early 1980s, before decreasing as diminished winter snow accumulation accompanied warm and dry summers between 1982 and the 2000s. Declining glacier area, and hence reducing percentage glacierisation, influenced discharge in more highly glacierised basins during the twentieth century. Runoff in general, with the exception in highly-glacierised basins of years with extreme energy availability for melting ice, declined from the early twentieth to early twenty-first century, suggesting that runoff since the Little Ice Age declined overall rather than first increasing and then declining.

***Keywords:*** runoff, deglaciation, glacierised basin

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**HS1003** **Oral Presentation** **4146**

# Analysis of spatial variability of the regional precipitation using Kriging: the Paraiba Do Su Basin, Southeast of Brazil

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***Walquiria Marins Da Silva***

The emphasis in this research is to evaluate the spatial distribution of the precipitation using kriging techniques and to understand the causes of spatial climatic variability in the Paraiba do Sul basin, Southeast of Brazil. This basin is of great economic and environmental importance and also constitutes a major corridor connecting the two Brazilian largest cities: Sao Paulo and Rio de Janeiro. The area of study comprises nearly 15,300 km2 and is characterized by elevated variation in altimetry ranging from 450 m to 2,400 m. In the Paraiba do Sul basin, the average annual precipitation is on the order of 1,400 mm, but exhibits large interannual variability ranging between 800 mm to 2000 mm. Almost 70% of the total annual precipitation is concentrated in rainiest season (summer). The analysis was performed by seasonal times scales considering daily and monthly precipitation records from forty two stations. The analysis of spatial precipitation have been carried out by using ordinary kriging method and the software packages used for geoestatistical analysis were SPRING and ArcGIS 9.0. The analysis of seasonal pattern showed significant spatial precipitation variability. Comparison with deterministic methods (Thiessen) showed that kriging was most appropriate to detect the shifts that occurred between summer and winter. The causes of this variability were also analyzed. The Convergence Zone of Atlantic South (CZAS) plays a more important role during the summer and transitory seasons. On the other hand, both cold fronts and the orographic effects are responsible by shifts of spatial precipitation during the winter. In regions with great complexity in climatology and geomorphology characteristics, kriging demonstrated be a powerful statistical interpolation method.

***Keywords:*** geoestatistics, precipitation variability, climatology

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**HS1003** **Poster presentation** **4147**

# Etude du ruissellement dans les monts de beni-chougrane : utilisation de la simulation de pluie

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***Boudkhil Morsli, Mohamed Menad***

Les possibilits d'infiltration de l'eau dans les diffrents types de sol, les probabilits de ruissellement des pluies et les risques d'rosion sur les sols sont des donnes essentielles que les hommes de recherches essais de comprennent et de mesurer depuis longtemps. Il est vident pour tudier de manire adquate les phnomnes induit par la pluie, l'idal serait de pouvoir rpter volont des vnements pluvieux connue et contrle, en grant tous les paramtres, pouvoir les modifier ou les faire varier pour mettre en vidence le rle de chacun, tout en s'affranchissant du hasard et des caprices de la nature. La simulation de pluie est une mthode qui tente de rpondre cet objectif. Elle permet d'obtenir sur le terrain, de faon exprimentale dans un temps relativement court, de nombreuses donnes mesures sur le comportement de l'eau en surface et dans le sol. Dans cette tude, nous nous sommes intresss aux Monts de Beni-Chougrane. Ces derniers se trouvent dans le Nord-Ouest algrien. Ils sont l'un des principaux monts chanantes du tell occidental d'Oranie. Ils se caractrisent par une topographie extrmement confuse. Leur altitude s'lve en gnrale du Nord-Ouest au Sud-Est passent de 300 800 mtres. Les expriences ont t faites sur des sols sec, humide et trs humide. Les pentes choisies sont 12,5 et 25 %. Les intensits de pluies simules retenues sont 30, 50 et 80 mm/h. Les pentes et les intensits ont t choisies sur la base dune tude dtaille de la rgion. Pour les diffrentes expriences, le temps de la phase d'imbibition varie de 8 27 minutes (6 13,5 mm de pluie) pour les sols secs, 0,41 2 minutes (0,3 1 mm de pluie) pour les sols humides et de 0,16 1 minute (0,12 0,15 mm de pluie) pour les sols trs humides. Lorsqu'on passe de 30 80 mm/h d'intensits, la dur de la phase d'imbibition diminue de 48 69 % pour les sols secs, de 25 72 % pour les sols humides et de 22 78 % pour les sols trs humides. L'humidit pralable du sol et l'intensit de la pluie sont inversement proportionnelles la dure de la phase d'imbibition. L'effet de la pente sur cette phase n'est pas ngligeable, lorsque la pente augmente la dure de la phase d'imbibition diminue. Le ruissellement ne cesse d'accrotre durant l'exprience jusqu' atteindre un ruissellement maximal qui est la valeur plancher d'installation du rgime permanent. L'volution du ruissellement, enregistr, la mme allure que celle enregistre par Lafforgue. Pour les conditions les moins favorables (tat trs humide, intensit forte et pente relativement forte), le coefficient de ruissellement maximal a atteint 97 % qui correspond une infiltration minimale de 2.2 mm/h. En gnrale, le coefficient de ruissellement varie entre 66 et 97 % pour les diffrents traitements raliss. On appelle le temps allant du dbut de goutte goutte jusqu'au dbut de la stabilit du ruissellement : temps de la phase de transition. Dans notre cas, Tm varie en fonction de l'humidit pralable du sol et de l'intensit de la pluie. Lorsqu'on passe d'un sol sec un sol humide, la dure de la phase de transition diminue de 26 40 %, lorsqu'on passe d'un sol humide un sol trs humide, elle diminue de 18 52 % et lorsqu'on passe d'un sol sec un sol trs humide, elle diminue de 40 71 %. C'est dire, pour un sol trs humide le ruissellement atteint rapidement la valeur maximale, l'installation du rgime permanent est trs rapide. Dans ce cas, le risque de ruissellement est trs grand. Donc, la dure de la phase de transition est inversement proportionnelle l'humidit pralable du sol. Lorsqu'on passe de 30 80 mm/h d'intensit de pluie, le temps de la phase de transition diminue de 25 50 % pour les sols secs, de 15 42 % pour les sols humides et de 1 15 % pour les sols trs humides. La dure de la phase de transition est inversement proportionnelle l'intensit de la pluie et l'humidit pralable du sol. L'infiltration finale (Fn) varie entre 1.2 et 26 mm/h sur sol de type brun calcaire (argileux) pour les diffrentes situations. En gnrale, Le ruissellement est directement proportionnel l'humidit pralable du sol, la pente et l'intensit de pluie.

***Keywords:*** ruisselement, pluie simulee, beni chougrane

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**HS1003** **Poster presentation** **4148**

# Hydrogeology of the North West Indian Himalayas: Traditional observations, natural processes, geodynamics and the changing climatic conditions.

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Hydrogeology of mountain regions in general and Indian Himalayas in particular are a very poorly understood and documented science. All the research data and scientific exploration to understand the hydrology and hydrogeology in the past was confined to the inter mountain valley regions only. Mountains in general were considered to be devoid of significant groundwater resources. The mountain regions specially the headwater regions of the Indian Himalayas (which is source of major Indian rivers) were categorised to be in high altitude cold mountain deserts. The geo-environmental conditions were very fragile and the peaks were subjected to extreme climatic conditions. Hence these were considered to be devoid of any significant groundwater resources. But today with the advent of modern drilling technology and recent development in hydrogeological sciences these regions are today the highest groundwater resources of the world. Borewells drilled in Leh at an altitude of 11000 feet above the mean sea level have resulted in artesian conditions and the discharge increases in winters when temperatures drop to minus 30 degrees centigrade. Present paper highlights the significance of the data obtained after drilling more then 15000 borewells in the different hydrostratigraphic zones identified by Arya (1996) to understand the hydrogeological cycle in the Hindu-Kush- Himalayas The anthropogenic increase (mainly due to military and tourist compulsion) has led to occupancy of those areas, which were traditionally considered to be unsafe for human settlement. These sites are today under great threat from the natural hydrological processes and their very existence will be in danger in near future. The author strongly feels that there is urgent need to blend the traditional wisdom with the modern science, understand the natural processes laying special emphasis on the climatic changes taking place due to global warming leading to change in the snow cover line and its overall impact on the geodynamic nature of the mountains in general and peaks in particular.

***Keywords:*** hydrogeology, himalayas, groundwater

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**HS1003** **Poster presentation** **4149**

# Real-time flood forecast by a statistically-based watershed model coupled with Kalman filter

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***Zhongmin Liang***

The process of real-time flood forecast is generally implemented by watershed models or hydrologic methods based on the momentarily updated meteorological and hydrologic data. Recently, many researches focus on combining watershed models with real-time calibration technique, and the latter could calibrate parameters or structure of a watershed model with the newly imported data continuously, thus the result of prediction could be expected more accurate. In other words, the prediction accuracy depends on a well-developed watershed model and an effective calibration method besides correct real-time data. In this paper, a statistically-based watershed model considering spatial variation was presented firstly, and by coupling its part of river routing with the technique of Kalman filter, real-time calibration is carried out to update result of prediction. The generation of runoff is controlled by hydrological and meteorological conditions such as rainfall and evaporation, and also influenced by underlying surface including geology, topography, soil type and structure etc, among which, the spatial variation of rainfall is a pivot influencing factor. However, it is usually neglected and taken as a uniformly value for a certain divided computing unit (sub-basin), especially in some of conceptual runoff-yield models. This on the one hand largely simplifies the computation of runoff, but on the other hand it could not be the exact realization of runoff-yield process, thus in turn decreases the computation accuracy. The statistically based runoff-yield model just takes into account the spatial variation of rainfall and soil infiltration capacity over a basin. It introduces an exponential function as the probability density function(pdf) of rainfall to describe its spatial distribution, and meanwhile, the soil infiltration capacity over a basin is simulated by a parabolic type pdf. According to the joint probability distribution of rainfall and soil infiltration capacity, Horton mechanism was adopted to compute the surface runoff and soil infiltration. Part of the infiltration water supplements to the soil moisture, and the rest recharges to ground water through using a water storage capacity curve of soil moisture. The total surface runoff is composed of both rainfall excess runoff and saturated runoff, which are routed together to the river by unit hydrograph, while groundwater is routed by a lag time method. This model, from another point of view, is initially applicable to basins with both rainfall-excess and saturated runoff yield mechanisms. Because of the exponential and parabolic type pdfs of rainfall and soil infiltration used in this model, explicit expression of formulas for runoff generation are available, which brings the convenience for model application. The matrix solution of Muskingum method is utilized to simulate river routing, which could construct a state equation to link the whole forecast system, and especially, provide a computation platform of formal kalman filter method. According to the real input of water stage or discharge, the routing parameters and previous predicted results could be updated, thus the accuracy of prediction is expected to be improved. As an example, the model was used to forecast flood for the basin above Lushi hydrological station of Luohe River, a branch of Yellow River. Results show that the accuracy of prediction is acceptable, especially superior to the results predicted by the model without real-time calibration of Kalman filter. It indicates that, this model is applicable for real-time flood forecast of such a typical semi-humid and semi-arid basin.

***Keywords:*** statistically based model, spatial variation of rainfall, matrix solution of muskingum m

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# Water harvesting on sloping lands a hydrological need

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In the hilly and mountain areas of the entire Himalayan region, about 80% of rainfall is received from monsoon rains during three months from mid June to mid September. Continuous dry spells are experienced before and after this period. Long dry spells even during monsoon period are not uncommon. Hence, these regions face too high too little water syndrome and crops suffer either due to excess or deficit of water. On the other hand, huge amount of rain water is lost as runoff causing loss of this precious input and of fertile top soil. It is recommended to harvest and store water in the natural depressions in ponds in a watershed at the end of the slope. This is done for the sake of convenience of available site for water storage rather than convenience of water application to the crops grown at elevations higher than the pond. These ponds remain full of water during monsoon season when water is not required for irrigation of crops. However, water is either too less or not available at the time of irrigating crops grown at the upper and middle reach of a watershed due to huge percolation losses from the ponds. This is because the land at the natural depressions is too shallow and boulder-ridden which is unable to store water even few years after siltation of ponds. More than 80% of farmers in the Himalayan regions of India and across India are small and marginal with land holdings of less than 0.5 ha which are scattered and fragmented. Invariably, they are not willing to participate in the watershed management programme in a participatory mode as direct benefits of water harvesting do not accrue to them. It is for this reason they are unwilling to spare land to construct pond for water storage in the watershed on a community basis. Although, these ponds serve the purpose of recharging of the underground water, several kilometers away from their area of operation, little water is left for irrigating their crops. Whatever little water is stored in the pond is to be lifted to irrigate fields in the upper reaches of the pond requiring power and pumping units, not easily available to the poor farmers of the region. On the other hand farmers in the hilly and mountainous regions are blessed by nature with gravity. Under such situations it is desirable to follow intra-terrace water harvesting in small dug-out poly-lined tanks, located suitably at higher elevation to make use of gravity for irrigating the lower terraces. Further, there are innumerable natural springs whose outflow is lost. This outflow can also be directed and stored in these small tanks to provide irrigation to raise nursery and grow vegetables and other commercial crops. The rainwater from roof-tops and snow-melt in the cold-desert areas can also be diverted and stored in these cost-effective poly-lined tanks. There is a traditional kuhl (natural gravity stream) irrigation system followed in hilly and mountainous regions, the efficiency of which can be increased by constructing auxiliary tanks along the length of the kuhl at different places. The water can be stored in these tanks for use when there is a scarcity of water in the kuhl. These tanks can also be used to raise fish to increase productivity of the stored water. Furthermore, the farmers have the independence to use water and convenience of maintenance of individually owned tanks. The paper discusses such options as how the water can be effectively stored on sloping lands and productivity of stored water can be increased by growing commercial rather than traditional crops and maintaining hydrology to recharge the underground water which largely benefits the plain areas. Some case studies done at the farmers field are also discussed.

***Keywords:*** slopinglandswaterharve

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# Critique et homogeneisation des donnees pluviometriques annuelles sur le versant sud des Monts Bambouto (Ouest-Cameroun)

***Dr. Lucas Kengni***
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***Georges Wouendeu, Paul Tematio***

La pluie en temps que phnomne naturel est discontinu et variable. L'impact de cette variabilit se traduit dans les changements intervenant sur les ressources en eau, le dynamisme des populations ou des vgtaux. A cet effet, les enregistrements de pluie qui constituent des sries temporelles doivent tre minutieusement analyss afin de s'assurer que les variations observes sont naturelles et de tirer des conclusions utiles. Tout ceci n'est possible qu' partir de bases de donnes fiables. Le prsent article consiste en une analyse critique, l'homognisation voire l'extension des donnes pluviomtriques annuelles disponibles sur le versant sud des monts Bambouto. Ces donnes pourront fournir des lments de validation pour les travaux de modlisation visant individualiser les rles respectifs du climat et de l'environnement sur ce versant o la couverture temporelle varie selon les sites d'observation. Ce bassin versant couvre une superficie de 655 km2 o l'altitude varie de 800 m 2740 m au mont Mltan engendrant un climat trs contrast marqu par une longue saison de pluie (8 mois) et une courte saison sche. Il est abondamment arros, le climat est frais et doux dans l'ensemble. La mthodologie mise en uvre utilise des techniques classiques de comparaison des totaux cumuls et de rgression linaire entre stations. Les analyses ont t effectues sur une priode de 64 annes (1941-2005). Il en ressort que la mthode des totaux cumuls ne montre pas d'anomalies systmatiques et indique que ces stations se situent dans une mme grand rgion climatique. Cependant la mthode de rgression linaire montre des coefficients de corrlation d'autant plus faibles que la distance est grande entre les stations d'autant plus que la topographie intervient. Par consquent, l'extension des sries n'est possible qu'entre stations proches.

***Keywords:*** pluie, homognisation, rgression

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**HS1003** **Poster presentation** **4152**

# Long term change of water balance components in the river basins of snow and ice melted feeding

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Temporal and spatial variability of the following main components of yearly water balance: precipitation, evaporation, glaciers runoff and dynamical storage of water which related to the runoff formation area of Zeravshan river basin (total area equals to 10 200 km2) was determined at the first time during of 1935-1990. Long term data on runoff were obtained by measurements and by computations for the rest components. The theoretically substantiated method of determination average value of certain variable on the mean weighted altitude of watershed was used in this case as well as local and regional empirical relationships. Data on glaciers runoff were computed by means of authors model on accumulation and ablation processes in high mountain areas. Quality control showed that in 46 cases from 56 ones the relative error of computed runoff was 10%. The mean value of coefficient of runoff turned out to be equal to 0.77. Long term variability of precipitation characterizes rather noticeable positive trend. All procedures used for determination of water balance components are applicable for mountain river basins within Central Asia. New method of computation and mapping of maximum elevation of snow line was elaborated also. Method combines data on this index obtained for glacier and not glacierized areas.

***Keywords:*** water balance modeling, central asia, snow line variability

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# The relation between forest density and snowpack distribution in a Pyrenean site

***Dr. Ignacio Lopez***
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There is an extensive snow cover in the Pyrenees from December to April, especially above 1600 m a.s.l., that is, the location of the cold season 0C isotherm. The existence of large forested areas below 2400 m represents a drawback for assessing the amount the snow water equivalent (SWE) in a basin by means of snow models or interpolating local data. In order to improve the knowledge about the role of the forest on snow pack evolution an intensive sampling of snow depth and density has been carried out in a mixed forest (silver fir and beech) during two consecutive years. In addition, two stations have collected some meteorological data which affects the snow-surface energy balance, such as relative humidity, solar radiation, temperature and wind speed. One was installed in a forest clearing and the other under a dense forest site. Results indicate that forest cover introduce a high variability in snow accumulation within the analysed area. This variability is closely related to the measured density of the canopy. Maximum snow water equivalent was reduced more than a 50% regarding the open areas. Differences increased during the melting period. We also found significant differences related to canopy density in the temporal patterns of snow accumulation and melting. Thus, as canopy density increases melting occur earlier and faster. However, the particular meteorological conditions of the antecedent days to the SWE measurement can produce a different response of SWE to forest cover, with lower melting rates observed beneath dense canopies.

***Keywords:*** snow, forest, canopy

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**HS1003** **Poster presentation** **4154**

# The role of snow cover conditions in the hydrological regime of a mountain area

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***Andrew C. Whitaker, Kaichi Hayakawa***

The object of this paper is to discuss and evaluate the role of snow cover conditions in the hydrological regime through hydrological characteristics, such as water balance and runoff phenomena, by examining snowmelt and SWE (snow water equivalent) computed with a snowmelt model, and by analyzing hydrological information obtained from observed hydrological data. Hydrological variables in an experimental watershed (A=19.45 km2) located in a snowy mountain area in the winter monsoon zone have been observed and measured in detail from October 2000. Results of the autocorrelation function for hydrological data show that daily flows during the cold season have much more persistence than that during the warm season. From the information obtained by an application of the master recession curves, it is suggested that flow during snowmelt season is generated by a combination of groundwater having recession constant 0.018d-1 and diurnal flow having recession constant 0.015h-1. The orographic precipitation enhancement rate during the cold season (December-April) is estimated by satisfying the water balance. The seasonal water balance indicates that the ratio of discharge to precipitation during the cold season is about 90 % every water year without being affected by the amount of precipitation during the cold season. It is also shown that the ratio of total snowmelt discharge during the cold season to annual discharge is 50-57 %, and this large ratio suggests that snowpack and snowmelt play an important role in river recharge. The time of maximum SWE and the beginning of the rise in the hydrograph due to snowmelt occur almost simultaneously. This strong response means that the date of maximum SWE can be considered as an indicator of the starting date of the main snowmelt runoff season. By examining the relationship between the occurring date of droughty variables and starting date for the snowmelt season, it is suggested that the earlier snowmelt runoff is correlated with the earlier occurrence of droughty events. It is a logical conclusion that the earlier snowmelt causes promotion of earlier droughty phenomena. Additionally, the validity of an improved temperature index snowmelt model is shown with the comparison between the estimated SWE and the SWE measured by snow survey.

***Keywords:*** snowpack, hydrological regime, swe

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**HS1003** **Poster presentation** **4155**

# Dynamics and mass balance of a seasonal snowpack in the winter monsoon climate of Niigata, Japan

***Dr. Andrew Whitaker***
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***Hironobu Sugiyama***

The Shinano River, in the winter monsoon region of the Japan Sea, has the largest total annual runoff in Japan. Snowmelt is the major source of runoff for this heavily forested region, and therefore it is important to understand the dynamics and mass balance of the seasonal snowpack for the evaluation of water resources and flood hazards. This study investigates the key characteristics of a seasonal snowpack in the Japan Sea region through field observations under contrasting forest canopy conditions. Microclimatic data, snow accumulation, albedo, and lysimeter runoff is given through four complete winter seasons 2002-2006 in: (1) mature cedar stand, (2) larch stand, and (3) open site with regenerating cedar stand. The accumulation and melt of seasonal snowpack strongly influences streamflow runoff during December to May, including winter base-flow, mid-winter melt, rain-on-snow, and diurnal peaks driven by radiation melt in spring. Lysimeter runoff at all sites is characterised by constant ground melt of 0.8-1.0 mm/day. Rapid response to mid-winter melt or rainfall shows that the snowpack remains in a ripe or near-ripe condition throughout the snowcover season. Hourly and daily lysimeter discharge was greatest during rain-on-snow (e.g. 7 mm/h and 53 mm/d on 17 December 2002) with the majority of runoff due to rainfall passing through the snowpack as opposed to snowmelt. For both rain-on-snow and radiation melt events lysimeter discharge was generally greatest at the open site, although there were exceptions such as during interception melt events. During radiation melt instantaneous discharge was up to 4.0 times greater in the opening (e.g. 5 mm/h on 26 March 2003) compared to the mature cedar, and 48-hour discharge was up to 2.5 times greater. Perhaps characteristic of maritime climates, forest interception melt is shown to be important in addition to sublimation in reducing snow accumulation beneath dense canopies. While sublimation represents a loss from the catchment water balance, interception melt percolates through the snowpack and contributes to soil moisture during the winter season. Strong differences in microclimate and snowpack albedo persisted between cedar, larch and open sites, and it is suggested further work is needed to account for this in hydrological simulation models. The largest source of error in constructing a lysimeter snowpack mass balance is due to problems in measuring winter precipitation. The formation of ice layers and lateral flow within the snowpack is not found to be a significant problem. Indeed, the data shows that winter rainfall is readily transmitted through the snowpack, often with lysimeter outflow closely matching measured precipitation in timing and amount. During melt season, the relationship between air temperature and melt is strongest for the mature cedar site, indicating high potential for temperature-index modelling in forested areas.

***Keywords:*** snowmelt, rain on snow, snowpack

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**HS1003** **Poster presentation** **4156**

# Modelling of glacier and snow hydrological processes in a small mountain basin on the Tibetan Plateau

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Dongkemadi River basin lies at the mountainous area of the Tanggula Range on the Tibetan Plateau. Its basin area is 50.96km2. The range of altitude above sea level is from 5000 to 6104m. There is a big glacier, Dongkemadi Glacier with an area of 16.40km2, in the basin. Permafrost is well-grown due to annual mean air temperature of -6. Snow falls largely in the autumn and spring. Snow cover mostly distributes in the glacierized area, at the top of mountains around the glacierized area, and in some lowlands. So the Dongkemadi River basin has been seen as a typical and representative basin of studying mountainous hydrological processes on the Tibetan Plateau. Hydrological and environmental conditions in the basin were investigated from May to the second ten of October in 2005. In this work glacier and snow hydrological processes from May 25th to September 30th 2005 are modeled in the basin using measured hydrological and meteorological data obtained in this fieldwork and snow coverage data from Moderate Resolution Imaging Spectroradiometer (MODIS) images (MOD10A2), with spatial and temporal resolutions of 500 meter and 8 days, respectively. The authors used snowmelt-runoff model because of as follows several reasons: 1) runoff data is short, from May 25th to September 30th of 2005; 2) some parameters about glacier and permafrost are difficult in obtaining at present; 3) groundwater conditions in the mountainous areas is not clear on the Tibetan Plateau nowadays; 4) SRM is relative simple, including three variables, temperature, T, precipitation, P, and snow coverage, S. The simulated results show that two SRM average goodness-of-fit statistics for simulations, Nash-Sutcliff coefficient (R2) and volume difference (DV), are 0.83 and 0.95%, respectively. The results also show that SRM can be a validated snowmelt runoff model capable of being applied in the mountainous basins with glacier cover. On the basis of snowmelt runoff simulation, together with a set of simplified hypothetical climate scenarios, SRM is also used to simulate the effects of climate change on snow cover and glacier and the consecutive snowmelt runoff. For a given hypothetical temperature increase of 1, the runoff simulated don't shift towards earlier dates. But the total runoff has increased noticeably from 25.5~106m3 to 33~106m3. The mass equilibrium line in glacier will rise from current 5600m to 5750m, as a result, glacial ablation area will enlarge markedly from current 5.8km2 to 13.5km2 and glacial ablation will increase significantly. The simulation results show that the snow cover and glacier are very sensitive to changes of climate, especially to the increase of temperature. The major effects of temperature increase are to change precipitation form and speed up snow and glacier melt in the high-cold mountainous basin on the Tibetan Plateau.

***Keywords:*** hydrologicalprocesses, snowmelt runoffmodel, tibetanplateau

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**HS1003** **Poster presentation** **4157**

# Hydrologic cycle in a mountainous catchment, Northern Japan Alps

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In the Maekawa River catchment at the east slope of Mt. Norikura, Northern Japan Alps, the water balance and mass balance were examined for three years. The precipitation frequency is high from the rainy season to the autumn in the catchment. Then, the stream discharge increases temporarily in these seasons. The base flow discharge becomes biggest for the spring snowmelt season. The pH and electric conductivity of stream water increase gradually during the winter. The pH and electric conductivity of stream water decline rapidly with the beginning of the snowmelt runoff. When the discharge increases temporarily in the rainy season or at a typhoon event, the pH and electric conductivity of stream water decline temporarily. The Cl- concentration of stream water increases in the early stage of snowmelt season. In addition, the NO3- concentration of stream water increases when the rainfall increases discharge. The major ion concentration of stream water except Cl- and NO3- almost synchronizes with the change of electric conductivity. In the mass balance of the cation, the runoff rate from the catchment exceeds absolutely compared with the atmospheric deposition rate to the catchment. The reason is because there is extremely much elution of ions from rock and soil which are composed by the new volcanic structure. As for the Cl- ion, the runoff rate from the catchment balances with atmospheric deposition rate to the catchment. Also, the atmospheric deposition rate of NO3- ion is bigger with the biological consumption in the catchment than the runoff rate from the catchment.

***Keywords:*** stream water, snow cover, mass balance

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**HS1003** **Poster presentation** **4158**

# Hydrology and Management of Small Dams in Ethiopia and Yemen

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Abstract Although many small dams are constructed in Ethiopia and Yemen they are not found to be very effective as anticipated in alleviating the poverty of people by effectively utilizing the water resources. The major aims of the dams in Yemen is to recharge ground water whereas in Ethiopia is to store the flood water in the rainy season for dry season irrigation. There are several problems for effective operation of the dams, some of them are: Socio-economic, such as conflict of interest between up stream and downstream users Land use and land tenure systems Hydrology (In adequate hydrological study of catchment and sediment yield) Design problems such as water distribution system Agronomic, such as absence of good knowledge in crop water requirements The major aim of this study is to address the above problems and come up with suitable solutions so that the dams will be more beneficial to the users. Two small dams from each of the countries are selected to be studied, Gomit dam at Iste and Tebi dam at Meqdella in Amhara Region North West of Ethiopia and Methbel and Mikhtan dams in Yemen. The dams are located in the Abbay (Blue Nile) basin in Ethiopia and Sanaa Basin in Yemen. Whereas Sanaa Basin suffers from shortage of water the Abbay basin receives large amount of rain during the rainy season of June to September. Though the two areas receive different amount of rainfall their source and major mechanism of rainfall is the Inter Tropical Convergence Zone (ITCZ). The Mean Annual Rainfall (MAR) in the Abbay basin is about 1400 mm whereas in Sanaa basin the MAR is about 250 mm. That will be the major reasons to define the purpose of the dams ground water recharge in Sanaa basin and surface water harvesting in Abbay. Both areas belong to high altitude above 2000 meters above sea level. Agriculture is the major livelihood of the people. Soil and Water Conservation such as terracing and contour bunds are much developed in Sanaa Basin. Cash crops such as Qat, Grape, and vegetables dominate in Sanaa basin but cereals dominate in Abbay. Research based studies at small scale is not very common in both countries where data was most required to design projects. The major aim of this research will be on hydrological problems of small dam designs and operation and socio-economic problems why farmers couldnt utilize the existing dams effectively and what remedial measures should be taken in the future planning and design of small dams.

***Keywords:*** yemen, ethiopia, dams

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**HS1003** **Poster presentation** **4159**

# Vegetation Influence on the Measurement and Modeling of Turbulent Fluxes Over Snow

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Sensible and latent heat and mass flux represent a significant component of the snowcover energy and mass balance in mountain environments. Though these fluxes are computed in energy balance snow models, limited measurements exist for comparison or validation in complex, mountainous sites. Sensible and latent heat and mass flux can be determined directly from the turbulent fluctuations measured by fast-response sensors using eddy covariance (EC) theory. Two EC study sites, which are operated through the winter, are located in southwestern Idaho in a small headwater catchment of the Reynolds Creek Experimental Watershed, located approximately 80 km southwest of Boise, Idaho. One, a protected, below canopy site is located within a stand of aspen trees, and the other, an exposed site, is located nearby on a ridge over mixed sagebrush. Corrections and post-processing of eddy covariance data are discussed and EC-measured fluxes from the two sites are compared to better understand the manner in which terrain and vegetation influence turbulent fluxes over snow. Turbulent fluxes are also modeled at these two sites using the Snobal energy balance snow model, and differences between simulated and measured fluxes are evaluated. In addition, the methodology used to model the turbulent fluxes will be evaluated. This research will improve our understanding of how heat and mass flux from the snowcover impacts water resources in areas dominated by, high winds, complex terrain and variable vegetation conditions, provide validation data for snow models, and ultimately improve water supply forecasts required for management decisions.

***Keywords:*** eddy covariance, turbulent, fluxes

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**HS1003** **Poster presentation** **4160**

# A distributed water-heat coupled (DWHC) model for mountainous watershed of an inland river basin in Northwest China (II): model results using the measured data at the meteorological & hydrological stations

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***Shi-Hua Lu***

Using the daily precipitation data at the 26 hydrological & meteorological stations, daily averaged air temperature data at the 11 stations and daily pan evaporation data (E601) at the 14 stations in 2000, the distributed water-heat coupled model (DWHC) was calibrated. Six numerical tests using different spatial interpolation methods to calculate the daily precipitation, daily averaged air temperature and daily pan evaporation (E601) in each grid, were designed to simulate the mean daily runoff in 2000 at the Yingluoxia station, where the runoff amount discharged from the Heihe mountainous watershed was measured. Due to the spatial sparsity and asymmetry of the hydrological & meteorological stations, the results of the 6 numerical tests had little differences. The interpolation method in 3-D mode considering the altitude was little better than the methods taking no account of the altitude. When the daily data measured at the 2 stations far from the research watershed were complemented, the model results were not better. At last the nearest neighbor interpolation method in 2-D mode was used to calibrate the DWHC model. The Nash-Sutcliffe equation value NSE, the balance error B and the determinate coefficient R2 was about 0.6101, 0.0808% and 0.73, respectively. Using the daily data in 1999 to validate the model, the NSE, B and R2 was respectively 0.6270, 2.9824% and 0.77. The reason that the model result was not favorable was that it was lack of detailed soil information, meteorological data and vegetation data, the basic equations for runoff generation processes derived mainly from the research results in other regions and the flow concentration method should be improved. The spatial and temporal water balance of Heihe mountainous watershed in 2000 was also discussed in this paper. Though the runoff simulation results were not favorable, the estimated evapotranspiration and runoff components were in accordance with the usual knowledge qualitatively, part of which met with the field measurements. According to the model results, the runoff was mainly generated from the land surfaces and shallow soil layers in this cold mountainous watershed. The alpine meadow has evident water conservation function based on the model results, field investigation and field observation results. The DWHC model also reproduced the formation processes of the thick-layered ground ice to some extent, though it was suppositional due to lack of detailed soil, vegetation and meteorological information.

***Keywords:*** numericaltest, groundice, waterbalance

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**HS1003** **Poster presentation** **4161**

# A distributed water-heat coupled (DWHC) model for mountainous watershed of an inland river basin in Northwest China (III): model results using the outputs from MM5 model

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Using Mesoscale Model version 5 (MM5) to calculate the daily precipitation, daily averaged air temperature at the 2.0m heights and daily potential evapotranspiration, from Feb. 11 to June 30, 2003, of the Heihe mountainous river basin and its near area, with a geographical boundary of 96.786~102.284E, 37.328~40.601N and an area of 17*104km2, which was much larger than the area of the Heihe mountainous river basin (10009km2), the DHWC model was calibrated. The spatial resolution of the MM5 is 3km, the integral timescale is of 3s, and the calculated cycle is about 10d. In the MM5 model, the Grell scheme cumulus parameterization method, the Dudhia option, the explicit moisture scheme (IMPHYS), the cloud-radiation scheme, MRS PBL option and the modified Oregon State University Land-surface model (OSULSM) were chosen to use. According to the geographical position of the MM5 results and projection transform methods, the MM5 results were projected into Alberts coordinate, which was the coordinate of the DWHC model, and were interpolated into 1km*1km, using nearest and cubic methods. The results showed that, when the nearest method was used, the Nash-Sutcliffe equation value of the daily averaged runoff was of 0.79, the balance error was of -0.79%, and the R2 value was of 0.81. When the cubic method was used, the Nash-Sutcliffe equation value, the balance error and the R2 value was of 0.79, -0.65 % and 0.80, respectively. Though the evaluation criterion values is not very high, the model results are much better than the model results using the data at the meteorological and hydrological stations, which with a Nash-Sutcliffe equation value as 0.61. The model results are not very good because of the lack of the detailed soil and vegetation data. The MM5-DWHC model results also showed that the runoff production processes mainly occurred on the soil surface and in the shallow soil layers. The calibration results showed that, the MM5 results were singular to some extent.

***Keywords:*** mesoscaleclimaticmodel, initialparameters, singularfeature

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**HS1003** **Poster presentation** **4162**

# Analysis of precipitation events in a mountain region (Piemonte NW Italy) through a new Raingage-Disdrometer, PLUDIX

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***Angelo Piano***

An innovative X-band continuous wave (frequency 9.5 GHz) bi-static RADAR, named PLUDIX, has been installed in Bardonecchia (1312 m a.s.l., Piemonte, NW Italy), in the Dora Riparia basin. The analysis of micro-physical precipitation properties, such as the Z-R relation, obtained through PLUDIX data, has been performed and will be shown here. The data have also been compared with the informations of the pluviometers of the Regional Meteorological Office network in the position closed to PLUDIX.

***Keywords:*** remote sensing, radar, precipitation micro physics

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**HS1003** **Poster presentation** **4163**

# Two different processes of groundwater generation in soil layers observed in a granitic headwater catchment in Central Japan

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***Kenichirou Kosugi, Suemi Okunaka, Takahisa Mizuyama, Tasuku Mizutani***

Hillslope hydrology has conventionally taught us that groundwater is developed in soil layers in response to rainfall events due to much less permeability of bedrock than that of soil layers, and that this type of groundwater rapidly disappears after the cease of the events. However, the detailed observations in a granitic headwater catchment in central Japan revealed that groundwater in soil layers generated by relatively large rainfall events in this catchment is often kept formed for several months even after the events. In this study, we referred to the former (i.e., groundwater which disappears rapidly after the cease of rainfall) as ephemeral groundwater and the latter (i.e., groundwater which is kept formed for several months) as semi-perennial groundwater. To clarify the groundwater generation processes in this catchment, including semi-perennial groundwater, we first examined groundwater dynamics in soil layers observed at four points A, B, C, and D (from upslope to downslope) in this catchment. While only ephemeral groundwater was observed at A, both ephemeral and semi-perennial groundwater were observed at B through D. As the annual rainfall increased, the number of points at which semi-perennial groundwater is observed increased. The rainfall events which triggered semi-perennial groundwater were generally of large scale, but the largest rainfall events in individual years did not always generate semi-perennial groundwater. These facts suggest that semi-perennial groundwater generation is explained by the relatively long-term rainfall effects rather than by the scale of individual rainfall events. Hence we next employed the antecedent precipitation index with the half life of 480 hours (API480). The comparison between API480 and the groundwater level observed at each point suggests that (1) semi-perennial groundwater generation at B coincided with API480 exceeding 300 mm, and (2) API480 was always greater than 200 mm during the periods when semi-perennial groundwater was developed at points C and D. Moreover, it took 3 to 14 days for semi-perennial groundwater level to recess to zero while ephemeral groundwater always disappeared within 1 day, implying different water sources between semi-perennial and ephemeral groundwater. We conclude that (1) the less permeability of the bedrock than that of the soil created ephemeral groundwater on the soil-bedrock interface (in fact, the saturated hydraulic conductivity of the soil layers ranged from 1.210-2 cm s-1 to 2.110-1 cm s-1 whereas that of a shallow bedrock layer was 2.310-6 cm s-1), and (2) runoff of water stored in the deep bedrock layers into the soil layers generated semi-perennial groundwater. It was also inferred that the groundwater level within the bedrock, which is presumably affected by relatively long-term rainfall properties, determine the points of semi-perennial groundwater generation; i.e., the rise of the groundwater level within the bedrock can generate semi-perennial groundwater not only at C but also at B.

***Keywords:*** semi perennial groundwater, ephemeral groundwater, bedrock

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**HS1003** **Poster presentation** **4164**

# Distributed snowmelt and hydrologic modelling in an arid, mountainous environment: Sprague River, Upper Klamath Basin, Oregon, USA

***Dr. David Garen***
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The Sprague River, a major tributary to Upper Klamath Lake, is located in a dry, mountainous area east of the Cascade Mountains in southern Oregon, USA. With a catchment area of 4050 km2 and an elevation range of 1285-2525 m, it is characterized by volcanic geology and high spatial variability of climate, making it a challenging environment in which to apply hydrologic models. Several parallel efforts have been undertaken to apply hydrologic models in this catchment to simulate and predict snowmelt and streamflow for water management purposes and to utilize and evaluate the meteorological network available to provide forcing data. Model applications include: (a) the use of a point energy balance snowmelt model (SNOBAL) to simulate snow accumulation and melt at selected stations; (b) the application of a spatial version of the same energy balance model (ISNOBAL) over the catchment; (c) the application of a high-resolution grid-based hydrologic model (DHSVM) over the catchment; (d) the regional application of a conceptually simpler macroscale grid-based model (VIC) to predict streamflow; and (e) the application of a semi-distributed conceptual watershed model (PRMS) to predict streamflow. The ability of each model to simulate snow water equivalent or streamflow is evaluated. Each model has strengths and weaknesses with respect to usability, data requirements, simulation accuracy, and physical realism. These are brought to light in the comparisons among the various model applications along with implications for data collection, spatial interpolation of forcing data, prediction accuracy, and operational use. The ability of each model to represent physical processes and the successes and failures of each under various conditions is instructive in assessing modeling approaches for immediate use and long-term development.

***Keywords:*** distributed modelling, snowmelt, streamflow simulation

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**HS1003** **Poster presentation** **4165**

# Rainfall-runoff modelling for a large monsoon-dominated catchment

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***Han She Lim, Keith Richards***

Hydrological modelling for water resource and flood management in large monsoon-dominated sub-tropical catchments has not been the subject of extensive research, and it is not clear what the appropriate model structures and data requirements may be. High degrees of seasonality, limited data availability, rapidly changing hydrological regimes as a result of land use change and climate variability, and a lack of complete understanding of the details of the physical hydrology in these regimes/regions all contribute to this situation. This paper uses Data Based Mechanistic modelling methods to explore the hydrology of the 3,853 km2 Mae Chaem catchment in northern Thailand, where there is an unusually rich database of runoff and rainfall data. This is used to examine the appropriate model structure and parameter values in DBM models, and the effects of using the available rainfall and runoff data in a range of different ways. Rainfall data are area-weighted using Theissen polygons, within which altitude adjustment is effected on the basis of evidence for an increase of about 0.5mm of rain per rainday for each 100m increase in elevation above 1000m, in the monsoon season only. The model structure suggests a two-store model, and the parameter values seem to be rather stable when higher quality rainfall data are used. Furthermore, it is possible to maintain reliable flow simulations by cascading a series of runoff prediction regression models that predict a downstream flow from an upstream flow and the incremental rainfall between gauging stations.

***Keywords:*** data based mechanistic model, monsoon, semidistributed rainfall flow

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**HS1003** **Poster presentation** **4166**

# Observation of leaf-litter dynamics by using ubiquitous technology

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***Kuniyoshi Takeuchi, Hiroshi Ishidaira***

This research reported an application of ubiquitous technology such as IC tag or Radio Frequency IDentification (RFID) for observation of leaf-litter dynamics in temperate forest. The small size IC tags were attached to the living leaves to be tracked by using RFID from their abscission to transport into the stream. As a result, the comparison of observed leaf-litter tracking data and meteorological data allowed us to explain the mobility of leaf-litter on the forest floor. These measurement and observation technology may contribute for understandings of material transport from forest to stream.

***Keywords:*** ic tag, rfid, decomposition

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**HS1003** **Poster presentation** **4167**

# Seven years of daily snow depth records in a small Pyrenean basin

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In a small Pyrenean basin (33 ha, at 2060 m a.s.l.), the depth of snow in a single point was continuously recorded, during seven hydrological years (1997/98 to 2003/04), with an automatic ultrasound sensor. Usually the basin becomes snow covered during November, although snowfalls are not rare in October (and are possible, but infrequent, in September). The highest depth of snow recorded reached 2.6 m, and the smallest yearly maximum value registered was of 1.3 m. There are some temporal patterns in the snow accumulation that are repeated along various years, especially considering the period with snow consolidation between December and April (in this last month begins the melting of the snow mantle, that is concluded in May)-. The similarity between the patterns of snowfalls makes that, for some years, they are equivalent (statistically significant) when compared day by day with a t-test for paired samples.

***Keywords:*** snow depth, small basin, pyrenees

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**HS1003** **Poster presentation** **4168**

# A comparison of satellite-derived and modelled snow cover extent on a regional scale in the Swiss Alps

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***Manfred Sthli, David Gustafsson, Michael Lehning***

An accurate determination of the snow cover extent and duration on various temporal and spatial scales has become more important in addressing research questions regarding the hydrological, socio-economic, and ecological impacts of a changing climate. In this paper, we compare the snow cover extent derived from a distributed numerical snowpack heat and mass balance model (ALPINE3D) with an operational sub-pixel snow cover product generated from NOAA AVHRR data. These two methods were applied on a regional scale represented by the region of Davos in southeastern Switzerland including an area of approximately 630 km2. Data from several days with different snow conditions during the snowmelt season in 2003 and 2004 have been selected. The inter-comparison analysis is performed on a visual pixel-by-pixel comparison and on skill score measures based on 2x2 contingency-tables. In this study we evaluate the influence of two fundamental different data scaling approaches: aggregating or upscaling the high-resolution model output to the coarser satellite data and disaggregating or downscaling the AVHRR pixels to the model grid cells. The snow extent simulated by ALPINE3D was reasonably consistent with AVHRR-derived snow cover maps. The ALPINE3D exhibits a slight underestimation of the snow-covered area compared to the satellite observations. The average agreement between simulated snow-covered grid cells and satellite snow cover determination, was 88%. A decrease of the relative spatial accuracy between model and satellite has been observed for the snow-covered area when snowmelt period advances dropping from around 90% to 75%. The accuracy degrades below 70% for forested areas when satellite data estimates less snow than the model. Aggregating the high-resolution ALPINE3D to the coarse AVHRR pixels nor disaggregating the satellite data to the ALPINE3D has a significant effect on the overall comparison between model and satellite data. However, the corresponding accuracy between model- and satellite-derived data was lower in subalpine forested areas. This can be attributed in part to the snow cover retrievals from satellite data which are affected by the obscuring effect of the forest canopy that causes snow misses. Alternatively, ALPINE3D derived snow cover maps may differ from AVHRR maps due to the models over- and underestimation of topographic effects at a later date of the snowmelt season. The presented results from this inter-comparison study represent the initial stage in the future planned studies to investigate the potential value of assimilating satellite-based snow cover data into ALPINE3D.

***Keywords:*** swiss alps, alpine3d, snow cover

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**HS1003** **Poster presentation** **4169**

# Spatial scaling of snow depth at forested and open sites

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***Steven R. Fassnacht, Kelly J. Elder***

Knowledge of spatial patterns of snow accumulation is required for understanding the hydrology, climatology, and ecology of mountain regions. Spatial structure in snow accumulation patterns changes with the scale of observation, a feature that has been characterized using fractal analysis of lidar-derived snow depth data. Previous work has shown that the fractal structure of snow depth distributions differs between sites with different vegetation and terrain characteristics. Attempts to predict snowpack structure in forested areas are typically made using measurements from unforested areas because field measurements are more easily obtained in unforested areas and remotely sensed snow depth retrievals are complicated by the presence of forest canopy. This study demonstrates differences in spatial structure and scaling properties of snow depth between forested and unforested areas. Subsets are examined from the NASA Cold Land Process Experiment (CLPX) study sites. Relief characteristics are also examined, as prior studies have suggested that study site relief influences the scale break distance. The forested areas show a transition to an essentially random spatial distribution at a much shorter lag distance than do unforested sites. Thus forested areas could be characterized at much smaller scale lengths or model resolutions using a probability distribution function (PDF) based on a field estimate that details the statistical distribution of depth. The open areas, however, show strong spatial structure for a much wider scale range, and is usually the source of the majority of spatial pattern observable in the full study sites. Using a PDF to characterize snow amounts in open/tundra areas is likely to encounter significant scale issues, and the choice of resolution (dictated by satellite sensor resolution, DEM resolution, field survey resolution, etc.) is likely to strongly affect the estimates of snow accumulation and amount of spatial variability. These results indicate that snow cover models need to focus on deterministic approaches in unforested areas, while a less complex statistical approach may be adequate in forested areas. These two approaches themselves are scale dependent, but defensible at the hillslope to basin scale.

***Keywords:*** snow, scaling, landcover

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**HS1003** **Poster presentation** **4170**

# Comparative study on multi-branch river runoff forecasting method

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In the runoff forecastingCthe prediction on multi-branch river is much more difficult and complicated than that does not have branches. And the more branches, the more difficult and complicated to predict. But many areas with significant control reach, or areas where economy is more developed, are all on the multi-branch rivers. Today, making proper use of water resource is becoming more and more important. So improving the precision of multi-branch river runoff forecasting to meet the request of the operation and management of reservoir, is an urgent subject to be solved. In the recent several years, various mathematic techniques have been widely applied to runoff forecasting. Like fuzzy mathematics, stochastic model, regression analysis in the early researches, and now artificial neural network model has become a new focus. These methods have their own superiority and insufficiency on various aspects, such as the establishment and solution of model, forecast accuracy, applied effectCsuitable condition and so on .This paper attempts to do some research on three kinds of models with different influence factors. The methods to be discussed include multivariate linear regression analysis model, water balance model and 3-layers BP neural network model. In multivariate linear regression analysis, it carries on correlation analysis to select predicting factors tentatively; then sieves the predicting factors out according to the result of calculation; finally sets up the optimum multivariate linear regression model. Water balance model is founded on the basis of water balance equation, obtains the output variables by the input variables. Because some input variables are unknown, the model ascertains them through establishing response relation between the unknown terms and the known variables. The BP network model readjusts weight value continually through training the sample repeatedly, causes the network to restrain, thus forms the function mapping of input - output. The application of three models to the watershed of Tarim indicates that the discharge hydrograph simulated and predicted are satisfying. Although the effects of some other factors are considered, the forecast accuracy will not be improved obviously. Above all, through analyzing the structures, parameters and forecast precisions of these models, artificial neural network model is better as compared with other two. In the end, this article puts forward some proposals about how to strengthen the predict abilities of multi-branch runoff forecasting methods.

***Keywords:*** runoff forecasting, multivariate linear regression, artificial neural network mode

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**HS1003** **Poster presentation** **4171**

# Application of the Xinanjiang vegetation-hydrology model to streamflow simulation over the Hanjiang River basin

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***Ren Liliang***

The effect of vegetation characteristics on hydrological processes is seldom considered explicitly in most of conceptual watershed models, which limits their applicability to evaluate the impacts of climate and land use/cover change on hydrological cycles. In this paper, a physically-based vegetation-hydrology mechanism was added to the Xinanjiang conceptual hydrological model, namely the Xinanjiang vegetation-hydrology model, in which the effect of vegetation phonological characteristics (leaf area index), root depth, physiological features (stomatal opening and closure) and surface roughness on evapotranspiration, runoff generation and overland flow processes were explicitly described. Then the Xinanjiang vegetation-hydrology model was applied to daily streamflow and flood event simulations at the Hanzhong hydrological station in the upstream of the Hanjiang River and obtained satisfactory results. Furthermore, a model to assess the impact of climate change on runoff in the Hanjiang River basin was established using the Xinanjiang vegetation-hydrology model with the grid system at a 0.5-degree spatial resolution. This model was further one-way coupled with the PRECIS (Providing Regional Climate for Impacts Studies) regional climate model to evaluate the possible trends in runoff in the Hanjiang River basin under the IPCC-SRES (Intergovernmental Panel on Climate Change-Special Report on Emission Scenarios) greenhouse emission scenarios. Model simulation indicates that mean annual runoff averaged from 1991 through 2100 will increase by about 4.7% in the Hanjiang River basin as compared with the baseline years (1961-1990) and represent more remarkable spatial variability, implying a rise in the possibility of flood and drought occurrence in some local area of the Hanjiang River basin.

***Keywords:*** runoff, vegetation, climate change

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**HS2004** **4172 - 4249**

## Symposium
## Quantification and Reduction of Predictive Uncertainty for Sustainable Water Resources Management (Sponsors ICCLAS, IAHS/WMO Working Group on GEWEX , ICWRS, ICRS, IAMAS-ICCL and PUB)

**Convener :** Mr. Eva Boegh
**Co-Convener :** Dr. Harald Kunstmann

The symposium aims at a multidisciplinary view of the uncertainties in the end-to-end prediction of hydrological variables, beginning with the atmospheric driving and ending with the hydrological calculations for scientifically sound decisions in sustainable water management. The symposium focuses on uncertainty quantification and reduction for (1) improving the hydrologic predictability of hydrometeorological forcing variables by better representation of land surface processes; and (2) minimizing risks in water management decisions by accounting for the coupled land-atmosphere system Particular emphasis is put on studies dealing with areas of weak infrastructure such as the less developed countries in climate sensitive regions. The symposium will cover associated programs such as GEWEX, MOPEX, CLIVAR, THORPEX, TIGGE, THEPS and HEPEX which integrate across the above areas. The symposium will be composed of two sub-sessions. The first sub-session will consider the quantification and reduction of predictive uncertainty in hydrometeorological forcing and land surface processes. It will offer a forum where both meteorologists/climatologists and hydrologists can share their expertise in downscaling meteorological fields for applications in large basin surface/subsurface hydrology. It will examine the predictive capability of meteorological models when applied both to short-term and long-term hydrological simulation, including 1) impact studies of land surface parameterisations on the quality of weather predictions, 2) data assimilation for prediction, 3) ensemble predictions for climate and hydrology uncertainty assessment, 4) model parameterization, validation and intercomparison studies, and 5) the transferability of methodologies between different geographical regions. The second sub-session will consider the minimization of risks in water management decisions by improving the understanding of the coupled land-atmosphere system. Its purpose will be to incorporate data and understanding of the coupled land-atmosphere system to minimize risk in model based hydrological predictions for sustainable water management. Topics addressed will include 1) the understanding of the coupled land-atmosphere system to quantify and reduce uncertainties in hydrological predictions; 2) the use of spatial data (ie. remote sensing, GIS data) to quantify and evaluate impacts of land use and land surface patterns on hydrological predictions; and 3) the application of land-atmosphere representation in hydrological models to assess and mitigate responses to extreme events, i.e. droughts and floods. Scientists, water managers and policy makers are encouraged to contribute to the sub-session.

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**HS2004** **Oral Presentation** **4172**

# Joint high resolution climate - hydrology simulations for the upper Jordan River catchment

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Sufficient freshwater availability is a central prerequisite for agricultural and industrial development in the water scarce environment of the near east. Political peace in the region is strongly linked to the satisfactory compliance of increasing water demands. Sustainable management of water resources requires scientific sound decisions on future freshwater availability, in particular under global climate change and increasing greenhouse gas emissions. Behind this background, the impact of climate change on water availability in the Upper Jordan River catchment (UJC) is investigated within the framework of the GLOWA-Jordan river project (http://www.glowa-jordan-river.de). A focus is set on the Upper Jordan in this study as it provides 1/3rd of freshwater resources in Israel. This is achieved by high resolution joint regional climate hydrology simulations. Two 30 year time slices (1960-1990 and 2070-2100) of the global climate model ECHAM4 (emission scenario B2) were dynamically downscaled using the non-hydrostatic meteorological model MM5 in 2 nesting steps with resolutions of 54 km and 18 km. The meteorological fields in turn are used to drive the physically based hydrological model WaSiM applied to the UJC which has an area of about 855 km. The hydrological model computes in detail the surface and subsurface water flow and water balance in a horizontal resolution of 90 m and dynamically couples to a 2-dim numerical groundwater model. The ability of the hydrological model to describe the observed river discharges in this hydrogeologically extremely complex region is discussed. The simulated mean precipitation for 1960-1990 showed excellent agreement to long-term station observation. The impact of predicted atmospheric change for 2070-2100 on terrestrial water availability (flow components, evapotranspiration, groundwater recharge, etc.) is shown.

***Keywords:*** water availability, climate change, dynamic downscaling

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# Investigation of hydrologic predictability of global data sets for high latitude river basins

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The aim of the present work is investigation of hydrologic predictability of global data sets for the northern river basins using the Land Surface Model (LSM) SWAP (Soil Water Atmosphere Plants). SWAP allows the simulation of the dynamics of the heat and water balance components for river basins at different spatial scales and under a great variety of natural conditions. It was widely validated against observations and compared with the other models when participated in numerous international intercomparison projects (such as PILPS, SnowMIP, MOPEX, Rhone-AGG, GSWP-2, etc.). Input data for the model represent hydrometeorological forcing variables and land surface (soil and vegetation) parameters. Here, the input data were taken from the global 1-degree data sets provided within the framework of the Second Global Soil Wetness Project (GSWP-2). The applied meteorological forcing variables (prepared with 3-hour time step for the period of 1983-1995) represented a hybrid of the results of re-analysis with monthly observations. Application of the global data (without downscaling of meteorological forcings and calibration of model parameters) for the simulation of river runoff in high latitudes has shown poor results. To improve the results the model calibration against measured streamflow was performed for one of the high latitude river basins, namely, the Mezen river basin (area: 78000 km2) located in the north-eastern part of the European territory of Russia (6430-66 N, 44-50E) at the boundary between taiga and tundra. Nearly 80% of the basin is forested. The rivers feed is mixed with a prevalence of snow feed because the winter lasts 6-7 months in that region. To run the model the Mezen river basin was schematized by 10 1-by-1 grid cells connected by a stream network. Runoff was simulated for each grid cell and then routed through the river network by means of a simple linear model for water balance formation. Only 7 land surface parameters were calibrated using streamflow measured at the Malonisogorskaya river gauging station (the measurements were provided by the Global Runoff Data Centre - GRDC). Since meteorological forcing data may contain systematic errors, correction of the most important variables precipitation and incoming radiation - was undertaken using four adjustment factors: for rainfall, for snowfall, for shortwave and for longwave incoming radiation. So, the model was calibrated with 11 parameters. The calibration was performed for 1986-1990 using stochastic optimization techniques. The period of 1991-1995 was used for model validation. Analysis of the simulated streamflow has shown fairly good results. For the calibration period, the Nash-Sutcliffe efficiency of simulation was equal to 0.80 for daily and 0.93 for monthly streamflow. For the validation period the corresponding values were 0.82 and 0.94, respectively. So, it should be concluded that global 1-degree data sets may be applied for streamflow simulation and prediction (at least, using LSM SWAP) in high latitudes with appropriate model calibration.

***Keywords:*** streamflow, calibration, global data sets

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Oral Presentation** **4174**

# Assessement of rainfall-runoff model input data uncertainties on simulated runoff in Southern Africa.

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Rainfall-runoff models are used extensively in southern Africa for the purposes of water resource planning and management. It is well understood that the outputs from such models are subject to uncertainties related to the input hydrometeorological data, the ability of the model to simulate real hydrological response and the quantification of the model parameters. However, there have been few previous studies in the region that have attempted to quantify the various sources of uncertainty. The problems of uncertainty associated with input data are exacerbated in the southern Africa situation due to sparse observation networks, which have been shrinking over the last several decades. While the implications for estimating basin average rainfall inputs to hydrological models are clear, there have been few attempts at quantifying the effects. With respect to estimating evaporation demand, it has been common practice to use mean monthly values within models, largely due to the lack of available information in most basins. The quantitative effects on simulated patterns of runoff of ignoring the time series variations of evaporation demand have also not been addressed satisfactorily. This paper presents an assessment of the uncertainties associated with estimating the rainfall and evaporation inputs into commonly applied hydrological models in the southern Africa region, as well as examining the extent to which those uncertainties are translated into uncertainties in runoff estimation. It has been assumed that these uncertainties will be different in different climate and hydrological response zones and therefore a sample of basins drawn from both semi-arid and temperate parts of South Africa has been used. The selected basins all had relatively (compared to other basins in the region) dense rainfall gauging networks in the past which have subsequently been reduced. For each basin, several realizations of spatially averaged rainfall have been generated using an inverse distance squared weighting procedure. The different realizations are generated for a common time period, but based on those gauges that were open at different times. The analysis is based on comparing the best available estimate (the realization using the highest number of raingauges) with the alternative estimates using smaller numbers of gauges. Comparisons are made between the spatially averaged rainfall data (both daily and monthly) as well as between the patterns of runoff simulated by a monthly rainfall-runoff model using the different rainfall realizations. The rainfall-runoff model parameters for each basin are fixed for all the rainfall realizations and have been taken from a previous study. With respect to the evaporation inputs to models, the study is confined to assessing the effects on simulated runoff patterns of using either fixed monthly values or time series of variations based on data from the very sparse network of evaporation pans. The discussion focuses on the implications of the input data uncertainties for model calibration and parameter estimation (where observed flow data are available), as well as for the estimation of runoff in un-gauged basins using regionalized parameter sets.

***Keywords:*** model input data, uncertainty

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**HS2004** **Oral Presentation** **4175**

# The use of physical basin properties and runoff generation concepts as an aid to parameter quantification in conceptual rainfall-runoff models.

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***Evison Kapangaziwiri***

A monthly time step, conceptual type rainfall-runoff model (the Pitman model) has been used for many years in Southern Africa for estimating water resource availability in medium to large scale basins (>50 km2). However, the uncertainty associated with parameter quantification, especially in un-gauged basins, remains largely unsolved. Various methods of parameter regionalisation have been used, but they have normally been based on either statistical analysis of calibrated parameter values against some measurable basin properties, or on simple mapping of parameter values using assumptions of regional hydrological similarity. One of the inherent problems with both of these approaches is the limited amount of available observed streamflow data that can be used to establish the calibrated parameter sets. A further problem is the uncertainty associated with the extent to which the observed streamflow data are impacted by upstream water resource developments and are therefore representative of natural hydrological processes. Despite the coarse spatial and temporal modelling scales, the model is nevertheless made up of components that have a sound basis in conceptual hydrology. This paper therefore addresses the question of whether physical basin properties and the role that they play in runoff generation can be used more directly in the estimation of parameter values. If the answer to this question is yes, then it may be possible to develop procedures for parameter estimation in un-gauged basins that are less reliant on limited calibration results that are themselves likely to generate values with a degree of uncertainty. The motivation for this approach is that information on the physical properties of basins is becoming more readily available through satellite and GIS technology. The model and our conceptual understanding of physical hydrology have been available for many years, but they have not been linked very satisfactorily. One possible reason for this is that the model is normally used at scales (spatial and temporal) that are coarser than hydrologists are accustomed to conceptualizing rainfall-runoff processes. This study attempts to define potential links between parameter values and physical basin properties as a preliminary step toward improved parameter estimation in un-gauged basins. The geographic context is southern Africa and the constraints of data (hydrometeorological and basin properties) availability have been taken into account at all stages of the study. The paper outlines the potential links, includes some initial evaluations of the approach using gauged basins and compares some parameter estimates in un-gauged basins with existing methods. One of the potential uses of the results of the study is to identify the type of basin information that might be required for the successful implementation of the proposed parameter estimation approach. These requirements then need to be assessed in the light of existing and future potential sources of such data.

***Keywords:*** rainfall runoff, parameter estimation, basin properties

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**HS2004** **Oral Presentation** **4176**

# Predictive uncertainty in climate change impacts on floods

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Global climate changes may result in an increased occurrence of flooding events. It is therefore crucial for flood management that information about the impacts of climate change on floods and the predictive uncertainties herein becomes available. The objective of this study is therefore to assess the predictive uncertainty in the impacts of climate change on floods in the river Meuse in Northwest Europe. Changes in climate variables, in particular precipitation and temperature, are assessed using observed station data and results from Regional Climate Models (RCMs) from the EU-project PRUDENCE. The uncertainty in the climate change projections of climate variables is assumed to be mainly the result of different emission scenarios, sampling errors, different boundary forcing by Global Climate Models (GCMs) and different RCMs. This uncertainty is summarised by probability distributions for relevant statistics of the selected climate variables. In the uncertainty analysis, statistics are randomly drawn from these probability distributions and used to transform current and changed climate series. The conceptual hydrological model HBV is used to simulate the hydrological regime for current and changed climate conditions. The calibration of HBV for current climate conditions is done using a fuzzy measure as objective function. This fuzzy measure combines several objective functions for simulation of floods and the discharge regime. Validation of the model is done for a period different from the calibration period. The uncertainty in the hydrological model is assumed to be represented by the difference between observed and simulated discharge and incorporated in the uncertainty analysis through the model parameters. Similarly as for the climate variables, in the uncertainty analysis, parameters are randomly drawn from their probability distributions. The different uncertainty sources (emission scenarios, sampling, boundary conditions, RCMs, HBV parameters) are propagated through the HBV model using Monte Carlo analysis. This finally results in a probability distribution of floods for current and changed climate conditions. This enables an assessment of the significance of changes in flooding conditions with climate change by comparing changes and uncertainties. The flooding event of particular interest is the flood with a return period of 100 years. The RCM results show an annual average increase in temperature of 4.0 C for climate change conditions (2071-2100) varying between 3.3 C in DJF (December-January-February) and 5.1 C in JJA (June-July-August). Precipitation decreases slightly by 2.5% on an annual basis varying between +24% in DJF and -35% in JJA. Uncertainties with climate change (expressed as standard deviation) vary between 1.1 C in DJF and 1.8 C in JJA for temperature and 9.8% in MAM (March-April-May) and 14.6% in JJA for precipitation. Results of the HBV model calibration show good performance for high flow as well as for average and low flow simulation using the fuzzy measure. Validation results are slightly better than calibration results due to the better data quality for the validation period. The parametric uncertainty for different sub-basins is between 22% and 31% forcing Nash-Sutcliffe coefficients for pairs of simulated discharge series to be equal to Nash-Sutcliffe coefficients for pairs of observed and simulated discharge series. Combining RCM and HBV results enables an assessment of climate change impacts on floods and related predictive uncertainties. Climate change results in an increase of the 100-year flood of about 900 m3/s or 25%. This increase is primarily caused by an increase of precipitation in DJF. The uncertainty in this impact (expressed as standard deviation) is about 950 m3/s or 20% resulting from uncertainties in climate change (49%) and uncertainties in HBV parameters (51%). It thus can be concluded that the impacts of climate change on floods are considerable resulting in an increased occurrence of floods in the river

Meuse. Uncertainties in these impacts are large, although only partly disguising the climate change signal.

***Keywords:*** climate change, floods, uncertainty

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**HS2004** **Oral Presentation** **4177**

# May a land surface model simulate runoff with the same accuracy as a hydrological model?

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Land surface models (LSMs) parameterizing heat and water exchange between the land surface and the atmosphere were initially designed for coupling with atmospheric models and represented simple parameterization schemes. By the moment they evolved into complex physically-based models which may be used in a stand-alone mode for simulating different components of heat and water balance at the land-atmosphere interface as well as different characteristics of hydrothermal regime of hydrological and ecological objects. Outputs of LSMs include more than 50 variables, including runoff. In hydrological community, there is an opinion that LSMs cannot be as successful as hydrological models (HMs) with respect to runoff simulation because LSMs, being too complicated, suffer from accumulated errors in the larger number of forcing data and model parameters they require relative to the lesser data demands of HMs. Better performance of HMs compared to LSMs (including our land surface model SWAP) was obtained after model calibration within the framework of the MOPEX project (Duan et al., 2006). This arises the following questions. Why did HMs overperform LSMs? What should be undertaken to make LSMs as successful as HMs? The present work is an attempt to investigate these issues using the LSM SWAP and the results of streamflow simulation for 12 MOPEX basins by the deterministic, lumped-parameters, conceptual hydrological Sacramento model (SAC-SMA) (Gan & Burges, 2005) which was among the best in the MOPEX project. Analysis of the results obtained within the MOPEX project allowed us to suppose that the main reason of worse performance of SWAP is poor model calibration. It should be noted that LSMs are usually not calibrated and we are not so experienced in calibration as hydrological modelers. In the MOPEX experiment, SWAP was calibrated manually by tuning only one parameter (hydraulic conductivity at saturation) to minimize mean bias between simulated and measured annual streamflow. Improved model calibration using 6 soil parameters, which effect runoff to the most extent, and automatic procedure for optimization (by minimization of root-mean-square-deviation between simulated and measured hydrographs) based on a stochastic or Monte-Carlo technique resulted to better hydrograph simulations. However, again SAC-SMA was better than SWAP (Gan et al., 2006). Since SAC-SMA was calibrated using 16 parameters (11 land parameters, three unitgraph ordinates, precipitation scaling factor and the potential evapotranspiration adjustment factor), we decided to increase the number of calibrated parameters in SWAP by inclusion of main vegetation parameters and scaling factors for precipitation and incoming radiation. After such a calibration we have managed to obtain the results which, on the average, are close to those of SAC-SMA. Thus, daily Nash-Sutcliffe efficiency, averaged over 12 basins, equals to 0.66 for SAC-SMA and 0.64 for SWAP, mean bias is 2.4% for SAC-SMA and 1.1% for SWAP. These results demonstrate that LSM SWAP under appropriate calibration may simulate river runoff with the same accuracy as HMs.

***Keywords:*** mopex, runoff simulation, land surface model

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**HS2004** **Oral Presentation** **4178**

# Modelling regional climate change and the impact on surface and sub-surface hydrology in the Volta Basin (West Africa)

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The Volta Basin is a climate sensitive, mainly semi-arid region. To estimate the effect of a possible anthropogenic influence on the water balance in the Volta Basin (400,000 km), joint regional climate hydrology simulations were performed. In a first step, regional climate simulations were carried out, using the mesoscale meteorological model MM5, fully coupled to a 1D SVAT model, to account for soil properties and soil-atmosphere feedback mechanisms. The scenario IS92a of the global climate model ECHAM4 (2.8) was downscaled dynamically to a resolution of 9 km for the region of the Volta Basin. The simulated years were 1991-2000 for present day climate, and 2030-2039 for future climate. To investigate the impact of atmospheric change on the terrestrial water balance, the distributed, physically based hydrological model WaSiM was coupled in a one-way approach to the regional climate model. For the hydrological simulations, a horizontal resolution of 1 km was chosen, allowing a detailed analysis e.g. of changes in evapotranspiration and the different runoff components. The calibration of the hydrological model was limited by meteorological, as well as hydrological data availability and an insufficient knowledge on several physical parameters. These problems and the applied calibration strategy, including manual and automatic parameter optimization will also be discussed. The regional climate simulations show a spatially heterogeneous precipitation change ranging from -20% to +50% for the Volta region. A mean delay in the onset of the rainy season accompanied with an increase in inter-annual variability of precipitation in the early stage of the rainy season could be delineated. In case of temperature, a clear increase could be observed. Major changes in aridity, expressed through the de Martonne aridity index could not be delineated. No significant changes in discharge follow the precipitation decrease at the onset of the rainy season. Due to the increase in potential evaporation, following the increase in temperature, most of the surplus rainfall in the rainy season evaporates. The highest sensitivity of the hydrological model to changing meteorological input conditions is found for direct runoff. The main factors explaining changes in runoff are changes in rainfall, potential evaporation and soil moisture conditions. The discussion of these joint modelling results, will focus on the judgement of the climate change signal of certain hydrological variables with respect to the simulated inter-annual variability. Within the Volta region, which is characterized through a high inter-annual variability of rainfall, changes in the atmospheric, as well as surface and sub-surface components of the hydrological cycle do seldom exceed simulated present-day inter-annual variability.

***Keywords:*** climate change, climate hydrology modelling

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**HS2004** **Oral Presentation** **4179**

# Regionalisation of parameters of hydrological models: Inclusion of uncertainty in regional and local model in modeling ungauged basins

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Regional models are a straight forward approach to model ungauged basins. Uncertainties in model parameter and catchment attribute thwarts regionalisation. The study proposes a framework to model ungauged basin by coupling regional model with the posterior distribution of parameters to reduce the inconsistencies among different regional model and improve the performances. TOP Model is calibrated and regionalized using data from humid catchments lying in different parts of Nepal, Japan, UK, Australia and France. Using a 3-year calibration period, the best parameters sets were determined for each catchment using non-dominated sorting genetic algorithm (NSGAII). The optimized parameters set well reproduced the observed flow for catchments used for the calibration of regional model. The performance of different regional model structure are evaluated by comparing the spatial loss in performance. Averaging the parameter value of all regional models provided better regionalisation results. An indirect calibration method, in which the parameters of regional model are optimized directly instead of optimizing the model parameter resulted better regionalisation during validation, and provided the compromise performance on catchments considered for calibration of regional model. The prospect of constraining the regionalisation result by the prior ranges of parameter is investigated which resulted in reduced, inconsistency among different regional model and spatial loss in performance. Along with spatial loss in performance, the quantification of uncertainty induce by each regional model structure is essential for comparsion of different structure. The non parametetric boots trap methodology which is used to reckon the uncertainty in flow due to regional model reveled that, indirect calibration induce more uncertainty on the result of regionalization compared to other regional model implemented in this study. In all regional models, the effect of uncertainty of parameter in simulated flow for validation intimately followed the result of calibration. The Uncertainty in the result of regionalization due to uncertainty in the parameters of hydrological model parameters is also assessed using Multi-normal approximation. The effect of simulated paraemter uncertainty on flow evaluated here using multinormal approximation closely followed the effect of parameter uncertainty in flow when all basin are preasumed gauged. The effect of parameter uncertainty of hydrological model induces more uncertainty in flow compared to uncertainty in the parameters of regional model. A regionalization framework to prooagate the uncertainty in hydrological model and regional model is sucessfully demostrated here in this study.

***Keywords:*** regionalisation, uncertainty, multi objective

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**HS2004** **Oral Presentation** **4180**

# A recurrent neural network for monthly reservoir inflow forecasting

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A recurrent artificial neural network (RNN) trained by the back-propagation algorithm is proposed for monthly reservoir inflow forecasting. The RNN architectures have recurrent connections that implicitly allow the network to detect and produce time-varying patterns, which makes them very suitable for the prediction of water resource time series. The process consists of generating one-month-ahead inflows forecasted by RNNs and using them to find monthly reservoir optimal releases by an implicit stochastic optimization (ISO) procedure. The RNN model relates current-period rainfall and the previous reservoir inflow in order to predict the current inflow. The historical data utilized in the procedure contain 20 years of monthly inflows. The RNN was calibrated using the monthly inflows of the first 12 years and validation was carried out over the last 8 years. The ISO procedure consists of the three basic steps described below: 1) Generate M synthetic N-month sequences of inflow; 2) For each inflow realization, find the optimal releases for all N months by a quadratic deterministic optimization model; 3) Use the ensemble of optimal releases (M N data) to develop operating rules for each month of the year. The releases obtained by the optimization model were related to reservoir storage at the end of the previous time period and inflow during the current time period. Therefore, with information of initial reservoir storage and forecasted inflow for the current month, the amount of water that should be released can be defined by the particular rule. The methodology is applied to the Ishitegawa Dam, which is the reservoir that supplies the city of Matsuyama in Japan and is also used for irrigation. Scarcity of water is a periodical problem in this city and thus it is very important to improve the water resources in the region. The reservoir operation is carried out by using the RNN-forecasted one-month-ahead inflow as input to the release rule defined by ISO. Optimal releases using the ISO procedure assuming the inflows as perfect forecasts were also performed for comparison. The correlation between historical and RNN-forecasted one-month-ahead inflows was 96%. The correlation regarding water allocation between the results obtained by the ISO procedure using the RNN forecasts with the ones using perfect forecasts was 80%. The excellent accuracy obtained by the RNNs suggests that they are very effective for one-month-ahead forecasting of reservoir inflows. Furthermore, the optimal reservoir releases obtained by the ISO using the RNN-based forecasts showed to be highly correlated with the ones using perfect forecasts. Thus, this suggests that temporal neural networks such as RNNs may provide reliable alternatives for sustainable water resources management.

***Keywords:*** rnn, reservoir, forecast

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**HS2004** **Oral Presentation** **4181**

# Representativeness of point soil moisture observations, upscaling and assimilation

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Large area hydrological modeling typically requires a coarse grid cell resolution to be computationally feasible. Observational information to calibrate and initialize these models should be available at a similar resolution to be directly useful, or point measurements should at least be representative for the area they are assumed to cover. In general, there is a mismatch in scale between the classical point measurements in field experiments and the areally averaged estimates from remote sensing or land surface modeling. To estimate the temporal evolution of the spatial mean soil moisture in the Optimizing Production Inputs for Economic and Environmental Enhancement (OPE3) field, the relationship between point measurements and the average behavior of the field scale soil moisture has been investigated. Furthermore, the assimilation of point data to estimate the spatial mean soil moisture was studied. Point measurements were ranked based on the time-mean differences with the spatial mean. Due to the complex hydrogeology of the field, it was not possible to indicate for which terrain characteristics the most representative soil moisture values can be obtained. Simple statistical methods, as well as models in both the time and frequency domain were explored to scale up point measurements to field averaged soil moisture. Cumulative distribution function (cdf) matching generally provided the best estimates in terms of most performance indices. Assimilation of data from representative sites was more beneficial than data from any other site to constrain a land surface model (CLM2.0) to estimate the spatial mean soil moisture in the OPE3 field. Further improved spatial mean analysis results can be obtained after upscaling of the point measurements.

***Keywords:*** soil moisture, upscaling, assimilation

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**HS2004** **Oral Presentation** **4182**

# AMMA multi-scale resolution forcing data for a better understanding of the West-African Monsoon surface-atmosphere-hydrology interactions

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West Africa has been subjected to extreme climatic variability over the last half century, with relatively wet years during the 50s and 60s being followed by a much drier period during the 70s-90s. These radical fluctuations in the regional hydro-meteorological regime correspond to one of the strongest inter-decadal signals observed for the entire planet over the last century, and they have had dramatic socio-economic consequences for the people and the relatively agrarian-dominated economies of this region. Seasonal to inter-annual prediction of the West-African monsoon (WAM), which is the main precipitation driving mechanism, has therefore become a research topic of importance. However, difficulties modeling the African monsoon arise from both the paucity of observations at sufficient space-time resolutions, and because of the complex interactions of the attendant processes at various temporal and spatial scales between the biosphere, atmosphere and hydrosphere over this region. One of the main goals of the AMMA (African Monsoon Multidisciplinary Analysis) project is to improve the understanding and prediction of the WAM on both relatively short (sub-diurnal to several days) and long (seasonal) timescales in order to improve sustainable water management and related activities over western Africa. This is being addressed through a prolonged period of intensive and enhanced multi-year field observations, and through the development and use of various remote sensing-based products. AMMA, therefore, provides the perfect context for improving upon the current understanding of the surface-atmosphere-hydrology coupling over the pertinent spatial and temporal scales. Land-atmosphere coupling is theorized to be significant in this region, thus improvement of the modeling of the related processes is critical. A key aspect of this coupling is the relationship between the meridional soil moisture (and the corresponding surface fluxes) gradient and it's feedback with the regional atmospheric circulation. To this end, a multi-scale land-surface model atmospheric and land surface parameter forcing database is being constructed using a variety of sources; NWP forecast data, remote sensing products and local scale observations. One of the main uses of this database is to drive a host of land surface, vegetation and hydrological models over a range of spatial scales (local to regional) in order to gain better insights into the attendant processes. This is being done under the auspices of the AMMA Land surface Model Intercomparison Project (ALMIP), and through the development of an African Land Data Assimilation System (ALDAS). This talk will present an overview of the current status of the forcing database, and some off-line regional scale land surface model results.

***Keywords:*** amma, land surface modeling, forcing database

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**HS2004** **Oral Presentation** **4183**

# Reducing uncertainty in selecting climate models for hydrological impact assessments

***Prof. Andrew Pitman***

*Do not understand what is required here Do not understand what is required here IAMAS*

***Sarah Perkins***

All climate models are not equally good at simulating the present day climate and are unlikely to be equally good at projecting future climates at global, continental or regional scales. Deciding which climate models to use for providing hydrological forcing in attempts to assess the impact of climate change on water resources is difficult. It is particularly difficult in environments where extreme precipitation dominates the vulnerability of water resources. We show that assessing climate models based on their simulation of total precipitation is unreliable B the means provide little guidance on the ability of the models to simulate the more extreme events that affect hydrological systems. In contrast, a probability density function based assessment using daily climate model data compared to daily observations provides a good basis for confidence in a model=s ability to simulate 80th, 90th or 95th percentile rainfall events. We explain the approach, demonstrating that climate models have surprising skill in simulating observed probability density functions for precipitation over Australia, although the well-known bias of excess rainfall at low rates remains clear in most models. We identify which of the climate models produce the best estimates of rainfall extremes over Australia and identify remaining systematic biases in the simulation of rainfall at both ends of the probability density function. We use the approach to provide improved estimates of model ensemble projections of changes in rainfall over Australia due to projected changes in climate. While we apply our approach to Australia, the methodology is applicable to other regions and other variables provided observations exist.

***Keywords:*** model evaluation, precipitation, reducing uncertainty

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# Multi-model climate change scenarios for Southwest Western Australia and potential impacts on streamflow

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***Stephen P. Charles***

In recent decades observed rainfall and streamflow across southwest Western Australia (SWWA) have declined significantly. This decline has occurred simultaneously with changes in the large scale atmospheric circulation, currently attributed to both natural variability and the enhanced greenhouse effect. Given that climate change scenarios project a continued decline in rainfall for SWWA, these changes pose a major challenge for regional water resources management and planning. This study evaluates projected SWWA climate, mainly temperature, rainfall, and sea level pressure, obtained by exacting (temperature and sea level pressure) and statistically downscaling (rainfall) different emission scenarios from 13 general circulation models (GCMs) used in the IPCC Fourth Assessment Report. The multi-model results are weighted according to a Climate Prediction Index (CPI), an objective measure of reliability and is based on estimated relative likelihood that they will correctly predict climate change in the real world (IPCC 20C3M simulations). The uncertainties associated with emission scenarios and model structure and parameterization of processes are discussed. The potential impact on SWWA streamflow analysed and implications of these results for water resource managers also are briefly addresses.

***Keywords:*** gcm uncertainties, water resource management, southwest western australia

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# Rain gauge reinforcement by external drift kriging for reducing predictive uncertainty of rainfall intensity of extreme events

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***Afef Chebbi***

The hyetograph is among key inputs to the rainfall runoff transformation and for the estimation of soil erosion due to rainfall impacts. The rainfall Intensity Duration ID relation is in effect decisive for the hydrograph response (especially for peak discharge and time to peak) and for the soil detachment quantity. For a rainfall event, it relates the observed maximum rainfall intensity Imax to its duration scale D. This decreasing relation is often established locally at rain gauge site whereas the hydrograph and soil erosion are global responses to the area rainfall repartition which are also critical for flood mitigation. Really, the derivation of averaged ID relation over a fixed area ought to take account for spatial variability of rainfall. Geostatistic approach is a suitable way to handle with these issues since kriging allows for the establishment of optimal mean spatial intensity estimator. On the other part, this approach is powerful to quantify predictive uncertainty of interpolated values. Moreover, the variogram is an effective way to appraise the rainfall spatial variability. In the 3-D case, a vector (location duration - intensity) is associated to each observed site while the 2-D approach is based on the location and intensity, conditional on the duration scale. However, 3-D approach is rarely used in practice. In this presentation, we first compare 3-D and 2-D approaches. Effectively, owing the spatial and temporal structure of rainfall, it is expected that parameters of the 2-D variogram are driven by the duration scale. On the other hand, uncertainty about the model variogram structure (3-D versus conditional 2-D) and parameters (reaches, seals, nugget effects values) are studied through cross validation. Finally, operational issues related to rain gauge network extension are considered in order to reduce the predictive uncertainty of rainfall estimation. To this purpose, kriging with external drift ED is adopted while the site altitude is taken as ED along with the use of conditional 2D- variogram. Choose of the scale duration obeys to hydrological considerations: a one -hour duration scale is adopted, which seems an adequate scale in regard to the hydrograph response of mid-scale watersheds (up to 400 km). Error estimations associated with kriging properties allow identification of nodes of the mesh grid where network reinforcement is required. This is completed through the adoption of a target value for the coefficient of variation of the estimated intensity: nodes where the target value is exceeded are planned for implementation of a new rain gauge. Two extreme events case studies are presented: the extreme event of Marsh 1973 in the North part of Tunisia and the extreme event of September 1986 in the North-eastern part of Tunisia. These two events that led to very high total rainfall amounts at large scale, differ from each other by the intensity - duration behavior. In effect, intensities in the Marsh 1973 event were relatively small (locally up to 22 mm/h in 15 minutes) but were related to strong durations while intensities in the September 1986 were quite heavy (locally up to 108 mm/h in 15 minutes).

***Keywords:*** external drift kriging, rainfall intensity, network optimisation

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**HS2004** **Oral Presentation** **4186**

# The Xinanjiang model towards the perspective of PUB

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The progress of the Xinanjiang model, a semi-distributed conceptual hydrological model for use in humid or semi-humid regions, including model inputs, model structure and model parameters, will be reported towards the perspective of PUB science and implementation plan. This presentation comprises five parts: introduction, model inputs, model structure, model parameters, and future research. Model inputs are of great importance in a hydrological forecasting system because their distributions both in space and in time make a notable impact on computed results. Model inputs rank first in reducing hydrological uncertainty in the context of PUB. Novel data can be from space-borne, air-borne and on-ground measurement, as well as from computed models, such as GCM (General Circulation Model), QPE (Quantitative Precipitation Estimates, Vieux et al., 2003) or HEP (Hydrological Ensemble Prediction, Schaake, 2004). Model inputs need interdisciplinary development. The focus of this presentation is on the structure and parameters of the Xinanjiang model. The Xinanjiang model has four superiorities: (a) to compute runoff depth over partitioned spatial units in horizontal direction; (b) to estimate evapotranspiration using a three-layer method in vertical direction; (c) to separate runoff components into surface, subsurface and groundwater flows according to flow velocity; and (d) to conveniently transfer partial model parameters across temporal scales by means of relations between those parameters on different time scales, e.g. to derive the outflow coefficients of the free-water storage to groundwater and subsurface flow in an hourly mode from those in a daily mode, based on the fact that daily hydrological data are more available than hourly data in the real situation. Soil moisture is a key component in describing the transfer and distribution of mass and energy between the land and the atmosphere. It is a state fundamental variable in biosphereatmosphere transfers, biogeochemistry, ecosystem processes, and the rainfallrunoff process itself. Based upon the assumption that the use of an inadequate model structure may be more problematic than the use of sub-optimal parameter values, the experience and progress in the HUaihe River Basin EXperiment (HUBEX) during the intensified observation period from 1998 to 1999, as a component of the GEWEX Asian Monsoon Experiment (GAME) Project, is reported here. The focus is on the realism of the Xinanjiang model structure, which is evaluated not only by discharge hydrographs observed upstream (Huangnizhuang station) and downstream (Jiangji station), but also by volumetric soil moisture data gauged at three sites, Meishan, Nianyushan, and Jiangji. In addition, some research progresses will be introduced, such as the relation amongst sensitive parameters and catchment characteristics, biological (mainly refer to vegetation) aspects taken into consideration especially in the estimation of evapotranspiration using energy conservation principle, which provides a scientific basis for balancing water for humans and nature, a new approach in ecohydrology. The Xinanjiang model considering vegetation could be used to evaluate green flow and blue flow, and to transform from measured basins to ungauged ones, which is very significant content of the decadal PUB science plan.

***Keywords:*** xinanjiang model, runoff generation, soil moisture

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# Predictive models of reservoir storage-yield-reliability functions: inter-comparisons of regression and multi-layer perceptron artificial neural network paradigms

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The determination of storage-yield- reliability functions for reservoir planning purposes is better carried out using observed runoff data at the project site with one of the many available sequential methods of analysis such as the behaviour simulation. However, there are many situations in the world where the needed data are either unavailable or insufficient for the purpose. This is particularly true of developing countries where investment in hydro-meteorological data collection has been drastically cut or non-existent and where the few networks that exist are in very bad state of disrepair. In such situations, the need for relatively accurate predictive equations for inferring the storage-yield-reliability characteristics for reservoir planning, especially where within-year and over-year storage requirements are equally important, becomes paramount. In this study, generalised functions for predicting the total (within-year plus over-year) storage, given the yield (or water demand) and reliability, have been developed using first, classical multiple regression and secondly artificial neural networks. The basis of the models is the storage-yield-reliability analysis carried out using the sequent-peak algorithm with data from 18 international rivers. The rivers were carefully selected on the basis of their variability to be representative of world conditions. The input parameters for the ANN are the yield, reliability and basic streamflow parameters such as the mean runoff and the coefficient of variation of flow but the regressions models used in addition the over-year storage capacity as an explanatory variable. This is a major limitation of the regression models because while the basic streamflow parameters can be obtained directly at gauged sites or indirectly at ungauged sites using proven techniques, the over-year capacity estimate requires at least annual runoff data to be available, which might preclude the ready application of the regression models at ungauged sites unless of course another method of estimating the over-year capacity can be devised. The paper will present the results of the calibration, verification and validation of the models. In particular it will be demonstrated that while the regression models were relatively more successful during validation, sometimes doing (unusually) very well when applied in an extrapolation mode, the ANN models should be preferred because they require only basic streamflow parameters to run. In other words, the ANN models are truly ungauged-catchment friendly; however, ways of making available the over-year capacity for the ungauged sites application of the regression models are presented and discussed.

***Keywords:*** storage yield reliability, prediction, ann

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# Linking West African monsoons onset with prominent atmospheric circulation patterns over the North Atlantic Ocean

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***Harald Kunstmann, Andras Bardossy***

Particularly in regions, where precipitation is limited to only a few months per year, the reliable determination of the rainy seasons onset and thus the start of the sowing time on a daily basis is of crucial importance for sustainable water management and food production. A fuzzy-logic based onset definition on a regional scale which is accounting for the most important plant physiological aspects on the basis of rainfall indices has been developed. This study is presenting a methodology, which is conditioning the single event onset of the rainy season to daily large-scale atmospheric circulation within a North Atlantic sector via automated fuzzy rule based objective circulation pattern classification. These fuzzy rules are obtained using a simulated annealing optimization of the classification performance. By comparing the occurrence probabilities of the onset patterns with the patterns of the whole year highly responsible patterns for the onset of the rainy season can be detected. Sensitive predictor variables with regard to the onset of the rainy season in West Africa, as well as their spatial patterns, are presented and discussed towards an overall integration in a hydrometeorological Decision Support System (DSS).

***Keywords:*** onset of the rainy season, circulation pattern analysis

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# Seasonal Streamflow Forecast for the State of Ceara, Brazil

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This paper presents the methodologies employed to generate monthly and seasonal streamflow forecasts for the State of Ceara, located in the northeast of Brazil. The procedure uses a variety of linked models. Seasonal climate forecast provided by the General Circulation Model ECHAM 4.5, developed by the Max Plack Institute, is used to feed two regional atmospheric models, the Regional Spectral Model (RSM) and the Regional Atmospheric Modeling System (RAMS), that provide monthly and seasonal regional precipitation forecasts for the State. These precipitation forecasts are then interpolated into a finer resolution grid that will be served as the basis for the estimation of the averaged-basin monthly precipitation. A bias-correction procedure is applied to these forecasts in order to be used by a conceptual lumped hydrologic model to generate monthly and seasonal streamflow forecasts for several sites within the state. This paper also discusses the bias-correction procedure applied for the precipitation forecast, the strategy to estimate the hydrologic model parameters for sites at which streamflow data are not available, and the use of ensemble forecasts

***Keywords:*** ensemble, streamflow, forecast

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# The effect of meteorological input resolution and uncertainty on the accuracy of hydrological models

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Through coupling of meteorological and hydrological models one has the impression that one has a more complete description of the complex of rainfall/runoff processes. For short term forecasting a one way coupling through the use of the meteorological model output as input for the hydrological models is reasonable. The question whether or to what extent do these coupled models lead to better forecasts and better decisions is of central importance. The purpose of this paper is to investigate the predictive hydrological model uncertainty under different meteorological input uncertainty scenarios. These scenarios include Perfect forecast Probabilistic forecasts of the mean and subsequent spatial disaggregation Probabilistic scenarios Probabilistic scenarios using circulation pattern classification These scenarios (for precipitation and temperature) are used as an input to a hydrological model with different spatial resolution. The assessment of the optimal combination of available past information, hydrological model resolution and meteorological model forecasts is final goal of this contribution. Examples using different subcatchments of the Neckar catchment in South-West Germany are used to illustrate the methodology.

***Keywords:*** uncertainty, resolution

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# Weather Radar- Based the Rainfall Data Assimilation

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***Xia Jun, Zhang Li-Ping***

Precipitation is one of the key components of hydrologic cycles. So the study of the characteristic of spatial and temporal precipitation is very important in both theory and application. There are some algorithms of radar rainfall estimates at home and abroad now. In spite of its unique characteristic, each algorithm has its limitation and problem. This paper proposes the R-G Combination Method to estimate the rainfall spatial distribution based on radar-derived and rain gauge data. By combining the rain gauge data together with the radar-derived rainfall data, the R-G Combination Method is intended to obtain the accurate and reasonable spatial distribution of rainfall over a basin. The case of eastern area shows that the R-G Combination Method that this paper puts forward can accurately reflect the rainfall spatial distribution and improve the estimates of the precipitation data.

***Keywords:*** data assimilation, radar rainfall, spatial distribution

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# Estimation of extreme flow quantiles and quantile uncertainty for ungauged catchments

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***Taha Bmj Ouarda, Chang Shu, Yves Tramblay***

Pooled frequency analysis is used to estimate extreme event quantiles at catchments where the data record is either short or not available. This can be accomplished by combining (pooling) information from hydrologically similar sites to increase the available data for estimating the required extreme event quantiles. Extreme event quantiles are required for the design of many types of water resources infrastructure. This paper will address issues associated with estimating extreme event quantiles at an ungauged catchment using a focused pooling approach. A focused pooling group is a collection of gauging stations that are used to estimate quantiles for a hydrological extreme at a target ungauged location. In addition to estimating extreme event quantiles, the uncertainty associated with extreme event quantiles will be determined. A variety of methods for estimating extreme event quantiles will be evaluated in terms of the accuracy of the extreme quantile estimates and the amount of uncertainty associated with the estimates. A preferred estimate will have high accuracy and low uncertainty. The options that will be evaluated and compared include several nearest neighbour approaches, several approaches based on canonical correlation analysis, several approaches based on artificial neural networks and the classical hierarchical clustering approach. The techniques will be demonstrated and evaluated using data from a collection of catchments in the Canadian province of Ontario.

***Keywords:*** extreme events, uncertainty, pooled frequency analysis

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# Quantifying the availability and reliability of water resources in a large agricultural watershed using a coupled atmospheric-hydrological model

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***Vincent Fortin, Stphane Blair, Diana Verseghy, Pierre Pellerin***

The concept of sustainable agriculture acknowledges that agriculture, although an important user of water is one of many and must share Canadas water resources. It also recognizes that agriculture must be carried out in a way that neither contributes to water pollution nor threatens the health and viability of other water users, communities or ecosystems. This cannot be achieved without the wise stewardship of water resources. In a demonstration project carried out on the South Saskatchewan River Basin as part of the National Agri-Environmental Standards Initiative (NAESI), Environment Canada is implementing a coupled atmospheric-hydrological model and land data assimilation system designed for assessment of water cycle variability in a large agricultural watershed. The development of this system has been achieved through years of collaborative research in Canada and under a variety of research programs including the Mackenzie GEWEX initiative. Our approach has been to combine land-surface schemes with hydrological streamflow models to provide stand-alone and coupled simulation systems. This modeling framework can provide spatially coherent estimates of water availability in both hindcast and forecast model, helping to quantify the availability and reliability of water resources (including precipitation, snowmelt, soil moisture and surface water) across major agricultural regions over various time scales. While this system is designed to integrate in a coherent manner various sources of information on the state of the system, including point observations and remote sensing products, it can also be used in data-sparse regions by relying on a first guess obtained from an operational meso-scale numerical weather prediction system. In this paper, we present preliminary results obtained with the first version of this system.

***Keywords:*** coupled modelling, data assimilation, water availability

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# Adjusting ensemble forecast probabilities to reflect climate information

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***Jery Stedinger***

Ensemble forecasting is an active research topic in meteorology and hydrology. An activity of growing importance is the use of forecast information to update meteorological and hydrologic series and their associated probabilities so as to describe the distribution of future events of interest. Often forecast information is given as the conditional probability of below-normal, normal, and above-normal temperature or rainfall depths, though forecast information also can be described by the conditional mean and standard deviation of key variables such as seasonal runoff. Probability adjustment methods developed by Croley and by Wilks assign the same probability to all climate series in selected categories. This results in a discontinuity at the interval boundaries, and can seriously misrepresent the mean and variance of the conditional distribution of the key variables. This paper proposed a simple but flexible adjustment called the pdf-ratio method. It can be used with different families of distributions describing the initial and target distributions for climate variables. The proposed method allows derivation of a consistent and smooth set of probabilities for climate series across the entire range of the key variable reflecting the change in the likelihood of each individual climate series. Several examples illustrate the improvements obtained in the approximation of the moments and the cumulative distribution function. The paper also considers multivariate adjustments to reflect several forecasts considering different forecast periods or different basins. Examples demonstrate that if separate and independent adjustments are adopted to capture the conditional probabilities of different variables (temperature, precipitation, or seasonal flow) for different forecast periods or different basins, then the resulting joint distribution of such variables can be grossly distorted.

***Keywords:*** ensembleforecasts, probability, adjustment

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# Downscaling and forecasting of evapotranspiration using a synthesis of wavelets and SVMS

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The scale reconciliation issue has gained in extra attention with remote sensing data coming in and the shift towards the distributed approach for hydrologic modeling. Providing reliable forecasts of evapotranspiration (ET) at the farm level is a key element towards ideal water management in irrigated basins. This algorithm provides a means to downscale and forecast ET images. The idea behind this algorithm is to build multiple relationships between inputs and outputs at all different spatial scales, and then use all these relationships to downscale and forecast the output at the finest scale. This downscaling/forecasting algorithm is designed for dependent properties such as ET. Decomposing and reconstructing processes are done using 2D discrete wavelet decomposition with the basis functions that suit the property in physical terms. 2D wavelet decomposition for one level will result into one datum image (Low-Low pass filer image or LL) and three detail images including at least one High pass filter component, namely LH, HL, and HH. The underlying physics between the input variables versus the output is learnt by using Support Vector Machines (SVMs) at the resolution of the output. The machines will then be applied at higher resolution to produce detail images to help downscale the output. The output image can be shifted ahead in time. This way the algorithm could not just serve as a means for downscaling but also for forecasting. The algorithm has been applied on case study in Iowa and the results were validated against ground-truth observations as well as outputs from a mechanistic model.

***Keywords:*** wavelets, svms, evapotranspiration

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**HS2004** **Oral Presentation** **4196**

# Uncertainties in estimating global energy and water balances assessed by an multi-model analysis of the global soil wetness project

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***Yanjun Shen, Shinjiro Kanae, Naota Hanasaki, Paul A. Dirmeyer***

Under the Global Land/Atmosphere Study (GLASS), Phase 2 of the Global Soil Wetness Project (GSWP-2) produced the first global (excluding Antarctica) 1x1 degree Multi-Model Analysis (MMA) of land-surface variables and fluxes for the 10-year period of 19861995 at the daily time scale. Thirteen land-surface models (LSMs) were driven by the best possible forcing data of the atmospheric conditions, such as precipitation, downward radiation, wind speed, air humidity and air temperature with temporal resolution of 3-hourly or higher. In general, the MMA product has been found to be superior to the products of any of the individual models and is as good as or better than the best model at each place and time validated by in situ soil moisture observations (Dirmeyer et al., 2006). Analyses of the product indicate that the interannual range of the annual mean hydrological quantities on the global scale is smaller than the intermodel range. This suggests that the uncertainties in the estimates by individual models may be higher than the natural variations of these quantities. Detailed analyses for each climatic zone will be introduced in the full paper.

***Keywords:*** multi model analysis, land surface models, global soil wetness project

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# Comparing model performance of the HBV and VIC models in the Rhine Basin

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*IAHS*

***Ruud Hurkmans, Jeroen Aerts, Han Dolman***

It is expected that climate change will have major implications on the discharge regime of the Rhine basin. Seasonal streamflow is projected to shift to more discharge in winter and less discharge in summer and the frequency and severity of floods and droughts are expected to increase. Although basin wide hydrological models such as HBV (Hydrologiska Byrns Vattenbalansavdelning) are available, much uncertainty remains in modelling feedback processes between the soil and the atmosphere. They are of major importance for the simulation of timing and magnitude of extreme flood events. These processes are not well developed in HBV; groundwater recharge and actual evaporation are simple functions of actual water storage in a soil box and runoff formation is represented by three simple linear reservoir equations. Therefore, a basin-wide VIC (Variable Infiltration Capacity) model has been developed. VIC is a distributed, physically based, macro scale hydrologic model that allows sub-grid scale variation in vegetation and infiltration capacity and which solves both the water and energy balance. It is assumed that the representation of land surface processes is improved in VIC as compared to HBV with the aim to improve the hydrologic predictability based on changes in both climate variables or land surface characteristics in the catchment. However, there is an ongoing debate in hydrological research on the sense of using more complex distributed models that aim to describe all physical processes, including soil-atmosphere feedback processes, in rainfall-runoff modelling. The general idea of distributed modelling is that it represents reality better than lumped model approaches as it takes into account spatial information and -more important- it uses physical law (mass balance and energy equations) to describe the hydrological processes. It is, however, well recognized that the available approaches are often still far from providing a satisfactory representation of rainfall-runoff transformation and that more complex modelling does not always lead to better results. The goal in this paper is to compare the hydrological models HBV and VIC of the Rhine basin by testing their performance using historical discharge data. The Rhine basin is unique in the sense that long-term and high-resolution (temporal and spatial) datasets are available. The models are compared at sub-catchment and basin scale using multiple objective performance functions. Effort is put in defining weight factors that will produce informative numbers of the performance indicators during extreme flood and drought events. This results in a founded decision of which model to use as predictive model when estimating the effects of extreme weather conditions and of climate change on the hydrologic behaviour of the Rhine basin.

***Keywords:*** model performance, comparison, extreme events

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# Real Time Flood Forecast and Flood Alert Map over the Huaihe River Basin in China Using a Coupled Hydro-meteorological Modeling System

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***Charles A. Lin, Guihua Lu, Zhiyong Wu, Jianyun Zhang, Yang Yang***

A coupled hydro-meteorological modeling system is established for real time flood forecast and flood alert map over the Huaihe River Basin (270,000 km2), China. The system consists of the mesoscale atmospheric model MC2 (Canadian Mesoscale Compressible Community) that is one-way coupled to the Chinese distributed Xinanjiang hydrological model, a grid-based flow routing model, and a module for acquiring real time gauge precipitation. The system had been successfully tested in a hindcast mode using 1998 and 2003 flood cases in the basin, and has been running in a real time mode for the summers of 2005 and 2006 over the Wangjiaba sub-basin (30,500 km2) of the Huaihe River Basin. The MC2 precipitation combined with gauge values is used to drive the Xinanjiang model for hydrograph prediction. The performance of the system is illustrated through an examination of the real time flood forecasts for the severe flood case of July 4-15, 2005 over the sub-basin, which was the first major flood event encountered. The 96-hour forecasts of MC2 precipitation is first evaluated using observations from 41 rain gauges over the sub-basin. The forecast hydrograph is then validated with the observation at the outlet of the sub-basin. MC2 precipitation generally compares well with gauge values. The flood peak was predicted well in both timing and intensity in the 96-hour forecast using the combined gauge-MC2 precipitation. The real time flood alert map can spatially display the propagation of the forecast floods over the sub-basin. Our forecast hydrograph was used as operational guidance by the Bureau of Hydrograph, Chinese Ministry of Water Resources. Such guidance has been proven very useful for the Office of State Flood Control and Drought Relief Headquarters in operational decision making for flood management. Our encouraging results demonstrate the potential of improving hydrological predictability using precipitation from a combined source of gauge and mesoscale atmospheric model. High resolution regional atmospheric models offer promising quantitative precipitation forecast (QPF) potential that could extend the precipitation forecast lead time compared to extrapolation methods based on rain gauges, statistical forecast or radar nowcast.

***Keywords:*** hydro meteorological, modeling

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# Coupling meteorological and hydrological models for medium range streamflow forecasts in the Parana Basin

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Forecasts of inflow into major reservoirs of the Brazilian hydroelectric power system are essential to the operation planning of this system in ranges from a few hours to several months. Medium range forecasts of the order of a few days to two weeks were usually obtained by simple ARMA models, which do not include information of observed or forecast precipitation, neither streamflow observations from upstream gauging stations. Recent improvements in skill of numerical weather prediction models motivated the coupling of meteorological and hydrological models for medium range streamflow forecasts in basins larger than ten thousand km2. We present results obtained by using a methodology based on one way coupling of the ETA regional atmospheric model run by the Brazilian Center for Weather Prediction (CPTEC) with the MGB-IPH large-scale hydrological model in three sub-basins of the Paran river basin, with drainage areas ranging from 50.000 to 150.000 km2. Results were compared to the currently used ARMA model, showing that clear reductions in errors of inflow forecasts could be obtained. Comparison of results in different sub-basins suggest that the quality of rainfall forecasts depends on the climate, being better in the north of the basin where a clear humid season exists, and decreasing to the south, where rainfall may occur at every month.

***Keywords:*** forecasting, real time, reservoirs

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**HS2004** **Oral Presentation** **4200**

# Predictive uncertainty: new approaches and perspectives in flood forecasting

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In recent years, the availability of new technological tools based on RADAR and Satellite technology opened new perspectives in flood forecasting. Geomorphologic data, land use and soil maps are today widely available on GIS format together with distributed rainfall fields produced using rain gauges, RADAR or Meteosat images. In addition quantitative rainfall field predictions are generated using nowcasting techniques or meso-scale atmospheric models as single predictions or as part of ensemble predictions. This new availability of data combined with the increased power of available computer resources, promoted the development of new technologically advanced distributed physically based rainfall-runoff models, such as LISFLOOD or TOPKAPI, that can be directly linked to the distributed rainfall forecasts in order to generate flood forecasts. Unfortunately, the level of uncertainty involved in quantitative rainfall field forecasts is still quite large and becomes larger with the increasing lead time. Therefore, the aim of current research approaches is to assess and to account for all the sources of uncertainty that converge in flood forecasts and to estimate the so called flood forecasting predictive uncertainty. The predictive uncertainty is the key issue to be used in decision schemes aimed at releasing water from a reservoir or at issuing flood alerts. The paper discusses the concept of predictive uncertainty together with that of total uncertainty (in which all the sources of uncertainty are taken into account), as opposed to conditional uncertainty (that is the uncertainty deriving from the use of a specific model with given parameters). In addition the paper discusses different alternatives for accounting for input uncertainty, namely the uncertainty induced by the quantitative precipitation forecast and its effects on the predictive uncertainty.

***Keywords:*** predictive uncertainty, flood forecasting, conditional uncertainty

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**HS2004** **Oral Presentation** **4201**

# Effects of soil moisture parameterization on a real time flood forecasting system based on rainfall thresholds

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The pluviometric flood forecasting thresholds are an easy method that helps river flood emergency management collecting data from limited area meteorologic model or telemetric raingauges. The thresholds represent the cumulated rainfall depth which generate critical discharge for a given river cross section. The thresholds are calculated for different sections of the Arno river (Italy) and for different antecedent moisture condition using the flood event distributed hydrologic model FEST. The model inputs are synthetic hyetographs with different shape and duration. Representation of moisture condition is based on the AMC (Antecedent Moisture Condition) of the classical CN method which recognize three classes according to the total amount of rainfall of the past five days. To better represent soil moisture condition an extension of the SCS-CN method for the continuous simulation is developed and discussed. A detailed analysis of the most recent events is presented. The alarm system has been implemented in a dedicated software (MIMI) that gets measured and forecast rainfall data from Autorit di Bacino and defines the state of the alert of the river sections.

***Keywords:*** rainfall thresholds, real time flood forecasting, soil moisture

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**HS2004** **Oral Presentation** **4202**

# Reducing the uncertainty of flood forecasts using multi-objective optimization algorithms for parameter estimation

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The focus of this study was to characterize the extrapolation uncertainty resulting from different calibration strategies. A single-objective parameter estimation based on Monte-Carlo simulations as well as a multi-objective optimization, are employed for the calibration. The extrapolation uncertainties that were obtained with these methods are evaluated with an extreme flood event. The results demonstrate that a unique parameter set, suitable for the entire hydrograph, does not exist. Utilization of a multi-objective optimization approach proved that the considerable uncertainty regarding model extrapolation originates from structural model inadequacies, which cause an inability of the model to reproduce all aspects of the hydrograph equally well with a single parameter set. It is suggested to use a multi-objective optimization strategy, which utilizes a problem-oriented definition of the performance measures to reduce the prediction uncertainty of peak flows. This method has been applied for flood modelling in Germany.

***Keywords:*** parameter assimilation, multi objective optimization, predictive uncertainty

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**HS2004** **Oral Presentation** **4203**

# Effect of uncertainties on the real time operation of a lowland water system in the Netherlands

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*Water Management Delft University of Technology IAHS*

***Peter-Jules Van Overloop, Elgard Van Leeuwen, Nick Van De Giesen***

The storage canals (or Boezem-canals) in the water board of Delfland in the west of the Netherlands have the function to convey water, pumped from low lying polders and draining from the higher lying areas, to the boundaries of the canal system. From there, five main pumping stations discharge the water to the sea and a tidal river. Apart from the transport, temporary storage is also an important function, as pumping capacity is limited and can sometimes be exceeded by the inflow into the storage canal system. The maximum allowable water level variation to accommodate this storage is also limited. Low water levels are associated with long term effects such as acceleration of land subsidence, decay of foundations and instability of embankments. High water levels can cause flooding, risk of dike breach and the necessity to impose a pump stop for the polders, causing flooding problems there. The challenge for the operators is to secure the evacuation of water, discharged from the surrounding land, while balancing the short and long term costs associated with high and low water levels. From a democratic process, a target water level has been decided, that is the objective of operation. Both positive and negative deviations are undesirable, but at the same time unavoidable. In case of heavy rainstorms, inflow exceeds pumping capacity and water levels will rise. To use the full available storage and avoid extreme water level deviations, operators usually lower the water level in advance when such an event is predicted, trying to balance positive and negative deviations. The real-time control problem can be formulated an optimization problem, that is solved repeatedly . This has been implemented in a Decision Support System (DSS), based on Model Predictive Control algorithm (MPC). This technique from control theory uses a model of the water system to predict future states. It minimizes a quadratic cost function of states and control actions over a fixed time horizon. The decision about the timing and magnitude of the pump flow is taken by the operators, aided by this DSS. The DSS is also able to function as a control system, automatically operating the pumping stations. Optimal operation, given a rainfall event, is only possible with perfect information and foresight. In practice however, there are large uncertainties concerning water system states, behavior and past and future rainfall. As a result of this, control actions are never optimal in hindsight. Reduction of uncertainties leads to decisions closer to the optimal ones and therefore has a certain value, which can be balanced against the costs of more accurate information or extra measurements to reduce uncertainty. This is investigated for the case of the Delfland water system. Optimal operation, given the uncertainties and the information that is available, is only possible by using a stochastic approach to the optimization problem, routing the uncertainties to the objective function, which will then express risk instead of costs. This is approximated by using different inflow scenarios in a multiple model configuration of MPC.

***Keywords:*** real time control, uncertainty, risk

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# Similarity indices to reduce predictive uncertainty on ungaged basins

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***Ludovic Oudin, Vazken Andrassian, Claudia Rojas-Serna, Nicolas Lemoine, Claude Michel***

On ungaged watersheds, the common approach for estimating the parameter values of lumped rainfall-runoff models usually consists in a two step approach. First, relationships between watershed characteristics and parameters values are obtained on gaged sites, and second, these relationships are used to estimate parameter values on ungaged sites. However, several studies have suggested that there were strong limitations to this approach and that consideration for similarity and/or proximity offered a better outlook. We propose here an original approach based both on similarity considerations and multi-model methodology. First, gaged watersheds are clustered into 27 classes depending on the values of three characteristics (either physical or hydro-climatic). Then, for each ungaged watershed, we used the calibrated parameters of similar gaged watershed, i.e. from the same class. Then, a combination of the simulations obtained with the several sets of parameters is performed. The methodology is based on the GR4J rainfall-runoff applied on more than 1000 basins located in France. Results show a slight but significant improvement over regression-based regionalization approaches.

***Keywords:*** multi model, rainfall runoff, basins similarity

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# Uncertainty characterization in integrated atmospheric and hydrologic modeling for short-term and basin-scale forecasts in a tropical semi-arid context

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Evaluating the reliability of flow forecasts at the basin scale, driven by atmospheric predictions, involves detailed understanding of: local and regional precipitation processes and its temporal and spatial patterns; sensitivity of the hydrological regime to the precipitation patterns; forecast models, both atmospheric and hydrological, and their parameterizations. In tropical regions, such as the Brazilian semi-arid, weather forecasts are quite uncertain, due to the convective characteristics of the rainfall systems. However, they are very important to water management, either for flash floods forecasting or reservoir operation decision making. Downscaling of rainfall forecasts through regional models nested into global atmospheric models represents promising possibilities of better weather forecasting at the basin scale. The refined grid of the regional atmospheric models could potentially better simulate the rainfall patterns at such basins and, thus, contribute for more reliable flow forecasts. This paper presents an investigation of the potential use of coupled atmospheric and hydrological models for producing flow forecasts based on rainfall derived from numerical weather predictions. A set of five events with different characteristics of duration, intensity and spatial distribution were studied in a medium-size basin (4550 km2) in northeastern Brazil. Rainfall forecasts were produced by BRAMS regional atmospheric model at two grid resolutions (5 km and 20 km), nested into Brazilian CPTEC global model. The rainfall data was input to a lumped hydrological model to produce the flow forecasts. The main objective of the investigation was the characterization and quantification of the uncertainties in the outcome of the atmospheric model relevant to hydrological prediction and its impacts on the hydrological models response. The characterization included uncertainties related to the spatial distribution of rainfall (location of the rainfall systems within and around the hydrographic basin) and their impact on the areal mean precipitation amount that was input to the lumped hydrological model. The propagation of these uncertainties through the hydrological modeling process into the predicted flows was also examined. The results showed that the resolutions of the regional models grid did not cause significant differences in the forecast skill. The conclusions of the investigation are that the errors in forecasting the spatial distribution of the rainfall fields were critical to the flow prediction and systematic underestimation of rainfall amounts was detected. However, it seems that the associated uncertainties present more or less defined patterns, which suggests that heuristic correction procedures can eventually be used to reduce the predictive uncertainty.

***Keywords:*** runoff forecast, precipitation forecast, coupling

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**HS2004** **Oral Presentation** **4206**

# GPS and satellite meteorology in understanding the monsoon dynamics over Indian sub-continent

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Atmospheric water vapor plays a major role in the radiative balance and hydrological cycle over the Indian sub-continent. Like greenhouse gases, water vapor also interacts with the incoming and outgoing solar radiation and influence the thermodynamics and energy balance of the atmosphere. The atmospheric water vapor over the Indian sub-continent is found to be very dynamic, and is highly variable over the Indo-Gangetic (IG) plains which is home of 600 million people. The IG plains is one of the agriculturally very productive regions in India where a strong coupling is found to exist between the land and atmosphere. The strong coupling is found to be very dominating due to anthropogenic activities which significantly affect the trend of the Indian monsoon and hydrological cycle. In recent years, large deviations in the monsoon rainfall have caused increased droughts and floods over India. Floods due to monsoon rainfall (year 2006) in the Thar Desert (Rajasthan province) have broken known rainfall record in the last 200 years over this region. During 2001-2006, increased monsoon rainfall (and Floods) has been observed in the western parts of India with decrease in the total monsoon rainfall (and increase in droughts) in the eastern parts of India (north-eastern states of India, Uttar Pradesh and Bihar Province) based on satellite (TRMM- Tropical Rainfall Measuring Mission) and ground data. Besides geodetic applications, Global Positioning System (GPS) also provides continuous (every sec or 30sec or hourly average) total column water vapor estimates (IPWV- Integrated Precipitable Water Vapor) over ground based stations using very high-ultra high frequency (VHF-UHF) radio waves (0.1-3Ghz) from a constellation of GPS satellites. GPS has all weather (rainy and cloudy days) as well as day and night capability of data recording. The MODIS (Moderate Resolution Imaging Spectroradiometer) Terra and TRMM satellites provide total column water vapor estimates. The dedicated meteorological satellites of new generation give data every hour or 3hours. We have carried out detailed GPS and satellite (MODIS, TRMM) water vapor over Kanpur (lying in the IG plains) and two stations in the southern parts of India (Hyderabad and Bangalore) to assess loss or gain in atmospheric water vapor content since 1996. GPS IPWV shows a strong sensitivity to high level of water vapor in the atmosphere during the dust storms, onset of monsoon and compares well with the ground measurement of rainfall. The seasonal variability over multiple years reveals important details of atmospheric water vapor fluctuation that varies with the location of station. The role of GPS and satellite derived meteorology in understanding the dynamics of the monsoon over Indian sub-continent will be presented. Further, the GPS water vapor has been compared with the MODIS derived water vapor that shows one to one correlation.

***Keywords:*** gps, monsoon, modis

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# Data assimilation in a large-scale distributed hydrological model for medium range flow forecasts

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At present, hydropower operational planning in Brazil uses flow forecasts as input to dam operations for the management of energy demand, flood control and other water uses. This management has been developed for an integrated grid which distributes energy from a system of hydropower dams. However quantitative precipitation forecasts (QPF) together with a rainfallrunoff hydrologic model may decrease the standard error of streamflow forecasts for long lead-times. Measured rainfall could then be used up to the time that forecasts are issued, and forecasts of rainfall used throughout the lead-time period. An additional benefit is obtained from the inclusion of recent observations of streamflow data, used to update hydrologic model state variables. As part of a research project to improve medium-range streamflow forecasts (lead-time up to two weeks) for use in the operational planning of Brazilian hydroelectric power systems, a large-scale hydrological model is being used, and several configurations of an empirical procedure have been tested for the purpose of updating forecasts as new field measurements become available (data assimilation). This study has used data from the Rio Grande basin (drainage area of 145,000 km2), a sub-basin of the Parana River basin. This basin is one of the test beds of the Hydrologic Ensemble Prediction Experiment (HEPEX). Flow forecasts of up to 12 days was obtained using a large scale distributed hydrological model (MGB-IPH) and QPF from the ETA regional atmospheric model run by the Brazilian Center for Weather Prediction (CPTEC). The MGB-IPH model was developed based on VIC and LARSIM models, and is distributed in regular cells of approximately 10 x 10 km. The model has already been applied to several large South American basins (e.g. Sao Francisco, Tapajos, Uruguai, Taquari) with acceptable results. A data assimilation procedure was introduced such that recorded discharges are used to update model state variables prior to forecast issue. Updated variables are streamflow values calculated along the river network and groundwater, or baseflow, in each model cell. Updating is weighted according to distance to the location where observed data is available. During low flow periods, the linear reservoirs that represent groundwater in cells located upstream of each gauging station have their water content updated according to a factor calculated for each gauging station. This paper presents results obtained by applying the data assimilation methodology to medium range flow forecasting in the Rio Grande basin. Tests have analyzed the influence of updating procedure parameters on flow forecasting skill. The forecasts were largely improved by updating state variables. Best results were achieved using an updating factor that decreases exponentially along river network.

***Keywords:*** data assimilation, streamflow forecast, updating procedure

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**HS2004** **Oral Presentation** **4208**

# Space-time representativity of precipitation for rainfall-runoff modelling

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Precipitation is the most important input for rainfall-runoff modelling. For distributed hydrological modelling precipitation data with high temporal and spatial resolution are needed. This poses high requirements on the observations which usually cannot be satisfied by the conventional precipitation measurement networks. Alternative measurement techniques like weather radar and modern methods for spatial interpolation and space-time simulation of rainfall need to be employed and refined. This contribution discusses possibilities to improve the space-time representativity of precipitation for tasks like flood forecasting, flood simulation and derived flood frequency analysis based on some case studies. Considering the spatial representativity of precipitation one example is presented for optimal interpolation of hourly rainfall using multivariate geostatistics with additional information from weather radar, daily data and topography. A second example discusses the conditional spatial simulation of precipitation for flood simulation in a mesoscale catchment. The special focus is here on considering the uncertainty of rainfall-runoff modelling resulting from uncertain precipitation input. Regarding the representativeness of precipitation in time two examples are shown in which long continuous hourly rainfall series are generated for rainfall-runoff modelling derived flood frequency analysis. Disaggregation of daily rainfall using a multiplicative random cascade model and stochastic simulation based on a modern alternating renewal model are discussed for a large mesoscale basin.

***Keywords:*** precipitation modelling, uncertainty, weather radar

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# Experimental hydrometeorological and hydrologic ensemble forecasts in the U.S. National Weather Service and their verification

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***Limin Wu, Dong-Jun Seo***

An ensemble preprocessor is being developed by the Office of Hydrologic Development of the NOAA/National Weather Service (NWS) to produce reliable short-term hydrometeorological ensemble forecasts from the single-value forecasts of precipitation and temperature. The hydrometeorological ensemble forecasts from the preprocessor are then ingested in the NWS Ensemble Streamflow Prediction (ESP) system to produce probabilistic hydrologic forecasts that reflect the hydrometeorological uncertainty. The preprocessor methodology attempts to remove biases from single-value forecasts, and capture the skill and uncertainty therein while preserving the space-time properties of the hydrometeorological variables. The procedure constructs, for each hydrometeorological variable, the joint distribution of forecasts and observations from historical pairs of values. The probability distribution function of the future events that occur given a particular single-value forecast is the conditional distribution function of observations. To generate individual ensemble members for each lead time and each location, the historical observed values are replaced with values sampled from the conditional distribution. The replacement procedure matches the ranks of historical and rescaled values to preserve the space-time properties between precipitation and temperature. The ensemble preprocessor currently operates experimentally at four NOAA/NWS River Forecast Centers in the U.S. using the operational deterministic forecasts for lead times of one to five days. To evaluate the performance of the hydrometeorological and hydrologic ensemble forecasts, an ensemble hindcaster has been developed to generate these forecasts in the retrospective mode. In this contribution, we present probabilistic verification results obtained thus far for precipitation, temperature, and streamflow ensemble forecasts. To separate the hydrologic and input uncertainties, streamflow ensemble forecasts were evaluated against observed flows and simulated flows generated from perfect input. The verification results show that the use of preprocessed hydrometeorological ensembles improves the streamflow forecast performance and that hydrologic uncertainty has large impact on the resulting ensemble forecasts.

***Keywords:*** ensemble, uncertainty, verification

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# Reducing the uncertainty of flood forecasts through single-step calibration strategies

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This paper looks at hydrological prediction from the point of view of flood forecasting, and it focuses on methods based on a rainfall-runoff (RR) modelling approach. For years, the traditional approach to flood forecasting was to use simulation models as forecasting models, through a two-step strategy. The model would be calibrated once for all, and then updated/recalibrated in real-time to improve model forecasts, based on the last available runoff information. A common belief among hydrological modellers was that a rainfall-runoff model and the updating procedure used for its application in forecasting mode could be chosen independently, i.e. that any updating procedure could be applied to any rainfall-runoff model. In recent years, the apparition of data-driven approaches (with relatively good performances as forecasting models) demonstrated that a two-step approach was not an absolute requirement, and it suggested us to try a new calibration approach that would calibrate classical RR models directly in forecasting mode. This required modifying the RR model in order to make the updating procedure an integral part of the model. Here, we discuss the respective merits of one-step vs two-step calibration strategies, the changes in RR model required to make the one-step strategy possible, and we show on a large set of 188 catchments how the one-step strategy does reduce predictive uncertainty.

***Keywords:*** flood forecasting, rainfall runoff modeling, model updating

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**HS2004** **Oral Presentation** **4211**

# Outlier catchments: for a realistic assessment of predictive uncertainty in rainfall-runoff modelling

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***Le Moine Nicolas***

When it comes to reducing the predictive uncertainty in hydrological studies, the easiest and perhaps most widely used approach perhaps consists in hiding those catchments which we cannot understand with our models, on the grounds that input or calibration data are most probably of bad quality. If we agree with Beven [2001] who describes the modelling process as an attempt to map a catchment into a model space, using hypothesis to constrain the mapping, then is obvious that in the development and validation of a rainfall-runoff model we will encounter data that do not fit into this conceptual frame at all, especially when working with large datasets. The purpose of this communication is to focus on these catchments that many modellers consider as obvious outliers and often discard out of their datasets, for they give very poor results (e.g., highly negative Nash-Sutcliffe values). We would like to address the following questions: What does characterize these tail-of-distribution catchments? Can we find a method to screen out major data inconsistencies without checking data series one by one (i.e., distinguish between model failures and measurement errors)? Should we get rid of those outliers in the validation phase of a RR model? We present several tests that have been performed on a large dataset of 1000 French catchments, using three models: the monthly GR2M model [Mouelhi et al., 2006], the daily GR4J model [Perrin et al., 2003], and the hourly GR4H model [Mathevet, 2005]. The main issues that we address here mainly deal with water balance closure from the surface hydrologists point of view: the initialization of RR models for humid catchments, the problem of groundwater-dominated catchments; long-term, interannual behaviors; and intercatchment groundwater flows, and also the limits of NS criterion for both intermittent and groundwater-dominated catchments. Last, we discuss the implications of a 'rehabilitation' of outlier catchments for a realistic assessment of predictive uncertainty in rainfall-runoff modelling. References Beven, K. J. (2001), On hypothesis testing in hydrology, Hydrological Processes, 15, 16551657. Mathevet, T. (2005), Quels modles pluie-dbit globaux pour le pas de temps horaire? Dveloppement empirique et comparaison de modles sur un large chantillon de bassins versants, Ph.D. thesis, ENGREF, Paris. Mouelhi, S., C. Michel, C. Perrin, and V. Andrassian (2006), Stepwise development of a two-parameter monthly water balance model, Journal of Hydrology, 318(1-4), 200214. Perrin, C., C. Michel, and V. Andrassian (2003), Improvement of a parsimonious model for streamflow simulation, Journal of Hydrology, 279, 275289.

***Keywords:*** rainfall runoff modeling, outliers

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# Uncertainty quantification in a combined IR/Microwave scheme for remote sensing of precipitation

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***Aris P. Georgakakos, Christa Peters-Lidard***

Environmental satellites represent an economic and easily accessible monitoring means for a plethora of environmental variables, the most important of which is arguably precipitation. While precipitation can also be measured by conventional rain gages and radar, in most world regions, satellites provide the only reliable and sustainable monitoring system. This paper presents a methodology for estimating precipitation using information from the satellite-borne precipitation radar of the Tropical Rainfall Measurement Mission (TRMM). The methodology combines the precise, but infrequent, TRMM data with the infrared (IR), visible (VIS), and water vapor (WV) images continuously produced by geostationary satellites to provide precipitation estimates at a variety of temporal and spatial scales. The method is based on detecting IR patterns associated with convective storms and characterizing their evolution phases. Precipitation rates are then estimated for each phase based on IR, VIS, WV, terrain, and month information. Further, the methodology explicitly quantifies the uncertainty of the precipitation estimates by computing their full probability distributions instead of just single optimal values. Temporal and spatial autocorrelation of precipitation are fully accounted for by using spatially optimal estimator methods (kriging), allowing to correctly assess precipitation uncertainty over different spatial and temporal scales. This approach is tested in the Lake Victoria basin over the period 1996-1998 against precipitation data from more than one hundred rain gages representing a variety of precipitation regimes. The precipitation estimates were shown to exhibit much lower bias and better correlation with ground data than commonly used methods. Furthermore, the approach reliably reproduced the variability of precipitation over a range of temporal and spatial scales.

***Keywords:*** precipitation uncertainty, sequential simulation, lake victoria

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**HS2004** **Oral Presentation** **4213**

# Approche quantitative de calcul du deficit d'écoulement dans le bassin hydrographique du Cheliff Zahrez en Algerie du Nord.

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TOUAIBIA BENINA 1, Rosales Wenceslao Martin 2, Gisbert Gallego Juan M 3. 1. Laboratoire dHydrologie. Ecole Nationale Suprieure de lHydraulique. BP. 31. 09000. Blida. Algrie. touaibia@yahoo.fr 2. Departamento Geodinmica. Universidad de Granada. E-18071. Granada. Espaa. wmartin@ugr.es 3. Departamento de Hidrogeologa y Qumica Analtica. Universidad de Almera. E-04120, Almera. Espaa. jgisbert@ual.es A chaque fois que nous dcidions de faire un dimensionnement dun ouvrage hydrotechnique sur des petits bassins versants, nous nous heurtons labsence de la donne hydromtrique. La ncessit de construction des hydrogrammes de crues diffrentes priodes de retour nous oblige recourir des formules empiriques souvent tablies dans des conditions non similaires aux conditions algriennes ou des mthode utilisant au moins la prcipitation maximale journalire. La mthode de lhydrogramme synthtique appele aussi mthode des isochrones permet de construire les hydrogrammes de crues diffrences frquences. Son application ncessite trois paramtres importants savoir lexposant climatique issu dune tude des pluies de courtes dures, la prcipitation maximale journalire et le dficit dcoulement. Si les deux premiers paramtres sont plus ou moins disponibles, le troisime nest pas vident. Cest dans ce contexte que ce travail est conu. Une approche de calcul simple est propose, base sur un bilan hydrologique, pour llaboration dune carte susceptible daider les dcideurs dans leur prise de dcision. Notre choix exprimental a port sur le bassin hydrographique du Cheliff-Zarez, drainant une surface de plus de 50000 Km.

***Keywords:*** deficitecoulement, cheliff zahrez, hydrogrammesynthtique

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**HS2004** **Oral Presentation** **4214**

# Propagation of Convection in Africa: Implications for predictability of precipitation

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The vulnerability of most African populations to weather-related disasters has been dramatically highlighted during recent decades. As recently as September 2006, floods in West Africa left tens of thousands of people homeless. The ability of African societies to reduce their vulnerability to environmental disasters is tied to better understanding and prediction of precipitation. In addition to hazard reduction, knowledge of the spatial and temporal variability of precipitation is needed to manage agriculture, water resources, public health, and renewable energy. Results from this study infer the potential for increased predictive skill in sub-seasonal weather prediction and in projections of seasonal to interannual variability, which could enable substantial societal benefits. This study examines the occurrences of organized convection in Africa using five years (1999-2003) of digital infrared imagery. Reduced-dimension techniques are used to document the properties of cold clouds, which serve as proxies for deep convection and precipitation. The continent is divided into three domains for tracking deep convection. The northern domain encompasses 0 to 20N and 20W to 40E from May to August. The central domain covers 15S to 15N and 20W to 45E. The mid-latitude domain covers 35S to 15S and 10E to 45E from November to February. Global analyses are used to diagnose the large-scale environments associated with the evolution of deep convection. The analyses are on a 1-degree grid and are provided daily at 0000, 0600, 1200, and 1800UTC. It is evident that a sizeable fraction of the rainfall in Africa results from long-lived episodes of deep convection. Episodes are coherent sequences of organized convection that propagate and regenerate on regional and continental scales. In tropical North Africa, a few episodes last through as many as five diurnal cycles while undergoing stages of regeneration. The phase speeds for most convective cloud streaks are 10 - 20 ms-1, which is similar to those in the US and East Asia although the average zonal span and duration of episodes in Africa are greater than those in other regions. A large fraction of the convective episodes initiate in the lee of high terrain (e.g, the Ethiopian highlands, Darfur Mountains, Jos Plateau, Guinea Highlands, the South African Escarpment, and the plateaus of central East Africa). While clearly insufficient in itself, a major generating factor is thermal forcing associated with large scale elevated heat sources. Episodes occur in the presence of moderate vertical shear of the horizontal wind. In mid-latitude southern Africa, this is a common condition associated with the deep westerlies, while in Sahelian Africa, it is associated with the migration of the African Easterly Jet. Organized, propagating systems are associated with a large fraction of the rainfall inferred. Based on the coherent behaviour of organized, propagating systems, inferences may be made regarding the prediction of precipitation beyond one of two days.

***Keywords:*** convection, precipitation, africa

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**HS2004** **Oral Presentation** **4215**

# GEWEX Hydrology

***Dr. Alan Hall***
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GEWEX HYDROLOGY ALAN HALL 1 et al 1. Chair IAHS/WMO Working Group on GEWEX, 17 Crisp Street, Cooma, NSW, 2630, Australia The Global Energy and Water Cycle Experiment (GEWEX), of the World Climate Research Program (WCRP), was commenced in 1988 and has coordinated the activities of the Continental Scale Experiments (CSEs) and other land surface research through the GEWEX Hydrometeorology Panel (GHP). The GHP was established in 1995 to contribute to the WCRP objective of developing the fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicted and the extent of mans influence on climate. More specifically the GHP contributes to the GEWEX objectives such as determining the hydrological cycle and energy fluxes, modelling the global hydrological cycle and its impact, developing a capability to predict variations in global and regional hydrological processes and fostering the development of observing techniques, data management and assimilation systems. GHP activities include diagnosis, simulation and prediction of regional water balances by various process and modelling studies aimed at understanding and predicting the variability of the global water cycle, with an emphasis on regional coupled land-atmosphere processes. GHP efforts are central to providing a scientific basis for assessing critical science issues such as the consequences of climate change for the intensification of the global hydrological cycle and its potential impacts on regional water resources. This paper discusses the more relevant scientific issues relating to hydrology being addressed by the GHP in collaboration with the international science community, in particular the IAHS Prediction in Ungauged Basins (PUB). The GEWEX Water Resources Applications Project (WRAP) was established in 2000 to facilitate broader use of GEWEX products in water resource applications. The group has promoted dialogue between the GEWEX community and the water resources community. With members from each of the CSEs, IAHS, UNESCO programmes, and the World Meteorological Organization (WMO), this group has provided a wide range of expertise related to water management. WRAP relies on the development of physically based hydrology and application or decision support models, and the coupling of these models with regional climate models. Application studies require a capability to downscale large area (model grid square) precipitation forecasts and observed averages, statistical analyses of the relationships between SST anomalies and seasonal streamflow, and analysis of the value and utility of seasonal forecasts in water management decisions. WRAP is to be replaced by the Hydrologic Applications Project (HAP) which will be defined in October 2006 together with the Roadmap for the third phase of GEWEX. This paper summarises the achievements of GEWEX to date pertaining to hydrology and gives an indication of the planned hydrological outputs of the project over the next five years.

***Keywords:*** global, hydrology, water resources applications

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**HS2004** **Oral Presentation** **4216**

# Ensemble Forecasting of Flash-floods in Semi-arid Regions across Spatial Scales

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About one-third of the earths landsurface is located in arid or semi-arid regions, often suffering from the negative impacts of desertification and population pressure. Reliable hydrological forecasts across spatial and temporal scales are crucial in order to achieve water security protection from excess and lack of water for the population in these areas. At short temporal scales, flash floods are extremely dangerous hazards accounting for example for more than 80% of all flood related deaths in the US. Forecasting of these floods requires a connected spatially-distributed hydro-meteorological modeling system which accounts for the specific meteorological and hydrological characteristics of semi-arid watersheds, e.g. convective events and transmission losses. The spatially heterogeneous nature of the precipitation and the non-linear response behavior of the system demand the explicit accounting and propagation of uncertainties into the model predictions. We will present the results of a multi-year study in which such a system was developed for flash-flood forecasting in the semi-arid southwestern US. We will present model applications to watersheds across spatial scales and explicitly discuss our effort to understand and estimate underlying uncertainties in such a modeling system.

***Keywords:*** flash floods, semi arid, uncertainty

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**HS2004** **Oral Presentation** **4217**

# Improved scenario prediction by using coupled hydrological and atmospheric models

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The hydrological model MIKE SHE with a new energy-based land-surface module has been dynamically coupled to the non-hydrostatic atmospheric model ARPS. Using data from the FIFE experiment both the land-surface module and a 1D coupling of the models have been validated. Subsequently, a hypothetical scenario, where grassland is turned into agriculture, has been investigated by running the model system in both uncoupled and coupled mode. It is found that the uncoupled system significantly over-predicts the change in evapotranspiration caused by the land-use change in comparison to the coupled model results, emphasising the importance of taking feedback effects at the land surface into account.

***Keywords:*** land surface modelling, coupled models, land atmosphere feedback

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**HS2004** **Oral Presentation** **4218**

# Appropriated use of ensemble forecasts in operational flood management

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Ensemble forecasts of floods are opportunities to characterize the uncertainties of forecasts, resulting from the incomplete knowledge about the further development of the meteorological input data and the uncertainties of the hydrological model and its parameters. Strongly related with the physical limitations of fast-reacting watersheds and of complex meteorological situations these uncertainties can not be avoided. Hydrological ensemble forecasts based on meteorological ensembles are a way to describe the uncertainty of the potential future development of the hydro-meteorological situation. However other sources of uncertainties, e.g. model or parameter uncertainties have to be considered also. The demand of practitioners for single, reliable forecasts which could be used to decide about flood warnings or flood control measures, can not be fulfilled by ensembles only. To support their decisions additional characteristics are needed to differentiate among the ensemble members. Here a methodology for a probabilistic evaluation of ensemble members is presented. It considers the expected possible consequences of floods as well as the options to improve the information base to quantify uncertainties in real-time by data assimilation. The applicability of this methodology is demonstrated with a case study for the mountainous Mulde River basin in Eastern Germany. Here specific meteorological conditions resulting from orographic factors in combinations with fast-reacting watersheds cause high uncertainties of meteorological and hydrological forecasts. It is shown how meteorological ensemble predictions derived from the COSMO-LEPS for the years 2002-2006 can be used to estimate flood ensembles and how flood warnings could benefit from them. It is shown that the main benefits of the proposed methodology consist in combination of ensemble forecasts, real-time data (including radar) and an evaluation of possible consequences of the forecasted floods.

***Keywords:*** ensemble forecasting, uncertainty, flood risk management

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**HS2004** **Oral Presentation** **4219**

# Earth system science perspectives for improved water management: a prototype system-of-systems

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The notion of water as a key to successful development and human well-being continues to gain momentum in international policy circles. Water figures prominently in high profile development initiatives established through the WSSD, CSD, Millennium Project, World Water Assessment Programme, UNESCO International Hydrological Programme, WMO, and UN-Water. These efforts, at their core, address complex, multi-stakeholder issues requiring the highest quality of environmental observations, technological innovation, and scientific insight. Using approaches designed for use in the Millennium Assessment that combine geophysical information products and social science data sets, a strategy for end-to-end data processing streams will be presented. Examples of prototype indicators and end-to-end tests will be presented. The first will address the issue of water resource stress arising from the conjunction of upstream source area/downstream use distributions. The second will demonstrate how operational water cycle products can be used to assess time-varying societal vulnerabilities arising from extreme rainfall. The effort is designed to serve as a prototype community-based effort in support of GEOSS, with an initial emphasis on water resources and watershed services. An evaluation process is also discussed, one which unites data suppliers with the needs of data consumer communities.

***Keywords:*** water, resources, geoss

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**HS2004** **Oral Presentation** **4220**

# Water balance evaluation using remote sensing driven land surface modeling and spatially distributed hydrological modeling

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***Lars Troldborg***

In Denmark, 99 % of the water supply is based on groundwater. In some areas, an excessive use of groundwater results in very low stream flows during summers with adverse impacts on stream ecology. In order to improve water management, it is important to have an accurate overview of water balance components at the larger scale and, in particular, to know the rate of groundwater recharge and interactions between stream and ground water flows. The present paper compares and discusses two different methods applied for large-scale water balance evaluation in Denmark. One method is based on a detailed remote sensing driven land surface model (DaisyGIS) and another method uses a spatially distributed hydrological model setup (MIKE SHE) emphasizing sub-surface water flows and surface-groundwater interactions. The purpose of this paper is to investigate which elements of the two approaches are most important for accurate water balance estimation and eventually to discuss how they could be efficiently combined to improve the water management basis at the national level in Denmark. The two models were set up for Sjlland (7330 km2) which is the major island of Denmark upon which the capital Copenhagen is also located. The region holds more than 50 catchments which are characterized by different degrees of various land uses such as agriculture, natural and recreational forests and impervious urban regions. Water balance results are extracted and evaluated for 3 catchments dominated by agricultural land use, forest areas and urban settlements respectively. In the paper, the major differences in methodology and model performance between the two model types are outlined and discussed at catchment level and for all of Sjlland.

***Keywords:*** large scale, water balance, modelling

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**HS2004** **Oral Presentation** **4221**

# Seamless daily to seasonal ensemble flood forecasting for Bangladesh

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***Peter Webster, Hai-Ru Chang***

The country of Bangladesh experiences life-threatening floods in the basins of the Ganges and Brahmaputra rivers flowing through the country with tragic regularity. These floods result in loss of life on a scale that often greatly eclipses the deaths due to natural disasters in developed countries. Flooding in these basins can occur on weekly time scales (as occurred during the severe Brahmaputra floods of 2004) to seasonal time scales (as occurred during the disastrous floods of 1998). Beginning in 2003, the Climate Forecasting Applications for Bangladesh (CFAB) project began issuing operational flood forecasts to the country of Bangladesh over a wide-range of time scales to provide advanced warning of severe flood-stage discharges in the catchments of the Ganges and Brahmaputra basins. In this paper we discuss the real-time operational multi-model flood forecast schemes for the upper basins of the Ganges and Brahmaputra rivers based on a seamless application of the current European Centre for Medium-Range Weather Forecasts (ECMWF) 51-member ensemble weather forecasts and 41-member climate forecasts. Currently, CFAB produces separate precipitation and discharge forecasts from an enhanced model at intra-seasonal time-scales. Although in the near future we anticipate a statistical merger of these multi-time scale forecasts, here we focus on the results of applying the current operational ECMWF weather and seasonal ensemble forecasts to probabilistic discharge forecasting for Bangladesh. In addition to the ECMWF products, the discharge forecasts utilize near-real-time GPCP and CMORPH satellite and NOAA CPC rain gauge precipitation estimates and near-real-time discharge estimates from the Bangladesh Flood Forecasting and Warning Centre. In order to generate fully automated probabilistic river discharge forecasts from 1-day out to 6-months in advance, these schemes utilize statistical dressing and a downscaling technique to merge the ECMWF weather and seasonal forecasts. These techniques also ensure reliability in both the weather and discharge forecasts and skill no worse than a climatological forecast or persistence.

***Keywords:*** forecasting, flooding, uncertainty

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Oral Presentation** **4222**

# Flood prediction and sustainable water resources management in part of Lagos N.E.

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Massive development to meet the socio-economic needs of the emerging metropolises and mega cities without adequate consideration for the hydrological environment has brought about many challenges, like the need to sustainably manage the increasing incidence of more destructive flood, even in regions that used to be considered safe. Causes of flooding in Lagos (the industrial and commercial hub of Nigeria and the West African sub-regions) include increasing encroachment of urban facilities on to the flood plain and unprecedented land reclamation without provision of adequate drainage paths; prolonged heavy rainfall, unplanned development and blockage of natural and artificial drainage paths and the physical characteristics of Lagos, as a coastal region, which further compound the flooding problem within the region Hence, in order to address the flood uncertainty and calculate the flood design risk and vulnerability within part of Lagos N.E., this study entails estimation of probably peak discharge at assumed steady and uniform rainfall intensity for different return periods over the entire region, using rational formula. Also, Digital elevation model (DEM) was generated for the region. Reclassification and cross-tabulation of the DEM dataset was carried-out, in order to identify floodable and non-floodable area in relation to selected threshold elevation value. In addition, flood probability maps were generated at acceptable risk level of 20%, 10% and 5%. This is necessary for adequate pre-disaster measures and the establishment of a lead-time preparation for a wide variety of flood mitigation towards scientifically sound decision in sustainable water resources management within Lagos N.E. region.

***Keywords:*** flood design, probability maps

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Oral Presentation** **4223**

# Long-term probabilistic forecasting of spring flood characteristics and investigation of forecast uncertainty.

***Prof. Lev Kuchment***
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A technique of long-term (with the lead time of 2-3 months) ensemble forecasting of the spring runoff volumes and the peak discharges has been developed. The technique is based on the use of the physically based model of runoff generation combined with the weather generator. The distributed physically based model includes description of snow accumulation and melt, soil freezing and redistribution of soil moisture during autumn and winter period, processes of runoff generation after the beginning of spring snowmelt period. The weather generator consists of the stochastic models of daily temperature and precipitation. The physically based model is applied to calculate, using meteorological data for the autumn- winter period, missing initial river basin conditions before forecasting (commonly, the soil moisture and depth of frozen soil; sometimes, the snow water equivalent) and to estimate the runoff hydrographs during the lead-time period. The weather generator with Monte Carlo simulations, weather predictions or chosen weather scenarios are used to provide opportunities of assessing the meteorological inputs for lead-time periods and to estimate the probability distributions of the forecasted runoff volumes and peak discharges. The results of forecasting of spring runoff volumes have been compared with the results received on the basis of using the averaged meteorological conditions for lead-time periods or regression relationships between spring runoff volume and the initial indexes of river basin conditions before forecasting (the present day procedure of long-term spring flood forecasting). The case study has been carried out for the Sosna River basin (catchment area is 16400 km2) and for the Seim River basin (catchment area is 7500 km2). The best predictors have been chosen and the uncertainty of the forecast has been estimated.

***Keywords:*** forecasting, flood characteristics, uncertainty

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**HS2004** **Oral Presentation** **4224**

# Predictive Uncertainties in Optimization of Sustainable Water Resources

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***Nisai Wanakule, Armen Der Kiureghian, Steven Gorelick***

This paper presents a reliability-based water resources management framework that utilizes stochastic optimization techniques to account for uncertainties associated with of prediction of climatic condition, water demand, surface water availability, baseline groundwater levels, non-anthropogenic reservoir water budget, and hydrologic/hydrogeologic properties. The framework was developed to manage water resources from over 160 groundwater production wells, stream flow withdrawal, regional reservoir, and desalination plant in the Tampa Bay region in Florida, USA. The developed method maximizes the reliability of achieving the goals that all protected wetlands in the area are healthy and sea water intrusion is prevented. The framework involves (1) a system simulation model to represent the water resources routing under the OROP and (2) a Monte Carlo simulation model to generate realizations of climatic events, water demand, available surface water quantity, and (3) a unit response matrix (URM) that relates groundwater level response to groundwater extraction. The URM was derived from a surface water-groundwater interaction model developed based on integrating a HSPF surface water model and a MODFLOW groundwater model. The stochastic climatic model accounts for the spatial and temporal characteristics observed from historical data and is conditional on the information available at the time of updating. The inputs to the stochastic water demand model include the results from the climatic model and other socioeconomic parameters, such as population, type of dwellings, employments in commercial sectors. Because the actual quantities of water demand and available surface water would likely be different from the forecasted values, water supply operators would adjust the optimized rates of groundwater extraction, surface water withdrawal, and reservoir inflow/outflow according to meeting the water demand in all circumstances. A set of rules of practice was developed as guidance for the operators. Because the regional reservoir and surface water withdrawal will be operated under a set of nonlinear rules, the reliability optimization problem is solved using a differential evolutionary algorithm.

***Keywords:*** water resources management, climate, uncertainty

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**HS2004** **Oral Presentation** **4225**

# Efficient Numerical Methods for Assessing Uncertainty for Computationally Expensive Simulation Models of Environmental and Water Resource Systems

***Prof. Christine Shoemaker***
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***Pradeep Mugunthan, Pradeep Mugunthan, Nikolai Bliznіouk, David Ruppert, Rommel Regis, Stefan Wild***

Computational limitations can restrict our ability to examine uncertainty in computationally expensive simulation models in water resources and environmental analysis. Most uncertainty methods assume we can make thousands or tens of thousands of simulations, which is not feasible for computationally expensive models. This paper discusses two methods for substantially improving our ability to quantify uncertainty with relatively few model simulations. For both methods, an optimization method is used to search for the global maximum of the goodness-of-fit function; and the values of the simulations used in the optimization search are re-used for the uncertainty analysis. The first method (ACURARS) is applied to a complex partial differential equation, multi- species model of bioremediation of chlorinated ethenes in groundwater. ACURARS corrects for the bias in optimization sampling due to over sampling the high goodness of-fit areas. The correction is based on declustering. The method has a similar philosophy to GLUE but requires only about 1/8 as many simulations as GLUE to get an accurate result. The second method is somewhat more computationally expensive but fits into a full Bayesian analysis using Markov Chain Monte Carlo (MCMC) and includes transformations for non-normal data. The method uses the values from the optimization search plus some additional simulations to approximate the likelihood function. The MCMC analysis to assess uncertainty is then performed using the function approximation of the likelihood function instead of the true function. This method is applied to a problem of spilled contaminant diffusing in a stream. Numerical results for the approach using the function approximation are shown to be accurate because they are similar to results obtained from the traditional MCMC analysis of the full diffusion model, which requires at least 10,000 simulations. However, the function approximation approach requires only 150 simulations, which is about 1/66 of the computer time required by conventional MCMC analysis. This very large reduction in computer time means this function approximation method can potentially be used with computationally expensive simulation models for which the conventional MCMC is not computationally feasible. Between the two methods, the cell declustering method is less computationally demanding, and the function approximation method is more closely based on statistically rigorous Bayesian Analysis using MCMC to determine uncertainty. Both methods give us tools that potentially can accurately quantify uncertainty for complex models for which there is currently no other numerically feasible method.

***Keywords:*** uncertainty, numerica lmethodology

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Oral Presentation** **4226**

# Accounting for uncertainty in hydrological forecasts

***Dr. John Schaake***
*na na IAHS*

***Roberto Buizza***

This presentation discusses the importance of the work of the IAHS to the success of the international Hydrologic Ensemble Prediction Experiment (HEPEX). HEPEX is an independent non-governmental activity that is open to anyone wanting to participate. The goal of HEPEX is to develop the capability to produce skillful and reliable ensemble hydrological forecasts. HEPEX was initiated at a workshop hosted by the European Center for Medium-range Weather Forecasting (ECMWF) and the U.S. National Oceanic and Atmospheric Agency (NOAA) at the ECMWF in March 2004. A 2nd workshop was hosted by the National Center for Atmpospheric Research (NCAR) at NCAR, July, 2005. The 3rd workshop will be hosted by the European Unions Joint Research Center (EU/JRC) at Stresa, Italy, June, 2007 the week before the beginning of this IUGG meeting. The HEPEX web site is http://hydis8.eng.uci.edu/hepex/. HEPEX is affiliated with several international activities including GEWEX, WWRP, WMO hydrology program and IAHS. A draft implementation strategy for HEPEX has been completed and will be discussed. A summary of the 3rd workshop also will be presented. HEPEX plans to achieve its goals through three types of activities: (i) test-bed projects that focus on specific science issues; (ii) development of shared data sets and (iii) development of procedures that could be components of a Community Hydrologic Prediction System (CHPS). There is a strong complementary relationship between the science needs of HEPEX and the science activities of several PUB working groups. This presentation will illustrate some of the most urgent needs of HEPEX and note related activities being accomplished by IAHS and PUB. This includes work being facilitated by the IAHS/WMO Working Group on GEWEX.

***Keywords:*** ensemble prediction, forecasting, uncertainty

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**HS2004** **Oral Presentation** **4227**

# A multi-index approach to inflow prediction for water resources management

***Prof. Stewart Franks***
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***Adam Wyatt***

Significant variability in reservoir inflows is experienced across Eastern Australia as a result of a number of known, identified climate modes. In particular, the El Nino Southern Oscillation (ENSO) affects primarily summer (Oct-Mar) inflows, whilst the Indian Ocean Dipole (IOD) appears to impact on winter (Jun-Aug) inflows. In this paper, a software suite is presented that enables (i) the routine prediction of ENSO and IOD events, (ii) the assessment of likely inflow on monthly and seasonal timescales and (iii) the updating of both climate and inflow prediction as new data are received. The scheme is demonstrated in application to the Warragamba reservoir that supplies 80% of the potable supply for metropolitan Sydney. The tool is generalized and can be applied anywhere that significant correlations between ENSO, IOD and inflows are found.

***Keywords:*** climate variability, inflow, prediction

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Oral Presentation** **4228**

# Integrating meteorological and uncertainty information in flood forecasting: The FLOODRELIEF Decision Support System

***Dr. Michael Butts***
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Flood forecasting specialists and operational water managers require ready access to a wide range of information such as catchment status and meteorological forecasts, to make decisions that initiate flood response measures including flood warnings. Substantial improvements in forecast lead-time, the time available to respond before a flood peak occurs, can be achieved by using Quantitative Precipitation Forecasts, (QPF) based on numerical weather models. An important challenge is to derive QPFs at the appropriate temporal and spatial scales appropriate to determine flood response. At the regional scale effective flood forecasting systems must provide reliable, accurate and timely forecasts for a range of catchments; from small rapidly responding upstream catchments to larger, more slowly responding downstream locations. To have real value, however, decision-makers are now recognising that real-time flood management decisions must be based on an understanding of the uncertainties and associated risks. It is therefore critical for effective flood management tools to provide reliable estimates of the forecast uncertainty. Only by quantifying the inherent uncertainties involved in flood forecasting can effective real-time flood management and warning be carried out. Forecast uncertainty requires the estimation of the uncertainties associated with the hydrological model inputs (precipitation observations and forecasts), model parameterisation and calibration, and requires methodologies that predict how the uncertainties from different sources propagate through the hydrological and hydraulic system. To address these requirements the EU project FLOODRELIEF has focussed on methods for estimating forecast uncertainty and the development of the FLOODRELIEF DSS integrating meteorological and uncertainty information. This decision support system has been designed together with FLOODRELIEF forecasting end-users to provide flood management and forecast information in a flexible, efficient and easily understood manner to operational users and decision makers. Comprehensive facilities for accessing and presenting both meteorological observations and numerical weather forecasts are available. Ensemble forecasting using different forecasting inputs provides a flexible method of estimating uncertainty. For example, alternative rainfall forecasts using meso-scale meteorological forecasts or weather radar forecasts can be used by operational forecasters to models to estimate an uncertainty range. In this manner a direct and intuitive estimate of forecast uncertainties that can be communicated to flood managers and decision-makers, is achieved. This paper will present the main results of the FLOODRELIEF project including the application of the decision support system to regional flood forecasting in the UK, in the FLOODRELIEF study catchment, the Welland and Glen.

***Keywords:*** flood forecasting, decision support systems, uncertainty

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Oral Presentation** **4229**

# Rainfall-runoff modeling for ungauged catchments in arid and semi-arid regions-towards a decision support system

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***Dr. Iranjali Jayasuriya, Dr. Maazuza Othman, Dr. Anan Jayyousi***

Water scarcity and low per capita water allocation is the major characteristic of arid and semi-arid regions. In such environment water becomes an important and precious resource for domestic and agricultural supplies and social and economic development. This situation is further exacerbated when such areas are agriculturally dominated and encounter a high population growth rate, compelling the motivation for developing a decision support system framework that integrates diverse modules of surface water and groundwater models and a GIS technology to facilitate processing and visualization. The Faria catchment in the West Bank is one of these semi-arid regions where the lack of proper management of natural resources, accompanied with the recent prolonged drought periods in the catchment have negatively affected the existing obtainable surface water and groundwater resources. The rapidly growing rural population, about 3.5 percent annually, has resulted in increased demand for natural resources, mainly land and water. Assessment and modelling of the sustainable-yield limits of water resources within the catchment including surface water and groundwater should be carried out considering climatic changes and land use patterns. Most surface runoff in the catchment is not utilized as there are no dams in the catchment to store the excess water. For ungauged catchments, the practice among researchers has often been to consider a number of physical variables and then empirically relate them to indices of frequency curves, flow duration curves, mean annual and monthly discharges or to rainfall-runoff model parameters. The majority of these studies reveal two important problems, one associated with the use of physically definable variables and the other related to statistical methods. In general, continuous simulation models developed worldwide need parametric calibration in order to work for local catchment conditions other than the areas where such models had been developed or calibrated. Furthermore, although some studies have attempted to relate model parameters to catchments physiographical characteristics the lack of observed data required for the calibration of such models makes it difficult to successfully apply such models in ungauged situations. The paper provides a methodology to determine streamflow yield from ungauged agricultural-dominated catchments. The basic approach involves the utilization of a simple event-based geomorphological instantaneous unit hydrograph model that is capable of determining the runoff based on rainfall data and catchment geomorphological characteristics obtained from GIS tools. The paper also investigates the sensitivity of geomorphological properties of the catchment to model estimates. The rainfall-runoff model has been successfully applied and validated against observed flow data from the Badan and Faria streams within Faria catchment in Palestine, indicating a promising potential of using such a model for predicting runoff as part of the modules needed for the decision support system framework proposed for ungauged catchments. The model estimated peak discharge increased as the overland flow roughness coefficient decreased which reflects the variation of surface roughness conditions within the catchment. Such an approach typically addresses integrated management of agriculture-dominated catchments in arid and semi-arid regions with application to Faria catchment. This application in turn can be generalized to similar areas in the region and worldwide.

***Keywords:*** rainfall runoff modeling, optimal water use, arid catchments

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS2004** **Poster presentation** **4230**

# Water Consumption of Populus euphratica Woodlands in an Arid Region of China

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The Ejina basin, a subwatershed in the lower reaches of the Heihe River basin, is situated in an exceedingly arid region, China. On the banks of the Heihe River there are zones of oases nourished by groundwater supplied by the river's upper and middle reaches, but the remainder of the region is desert. In recent years, increasing use of water from the Heihe's upper and middle reaches has reduced the volume of flow into the Ejina basin, and altered the seasonal timing of flows. This endangers the ecology, environmental quality and social development of the areas downstream. Exploitable water sources are reduced, vegetation withers, land salinity increases, farmland shrinks and desert expands. Together these trends are causing the Ejina basin to become a source region for sandstorms. Populus euphratica is the predominant tree species forming natural woodlands in the Ejina basin, which exist primarily in the riverside oasis zones of the Heihe River. The survival of the woodlands is of utmost importance to the existence of the Ejina oasis system, and changes in the Populus euphratica woods symbolize changes in the Ejina basin's ecology. Understanding the quantity and pattern of water consumption of Populus euphratica woodlands in the Ejina basin will provide a scientific basis for maintaining its present ecological environment and can help prevent deterioration. So, ecological water consumption of P. euphratica is determined by an improved Penman-Montieth method, soil moisture content and effective roots distribution density and the pattern of water consumption of Populus euphratica is analysised. The results shows that to maintain the current area and condition of Populus euphratica woodlands, a minimum of almost 145 million cubic meters of water per year must reach the Ejina basin in the lower Heihe river.

***Keywords:*** arid desert regionejina bas, water consumption

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**HS2004** **Poster presentation** **4231**

# Long-Term Prediction for the Annual Highest Tide Stage at Huangpu in Shanghai

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The annual highest tide stage in the coming year at Huangpu park is a very important index in the flood defense decision for Shanghai, so how to predict it with a high accuracy is paid more and more attention by Chinese hydrologists. Its said that the affecting factors for annual highest tide stage doesnt only include the flow of upstream of Huangpu river ,a tributary of Yangtze river, but also the runup of astronomical tide and typhoon, so there is a large difficulty for predicting it well by using the time series analysis methods ,such as AP(p) model, Grey model GM(1,1),and threshold autoregressive model. For the high water tide stage years in 1981,1997,2000,there is a large error for its prediction ,in which the mean absolute error is about 0.9m.For improving its prediction accuracy, some physical genetic analysis methods are used to make the prediction in the paper. In term of correlation analysis, some ocean temperatures, Southern Oscillation index and sunspot number are considered as prediction factors. The prediction methods includes the stepwise multiple regression, the empirical orthogonal function(EOF), the projection pursuit regression(PPR).By comparing with all other predictions methods mentioned ,the results show that EOF is the best method to predict the annual highest tide stage with the absolute errors less than 05 m for all prediction period from 1981 to 2000,and the mean absolute error less than 0.3 m for the years in 1981,1997 and 2000.In a word , its said that the physical genetic analysis method is feasible to make a prediction of the annual highest tide stage. Keywords: long term prediction; annual highest tide stage ;Shanghai; stepwise multiple regression; empirical orthogonal function; projection pursuit regression; ocean temperature; Southern Oscillaiton index.

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**HS2004** **Poster presentation** **4232**

# regionalization of river yields by cluster analysis in the Sakarya River Basin

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Watershed assessments can be used to meet a wide variety of goals. Watershed yield or water harvest is an important parameter for the planning and design of water structures. For example, it has been emphasized in recent years that the development of small hydropower plant projects are needed in Turkey. The Sakarya River basin is one of most suitable regions for the development of hydropower schemes. However, there are not enough river gauging stations, especially in the desired region or at points where hydropower plants are to be established. It is costly to obtain hydrological information by setting up gauge stations for every desired point. Clustering is necessary for the lack of data in a basin based on hydrometeorological homogeneity. Hydrological regionalization, the classification of gauged watersheds into regions according to preset criteria, provides a way to extend information from gauged watersheds to ungauged ones. The purpose of this study is to develop a regionalization scheme to classify watershed yields into regions and identify the regional membership of watersheds. Monthly river yields of 118 gauging stations in the Sakarya River basin which is located in northwestern Turkey were classified by cluster analysis on the basis of hydrological homogeneity. Monthly average yields (m/s/km) are obtained for dividing river flow discharges by drainage area. It is aimed that for the clusters to be homogeneous, the elements of the same cluster must be similar, while they are not similar to those of a different cluster. In this manner, most meaningful groups can be identified. The cluster number is found by using the agglomerative hierarchical cluster analysis method. The square Euclidean distance function is used as a similarity metric to measure the distance dij between two objects i and j. Wards method, one of the most popular linkage methods, is used to classify data. The Ward method tries to minimize the total within-group or within-cluster sums of squares as a measure of homogeneity. In the clustering process standardization is essential when variances among variables differ to any great extent; therefore, standardization techniques were applied to data. However, the original data were used in the analysis to compare the results of magnitude differences among stations. In order to find the number of cluster, Root Mean Square Standard Deviation (RMSSTD), Semi-partial R-Squared (SPRQ), and R-Squared (RSQ) tests are conducted that stations from different geographic locations are considered in the same cluster independent of their geographic position. Distance Analysis (DAN) test analyzing the dendrogram of data is also developed to find the number of cluster. The Sakarya River basin is separated into 4 homogeneous regions and the yield distribution map of the basin is obtained. 74, 32, 10, and 2 of 118 stations come together in Clusters 1, 2, 3, and 4, respectively. The average watershed yields are 0.001966, 0.007336, 0.016795, and 0.024784 for Clusters 1, 2, 3, and 4, respectively, while the average watershed yield of the basin is 0.005066. Correlations (R) vary generally between 0.75 and 0.99 among each cluster and stations within the same cluster.

***Keywords:*** regionalizatin of river yield, classification, cluster analysis

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**HS2004** **Poster presentation** **4233**

# Multilevel River Classification as the Methodological Basis for Analysis of Maximum Runoff Values in Different Geographical Regions

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This investigation presents the transferability of methodology between different geographical regions. Methodological approach determines an influence of different climates on the maximum runoff values. The methodology usage is illustrated by the case of the rivers those are under influence of the continental, semiarid, tropical and equatorial climates. In global scale, research of runoff requires to take into account some peculiarities: (1) great diversity of climatic parameters, because climates vary from hot to cold and from wet to dry; (2) diversity of environmental conditions - tundra, forests, steppes, savanna; (3) effect of local environmental conditions of certain catchment such as lakes, bogs, karst fenomena, etc.; (4) effect of morphometric characteristics of certain catchment such as square, elevation, gradient, density of river network, catchment shape. It needs, on the one hand, to combine this different information and, on the other hand, to distinguish the climate affects on the maximum discharges. Runoff formation on a catchment are governed principally by the climatic and natural zonality. Therefore, the methodology intends to select the catchments where the maximum discharges are being formed under uniform climate within single natural zone. It needs to input the notion of local and transitional runoff. The term of local runoff is used for the rivers located within the same climatic and natural zone. Rivers passing several climatic zones have the transitional runoff. Additionally, the local runoff can be divided into zonal and intrazonal runoff to take into account local environmental and morphometric characteristics of certain catchment. The zonal and intrazonal runoff are formed within the same climatic and natural zones but the values of intrazonal runoff are changed by individual properties of catchment. Only the zonal runoff should be analyzed to determine an influence of climate effects on the maximum runoff values. For detecting the rivers with uniform conditions of maximum discharge formation the tool is the multilevel zoning of territory on climatic subzones, on environmental subzones, on types of runoff, and also a belonging of catchments to the same diapasons of square, elevation, gradient.

***Keywords:*** methodology, runoff, climate

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**HS2004** **Poster presentation** **4234**

# Uncertainties in water balance estimations due to scarce meteorological information: A case study for the White Volta catchment in West Africa

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Scientifically sound decisions in sustainable water management are usually based on hydrological modeling which can only be accomplished by meteorological driving information. Especially in regions with weak infrastructure, where meteorological data is not available in sufficient spatial and temporal resolution, the spatial interpolations of coarse-resolution meteorological point observations are afflicted with uncertainties, particularly in case of discontinuous variables like precipitation. These input uncertainties are passed into the hydrological simulations. The uncertainties resulting from precipitation interpolation and their effect on model based water balance estimations are investigated. First, the results of different spatial interpolation techniques are compared and analyzed including estimation errors. Second, the results of the hydrological simulations driven by these meteorological fields are investigated to estimate the propagation effect of the precipitation uncertainties on water balance estimations. The consequential uncertainties/ranges of the water balance variables are analysed. In case of insufficient meteorological observations, meteorological models can be applied for generating the required input to hydrological models. The advantage is that the driving global, atmospheric fields for the dynamical downscaling are operationally available through public data sources. The potential and limitations of this method are investigated in comparison to the afore mentioned interpolation of coarse-resolution point observations. Research area is the White Volta catchment (100 000 km) in the semi-arid environment in West Africa for which basin-wide uncertainty estimates are a basic requirement for sustainable water management decisions.

***Keywords:*** precipitation uncertainties, propagation effect, water balance estimations

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**HS2004** **Poster presentation** **4235**

# Using GIS to evaluate the impact of selected landuse types on surface water quality downstream of Asa dam, Ilorin, Southwestern, Nigeria

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This study examines the impact of selected landuse types on surface water quality downstream of Asa dam in Ilorin, Southwestern Nigeria. Water samples were collected at seven points (including a control, 50m from Asa dam). Four-sample points fall within agricultural land use area, two within light industrial/residential area and the control was within an undisturbed natural environment. The level/concentration of ten physico-chemical parameters, colour, total dissolved solids, dissolved oxygen, biochemical oxygen demand, total hardness (CaCO3), calcium magnesium, chlorine, and nitrate were determined using standard procedures. GIS was used to determine the extent of land cover by Asa dam and its downstream environment including the length of River Asa in respect to sampling points. This was achieved through the map generated from satellite imageries and the use of GPS This paper presents and discusses the results of laboratory analyses undertaken, spatial variability in the level/concentration of the water quality parameters as well as the consequences of sustained use of River Asa water without treatment for domestic purposes The results show that the quality of R. Asa downstream of the dam was impaired to different degrees using WHO standards for the selected parameters and landuse types. Consequently, using the water for domestic purposes in particular as currently obtains in the area, portends grave danger to human health and the situation will be worse in nearest future if necessary control is not put in place.

***Keywords:*** land use, water quality, asa

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**HS2004** **Poster presentation** **4236**

# Estimation of the water consumption over the irrigated area along downstream of the Yellow River

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***Dawen Yang; Xinbing Liu; Shinjino Kanae***

Water shortage has became more and more serious in the Yellow River basin because of the expansion of irrigation area and overirrigation, which has resulted in the drying up in the main river during irrigation season since 1972. Therefore, the primary task for the agricultural irrigation in this area is to understand the water consumption and improve the water use efficiency. In this research, a case study was carried out in the Weishan Irrigation District along downstream of the Yellow River. This region, where the crops are dominated by the winter wheat and summer maize rotationally, has little water inflow and takes about 1.3 billion cubic meters water for irrigation from the Yellow River annually. According to the meteorological data of more than 40 years from three weather stations together with the discharge and irrigation water data, the long-term changes in precipitation, air temperature, pan evapotranspiration, irrigation, actual evapotranspiration and discharge were examined in order to investigate the water use situation and the influences of climate variability and irrigation on the water resources. Moreover, the interactions among the water use, irrigation areas, and crop yield were investigated during the 1970s to 1990s. Particularly, in order to identify the mechanism of water consumption in the coupled land-atmosphere system, the seasonal variation of water balance under the effects of meteorology and crop was analyzed from the year 2005 to 2006 at a flux observation station located at the center of this region. Meanwhile, a land surface process model was used for simulating the energy-water fluxes, and was compared with the in situ measurements.

***Keywords:*** irrigation, water consumption, land surface process model

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**HS2004** **Poster presentation** **4237**

# Slug test interpretation along contact zones in crystalline rocks: A case study from Andhra Pradesh, India

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Extremely high variability of the hydraulic parameters and uncertainties and ambiguities in their interpretation compels to carry out experiments at many places to capture the variability of the parameter but it makes the whole study cost ineffective. Thus a variety of hydraulic tests are employed depending on the hydrogeological conditions and other factors such as cost and feasibility. Obviously less expensive and simple tests are thus preferred so that they could be performed at numerous places. The present study deals with the characterization of the hydraulic properties of hard rock aquifer along contact zones with the help of slug tests carried out in the Maheshwaram watershed in the Ranga Reddy district of Andhra Pradesh. The slug tests are comparatively less expensive and less time consuming method for determining the local hydraulic conductivity of an aquifer. The results of slug-tests can be affected by a number of factors and most of these result in under estimating the permeability values of the formation. One of the most significant factors responsible for giving these low values of permeability by slug tests is the presence of well skins, which is a zone of altered permeability immediately surrounding the well caused by drilling disturbances. The radius of formation affected by slug tests generally lies between 1m and 2m (Rovey, 1998) and hence measure the K values immediately around the borehole. The results of permeability thus obtained are biased by the affect of bore well skin. Six slug tests have been carried out at the contact zone of granites and quartz in the watershed and the results have been interpreted using the Bower and Rice method (1962). The hydraulic conductivity calculated fall within the same order of magnitude for all the wells and no special influence of the structural feature in the form of quartz vein is evident from these tests. The results lie within the same order of magnitude as obtained away from the contact zones by Marchal et al, 2004. As already stated that a very small formation volume is involved in slug tests, it cant give a global permeability of the aquifer on a watershed scale and also the influence of the structural disturbance is highly under rated. Long duration pumping tests can be useful in analysing the impact of these structural features on the hydraulic property of the aquifers along the contact zones. Although, the slug test interpretation provide local and some times very local permeability but this method combined with Discrete Fractured Network Models and Application of the Theory of Regionalized variables have provided meaningful results in regionalizing as well as up-scaling the parameter.

***Keywords:*** slug test, contact zones, hardrock aquifers

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**HS2004** **Poster presentation** **4238**

# Ensemble Kalman Filter Data Assimilation for a Coupled Model of Surface and Subsurface Flow

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In this study the ensemble Kalman filter (EnKF) is implemented in a detailed catchment-scale hydrological model that couples a three-dimensional finite element Richards equation solver for variably saturated porous media and a finite difference diffusion wave approximation based on a digital elevation data for surface water dynamics. In data assimilation, the Kalman filter (KF) updates the system state based on the relative magnitudes of the covariances of both the observations and the model state estimate. EnKF has been demonstrated to be a valid alternative to KF for nonlinear filtering problems, and is based on the approximation of the conditional probability densities of interest using a finite number of randomly generated model trajectories. We describe the implementation of EnKF for our coupled groundwater--surface water model, and will examine issues of robustness and computational efficiency, important for such a detailed numerical model characterized by strong nonlinearities in the pressure--moisture and pressure--conductivity relationships and by complex interactions across the land surface boundary. The implementation is tested for a synthetic soil moisture profile retrieval experiment described in Entekhabi et al. (IEEE Trans. Geosci. Remote Sensing, 1994). In this column experiment surface observations are assimilated to retrieve the true moisture profile starting from a poor estimate of the initial moisture state of the system.

***Keywords:*** ensemble kalman filter, richards equation, coupled model

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**HS2004** **Poster presentation** **4239**

# Reduction of predictive uncertainty in flows at ungauged basins

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***Dave L.E.H. Deckers, Tom H.M. Rientjes, Maarten S. Krol***

The prediction of flows at ungauged basins is the centre of attention in hydrology due to the Predictions in Ungauged Basins (PUB) initiative. One of the aims of PUB is to reduce the predictive uncertainty in modelled flows at ungauged basins. The objective of this study is to contribute to the reduction of predictive uncertainty in flows at ungauged basins through application of a regionalisation method to 56 well-gauged basins in the United Kingdom. The classical approach of regionalisation is adopted, where relations between calibrated hydrological model parameters and physical characteristics of the basin are established and used to estimate parameters at ungauged basins. The conceptual hydrological model HBV is used to simulate the hydrological regime of UK basins. The calibration of HBV is done using a fuzzy measure as objective function. This fuzzy measure combines four objective functions for simulation of the average discharge regime, floods and low flows. In this way, optimal parameter sets for 48 basins, regarded as gauged, are determined. The physical characteristics of the basins are selected based on previous research on regionalisation using HBV and the availability of data on these characteristics for the UK basins. These are basin area, average elevation, hypsometric integral, basin shape, land use type, permeability of bedrock and average annual precipitation. Relations between calibrated parameters and physical characteristics are established using multiple linear regression. The parameters for the remaining 8 basins, regarded as ungauged, are estimated using these relations enabling a kind of validation. Moreover, it can be verified whether the predictive uncertainty is reduced when using regionalised parameter values instead of default ones. The HBV calibration resulted in optimum parameter sets for 48 basins. The basins to be included in the regression analysis are selected by introducing two conditions which have to be satisfied. These two conditions are related to the absolute values of two objective functions used in the fuzzy measure (Nash-Sutcliffe coefficient and relative volume error) and frequently used in the literature. This finally resulted in 24 basins for the regression analysis. Preliminary results of the regression analysis show only for a few combinations of HBV model parameters and physical characteristics of the basin significant relationships. In particular, relations related to the soil moisture routine in HBV seems to be promising. Further analysis in the next few weeks will reveal all significant single and multiple relations. Furthermore, improvements with respect to the default situation and deteriorations with respect to the gauged situation will be revealed.

***Keywords:*** regionalisation, multiple objective function, uk catchments

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**HS2004** **Poster presentation** **4240**

# Integration of a hydrological model within a geographical information system

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***Sidiropoulos Epaminondas, Loukas Athanasios***

The object of Operational Hydrology is to control the operation of water systems and to provide aid in dealing with problems of water use and water management. Watershed simulation software used for operational purposes must possess both dependability of results and flexibility in parameter selection and testing. The UBC watershed model, created initially at the University of British Columbia, has been extensively applied and tested in watersheds around the world, under a great variety of climatic conditions and physiographic characteristics. Also, it contains a wide spectrum of parameters expressing meteorological, geological, as well as ecological watershed characteristics. The UBC source code has been rewritten in a Visual Basic 6 environment and subsequently the hydrological model was coupled to the MapInfo GIS, via code written in MapBasic, the programming language associated to MapInfo. The software thus created was named Watershed Mapper. Watershed Mapper is endowed with several features permitting operational utilization. These include input data and basin geometry visualization, exporting of statistical results and thematic maps and interactive variation of disputed parameters. For the application of Watershed Mapper, the watershed of Germasogeia in Cyprus was selected. It is located to the north-east of the city of Lemesos with an extent of 160.4 km2 and an average geographic width of 34o49. At the outflow of the basin the Germasogeia dam is situated providing with water all the surrounding regions. In the example of Germasogeia, data from digitized maps were used. The elevation data came from contour lines of 20 m from maps of scale of 1:50.000. Maps of the same scale were used for the extraction of geological and land cover data. The Germasogeia area is afflicted with problems of water scarcity. Land use and the extent of canopy affect significantly the hydrological regime of the basin. Possible scenarios of land use changes and restructuring of cultivations are introduced into the Watershed Mapper and their effect is evaluated on the hydrology of the watershed. Related sensitivity studies are also carried out. The impacts on land use and cultivation pattern changes could be easily evaluated and facilitate decision making.

***Keywords:*** watermanagement, gis, landuse

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**HS2004** **Poster presentation** **4241**

# Assessing prediction uncertainty in the BIGMOD model: Shuffled complex evolution metropolis algorithm approach

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There are a number of computer models being used in Australia to support the development and implementation of salinity management strategies in the River Murray system. BIGMOD is one such model used by the Murray Darling Basin Commission to make flow and salinity predictions. The model covers about 2000 km of the River Murray between Dartmouth Dam and Lake Alexandrina. The BIGMOD model was originally calibrated against historical data. The calibrated model has been used extensively to provide salinity predictions to Murray Darling Basin managers who have been making important salinity management decisions based on the predictions. The accuracy and reliability of the model predictions play a vital part in the success of the salinity management strategy. However, like predictions obtained with any other complex and large scale hydrological and water quality model, the BIGMOD model predictions contain uncertainty. Traditional uncertainty analysis approaches can be used successfully to quantify prediction uncertainty in simple hydrological models. However, these methods cannot be used with large integrated model such as BIGMOD, as computational requirements are too high. This study focuses on estimating the confidence intervals for BIGMOD salinity predictions by quantifying the uncertainty associated with significant parameters in the BIGMOD model using the recently developed Shuffled Complex Evolution Metropolis (SCEM-UA) algorithm. The SCEM-UA algorithm is an adaptive Markov Chain Monte Carlo sampler. It is an efficient parameter uncertainty assessment algorithm that combines the strengths and capabilities of two well-known algorithms, the Shuffled Complex Evolution-University of Arizona (SCE-UA) global optimization algorithm and the Metropolis algorithm. The Metropolis algorithm ensures that the SCE-UA algorithm does not converge to a unique best parameter set, while the SCE-UA algorithm allows shuffling that improves the efficiency of the Metropolis algorithm. The resulting SCEM-UA algorithm is capable of estimating the most likely parameter set and the underlying posterior distributions within a single optimization run. Part of the South Australian reach of the River Murray system, from Lock 5 to Morgan was modelled in this study. The salinity predictions at Morgan are an important consideration as it is necessary to implement salinity management strategies which would guarantee that by 2020, the salinity of the water in the River Murray at Morgan is less than 800 EC for 95% of the time. Prior knowledge of the modeling processes under investigation was used to select the significant parameters whose uncertainty was assessed using the SCEM-UA algorithm. These parameters include travel time, volume of dead storage and the pan factor. The 95% prediction uncertainty associated with salinity predictions at Morgan were computed using 10,000 samples of parameters generated after convergence to a posterior distribution. The results illustrate the importance of uncertainty assessment of model predictions and give valuable information to managers enabling them to make more informed decisions about the feasibility of potential salinity reduction strategies.

***Keywords:*** parameter uncertainty, prediction, salinity

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**HS2004** **Poster presentation** **4242**

# Prediction of rainfall - runoff model parameters in ungauged catchments

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Although a great deal of experience has been gained with parameter estimation methods for ungauged catchments, there is a continuing need to upgrade these methods and to test them against practical requirements, since the problem of regional parameter estimation still constitutes the largest obstacle to the successful application of models in ungauged catchments. The paper presents a modification of a common procedure used in model parameter estimation in ungauged basins Aim of the study was to derive parameter values of conceptual rainfall-runoff model by various regional methods using physiographic characteristics of ungauged catchments as also spatial interpolation methods. As a study area the Hron River basin to station Brehy was selected and divided to 23 sub-catchments. Data of daily flow, precipitation and air temperature time series needed for calibration of the model were collected and values of physiographic characteristics were derived for each sub-catchment. Lumped conceptual rainfall-runoff model built on HBV model principles was applied. Model consists of snow, soil and runoff routines, uses daily sub-catchments average values of precipitation, air temperature and runoff, monthly values of potential evapotranspiration and has 15 parameters to calibrate. Several regionalisation methods for parameter estimation at ungauged catchments based on spatial averaging and interpolation, spatial proximity, similarity measures and multiregression relationships to physiographic characteristics were applied and tested. The regionalisation methods were finally compared by simulation of runoff computed by calibrated as well as regionalised model parameters to observed runoff. We can conclude that regional methods for estimation of model parameters can be considered as applicable for rainfall-runoff modeling in ungauged catchments in the Hron region of Slovakia.

***Keywords:*** ungauged catchments, model parameters, regionalisation methods

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**HS2004** **Poster presentation** **4243**

# Modelling the Effects of Afforestation on Streamflow: Efficiency and Robustness: Mechanistic vs Transfer Function Modelling

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***Kyle Tomlinson, Graham Jewitt, David Le Maitre, Mark Gush***

Several sets of experimental catchments were set up in South Africa between 1935 and 1980 to assess the impacts of afforestation on streamflow. Measurement concentrated on rainfall and streamflow, but other climatic data such a temperature were also captured. Regulation of commercial forestry has been based on several analyses of this data. The analyses have moved from nomographic on an annual time-step, to statistical on a monthly time step; to, most recently, mechanistic on a daily time step. The mechanistic model used is one dimensional, and has some seventy parameters. In this study, a daily step transfer function model using less than ten parameters was derived. The robustness and predictive power of the model is compared to that of the mechanistic model. The results of the exercise may be used to identify redundancies and shortcomings in the mechanistic model, particularly concerning the prediction of low flows. These periods are crucial in riverine and water resources management, under South Africas water-poor conditions.

***Keywords:*** afforestation, model, robustness

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**HS2004** **Poster presentation** **4244**

# Estimation of the Maximum Runoff for Very Deep Charcoal Quarries

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Motru's piedmont in Romania is a well-known coal basin that disposes of lignite lenses that occur from 2-7 m under the soil, down to tens of meters deep. The energy needs imposed the elimination of the soil and the implementation of quarry exploitations, which created a new landscape such as terraces, earth dams and steep slopes that disorganized the hydrographic basins and the natural discharge. The present article evaluates the new characteristics of the maximal runoff from the Rosiuta perimeter, where more than 500 mil. m of soil, sand, clay and lignite were removed from a surface of around 800 ha, in some places the digging reaching 90 m of depth. This study is necessary for the estimation of new risks of flash flooding, much higher today than before, threatening the villages in the affected area. Because these are ungaged basins, both the scenario of maximal discharge before impact and the one after impact are realized through indirect, GIS-assisted methods. Noting that the heavy rainfall intensity didn't change in the last 25 years, since the works on the quarry started, the rational method was used. Examining maps drawn before impact and topographical relevees after impact, we used GIS functions to quantify the land use reality at the two moments; the resulting grid data being used to create the two scenarios. The increase of the maximum discharge on new surfaces much more steep and lacking a protective soil and vegetation layer is carefully detailed. The comparison between scenarios shows the increase rate in the risk of flash flooding, as well as the danger that menaces the neighbouring settlements.

***Keywords:*** maximum runoff, gis, charcoal quarries

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**HS2004** **Poster presentation** **4245**

# Empirically-Based Generator of Synthetic Radar-Rainfall Data

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***Witold F. Krajewski, Grzegorz J. Ciach***

Large uncertainties are associated with radar rainfall (RR) estimates by the U.S. national network of WSR-88D radars. These errors are due to the combined effects of not fully understood physical processes, parameter estimation, and the measuring device itself. However, RR estimates are deterministic products and neither producers nor users know quantitatively the magnitude of the uncertainties associated with them. Their quantitative knowledge would be beneficial in propagating radar rainfall errors through all those models for which RR is used as initial condition, such as precipitation forecast, or as input (e.g., hydrologic models). This would result in improving our understanding and interpretation of the obtained results. A possible solution to this problem would be to provide radar rainfall estimates in a probabilistic form. The authors developed an empirically based model, in which the relationship between true and radar rainfall can be described by a deterministic distortion function and a random component. These two components are estimated through a nonparametric approach and the true rainfall is approximated by rain gauge measurements. The proposed results are based on a large sample of six years of Level II data from the Oklahoma City radar site (KTLX). The radar data are complemented by rain gauge measurements from the Oklahoma Mesonet, and the Agricultural Research Service Micronet. This model has the flexibility to account for different spatio-temporal resolutions, distances from the radar, synoptic conditions, and space-time dependence of the errors. Additionally, the effects of the selection of different Z-R relation on the parameters of the model components are discussed. In this paper, two possible scenarios are presented and described: an ensemble generator and a static estimation of probability maps. In the former, given a time series of hourly radar rainfall fields, a user can generate an ensemble of synthetic RR data congruent with the error models characteristics. As far as the second scenario is concerned, given hourly RR maps, it is possible to generate fields with the probability of exceedance of some arbitrary thresholds by the true rainfall. The authors discuss possible applications of both scenarios in forecasting and hydrologic models.

***Keywords:*** errors in radar rainfall, ensemble forecasting, radar hydrology

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**HS2004** **Poster presentation** **4246**

# Hydrological Simulation and Prediction in Environment Change

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With the impacts of the climate change and the heavy human activities, a remarkable decreasing trend of flow has been recognized along main rivers in China. In this paper, first of all, the flow data series of controlling gauge-stations along main rivers were presented, and the decreasing trends of the data were analyzed. Secondly, the hydrological simulation, flood forecasting models, flood forecasting systems and their application in China were briefly introduced. Finally, it was pointed out that the new hydrological prediction methods, models and systems, such as the distributed hydrological model based on the geography information, should be studied and developed as the measured long-time data series will become no-useful for model calibration with the environment change.

***Keywords:*** hydrological, simulation, environment

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# Analyse des priodes sches pour la gestion dun barrage au Nord de la Tunisie

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***Lebdi Fethi***

Cette contribution porte sur lemploi de lanalyse des priodes sches pour la gestion des barrages rservoirs sur une base diffrente de celle des observations faites intervalle de temps rgulier. Le cas dtude est le barrage Ghzala localis au Nord de la Tunisie climat mditerranen. Les vnements secs sont constitus dune srie de jours secs encadrs par des vnements pluvieux. Un vnement pluvieux est une srie ininterrompue de jours pluvieux comprenant au moins un jour ayant reu une prcipitation suprieure ou gale un seuil de 4 mm. Les vnements pluvieux sont dfinis par leurs dures et hauteurs qui ont t trouves corrles. Une analyse de la hauteur de pluie par vnement conditionne par la dure de lvnement a t effectue. La loi binomiale ngative apparat la meilleure loi pour lajustement de la hauteur de pluie par vnement de dure un jour. La dure de lvnement de pluie suit la loi gomtrique alors que celle de lvnement sec suit la loi binomiale ngative. La loi Gamma sajuste la longueur de lanne hydrologique. Une procdure de simulation de lois de probabilit a t excute pour gnrer des squences synthtiques dvnements pluvieux et secs avec les longueurs correspondantes des saisons de pluie. Ces squences permettent de dfinir et de calibrer des modles de simulation pour la planification raliste des rservoirs, lestimation de la demande en eau dirrigation et ltude des effets dun changement climatologique.

***Keywords:*** priode sche, vnement pluvieux, gestion de barrages

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# Water Resource Research of Distributed Hydrologic Model in Ningmeng Irrigation Area

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Water resource is the one of the most important resources in society development and more and more human activities have been performed on river basin. and climate changed at the same time. As the result, spatial and temporal change of the water resource in distribution and quantity has occurred and the underlaying surface becomes more and more complex. With this situation, we need more spatial information to analysis the water resource distribution and the influence of human activities impact on. So the traditional conceptual hydrologic model isnt competent for the prediction and management today. Then we employ distributed hydrologic model with GIS and RS to make some exploration research in this field. Distributed hydrologic model with physical foundation can de the mechanism of hydrologic process exactly and makes parameters distribution into consideration fully. The LL-III (Developed by Prof. Lilan, WuHan University) is one of the full distribution hydrologic model in the world, which had participated in Distributed Model Intercomparison Project (DMIP) host by The Hydrology Laboratory (HL) of the National Weather Service (NWS). In this model, GIS, RS and Radar rainfall data and information, such as DEM, landuse, soil data, water conservancy information, are made use to modeling hydrologic process. The research drainage basin is Ningmeng irrigation area located in Yellow River basin. This basin is influenced by a continental monsoon climate and the whale region is arid and semiarid, and agriculture irrigation is the main human activity which impact a large affection on water resource distribution and quantity. So we apply LL-III model to modeling and predict spatial and temporal change and distribution of water resource, which include rainfall, evaporation, runoff, interception, infiltration and so on. According to the research, we find the distribution situation of rainfall, evaporation runoff, interception, infiltration and the variation of runoff and evaporation with rainfall, and water resource series Stat. data. This application is successful.

***Keywords:*** distributed hydrologic model, water resource, irrigation area

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# Analysis of the uncertainty generated by coincidence and superposition of floods in a braided river system

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***Csik, Andras, Szilagyi, Jozsef, Gauzer, Balazs***

Major floods on the Upper Tisza down to the confluence of the main river with tributary Bodrog usually are the results of the superposition of several flood waves from upstream sections and also their coincidence with floods of the tributaries. This phenomenon was the basis for simulation exercises which were carried out for a limited number of scenarios generated from the combination of a few historical events. A more complex approach using a hybrid, seasonal, Markov chain-based model for daily streamflow generation were also used combined with the DLCM based flood routing system of the complicated river network. Diurnal increments of the rising limb of the main channel hydrograph, increments of the ascension hydrograph values at the tributary sites and recession flow rates of the tributaries as well as of the main channel were distinguished and submitted to different statistical methods. The model-generated daily values retain the short-term characteristics of the original measured time series as well as the probability distributions and basic long-term statistics of the measured values. Additional investigations targeted the analysis of the possible causes of floods in upstream sections and helped to establish modified methodologies for the assessment of design floods. One of this group of tasks is to identify the common meteorological features occurring prior to floods. Large-scale atmospheric circulation patterns are considered for this purpose. The time series of these variables shows non-stationary behaviour. The time series of circulation patterns is investigated for the frequencies of the patterns and their duration. The relationship of the circulation patterns and discharge changes helps to identify the amount to which climate change or climate fluctuations are responsible for the unusual behaviour of the upper Tisza River. Results received produce possible future scenarios of flood events. This may help water managers to prepare for events that have not yet been observed in the past but none the less can be expected in the future.

***Keywords:*** tisza, hybryd markov chain, circulation patterns

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**HS2005** **4250 - 4311**

## Symposium
## Water Quality and Sediment Behaviour of the Future: Predictions for the 21st Century (Sponsor ICWQ, ICCE, ICGW, PUB and ICT)

**Convener :** Prof. Bruce Webb

From the local to the global scale, surface- and ground-water quality is becoming as important and as critical as water quantity. Over the 21st century, changes in climate, land use and population, among other factors, will affect many different aspects of freshwater quality, often to the detriment of aquatic ecosystems and human use of water. The objective of this symposium is to bring together experts to provide a state of the art review of our current understanding of the potential water quality changes resulting from climate and land use change during the 21st Century. It will interpret water quality broadly to include not only chemistry but also sediment and sediment-associated substances, as well as other quality aspects such as temperature for both surface waters and groundwater. Water quality has been identified in the PUB Science Plan as an integral part, and this Symposium would contribute to PUB activities. The focus of the proposed Symposium would be on the following major themes: - How will the water quality of the surface and subsurface, and the interactions between these environments, and the behaviour of sediment change in response to changes in climate, land-use, population and other driving factors during the 21st Century? - How will point and diffuse sources of pollution change over the next 100 years and how will they impact on water quality? - What will be the impacts and implications of changes in water quality and river sediments during the 21st Century for human use of water and for freshwater ecosystems? - How well is the science of water quality and sediment behaviour for these environments equipped to understand and model future changes in water quality and the challenges they will pose? - How can we improve and develop our ability to predict surface- and ground-water quality, including our ability to cope with the uncertainties inherent in these predictions? - How much will ungauged basins be used and how do methods of analysis need to be adapted to these circumstances?

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**HS2005** **Oral Presentation** **4250**

# Heavy metal pollution in a highly regulated river

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Dams and weirs are efficient traps for sediments and pollutants. Their physical presence interrupts the downstream conveyance of material which can lead to changes in sediment composition both within impoundments and along the river system. The 830-km Lower River Murray, in SE Australia, is regulated by a series of 10 weirs, constructed in 1929-35. Large quantities of sediment have accumulated in each of the weir pools as a consequence of catchment denudation and channel adjustments due to flow regulation. Surface sediment samples taken along 100 kilometres of the river between weirs 2 and 4 demonstrate the impact of these structures on the textural and geochemical composition of the sediment. Downstream of the weirs surficial sediments are well-sorted medium sands grading to poorly-sorted fine sands above the next successive weir. Concentrations of Cr, Cu, Ni, Pb and Zn have increased over time, and levels of Pb and Zn in the uppermost layers of sediment now are five times those in pre-1950s sediments, reflecting increased urban development in the upstream catchment. Heavy metal concentrations display distinct spatial patterns along each weir pool. Peak heavy metal loadings in the surface sediment occur in the depositing areas above the weirs rather than the near vicinity of the urban areas. Thus maximum disturbance is at a distance from the urban development. Heavy metal loads are amplified by changes in sediment texture, thus the spatial pattern of these pollutants may reflect changes in sediment transport associated with flow regulation. With further urban development planned for this section of the River Murray future consequences of heavy metal pollution is modeled.

***Keywords:*** sedimentpolltuion, weirs

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# Evaluation des methodes destimation de flux evenementiels de nitrate et datrazine sur un bassin agricole

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***Adilson Pinheiro, Flavie Cernesson, Jean Franois Dubernet***

Lestimation des flux de polluants sur un bassin versant est un problme rcurrent pour le gestionnaire des ressources en eau. La littrature prsente diffrentes mthodes destimation de ces flux. Ce travail a pour objectif principal lvaluation de lapplication de diffrentes mthodes pour lestimation de flux de nitrate et datrazine lors dvnements pluvieux gnrateurs de crues. De plus, on value la prcision des estimations de ces flux pour diffrents pas dchantillonnage. Les sries de donnes de dbits et de concentrations ont t acquises sur le bassin versant du Ruin, situ dans le sud-ouest de la France, et ayant une superficie de 5,47 km2. Ce bassin versant est quip depuis 1991, dune station de mesure de dbit et dun prleveur-chantillonneur, situs lexutoire principal. Les chantillons deau sont prlevs de faon manuelle toutes les semaines, et automatiquement, au pas de temps horaire, lors des crues. Dans cette tude, on retient les 18 vnements de crues, pour lesquels il y a eu un suivi complet des concentrations de nitrates et/ou datrazine. Ces vnements peuvent tre une crue simple constitue dun seul dbit de pointe ou une crue complexe prsentant plusieurs pics successifs. Par la suite, les sries horaires de dbits ou de concentrations ont t dsagrges aux pas de temps de 2, 4, 6 et 12 heures en partant de linstant de la premire mesure de concentration. Cinq mthodes destimation des flux de nitrate et datrazine ont t retenues. Le flux calcul avec les donnes horaires est pris comme rfrence. Deux critres dvaluation sont utiliss : (1) la diffrence entre le flux estim et le flux de rfrence pour chaque vnement, (2) puis, pour chaque pas dchantillonnage, le RMSE (Root-Mean-Square Error) dtermin sur lensemble des vnements. On constate des diffrences significatives et qui augmentent avec le pas de temps dchantillonnage. Les diffrences sur les flux estims pour latrazine sont systmatiquement plus importantes que pour les nitrates. Ainsi, les RMSE prsentent des variations comprises entre 0,07 et 0,28 pour les nitrates et entre 0,21 et 0,39 pour latrazine pour les flux estims partir dun pas dchantillonnage de 12h. Dans notre cas, la mthode qui prsente la meilleure qualit des estimations que ce soit pour les nitrates ou latrazine, est celle qui, pour chaque pas de temps, retient la moyenne des dbits aux bornes et la concentration de lchantillon. On dmontre que le choix dune mthode destimation est une tape pralable importante pour le gestionnaire, et quil est intressant de prendre en compte les incertitudes lies la mthode destimation ainsi adopte.

***Keywords:*** incertitude, flux de polluants, gestion de leau

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# Implications of changes in the river sediments on the freshwater ecosystems in the Northeastern region of India

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Water is critical for health both for human and ecological systems and an important element in many of our social and economic activities. The susceptibility of freshwater to degradation is a matter of concern in northeastern region of India and would be the key issue during 21st century. The major problem of facing the harmonious development and management of water resources in the region, apart from economic constraints, is the prevalence of shifting cultivation which involves deforestation, paucity of reliable data and lack of human and institutional capacity necessary to face the complex interactions of the hydrologic cycle with the societal needs and the environment. The gradual degradation, pollution and spatial and temporal scarcity of fresh water in northeastern region demand integrated water resources planning and management, considering quantity and quality aspects. Human interference has been identified as the major cause of degradation of freshwater ecosystems due to huge sediment generation caused by shifting cultivation, deforestation, and mismanagement of rainwater. The soil erosion is the major agent of lateral material transport on the anthropogenically disturbed lands of the region, affecting freshwater ecosystem and the environment. The use of newly evolved regression equation; sediment yield ( tha-1) = 41.73 + 0.187 x slope(%) + 0.046 x rainfall(cm) 0.387 x clay(%) 8.125 x vegetative cover ( in 1 to 5 scale), showed that the annual sediment delivery in the rivers of the region is 601 million tones. The sediment yield is expected to increase to about 981 and 1167 million tones by the year 2050 and 2100, respectively, considering the present decline in rainfall and drastic decrease in vegetative cover. This will substantially increase the river sediments, thereby increasing the flood incidences and magnitude, affecting the freshwater resources and environmental quality. In pursuit to increase agricultural production to feed the fast growing population in the region, an increase of 102%, 387% and 286% has been registered in the use of N, P2O5 and K2O fertilizers, respectively, between 1996-97 and 2001-02. This trend of use in agricultural chemicals will further degrade the freshwater resources and affect the health of human and aquatic ecosystem as well as alter carbon cycle, biological systems and life support ecosystem in the region. The demand for water will increase as a result of increase in temperature due to greenhouse gases, decline in rainfall and other human activities if this trend will not be curbed. Soil erosion and sediment transport are part of the natural evolution but to keep them within limits is of great importance for the security of fresh water resources. The measures required to ensure restoration, maintenance and sustainability of freshwater resources in the region are; introduction of eco-friendly, economically viable, socially acceptable and sustainable land use systems, increase in vegetative cover, judicious management and more in-situ retention of rainwater, discourage free range grazing, awareness and government will. A multidisciplinary long-term study, based on watershed approach, is in progress since 1983 to take care of these aspects and a lot of useful data has been generated and discussed.

***Keywords:*** river sediments, freshwater resources, northeastern region of india

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# Hydrogeochemistry of groundwater in a part of hard rock terrain of Central India

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Hydrogeochemical investigations have been carried out to determine the sources of dissolved ions in groundwater in a part of hard rock terrain of Central India. The high concentration of SiO2 and various geochemical signatures reflect the weathering of minerals. The chemistry of groundwater favours the formation of clay minerals due to evaporation. The positive saturation index of calcite and the higher ratio of Mg/Ca and Na/Ca also supports the occurrence of evaporation. The evaporation enhances the concentration of ions in groundwater during the summer. The high content of sulphate and chloride in some groundwater and the occurrence of kankar in the area suggest a long history of evaporation. Greater ion concentration in the groundwater of post monsoon compared with the pre-monsoon indicates the increasing addition of leachates into the groundwater from the soil and anthropogenic activities, which leads to a deteriorating quality of groundwater Gibb's diagram shows that the groundwater chemistry is controlled by rock weathering to some extent and evaporation is a dominant factor leading to the deterioration of quality of groundwater in the area.

***Keywords:*** hydorgeochemistry, hardrock, centralindia

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**HS2005** **Oral Presentation** **4254**

# Measuring the Fluxes of Suspended Sediment, Trace Elements, and Nutrients for the City of Atlanta, U.S.A.: Insights on the Global Water Quality Impacts of Increasing Urbanization.

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***Kent A. Elrick, James J. Smith***

During the mid-20th Century, through the beginning of the 21st Century, world urban growth has been substantial. Projections through 2050 indicate that while the growth rate may be declining, it will remain substantial. Between 1950 and 2050 the per-centage of the Worlds population living in urban areas is projected to increase from 29 to 67%. Population growth and urbanization cause impacts on local landscapes, on the quantity and quality of nearby rivers and streams, as well as on downstream receiving waters. Typical impacts may include: (1) disruption of the normal hydrologic cycle through increases in the areal extent of impervious surfaces that limit infiltration and raise the velocity and volume of surface runoff; (2) increased suspended sediment and chemical (organic, inorganic, and nutrient) loads to local and downstream receiving waters due to industrial sources, nonpoint-source runoff, and leaking and/or inadequate wastewater treatment facilities, or sewer systems; (3) direct or indirect soil contamination from industrial sources, power-generating facilities and landfills; and (4) reduction in the quantity and quality of aquatic ecological habitats. Atlanta, Georgia, has been and continues to be one of the most rapidly growing urban areas in the U.S. Between the early 1970s and 2000, the population of Metro-politan Atlanta increased by about 125%; contemporaneously, depending on the applic-able definition, urbanization increased between 115 and 210%. Beginning in 2003, the U.S. Geological Survey (USGS) established a major long-term water quantity and quality monitoring network for the City; the program may well be the single largest urban hydro-logy program in the U.S. The results obtained during the first three years of the program have provided unique insights into the requirements needed to accurately determine the extent of urban impacts on local and downstream water quality, especially in terms of estimating the annual fluxes of suspended sediment, trace elements, and nutrients. During 2004 and 2005 suspended sediment fluxes from the City to downstream receiving waters amounted to about 150,000 tonnes per year; ≥94% of the transport was event-driven. This occurred despite the relatively short-term duration of most runoff events, which, cumulatively ranged from a minimum of 6 to a maximum of 35% of the year, depending on the size of the drainage basin. As a result of both logistic and time-constraints, automatic samplers were required to help capture the extent of the transport. Normally, annual suspended sediment loads are determined by summing daily loads based on a single calculation step using mean daily discharge. Due to the relatively small size of Atlantas urban streams, and the short duration of many of the events, this ap-proach could lead to underestimations ranging from 25 to 64%. Accurate estimates (15%) required calculation steps as short as every two hours. Based on annual median chemical concentrations for baseflow and stormflow, the annual fluxes of about 90% or more of trace elements (e.g., Cu, Pb, Zn, Ni, Cr), major elements (e.g., Fe, Mn, Al), and total P occurred in association with suspended sediment. Hence, better than 90% of the transport of these chemical constituents occurred in conjunction with storms. As such, baseflow sediment-associated and dissolved contribut-ions represent an insignificant portion of the total annual load. One of the few exceptions was total nitrogen whose sedi-ment-associated fluxes ranged from 50 to 60%. Even so, the storm-related transport of total nitrogen exceeded 80%. The concentrations of chemical constituents in urban water can range over two orders of magnitude. Such factors as discontinuous point sources (e.g., illegal discharges, sewer overflows) and the length of antecedent dry conditions between storm events, contribute to the extent of the

variability. As such, the use of annual mean/median chemical concentrations, based on limited manual baseflow, and limited manual and autosampler storm sampling for load estimates, may lead to substantial over- or underestimates of actual annual urban chemical fluxes. As no acceptable surrogate could be identified to predict dissolved (filtered water) nor sediment-associated chemical concentrations, accurate chemical fluxes may only be produced through the collection of continuous composite samples using refrigerated autosamplers. For logistical reasons, these are being collected using fixed-time intervals rather than fixed-flow intervals. Typical weekly automatic sampler composites are produced by combining 56, 100 mL aliquots that are collected every 3 hours for 7 days. To limit costs, 2, 7-day composites are then combined prior to chemical analysis. A prototype program to evaluate the use of composite samples began in July 2003. Comparisons with fluxes based on annual median concentrations must await the conclusion of the prototype program in December 2006. The estimated annual sediment yields and chemical fluxes for Atlantas urban streams are markedly higher than values determined for other land-use categories, and similar annual flow rates. As such, continued urban growth is going to place a greater and greater strain on existing infrastructure (e.g., drinking water, wastewater treatment), as well as downstream water quality. Given the projected growth rate for urbanization, cities may well become the single most significant source of water quality impairment during the 21st Century.

***Keywords:*** urbanization, water quality, fluxes

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# Community based monitoring and the science of water quality

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Reductions in funding for hydrological monitoring by government agencies, the recognition of the need to involve communities and stakeholders in the planning and delivery of sustainability, increasing mistrust of the governments care of the environment and the continued rise in environmental consciousness are all factors which have led to the proliferation of community based monitoring (CBM) initiatives. CBM is a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track, and respond to issues of common community concern. The UNEP has stated that public participation is an essential component of sustainability, and it has been argued that the integration of community based monitoring into resource management is one of the most significant developments in this area since the environmental movement itself. The PUB Science plan, among other purposes, intends to actively promote capacity building activities in the development of appropriate scientific knowledge and technology to areas and communities where is it needed. This paper draws on the expertise and experience of working on CBM initiatives through Environment Canadas Ecological Monitoring and Assessment Network (EMAN) as well as the Community Based Environmental Monitoring Network in Nova Scotia. Examples are drawn from Nova Scotia, where community watershed groups have undertaken water quality monitoring activities in more than 10 of Nova Scotias watersheds. Since the early 1990s they have gathered in excess of 55 monitoring-years of water quality data at over 200 sampling sites. CBM initiatives, in close collaboration with government and academia, following standardized monitoring protocols with careful quality assurance and quality control programs, have the ability to address otherwise uncertain changes as a result of land use alterations and climate change. Science alone is not well equipped to model and understand future changes and scientists are even less equipped to reach decision-makers. The community serves a role and a purpose here.

***Keywords:*** community based, water, quality

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# The Distribution of Metal Concentration, as Co, As and Zn, in a Residential Urban Watershed, Typical in Brazilian Suburbs

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The environmental contamination by heavy metals has been a constant concern in areas of industrial activity, however little attention has been given to the research of metal presence in residential areas, especially in urban suburbs. In Brazil, these areas are characterized by the disordered urban development and mixed occupation of residences, business and services. In these areas there is normally no control on the sources of punctual pollution (domestic sewer and mineral oils) or diffuse pollution (sediments from paved and non-paved streets); and therefore it is important the accomplishment of studies to identify the presence of toxic pollutants, such as heavy metals, in these environment. This work was developed in an urban watershed of 0.83 km long in the suburb of the metropolitan region of Porto Alegre, and had as its main purpose to verify the metal concentrations of Co, As and Zn in the terrestrial and aquatic environments. Collections of samples (47 samples per km) in the main diffuse sources of the urban environment, represented by paved and non-paved streets had been taken, beyond the area with remaining vegetation, of the bed and the margins of the river. It was also studied the presence of metals in the fluvial sediments in suspension of this river that crosses the studied area as well as the geochemical compartments occupied by these metals. The results had shown that the metals studied distribute themselves all over the studied area; but the bigger concentrations were identified in the streets with more intense car traffic. In relation to the presence of metals in the fluvial sediments, they are found in concentrations above the reference values considered toxic for the health and the environment, according to the standards of metal concentration in sediments stipulated for the Brazilian Guidelines. But in relation to the metal presence in different geochemical compartments of the fluvial sediments in suspension, they had been determined through sequential extractions and had shown that both Co and As, are found mainly in the crystalline phase of the sediments, offering little risk to the aquatic environment. Nevertheless, Zn presented concentration distributed among the organic matter (10%), oxides (50%) and carbonates (30%), what represents a greater mobility of the metal in the aquatic environment, and it can be discharged if occur changes in the pH and/or in the Eh of the water. Thus, it was observed that the studied area presented high concentrations for the three metals studied, even it was not in an industrial area, but that according to the results presented by the sequential extraction, only the Zn offers a greater risk of contamination in the aquatic environment, just by being absorbed in geochemical compartments more susceptible to the influence of the aquatic environment.

***Keywords:*** sediment quality, metals concentration, urban watershed

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# The appropriate use of catchment models for water quality target setting and land use management

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***Jon Brodie, Lex Cogle***

Management of land use and water quality on the whole-catchment scale is typically constrained by a lack of observational data on which to base decisions. Typically, GIS-based models are used to interpolate and extrapolate a limited observational data set to cover an entire catchment and these derived values are used subsequently as input to catchment contaminant generation and transport models. Catchment model predictions using these derived values often provide the foundation upon which water quality targets may be set and alternative land use management scenarios compared. Here, we examine the impact of the intrinsic uncertainty in such derived values on catchment model predictions and the consequences of this uncertainty for land use management planning. The catchment sediment and nutrient model, SedNet/ANNEX, is applied to all catchments contributing significant human-enhanced nutrient loads to the Great Barrier Reef in Queensland, Australia. Model input values derived using remote sensing techniques to estimate bulk soil properties from a sparse data set (% clay, % phosphorus, % nitrogen) exhibited both a high bias and high standard deviation when compared with direct measurements of soil properties. The high bias limits the usefulness of model predictions for setting quantitative targets often desired by organisations responsible for large-scale resource management and policy formulation. The high standard deviation requires model results to be aggregated over scales considerably larger than the intrinsic model grid to facilitate comparison of contaminant export rates between spatial units, i.e. to target contaminant-generating hot spots. This impacts particularly upon groups responsible for site selection and implementation of land management practices. Assessment of competing land management scenarios is not severely impacted by model uncertainty provided the interpretation of results is limited to relative changes in contaminant export. As well, model predictions are compared with observed sediment and nutrient loads for a number of locations impacted by intensive agriculture and grazing. Sediment and dissolved nutrient loads are well predicted whereas particulate nutrient loads exhibit a much greater absolute error. The difference in the accuracy of particulate and dissolved nutrient load predictions can be explained on the basis of the mechanisms used in the model to generate loss of the different nutrient forms from the landscape.

***Keywords:*** catchment modelling, sediment, nutrients

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# Assessing water-sediment geochemical processes of metals in rivers polluted by mining, to predict environmental impacts in developing countries.

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Mining activities are one of the most important pollution sources of metals in countries with ore extraction tradition. Millions of tons of wastes settled on river shores may release toxic elements to the rivers. Once in the water, metals and metalloids may be transported long distances affecting ecosystems. However, the pollution extent depends on complex processes occurring within the river water and the bed sediments. Water-sediment geochemical processes influencing As, Pb, Zn, Cu and Fe mobilization were investigated in a river flowing in the historic mining area of Taxco, Mxico. Total and fractionated contents of metals in sediments; physico-chemical parameters, main ions and heavy metals in water, were determined from samples taken along the river. Metal processes and environmental impact were determined through geochemical modeling and multivariate statistics. Wash off and acid mine drainage of tailings, jointly with mine water discharges, have led to concentrations of metals in sediments well above the regional background: Pb (up to 9140 mg/kg), As (up to 1030 mg/kg), Fe (up to 76000 mg/kg), Zn (up to 19364 mg/kg), and Cu (up to 466 mg/kg). Zinc and lead associate mainly to the carbonate fraction of sediments followed by Fe oxi-hydroxides and organic matter/sulfides fractions. Arsenic and Fe concentrate in the residual fraction followed by organic matter/sulfide and Fe oxi-hydroxides. Copper is present mostly in the residual and carbonate fractions. Metals are mainly transported as particulates in the water. Total contents in the dry season were: Fe (up to 0.6 mg/L), Pb (up to 0.25 mg/L), Zn (up to 3.50 mg/L), Cu (up to 0.05 mg/L), and As (up to 0.0463 mg/L). Concentrations of dissolved Fe, Cu and Pb were below detection levels, As reached 0.037 mg/L and Zn 1.90 mg/L. Hydrogeochemical modeling showed oversaturation of calcium, silicate and iron minerals, reflecting the drainage basin geology and the tailings influence in the water. This influence determines also the contaminants behavior. Zinc and lead form carbonate and bicarbonate complexes that enrich the sediments. Iron, As and Cu are mainly released as sulfides from tailings. Dissolved arsenic and zinc interact with iron oxi-hydroxides and settle onto the sediment bed. Principal components analysis indicated that Zn, Cu and Pb may be released to the water column upon small changes on physico-chemical and/or hydrogeological conditions. A simple filtration would produce water complying with drinking water standards in most sites. However, use of raw water for irrigation may increase metals contents in crops. Presence of limestones plays a key role on the contaminants behavior. Application of straightforward analytical techniques jointly with geochemical and statistical evaluation of results may be an affordable alternative to clarify the environmental impact of mining wastes in developing countries.

***Keywords:*** mining, metals mobility, multivariate statistics

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# The assessment of groundwater vulnerability in China

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China is one of the countries being severely short of water resources, with only 1/4 of the world average per capita. According to the results of new investigation from 2000 to 2002 in China, the fresh groundwater is about 883.7 billion m3, which covers 1/3 of the total water resources. Moreover, the groundwater plays an important role in water supply, nearly 20% of the total water consumptions depend on groundwater. Especially in regions of north China, such as Beijing, Hebei, Shanxi, Henan, Shandong and Liaoning, the percentage of ground water supply exceeds 50%, some even up to 80%. Under such a great amount exploitation, as well as unreasonable development ways and means, many environmental problems caused by groundwater pollution and overexploitation are presented against human beings. Therefore it is crucial to understand the characteristics of ground water quantity and quality, then to adopt reasonable exploiting ways to keep groundwater utilization sustainable. Groundwater vulnerability is referred to the potential possibility that to be polluted due to some unexpected reasons. It results from the complicated influences of geomorphology, geology, climate, etc.. The assessment of groundwater vulnerability is the foundational work to maintain sustainability during groundwater development and protection. In this paper, a research on assessment of groundwater vulnerability in China is carried out combining with the Second National Water Resources Integrated Planning (NWRIP) from 2002. Based on abundant data related to groundwater and GIS software, an integrated assessment model is developed to evaluate the groundwater vulnerability throughout the country. According to data availability, an index-system with 8 key indices is established, which consist of slope, soil media, aquifer media, aquifer capacity of water storage, shallow groundwater depth, recharge by infiltration, groundwater exploitation coefficient, soil organic content, etc.. The unit assessment is based on grid with size of 1km*1km, and then aggregated to the third-class subareas of water resource to do statistics and analysis (there are total 214 subareas according to the Second NWRIP). Depending on the scores of each grid unit and subarea, the spatial distribution of groundwater vulnerability in China is analyzed. In brief, the groundwater vulnerability increases from north to south, as well as from west to east. And slope, shallow groundwater depth, aquifer media are the top 3 dominating factors influencing the groundwater vulnerability in China.

***Keywords:*** groundwater vulnerability, assessment, integrated assessment model

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# Kohonen Self Organising MAP (KOSOM) extracted features-enhanced MLP-ANN prediction models for BOD5

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The dissolved oxygen used during the bacterial oxidation of organic pollutants, usually determined under standard conditions of incubation of 20 over five days, is known as the 5-day biochemical oxygen demand or BOD5 and has been used for a long time for assessing water quality, the biotreatability of wastewater, the performance of wastewater treatment operations and the assessment of organic loadings to treatment plants for the purpose of sizing aeration facilities. The BOD5 is also an important index of discharge consents for wastewater treatment plant facilities in many countries. However, despite its significance, the usefulness of the BOD5 for the effective monitoring and control of water pollution is hampered by the long time it takes to obtain an estimate, which precludes its use in real-time. For example, if there is sustained excessive depression of the dissolved oxygen content in a river due to the discharge of inordinately large amount of organic pollution, it means that it will take a delay of 5 days before the problem can be effectively diagnosed and remedial actions taken, which may be too late. This makes it very desirable to have a rapid and reasonably accurate inferential model for BOD5 prediction, thus removing the five-day time delay that is inherent in its laboratory-based, bioassay measurement. On the other hand, efforts to solve this problem by the development of more rapid biosensors have met with limited success. This paper presents the results of developing soft sensors for the rapid prediction of the BOD5, using a large array data from a main wastewater treatment facility in Edinburgh, Scotland. The analysis comprised two aspects. First, multi-layered perceptron artificial neural networks (MLP-ANNs) were developed to predict the BOD5 from other easily measurable water quality determinands like flow, suspended solids, pH and COD, using the available large array data. Then using the Kohonen self-organising maps (KSOM) modelling, significant features of the original large array of data were extracted and the resulting low-dimensional data were again used in developing a new set of MLP-ANNs. The results show that although the ordinary MLP-ANNs performed satisfactorily in reproducing the BOD5, the KSOM features-enhanced MLP-ANNs were much better and in some cases matched the observed BOD5 exactly. This study offers significant potential for more timely intervention and cost saving during problem diagnosis in wastewater treatment and during water pollution control activities.

***Keywords:*** bod5, ann, kosom

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# An Assessment of water quality changes within the Athi and Nairobi river basins in the last decade

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This paper examines the changes in water quality that have occurred within the Athi and Nairobi river basins in the last decade. The main focus is to examine the trends in water quality degradation, pollutant sources and pollution levels since 1090's to 2000. It draws its major findings from two research works done within the basins over the last decade. The two research works revealed increasing trends in water quality degradation due to changes in land use systems. Industrial, population (rural-urban migration) growth and agricultural activities were found to contribute significant amounts of water pollutants, thus degrading the water quality status in the two river basins investigated. This is a major concern to the water policy makers, environmentalists as well as the Kenyan government in general. This paper reviews some of the possible mitigation strategies as means of mitigating against future water quality degradtion trends and to abate the problem in good time. The use of riverine vegetation (macrophytes) and storm water run-off are recommended in reducing water quality degradation status in the basins and other similar catchment areas in the country. Plant species Commelina benglensius, Sphaeranthus napirae and Xanthium pungens proved useful in adsorbing some of the pollutants especially haevy metals.

***Keywords:*** waterquality, riverine vegetation, storm water

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# Modelling discharge, water chemistry and sediment load from a subarctic river basin: the Tanana River, Alaska

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The smog from large forest fires in 2004 and 2005 sporadically covered glacierized regions in the Tanana river basin, Alaska, which was found by field observations and satellite images. Considering the elevation effects on air temperature and rainfalls, the runoff analyses by the tank model reproduced reasonably time series of discharge, silicate and suspended sediment concentration of the Tanana River throughout the glacier-melt periods of 2002 to 2005. However, the correlation between observation and calculation was relatively low for the smog-covered periods of 2004 and 2005. The suspended sediment and the silicate originate mostly from the glacierized regions and the permafrost regions, respectively. The energy balance observed in a glacierized basin indicated that the positive-degree day approach (PDDA) applied tends to overestimate the glacier-melt amount and sediment load during the smog-covered periods. The consideration of the energy balance in addition to PDDA promoted the calculated results with r = 0.845 to 0.970 for discharge, r = 0.940 for silicate and r= 0.746 to 0.928 for suspended sediment concentration. The calculation revealed that the glacier-melt discharge occupies 63 to 83 % of the Tanana discharge in spite of 4.6 % glacierized area in the river basin. The impact of global warming and frequent forest fires on the Alaskan glaciers is now in a critical stage. A change in the mass balance by increasing glacier-melt and permafrost-melt could affect the eco-system in the Tanana and Yukon rive basins and also in the Bering Sea.

***Keywords:*** forest fires, glacier, tank model

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# Simulation by IPTM-CS model of pesticides found in surface water and groundwater of the Fucino Plain, Italy

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The Fucino Plain was the largest lake in Central Italy, totally reclaimed in the 1800s for agricultural purposes, with an extent of 130 km2. During the past 15 years historical farm crops, mostly wheat, potatoes and sugar beet, have been progressively replaced with more profitable horticultural crops. This transition to an intensive agriculture, characterized by double and sometimes triple harvest, has been accompanied by high water demand and by wide use of pesticides. Surveys conducted in 2004 and 2006 showed the presence of pesticides, mainly Linuron, Dicloran and Carbaryl, with concentrations ranging from 2.8 to 0.02 microg/L in surface water and from 0.5 to 0.03 microg/L in groundwater. By taking into account pesticide application, irrigation practice, rainfall, evapotranspiration, and soil characteristics, mathematical simulations were conducted using IPTM-CS (Chu and Marino, 2004). The latter is an integrated pesticide transport model for a canopy-soil system, using a semidiscrete solution method that integrates analytical and numerical techniques. Simulations were conducted to verify if measured pesticide concentrations agree with a conceptual model considering the amount of pesticide application and its transport into the water system by runoff or infiltration. Specifically, we have considered a sandy loam potato field of 10000 m2, in which the root zone ranges from 30 to 70 cm and the water table is from 1 to 2.6 m below the ground. Based on field permeameter experiments and available data, the permeability coefficient for the root zone is considered to be 6 x 10-6 m/s and for the vadose zone 6 x 10-5 m/s. Results indicate that Dicloran and Carbaryl are not persistent in the root-soil system and their simulated concentrations are very low (maximum values: < 10-5 microg/L); consequently, their presence in surface waters can be attributed to runoff. Conversely, simulations of Linuron, whose use has been banned in Italy since 2005, showed a higher persistence. This pesticide is washed by runoff only partially (10-15%) and a high infiltration rate has been registered. Where the root zone is thin (no more than 30-40 cm), Linuron concentrations in the vadose zone (< 1m from ground surface) range from 0.4 to 0.02 microg/L, showing slight accumulation process through the years and high sensitivity to rainfall and irrigation time and duration. To sum up, while law limit in Italy for pesticide concentration is 0.1 microg /L in groundwater, performed simulations suggested that use of Linuron in the Fucino Plain allows its transfer to surface water both by runoff and infiltration; whereas in thin vadose zones, this pesticide can reach the water table, justifying its presence in the shallow groundwater system. Accumulation processes in the vadose zone can increase pesticide concentration in groundwater, as a result of infiltration correlated with rainfall and/or irrigation.

***Keywords:*** pesticides, groundwater, simulations

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# Neuroevolution Methodologies Applied To Sediment Forecasting

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Neuroevolution (NE) is the application of a genetic algorithm to the development of neural networks. This approach is advantageous in situations where the performance of a model can be measured in terms of a specified set of straightforward outcomes, but difficult or impossible to create the correct syllabus of teaching and learning patterns for use in a supervised learning environment. The NE approach is starting to be applied to neural network hydrological modelling; the findings of Dawson et al. (2006) has demonstrated the potential benefits of using the relevant software packages and customisable technological toolboxes. NE has several advantages including the use of different target functions and optimisation procedures or measures of fitness such as relative error and the application of a timing error correction factor. This paper will report on the application of NE to sediment forecasting. The need to obtain accurate estimations of suspended sediment quantities is of great importance for both watershed management operations and environmental impact assessment. However, suspended sediment forecasting and prediction presents a significant modelling challenge, two fundamental problems being that suspended sediment transfer and throughput is 'source limited' and subject to 'hysteresis effects'. Previous modelling attempts have focused on the use of conceptual models with empirical foundations that attempt to approximate the physical processes in a catchment. More recent suspended sediment explorations have started to exploit the potential advantages and opportunities related to the use of neural networks. Cigizoglu & Kisi (2005) used 'k-fold partitioned' and 'range dependent' neural network solutions to perform a series of suspended sediment forecasting operations. Their results showed improvements in the estimation of sediment volume when compared to regression approaches and individual neural network solutions. Two important issues can nevertheless be highlighted. The modelling process had to be deconstructed into a set of simpler modelling operations and negative sediment outputs were sometimes observed This paper extends the earlier suspended sediment explorations of Cigizoglu & Kisi (2005). Forecasting comparisons with their findings are presented using identical datasets and a customised version of the NE software package JavaSANE (Moriarty and Miikkulainen, 1998). NE has been used to evolve more complex solutions that were optimised on total sediment load. Severe penalties were also applied in the case of negative sediment predictions. Further planned experiments are discussed.

***Keywords:*** neuroevolution

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# Sediment yield status of Daryacheh Namak Drainage Basin,Iran and its relation to landuse changes

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The processes of sediment production and transportation and sedimentation are parts of hydrologic cycle . The estimation of river sediment yield is important in determinig dam reservoir life time and also in investigating erosion status of drainage . basins . Therefore, for being informed about erosion situation of drainage basins , the amount of sediment yield usually measured and analy zed. in this reseaech amony lq hydrometric stalions , to situable stationis were chosen and by using spss and Excel softwares, sediment yield variations of ten subcatchments in Daryacheh Namak Drainage Basin For 24-year period were investigaled and Monthy and Total variations were analy zed . Investigating these Variations has shown that the highest amount of specific suspended sediment yield is related to Razin Station and the lowest to solan station . the Reason for these changes is due to high variation of land use in Razin sub catchment , but in solan Station , due to presence of resistant to nearly resislant geological formations , the sediment yields have been low . In the case of monthly variation of sediment yield , the highest amountis from April , March, May and November and the lowest amount is from September and August. Almost in all stations , the highest amount of sediment yield is related to spring seasom , the reason for this in probably due to increased rainfull of this time . there fore , the main factors for sediment production in the Studied subcatchments are spring rainfalls , assocated with snow melting and the presence of erodible formation high variations of landuse,and presence of erodible formations.

***Keywords:*** sediment yield

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# The effect of parent rock and landuse on soil erosion, Taleghan Drainage Basin, Iran

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The aim of this research is investigation of the effect of parent material and different landuses on soil erosion in Taleghan Drainage Basin. For doing this, by photogeological investigations and field work , geological map of the basin was prepared and in each geological units with similar morphology, pedological profiles were made, they were sampled and the samples were analyzed for physical and chemical characteristics. For grouping of lithological units according to physical and chemical characteristics of soils, a matrix was prepared based on soil characteristics and the types of lithlogies and factor and cluster analyses were performed. Based on cluster analyses, three homogeneous lithological (parent material) units were obtained. In each homogeneous lithological unit, three kinds of landuses of range, cultivation and dry-farming were tested and k-factor os soil erodibility in USLE method was obtained and the results were analyzed using variance analysis. The results have shown that lithological unit one consisting of marl and gypsiferous marl is the most erodible, group two consisting of recent alluvial deposits, alluvial fan and landslip deposits is medium erodible and group three consisting of igneous rocks, dolomite and conglomerate is the least erodible. Also, soil erosion on different parent rock is affected by the type of the landuses such that, dry-farming lands are most erodible, cultivated lands are medium-erodible and rangelands are the least erodible in homogeneous parent rock types.

***Keywords:*** parent rocks, landuse, erodibili

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# Some reflections on the future of the water quality at the Corumbata River Basin, SO Paulo State, Brazil

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The Corumbata River basin extends over an area of about 1,581 km2 in the middle-east part of the So Paulo State, Brazil. It is a sub-basin of the giant Paran sedimentary basin that extends over an area of 1,700,000 km2 (1,000,000 km2 in Brazilian surface). Rio Claro city is the most important municipality in the basin, with 170,000 inhabitants. Monthly measurements of the flow rate during the last 26 years have indicated that 37.4% of the observed values are between 10 and 20 m3s-1. The climate of the region is tropical, being characterized by wet summer and dry winter. The mean annual rainfall generally corresponds to about 1,600 mm, with the flow rate at Corumbata River being directly bounded to rainfall. The waters of Corumbata River are extensively used for human consumption, and their quality have been modified due to increasing pressure caused the population growth observed at Rio Claro city, which was accompanied by a more accentuated industrial development that occurred at the whole So Paulo State in the early 1970s rising up to about 16% in its interior. The transport and plastic industries developed much during this period at the Corumbata River basin. Traditionally, the drainage in the Corumbata River basin has received along the time significant in natura emissions of municipal waste products and discharge of waste water, sludge, sewage, sanitary and industrial effluents, among others, being only inaugurated in the end 1990s the first plant for treatment of effluents at Rio Claro city. The evaluation of the actual stage of the water quality in the area allows some reflections about its future evolution, as a consequence of the impacts already caused by the human occupation. In order to perform this, it was determined the chemical composition of water samples collected from rainwater and two widely spaced locations in the Corumbata River basin, i.e. upstream from Rio Claro city at Ferraz-Ajapi district (high reach) and downstream from Rio Claro city, at the confluence of Corumbata River with Piracicaba River (Santa Terezinha district, Piracicaba city) (low reach). These sites were chosen so the changes in the concentrations of constituents could be related to the presence of Rio Claro city in the basin, which has been recognized to be the major responsible for modifications on the surface water quality. The following parameters were evaluated: pH, conductivity, dissolved oxygen, hardness, dry residue, sodium, calcium, potassium, magnesium, sulfate, nitrate, chloride, bicarbonate, and phosphate. The results indicated important modifications on the surface water quality due to the presence of Rio Claro city, suggesting strong initiatives/efforts to be held by the municipality in order to improve and preserve the water quality in Corumbata River basin for the 21st century.

***Keywords:*** waterquality, chemicalcomposition, corumbatairiverbasin

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# Runoff erosion control for a sustainable water supply in Niamey, Niger Republic

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Runoff erosion is very noxious to the soils and their use especially in semi-arid countries, and controlling it represents a day-to-day preoccupation of people and governments. The flowing water erodes farms and destroys infrastructures. Also, overland flow transports silts and deposits them into depression. This silting is one of the most important causes of the reduction of the river Niger flow. As well, the river Niger serves as the source of domestic water supply of Niamey and other riverside towns and villages. So, for protecting this river, the riverside living people, the Niger Republic and the Niamey Urban Communality (CUN) governments, adopt a number of measures to control runoff erosion so as to guaranty three million cubic meters of domestic water needs of only few days. They use mostly structural and/or agronomic methods. This work examines the control measures in Niamey Township from 2000 to 2006. The methodology used includes interviews with the local population, technicians and engineers handling the erosion control activities. Some field investigations are also undertaken for determining the sediments caught upstream of the constructions, and for viewing the effectiveness of the control measures. After a critical examination of the techniques implemented, it comes out that not all are effectively constructed. The efficiency of any erosion control measure is conditioned by the total involvement of the local population. There is, therefore, a need of for large-scale campaign to enlighten the people on the importance of the control activities so as encourage them to fully participate in the control work and in maintaining the existing constructions.

***Keywords:*** erosioncontrolrivernigercun, niameyurbancommunality

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# Modelling catchment scale nutrient transport using a combined process based and data driven approach

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The diffuse nitrate pollution in rivers is driven by complex bio-chemical and hydrological processes related to nitrogen and water cycles. Although the hydrological processes can be relatively well simulated using process based models, the simulation of the nutrient transport processes is associated with large uncertainties due to a limited understanding of the processes and restrictive data availability. On the other hand, a number of studies on the temporal and spatial variability of nutrient transport processes (Hornberger et al. 1994, Stieglitz et al., 2003) indicate that the subsurface flow as a dominant driving variable for catchment scale nutrient dynamics. In this study, a combined process based - data driven approach is used for the simulation of catchment scale nitrate transport processes based on the dominant driving variables. The approach combines the results of process based distributed water balance model WaSiM-ETH with observations for the simulation of stream nitrate concentration using data driven artificial neural network (ANN). The study was undertaken using the data from the Weida catchment in the North-Eastern Germany, which is a 100 km subcatchment of the Weisse Elster in the Elbe river basin. The simulation of the water balance and runoff components in the WaSiM-ETH model is done using the TOPMODEL approach. The model is calibrated using an automatic parameter estimation program PEST. The simulated subsurface and surface runoff components together with the mean air temperature are taken as input variables for the ANN model. The Levenberg-Marquardt algorithm with Bayesian regularisation is used for the ANN training. The data for the ANN is training, cross-validation and test consists of three years, two years and 15 months of time series data respectively. The model results are assessed individually for water balance and water quality simulation. The water balance simulation shows a very good match between the observed and simulated streamflow for both the calibration and validation period. The ANN simulation also produced a good performance with regards to the dynamics and magnitude of the streamflow nitrate concentration for training, cross-validation and test period. Hence it can be concluded that the integrated process based data driven approach offer an effective and efficient methodology for modelling the catchment scale nitrate dynamics.

***Keywords:*** nitrate transport, water balance, artificial neural network

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# Impacts of human activities on the sediment regime of the Yangtze River

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The Yangtze River (Changjiang) is one of the most important rivers in the world. It is the third longest in length, ninth largest in catchment basin, third largest in annual runoff and forth largest in sediment load. As an artery river on the earth planet, it plays a critical role in global water cycle, sediment cycle, energy balance, climate change and ecological development. The alterations in its hydrological regime therefore have global-scale impacts. However, with population increase and economic growth, the sediment regime of the Yangtze River has been altered to some extent by human activities including dam construction, deforestation, land-use change, soil and water conservation, etc. The variations in the sediment regime of the Yangtze River will unavoidably influence its morphology and geomorphology, the delta evolution and the ecosystem health and stability. To assess human-induced alterations in the sediment regime of the Yangtze River quantitatively, this paper selected three key hydrological stations (i.e. Yichang, Hankou and Datong stations) on its middle and lower reaches as case study sites. Yichang station is the control point of the upper Yangtze River basin and located at the starting point of the middle reach of the Yangtze River, 44 km below Three Gorges Dam and 6 km below the Gezhouba Dam. Hankou station is located 1.15km below the confluence of the Yangtze River and its biggest tributary the Hanjiang River, on which the second largest reservoir in terms of storage capacity in the Yangtze River basin, the Danjiangkou reservoir, was built in 1967. Datong station located at the tidal limit of the Yangtze River is the controlling station for the measurements of water and sediment discharges from the Yangtze River to the sea. On the consideration that the Danjiangkou Reservoir, the Gezhouba Reservoir and the Three Gorges Reservoir may impose impacts on the sediment regime of the middle and lower reaches of the Yangtze River to different extents respectively, the whole study periods were divided into 4 subperiods by the years when these three reservoirs started to store water respectively. On the basis of about 50-year long time series of daily sediment discharge from three stations, the alterations of their annual sediment load, wet seasonal sediment load, dry seasonal sediment load and monthly sediment load in different subperiods were analyzed and compared. The results revealed: the impacts of reservoirs on river sediment regime varied with reservoir regulation capacity, reservoir operation pattern and the distance between the target reservoir and case study site; deforestation and land use change resulted in an increase in annual, wet seasonal and dry seasonal sediment load; the trapping of sediment in reservoirs together with soil and water conservation caused a significant reduction in annual, wet seasonal and dry seasonal sediment load; the operation mode of storing clear water and releasing turbid water for reservoir operation altered the distribution of monthly sediment load, i.e. the percentages of sediment load in high flow months increasing and the ones in low flow months decreasing; the 1200 km river stretch between Yichang and Datong acted as a regulator for the river sediment load, although most sediment measured at Datong comes from Yachang. The output of this paper could provide reference for the assessment of the impacts of human activities on the long-term health and stability of the Yangtze River ecosystem.

***Keywords:*** yangtze river, sediment, alteration

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# The impact of groundwater - surface water interactions on the water quality in the riparian zone of a North -German lowland river

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The hydrology of floodplains of lowland rivers is often controlled by exchange fluxes between groundwater and surface water. These interactions can be spatially and temporally variable and fluxes can change it directions in a seasonal dynamic. With these exchange fluxes advective dispersive transport of nitrate can occur along the groundwater surface water interface. Riparian floodplains can react as sinks of nitrate due to natural attenuation processes as denitrification within anoxic groundwater and thus, can reduce the nitrate concentrations in groundwater and surface water. On the other hand floodplains may also represent potential nitrate sources, e.g. the use of fertilizer in agriculture can result in high concentrations of nitrate in groundwater which is transported into the river and can therefore severely effect the aquatic ecosystem. The objective of this study is to investigate the importance of the exchange fluxes at the groundwater surface water interface for the floodplain water balance of a riparian floodplain which is representative for many lowland rivers in central Europe. Furthermore the impact of interactions between groundwater and surface water on the nitrate dynamics within the floodplain and the river are analysed and quantified. Experimental investigations in the research area detected that the floodplain water balance is characterised by infiltration of surface water into the floodplain during wet periods from autumn to spring and exfiltration of groundwater into the river during dry periods at summer. The IWAN model (Integrated Modelling of Water Balance and Nutrient Dynamics) was set up for the research area in order to quantify the effect of the observed exchange fluxes onto the floodplain water balance and nitrate dynamics under current conditions. Furthermore landuse change scenarios were developed and simulated in order to predict possible effects of changing conditions on the floodplain water balance and nitrate dynamics. Model simulations of a 13 year time period have shown that the infiltration of surface water is the major cause for groundwater stage rises in winter. The exfiltration of groundwater into the surface water represents only 5% of the river discharge in the entire year but can form up to 30% during low flow periods in summer. This contribution can be very significant for the river ecology as the model results also proof that the proportion of riparian groundwater born nitrate can make up to 28% of the nitrate loads contributed to the river during summer. Simulation of the landuse change scenarios detected only marginal effects of the assumed landuse changes onto the floodplain water balance and groundwater dynamics. However, it could be shown that a reduction of the very dense drainage network in the floodplain could enhance the water balance retention capacity of the floodplain. The simulation results furthermore proofed that more sustainable practices in landuse and management could significantly decrease the nitrate concentrations in groundwater and thus improve groundwater quality and minimise its nitrate contribution to the river in summer. Taking into account the substantial proportion of groundwater born nitrate on the summer loads of the river this would represent an important improvement of river quality during the ecologically most critical period of the year.

***Keywords:*** riparian zone, water quality, nitrate

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# Novel methods for the 21st Century: Quantifying sediment deposition and the spatial variability of sediment-associated metals in ponds treating urban diffuse pollution

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With the prediction of anthropogenically-enhanced global warming invoking extreme rainfall conditions and high rates of urbanisation engendering increased point-source and diffuse pollution over the next century, a need exists for long-term sustainable intervention and management of our watercourses at a wide range of scales. For example, the EU Water Framework Directive (WFD) aims to improve the chemical and ecological status of watercourses, which will require, amongst other measures, control of urban diffuse pollution. Retention ponds, as part of SUDS (Sustainable Urban Drainage Systems) techniques, are promoted for controlling flood risk and diffuse water pollution within urban catchments. However, little is known about the long-term sustainability of retention ponds if potentially contaminated sediment is permitted to accumulate. In order to manage sediment within these ponds the rates of accumulation and extent of contamination (often highly spatially variable) need to be assessed. Current assessment methods, normally individual core samples at intervals of metres, are highly laborious, time-consuming and cannot take account of spatial variability. Hence the aims of this research were to: 1) examine the use of ground penetrating radar (GPR) for estimating sediment depth and 2) investigate spatial variability in sediment contaminants (potentially toxic metals) in relation to sedimentary structures in order to devise appropriate sampling strategies. The research was conducted in a SUDS retention pond in central Scotland, UK, that receives drainage from commercial premises. The retention pond has a surface area of approximately 1.65 ha, a water volume of 23,020 m3 and mean water depth of 1.8 m. Two separate GPR antennae (200 and 450 MHz) and a differential GPS (Global Positioning System) unit were mounted in a boat which was moved around the pond to collect data to rapidly delineate pond bed morphology and sediment depth. Pond water depth was also measured manually to validate the GPR results. Provisionally corrected GPR data for the 450 MHz antenna demonstrated an ability to acquire a water-sediment boundary with 2 cm depth resolution, increasing to approximately 5.5 cm for subsurface sediment features. The 200 MHz antenna resolved the water-sediment boundary with an overall error of 6 cm, and approximately 15 cm for the subsurface resolution. The benefits and limitations of the GPR technique for identifying surface and subsurface sediment horizons, and assessment of sediment volumes and spatial variability within the pond will be discussed in the paper. To assess spatial variability in sediment contamination, sediment was intensively sampled (n=30) in a 1 m2 quadrat at the pond inlet and analysed for potentially toxic metals (Cr, Cu, Fe, Ni, Pb, and Zn). Geostatistical analyses showed that sediment metal concentrations tended to be highly variable isotropically at the centimetre scale, although a degree of anisotropy was apparent in the direction of the inlet for Fe concentrations. Fe concentration was influenced by sediment moisture content, organic matter content, and in particular, sediment depth, suggesting that anaerobically-induced mobilisation of Fe may be a dominant process in defining its variability. The concentrations of other metals appeared to be random, at least near the inlet, suggesting that this spatial variability needs quantifying so that an optimal dredging regime can be implemented. The paper will explore possible factors controlling the observed metal distributions and also the variability of metals in pond sediments at the metre scale.

***Keywords:*** sediment, contamination, urban drainage

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# Scaling Phosphorus and Sediment Transfers in Small Agricultural Catchments

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Gaining a better understanding of the processes and linkages operating in agricultural catchments is essential in understanding how diffuse sources of pollution influence the water quality of fluvial systems. Key limitations include lack of available data at appropriate scales for modelling, poor comprehension of processes operating at scales between the hillslope plot and the catchment, and little knowledge of whether data can be transferred across scales. Researching these issues has the potential to improve predictions of water quality both in gauged and ungauged agricultural catchments, which is particularly important given changing climate and land use. In this context, event-based fluxes of sediment and phosphorus were monitored at different scales of observation in a first-order agricultural catchment. A flexible sampling design, using on-site observation and point sampling during events, was developed and used for monitoring hillslope patch scales (< 2 ha). This was integrated with automated sampling of a hillslope flume, drainage outfalls, and catchment outlet (30 ha). These data enabled quantification and comparison of sediment and phosphorus fluxes at varied scales, and identification of responses to different drivers. Using these relationships, it was possible to determine where and how transfers between scales of observation may be feasible.

***Keywords:*** phosphorus, scaling, catchment

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# Assessing the effects of design and climate change on sediment removal efficiency in urban stormwater ponds

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During the last decade stormwater ponds have been increasingly used worldwide to minimise the impact of urbanisation on the water environment. In these systems flow attenuation occurs by temporary storage of runoff followed by a delayed and slow release to a receiving watercourse, while water quality improvement occurs primarily by the capture of sediment in the pond through the settling of suspended solids. The guidance for designing these ponds normally only considers individual storm events and is often inconsistent; some approaches stress designing for flow attenuation whilst others emphasise design for water quality enhancement, by sizing ponds to hold treatment volumes that are a function of runoff from the catchment impervious area. Furthermore, there has been no investigation as to whether ponds designed using the current recommended methodology will provide adequate water quality improvement for the increased frequency and magnitude of storm events predicted as a result of climate change. The impacts of these design issues are explored for sediment removal (by settling) through both modelling of generic cylindrical ponds designed using current UK guidelines, and simulation of sediment attenuation in Linburn Pond, a stormwater pond in a recently-urbanised area of central Scotland. Results showed that ponds designed for flow attenuation actually have a higher sediment removal efficiency (78% of incoming sediment settled for the 1 in 2 year storm event) than those designed for water quality enhancement (only 21% removal for the same storm event). Sediment removal efficiency remained almost unchanged when sequential rather than single storm events were routed through ponds designed either for flow attenuation or water quality enhancement. Simulations conducted with different storm sizes showed that the efficiency of sediment removal decreased in all pond designs with increasing storm event magnitude (e.g. for ponds designed for flow, incoming sediment settlement decreased from 98% for an event with a peak flow of 28.7 l/s to 78% for an event with a peak flow of 125 l/s). Whilst the modelling results suggest that the enhancement of water quality (through sediment settlement) will decrease in the more intense storm events predicted as a result of climate change, it appears that more frequent occurrence of storm events will have little effect on sediment removal under Scottish conditions (although flow attenuation performance is very significantly impacted). The methodology used to design urban stormwater ponds, i.e. whether they are designed for flow attenuation or for water quality enhancement, has a significant effect on pond performance with ponds designed using the flow attenuation guidelines being more successful in terms of both flow and sediment attenuation.

***Keywords:*** sediment, urban stormwater, design

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# Local and regional frequency analysis of extreme suspended sediment concentrations in North America

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Extreme suspended sediment concentrations (SSC) are a threat to aquatic life and possibly carry high amounts of pollutants. Only a few rivers in the world are monitored daily for SSC, this lack of measurements makes it difficult to predict and quantify extreme events. There is a need to develop approaches to estimate extreme SSC on ungauged rivers. Inspired by the statistical methods developed for local and regional flood frequency analysis, this probabilistic approach is used to quantify extreme events of SSC for gauged and ungauged rivers. Using a database of 209 stations in North America with daily discharge and SSC values for 10 years or more, a local frequency analysis of annual maximum of SSC was first performed. Probability distributions were fitted to the series of annual maximums of SSC in order to estimate quantiles of SSC for different return periods from 2 up to 50 years. With such statistical modeling of extreme SSC events it is possible to associate return periods for given values of SSC (for example lethal threshold for specific fish species). The most adequate probability distributions to model extreme events of SSC were selected based on the Aikaike and Bayesian information critieria, and seasonal patterns of occurrence of extreme concentrations were analysed. Annual maximum of SSC usually occur in spring and summer. A significant correlation of extreme SSC with corresponding discharge was found only in half of the stations. The most commonly used distributions were Log-Normal, Exponential, Weibull and Gamma for 80% of stations. Then, assuming that magnitude of extreme SSC were correlated with stream characteristics and physiographic features of the watersheds, a regional approach is tested to estimate annual maximum concentrations at ungauged sites. Correlations between annual maximum SSC and a large range of physiographic characteristics are investigated in order to select the most significant ones. The first step consists in identifying homogenous regions through cluster analysis or neighbourhoods of stations delimitated by canonical correlation analysis, using physiographic characteristics. The second step is to predict quantiles with multiple regression for ungauged watersheds using regional information. These methods are tested using information from quantiles obtained by local frequency analysis and watershed characteristics such as soils, topography, climate and land cover derived from a Geographic Information System database developed for this project. In order to estimate the reliability of this approach, we used Jack-Knife re-sampling to calculate error statistics such as relative root mean square error on estimated quantiles.

***Keywords:*** suspended sediments, frequency, regionalisation

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# Development and application of a Watershed Information System (WIS) for water quality analyses

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This paper describes the development, implementation and evaluation of a watershed information system (WIS) to assist in the prediction of pollutant concentrations and in the planning of programs for water quality control in river basins incorporating both point and non-point pollutant sources. The system simulates rainfall-runoff processes and the subsequent transport of water quality constituents and sediment. Water quality constituents are transported in the water as well as on the sediments. WIS includes two alternatives of non-point source models, a network design component, a flow and sediment routing component and a water quality transport component. Relatively simple model of rainfall-runoff and water quality were selected for use in this watershed information system. The use of simple models provides a preliminary screening tool for analyzing environmental systems processes in watersheds, streams and rivers. The models in the system are integrated through their inputs and outputs. Beginning with the simulation of flows and pollutant loads from land at sub-basin scales, non-point source models generate inputs for the routing of flows and pollutant loads (including sediment) along the main channel of the watershed. Likewise, outputs from the routing component are inputs for the in-stream water quality component. The first alternative of non-point source model is based on a parameterized set of equations describing the governing hydrological processes in the catchment. The accumulation of pollutant on the land is represented by a build-up function and its transport from the land to the main channel of the watershed is described by a wash off function. The second non-point source model is a revised version of the Generalized Watershed Load Function model. The network design component defines the configuration of the river basin using nodes and links to represent the sub-basins and streams. The water quality component incorporates a new routing approach that significantly decreases the computational time. It involves a built-in algorithm that is applied for each node along the network at each time step. Graphical user interfaces were developed to facilitate the interaction user-models and an object oriented approach was used to write the computational codes using Delphi computer language. The system WIS was applied in a watershed in Delaware County, New York, and in a watershed in Cear state, Brazil. The results showed that WIS is a suitable computational tool to identify source areas of pollution in river basins and indicate where more complex modeling and analysis might be recommended.

***Keywords:*** water quality, information system, sediment

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# Long-term trend of uranium status in Beaverlodge Lake, Saskatchewan of Canada, under mine decommissioning

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As one of the leading industries in Province of Saskatchewan, Canada, uranium mining and milling have been causing concerns and challenges of water quality or environmental protection to industries, regulatory agencies and public interest groups. Beaverlodge Uranium Mine was the first uranium operation in Canada, operated in 1951-1982 without strict regulations or sound environmental protection. It was shut down in 1983 and initially decommissioned in 1983-85. Since then the mine was under post-decommissioning monitoring and occasional cleanup or remediation activities. The Beaverlodge Lake downstream the mine/mill site was polluted by metals and radioactive materials during operations, and has been in the recovery process. Among residual risks and concerns, the uranium in lake water which is less than the close-out objective but higher than drinking water criteria is selected for our analysis. The lake has a water area of 50.6 km2 and a drainage area of 230.8 km2. The two pollutant-contributing creeks which were affected by mining and milling cover a drainage area of 172.4 km2. Only limited hydrological and water quality data were collected by the operators one monitoring station in the lake and two stations in the creeks. Uranium trend analysis is tried for the 21 years of 1985-2005 that have had data, and into the future period till the uranium concentration reduces to drinking water criteria. Mass balance of water and uranium for the lake is analyzed annually. The relationship of precipitation-runoff of Ace Creek Watershed, a sub-basin of the lake basin, is used to calculate annual runoff at the lake outlet, which is also outflow volume of the lake. Annual loading of uranium from two creeks decreased from 16,000 kg/a to 1,610 kg/a during 1985-2005, the uranium output from lake decreased from 9,900 to 4,700 kg/a, and the U concentration of water reduced from 0.35 to 0.16 mg/L. A decreasing loading pattern is supposed by considering existing and future decommissioning plans, then continue the balance analysis from 2005 into future till the concentration in lake reaches the criteria level 0.025 mg/L. About 100 years or more would be required to reach that level. This prediction, based on limited data and many simplifications, is an example of water quality prediction for a remote or ungauged basin. Impacted water resource and environment will need long time to recover even with decommissioning activities. Complete regulations and monitoring programs are badly required.

***Keywords:*** uranium, analysis, beaverlodge

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# Flood flow water quality analysis using low-cost samplers in small rivers

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Water quality and sediment transport studies require field data for assessment and mathematical simulation. Manual collection of water samples during floods in small rivers is very difficult due to short event duration and quick response to rainfall. Automatic mechanical sampling equipments usually are expensive and, in low income countries, the problem is aggravated by vandalism and theft in areas nearby cities. Some low cost siphon samplers presented in the literature have been developed and adapted to collect event based samples but they only collect samples when the stream stage is rising. This work presents a new design for the low cost siphon sampler developed to allow collection when the stream stage is decreasing. The equipment was tested in laboratory with good results. Both types of siphon samplers were installed in a river with flood flows strongly dominated by urban runoff and in which untreated sewage of more than 500.000 inhabitants was dumped until 2005. Some results of the water quality analysis of the samples collected are discussed in view of the flood hydrographs. The major problem faced in the field work was to keep the samplers in place due to the amount of debris carried by the floods. Some of the samplers were washed away by the floods. Further laboratory tests showed water intrusion in the sampler during stage rising and further improvement is proposed to solve the problem.

***Keywords:*** sampler, low cost

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# Is the past the key to predicting the future? assessing the relative influence of climatic variability and land use change on upland water quality using long-term data sets

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The influence of forestry on water resources remains unclear. It is increasingly apparent that impacts of land management can be confounded by climatic variability and longer-term environmental change. Understanding is often limited by a lack of long-term data sets to assess the relative importance of different drivers of hydrological and hydrochemical change. At Loch Ard, Scotland, long-term (34years) hydrological and hydrochemical data sets were analyzed to assess how forest operations and climatic variability interact to affect the hydrological functioning of upland catchments. Weekly records of chloride concentrations in precipitation and streamwaters were used in lumped parameter residence time models. These were used to assess how catchment mean residence times and residence time distributions, fundamental but rarely defined deors of catchment hydrological function, were affected by clear-felling and climatic variability. In control catchments mean residence times estimated for groups of years within the 34 year record varied between 60 days when precipitation was high (2300mm) and 140 days when it was low (1400mm). Clear-felling of comparable treatment catchments had no statistically significant effect on mean residence times or residence time distributions. However, there was evidence that flows increased as a result of increased effective precipitation. Chemically-based two component hydrograph separation using End Member Mixing Analysis was used to examine any changed in the dominant sources of runoff. This showed that groundwater contributions to annual runoff were similar in both control and felled catchments. This varied between 28-37 percent in individual years, and there was no evidence that clear felling changed runoff sources in a significant way. It is concluded that the cool, wet climate and dominant histic gley soils which cover these catchments create responsive hydrological systems that appear to be relatively insensitive to the impacts of forest operations. Thus, climatic variability has a more marked impact on water resources than forest operations in this particular environmental setting.

***Keywords:*** long term, trends, forestry

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# Groundwater of the Future in the Roussillon floodplain (France): present day situation and solutions for the 21st Century

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In Mediterranean regions, generally, water resources are not very important. Then, it is obvious that a better water management should be planned in order to protect these vulnerable resources. It has often been the case, in the past centuries, for water surface but the groundwater has been neglected. In fact, the practices show that even now, this groundwater is often used without any restraint. In France, this is precisely the case of the floodplain of the Roussillon, situated in the western part of Mediterranean Sea. There, important quantities of water are pumped from the deep Pliocene aquifers by land owners, private companies and the local communities. For three decades, the pumping has become more and more important, in particular because of the population increase, especially in summer when the number of tourists is very high and the climate often very dry. The consequences are clear: all the levels of aquifers are drawing in (-2,6m), and the quality of water getting worse. The Pliocene Aquifer is concerned by this excessive pumping. This is a very serious problem because this water is renewed with an average long period of 5000years to 7000 years BP (C14 datations). In theses conditions, the sustainable management of this water is not any more possible. In some wells of the plain, the signs are alarming, with lower levels of aquifers and pollution by nitrates. Near the Mediterranean Sea the penetration of the salted bevel has even been noticed. Moreover, it is well known that water resources could decrease, round Mediterranean regions, during the 21st Century, because of warming climate around the world (Global Change). General principles defined by the European Water Directive (2000/60/CE) imply a better management of this resource. Several solutions can be put forward such as the use of water coming from karstic tanks of the Corbieres Mountains as well as the treatment of river water, stored by means of existing dams. But any of these solutions has a real cost...

***Keywords:*** groundwater, overexploitation, mediterranean regions

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**HS2005** **Oral Presentation** **4281**

# Future impacts of fresh water resource management: sensitivity of coastal deltas

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We present here an assessment contemporary and future effective sea-level rise (ESLR) drawing insight from a sample of 40 deltas distributed worldwide. For any delta, ESLR comprises a net rate, defined by eustatic sea-level rise, natural gross rate of fluvial sediment deposition and subsidence, and accelerated subsidence due to groundwater and hydrocarbon extraction. ESLR is estimated under present conditions using a digital biogeophysical data set and a simple model of deltaic dynamics. The associated upland basins drain 30% of the Earth's landmass and 42% of global runoff and have nearly 300 million inhabitants. Contemporary ESLR ranges from 0.5 to 12.5 mm yr-1. Reduced accretion of fluvial sediment from upstream siltation of reservoirs and consumptive irrigation are the primary determinants of ESLR in nearly 70% of the deltas. Approximately 20% of the deltas show accelerated subsidence, while only 12% show eustatic sea-level rise as the predominant effect. This study thus finds that direct anthropogenic effects determine ESLR in the majority of deltas studied, with a relatively less important role for eustatic sea-level rise. Future impact scenarios are presented and indicate a much larger impact on deltas than previously estimated, for example as part of the IPCC assessment process. Serious challenges to human occupancy of deltaic regions worldwide are thus conveyed by factors which to date have been studied less comprehensively than the climate change-sea-level rise question.

***Keywords:*** sediment, deltas, watersheds

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# Effect of frequent storms on nutrient discharge from a catchment to inland sea surrounded by steep mountains in Western Japan

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***Mitsuyo Saito, Misa Sawano***

The number of storm event has been increasing and the rainfall intensity has been rising during last 20 years in a temperate, humid region. On the other hand, both of a number and intensity of draught has also been increasing. These climate changes would act on nutrient discharge as well as water discharge in a watershed. Japanese river catchments are generally characterized by relatively steep gradient and those have mountainous headwater areas and alluvial fan with coarse grain sediment. To forecast the nutrient discharge in a steep catchment in future, it is necessary to confirm the variation in nutrient discharge by not only river but also groundwater in various climate conditions, such as storm and drought. The objectives of this research are to confirm the variation in nutrient discharge by river and groundwater, using long-term records of water quality and runoff, and to evaluate the effect of frequent storm on the nutrient discharge. The study area is located in Ashida river catchment, flowing to Seto Inland Sea, western Japan. The area of the catchment is about 1000km2. In this research, we analyzed the long-term records in a large river catchment, using the simple model. In addition, we confirmed the relationship between river runoff and wetness in various slope gradients and estimated the relation between groundwater and river runoff in a various wet condition, using the simple water balance model. The groundwater level distribution at the delta area indicated stable groundwater flow from river to ocean in both periods of wet and dry. The seasonal variations of water level were about 1m. Groundwater flux during the dry season was estimated to be about a half of that during wet season by the simple model. This relationship of groundwater flux and river runoff by the model supported that groundwater discharge decreased but the flux to ocean existed during the drought period in the river. On the other hand, it was suggested that river runoff increased in the magnitude of more than 2 orders but groundwater flux increased only several times even in the maximum. These results indicate that groundwater discharge was dominant in the draught period, but river discharge was dominant and more than 100 times of groundwater. The nutrient component of river and groundwater was nitrogen rich and phosphorus and silica rich, respectively. The groundwater was also contaminated by nitrate under the agriculture land as well as river water, but the nitrate elimination occurred with groundwater flow. Therefore, it was estimated that nitrate discharge with groundwater was little. Consequently, nutrient discharge was suggested that phosphorus and silica discharge by groundwater during a drought period and nitrogen discharge by river during a flood period were dominant, respectively.

***Keywords:*** storm, nutrient, groundwater

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**HS2005** **Oral Presentation** **4283**

# Nitrate contamination in the groudnwater of the yellow river delta and its effect on the marine environment: current condition and prediction for the future

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***Shin-Ichi Onodera, Kunihide Miyaoka, Jianyao Chen, Makoto Taniguchi, Guanqun Liu, Yoshihiro Fukushima***

Because of the extremely high sedimentation rate, the total area of Yellow River delta have increased approximately 20km2~25km2 in last two decades. As a result, agricultural and urban areas rapidly have been developed in the new land area of the delta. It means that the nitrogen inputs by human activities also increase in recent years. Evaluation of the current condition of nitrate contamination in groundwater is very important to maintain the water resources in such a developing region. It is also necessary to clarify the nitrate transport process with groundwater flow, to predict the effect of nitrate discharge on the marine environment in the future. The objectives of this study are to confirm the recent trend of nitrate contamination in groundwater of the Yellow River delta, and to evaluate its transport from land to the sea in the future. The authors conducted field observations at the 15 observation boreholes with 15m to 50m depths at September 2005 and 2006. Groundwater samples were collected at more than 3 different depths such as the surface, middle, and bottom of the water body in the boreholes. In addition, we conducted field experiment to evaluate the denitrification capacity in the groundwater at a borehole located on near the sea. Water samples were analyzed for the concentrations of major anion (NO3-, Cl-, HCO3-, SO42-), major cation (Na+, K+, Mg2+, Ca2+), DN (Dissolved Nitrogen) and nitrogen stable isotope (15N) in aqueous NO3-. The amount of nitrogen in the aquifer with 20m of thickness was estimated to be about 1.0t/ha at the recharge area near the Yellow River, and it is almost similar to the accumulated amount for 20 years. The accumulated amount in the recharge area was estimated to be more than twice as large as that in the discharge area. These results imply that nitrogen loaded around the recharge area have not reached to the discharge area yet, because groundwater velocity is so low in the delta area. Previous researches in UK indicated that nitrate accumulated in the aquifer has been discharged to the river with delay. However, the results of field experiment and 15N analysis suggest the denitrification process in the aquifer near the sea. Based on these results, it is suggested that some amount of nitrate load applied on the delta area will be reduced by denitrification in the coastal aquifer before it reaches to the sea. On the other hand, it implies that the nitrate in groundwater is reduced to nitrogen gas (N2) including nitrous oxide (N2O) that is global warming gas.

***Keywords:*** groundwater, nitrate transport, yellow river delta

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# Estimating the impact of projected change in farming by 2015 on the importance of the agricultural sector as a sediment source in England and Wales

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In association with a major initiative aimed at identifying policy packages for inclusion in the Programmes of Measures (POMs) comprising River Basin Management Plans (RBMPs), ADAS has recently been commissioned to evaluate the gap between current and compliant suspended sediment losses due to farming across England and Wales. The work required national scale sediment source apportionment to assess the current contributions of diffuse agricultural and urban sector losses, channel bank erosion and point source discharges to the total suspended sediment loads delivered to all rivers. Results suggested that the agricultural sector dominates present day (year 2000) sediment inputs to rivers (1929 kt = 76%) compared to eroding channel banks (394 kt = 15%), diffuse urban sources (147 kt = 6%) and point source discharges (76 kt = 3%). Projected change in farming by 2015, represented by the Business as Usual forecast of structural developments and predicted uptake of sediment mitigation methods, suggested a 9% reduction in sediment losses from the agricultural sector across England and Wales. Based on this analysis, further mitigation of diffuse agricultural sediment transfers to watercourses will be necessary under RBMPs to ensure good ecological status in some catchments.

***Keywords:*** change agriculture, suspended sediment sources, water framework directive

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**HS2005** **Poster presentation** **4285**

# Modelling Nutrients Contributed by Diffuse sources in the Krishna River Basin

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Krishna river basin is one of the important region draining three important states of South India. Currently the basin plays a major role in the socio-economic development of the people in the region. The climatological conditions of the basin are characterized by long dry spells during summer and short wet spells during the monsoon and winter season. Monitoring all sources of pollution to assess the loads contributed by these sources is rather difficult/impossible and expansive and subjected to analytical errors. Hence modeling which is relatively cheaper and less time consuming allows for estimation of loadings which otherwise could not be measured. This paper presents the applicability of different models developed for predicting the nutrient loads contributed by overland flow. The discharge - concentration relationships are used to separate base flow contributions and hence, surface loads are assessed. Mass balances between the monitoring stations are useful in estimation of unit area loads (UAL). Regression models developed for prediction of nutrient loads from the river basin represented good applicability. The model predictions are tested using different data sets and the model results are found to be in good agreement with observed values. The unit area loads estimated during the study are similar to those reported in literature. Deviations in some cases are due to variations in meteorology, soil geomorphology, rainfall pattern, land use pattern, agricultural practices, etc,. Nitrogen : Phosphorous ratios are used to find out the nutrient limiting conditions in the river. The results of the study indicated that nutrient contribution is considerable from the overland flow. Hence, it is essential to take up basin wide management plans for controlling nutrient inputs into the rivers. The nutrient application rates, agricultural practices and wastewater treatment are some of the activities which need to be thoroughly monitored and controlled in order to control water quality degradation in the river. The present approach serves as a useful tool to assess nutrient loads in river basins where the availability of data is limited and financing of extensive experimental monitoring water quality programs is difficult.

***Keywords:*** waterqualitymodeling, regressionmodels, unitarealoads

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**HS2005** **Poster presentation** **4286**

# Estimation of river sediment concentrations during hydrologic event

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***Hong Jiang, Kuniyoshi Takeuchi***

Analyses undertaken in this paper show that the Universal Soil Loss Equation (USLE) fails to predict the soil losses during hydrologic events, especially for arid region. The cause is due to the neglect of runoff in predicting the rainfall erosivity index. In this paper, the erosivity index in USLE is modified by relating the kinetic energy with rainfall, infiltration and runoff processes. The modified USLE model is verified to reflect the hydrological processes more accurately and to be capable of estimating event soil losses. As a new approach for modeling the event-based soil erosions in large catchments, the proposed erosion model also takes the channel erosion into account, together with sediment deposition and transport simulations; its application is broadened to model the variations of sediment concentrations during single events. Through a case study in the large arid region - Lushi River basin in China, the designed erosion model is validated to have good performances during most hydrologic events.

***Keywords:*** usle, sediment, event

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# Estimation of river sediment concentrations during hydrologic event

***Mr. Guojiang Wang***
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Analyses undertaken in this paper show that the Universal Soil Loss Equation (USLE) fails to predict the soil losses during hydrologic events, especially for arid region. The cause is due to the neglect of runoff in predicting the rainfall erosivity index. In this paper, the erosivity index in USLE is modified by relating the kinetic energy with rainfall, infiltration and runoff processes. The modified USLE model is verified to reflect the hydrological processes more accurately and to be capable of estimating event soil losses. As a new approach for modeling the event-based soil erosions in large catchments, the proposed erosion model also takes the channel erosion into account, together with sediment deposition and transport simulations; its application is broadened to model the variations of sediment concentrations during single events. Through a case study in the large arid region - Lushi River basin in China, the designed erosion model is validated to have good performances during most hydrologic events.

***Keywords:*** usle, sediment, event

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**HS2005** **Poster presentation** **4288**

# Estimation of sediment-associated fecal indicator bacteria export in a mountain watershed

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***Kei Nishida, Yasushi Sakamoto***

The association of microorganism with sediment particles is one of the primary complicating factors in assessing microbial fate in aquatic systems. The literature indicates that the majority of enteric bacteria in aquatic systems are associated with sediment and that these associated influence their survival and transport characteristics. Yet, the nature of these associations has not been fully characterized. In this study, a combination of field experiment and mathematical modeling were used to better understand the processes which control the fate and transport of fecal indicator bacteria (FIB) in streams. The research area of this study is Mizugaki mountain watershed, Kofu city, Japan. We estimate there were not obvious fecal bacteria sources through the investigation. But the concentration of FIB dramatically increased during the rainfall and partly corresponded to the sediment variation process. With the enough observation data, A modeling framework based on hydrological simulation program-FORTRAN (HSPF) model has been developed. Free and particle-associated fecal bacteria can be modeled explicitly using the developed model. The two types of bacteria adsorption relationship (weak adsorption, strong adsorption) are incorporated into the model. The deposition and resuspension fluxes of fecal bacteria across the sediment bed-water interface are calculated coupled with the sediment deposition and resuspension flux. The model was applied to simulation the FIB process during the rainfall and calibration and validation the important parameters using the experiment data. Using this model, the contribution of fecal bacteria from sediment bed and from the watershed can be modeled separately and explicitly.

***Keywords:*** fecal bacteria indicator, sediment, hspf

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**HS2005** **Poster presentation** **4289**

# The Aquatic Ecological Attribute in Huaihe River Basin,China

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***Jun Xia, Weijin Yan***

From the April 24th to April 31st, 2006, we investigated 22 typical ecological sections in the water bodies consisting of streams and reservoirs in Huaihe River Basin, China, when we collected the samples of phytoplankton and zooplankton from the river or reservoir water and of zoobenthos from the river or reservoir bed. Then we analysized the relationship between the biomass or the biomass density and the water quality indice such as DO, BOD5, CODCr, CODMn, NH3-N and aquatic temperature. The results show that BOD5, CODCr, NH3-N are the principal influencing factors of the biomass and biomass density of phytoplankton, zooplankton and zoobenthos of Huaihe River Basin. At last, the empirical equations between the biomass and the water quality indice are given in order to estimate the biomass in the water bodies of Huaihe River Basin under different degrees of water-pollution.

***Keywords:*** biomass, huaiheriverbasin, waterqualityindice

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**HS2005** **Poster presentation** **4290**

# A Preliminary Study on Natural Erosion Rates in A Small Watershed of the Sichuan Hilly Basin

***Prof. Xinbao Zhang***
*IAHS*

Yangtze River cutting through the Three Gauge in the middle Pleistocene has led to rapid cut-down of river beds in the Sichuan Hilly Basin. Therefore, the formal wide plains along the rivers have been dissected to become hills by tremendous gullies and the isolated hill tops often used to be formal plain surfaces. However, the cavity volume of a gully can represent the total eroded volume of the gully since its formation due to the rapid cut-down of the main river .A small watershed of the Xiaohegou Gully near Neijiang City was selected for a study on natural erosion rates in the Sichuan Hilly Basin. The rates were estimated according to the gully cavity volume calculated by using the DEM Model method and to the terrace age. However, the volume of accumulative deposits in the gully was investigated to estimate the natural sediment delivery ratio The Xiaohegou Gully has a drainage area of 10.88 km2 , an eroded gully cavity volume of 0.657 billion m3 . The ages of the highest Terrace IV and the second highest Terrace V are 0.7 Ma yrs BP and 0.4 Ma yrs BP Crespectively. Correspondently, the natural erosion rates are 216 t·km-2·a-1 for the erosion duration the period of 0.7 Ma yrs and 378 t·km-2·a-1 for the period of 0.4 Ma yrs, respectively, which are close to the modern sediment yield rate of 397 t·km-2·a-1 for the Sichuan Hilly Basin region of the Tuojiang River. In addition, there is at most 2 million m3 of accumulative deposits in the gully and the natural sediment delivery rate for the gully is 0.97, which is close to 1.

***Keywords:*** small watershed, natural erosion rates, natural sediment deliveryrate

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**HS2005** **Poster presentation** **4291**

# Advances in spatially distributed sediment budgets for managing water quality and habitat

***Dr. Scott Wilkinson***
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Spatially distributed sediment budgets provide a useful way to assemble process understanding and spatial data to assess sediment sources and downstream impacts, and to prioritise rehabilitation. Recent advances in modelling spatially distributed sediment budgets using the SedNet model have improved prediction of spatial patterns in material fluxes and better defined remaining uncertainty. The advances are based on process modelling, improved input datasets and testing the sediment budgets against independent data on fine sediment yields and bed material accumulation. This paper describes those advances and demonstrates application of the method across a 17,000 km2 basin in south-east Australia. The advances have reduced uncertainty in fine sediment flux to 50% for 1,000 km2 subsets of the basin, decreasing to 20% at the basin outlet. Riverbank erosion is the largest sediment source, with gully erosion and sediment delivered from hillslopes making smaller contributions. Knowledge gaps remain in predicting spatial patterns in riverbank erosion and hillslope sediment delivery. Further research should seek to better quantify the effect of vegetation on erosion rates.

***Keywords:*** sednet, spatial modelling, sediment budget

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**HS2005** **Poster presentation** **4292**

# Investigating the Role of Landuse changes and Erodibility of formations to sediment yield, case study: Daryacheh Namak Drainage Basin,Iran

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. In this research, three subcatchments of Daryacheh Namak Drainage Basin including khomain, pole - Doab and Rasin that have situable temporal landuse information and sediment yield data in their hydrometrie stations, were chosen as the studied area. By using remote sensing data, land use of these sub - chments were studied in two time intervals of 1965 and 1995, the maps of landuses were prepared and landuse changes were investigated. By using geologic maps of the area and field controls, the map of formations and rocks erodility of each subcatchment was prepared. Based on discharge and sediment yield data of subcatchment hydrometric stations obtained from TAMAB, temporal changes of suspension sediment yield of subcatchments were also investigated. Statistical analyses were done by SPSS and mapping and calculation of areas, were done in GIS environment by ILWIS software. The results have shown that from the view point of landuse changes and erodibility of formations. Three studied subcatchments have following characteristics: the highest amount of landuse change are present in Razin, mediun amount in khomein and the lowest amount in Pole - Doab, catchment. The area of susceptible formations and rocks to erosion is the highest in pole-Doab medium in khomein and the lowest in Razin. Razin has the highest, khomein the medium and Pole -Doab has the lowest amount of sediment yield in the studied years. Therefore, Pole - Doab subcatchment has the lowest amount of landuse changes and its rocks and formation have the lowest amount of sediment yield, but in Razin swbcatchment although the rocks and formations are less erodible, there is the highest amount of sediment yield. The results have shown that landuse changes are more effective than the erodibility of rocks and formations in sediment yield of subcatchments. Keyworlds: landuse, sediments yield, sediment yield potential, erodibility of rochs and formations, Darya cheh - Namak Drainage Basin. the lowest amount of sediment yield, but in Razin swbcatchment although the rocks and formations are less erodible, there is the highest amount of sediment yield. The results have shown that landuse changes are more effective than the erodibility of rocks and formations in sediment yield of subcatchments.

***Keywords:*** landuse, sediments

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**HS2005** **Poster presentation** **4293**

# Research on the Phosphorus and Nitrogen Transport in an Agricultural Watershed

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***Yu Zhongbo, Cui Guangbai***

Nonpoint source pollution (NPS) originated from agricultural activities has become the main factor contributing to the eutrophication in the Taihu basin, China. With the increased deterioration of water quality, the water shortage due to the worsened water quality has restrained the sustainable development of society and economy in the region. The paper mainly studies the phosphorus and nitrogen transport with hydrologic processes in a watershed of 73.7 hm2 in the Taihu basin whose land use is predominated by cultivation. The mechanism of variable source area (VSA) for surface runoff generation has been recognized as a flow generating process in the humid area. The runoff and pollution generating processes with the precipitation are observed in different experimental sites with different land uses and in the outlet of the watershed simultaneously. The objectives of the research are to quantify the mechanisms of runoff and nonpoint source pollution generation, flow contribution, pollution transport and the interaction between flow and the pollution. The distributed hydrologic model with physical base and the quantified transport model for N and P are established based on the results of field observation as well as laboratory work. With the developed model, the reactive and transport processes of N and P in the watershed can be investigated. The influences caused by many factors (e.g., soil type, land use, terrain, management strategy) to the hydrologic processes, yield and transport of N and P are also examined. The research results would further our understanding on the runoff generation mechanism and also transport mechanisms of N and P, and provide the basis for the control measures of agricultural NPS output in the region.

***Keywords:*** nonpoint source pollution, variable source area, agricultural watershed

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**HS2005** **Poster presentation** **4294**

# State-of-the-Art Technology in Suspended Sediment Monitoring

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***Harald Fugger***

The measurement of suspended-sediment concentrations (SSC) is an important problem that merits continuing research. Knowledge of the rate of sediment transport generally in rivers is important for any problem associated with the flow in alluvial channels. Suspended sediments play a major role in the uptake, release and transport of pollutants. They are also a part of the interactions between sediment bound nutrients and contaminants with water and biota. Suspended sediments are a global-scale pollutant whose amount has been estimated at 20 billion tons per year. Information on water discharge in an open channel is relatively easy to obtain, accurate measurements of suspended-sediment concentration are more difficult to obtain because suspended-sediment load is highly variable in both time and space. The amount and nature of suspended load in a water body is affected by the availability of sediment and by the turbulent forces in the water. Accurate measurement and estimation of suspended sediment transport is dependent on the timing and frequency of data collection, because most of the annual suspended sediment is transported in a few large runoff events. Important flows are unpredictable and infrequent and so it is hard to collect the required information with manual methods. Accepted methods of collecting sediment data are labour intensive, expensive and may be of unknown accuracy due to the large spatial and temporal differences associated with the transport of suspended sediment. To fill this data void it is essential to develop automatic, cost effective techniques to capture such events and to collect high quality data. The findings indicated that multi-frequency acoustic methods show merit for use in SSC measurement. The ability to measure SSC in a vertical section, while estimating particle size distribution makes it a good choice for many applications. In general, no single technique or instrument is capable of estimating SSC under all conditions, but all methods analysed show promise, although some applications are more limited than others. Variations in hydrologic conditions, particle size and composition and concentration of suspended material may require use of multiple frequency instruments or even multiple instrument types to determine the concentration to a reasonable degree of accuracy. Additional testing is needed for all methods, particularly those in development. This testing should include side-by-side evaluation of various instruments and techniques and the calibration with established techniques like isokinetic samplers.

***Keywords:*** suspended sediment devices, calibration, harmonisation

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**HS2005** **Poster presentation** **4295**

# Assessment of stratification effects on hydrodynamics and water quality in lakes

***Dr. Sebnem Elci***
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This paper investigates the hydrodynamics in stratified lakes where stratification present challenges on water quality. The implications of changes in water quality and the interrelations of water quality parameters are investigated to understand and model the future changes in the stratified lakes. The study site was selected as the main pool of Tahtali Reservoir since 40% of the water used in the city of Izmir (Population ~ 3 million) is provided by Tahtali. The lake is 21 m deep (average) with a surface area of 18 km2. Tahtal Lake is strongly stratified from June to October where temperatures vary from 14 to 27 C in the vertical water column. In combination with the lack of water inflow during these months, the habitants are under the risk of bad drinking water quality. Lake water quality was characterized by monthly measurements of temperature, dissolved oxygen, turbidity, conductivity and pH profile data collected at buoys located in the main pool. A multiparameter portable field instrument with a depth sensor is used for simultaneous measurement of parameters. The water quality measurements were supported with weather data obtained from a meteorological station set up on site measuring atmospheric pressure, air temperature, wind speed and direction, humidity and rain. Flow velocities were obtained from measurements of Acoustic Doppler Current Profiler (ADCP) RiverCat System with fiberglass pontoons. Mixing processes in the lake were observed and modeled numerically. The Environmental Fluid Dynamics Code (EFDC), a general-purpose modeling package for simulating three-dimensional (3-D) flow, transport, and biogeochemical processes in surface water systems, is used for this purpose and the model simulations were validated by flow measurements. It was observed that stratification alters velocity profiles drastically and thus affects water quality in the reservoir. Therefore, the sensitivity of water quality parameters to wind and stratification was investigated; useful for mitigation of pollution problems as well as predictions of reservoir water quality and development of maintenance schemes. The water quality parameters are found to be correlated to temperature profiles in the vertical except at the thermocline. It was observed that thermocline behaved as a barrier for dissolved oxygen, which dropped well below the standard limit of 5mg/l at the thermocline leading to the development of anoxia. The complex behaviors of other parameters such as turbidity, which can provide attachment sites for heavy metals, are further investigated through analytical data processing.

***Keywords:*** stratification, hydrodynamics, lake

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**HS2005** **Poster presentation** **4296**

# Design, construction and performance of a low-cost automatic water sampler

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***Jefferson Doolan Fernandes, Pablo Javier Alsina***

This paper aims to describe the design, construction and the performance of a low-cost water sampler. The prototype consists of 16 sampling 1950ml bottles, a small 12V diaphragm pump and a hydraulic system (PVC tube + solenoid valves) connected to an electronic system (microcontroller) which activates the system and stores data. An ultrasonic sensor allows relating water samples as a function of water discharge. Furthermore, the microcontroller may be programmed in order to accomplish different sampling routines.

***Keywords:*** watersampling, automation, ultrasonicsensor

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**HS2005** **Poster presentation** **4297**

# Denitrification zone in volcanic confined aquifer of the Miyakonojo Basin, Japan, based on the regional groundwater flow system

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***Jun Shimada***

Miyakonojo basin is well-known agriculture area in Southern Kyushu, Japan and highly depends on groundwater resources for their everyday use. Local unconfined groundwater aquifer is widely polluted by Nitrate-Nitrogen originated from agriculture. It will become serious problem if this unconfined Nitrate pollution enlarges into the confined aquifer system which is used for local city water source. However, the detailed groundwater flow system between unconfined and confined aquifer system has not been cleared yet. The detailed three dimensional groundwater flow system study has been done by using existing wells in a basin to understand the three dimensional distribution pattern of Nitrate-Nitrogen in the aquifer. The field sampling for about 200 unconfined, intermediate and confined groundwater wells was done in July, 2005 and February, 2006 to analyze inorganic water chemistry, hydrogen / oxygen stable isotopes and tritium. For the unconfined groundwater, there exists clear difference for the groundwater flow pattern between the eastern and western basin, which is mostly affected by the surface topography. The unconfined groundwater flowed into the confined aquifer at the eastern part of a basin, while in the western part of a basin the unconfined groundwater on a plateau flowed into the confined aquifer somehow, but most part of the unconfined groundwater has been discharge out to small river valleys between plateaus. While for the confined groundwater, the topographic effect has been disappeared and basin scale groundwater flow from the basin margin toward the basin center is dominated. In the unconfined aquifer, basin wide distribution of Nitrate-Nitrogen content has been recognized and it is relatively higher in the western basin where the cattle farming are dominated. While in the confined aquifer, there are some high Nitrate-Nitrogen spots but do not have regional relations. It is considered that some part of the basin has not distributed the welded tuff layers which exist to separate between unconfined and confined aquifers and this may somehow influences the groundwater flow between unconfined and confined aquifers. Also the existing groundwater flow system based on the groundwater potential distribution clearly explains the denitrification zone in the confined aquifer. In order to understand more precisely this process, groundwater sampling along the flow line from unconfined aquifer to confined aquifer where distribute less welded tuff layers in-betweens those tow aquifers. The 130 samples along the flow line are now under analysis for inorganic water chemistry, hydrogen / oxygen stable isotopes. We hope to have a meaningful results concerning the evidence of denitrification process in the confined aquifer until the full paper submission for the IAHS 2007 meeting.

***Keywords:*** groundwater flow, denitrification, nitrate pollution

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**HS2005** **Poster presentation** **4298**

# Influence de l'activité volcanique dans la chimie du NAPO: affluent de l' Amazone venant des Andes èquatoriennes

***Mrs. Isabel-Carolina Bernal-Carrera***
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***Alain Laraque, Jean Loup Guyot, Francis Sondag, Cristelle Lagane***

Actuellement, la cordillre andine en Equateur est sous linfluence des activits volcaniques de diffrents volcans (Reventador, Guagua Pichincha, Sangay et Tungurahua). Aprs 25 annes dinactivit, le volcan Reventador situ lamont du bassin versant du Napo (Nord-Est du pays), est entr en ruption en novembre 2002 avec dimportantes missions de gaz et cendres. Limpact de cet vnement ruptif sur la physico-chimie des eaux a pu tre valu et suivi dans le temps grce au programme HYBAM (collaboration IRD/INAMHI) qui effectue au pas de temps dcadaire mensuel, une surveillance hydrologique et gochimique des rivires du bassin Amazonien. Ce phnomne sest traduit dans le Napo par une hausse ponctuelle des concentrations du matriel en suspension et en dissolution, en particulier des ions Ca2+, SO4-2 et Cl-1 et une variation de pH. Les concentrations d'ions K, Mg et Si n'ont pas t affectes significativement. Ce travail prsente les variations quantitatives et qualitatives des flux de matires solides et dissoutes de la rivire Napo qui draine une partie des flancs du volcan Reventador. Il renseigne galement sur le temps ncessaire pour que la rivire retrouve sa typologie gochimique dorigine. Une meilleure connaissance des impacts de ces phnomnes sporadiques mais de grande intensit, que sont les ruptions volcaniques permettra damliorer la gestion des ressources hydriques de ce bassin.

***Keywords:*** physico chimie eau, evenement eruptif, bassin amazonien

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**HS2005** **Poster presentation** **4299**

# Sensitivity of nutrient export by rivers to anthropogenic perturbation: dependence on modelling approach a study on the Rhine River Basin

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Riverine nutrient fluxes are susceptible to changes in climate, land use and human pressure (related to population growth and economic development). As a large part of worlds population lives in the coastal zone and relies on a sustainable quality of coastal waters, it is important to quantify the nutrient load input by river to these waters. Models are used to estimate nutrient fluxes at river outlets and to assess the effects of global change on the magnitude of these fluxes. Existing models on nutrient loads differ from simple empirical relations between upstream characteristics and river concentrations at the outlet to more sophisticated models in which hydrological processes are explicitly modelled and nutrient emission are spatially allocated. While many efforts have been made to understand and model nutrient export from river catchments, it is still hard to satisfactorily simulate nutrient transport in large basins. Although empirical relationships have been established that successfully estimate riverine nutrient export from nutrient emissions and basin characteristics, the representation of hydrology in existing large-scale models is often too much simplified to adequately predict nutrient export from river basins under changing climate. Therefore, to predict the combined effects of changes in climate and nutrient emissions, a more process-based modelling approach that considers both hydrology and nutrient transport is essential. In this study we compare the results of a dynamic hydrological distributed model with a global empirical model for the Rhine basin. The hydrological water balance model is run using a consistent global climate input dataset, while the same nutrient emissions are used in both models. Furthermore, in an anthropogenic perturbation study we compare the results of both models for their sensitivity to changing input variables, comprising (a) fertilizer loading, (b) climate variables, and (c) human pressure.

***Keywords:*** nutrient transport, river modelling, anthropogenic perturbation

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**HS2005** **Poster presentation** **4300**

# Changes in hydrological connectivity patterns under predicted future climate change induced rainfall time series

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It has long been accepted that for diffuse pollution to reach the river channel, there need to be both a source and a connection. Much work has been undertaken in determining to source risk (P-index, PIT, etc) however, little emphases has been placed upon determining the spatial structure of the connections. The work that is being undertaken in the SCIMAP project aims to build upon previous work on source risk by the incorporation of a detailed and explicit treatment of hydrological connectivity. The surface flow hydrological connections are driven by the generation of overland flow. For a connection to be made, a continuous flow path between the source point and the river channel is required. The amount of time that a connection exists between a point on the hillslope and the river channel network is determined by the temporal structure of the rainfall time series. This time series creates the conditions for connection, generates the overland flow and finally the connection to the river channel. Under predicted climatic change, global circulation models predict that there will be changes in the temporal structure of the rainfall on both the storm and seasonal scales. These changes may lead to changes in the hydrological connectivity and hence may lead to changes in the amount of diffuse pollution reaching the channel and the location of the critical source areas. The relationship between the surface flow connections and the rainfall time series has been investigated using a fully distributed hydrological model, CAS-Hydro 1.1. This model simulates the hydrological fluxes between cells arranged in a grid pattern and represents interception, surface storage, infiltration, flow through the soil evapotranspiration and river channel flow. The model has been applied to a catchment in North Yorkshire, UK. For a historical simulation the model was able to reproduce the daily time series of discharge with a Nash-Sutcliffe coefficient of 0.7 +- 0.018 and a RMAE of 285 +- 0.019. Model simulations for the current climate and the future climate as predicted by the HadCM3 GCM have been performed. The GCM output was downscaled to daily weather using the SDSM method. From the model output, the predicted patterns of soil moisture have been analysed to give the frequency and duration of connection by surface flow for each point in the landscape. Results are presented for the 2050s and the 2080s and the implications for catchment management of the changing locations of critical sources are discussed.

***Keywords:*** diffuse, connectivity, modelling

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**HS2005** **Poster presentation** **4301**

# Estimating suspended sediment load of rivers using different ANN techniques

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***Ibrahim Yuksel, Emrah Dogan***

Estimation of sediment concentration in rivers is very important for water resources projects planning and managements. The sediment concentration is generally determined from the direct measurement of suspended sediment concentration of river or from sediment transport equations. Direct measurement is very expensive and can not be conducted for all river gauge stations. However, sediment transport equations do not agree with each other and require many detailed data on the flow and sediment characteristics. It is also extremely difficult for an engineer to select appropriate one for a given river. In this study, the performances of three different ANN techniques, namely, the feed forward neural network (FFNN), radial basis neural network (RBNN), and the generalized neural network (GRNN), in estimating daily suspended sediment load are analyzed and discussed. The daily streamflow and suspended sediment data collected from Coruh River, Oltu Stream, Iyi Stream and Harsit Stream Stations in the Black Sea Region of Turkey are used as case studies. The sediment rating curve (RC) and multi-linear regression (MLR) are also applied to the same data. The ANN estimates are compared with those of the RC and MLR models. The root mean square errors (RMSE) and determination coefficient (R2) statistics are used to evaluate the performance of the models. Comparison results revealed that the RBNN model performs better than the other techniques in estimation of daily suspended sediment load.

***Keywords:*** daily suspended sediment, neural networks, estimation

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**HS2005** **Poster presentation** **4302**

# Sediment yield response to changes in occurrence of synoptic winter weather situations a model study from a low mountain catchment in Germany

***Dr. Gregor Ollesch***

***Meissner Ralph, Bischoff Hans***

Regional studies provide evidence that the probability of occurrence of synoptic weather situation is the most important characteristic for climate change in East Germany. However, a downscaling of this situation from global models or utilisation of weather generators is problematic. Thus, to reflect the influence of synoptic winter weather situations on soil erosion and sediment yield long term meteorological data were analysed and utilised for scenario calculations in a small low mountain catchment in Germany. The research catchment Schaefertal is located in the Harz Mountains, NE-Germany approximately 150 km southwest of Berlin. The outlet of the 1.44 km catchment is at an elevation of 392 m a.s.l. and the catchment ranges within 83 m. The orthic Luvisols and Cambisols, which have developed on the loess sediments on the slopes are used intensively for agriculture. The eutric Gleysols and Fluvisols at the valley bottom are utilised for pasture or meadow. Data recording started in the mid 1960s and included meteorological and hydrological data as well as sediment and nutrient loads since the late 1990s. The catchment is characterised by especially high suspended sediment concentrations and loads during winter snowmelt periods. The linked distributed hydrological winter erosion and sediment/nutrient-loading model IWAN was applied for the Schaefertal catchment to identify the influence of climatic variables and land use on runoff generation and sediment/nutrient loss. The continuous model system deliveres reasonable model results for a variety of measured erosion and sediment yield event. The trends in the observed time series of rainfall and temperature are in agreement with other observations and show an increase of winter rainfall by 5 % and an increase of winter temperature of 0.5 C for the last five years compared to the entire monitoring period. 13 years from the existing data set were selected to represent typical synoptic weather situation including i.e. frequent successions of low pressure system passages or stable high pressure systems. The hydrological model results show an increase in snow water equivalent for the scenarios with winter temperatures above and below the average which correspond to the extreme occurrence of the two typical weather situations. Due to the fact that surface runoff generation is linked to soil frost conditions the amount of rill erosion and sediment yield increases more for the stable high pressure situations. However, the higher frequency but lower magnitude of erosion during of frontal situations may lead to a negligence of the sediment and nutrient loss from the catchment. These findings point out the importance of climate change for future soil and water conservation measures.

***Keywords:*** snowmelt, wintererosion, iwan

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**HS2005** **Poster presentation** **4303**

# Effects of climate variability on nitrate loads estimation in a rural basin

***Mrs. Mnica Gelmi***
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***Rafael Seoane***

The objective of this investigation is to study the capability of the Simulator Water Resources in Rural Basins Water Quality model (SWWRRB-WQ) to estimate the mass of a nitrogenous fertilizer transported by runoff in a sub-basin of the Tapalqu River (Buenos Aires Province, Argentina) in present and future climate conditions. The area of the Tapalqu River basin is 1560 km2, with average slopes from 1.2 to 5, annual average precipitation of 903.6 mm and an annual average temperature of 15.3 C. The sub-basin under study has an area of 320 km2 with an agricultural production area of approximately 202 km2 obtained from the analysis of satellite images. Basically, the SWRRB-WQ model consists of a hydrologic and water quality complex deterministic representation and a probabilistic model for hydrometeorological variables generation. This model appropriately simulates the maximum and minimum temperatures and precipitation in a monthly time scale at the station located in the airport of Olavarra for the period 1988 to 1999. A linear regression model was applied to observed and estimated values of nitrate loads transported by runoff at the control section of the sub-basin. An adjusted determination coefficient of 0.81 was obtained as a result of this experiment. The MAGICC/SCENGEN 4.1 model was applied under different emission scenarios to obtain the change in mean temperature and precipitation for a monthly time scale. These results were transformed to a daily time scale according to Wilks (1992) and Wilby et al. (2002) proposals. This transformation was made to obtain the parameters required by the hydrometeorological variables generation model. The statistical analyses show that the obtained values of nitrate loads with the hydrologic and water quality model SWRRB-WQ calibrated at a monthly time scale are similar to observed values. The results of the experiments show the importance that variability in temperature and precipitation have on the estimation of nitrate loads in runoff at different time scales at the control section of the sub-basin under study.

***Keywords:*** water quality model

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**HS2005** **Poster presentation** **4304**

# Bed load sampling techniques for gravel-bed channels

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***Robert Timo Esmann, James Bathurst***

Only a few studies have described the entire range of bed load samplers deployed in recent decades for gravel-bed channels, including beds of gravel and sand mixtures. Methods of measuring bed load sediment transport and bed material in rivers are therefore reviewed and evaluated. A comprehensive analysis of direct measurement techniques, including net and trap samplers, as well as indirect techniques, such as tracers and acoustic devices, shows that they suffer from serious limitations. In particular, no single device has proved to be completely adequate for sampling all size fractions of sediment particles with the same efficiency, while leaving the natural flow and sediment movement patterns unaltered and while remaining in a stable position on the river bed. Perhaps the most serious disadvantage of the methods mentioned is that they deal with only small sample sizes. Even promising devices that hold hope for the future, such as the acoustic technique, can't overcome the stochastic nature of the transport process. Thus, of great importance is the means of calibrating the devices accurately in situ as well as under defined and repeatable laboratory conditions. In recent years a number of organizations have been founded, such as the Federal Interagency Sedimentation Project in Northern America, or the Bedload Research International Cooperative (BRIC), which aim to link individual researchers and develop common and generally accepted approaches to measurement and calibration.

***Keywords:*** bed load sampling, measuremen techniques, calibration

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**HS2005** **Poster presentation** **4305**

# Developing a distributed model for production, transport and deposition of sediments. application to an experimental catchment.

***Dr. Juan Jos Montoya***
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***Juan Jos Montoya, Felix Frances, Pierre Julien***

ETIS is a conceptual distributed hydrological model created to simulate all the important hydrological processes involved during a storm event. It is a complex model that represents a catchment as a cell arrangement interconnected by the topographic configuration, derived from a DEM. At each cell the model made a water balance in a bucket type conceptualization. With this conceptual approach it is possible to simulate the three main runoff components: direct runoff (produced by Hortonian and/or saturation production mechanisms), interflow and base flow. The hydraulic approach used in the TETIS model is based in an approximation of the Kinematic Wave. The hydraulic characteristics are estimated using

***Keywords:*** distributed modelling, erosion, sediment processes

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**HS2005** **Poster presentation** **4306**

# Climate, discharge and water quality in an Alpine glacierised basin

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***John Harrison***

Electrical conductivity was monitored continuously in the Gornera, which drains the 83% glacierised basin of area 82 km2 containing Gornergletscher, Pennine Alps, Switzerland, during summer months, in order to provide an indication of meltwater solute content during each of the four years 1979, 1983, 1987 and 1998. Discharge was also recorded between 1970 and 2005. Total May through September discharge of the Gornera was in the range V39.1% (1978) through +38.9% (1994) of the 1970-1999 period mean of 118.75 106 m3. Range of variability of July through September electrical conductivity was between V25.0% and +29.1% of the mean of 19.6 S cm-1 for the four study years. Intra-annual range of total July through September solute flux (as electrical conductivity x discharge) in the Gornera extended from -22.4% (in 1987, during which, of the four years, discharge for the three months was greatest) to +12.4% (in 1979, when discharge was the lowest) of the four study year mean, which represents an average cationic load of ~25 106 eq. In warmer years, overall, solute concentration was reduced with enhanced discharge flowing rapidly through the glaciers, whereas total solute flux was maintained as increased discharge offset reduced solute concentration. In future warmer years, as glaciers decline in area and discharge may be decreased despite warmer summers, and solute concentration may either increase or decrease. Such fluctuations in concentration will be coupled inversely with changes in flow, which will tend to stabilise solute flux.

***Keywords:*** nothing, nothing, nothing

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**HS2005** **Poster presentation** **4307**

# Evaluation des exportations de matieres

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Les premires mesures des exportations de matires en suspension effectues sur le fleuve Congo ne se limitaient qu des prlvements ponctuels. Ainsi, les concentrations ont t le plus souvent extrapoles dans le temps sans quune frquence de prlvements nait t bien dtermine au niveau de la saison ou de lanne ; do une forte dispersion des rsultats. Depuis 1986, ltude des transports en suspension sur le Congo a fait lobjet de grands programmes de recherches qui ont contribu une nette amlioration des rsultats. Les tudes ralises entre 1986 et 1992 puis reprises partir de 2005, visent tablir la relation entre les fluctuations et les tendances des flux solides et par consquent des concentrations des matires en suspensions du fleuve Congo celles de ses flux liquides durant tout le sicle pass dune part et de constituer une base de donnes dautre part. Lobjectif des recherches menes dans le bassin du Congo taient : - dexpliquer et de quantifier des phnomnes actuels et en particulier le fonctionnement de ce grand systme forestier intertropical ; - de comprendre le pass et la sdimentation dans locan Atlantique ; - de suivre les fluctuations hydroclimatiques et des flux particulaires et dissous. Loriginalit de ces tudes tient dune part dans le protocole de mesure et les quipements mis en uvre. Pour ce faire, cinq prlvements ont t effectus partir dune verticale dans la section. Celle-ci tant rpute reprsentative de ce qui se passe entre la surface et le fond sur lensemble de la section. En supposant que la concentration moyenne mesure sur la verticale constitue une bonne approximation de la concentration moyenne de la vraie section. Le dbit solide QS est obtenu en effectuant le produit de la concentration moyenne Cm par le dbit liquide Q : le dbit Q en m3/s tant connu par la relation hauteur-dbit de la station du Beach de Brazzaville. La concentration moyenne des transports est obtenue par la moyenne arithmtique des concentrations ponctuelles, lesquelles sont pondres par le rapport K (vitesse ponctuelle au point i par la vitesse moyenne de la verticale) : Cm = 1/5 K.Ci ou par intgration de la parabole des K.Ci. la vitesse moyenne tant calcule par intgration de la parabole des vitesses mesures sur la verticale. Des prlvements ponctuels raliss en 1971, 1973 et 1976 (81 au total), on aboutit lestimation de la charge moyenne 27 mg.l-1 . Les mesures systmatiques et rgulires effectues entre 1986 et 1992, dune part et en 2005 et 2006 dautre part , ont permis de prciser les concentrations des suspensions de ce fleuve ; celle-ci est comprise entre 25 30 mg.l-1, ce qui donne en terme de flux, un dbit solide compris entre 900 et 1200 kg.s-1, soit une exportation moyenne de 31 millions de tonnes, et une dgradation spcifique gale 9 t.km-2.an-1. De cette tude, on note une rgularit des rgimes dexportation solides et liquides. La rgularit saisonnire et inter annuelle des rgimes est le rsultat des diffrentes dynamiques fluviales de ses principaux affluents, drainant des sous bassins aux phyto-gomorphologies diffrentes situes de part et dautre de lquateur. Face un important module hydrologique, le rgime des matires transportes est faible et est peut tre trs rgulier dune anne une autre. Dans lensemble, le rgime de transport de matire en suspension semble tre en phase avec celui des coulements. La faible teneur des matires en suspension (26 mg.l-1) illustre une dynamique rosive en phase terminale, o un grand bassin versant dont le relief, avec un profil du fleuve infrieur 10 cm.km-1 est couvert sur plus de la moiti de sa surface dune fort quatoriale, soumis un lessivage intense sous linfluence dun climat humide. Ce bassin aplani, protg par son dense couvert forestier, nest plus sujet une rosion mcanique intense.

***Keywords:*** nothing, nothing, nothing

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**HS2005** **Poster presentation** **4308**

# An assessment of trace metal contamination in intertidal sediment cores of a tropical macrotidal estuary for evaluating sediment quality guidelines

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This work represents a first detailed document regarding concentration, distribution and possible sources of 11 metals (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) in 20-30 cm sediment cores (<63 m particle size) collected from the lower stretch of the tropical Ganges River estuary, north east coast of Bay of Bengal, India and an overall enrichment of the prevalent metals has been recorded at station Lot No. 8, located along the main stream of Ganges estuary. This work aims to evaluate the fluvio-marine and geochemical processes influencing the metal distribution and check the suitability of employing heavy metal data in evaluating biological effects on the basis of Sediment Quality Guidelines (SQGs). Total metal concentrations were determined by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP/AES) after microwave-assisted acid digestion. Metal concentrations were variable at different core depths, in upper, middle and lower intertidal zones as well as among the three sampling stations. In general, for all metals lower intertidal zone shows the minimum concentration. The station Canning is characterized by minimum metal content and the widest differences among zone concentrations. The most interesting feature is the downward increase of concentrations of majority of the metals with increasing depth reaching overall maximum values at a depth of 10-15 cm .As regards the pattern along the core depth, it can be noted that there is not a common trend for the metals in the stations. Gravitative infiltration of the heavy metals in the vertical profile of the sediments can justify the highest concentrations found in the deeper core layer in the case of Cd and Zn. An overall enrichment of all the metals for all three stations was noticed in the upper littoral zone, which might be due to the lixiviation processes caused by extremely high tidal regime, easy infiltration of polluted soil from adjacent coastal areas and sediment resuspension processes. Maximum concentrations of the prevalent contaminants As, Ni, Co and Pb were 18.3 g g-1, 56.9 g g-1, 15.1 g g-1 and 34.1 g g-1dry weight respectively. Moreover As and Ni exceeded most effect based SQGs (58.1%, 79.1% respectively) implying occasional or frequent adverse biological effects. For Cu and Cr, a smaller proportion of samples had exceeded the values by 27.9% and 2.3% respectively indicating that the dataset would be suitable for future use in evaluating predictive abilities of SQGs. High As values in sediments are coherent with the occurrence of high arsenic poisoning (arsenosis) in human being recorded in Gangetic plain of West Bengal. Correlation matrix showed high correlation (r) values (ranging from 0.245 to 0.999) among the metals indicating a similar behaviour during the transport to estuarine system. It can be found in the factor analysis result, that the prominent factor or the first factor explained 33.55% of the total variance (composed of variables considering all the metals) indicating the synergetic behaviour of Al, Co, Cr, Fe, Ni and Zn controlling other metals. Maximum pollution load index was recorded as 3.65. The coastal environment of West Bengal is in a stage of rapid degradation and changes in water quality and sediment behaviour may be taken to be obvious in near future. These processes could mobilize these metals and expose the biota to a chronic contamination, representing a serious threat for this fragile environment.

***Keywords:*** heavy metals, sediments, ecotoxicology

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**HS2005** **Poster presentation** **4309**

# Mathematical modelling of nitrate and salinity

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A physico-chemical water quality model has been developed and tested for the Rosetta Branch in the Nile Delta. This paper discusses the set up of this model, the investigation on sufficient availability of water quality sampling and pollution data to enable such modelling exercise, the extensive model verification by statistical techniques, as well as the model refinement and scenario analyses carried out by the model. The model has been set up making use of the MIKE11 river modelling software of DHI Water & Environment. The physico-chemical water quality (WQ) model is linked with a detailed full hydrodynamic (HD) model developed for the same Rosetta branch, and also implemented in the MIKE11 modelling system. The WQ model aims to describe and predict concentrations of dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrogen in the form of ammonium (NH4-N) and nitrate (NO3-N) and total dissolved solids (TDS), taking into consideration advection, dispersion and the most important biological, chemical and physical processes. All significant pollution sources along the Rosetta branch were considered. Pollution along the Rosetta Branch mainly originates from the drains. Three drains (El-Moheet, Sabal, and Tala) are monitored with different water quality variables measured on a monthly basis within the framework of the National Water Quality and Availability Management Program (NAWQAM). The measured concentrations for the modelled variables and the discharges along the drains and at the model boundaries are used as model inputs. In between the different instantaneous values for these observations, linear interpolations are made. The model is calibrated and validated based on the available sampling data along the Branch. Given the data limitations for calculation of the model input and for model calibration, the simulation results can be considered good after model calibration. The paper focuses on the model results for NO3-N and TDS, and links the results towards their use in water management applying the combined HD-WQ model as integrated decision support tool. This is illustrated in the paper by prior simulation of scenarios in the model.

***Keywords:*** nitrate, total dissolved solids, water quality modeling

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**HS2005** **Poster presentation** **4310**

# Proposing a new regional sediment discharge predictor for unguaged river basins

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***Prof. Kazuo Nadaoka***

Monitoring and prediction of global and regional sediment discharge is a mammoth undertaking due to the countless numbers of rivers worldwide. Currently, only less than 10% of the global rivers are monitored for sediment discharge. These has undesirable implications on the costal environment as basins having abnormal sediment discharge patterns may go unnoticed into coastal environments certainly posing a threat to the natural ecosystem responses. The conventional methods of predicting annual sediment flux by using basin area and mean elevation alone may become unreliable due to both the increasing impacts by humans on river basins and the change in the global climate. This paper presents a new regional sediment flux predictor by assessing annual sediment flux in Taiwan through the consideration of basin percentage vegetation cover, soil erodibility and basin run-off. Statistical multi-regression analysis of mean percentage vegetation cover, basin run-off and mean basin slope shows defining links to basin sediment flux with correlation coefficients, R , of 0.57, 0.54, and 0.63 respectively. Soil erodibility has a weak correlation factor R of 0.13 with sediment discharge, however, the variation of slope angle to soil erodibility displays a strong correlation factor R of 0.66. This new Regional Sediment Discharge Predictor in comparison to the observed annual sediment discharge data of 14 rivers in Taiwan displays a correlation factor R of 0.68. In comparison to the global sediment flux predictor known as the Area-Relief-Temperature (ART) predictor, the new predictor shows an improvement by 224% for the Taiwan case. RSDM was then applied to New Guinea Island. Annual river sediment discharge data from 5 rivers were compared against the RSDM model prediction. The RSDM showed a mean maximum error of 0.83 compared to 2.48 for the ART model. However, when omitting the river that displayed the maximum error for the New Guinea Island, the mean maximum error for the RSDM model improved to an astounding 0.13. River discharge, vegetation cover and soil type is successfully incorporated to do basin scale annual sediment flux prediction. Keywords: basin sediment flux, global warming, regional rainfall, average vegetation cover, soil erodibility, river discharge.

***Keywords:*** basin sediment flux, mean vegetation cover, mean soil erodibility

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**HS2005** **Poster presentation** **4311**

# Urbanization effects on groundwater quantity and quality in the Zahedan aquifer, in southeast Iran

***Mr. Alireza Mahjoub***
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Because water is a critical natural resource, it has always played a vital role in progress and development. Since the first known human empire was established thousands of years ago in the southeastern part of , water has played a key role in any social changes that have taken place in this country. For many people viewing from outside of the country, water scarcity in this country may not appear to be as serious as in other countries of the Middle East.Nevertheless, with a population of more than 65 million people, is actually one of the driest countries of the world. Today, the consequence of rapid population increase pressure for rapid water and land development. In addition, the processes of urbanization and industrialization and the development of irrigated agriculture to support population growth have raised the demand for water, but at the same time have reduced the supply. This paper investigates the quantitative and qualitative impacts of urban growth on the Zahedan aquifer (southeast ). Investigation revealed that the decline in groundwater level may reach about 15 m in some places, and that the direction of groundwater flow changes towards the area. In general it can be said that unplanned development of urbanization in the area has created a very difficult situation.

***Keywords:*** zahedan, groundwater, urbanization

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**HS3006** **4312 - 4376**

## Symposium
## Changes in Water Resources Systems - Methodologies to Maintain Water Security and Ensure Integrated Management (Sponsor ICWRS)

**Convener :** Prof. Nick van de Giesen
**Co-Convener :** Prof. Yoshihiro Fukusima

The issues of water shortage and related eco-environmental degradation are of great importance and urgency, particularly in developing countries. Accordingly, this symposium will address changes affecting water resource systems and their different functions: changes related to climatic conditions as well as those resulting from human activities. Many examples can be given of where these have had a devastating impact and threaten the long-term sustainability of local socio-economic systems. A key challenge therefore is to forecast over a wide range of time scales the changing quantity and quality of the freshwater resource. Key themes will include the water cycle processes impacted by climate change and high intensity human activity; changes in water use as a result of new economic factors; the evaluation of eco-water demands; and integrated management and rational water allocation. The symposium will have a particular focus on developing countries and will seek to evaluate different methodologies designed to maintain the multiple functions of water resource systems under change. An important aspect is how the different system components can adapt to new conditions. Since water resource systems are complex, a successful approach to dealing with change must be multi-disciplinary. Hence, in considering methodologies, account must be taken of social, economic and environmental factors, as well as the technical dimensions of the measures contemplated. In view of the large uncertainty in both future water resources availability and our potential to deal with the problems, focus will be on the flexibility and robustness of approaches and solutions.

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**HS3006** **Oral Presentation** **4312**

# Change of Water Resources System & Water Security in China

***Prof. Jun Xia***
*Hydrology & Water Resources Leading Professor IAHS*

China is a developing country with a variety of climate & much stress from its population & economic development in the world. Water problem, namely floods, droughts and water environment pollution, becomes a major limited factor to sustainable development in China. This paper will address the issues on change of water resources system to change environment & challenges of water security in present and future of China. Discussions will focus on two major impact aspects, namely climate change and human activity. Three emergency & conflict areas from North China, West China and Yangtze River basin are selected as examples to show water stress and challenges of water security. North China is the center area of politic, economic & cultural in China. The water security problem in both water shortage and water pollution is a big challenge very serious. In West China, water is the key issue for ecosystem and sustainability. How to balance water demands for social & economic development and eco-system requirements will be a long terms task. Yangtze River basin is the biggest river in China. Several big water projects, such as Three Gorges Projects were built up. How to maintain health Yangtze will be a big challenges in the future. All these aspects would be thought in whole picture. Thus, several perspectives and suggestions are given for the goal of water sustainable use in the emergency & conflict areas to support the sustainable development of China in the future.

***Keywords:*** water crisis, water security, climate change

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**HS3006** **Oral Presentation** **4313**

# The hydrologic impact zone in the lower reaches of the Yellow River

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***Jianyao Chen, Yoshihiro Fukushima***

The lower reaches of the Yellow River have been affected by water shortages since the 1990s. We suggest that water balance and resources in the lower reaches should be considered from the standpoint of water diversion and effects on the coastal zone. In this paper, we define a new concept of an impact zone to replace that of basin for discussion of water resources issues. The objective of this study are to identify the spatial and temporal changes in water use in the lower reaches over the last 50 years, and to evaluate the impact zone of the Yellow River, for integrated management of water resources. Yellow River water is connected to the groundwater hydraulically over the whole delta, and therefore, the impact zone of the river comprises the entire river delta. The river water and groundwater are also connected to the coastal water in Bohai sea, therefore the changes in water discharge by river and groundwater from land into the ocean alter the water, material and ecological balances in the Bohai sea. Integrated managements are necessary under the changes in water resources system in the lower reach of the Yellow River, and the concept of the Impact zone is the key for that. In addition to hydraulic connections between different waters in the lower reach of Yellow River, the impact zone includes not only natural water transfer but also human -induced water movement such as irrigation in the lower reaches of the river. Water diversion from the river may be a major contributor to the recent water shortage in the lower reaches. We propose that the impact zone concept be used for water resources issues, particularly over the lower reaches of the basin.

***Keywords:*** impact zone, yellow river, water diversion

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**HS3006** **Oral Presentation** **4314**

# Challenges Facing the Kruger National Park, South Africa, in Water Resources Management

***Dr. Thomas Gyedu-Ababio***
*IAHS*

The Kruger National Park is situated between growing industrial, agricultural and township developments on the west and the Republic of Mozambique on the East. The Kruger National Park is a preferred destination for many eco-tourists around the world. The rivers in the Kruger National Park originate from outside the park and the impacts on these rivers upstream and adjacent to the Kruger National Park have resulted into high silt levels in the rivers. Different forms of pollution are also on the increase and the decrease in the quantity of the water in the rivers (flow) which also affects the pollution level, has been a major source of concern. The aquatic biodiversity in the Kruger National Park including some fish species has been found to be decreasing as a result of the different impacts. The Ecological Reserve has been determined for some of the rivers in the Kruger National Park. The Ecological Reserve is however not being implemented by the Department of Water Affairs and Forestry and as such the rivers in the Kruger National Park do not receive the minimum amount of water and the quality that they deserve. The conflicts in the competing interests for water have led to some of the perennial rivers in the park drying up during the dry months. The National Protected Areas Act and the Ecological Conservation Act mandate South African National Parks to protect biodiversity in protected areas. Rivers in the Kruger National Park are very important in this regard. It is recommended that the environmental water requirements for all the rivers passing through Kruger National Park be determined as soon as possible and relevant legislation enforced when and where necessary, to ensure the proper and sustainable utilisation of water resources in the region.

***Keywords:*** biodiversity, sustainable, reserve

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**HS3006** **Oral Presentation** **4315**

# Changes and control processes of water and related ecology in the lower reaches of the Tarim River

***Dr. Qiting Zuo***
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The Tarim River, which is located in the arid region, is the longest continental river in China. The inflow of the mainstream of the Tarim River shrank because of the natural and human factors, as caused the stream flow to dry up for an extent of over 300 km in the lower reaches of the Tarim River. By grasping the chance of the high-water period from 2000 to 2003 and the high water level of the Bosten Lake, Chinese governments implemented 5 times of the urgent water diversion from the Bosten Lake to the lower reaches of the Tarim River for saving the ecology. Thus, the 30-year stream flow drying-up for an extent of over 300 km in the lower reaches of the Tarim River has been ended. This is first time and the most famous water diversion only for saving the ecology in China. In the paper, the changes of the stream flow drying-up was briefly explained, then control processes and effects of the water diversion were analyzed.

***Keywords:*** tarimriver, water resources, the ecology

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**HS3006** **Oral Presentation** **4316**

# Impact of Water Pollution and Water Impact of Water Pollution and Water Shortage on Economic Development of the Haihe River Basin

***Dr. Hao Huang***
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Haihe River Basin is one of the seven major river basins, which are of great ecological importance to China. On the one hand, Chinafs economy is developing rapidly; on the other hand, the ecological environment in that region is becoming increasingly worse, and the ecosystem there is getting extremely fragile, which is inconsistent with the countryfs rapid economic development. Originated from the general equilibrium theory of Walrus, CGE model (Computable General Equilibrium) can be applied to analyze impact of government policy on economic development. Environmental policies taken to reduce pollutant disposal and water consumption directly influence product price, production cost and even economic structure. Therefore, elements of environment and resource can be brought into CGE model so as to simulate general economic system of equilibrium and thus to identify the key elements. And those key elements will determine the overall mechanism of resource distribution and income distribution in market economy. In this paper, by building a simple CGE model, we analyze the impact of water pollution and water shortage on economic development in the basin region. And viewing water resource as one of the production factors and water pollution treatment as an independent entity, we also analyze the relationship between input and output of water resource, water pollution control and other economic activities. The analysis comes to the following points. First, through water pollution controlCthe traditional GDP decreases, but the green GDP increases; and moreover, the economy in the basin improves to a sustainable way. Second, compared to water shortage, water pollution crisis is more urgent. Through gdivert water from the south to the north projecth and technique index promotion, water shortage will get alleviated, but water pollution need further effort.

***Keywords:*** cge model, haihe river basin, water shortage

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**HS3006** **Oral Presentation** **4317**

# A water balance approach to indicate effects of man-made enhanced greenhouse warming on groundwater recharge in the Kalahari

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Groundwater is often the only available drinking water in drylands. Thus, reliable estimates of groundwater recharge are the key to a sustainable water resource management. The clear advantage of grid-based conceptual water balance models compared with other standard recharge estimation techniques is their ability to reflect both, temporal and spatial variations. In addition, such water balance models can be used to simulate changes in hydrological systems, as long as physical processes are understood, simulated appropriately and verified by independent data. Possible prediction scenarios are changes of land-use or climate. The distributed, process-oriented, physically based water balance model MODBIL used in this study considers the major water balance components of groundwater recharge, surface runoff, interflow, and evapotranspiration. MODBIL calculates a spatially differentiated water balance by simulating water fluxes and storages in a temporal and spatial resolution based on meteorological, topographic, soil physical, land cover and geological input parameters. Here it is set up for two Kalahari sub-catchments in northeastern Namibia and northwestern Botswana at a spatial resolution of 500 x 500 m for a period of 22 years with a daily resolution. The results are verified with the chloride mass balance and hydrographs. Then scenarios of climatic changes are simulated. Climatic time series under conditions of enhanced greenhouse warming have been produced based on statistical downscaling procedures of large-scale circulation models and regional climate. Results reveal that summer rainfall in northeastern Namibia will be temporarily more pronounced with significantly increased precipitation during January and February, but less precipitation in March. Predicted climatic time series for the water balance model were produced by using the recorded daily rain time series at Tsumkwe adjusted with factors for mean value and standard deviation. The factors were obtained from the comparison of CRU data from 1971 2000 (input data for the statistic downscaling) with the predicted monthly precipitation amounts. The model was then run with this new climatic time series. With this approach an increase in mean groundwater recharge and interflow is predicted for the Khaudum and Nhoma catchments.

***Keywords:*** water balance model, groundwater recharge, statistical downscaling

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**HS3006** **Oral Presentation** **4318**

# Integrated approach for assessing climate change impacts on a regional chalky aquifer in Belgium

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***Goderniaux Pascal, Brouyere Serge***

An integrated hydrological model was developed in order to study the potential effects of climate change on groundwater resources. This model considers most hydrological processes in a physically consistent way. More particularly groundwater flow is modelled using a spatially distributed finite element approach. After a detailed calibration of this accurate tool on the last 30 years and validation on recent periods, quantitative interpretations can be drawn from the groundwater model results for different scenarios. Predicting effects of climate change, one can speculate on how the recharge quantity and the duration of recharge will be affected. If an increase in winter rainfall is foreseen in temperate areas like in Belgium, a shorter recharge season is also suggested leading possibly in an uncertain trend for the total recharge of the aquifers. Considering IPCC climate change scenarios, it appears that, on a multi-annual basis, most tested scenarios predict a decrease in groundwater levels and reserves in the tested chalky aquifer in the Geer basin in Belgium. The river-aquifer interactions are explicitly taken into account in the model as well as the spatial heterogeneity of the chalk geology characteristics. First results indicate that groundwater deficits may be expected in the future. Moreover, this trend is computed for a very optimistic scenario (at this stage of the study) neglecting all other pressure changes on groundwater resources: i.e. no change in land use and in pumping conditions.

***Keywords:*** groundwater reserves, climate change, integrated modelling

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**HS3006** **Oral Presentation** **4319**

# Water resources management in Chile: different approaches in Easter Island and the extreme northern continental areas

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Global environmental impacts mean that carbon dioxide emissions in Mexico City and Shanghai contribute to climate change impacts in the South Pacific and Andean Regions. Responding to this unintentional blurring of geographic and environmental impact boundaries requires contributions from disparate scientific areas and joint-efforts among physical and human geographers, in order to address ecological and socio-economic problems associated with endangered paradises. Water security is as vital for Humanity as food sufficiency. The United Nations Millennium Development Goals (2000) recommend a trend toward sustainable development principles in Tropical Regions, encompassing social, economic, political and environmental components. The concept of environment incorporates the physical amounts of renewable and non-renewable resources, water being the most essential natural capital. The paper focuses two case studies from Chile, different water management approaches from quite frail ecosystems, a tiny Pacific island without a single river and extensive, mineral rich Andean semi-desert areas. Water legislation in analysis will be one sole and unchanged, for both territories are part of the Republic of Chile. Water legislation has not been equally applied to the whole country though, making the illustration of contrasting water privatisation and centralised management models possible in a single Latin American country. Case studies display diverse jurisprudence, based on disparate historical background and political status of regions, on mineral availability and exploitation through times, and resulting into dissimilar eco-environmental impacts. In fact, while climate change, water privatisation and high intensity industrial activity have impacted a near desert environment and are provoking dramatic surface and ground-water shortages in Extreme Northern Chile, on Easter Island rainfall fed hydrous systems have not been targeted by water concessions so far, the vital good being provided by exclusive public servicing, founded on historically centralised policy options that have maintained freshwater quality and quantity over a remote, poorly resource provided and rather critical Pacific island ecosystem. The paper further highlights the history of water legislation in Chile, evaluating different methodologies designed to address changing needs in an evolving and developing economy, until current Water Code (1981) imposed by a dictatorial regime that forced liberal soil and water laws. In considering methodologies the paper addresses social, cultural, economic and environmental factors, in order to explain how river depletion occurred in Chile and elaborate alternative water resource systems management.

***Keywords:*** water, management, chile

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**HS3006** **Oral Presentation** **4320**

# Evolution of property rights in groundwater irrigation system and food-water security in Haihe basin, China

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The evolution of property rights in groundwater irrigation system (PRGIS) may affect not only crops structure but potential output of water. Such impact is especially obvious in Haihe basin in which irrigation depends mostly on groundwater. So, the groundwater is the key factor that links the food security and water security in Haihe basin. By the method of sampling investigation, the econometric function, which reflects the correlation of property rights in ground irrigation system and crops structure, has been built up. As a result, with the ownership changing, from collective to non-collective, in ground irrigation system, the farmers prefer to plant water sensitive crops even if they needs more water for irrigation. At the same time, different kinds of ownership in ground irrigation system lead to different potential output of groundwater. Through investigation, we found the groundwater output per unit fixed asset can represent such difference. According to it, we choose the change ratio of water output per unit fixed asset to measure the change of potential groundwater resources caused by evolution of property rights. Then we choose the policy dialogue model (PODIUMSIM), which reflects the transformation relationship between food and water, as analysis tool. Based on above working, we could set up an evaluation system representing the impact on the food-water security which caused by the evolution of PRGIS in Haihe basin. Through scenario analysis, some important conclusions as below are obtained: (1)In regard to basin, the food security is mainly reflected by the degree of dependence on outside food supply and the ability to export economic crops which can earn more capital. Although the evolution of PRGIS will enhance the degree of dependence on outside food supply, the increasing of economic crops exporting can earn more money to exchange the food. So, the evolution of property right can improve the food security in basin. (2)The evolution of PRGIS will enhance the water requirement in whole basin. The reason is that more water sensitive crops have been planted, and the depletion of whole basin has enhanced accordingly. (3)The evolution of PRGIS has caused not only the increasing of water depletion but the increasing of net available water resources in basin. But the development of water resources has fallen off. Eventually, the degree of water security is raised in basin. (4)The evolution of PRGIS can enhance not only the coefficient of food security but the coefficient of water security in basin. Therefore, the government should construct better political environment, encouraging the evolution of PRGIS.

***Keywords:*** groundwater irrigation system, property rights evolution, food water security

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# Historical analysis of water use in irrigation and hydrological environment in two arid regions in South America

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An important issue in water management is the nature of unstable water availability during seasons and over the years. Many rivers have an irregular flow pattern, with large fluctuations in and over seasons and very low flows in the dry season. In such a setting it is difficult to match water availability with actual water requirements. Rational water use requires (to a certain extent) knowledge of river flow predictability. This paper will discuss two case studies dealing with these issues from a historical perspective. Both case areas are located in arid regions in South America, one in Argentina and one in Peru. History not only provides the data for optimization of models, but also helps to understand the nature of the relations between water, human intervention and environment. Historical understanding of modern problems shows that technologies and human activities do not develop in a vacuum just like that, but are historical products. The case of the Proyecto Ro Dulce irrigation area in Argentina shows that increased control of surface water flows has enlarged incoming flows into the PRD. The actual water use pattern, however, reproduces the former distribution schedule: when water in the river was only available during high rivers discharges and therefore large flows had to be used in relatively short periods. The stronger regulation of flows that allowed better-secured starting conditions for the crops and a better-regulated growing season did not change traditional practice at farm level. As a result, much more water enters the irrigated area than appears to be needed. The second case study discusses irrigated agriculture in the Pampa de Chaparr on the arid Peruvian north coast (900 AD - 1500), which depended heavily on the strongly varying discharge of the Ro Chancay. As the system intake will not have been adjustable, canal flows will have varied too. Water levels in the canals must have fluctuated considerably. How these fluctuations were dealt with and how they influenced water use is not clear yet. Many old canals are well kept; the area has been subject of intensive studies to understand its irrigated agriculture. Essential for irrigation is water availability and the ability to bring water to fields. About 80% of the irrigable area in the Pampa could be supplied with water in most years. Timing of irrigation would have been extremely important, with river discharges only high in summer. Crop modelling result suggest that planting crops in January gave secured starting conditions and made crops less dependent on water shortages later in the season (June/July).

***Keywords:*** irrigation, uncertainty, aridity

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# Hydrological impacts of field interventions in smallholder farming systems using geophysical observations and numerical modeling for semi-arid Northern Tanzania

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The challenge of achieving the Millennium Development Goals (MDGs) on food security is, to a large extent, achievable through balancing water, nutrients and farm management tactics. For sub-Saharan Africa, water is believed to be the limiting factor to crop productivity yet the majority of the population relies entirely on rainfed agriculture. The region has of late been experiencing reduced seasonal rainfall due to increasing uncertain climatic conditions. While irrigation is perceived to be the solution to bridging the impacts of dry spells during growing seasons, it is also accepted that irrigation schemes have only benefited a small percentage of the population in sub-Saharan Africa and, in most cases, the benefits from developed irrigation schemes have been generally insignificant. As an alternative, a number of in-situ and micro-catchment rainwater harvesting techniques have been promoted to provide additional water especially to rainfed smallholder communal agricultural systems. These interventions, which include floodwater diversion, infiltration trenches and conservation tillage techniques are being applied as soil and water conservation strategies. The challenge is to understand in more detail the hydrological processes at play due to these interventions. This paper presents results from a study being conducted in the semi-arid Makanya catchment, Northern Tanzania, where average rainfall is 400-600mm/a and is split over two seasons per annum. Combinations of water harvesting and soil moisture retention techniques were studied at five different sites. A comprehensive on-site measuring network was setup to measure the water partitioning processes. The parameters measured include rainfall, run-on and runoff from measured catchment areas, soil evaporation, transpiration and soil moisture using geophysical measurement techniques. The HYDRUS 2D model was used to simulate soil moisture dynamics as a result of the interventions. The results from the research showed that significant changes to the water balance mainly through improvement in soil moisture retention, hence more crop productivity, resulted from a combination of interventions and not a single technique. Soil moisture increased by between 30% and 50% where interventions were introduced. The study also showed that the zone of greatest soil moisture retention was at around 40-60cm depths, which also coincides with maximum rooting depths for maize crops under subsistence farming in the study area. As a result, yields for maize increased by between 40% and 235% depending on techniques applied and the total water made available at each site. The simulations also revealed that the benefits of these interventions are very localized and neither contribute to deep groundwater changes nor significant downstream subsurface flow. The research concludes that the chosen experimental set-up in combination with the model Hydrus 2D are appropriate to better understand and predict soil moisture dynamics. Output from the model serves as sound input for crop growth models.

***Keywords:*** field hydrology, water balance, rainfed agriculture

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# Quantifying the uncertainty in Nile runoff response to climate change

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A statistical downscaling model (SDM) is developed and tested with rainfall data from the Blue Nile Basin. The SDM allows daily gridded rainfall to be generated at a 20km x 20km resolution from monthly 2.5o x 3.75o GCM output. The statistical downscaling methodology uses the GCM-simulated rainfall as a predictor of the statistical properties of small-scale rainfall. Daily rainfall fields are generated using a stochastic generator that replicates the spatial and temporal correlation structure of the observed data. Three GCMs are employed in the study; (i) the Canadian Climate Model CGCM2 (ii) the climate model developed at the German Max Planck Institute ECHAM4 and (iii) the UK Hadley Centre model HadCM3. The statistics of the SDM generated rainfall over a baseline period compare well with observational data. Once calibrated, ensemble runs of the SDM are used to produce multiple traces of future daily rainfall over the Blue Nile Basin until the end of the century. These rainfall scenarios are fed into an operational distributed hydrological model to assess the sensitivity of Blue Nile flows to climate change. The issue of uncertainty is addressed by employing different GCMs combined with stochastic modelling.

***Keywords:*** climate change, uncertainty, nile

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# Multi-decadal climatic variability and future climatic scenarios in the North China Plain, China

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The water shortage issue and related eco-environmental problems in North China is one of the major emerging problems in China, not only because the average amounts of water resources in this region per capita and per hectare are one-fourth and one-fifth of the countrys averages respectively and the region has less than half the water availability amount per person than the absolutely water-scarce Egypt, but also the region, consisting of Beijing and Tianjin, is a densely populated area acting as the centre of politics, economy, culture and transportation in China. The climatic variability and climatic change would make the situation worsen as it has a major impact on the hydrological cycle and consequently on available water resources, and the potential for flood and drought. This paper will analyze the multi-decal climatic variability and its potential linkage with ENSO, and present the future climate scenarios from different GCMs outputs for the North China Plains. The impacts of climatic change on regional hydrological regimes are also discussed. The uncertainties of future climatic scenarios due to model inconsistent are also addressed. The results could help the local governments and decision-makers to make better water resources management and economic development planning.

***Keywords:*** climatic variability, north china, gcms

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# Integrated assessment for a more robust Murray-Darling Basin water resources system

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The Murray-Darling Basin contains Australia's most important surface water resource. Ecological degradation and threatened water security have led to a cap on further diversions, presently amounting to ca. 45% of water resources. An increase in environmental flows is now sought to restore river health. At the same time there are threats that may reduce water resources by 10-20% in 2020. These include climate variability and change, as well as changes in the use and management of land and water resources. Methods are under continued development to help evaluate the cunmulative downstream impacts of change scenarios on water security and flow regime. Available methods to translate scenarios into streamflow changes typically need to be scaled down in space and time to be useable, and their links to social and economic processes need to be defined. Furthermore, more accurate, comprehensive and process-based river flow accounting is crucial for more credible assessments. Integrating various disparate data sources, including station and remote sensing data, in a model-data fusion framework is an important step towards achieving this. Examples of integrated assessments that address both natural and human changes are presented.

***Keywords:*** integrated, assessment, scenarios

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# A real-time dynamic flood prevention storage control model for Qingjiang

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Qingjiang River is the second largest tributary of the Yangtze River in Hubei Province in China, winding through the southwest Hubei from west to east with a basin area of 16700km2. The total length of the mainstream is 423km with a hydraulic drop of 1430m. A three-step cascade reservoirs development scheme of the Qingjiang River is Shuibuya-Geheyan-Gaobazhou from upstream to downstream and the development task is mainly for power generation, flood control and navigation, etc. The two downstream reservoirs have been built and operated for many years, while the upstream Shuibuya reservoir is still in the construction and will be completed in 2008. The water resources system in the Qingjiang River basin will be changed when Shuibuya reservoir starts to storage water in the end of this year. A new methodology and operation policy for Qingjiang cascade reservoirs should be derived in order to maintain flood protection security and ensure integrated water resources management. According to the current operating schemes, two upstream reservoirs have reserved 500 million m3 flood prevention storage each during the flood season. The designed annual average hydropower output is 725.90 MkW for Qingjiang cascade and a large amount of flood water resources will be discharged during flood season. With the rapid development of Chinese economy, the issue of water shortage is of great importance and how to enhance the efficiency of reservoir system management is becoming more urgent than ever. As a large scale reservoir with strong regulation ability, the Shuibuya will change and enhance the existing flood prevention capability in the Qingjiang and downstream Yangtze River basins. By considering the information of real-time flood forecasting and storage compensate capacity, a real-time dynamic flood prevention storage control model for cascade reservoirs, named Successive Approximate Decomposition Coordination Model (SADCM), was proposed and developed. The objective of this study is to seek the optimum flood prevention storage operation scheme for the cascade reservoirs with the maximum social and economic profits. The SADCM consists of two components. First one is compensate operating module for obtaining the optimal operation processes of all the reservoirs with the suggested flood prevention storage constrains of the same iterative calculation. In this module, the objective function is to maximum hydropower output and water storage energy based on 7-day forecasting information and the real-time flood storage compensated capability of the cascade reservoirs. Second one is flood storage module for calculating the allowable minimum flood prevention storage for each reservoir. If the constrains of reservoir's flood prevention storage between these two modules are not coincident, an iterative approximate calculating procedure is continuing until there are all coincident. The daily runoff data during 1951-2005 was used to tested and validated SADCM, and compared with the current operation schemes for the Qingjiang cascade hydropower plants. The application results show that the SADCM can obtain the optimal dynamic flood prevention storage schemes for cascade reservoirs and enhance the efficiency of reservoir system management and floodwater resource utilization. The proposed model can generate extra 28.2 MkW hydropower (increase 2.82%) and save 848 million m3 flood water resources (increase 6.38%) annually without decreasing the original design flood prevention standard.

***Keywords:*** cascade reservoir, water resources, management

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# Case study of catastrophe theory to social assessment of integrated flood risks: Yangtze River

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Floods have both natural attribute and social attribute. Consequently, assessment of integrated flood risks should include technical assessment and social assessment. When carry through social assessment of risks, there are common three difficulties: to how much the ability of human to endure risk; to what risk level for human to accept (that is acceptable risk, or threshold), and to what extent a flood can affect the society. Combining with the transient attribute of flood disaster risk both in nature and society and considering the level of acceptable risk (or risk threshold), this paper analyses the basic composition of social assessment of integrated flood risks, which consists of risk of casualties of people, economic risk, environmental risk, and potential risks, from the perspective of sociology, and presents an assessing method of integrated flood risks based on catastrophe theory. Based on expatiating on primary models of catastrophe theory, the paper establishes the assessment index system for Yangtze River and ascertains catastrophe type on each layer of the assessment index system. Then, the calculation is carried out from lowest layer to the top layer where the social assessment index for integrated flood risk can be derived with orthogonal formula. The method offers an answer to the question to what extent a flood can affect the society. Rationality and practicality are proved by the case.

***Keywords:*** flood disaster, integrated risk assessment, catastrophe theory

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# Uncertainty in water resources distribution system ----- The analysis of available water in Danjiangkou Reservoir for the water transfer project from South to North in the Middle Routine

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Danjiangkou reservoir is one of the most well known reservoirs in China due to Water Transfer Project from South to North; it is situated in the upper stream of Han River, a tributary of Yangtze River. The basin area above reservoir dam site is about 95,200 km2, which is 60% of whole basin, and its active capacity is about 19.1 billion m3. The first task of reservoir is flood control, and water supply is in second rank instead of hydropower generation after being planned as water sources for Water Transfer Project from South to North in the middle routine. In 2010 the amount of 9.5 billion m3 water will be diverted to the north part of China from this reservoirs. The aim of this paper was to investigate the impact of uncertainty in changing climatic and socio-economic condition as well as water management strategies on the amount of water diverting from the reservoir in future. Considering global climatic change, human activities influence and socio-economic development of upstream in future, different stochastic simulation model are used to deal with uncertainty of reservoirs inflow based on the history runoff data analyse, and water demand from downstream in future, which is not only water demand from socio-economic development, but environmental water demand also, are very carefully considered by setting different scenarios and water management strategies. An integrated water management model, which is based on dynamic planning, is developed to calculate the amount of water could be diverting. In this model different priority for water users and targets was set to evaluate the uncertainty of water diverting by Danjiangkou Reservoir in future, and finally the correlation between water diverting, reservoir inflow and water demand of downstream, was assessed and examed. Stochastic process technique and probability theory were also used to achieve those goals.

***Keywords:*** uncertainty, stochastic processes, water security

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# Recent water shortages in the Heihe River Basin, western China

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Research into global warming forecasts suggests that while the worlds average precipitation is likely to increase, precipitation in arid and semi-arid areas is likely to decrease. The trend of rising temperatures has been observed in the Heihe river basin. With the increase, the melting of the glaciers accelerates and the resulting increase in river runoff results in increased river flows. Thus, while global warming may cause a decrease in precipitation, the increase in water derived from the melting glaciers will, to some extent, offset this loss. Certainly, there are data to suggest that the volume of runoff flowing from the upper to the middle reaches of the river over the past 50 years have not changed. Water shortages, however, become a big issue in the basin. In the grazing areas of the middle reaches of the Heihe River, ecological migration has been considered necessary for restoring grasslands degraded by overgrazing. As a result of ecological migration, new agricultural land would be required, both in the case of herders shifting from natural grazing to feedlot raising, and in the case of people adopting crop farming. The demand for irrigation water in the middle reaches alone has reached the Heihe rivers water supply capacity and any further increases in the demand for water by new migrants can only be met by using groundwater. In other words, ecological migration in the middle reaches has generated new demand for water, accelerating the fall in groundwater levels. This applies also to ecological migration at the lower reaches of the Heihe, which is directed at the restoration and conservation of poplar forests. At both the middle and lower reaches, there is now less water feeding groundwater reserves - equivalent to the amount of water that previously leaked from the water channels. This means that the introduction of modern water channels has inadvertently had the effect of lowering of groundwater levels in both areas. While considerable consideration has been afforded to prominent geographic features and characteristics of the environment, such as rivers, lakes, and vegetation, groundwater resources and their status often receive less consideration given that they are invisible. Groundwater resources take a considerable time to accumulate and serve us as a vital form of inheritance from previous generations. Yet, it seems that we are quickly exhausting this inheritance in our attempts to meet our short-term needs, without giving any thought about leaving anything for our descendants.

***Keywords:*** watershotages, ecologicalmigration, groundwater

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# Analysis of hydrological changes and their driving forces in Hailiutu River Basin

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In recent years, the research on hydrological cycle under changing environment, including global changes and human activities, has been the international frontier and the key problem. Hailiutu River basin is located in the sandy region of Wuding River Basin, characterized with drought, frequent wind, low vegetation coverage and fragile environment. In recent years, precipitation has rapidly decreased. Furthermore, a great deal of soil and water conservation measures has been carried out to effectively control soil erosion and water loss. While persistent effort of ecological construction has remarkably improved the ecological conditions, it has distinctly reduced the incoming water volume of the study area, and water cycle as well as water balance has been subject to significant disturbances. Therefore, it is essential to study hydrological responses to climate change and human activities in Hailiutu River basin. This study will provide scientific foundation for water allocation and sustainable development in the study region as well as the study on water cycle and its driving forces in typical sandy regions. First, through the diagnosis of the changing point for the observed runoff, the evolving process of annual runoff was divided into two periods, i.e. the base period (1960-1985) and the change period (1986-2000). And then, using time series method and Kendall method, the evolving trend of hydrological cycle was discussed in this study. The results indicated that annual rainfall and actual evapotranspiration had a tendency to descending on the whole and however, annual and monthly runoff showed the more distinct descending trend. Applying time series method of characteristic parameters, which included anomaly percent of annual rainfall and runoff, runoff coefficient, daily flow duration curve, and double accumulative curve of annual rainfall and runoff, river runoff change and its driving forces were analyzed. The results indicated that due to the climate factor as well as human factor, the mean annual runoff has decreased by 34.9 million cubic meters during the change period, which respectively accounted for 60.86% and 39.14% among the total decreased runoff. Hence, the effect of the former exceeded that of the latter. However, human activity, which mainly refereed to soil and water conservation in this study, has remarkable impacts on the hydrological cycle. It has not only decreased annual runoff, flood peak discharge and base flow, and but also altered runoff distribution during a year.

***Keywords:*** hydrological change, driving forces, hailiutu river basin

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# Application of multi-objective chaotic optimization arithmetic in optimal water resources deployment

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Water resources deployment involves economy, society, ecology, environment, projects and so on. It is a big system multi-objective nonlinear problem, which is characteristic of multi-analysis and space-time variability. Based on the chaotic characteristic analysis of water resources, a multi-objective chaotic optimization model is established for optimizing water resources deployment in the paper. The multi-objective programming method and the chaotic optimization arithmetic are coupled in order to avoid the difficulty that the objective function and the constraint condition must be continuous and differentiable. The arithmetic magnifies the chaotic series engendered by Logistic mapping to the feasible region, and seeks the best result by comparing and iterative calculation. The arithmetic is enhanced greatly. All the work has important significance in enriching and developing the optimal water resources deployment theory and optimization arithmetic.

***Keywords:*** deployment, multi objects, chaos

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# Externalities in watershed management

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In watershed programs all attempts are made to store effectively the rainfall in the soil profile, between the bunds and check dams, and in water storage reservoirs, so that the rainfall is more effectively utilized within the watershed. Negative externalities may be generated when such watershed activities cause increased loss of water in form of evapotranspiration; excessive detention of water in newly created water structures; resulting in lesser surface runoff for down-stream areas and thus stressing the down-stream community in fetching water for drinking, livestock and other uses. Negative watershed externalities are inefficient because they prevent the most productive overall landuse from being put in place and skew the distribution of benefits among land users, often in ways that harm the poor. Thus, it becomes imperative to measure the level of such negative externalities while formulating and implementing the watershed programs. Watershed management activities have also resulted in massive landuse changes in India. Joint Forest Management (JFM) is a scheme through which large-scale plantation is done alongside the watershed programs. Forest policy in India targets increasing forest cover from present 19% to 33% by the end of eleventh development plan i.e. year 2012. Such management scenarios affect the total water quantity available at the down-stream watersheds and are the cause of negative externalities. The present paper shall demonstrate the measurement of externalities in an experimental watershed through GIS based watershed modelling and using livelihood indices. The simulated results show that the surface runoff has reduced by 11.22% and 22.56% for the 2007 and 2012 futuristic forest policy scenarios. Heavy losses in surface runoff may deteriorate the water availability to down stream area stressing water demands especially during the water stressed months. This has also been reported in the primary survey conducted during the year 2004. An analysis shows that for a down stream village Amoli average time spent in water collection for domestic uses has increased by about 4%. The experimental micro-watershed Dudhi is located in the Raisen district of Madhya Pradesh State, India.

***Keywords:*** externalities, watershedmanagement, gisbasedmodelling

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# Risk, spatial developments, subsidence and climate change: adding or multiplying?

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Recent experience with heavy rainfall in The Netherlands has shown that many polder areas are vulnerable for inundations of short duration, as runoff may temporarily exceed the limited discharge capacity of drainage canals and pumping stations. This type of flooding is not life threatening, but can be extremely frustrating when the same farmer sees his harvest washed away in consecutive years. Moreover, it is likely that the frequency and damage of this type of flood events will increase in the future due to ongoing processes as climate change, subsidence, and urbanization. This makes water authorities anxious about the future and willing to anticipate with measures to stay in control of the risk of flooding. The question addressed in this paper is: how do climate change, subsidence, and spatial planning increase the risk of flooding? To answer this question a case study has been carried out for Flevopolder. For this area a detailed risk assessment has been carried out, using a combination of hydrological models, GIS and a damage model. The rationale behind risk analyses is explained in our paper, and illustrated with our case study. It will be shown that the combined risk increase by spatial developments, subsidence and climate change is larger then the sum of them separately. Furthermore, will be shown that the risk increase is not homogenously distributed over the areas. The surplus value of risk analysis is that it allows better cooperation between spatial planners and water authorities.

***Keywords:*** climate change, spatial developments, risk

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# Coping with water scarcity in Eastern Africa. The potential role of intra-regional virtual water trade

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Virtual water is the amount of water required for the production of a commodity. Trading commodities implies Virtual Water Trade (VWT).This study was conducted to determine the VWT derived from intra-regional trade of six cereals (maize, paddy rice, millet, sorghum, wheat and barley) for ten countries within Eastern Africa from 1998 to 2003.It involved quantifying the VWT, assessing the role of water scarcity in shaping VWT and determining the quantity and nature of water savings generated. Quantifying the VWT included delineating major crop growing zones and calculating Crop Water Requirement (CWR) using a model, CropWat. Virtual water contents derived from CWR were multiplied with intra-regional cereal trade flows to obtain the VWT. Results show that virtual water contents vary significantly within the region, being higher in the arid countries than the humid countries, partly because of water scarcity in these countries. Virtual water flows for the region averaged 150 Mm3/yr of water whilst water savings averaged 31 Mm3/yr. Sudan, Uganda and Tanzania are the only net virtual water exporters, exporting a combined volume of 110Mm3/yr whilst the other seven countries are net importers, the largest importer being Ethiopia. No correlation was found between a nations water scarcity status and virtual water imports suggesting that intra-regional cereal-derived VWT is not a conscious choice but arises for other reasons like comparative advantage. Sorghum and maize trade accounted for the largest virtual water flows, 36 percent and 38 percent respectively, the former due to the high unit virtual water content of the major exporting countries and the latter due to the large tonnage traded. In a regional virtual water policy Kenya, Sudan, Djibouti, Eritrea and Somalia can be potential virtual water importers whilst Tanzania, Uganda, Rwanda, Burundi and Ethiopia can be potential virtual water exporters. It was concluded that VWT had a big role in water savings in water scarce countries. This has been considered as a change in water resources systems and hence maintenance in water security and insurance in integrated management.

***Keywords:*** virtual water trade, water scarcity, water security maintenance

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# Concerning the paid water use in the agricultural sector in Post-Soviet Central Asian Republics

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In postsoviet Central Asian Republics (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan), the agricultural sector uses about 90% of water resources, and nearly 70% of the population lives in rural areas. The state of the national economies and the whole socio-political situation substantially depend on water availability for the agricultural sector, the agricultural production amounts to 30% of GDP, and the agriculture provides employment for more than 50% of the population. Having stood on the way to independent development (1991), Central Asian Republics (CARs) reoriented to the market economy, radical reforms are being conducted in water management system. At the Soviet time, the water sector in CARs was financed by using government finance. In general, special water use was paid, while common water use was free, and privileges for individual water users categories existed. In the context of new economic realities, it is recognized that it is advisable water users to cover costs to maintain water infrastructure themselves. It appears that the following factors are crucial in transition to paid water use (PWU): - development of regulatory legal acts (RLAs) concerning PWU. By now, they have been developed good in Kazakhstan and Kyrgyzstan; Tajikistan has transited to PWU as well; over-limit water use in Turkmenistan is to be paid; and irrigation water is free in Uzbekistan; - stimulation of water conservation (WC). In CARs, the Regulations on WC have legislatively been fortified (declared), but economic mechanisms for WC have not been developed yet; - differentiation of rates (tariffs) of paid water use by costs of water supply services under different conditions. The net cost of pumping irrigation is much more than gravity irrigation; - differentiation of water services for standard and above-standard use of irrigation water. For above-standard water use, it is necessary to fix higher tariff rates on a progressive scale; - toughening of punitive measures for water pollution; - solving of the issue of privileged subsidies and taxation in the initial stage of PWU introduction; - costs to maintain on-farm reclamation network (OFRN) can be imposed on water users, the government should assume costs to maintain reclamation network beginning from inter-farm level and above. At initial stage, the government should support farmers in covering a part of costs to maintain OFRN as well; - respective RLAs should stipulate transfer (for certain payment) of rights to water. Otherwise, stimulation of water conservation will not have desired effect; - paid basis for relationships between water users and suppliers; - real participation of water users in water management through introducing public water management forms (e.g. Water Users Associations); - organization and promotion of a training system in this field and so on.

***Keywords:*** central asia, agricultural sector, watercost

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# Groundwater evolution in no rainfall arid Turpan Baisin, West China

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Water stress is rapidly increasing in oasis at Turpan Basin due to expansion in population, agricultural, industrial and tourism since the past several decades. Add to the salinity of groundwater restrained the social and economic development in this area. The processes affecting salinization of groundwater were studied in the Turpan Basin, west part of China. The stable isotopes and chemical concentrations were used in this basin to gain insight into the mechanism of solute concentration and flow processes. The variability in δ18O and δD values of groundwater were used in association with chloride concentrations to provide information on mixing characteristics of groundwater within the basin. Chemical analysis indicates that, soluble salts of groundwater increased from mountain area to oasis and dramatically increased near the Flaming Mountains and Aiding Lake. The Ca HCO3 type of groundwater identified in front of the mountain area, the HCO3 Cl type and Cl SO4 Na K type identified in the oases, the Cl SO4 Na K type identified near the desert and lower part of the Flaming mountains. Groundwater evolution is an order of fresh water to saline water from beginning the basin to the end. Salinity of groundwater in the basin tends to increase with increasing the basin area. Chemical and isotopic data suggests that, salinity of the groundwater is not result of direct by the evaporation. Evaporation from the soil surface plays a major role as a mechanism of solute concentration in the unsaturated zone. The salinization of groundwater is dependent upon more than one of the following mechanisms: 1) Dissolution of aquifer minerals. 2) Evaporation of soil water from irrigation and leaching of salts by irrigation water. 3) Seasonal variation of groundwater table cause to extensive water soil interaction in the unsaturated zone.

***Keywords:*** groundwater, salinization, aridregion

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# Quantitative analysis of human impact on river runoff in West Liaohe basin through the conceptual Xinanjiang model

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An attempt is made on human impact on surface water resources. The Laohahe River, a tributary of the Liaohe River in Northern China, was selected as the area of case study where the reduction of river runoff exists as one of aridification manifestations in Northern China. The upstream area of Xiaoheyan hydrological station is 18112 sq. km within which the mean annual precipitation is 430.9 mm. The correlation coefficient between annual precipitation and observed runoff depth is 0.972, 0.898, 0.727, 0.834, 0.687, in 1950s, 1960s, 1970s, 1980s, 1990s, respectively. It could be seen that the correlation coefficient decreases gradually from 1950s to 1990s, viz. the relation between annual precipitation and runoff became less and less. The reason will be analyzed. It seems as if negative correlation between annual precipitation and observed runoff from 2000 through 2003. That has proven that the impact of some factors on runoff generation was so serious that the relation between precipitation and runoff was disordered in 2000s. The slope of regression equation is 0.5232, 0.3563, 0.2176, 0.0818, in 1950s, 1960s, 1970s, 1980s, respectively. It is obvious that the slope of regression equation decreases 84.37% in 1980s if compared with that in 1950s. Thats to say, same order of quantity of precipitation produced less runoff in 1980s than that in 1950s in the average sense. Quantitative analysis was made with the aid of the conceptual Xinanjiang model under the background of nature climate variability as well as human-induced climate change according to the long-term observational hydro-meteorological data. In the past, the human effect on surface water resources was estimated by investigating the impact of human activities on each item in the equation of water balance, so as to calculate water quantity of each item in the original natural status. It seems to be clear conceptually. It is appropriate just for the case of direct impact, such as water transfer from one basin to another, water storage by various scales of hydraulic projects, besides a huge amount of investigation and indeterminate statistics data when applied in practice. It is difficult for us to compute directly water consumption due to the implementation of measures for soil conservation, the improvement of farming techniques in agriculture, the growth of population in towns and villages, and the change of socioeconomic structure. In view of such situation, the Xinanjiang model was used to separate human impact from the climatic impact on water resources. Quantitatively human activity made river runoff decrease by 1.02, 50.67, 58.06 mm in 1960s, 1970s, 1980s, respectively, while by 97.2 mm in 1990s in the sense of annual average in the Laohahe River Basin.

***Keywords:*** river runoff, conceptual model, human impact

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# Planning and performance comparison of sustainable rural and urban water development projects in Nigeria: a practical example of the importance of participatory water resources management

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***A. Tokun***

There is acute water stress in practically every city, town and village in Nigeria. The reason for this condition is the reluctance of government at all levels to vote enough funds for the effective planning, development and management of water resources and water supply facilities in the country. This situation has been exacerbated by the rapid growth in urban and rural populations. While the government has toyed with the idea of solving the water shortage problem through the construction of ever larger water schemes, such has not materialized due to the harsh economic condition in the country, the long time required to plan and build such projects, their unpopularity with international donors because of their perceived negative environmental and other impacts, and the appalling record of maintaining and operating such schemes in Nigeria. Realising that attempting to solve the water scarcity problems through the development of mega schemes is a non-starter, the Nigerian Federal Government in 1997 voted large sums of money for an initiative to develop small, rural water supply projects across the country with the objective of solving one of the worst water scarcity problems ever known. To ensure the sustainability of these schemes, the government adopted the broad policy of government provides, the beneficiary communities operate and maintain. One of such projects is in the south-eastern Anambra State and comprises 36 rehabilitated and 44 new boreholes in 80 carefully selected rural communities. However, while still under construction the federal government abandoned the initiative, leaving the projects in varying stages of completion. Around the same period the Sustainable Ibadan Project (SIP), an offshoot of the Sustainable Cities Project funded by the United Nations Centre for Human Settlement (UNCHS) but totally independent of government, was involved in the development of sustainable urban water supply projects for Ibadan, a city in the south-western Oyo State. This paper will describe the two initiatives and report the results of a study carried out to assess their relative performances. In particular, it will be argued that by involving the beneficiary communities in all aspects of the projects, right from conception to post-completion operation, the SIP projects have been more successful than the federal government projects in ensuring long-term sustainability.

***Keywords:*** nigeria, participatory approach, sustainability

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# The Role of Dams in Securing the Surface Water in the Northen and Eastern Parts of the United Arab Emirates (UAE)

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The scarcity of water resources in the United Arab Emirates (UAE) hinders its sustainable development. In order to improve this situation, decision makers initiated integrated water resources management (IWRM) strategy to meet the increasing demands of water. One of these important strategies that is suitable for this arid region is constructing different sizes of dams, mainly in the northern and eastern parts of the UAE. Rainfall is extremely sparse and irregular in space and time. Some events of rainfall could generate flash floods (surface water) during heavy and intense period of rain with short duration. The surface water occurred after rainfall events is secured by building dams which have been designed in the UAE for two main objectives. These objectives include protecting from floods events and feeding or recharging main aquifers. The increasing water levels of boreholes downstream of the dams confirmed that a recharge to the aquifers has occurred. However, water level rise has fluctuated seasonally and this might be attributed to the sediments and deposits of silt which reduced the infiltration rate. Removal of sediments and deposits at the dam's sites is essential to enhance water infiltration and increase the water availability in the main aquifers of the region. This paper is aimed to assess the important roles of dams on managing water resources and maintaining the security of surface water in the northern and eastern parts of the UAE.

***Keywords:*** united arab emirates, dams, surface water

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# Dynamique dmographique, volution des tats de surface et modlisation hydrologique au Sahel: Cas du Nakamb Wayen (Burkina Faso)

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Dans les rgions sahliennes dAfrique de lOuest, le dsquilibre entre ressources naturelles (capacit de production et disponibilit des terres, vgtation et pturages, quantit et qualit des eaux) et besoins accrus dune population en croissance rapide perptue la situation de pauvret des populations. Les pratiques agricoles, encore traditionnelles et rudimentaires, ne permettent une augmentation des rendements qu travers un accroissement des superficies cultives. Les paysans dfrichent alors des parcelles dans les forts pluviales, labourent des pentes trop raides, colonisent les terres marginales et fragiles lrosion, raccourcissent, voire suppriment, les priodes de jachre Les tudes hydrologiques menes au Sahel ces vingt dernires annes ont mis en vidence une augmentation des coefficients d'coulements en dpit dune diminution marque de la pluviomtrie rgionale. Ces tudes ont galement montr que ce paradoxe hydrologique est lier laugmentation des surfaces cultives et des surfaces dgrades au dtriment de la vgtation naturelle. En effet, en milieu sahlien, la redistribution des prcipitations entre les grandes composantes du bilan hydrologique dpend fortement des tats de surface (couvert vgtal, nature des organisations pdologiques superficielles). Les interrelations entre dynamiques dmographiques, conditions socio-conomiques et pratiques agricoles et, leurs impacts sur les tats de surface conditionne l'volution de lhydrologie au Sahel. Peu dtudes se sont cependant intresses au couplage entre hydrologie, dynamique dmographique et dynamique des tats de surface. La prsente tude est un essai vers une intgration de la dynamique du milieu et de la population dans un modle hydrologique en utilisant la capacit de rtention en eau des sols (WHC: Water Holding Capacity) comme interface. Le bassin dtude est celui du Nakamb Wayen (Burkina Faso). La corrlation entre lvolution des superficies cultives et la dynamique de la population est dabord mise en vidence (R=0.93). Lvolution de quatre types dtats de surface (surfaces en vgtation naturelle, surfaces cultives, surfaces nues et dgrades, plans deau) est ensuite estime laide dun modle dmographique bas sur une fonction logistique dont les paramtres sont dtermins en utilisant des donnes dmographiques, de statistiques agricoles et des images satellites. Les proportions des types dtats de surface sur le bassin sont prises dune part comme indicateurs de pression anthropique et/ou climatique et, dautre part, comme units de comportement hydrologique. A chaque indicateur on associe un indice de production de ruissellement (coefficient de ruissellement). Lvolution annuelle des indicateurs est transcrite dans la WHC des sols et, des sries de donnes annuelles de capacit de rtention en eau des sols sont gnres. Elles sont intgrables comme donnes dentre dun modle hydrologique.

***Keywords:*** population, etat de surface, hydrologie

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# Impact of climate change and other drivers on the management of water resources in the Murray-Darling River Basin

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The Murray-Darling River Basin is about 1,000,000 km2 (one seventh of Australia). It is Australias most important agricultural region and is home to over two million people. Like most parts of the world, water resources in the Basin are almost fully developed and allocated. However, increasing demands are being put on the limited water resources by expanding urban populations, irrigation and industrial water use, and the formal inclusion of environmental water allocations. Climate model projections indicate that there is likely to be less rainfall in the Murray-Darling River Basin as a result of global warming. There are also other drivers that will contribute to reduced future water availability in the Basin, like increased amounts of farm dams, larger forest plantation areas, increased occurrences of bushfires, more groundwater development and reduced irrigation return flows. The water resources management problem in Australia is also compounded by the higher streamflow variability and lower runoff coefficient in Australia compared to similar climate regions in the world. This paper will discuss some of the challenges and opportunities that hydroclimatic variability present to the management of water resources in the Basin. The paper will show projections of climate change impact on runoff estimated using hydrological models with climate projections from global climate models for several greenhouse gas emission scenarios. The paper will also show estimates of likely decreases in water availability from the combined impacts of climate and other drivers. The paper will also discuss the need for consistent tools to estimate the combined impacts of the various drivers on water security of users throughout the Basin (irrigators, town water supply and environment), and fair water sharing policies in which everyone has most of the water they need, while at the same time, ensuring that the ecosystem has enough fresh water to thrive.

***Keywords:*** water availability, water management, murray darling

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# Policy learning in water resources management

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Water resources management in todays complex, dynamic water resources systems requires constant learning. Not only about the state and nature of our physical water resources system, but also about how to manage this system and how to live in it. The latter means that policy learning through the evaluation of existing water policies is essential. Strangely enough, policy evaluation does not receive the kind of attention one would expect from the interest in e.g. adaptive management. The main focus of attention in water resources management seems to be on the formulation of flexible and robust policies and forecasting of future trends. Although the importance of evaluation is widely acknowledged, evaluations are often absent or done in an ad-hoc manner. When done, evaluations consider the implementation of policy measures (e.g. trainings given to water users), policy outputs (e.g. water user associations formally established), and, sometimes, outcomes (i.e. trends in the state of the system). This is based on a black-box model that does not permit effective learning about water systems; the assumptions, or policy theories, that lead one to expect positive impacts from policy measures, are not being evaluated. The World Banks evaluation of its 1993 Water Resources Strategy (in 2002) is a point in case. The strategy was based on the assumption that reforms of water institutions, policies and planning would lead to improved water sector performance, but this link between institutional reform and sector performance was not part of the evaluation. Several explanations are possible for this phenomenon. Among those are the difficulties in establishing cause-effect relations between policy measures and outcomes in complex systems; the poor quality of existing water policies that lack assumptions on these cause-effect relations, meaning there seems to be no policy theory to evaluate; and/or the fact that various stakeholders with different values are involved, which makes it difficult to agree on the definition of policy success. Notwithstanding the truth in these arguments, the bottom line is that current practice severely limits our capability for much needed policy learning. Based on a review of theory on policy learning and current evaluation practice, this paper suggests some avenues to improve policy evaluation and learning in water resources management. These are centered on the use of theory-driven evaluations that use stakeholder inputs to reconstruct critical assumptions and to identify different success criteria. Methods which hold specific promise for such evaluations are those that enable policy analysts to extract, analyze and communicate causal models from multiple stakeholders. Theory-driven evaluations will not only enable learning about past policies, but will also provide a structure that supports future policy making and setting up/improving monitoring systems.

***Keywords:*** water policy, policy learning, policy evaluation

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# Impacts of the South-eastern Anatolia Project in Turkey on the performance of the Tabqa dam and hydropower plant in Syria

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The Southeastern Anatolia Project (GAP) is a multidimensional water resources development project in the Turkish part of the Euphrates-Tigris river basin. It involves the construction of 22 dams, 19 hydroelectric power plants with an installed capacity of 7,526 MW, and the irrigation of 1.7 million ha. With the completion of the Ataturk reservoir, Turkey has now enough storage capacity to control the headwaters of the Euphrates and to potentially divert huge volumes of water to the irrigation areas. The downstream riparian countries, Syria and Iraq, are concerned by the modification of the hydrological regime of the Euphrates river and its impact on the production of hydroelectricity from their hydropower plants and on the availability of water for irrigation purposes. This is especially important for Syria as Tabqa, its largest reservoir and hydropower plant (6,400 hm3, 800 MW), is located immediately downstream of the Turkish border. In response to the complaints formulated by its downstream neighbors, Turkey stresses the positive effects its storage capacity can have on downstream riparians by augmenting low flows during severe droughts and by absorbing flood waters. This study assesses the performance of the Tabqa reservoir and hydropower plant and balances the positive and negative effects of the altered hydrological regime on hydropower generation and on the reliability in meeting irrigation water demands. The performance is evaluated for several development scenarios of GAP in Turkey where each scenario is characterized by an irrigation area and by a set of dams, which define the GAPs storage capacity and its ability to alter the natural flow regime mainly through irrigation water withdrawals and the decisions to release water for power generation. To achieve this, the operating rules of the largest GAP reservoirs are optimized using a stochastic dual dynamic programming (SDDP) model. SDDP is an algorithm that removes the computational burden found in traditional SDP making possible the integrated analysis of large-scale water resources systems involving multiple reservoirs. SDDP can be seen as the combination of SDP and nested Benders decomposition with the former being able to handle a large number of stages but not a large state space, whereas the latter can handle large state space but not a large number of stages. Operating rules are then simulated over a planning period of 5 years with 50 hydrologic scenarios. The analysis of simulation results reveals that if GAP is completed as planned, the risk of not meeting the minimum cross-border flow of 500 m3/s increases substantially (up to 25%). In addition, the expected annual production of hydroelectricity from the Tabqa plant decreases from 1600 GWh to 1110 GWh despite the reduction in spillages losses due to more constant flows. In Turkey, the irrigation opportunity cost associated with the complete development scenario of GAP could reach 136.2 million USD.

***Keywords:*** optimization, trade off, reservoir

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# Classification-based Flood Forecasting Model by Artificial Neural Networks

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Flood forecasting takes a vital role for flood control and water resources managements of catchments. However, it is generally accepted that the relationship of rainfall and runoff is highly complicated, and for a basin, the under-lying mechanisms of streamflow generation in rain periods are quite different from those in non-rain periods. So we can decomposed the flow hydrograph to several segments, then establish the rainfall-runoff relationship separately. In this study, we employ two methods to divide flow hydrograph to several segments. One is Fuzzy C Means(FCM) method, and the other is the Self-Organizing Feature Map (SOFM). Based on the two clustering results, multi-layer Feedforward Networks(MFN) are used to simulate the rainfall-runoff relationship of each segement. In this way two hybrid artificial neural networks (FCMMFN & SOMMFN) are established. The methods mentioned above are applied to Wangjiachang Reservoir inflow forecasting, in Hunan province of China, for three-hour-header flood forecasting. Forty-five historical flood processes from 11 years (1982a-1992a) are applied for calibration whilst 14 flood processes happening in recent 3 years (1994a-1996a) are utilized for validation. Antecedent precipitation and streamflow data is input into FCM and SOM for flow hydrograph decomposing and clustering. The result shows that FCM and SOM are both able to find out the potential knowledge of flow, and that its easy to find that flow hydrographs as corresponding output is classifed into four different stages: (1) low flow, (2) rising flow, (3) flood peak, (4) recession. Then, for each segment, a MFN is applied to simulate its rainfall-runoff relationship. Results show FCMMFN and SOMMFN are both superior to MFN, which explains the two hybrid models can simulate precisely the rainfall-runoff relationship simultaneity in low flow, middle flow and high flow. Moreover, FCMMFN and SOMMFN are investigated and compared, and FCMMFN appears to be better.

***Keywords:*** artificialneuralnetworks, fuzzycmean, self organizingfeaturemap

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# The Service Provision Index (SPI): A pragmatic and flexible approach to linking environmental flows, ecosystem services and economic value

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Environmental flows are water for ecosystems - the silent water users. Ecosystems, in turn, provide a wide range of valuable services to people. In developing countries, the livelihood of rural people to a large extent depends directly on the provision of ecosystem services. Providing for environmental flows is, therefore, not exclusively a matter of sustaining ecosystems but also a matter of supporting humankind/livelihoods. Nevertheless, environmental flows are persistently under-valued and thus frequently omitted from decision-making. This marginalization has led to substantial misallocation of water resources and degradation of ecosystem. High economic costs, in terms of declining profits, remedial measures, damage repairs and lost opportunities, are associated with the degradation of ecosystems. The highest costs, however, are typically borne by people depending directly on ecosystem services. These people are generally among the poorest. One reason for the marginalization of environmental flows is the lack of operational methods to demonstrate the inherently multi-disciplinary links between environmental flows, ecosystem services and economic value. While several holistic and interactive environmental flows assessment methods have been developed, none of them explicitly links environmental flows to ecosystem services. Consequently, such methods cannot readily deliver inputs to economic valuation studies. Furthermore, existing holistic environmental flows assessment methods are very resource (time, money, data) demanding. This is a real constraint to undertaking environmental flows assessments, in particular in developing countries. This paper attempts to bridge the current gap between bio-physical scientists (e.g. ecologists, hydrologists), socio-economic scientists and decision-makers in IWRM by presenting and encouraging the use of a Service Provision Index (SPI). It is a pragmatic, operational and flexible approach that is easy to use while maintaining a holistic and comprehensive assessment of environmental flows.

***Keywords:*** environmental flows, multi disciplinary approach, developing countries

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# Groundwater and its association with sustainability of agriculture in the lower reach of the Yellow River and the North China Plain

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Study area in the lower reach of the Yellow River and the North China Plain (NCP) covers primarily three provinces: Hebei, Henan, and Shandong Province, which are the main agricultural production area in China. Water shortage in the last 20-30 years due to the decline of precipitation and the increase of the water demand caused many environmental problems, i.e., continuous drop-down of groundwater table in the piedmont of Taihang Mountain, no flow in the lower reach of the Yellow River. Monthly groundwater table data of 284 observation wells during the period of 1980-2000 in the lower reach, together with data set in Hebei Province, was collected and analyzed. Groundwater table in the lower reach remains relatively stable with a seasonal fluctuation of approximately 2 m, while it decreases roughly 1 m in the piedmont. Diversion of about 1.28x1010 m3/a from the Yellow River attributed to this spatial disparity, and varied temporal patterns were identified in details in the lower reach for irrigated and non-irrigated area. Groundwater resources plays an important role in water supply for irrigation, domestic water use, especially in the extreme year of drought and drying up of the river, and it is a main factor, in terms of either quantity or quality, affecting the sustainability of agriculture in the lower reach and NCP.

***Keywords:*** groundwater, yellow river, north china plain

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# Impacts of Human Activities on the Flow Regime of the Yangtze River

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The Yangtze River (Changjiang) is one of the most important rivers in the world. It is the third longest in length, ninth largest in catchment basin, third largest in annual runoff and forth largest in sediment load. As an artery river on the earth planet, the Yangtze River plays a critical role in global water cycle, sediment cycle, energy balance, climate change and ecological development. The alterations in its hydrological regime therefore have global-scale impacts. However, with population increase and economic growth, the flow regime of the Yangtze River has been altered to some extent by human activities including runoff impoundment (dam construction), soil and water conservation, water withdrawal from the Yangtze River, etc. To assess human-induced alterations in the flow regime of the Yangtze River quantitatively, this paper selected three key hydrological stations (i.e. Yichang, Hankou and Datong stations) on its middle and lower reaches as case study sites. Yichang station is the control point of the upper Yangtze River basin and located at the starting point of the middle reach of the Yangtze River, 44 km below the Three Gorges Dam and 6 km below the Gezhouba Dam. Hankou station is located 1.15km below the confluence of the Yangtze River and its biggest tributary the Hanjiang River, on which the second largest reservoir in terms of storage capacity in the Yangtze River basin, the Danjiangkou reservoir, was built in 1967. Datong station located at the tidal limit of the Yangtze River is the controlling station for the measurements of water and sediment discharges from the Yangtze River to the sea. On the consideration that the Danjiangkou Reservoir, the Gezhouba Reservoir and the Three Gorges Reservoir may impose impacts on the flow regime of the middle and lower reaches of the Yangtze River to different extents respectively, the whole study periods were divided into 4 subperiods by the years when these three reservoirs started to store water respectively. On the basis of about 50-year long time series of daily discharge from three stations, the alterations of their annual runoff, wet seasonal runoff, dry seasonal runoff, monthly runoff and daily runoff in different subperiods were analyzed and compared. The results revealed: the impacts of reservoirs on river flow regime varied with reservoir regulation capacity, reservoir operation pattern and the distance between the target reservoir and the study site; water withdrawal and climate change resulted in the variations in annual runoff; water withdrawal, reservoir regulation and extreme rainfall events were responsible for the variations in wet seasonal runoff and dry seasonal runoff; reservoir regulation and extreme rainfall events are major causes of the variations in the distribution of monthly runoff; generally speaking, reservoir regulation led to an reduction in the percentages of high daily flows and low daily flows at three stations, however, the percentages of the high daily flows at Hankou and Datong were also closely associated with the extreme precipitation events having occurred in the middle and lower Yangtze River basin. The output of this paper could provide reference for the assessment of the impacts of human activities on the long-term health and stability of the Yangtze River ecosystem.

***Keywords:*** yangtze river, runoff, alteration

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# Conflict analysis in implementing water resources management instruments

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Water resources management instruments are often pointed out as resolution tools for conflicts caused by water scarcity (first-order conflicts). However, attaining integrated water resources management means that one must consider second-order conflicts caused, indirectly, by the very tools adopted in order to manage water scarcity (Ohlsson, 2000). This paper describes second-order conflicts, which can occur from implementing water permits and bulk water fees which were considered as management instruments by the new Brazilian National Policy of Water Resources (Federal Law 9.433/1997) , analyzing the conflict (urban supply versus irrigation) over reservoir water use located in a semiarid region of Paraba River basin, northeastern Brazil. Based on conflict history, climate and hydrological regional conditions, and institutional, social and economic reality in reservoir influence area, several scenarios are built, considering three water management stages and different water permits and bulk water fees systems. For each scenario, the consequences second-order conflicts which reflect economic and social impacts - of adopting (or not adopting) water permits and bulk water fees, in order to resolve first-order conflict, are identified. Scenarios comparison gives information about management instruments attenuation/synergism potential, in relation to first-order conflict. Results presented by second-order conflicts modeling, applying GMCR The Graph Model for Conflict Resolution (Fang et al., 1993), can drive political decision making for effective first- and second-order conflict management.

***Keywords:*** second orderconflicts, water permits, bulk water fees

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# A review of soil water resource research

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In recent years, water resource can no longer meet the rapid development of economy and this often causes conflict between big agricultural water user and other water user, especially in regions of water shortage. People have to face water problem again and look for other water as a resources. About 60% of all food globally is produced under non-irrigated rain fed conditions. The soil water flux of China counts for 67.2% of total precipitation. However, of all water resources, soil water is probably the most under valued resource. Soil water is the connection of surface water and groundwater. It is of great significance in the formation, transformation and consumption of the water resources and has close relationship with agriculture, hydrology and environment etc, so that the soil water resource research has been drawn more and more attention and made great progress. After the concept of soil water resources and green water was introduced in the seventies of the twentieth century, a plenty of research has been focused on soil water resource study. This article defines soil water resource, stresses the significance of soil water resource research, states the processes of relevant theories and methodologies, analyses spatial and temporal distribution characteristics of soil water resource. It indicates that currently soil water resource study focusing on interdiscipline characteristic, estimation of soil water resource heterogeneity and development of soil water prediction model. In future, it is essential to develop a distributed land surface model based on remote sensing and GIS at large scale. Because soil water is a crucial part of water balance and water cycle, it should be a significant component of integrated water resources management. Based on the soil water balance theory, Taking Hebei province of North China Plain as an example, the author analyzed the soil water resource pointed out that the amount of water resources in soils and conditions of soil moisture content are two important aspects in the study to evaluate the suitability of the water resources in soils for crop growth, which could be beneficial to exploring the sustainable utilization ways of water resources and developing water saving agriculture for dry crops.

***Keywords:*** soil water resource, research review

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# Socio-economic Activities and Water Resource Supply and Demand Balance in the Yellow River Basin

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The Yellow River basin in China has been facing serious water shortage. Amount of water resource per person in the basin is approximately 580m3 which is 6% of world average and 24% of China average. And, a multitude of production and human activities in this basin depend heavily on the water resources of that one river. In recent years, water demand has been increasing particularly due to the growing population, the spread of irrigation-based agriculture, and industrialization. In this context, the severe water shortage, drying-up in 1997 gave a great shock to the leaders of the country. Consequently, the Chinese government played a central role in efforts to devise a comprehensive water resource management policy. As a result, after 1999 dry-up has been avoided in the river. But because water demand is likely to increase in the future due to rapid economic growth, the water shortage in the basin has not been completely eliminated. And, questions about what are the most rational ways to manage water resources in the basin is still remain. Hence, it is important to make certain the supply and demand balance - by region and by sector (agriculture, industry, and domestic) - and to implement the necessary policies that will promote the rational and efficient use of water resources. The imbalance between water resource supply and demand arises from resources that are unevenly distributed both spatially and temporally. In order to understand the mechanisms of water resource imbalance, it is essential to analyze the capacity of the amount of supply and demand system. This study expresses the supply and demand system by county and city level as the smallest administrative unit. The unit of county and city level is used in various official statistical reports and national policies. Water demand related to socio-economic activities is estimated by each county and city. Then, using these counties and cities as the basic unit, the study develops a basin-wide water resource management model that explicitly addresses the water resource cascade from upstream to downstream, in order to elucidate how much water resource has been existed in each county and city and in order to understand how much water has been demanded and been returned to the river from each county and city. Through this study, it becomes possible to consider the impact of gaps between seasonal water supply and demand at any region under the socio-economic growth, and helps to understand the mechanisms of the phenomenon of water supply and demand imbalance of the river.

***Keywords:*** yellow river basin, water resource management, socio economic activities

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# Impacts of human activity on long-term water balance in the middle reach of the Yellow River basin

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In recent years, serious water-related problems such as droughts, flooding, or water pollutions have affected most large rivers in China. In particular, water shortages are becoming more and more serious in the northern China because of dry climate conditions and heavy water demands. The Yellow River is the second largest river in China and is the most important river for agriculture, water resources managements, and socio-economical development. However, river discharges in the lower reaches of the basin have been decreasing continuously. The riverbed of the lower reaches is higher than the surrounding area due to the sediment depositions. Almost all the surface water in the lower reaches is supplied from the upper and middle reaches. Therefore, it is necessary to predict the water balances in the upper and middle reaches, and the integrated water resources management is effective to mitigate the water shortage and to utilize the limited water resource adequately. To clarify long-term water balances within the Yellow River basin and to supply its quantitative information for the water resources management, a hydrological model can be used. However, it is difficult to apply existing hydrological models directly to the Yellow River basin because the basin includes various artificial factors induced by human activities (i.e., irrigation water intake, reservoir operations, and human-induced land-use changes). Thus, we developed a new hydrological model applicable to the Yellow River basin using long-term (1960 to 2000) meteorological dataset and high-resolution land surface classification map. In the previous study, we confirmed that the model can predict the amount of annual water intake for irrigation reasonably and the effect of the large reservoir operation on river runoff in the upper reaches. In this study, we applied the model to the middle reaches and analyzed its long-term water balances to investigate the influences of land-use change induced by human activities. The long-term water balances simulated by the model indicated that the rapid decrease of river discharge from the middle reaches of the Yellow River basin in recent years is mainly caused by the increase of evapotranspiration losses induced by the land-use changes. This land-use change was estimated to be the effect of soil and water conservation project to prevent soil erosion from the wasteland ravaged by the overgrazing in the loess plateau of the middle reaches of the Yellow River basin.

***Keywords:*** yellow river basin, long term land use change, impacts of human activities

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# Computation methods of the minimum and optimal instream ecological flow

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Water is the source of life. The existence of stream species and the formation of stream population structure are closely associated with stream hydrological processes and their variations. On one hand, specific hydrological and environmental conditions are required for the life cycles of all stream living organisms, on the other hand the variations in stream hydrological processes and characteristics have significant effects on the alterations in stream living organism communities and ecosystem structure. Human activities can result in the alteration of stream hydrological processes and characteristics, which in turn unavoidably cause changes in stream ecosystem structure. As a result, the stability of stream ecosystem will be affected. Therefore, it is essential to explore the relationship between stream ecosystems and their hydrological processes and characteristics to provide a theoretical basis for the determination of instream ecological flow and the protection of stream ecosystem health. The paper analyzed human-induced variations in river hydrology and water resources, river ecosystem structure including spatial structure, substance composition and energy status, and the corresponding relationship between river ecosystem structure and river hydrological processes and characteristics. Under the consideration that the variations in river hydrological characteristics have impacts on river ecosystem structure and that river hydrological processes and characteristics play a critical role in maintaining the stability of river ecosystem, the concepts of the minimum instream ecological flow and optimal instream ecological flow, and their computation methods have been proposed. This paper selected the Yihe River and the Luohe River, two tributaries of the Yellow River, as case study sites, and analyzed the monthly runoff distribution at different cross-sections located in their upper, middle and estuary reaches. On the basis of the distribution characteristics of river monthly runoff and the requirements of hydrological processes for river ecosystem, the minimum instream ecological flow process and the optimal instream ecological flow process for the target sites were determined by use of long time series of monthly runoff and compared. The concept and the computation method of the upper limit of water resources that can be explored and utilized was proposed in wet, dry and average years respectively. In view of the current status and trends of water resources utilization of the Yihe River and the Luohe River, the protection standards for the hydrological processes and characteristics in different river reaches have been recommended.

***Keywords:*** yellow river, ecological flow, computation

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# Impact of agricultural water management on lake water budget: A case study of Lake Ikeda, Japan

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Lake water is variable freshwater resources for various industries. Hydrological assessment of the influences of water utilizations on a lake water budget is indispensable for proper lake water management. Freshwater of Lake Ikeda in southern part of Japan is used as municipal and agricultural water. Especially since 1983, when the agricultural water operation system was introduced by the Large-scale Upland Irrigation Project, lake water has been used as upland irrigation water. River water has then been transferred into the lake to compensate for the water loss. As such, the hydrological environments of the lake have changed considerably. The objectives of this study are to develop and verify a water level estimation model for Lake Ikeda based on hydrometeorological data from 1983-1999, and to examine the effect of agricultural water management on the lake water level by using the model. The daily water budget components in the model consist of precipitation, river water supply, tap water and agricultural water uses, lake evaporation, inflow from the lake catchment area, and leakage from the lake bottom. The lake evaporation is numerically computed by an energy budget method. The inflow and leakage are estimated based on the Tank Model and Darcys law in which the model parameters were optimized by the SCE-UA (Shuffled Complex Evolution) method. The calculated lake water level under the real condition of lake water uses and river water supply was in good agreement with the observed one. Thus, the model can be useful to investigate the lake water budget. Three simulation cases were analyzed with the model under the hypothetical conditions for 1983-1999. Run-1 is a simulation case under natural condition without human activities, i.e., without tap water use, agricultural water use and river water supply. Run-2 is a simulation case under the condition where lake water is used only as tap water. Run-3 is a simulation case under the condition of no water supply from rivers to the lake. The calculated lake water level under the condition of Run-1 is higher than that under the real condition. The result of Run-2 shows no significant difference between the lake water levels calculated under the hypothetical and the real conditions. In Run-3, the calculated lake water level under the condition of no river water supply gradually declines compared to the real condition. It can be said that the river water supply system is effectively operated to compensate the decrease in lake water by agricultural water use and maintain the stable lake water level. Therefore, the simulation analyses by the model developed in this study reveal that river water supply plays an important role in water management of Lake Ikeda as freshwater resources.

***Keywords:*** lake water management, agricultural water use, simulation analysis

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# Future change of world water resources under SRES climate warming scenarios: a multi-model analysis

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The people living in highly water stressed basins of the world are estimated as about 2 billion today. This number is predicted to be likely even increasing in future (Oki and Kanae, 2006). Apart from the increase of water demand due to socioeconomic development, the change of water resources availability will be another important factor to affect the stressed population. In most cases, the river discharge (or runoff) is considered as the maximum available renewable freshwater resources and scientists use the general circulation model (GCM) simulated runoff to evaluate the future water resources availability. However, the GCM forecasted runoff change is largely dependent on the model dynamics and parameterization, for example, one model predicts a region will possibly become wetter, but another model may give the completely reverse forecasts. Hence, there is large uncertainty if using the outputs of single GCM model. Recently, several attempts using multi-model ensemble analysis technologies are reported to reduce the model-specific uncertainty (e.g. Tebalti et al 2005; Nohara et al, 2006). But, comprehensive analyses on the available renewable freshwater resources change under SRES scenario families are still needed particularly at the finer temporal scale. In this study, we will analyze the potential change of future world water resources under climate warming using the outputs of 6 GCM models simulated for SRES scenarios A1b, A2, and B1. Firstly, the regions with significant change (increase, decrease, or no-change) in annual water resources will be extracted using the multi-model ensemble analysis. Then detailed analysis on the change of seasonal patterns in such regions are conducted to explore the implications to both the possible reasons (e.g. in the case of increase, caused by snow melting in spring or increase of precipitation intensity) and the corresponding countermeasures the society should adopt. Our preliminary analysis shows the climate warming is likely to mitigate the water stress in many basins, but to make severer in a number of basins as well. The detailed analyses as mentioned above will be introduced in the full paper. The work presented in this study is a part of our research project, Modeling global hydrological cycle and world water resources with considering human activities, which is supported JST. Other results of the project relating to hydrological cycle, global water balance, and water resources assessment has partly been published or in submission. We want to introduce the detailed analysis on water resources change due to climate warming on the IAHS assembly. We believe this can contribute the theme of the Symposium, Changes in Water Resources Systems.

***Keywords:*** multi modelanalysis, futurewaterresourceschange, sres

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# Multipurpose water use in a system of reservoirs

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Water resources management in a multipurpose scenario always represents an interesting issue, also because it is becoming very actual in Mediterranean countries where water contributions to river basins are more and more concentrated in short wet periods followed by longer periods of droughts. This meteorological feature has brought many countries, Italy included, to build several artificial reservoirs originally dedicated to supply agricultural uses. Lately, those reservoirs have been more and more used to satisfy several other water demands such as the increasing municipal use, resulting in a disadvantage for the agricultural areas. Besides these two traditional uses, we have to consider the amount of water that has to be released in the riverbed in order to guarantee compatible environmental conditions for the new recreational and social uses that lately are appearing along the river banks. These new conditions, related to a multipurpose use of the water resource stored in reservoirs, has brought on one side to a competition amongst the various uses during drought periods, and on the other, to the need of new management policies and planning tools for the total available resource. In the upper Tiber River Basin there is a complex network of artificial and natural reservoirs that can be considered a laboratory on which those tools and policies can be easily tested. In this context, a model at the basin scale for the superficial water resource management has been developed. This model has many features that allow the user to easily sketch the river network, to set up the management policies for each water use and to retrieve the output. The model is based on three fundamental algorithms: the first one models the river network in terms of the various uses displaced on the river basin, the second performs a water budget meant as the difference between the total demand and the available water amount, while the third manages the water resource over the basin. This last algorithm can also take into consideration the many political and administrative constraints that may bind the management criteria. These criteria can vary from a strict hypothesis of priority distribution to a more flexible management policy that tries to share, as far as possible, the water deficit.

***Keywords:*** multipurpose uses, simulation model, water management

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# Changes in water resources availability for crop systems: a case study in Umbria Region

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In central Italy and more generally in the developed countries, the topic of water resources management and especially the management of the large water reservoirs is becoming more and more important. Indeed the water resources management must solve the competition among multi-users. In particular water for irrigation purposes, that was traditionally the main factor to be satisfied, it now competes with other usage requirements which are of an increasing local and national strategic importance: civil, industrial, environmental. Along with these socio-political changes there are the climatic changes which influence both the availability and demand of water resources. In particular the agricultural water demand is greatly influenced by climatic changes which have a primary effect on the plant water balance (evapotranspiration, soil water content) and on the crop phenology. It is therefore necessary to quantify the effect of the climatic changes on the plant water requirement and eventually to study alternative crop patterns able to balance the effect of climatic trends on irrigation requirements, in order to avoid their increase. The aim of the paper is to evaluate the potential effect of climatic changes on agricultural water requirement and on agricultural drought risk. The paper summaries the results of an analysis finalized to detect the presence of trends in a set of meteorological, agro-meteorological and drought indices in Central Italy. The time series of these indices have been quantified processing long time series (not less than 54 years) of daily and monthly temperature and rainfall data in six climatic station in Umbria (central Italy). Time trends for all variables were analysed by means of both parametric and non parametric approaches. The results show a significant upward time trends over the past 54 years for the average annual and monthly temperature in all the six station analysed. For the rainfall and the drought indices the results differ from station to station. On the base of such results have been quantified the expected irrigation water volume increments needed to maintain the actual crop patterns in Umbria. Furthermore in the eventuality that the water volumes assigned to agriculture will not increase, alternative crop patterns have been considered.

***Keywords:*** climate, irrigation

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# Future change of world water resources under SRES climate warming scenarios: a multi-model analysis

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The people living in highly water stressed basins of the world are estimated as about 2 billion today. This number is predicted to be likely even increasing in future (Oki and Kanae, 2006). Apart from the increase of water demand due to socioeconomic development, the change of water resources availability will be another important factor to affect the stressed population. In most cases, the river discharge (or runoff) is considered as the maximum available renewable freshwater resources and scientists use the general circulation model (GCM) simulated runoff to evaluate the future water resources availability. However, the GCM forecasted runoff change is largely dependent on the model dynamics and parameterization, for example, one model predicts a region will possibly become wetter, but another model may give the completely reverse forecasts. Hence, there is large uncertainty if using the outputs of single GCM model. Recently, several attempts using multi-model ensemble analysis technologies are reported to reduce the model-specific uncertainty (e.g. Tebalti et al 2005; Nohara et al, 2006). But, comprehensive analyses on the available renewable freshwater resources change under SRES scenario families are still needed particularly at the finer temporal scale. In this study, we will analyze the potential change of future world water resources under climate warming using the outputs of 6 GCM models simulated for SRES scenarios A1b, A2, and B1. Firstly, the regions with significant change (increase, decrease, or no-change) in annual water resources will be extracted using the multi-model ensemble analysis. Then detailed analysis on the change of seasonal patterns in such regions are conducted to explore the implications to both the possible reasons (e.g. in the case of increase, caused by snow melting in spring or increase of precipitation intensity) and the corresponding countermeasures the society should adopt. Our preliminary analysis shows the climate warming is likely to mitigate the water stress in many basins, but to make severer in a number of basins as well. The detailed analyses as mentioned above will be introduced in the full paper. The work presented in this study is a part of our research project, Modeling global hydrological cycle and world water resources with considering human activities, which is supported JST. Other results of the project relating to hydrological cycle, global water balance, and water resources assessment has partly been published or in submission. We want to introduce the detailed analysis on water resources change due to climate warming on the IAHS assembly. We believe this can contribute the theme of the Symposium, Changes in Water Resources Systems.

***Keywords:*** multi modelanalysis, futurewaterresourceschange, sres

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# Decision support system for sustainable irrigation in Latin America

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In many developing countries the socio-economical pressure to increase the agricultural production is in conflict with the preservation of the environment and with other users of the natural resources. The intensification of the agricultural production in arid and semiarid regions includes activities such as irrigation and fertilisation, often associated with inadequate management and lack of knowledge, which produce serious contamination problems. In a bilateral research cooperation between the University of Concepcin (Chile) and the Leibniz University of Hannover (Germany) a Decision Support System (DSS) was developed to improve the sustainability of intensive irrigated agriculture. Environmental, socio-economical and technical aspects are included into the DSS. The structure is divided into three parts: a Geographic Information System for the visualisation through GIS maps, a Model Base System, which includes simulation and optimisation models (e.g. for irrigation design and management), evaluation criteria and scenario techniques, and a Data Base System to manage the data within the DSS. The integration of the local stakeholders, especially farmers, plays an important role to assure the sustainability of this research. Therefore socio-economic modules and an interactive training of the farmers are included. The DSS can be used through a user-friendly interface. Scenario techniques and measured data of the Chilean study area were used to test the functions of the whole system. It is intended to transfer the application of the DSS to less developed arid and semi-arid regions in Latin America.

***Keywords:*** decision support system, irrigation, sustainability

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# Perspectives on future flood management: Discovering underlying factors

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Transboundary river basin management is often dominated by strategic negation between countries that defend their national interests. In order to deal with the complexity of the issues at stake and with future changes and uncertainties, however, a rational discussion is required. In such a discussion the facts and values underlying the stated positions should be made explicit. The Working Group on Flood Management is a group in which experts of several administrative levels in Northrhine-Westphalia and the Netherlands cooperate. Together with the Working Group we started a study aimed at developing relevant scenarios for future change, a vision for the ideal situation in 2050 and robust strategies to reach this vision. We conducted seventeen semi-structured interviews to get an overview of their individual perspectives on future flood management. Subsequently, we used Q methodology to make the interview results more explicit: eight individuals sorted a set of statements that we prepared in order of personal agreement with the statements. Using factor analysis, we identified correlations between groups of statements and individuals. The interview results indicate that the higher consequences of an extreme flood in the Netherlands lead to a more proactive reaction to possible future changes such as climate change. The Dutch strategies focus on guaranteeing safety to citizens, whereas the Germans concentrate as well on self-responsibility and damage minimization. In the underlying factors that we identified using Q methodology, Dutch-German differences play only a marginal role. The identified factors could be summarised as Countries should guarantee safety against extreme events, We are doing fine, now and in the future and Fast (spatial) action behind river dikes is needed.

***Keywords:*** perspectives, flood management, future

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# Advances in water management of southern brazilian sub-tropical wetlands using Bio-indicators

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Around the world wetlands are losing area and resources to agricultural production. This is the case of the Brazilian southern sub-tropical wetlands and irrigated rice production. From 1960's the area of wetlands in this area decreased considerably, contrasting with the expansion of rice irrigated areas. An example of this type of ecosystem is the Banhado do Taim, a coastal freshwater wetland with approximately 315 km2 and a large biodiversity. In 1978 the Banhado do Taim was established as a federal environmental conservation unit. However the contribution watershed remained shared with rice irrigation. Over summer large amounts of water (~100m3.s-1) are lost to agriculture, altering Taim's natural hydrological regime. In 1996 it was shown that the ecosystem would not resist the constantly increasing water abstraction due the long term water level alterations. Some water management rules were defined for the complex Mangueira Lake-Banhado do Taim system based on hydrological statistical criteria for time series and scenarios simulations. However ecological criteria were not included to show the ecosystem quality. A small reduction in the water level is known to promote changes in biological communities that depend of specific habitat conditions to thrive or survive. If the stress promoted by water level changes exceed certain limits there is the probability of reduction of specimen numbers and biodiversity or even elimination of the survival possibility of some key species. Emerging macrophytes are among the most affected species due water level alteration. Besides food supply, habitat and refuge for a great number species, the macrophytes play an important role in the Banhado do Taim's hydrodynamics and carbon metabolism. In the south connection between Banhado do Taim and the adjacent Mangueira Lake the tall grass Zizaniopsis bonariensis prevails. The stands of this grass increase the hydraulic roughness in that region, reducing water velocity, and consequently reducing water and material changes between Mangueira Lake and Banhado do Taim. In this ecosystem the Z. bonariensis' presence is dictated by a specific water level range, frequency and duration. Any hydrological alteration can promote deep alterations in the Banhado do Taim's vegetation cover patterns. This work shows the procedure applied to incorporate bological indicators in the water level management criteria presented in 1996, emphasizing environmental quality for the giant grass Zizaniopsis bonariensis. The procedure used to set the habitat quality for this species was effective. After hydrological sceneries simulation through a cell model, results were combined with an environmental quality relationship. High quality sceneries were selected allowing to identify which are the appropriate water level for this species. The methodology also allows the addition of other biological indicators as a criterion, besides the single hydrological criteria, in the water management of sub-tropical wetlands. Restrictive conservation units and water for agricultural production can be managed in the same watershed with mutual benefit.

***Keywords:*** wetland, management, bio indicators

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# Development of Integrated Models and Modeling Environment for a Typical Inland River Basin in China

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China is speeding up her implementation of the historic West Development strategy. It is promising to make a breakthrough in both infrastructure and ecological construction of the comparable underdeveloped west region. However, for northwest China, the countrys most arid region, water resource shortage might become the major constraint to hamper the socioeconomic development. How to eliminate the water scarcity - this is a challenge that Chinese people must to face and to combat with. An important means to combat the water crisis is integrated watershed management, which, from the methodological viewpoint, needs model integration and data integration. Realized this, we initialized an effort for the Development of Integrated Models and Modeling Environment for Inland River Basins. The work was carried out in the Heihe River Basin, Chinas second largest inland river basin. The integrated modeling approach is focused on two major objectives. The first one is to develop a catchmental scale land data assimilation system. In the system, the forcing comes from meso-scale climatic model or downscaling of re-analysis dataset will be used to drive the land surface/hydrological models. The predictions are hydrological, ecological conditions by assimilating both conventional and remote sensing observations into the model states. Another effort is to develop a spatially explicit DSS. It will incorporate SWAT, PRMS, HBV, and some other hydrological models into the system by use a plug-in architecture. The objective is to couple the regional climate model (in an offline mode), distributed hydrological and water resource model, eco-hydrological model, and eco-economic model. The DSS will be used in the decision making for rational utilization of water resources. The data integration approach is implemented by developing a web-based information system which is called the Digital Heihe River Basin. It is a web-based information system that integrates data from different sources and in different scales. More than 200 GB of in situ observation data, experimental data, GIS maps, and remotely sensed data have been released on the web site. Various database and dynamic web techniques as well as Web-GISs were being used for data service. The Digital Heihe River Basin is the most comprehensive and open hydrological database in catchmental scale in China. Except the high resolution DEM, almost all the data are open to the science community and the public via Internet. The URL of the Digital Heihe River Basin is http://heihe.westgis.ac.cn.

***Keywords:*** model integration, data assimilation system, decision support system

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# Between aridity and humidity excess in Transylvanian Plain. The unique model approach

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The quantitative and qualitative evaluation of the water resources of a region represents the basis for any of the diverse scenarios that may be planned regarding water needs. This paper refers to an evaluation procedure of the dynamics of the water resources, from a quantitative point of view, at a monthly scale. Known as a semi-arid region, the Transylvanian Plain (3900 km2 , 200000 inhabitants) was affected sometimes by great oscillations of humidity at basins scale. With the help of the VUB rainfall-runoff model, we generated the time series that expresses this phenomenon, the extreme values being considered as generating aridity, respectively, excess of humidity. The plain is crossed by 7 internal rivers, which have hydrometric available observations. The Thyessen precipitations have been calculated on the basis of 18 stations, and an ETP series is available. All data are expressed in mm, the common period is 33 years, between 1968 and 2000. The 1968 1983 period is used for model calibration, while the 1984 2000, for simulation and validation. By frequency analyses the return period of these extremes was expressed. The XT quintiles of the return period T were emphasized in probabilistic form. The basic equation used, statistically valid for both extremes, was Log-Pearson III, estimated by the method of moments. With the help of GIS the XT quintiles for a certain return period were interpolated, the result being hazard maps. Then the territorial vulnerability maps were built, corresponding to certain values of the hazard. Considering both the extension and the social-economic characteristics of the territory exposed to different degrees of vulnerability, the risk of extreme phenomenon occurrence was expressed in probabilistic form. With the help of GIS we determined the spatial variation of possible damages for certain values of the risk of aridity or humidity excess. Knowing the location and the quantity of the internal water resources, and on the basis of the actual water demand, several water supply scenarios from the external area are discussed. For the present economic potential, the pumping from the neighbouring big rivers (Somes and Mures) is adequate, but on a long term, the sewer freshwater transfer from the mountainous territory should be the solution.

***Keywords:*** extremities, gis, scenarios

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# Water Quality and Its Impact on Agriculture and Environment: A case of Ala River in Nigeria

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Good water quality is needed to maintain ecological balance and for economic developmental activities. This study was carried out to determine the water quality of river Ala that runs through the Ondo state capital in Nigeria and to evaluate its impact on agriculture and the environment. Water samples were collected along the river at four locations: Aiyedun, Araromi, Okejebu and Fiwasaye. The parameters monitored include physical, chemical and microbiological characteristics. Water samples were put in sterilized bottles and taken to the laboratory for analysis using appropriate methods. Results obtained were compared to norms given by the European Council (EC) and World Health Organization (WHO). The coliform counts in all the four locations were high when compared with allowable limits. Counts were 300+, 300+, 300+, 91 cfu/ml at Fiwasaye, Oke-Ijebu, Araromi, and Ayedun respectively. The range of values for Biochemical Oxygen Demand (BOD), Total Suspended Solid (TSS), Dissolved Oxygen (DO), and Total Solids (TS) obtained were 7.78-12.7mgl-1, 0.028-1.200 mgl-1, 0.6-6.43 mgl-1, and 0.06-2.0 mgl-1 respectively. Total suspended solids at Ayedun, Araromi, Oke Ijebu, Fiwasaye are 0.031, 0.028, 0.10 and 1.20 mg/l respectively. However, the values of electrical conductivity obtained were within acceptable range. When compared with the norms, these result show that the river is highly polluted. This is due to the fact that domestic (and possibly industrial) wastes in liquid and solid forms are disposed directly to the river at various locations without treatment due to poor implementation of environmental regulations. The consequence of this is that the water from this river is unfit for domestic water supply, aquaculture and recreational activities and in some cases agricultural practices. The water can however be used for irrigation under adequate management and salinity control. The government should make know the results of these findings to the public and implement its regulations on waste disposal.

***Keywords:*** water quality, river ala, environment

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# Concordance between water utilization and environment protection in arid Northwest China

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There are very significant influences of agriculture on local water resources in the arid or semi-arid areas of Northwest China. In the early time of local exploitation, the development velocity and scale were principal for the water quantity was comparatively rich. But when some degree had been reached, serious environmental degradation and shortage between water supply and demand appeared, and some measurements like water abstraction limitation and advanced technology utilization were adapted to mitigate the contradictions. But unfortunately, the problems will not be solved completely due to the existed gross population and economy. As a result, we will live with them in quite a long time. So agriculture and concomitant water usages, environment protection should be dominated dynamically, and the agriculture economy and ecology are permitted to fluctuate between good and bad status. This article makes a case study in the midstream of inland Blcak River in Northwest China. The historical data of crop planting structure is counted, and a spatial analysis is applied to the data. Furthermore, local water balance is simulated. Depending on these two works, the changes of crop planting structure when water supply is adequate or not are evaluated, so do the influences of crop planting structure and technique level on local water resources distribution. Based the understandings of these two coupled aspects and the assessment or protection strategy of local environment, the adjustments of agriculture and environment protection in long or short term, even a certain year, are established to adapt to different conditions of water supply and demand. In this way, the states of economy and environment may not be best from the unilateral view, but will be acceptable and concordance from the overall perspective.

***Keywords:*** water, simulation

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**HS3006** **Oral Presentation** **4365**

# Study on water resources allocation in water-receiving area of East Route of South-to-North water transfer project

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It is well-known that water shortage and related eco-environmental issues in North China have become the most significant issue to impact sustainable development. In order to solve the water scarcity situation in the region, the Chinese government decided to divert water from south to north through 3 routes at the upstream, middle-stream and downstream sections of Yangtze River respectively and so is called South-to-North Water Diversion Project of China (SNDP). The SNDP is the biggest hydraulic project ever designed worldwide. The East Routes (EA) mission is to draw water from Jiangdu at downstream section of Yangtze River. It pumps water progressively northward through the Beijing-Hangzhou Grand Canal. According to planning the EA project will be build based on some present hydraulic facilities diverting water from Yangtze River to north part of Jiangsu Province, and pass through several big lakes to enhance its capacity to regulate the water. The diverted water by EA is mainly supply to agriculture in Jiangsu province, yet mainly to industry and domestic users in Shandong province and other area north of Yellow river. Therefore, its an extremely complicated but important issue to implement the optimal allocation of water at different district and among different sectors and operation of various hydraulic facilities for this complex system. Furthermore, assessment of impact on ecosystem and environment in the water-receiving area by EA project is also significant for related decision-making for operation and management of EA project. In addition, from point of view of economy, local water resources must be used with higher priority by water-receiving area than inter-basin diverted water since the cost of inter-basin diversion is much higher than local water exploitation. Diverted water can only be used in season of extreme dry or peak water demand. This is an insurmountable challenge for implementation of EA project because only insufficient diverted water could be accepted by water-receiving area in this way that could not support the sustainable maintenance of EA with limited benefit, and its not economical for operation of this complex system. Aiming at this problem, a strategy called two-step water price is planned to apply in regulation of water allocation to seek a reasonable balance in exploitation between diverted water and local water. Simply, a part of diverted water is compulsory to use prior to local water to guarantee operation of EA through that strategy. But it is still lack of research about how to design a holistic algorithm to realize that water allocation strategy with other constraints. To probe scientific and feasible technique for operation of EA, a computable model is present to realize the joint operation process of inter-basin based on the strategy of two-step water price in this paper. To design this model, the hydrological and socio-economic situation and requirements for EA route in water-receiving area are analyzed. Based on the realistic hydraulic relationship, the interaction of local water and diverted water is taken into consideration in the model. In this model, an algorithm called stepwise compensatory allocation of inter-basin diversion (DISAC) is presented to realize reasonable joint operation of local water. In this algorithm, there are basically three steps to realize the joint allocation. First of all, a part of diversion water is fixed to allocate to regular users with first priority; the second step is allocate local water to applicable users; the third step is to allocate the surplus diverted water to applicable users which are still unsatisfied. And the process of allocation is designed to comply with various constraints, general proportion for diverted water among different regions and optimum operational rules of related hydraulic facilities and controllable to carry out different scenario analysis with adjustable parameters. Based on this model, several scenarios with different strategies and major objectives are simulated and the possibility of the

network to deliver such a water diversion schedule according to the physical limitation is also verified. With multi-objective assessment technique the comprehensive influences of EA on the water-receiving area are analyzed and the reasonable scenarios for water allocation and operation of major hydraulic facilities related to EA.

***Keywords:*** inter basindiversion, waterresourcesallocation, multi objectiveassessment

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# Integrated Water Resources Management when Information is Limited: Case studies in the Semi-Arid Highlands of Ethiopia

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This study highlights two highly degraded watersheds in the semi-arid Amhara region of Ethiopia where integrated water resource management activities were carried out to decrease the dependence on Food Aid by improved management of green water. While top-down approaches require precise and centrally available knowledge to deal with the uncertainty in engineering design of watershed management projects, bottom-up approaches can succeed without such information by utilizing stakeholder knowledge. This approach often requires the development of leadership confidence within local communities. These communities typically face a number of problems, most notably poverty, that prevent them from fully investing in the protection of their natural resources, so an integrated management system is needed to suitably address the interrelated problems. The two study watersheds where this approach was attempted, brought together many different implementing agencies to address water scarcity, crop production, and soil erosion, but the most important step was enabling local potential through the creation and strengthening of community watershed management organizations. Leadership training and the reinforcement of stakeholder feedback as a fundamental activity led to increased ownership and willingness to take on new responsibilities. A series of small short term successes ranging from micro-enterprise groups to gully rehabilitation have resulted in the pilot communities becoming confident of their own capabilities and proud to teach others how to manage a watershed. A follow up visit five years after the start of the project is underway to evaluate the longer term impact of the approach followed. Parallels are drawn between the management of these two watersheds in Ethiopia and that of the watersheds in the Catskills Mountains from which New York city obtains its drinking water.

***Keywords:*** watershed, water management, participatory

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# Scenario Development for Water Resources Planning and Management in semi-arid Regions

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Although there have been many studies conducted in the nascent field of scenario analysis and development, very few of those have been explicitly applied to water resource issues. More evident is the absence of an established formal approach to develop and apply scenarios. We report progress on an effort to develop a unified framework for constructing scenarios for water resource management in the semi-arid Southwestern U.S.. Particular emphasis is placed on understanding forces external to the traditional water management process such as unforeseen changes in government institutions or climate change that may drive unanticipated change in environmental systems. Scenarios are developed for SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas), a National Science Foundation Science and Technology Center. Scenarios are used to drive multiple integrated models that focus on water leasing institutions, restoration of riparian areas, and multi-decadal vegetation change over various spatial and temporal resolutions.

***Keywords:*** scenarios, modeling, analysis

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**HS3006** **Oral Presentation** **4368**

# Forest hydrology project (UFSC-MOBASA) for water resources management in Rio Negrinho City, Paran State, Brazil

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The forest in the plateau region of the Southern Brazil was represented mainly by the Subtropical Ombrophilous Forest (Araucaria Forest). During more than one century of economic exploration without planning, this rich and unique forest has reached a situation of visible biological decay. The rare native forest remainders are now only 2% of its original area, because they have being suppressed to give their places to the agriculture and cattle breeding and reforestation, especially pine trees. Under this situation, many comments on the adequate land-use for this region have currently raised. Today environmentalists and communities condemn the pine reforestation activities by alleging the water quality deterioration and its quantity reduction. They request the transformation of the pine areas to the Subtropical Ombrophilous Forest, without consideration about that the regional economy is totally dependent on the reforestation activities. Which are the real implications in the hydrological role of the catchment when compared composed areas for native forest, pine reforestation and agriculture? Taking this comparison as base, which of these land-uses would be a sustainable alternative for the region? To answer these questions, it is important to carry out monitoring and modeling with experimental catchments. In this sense, through accord between Federal University of Santa Catarina (UFSC) and the Modo Battistella Reflorestamento (MOBASA), a Forest Hydrology Project was initiated in the Rio Negrinho city, State of Santa Catarina. This project is a part of the Environmental Project of the MOBASA, in which fauna, flora, soil and water have being investigates. The mean annual temperature and precipitation in this city are 18.3 C and 1,572 mm, respectively, and the mean annual potential evapotranspirao is 54.6% of the precipitation. The present project has 7 experimental catchments: Pine 1 (23.8 ha); Pine 2 (19.7 ha); Native Forest 1 (14.9 ha), Native Forest 2 (24.1 ha), Agriculture (19.7 ha), Mixture 1 (268.6 ha), and Mixture 2 (950 ha). The mixture catchments are characterized by the mosaic structure of three different land uses. In these catchments, the discharge, suspended solids, precipitation and some meteorological parameters are automatically monitored with 10 minutes interval. The obtained data will be available on the projects page in the internet. All the experimental catchments are used for the environmental education activities in local communities and also for the qualification lectures for technician of water and forest resources. Since there are very few researches on hydrological processes of the Subtropical Ombrophilous Forest and pine trees in Brazil, the present experimental catchments could serve as pilot model for this region. The present study shows some preliminary results.

***Keywords:*** forest, experimental catchment, education

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# Application of a Decision Support System for water management as an attempt to improve public knowledge and participation within the Canoas River Basin, Brazil.

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The paper presents the application of a Decision Support System ( DSS) to support the legal process of concession of water use at the Canoas River Water Basin, on Santa Catarina State in southern Brazil. Brazilian Water Federal Law. 9.433/97 requires water permit regulation, with priority at the basin level for human consumption and animal use. In this manner Brazil is trying to regulate water use in a sustainable way organizing the water rights and priorities. At the Canoas River basin, where this law has so far not been implemented, current water management has no technical instrument to implement this requirement, so decisions are still made in the traditional bureaucratic way from top to bottom. For this project a Geographical Information System using ArcHydro has been developed to estimate water availability based on ANA Agencia Nacional de Aguas hydrological data and an inventory of the water used at the basin level. In addition, a Decision Support System Model has been developed using MODSIM to evaluate possible scenarios of water use in the basin and to estimate the impacts of this use in the basin. This model is used to predict and evaluate the impacts of water consumption from activities such as increased housing and population growth, irrigation expansion, improved use of industrial and domestic wastewater, and land use change in general. This instrument will bring to public stakeholders, especially to newly forming water management at the community level, a tool for visualizing the effects and impacts of proposed alterations. Water managers, using this DSS tool, can understand better how the decisions they take affect the environmental quality of the basin.

***Keywords:*** decision support systems, water management, public participation

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# Drought prediction in the Vietnamese central highlands

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Rainfall over the Vietnamese central highlands is governed by the Asian summer monsoon. The El Nio-Southern Oscillation (ENSO) phenomenon and related large-scale circulation anomalies, however, introduce disturbances that may lead to drought in the central highlands. Droughts cannot be prevented but the consequences for human livelihood and economic losses can be alleviated, if better prediction tools become available. Sea surface temperature (SST) is an indicator for the ENSO phenomenon and has been used here in an effort to develop prediction models for precipitation in the Vietnamese central highlands with a lead-time of up to three months. SST in both the Indian and the Pacific oceans has been related to precipitation by means of canonical correlation analysis, a linear statistical technique. The best results were obtained for rainfall at the outset and the end of the rainy season. In order to further improve these results non-linear techniques in the form of artificial neural networks (ANN) were applied. Using this techniques also discharge in three river basins in the central highlands were predicted with SST and meteorological variables as predictors. Although local effects have a great influence in certain parts of the area, reasonable prediction results were obtained for both rainfall and discharge.

***Keywords:*** drought prediction, sea surface temperature, enso

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# Effect of human activity on nutrient discharge with groundwater flow to the ocean in the Yellow River delta, China

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As the human impact on water resource is expanding and becomes complex, we have to evaluate globally the control factors. Yellow River has kept the condition with a shortage of the river water since 1990s in the downstream area (Chen et al., 2003) by the increase of agricultural water use in the upstream area. The change in such a large river would act on the ocean environment as well as water resources, that is, on the global water and mass cycle. In addition, the Yellow river delta formed within the last 100 years has been used as agriculture land for last 20 years despite of extremely high salinity in the soil. Consequently, nitrate contamination of groundwater has been expanded there. To clarify the effect of such drastic changes on the ocean and groundwater, it is necessary to confirm the groundwater flow and nutrient transport in the delta area where the boundary of land and sea. However, the effect of human activity has not been considered in such large scale from upstream to downstream area. The objective of this research is to confirm the effect of human activity on nutrient discharge with groundwater flow to the ocean in the Yellow river delta. In this research, we measured variations of groundwater level automatically and examined distribution of groundwater table in the area. In addition, we collected samples of river water, groundwater, soil water, and seawater. Then we estimated groundwater flux in various river runoffs, using a simple aquifer model. The major chemical component was analyzed in the laboratory. The groundwater level distribution at the delta area indicated groundwater flow from river to ocean in both periods of wet and dry. The seasonal variations of water level were about 1m to 2m. Groundwater flux during the dry season was estimated to be about a half of that during wet season by the simple model. The relationship of groundwater flux and river runoff estimated by the model supported that groundwater discharge decreased but the nutrient flux to ocean maintained during the drought period in the river. On the other hand, it was suggested that river runoff increased in the magnitude of more than 2 orders during the wet period but groundwater flux increased only several times even in the maximum. These results indicate that groundwater discharge was dominant only during the completely draught period, but river discharge was dominant during the wet period and it is more than 100 times of groundwater. The nutrient component of river and groundwater was nitrogen rich and phosphorus and silica rich, respectively. The groundwater was also contaminated by nitrate under the agriculture land as well as river water, but the nitrate elimination occurred with groundwater flow. Therefore, it was estimated that nitrate discharge with groundwater was little. Consequently, nutrient discharge pattern was suggested that phosphorus and silica discharge were dominant during a drought period by groundwater, while nitrogen discharge was dominant during a flood period by river, respectively.

***Keywords:*** yellow river, delta groundwater, nutrient

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**HS3006** **Oral Presentation** **4372**

# Geospatial indicators to support water resource and water security assessments

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***Ellen Marie Douglas***

This study demonstrates the use of globally available Earth system science data sets as a detection system for early warning of water security problems and for water assessment in an otherwise information-poor region of the world, Africa. Geospatial analysis at 8 km resolution shows that 64% of Africans rely on water resources that are limited and highly variable. Where available, river corridor flow is critical in augmenting local runoff, reducing impacts of climate variability, and improving access to freshwater. A significant fraction of cropland resides in Africa's driest regions, with 39% of the irrigation estimated to be non-sustainable. Chronic overuse and water stress is high for 25% of the population with an additional 13% experiencing drought-related stress once each generation. Paradoxically, water stress for the vast majority of Africans typically remains low, reflecting poor water infrastructure and service, and low levels of use. Modest increases in water use could reduce constraints on food production, economic development, pollution, and challenges to human health. Developing explicit geospatial indicators that link biogeophysical, socioeconomic, and engineering perspectives constitutes an important next step in articulating the links between water and food systems over a continental scale and affecting nearly 800M people. A methodology for creating indicators of water supply stress and a brief analysis of the role of virtual or ebodied freshwater in the pan-African food system will be presented. The use of such an information system in civil conflict studies related to water will also be offered.

***Keywords:*** water, security, indicators

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**HS3006** **Oral Presentation** **4373**

# Effects of climate change and population growth on water resources in Korea

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Korean water resources have become scarce as a result of population and industrial growth. Korean population is expected to grow to approximately 50 million by 2020, creating 38 billion ton water demand. Accordingly, the current water resources will fall short by 2.6 billion tons. In addition to population and industrial growth, climate change is posing another stress on freshwater resources in the region, enhancing discrepancies between water supply and demand. Most climate change models suggest that increasing temperatures and increases in rainfall variability are likely to increase runoff variability for river basins in Korea. As the first national assessment, we assessed the combined effects of climate change and population growth on water resources in Korea. We produced fine scale climate change scenarios (20km X 20km) with a regional climate model (RegCM3) using a double-nested system. The simulation spans the eighty-year period of January 1971 through December 2050, and initial and lateral boundary conditions are provided from ECHO-G fields based on the IPCC SRES scenario. We divided the five major basins into 139 sub-basins and generated runoff scenarios. We used USGSs PRMS model to estimate long-term runoff between 1971 and 2050. For future vulnerability assessment, we used water scarcity index (WSI), the ratio of freshwater withdrawals to available renewable freshwater resources. Water use sectors include domestic, manufacturing, and agricultural water uses. Values in the order of 0.2 to 0.4 illustrate medium to high stress, while those greater than 0.4 show severe water limitation. Future water use projection is based on historical patterns of regional, sector specific water uses and projected population and industrial growth scenarios. With projected warming and increased evapotranspiration, mean annual runoff is projected to decrease in major river basins except in the Han River basin where the influence of increasing precipitation surpasses increases in evapotranspiration. The hydrologic impacts are more pronounced in high elevations where snow cover is projected to decline significantly. Summer months runoff decreased 8 to 40% in southern river basins. Mean annual runoff is projected to decline further by the 2030s. We developed three scenarios for assessing the vulnerability of future water resources (1) projected growth only; (2) projected climate change only; (3) combination of climate change and growth scenarios. Under the growth scenario, the Han and Nakdong basins experience more significant stresses than other basins. Climate change scenario could reduce mean annual runoff by more than 10% for basins located in south. The Nakdong River basin is projected to experience high stress by 2030 (WSI > 0.4). When climate change and growth occur concurrently, all regions experience further reductions in the relative availability of water as reflected by increases in the values of WSI

***Keywords:*** water stress, climate change, integrated assessment

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**HS3006** **Oral Presentation** **4374**

# Ecological impacts of water resources utilization in the Tarim River Basin in China

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***Hao Xinming***

Sustainability of the natural ecosystems in arid area highly depends on water resources, the recent fast growth of population and economic activities in the Tarim river has dramatically changed the temporal and spatial distributions of water resources in the area, and has made the existing problem of scarcity of water resources even more striking. During the last 5 decades, the water supplied from Aksu River, Yarkand River, and Hotan River, the three major tributaries of the Tarim river, has greatly reduced, due to the economic development in the source areas. The water contributed by the three rivers reduced from 51.79108m3 in the 1960s to 42.04108m3 in the 1990s, and then decreased progressively 0.25108m3 per year. Approximately 38% of cultivated land in the source area has experienced serious secondary salinization. Increasing consumption of water in the upper- and middle-reach areas caused droughts in the lower-reach area: The water consumption in the upper and middle reaches rose from 72.9% of the total water volume in the 1950s to 95% at present. The water arriving in the lower reach reduced from 13.53108m3 in the 1950s to 2.67108m3 in the 1990s, leading to the drying-up of the watercourse for more than 320km, and the drying-up of Tatema Lake and Lop-nor lake (the terminal lakes of the River).Water pollution is serious, which intensified the scarcity of water resources. The immediate consequence of these problems is the deterioration of groundwater condition in the Basin, especially in the lower-reach area. Due to the drying-up of the watercourses, the groundwater level in the vicinity of the lower reach dropped from 1-3m to 8-11m. The ecosystems in the lower-reach area have been suffering serious injuries. Vegetation relying on the groundwater has seriously degenerated. To protect water resources, integrated management and the sustainable use of water resources in the basin are needed: coordinating development for both ecology and the economy; taking the whole, the coordination, the circulation, the regeneration

***Keywords:*** water resources, water consumption, water management

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**HS3006** **Oral Presentation** **4375**

# Community perceptions, priorities and participation in managing water and environmental resources in the River Njoro Watershed, Kenya

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***F. K. Lelo, L.W. Chiuri, W. A. Shivoga, S. N. Miller***

The Njoro Watershed, typical of the semi-arid basins in the Rift Valley of Kenya, is undergoing a new phase of rapid land use change in the uplands portion of the watershed, and on-going significant growth in both rural and urban populations. Considerable negative environmental impacts are occurring, in particular to thequantity and quality of river water. Domestic, livestock, commercial, industrial, and institutional water users in the basin are affected, as well as important downstream habitat in Lake Nakuru, a large shallow saline lake designated a Ramsar wetlands site of international importance. In response to these concerns, a multidisciplinary applied research project called Sustainable Management of Watersheds Collaborative Research Support Program (SUMAWA-CRSP) was established. SUMAWA aims to demonstrate improved and integrated management of water and environmental resources in the Njoro Watershed through local stakeholder participation and action supported by scientific information and analyses. Preliminary results from elements of the SUMAWA planned process for stakeholder participation in management of the Njoro Watershed are presented. A mixture of participatory methods, discussion forums, awareness-raising activities, and local capacity building are being undertaken to address some of the challenges involved in engaging local stakeholders and communities in watershed action planning. The first phase of activities adapts Participatory Rural Appraisal methods to assess local residents? interests in and perceptions of the current condition of river water quality and quantity, of problems and their causes, and opportunities for local action in all the different communities along the length of the watershed.

***Keywords:*** community participation, rural watershed, multidisciplinary approach

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**HS3006** **Oral Presentation** **4376**

# Recharge artificielle et qualité des euax des nappes du systeme aquifere 'El Khairat'

***Mrs. Mouna Ketata***
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Le système aquifère d'El Khairat, dans la région d'Enfidha, comporte une nappe phréatique logée dans des formations sablo-argileuses et une nappe profonde logée dans les marnes du Vindobonien. Ces deux nappes sont interconnectées. Latéralement, ce système est subdivisé, par un seuil hydraulique (Seuil de Ain Garci), en deux zones distinctes : Ain Garci située, en amont et Enfidhaville, à l'aval. Ce système aquifère est surexploité, en raison de l'augmentation des prélèvements d'eau pour l'irrigation, la consommation humaine et l'activité industrielle ; ce qui a conduit à une baisse plus au moins généralisée du niveau piézomètrique. Il a été donc nécessaire de procéder à une recharge artificielle de ce système aquifère par les eaux du barrage collinaire de l'Oued El Khairat. Le présent travail a pour principaux objectifs de déterminer l'impact de la recharge artificielle du système aquifère d'El Khairat sur la piézomètrie et sur la qualité des eaux. Afin d'atteindre ces objectifs, une compilation des données piézomètriques disponibles et un suivi spatio-temporel, des paramètres physico-chimiques (T, pH, salinité et oxygène dissous) et des concentrations des éléments majeurs (Na, Mg, Ca, K, Cl, SO4 et HCO3), ont été entrepris. Les résultats du suivi piézomètrique, montrent que pour les trois campagnes de recharge artificielle réalisées entre 2002 et 2004, une remontée du niveau piézomètrique de la nappe phréatique d'Oued El Khairat, surtout au niveau de la zone « Ain Garci », avec des valeurs allant de +0,4 à +2,63m. La situation piézomètrique de l'aquifère profond a aussi enregistrée une remontée assez importante atteignant +3,82m. Les résultats des analyses chimiques des eaux du système aquifère d'El Khairat montrent que la charge saline totale varie de 1,33 à 3,77 g/l, pour la nappe phréatique et de 0,48 à 3,86 g/l, pour la nappe profonde. Cette salinité est contrôlée, principalement, par les teneurs en sodium, calcium, chlorures et sulfates qui sont les ions dominants. Ces éléments auraient pour origine l'altération chimique des formations traversées, au cours de l'infiltration des eaux, et celle de la roche réservoir. Pour la majorité de ces eaux, les valeurs des paramètres d'évaluation de la qualité dépassent les concentrations maximales, fixées par les normes de l'OMS, pour la consommation humaine. Quant à l'irrigation, les eaux de ce système aquifère peuvent être utilisées pour la plupart des cultures, avec une faible probabilité de développer un problème de salinisation

***Keywords:*** système aquifère, recharge artificielle, qualité des eaux souterraines

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**HS3007** **4377 - 4403**

## Symposium
## Remote Sensing for Environmental Monitoring and Change Detection (Sponsor ICRS)

**Convener :** Dr. Manfred Owe

Remote sensing technology continues to play a significant role in the understanding of our changing environment. It has evolved into an integral research tool for the natural sciences. Disciplines such as climatology, hydrology, and studies of the terrestrial biosphere have all developed a strong remote sensing component. Moreover, remote sensing has facilitated our understanding of the environment and its many processes over a broad range of spatial and temporal scales. This is a highly important aspect of hydrological research, especially in the detection of environmental change, water resources management, irrigation water management and environmental monitoring and prediction in remote locations. This symposium seeks papers describing recent research results in the application of remote sensing as relating to the hydrological sciences. Papers are especially sought on applications that emphasize monitoring and change detection in environmentally sensitive regions, remote locations or otherwise data-poor locations. Contributions using visible, near and thermal infrared, microwave as well as other wavebands, are solicited. The symposium is especially interested in papers which emphasize the use of satellite data, the synergistic application of multiple wavebands and sensors, and other new and innovative remote sensing applications.

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**HS3007** **Oral Presentation** **4377**

# Remote sensing estimation of land surface evapotranspiration of typical river basins over China

***Dr. Chesheng Zhan***
*HS3007 Remote Sensing for Environmental Monitoring Sponsor ICRS IAHS*

***Chesheng Zhan, Jun Xia, Zhi Chen***

Estimation of regional Land-surface Evapotranspiration (LET) is of major importance in hydrologic cycle, which is affected by a multitude of processes at the interface between soil, vegetation and atmosphere. This paper aims to simulate LET of typical river basins over China for the year 1991, 1995 and 1999 by means of quantitative remote-sensing methods. The meteorological data of reference height, NOAA/AVHRR images, soil & vegetation data and ground validation information of the year 1991 to 1999 were collected and processed, and these river basins LETs of every 10-day in the year 1991, 1995 and 1999 quantitatively were estimated on the basis of improving the original SEBS (Surface Energy Balance System) remote sensing model. At the same time, some experimental areas and typical basins were selected to do regional average LET validation with observation values, which showed that only the average annual LET simulation value of Yellow River was much higher than its observation value compared to the other basins, and generally the most simulation results of annual LET were good. In view of the LUCC (Land Use and Cover Change) patterns of different years, Yangtze river and Liaohe river basin were selected as the examples, and their average LETs of different land cover types for three years above were compared, and the LET space-time patterns corresponding to LUCC patterns of 1991-1999 were analyzed. Totally, the maximum average ET for every river basin appeared in 1995, and then in 1991, the minimum appeared in 1999, which was tightly related to climate change and LUCC patterns for recent ten years. Based on land use transformation of typical basins, the paper analyzed the ET changing trends corresponding with LUCC transformation trends from 1991 to 1999 in selected basins. The results showed that there are the similar relations between LUCC changes and ET changes for Yangtze River, Pearl River, Yellow River, Haihe River, and Liaohe River. It also showed that ET of the same area would decrease while paddy field, arid land, grassland, and built-up area were transformed to other land use types. However, ET of forestland had different tendency. ET increased in 1999 when forestland was transformed to arid land and grassland. For Liaohe river basin, ET increased when forestland transformed to other types while ET decreased when farmland and grassland were transformed to other types, and ET changed obviously when other land use types were transformed to built-up areas.

***Keywords:*** let, remote sensing, river basin

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# Infrared measurements to evaluate groundwater discharge in the coastal zone

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Direct groundwater discharge is now recognized as an important pathway for water and dissolved material from the land to the ocean. There are several methods to evaluate the magnitude of the groundwater discharge rate, however, the method of evaluating spatial distribution of direct groundwater discharge has not been established yet. In this study, the areas of groundwater discharge into the coastal zone were evaluated by uses of infrared method from remote controlled helicopters. Fiber cables and thermometers were used in situ to compare the surface temperature obtained by remote infrared data for evaluating the groundwater discharge into the ocean. Measurements have been made on August 21 to 23, 2006, by uses of Thermo-tracer TS7302 (NEC-SanEi Co.). Measurement wave length ranged 8 to 14 m, spatial resolution was 50 cm (from the height of 500ft), accuracy of the temperature was 2 %. Results show the area with cooler located in the inter-tidal zone where groundwater discharge occurred. Soil surface temperature measured in situ at the transect line with thermister thermometers and fiber cable agreed well with the infrared thermal data. The area shown with the cooler surface temperature also agreed well with the area with larger groundwater seepage rate observed by seepage meters. Remote sensing method by uses of infrared sensor to evaluate the spatial area of groundwater discharge into the coastal zone is useful, and good tool for monitoring and change detection of coastal environment including groundwater discharge.

***Keywords:*** infrared measurement, costal environment, groundwater

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# Assessing crop water stress using MODIS data during winter wheat growing period along downstream of the Yellow River, China

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Water resource is considered to be a major limiting parameter for local crop growth in northern China, where irrigation has been an indispensable method to insure a stable agricultural yield. Therefore, how to quantify the crop water use and realize a high efficient irrigation pattern is urgent to relieve the pressure on the scarce water resource. Weishan Irrigation District along the downstream of Yellow River, with a designed irrigated area of 360,000 ha, has an average annual rainfall of 500-600 mm, where 60-70 percent of local rainfall has been accumulated in summer and less than 15 percent in spring. Water stress in spring brings a big problem for local winter wheat growth from March to early June, which is a major growth period closely related to the wheat production. Remote sensing has provided an efficient guide for local irrigation agriculture through modeling the actual crop evaporation repeatedly and simultaneously combined with meteorological data to map the water stress in the region. In this paper, about twenty MODIS datasets including visible, near infrared and thermal infrared bands from March to June in 2006 have been collected and the Surface Energy Balance System (SEBS) model, derived by Bob Su, has been applied to monitor the daily energy flux changes. The drought index map based on the evaporation fraction (EF) has been made to estimate the soil water deficit and crop drought status, and is compared with daily in-situ measurements of the volumetric soil moisture, and vegetation water content (VWC) data during this period. The result shows that the drought index is useful as an indicator of the wheat water stress in the semiarid and subhumid zone.

***Keywords:*** water stress, modis, sebs

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# Towards a continuous monitoring of evapotranspiration based on MSG data.

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In the framework of the EUMETSATs Land Surface Analysis Satellite Application Facility (LSA-SAF), a method has been developed to estimate the evapotranspiration (ET) from satellite remote sensing over Europe. The methodology follows a Soil Vegetation Atmosphere Transfer (SVAT) approach in which main forcing comes from Meteosat Second Generation (MSG) derived data. Other LSA-SAF components provide basic fields driving the model like visible and infrared radiative fluxes (i.e. half-hourly downward short- and longwave radiation, daily surface albedo) and properties describing the state of the biosphere (i.e. fraction of vegetation cover and leaf area index at a daily time scale). Calculation of energy exchange between the atmosphere and the surface is performed for each type of vegetation composing a MSG pixel (tile approach) and aggregated to derive ET at MSG spatial resolution. The methodology takes advantage of the recently developed ECOCLIMAP database, well suited for the tile approach and describing the mean evolution of the surface properties. In practice the model is build with an increasing complexity corresponding to successive versions. Today, half-hourly ET maps over Europe are produced for demonstration, in near-real time, at the Portuguese Meteorological Institute (Host of the LSA-SAF). Current results will be discussed and illustrated. The temporal sampling allowed by MSG is particularly interesting to build correct ET temporal means taking cloud cover into account. Different patterns of ET over Europe are presented. Validation of the results is among the most important activities. Comparisons are done with ground flux measurements (from National Meteorological Services and Fluxnet network) and with outputs from Numerical Weather Prediction (NWP) models. The application is planed to be extended to Africa next years. The study of arid and semi-arid regions will be of special concern. The future METOP ASCAT microwave sensor is expected to provide valuable input about the upper soil moisture conditions through collaboration with the recent Hydrology-SAF.

***Keywords:*** evapotranspiration, msg, lsa saf

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# Comparison of Aster, Master, and Ground-based reflectance measurements

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This study compares reflectance measured in the visible and short wave near infrared wavelengths by the Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER), MODIS/ASTER Airborne Simulator (MASTER), and ground based Analytical Spectral Devices Spectroradiometer (ASD) over USDA ARS Jornada Experimental Range (Jornada) in a semi-arid area of the northern Chihuahuan desert in southern New Mexico USA. This study provides unique opportunities to compare remote sensing data for semi-arid rangelands from different platforms, scales, and plant communities. ASD visible and near infrared reflectance data (0.4 to 2.5 microns) for May 12, 2001, October 6, 2002, and May 2, 2003 were analyzed and integrated to match the 21 MASTER and 9 ASTER bandwidths for three different vegetation communities (shrub-mesquite, grass, and shrub-grass transition) at the Jornada. A strong positive correlation with a slope near one between the measurements indicated that the three sensors were measuring similar absolute reflectance values from the three vegetation communities. Reflectance was highest from the shrub community and lowest from the grass community with the shrub-grass transition being intermediate. This has implications for the energy and water budgets of the Jornada where shrub communities are invading and replacing grass communities.

***Keywords:*** semiarid rangeland, aster, calibration

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# Vegetation change detection using thermal band emissivities over Jornada, New Mexico USA.

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Detecting land cover change over semi-arid rangeland is important for monitoring vegetation responses to drought, population expansion, and changing agricultural practices. Such change can be frequently detected using vegetation indices constructed from visible and near infrared reflectance data. However, maps based on indicators such as NDVI do not represent densities of non-green vegetation and consequently are dominated by seasonal changes. Hence vegetation densities are inaccurate during dormant periods. An alternative monitoring technique is to observe spatial changes in thermal emissivities, a measure that responds to soil surface composition and vegetation canopy geometry. Because emissivity effects of soils are generally stable, observed temporal emissivity changes are likely due to changes in vegetation densities. Using ASTER thermal infrared observations, the technique is applied for a three year observational period over the Jornada Experimental Range in New Mexico between 2001 and 2003. The study outcome shows spatially coherent regions where broadband emissivities decrease by over 1%. For the same regions, no trend is discernible with NDVI analyses. These coherent regions appear to correspond with decreased vegetation densities, suggesting that observing thermal band emissivities can be very helpful for monitoring land cover change over sparsely vegetated landscapes.

***Keywords:*** aster, emissivity, jornada

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# Estimating evapotranspiration for arid regions using remotely sensed data

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Classified high resolution multispectral video imagery (pixel size of 0.16 m) and ground reflectance measurements were used to estimate and map the energy balance terms, namely, net radiation (Rn), sensible heat flux (H), and ground heat flux (G) in an arid (desert) environment. The data were gathered during summer, 1994, at Goshute valley, Nevada, USA. Energy balance fluxes were measured at 10 sites using Bowen ratio and eddy correlation systems. Ground-based and airborne remotely sensed data were taken at the same time during the experiment. Supervised classification was conducted on each high resolution image of the sites to estimate the proportions of each surface (i.e. playa, organic soils, Greasewood, Sagebrush, and Shadescale). Surface temperature was mapped for each site using airborne thermal imagery (pixel size of 0.30 m) from an infrared thermal scanner. Rn was estimated using the P/T ratio suggested by Jackson (1994). H was modeled using vegetation parameters extracted from the multispectral video imagery. The values of G/Rn were exponentially related to the soil adjusted vegetation index (SAVI). Maps of energy fluxes were produced based on the class distribution at each arid (desert) site. The good agreement between the observed and estimated surface energy fluxes suggests that maps of surface energy fluxes for sparsely vegetated arid regions could be produced at low cost using airborne sensors and used for input and verification of mesoscale atmospheric and energy balance models.

***Keywords:*** arid, remote sensing, energy

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# A comparative approach for the retrieval of leaf area index from earth observation data

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The use of Earth Observation (EO) data to retrieve biophysical variables of land surface such as the Leaf Area Index (LAI) has been proven to be useful in many operative tools to repetitively gather information at spatial and temporal resolution suitable for hydrological applications. In the last years, the diverse capabilities of airborne and satellite remote sensing imagery have been extensively exploited and several approaches have been proposed to estimate the LAI with different accuracy at scales ranging from individual plots to large areas. So far, empirical approaches based on vegetation indices (VIs) and alternative approaches based on inversion of radiative transfer models of vegetation have been successfully applied using both airborne and satellite data. The techniques and the setting-up of the algorithms to extract information can vary depending on the type and quality of remote sensing data available and according to the user requirements in terms of delivery time and accuracy of the LAI maps. The objective of this work is to evaluate the benefit of using high dimensionality (both in the spectral and the angular domains) of EO imagery and different levels of complexity in the methodologies for estimating LAI. In this context, CHRIS/Proba data, acquired during the SPARC 2003 campaign, have been exploited to evaluate the effectiveness, in terms of accuracy and computational complexity, for retrieving the LAI. The work was carried out on the one hand by means of empirical relationships, such as the simple CLAIR model proposed by Clevers (1989) and based on the Weighted Differences Vegetation Index (WDVI), and on the other hand by means of mathematical inversion of the combined radiative transfer models PROSPECT and SAILH. Preliminary results have shown that the inversion process is highly demanding in terms of computational time and complexity. Moreover, the accuracy and the stability of the inversion technique is affected by the accuracy of data correction. However, the accuracy of the LAI estimation for the two approaches resulted to be comparable. Thus the empirical approach seems to be as good as the model inversion approach but to perform better in terms of computing power and simplicity. On the other hand, the approach based on model inversion seems to be useful for the estimation of other vegetation parameters such as the canopy structure and soil reflectance. A feasibility analysis of the implementation of the two approaches is discussed in view of a definition of an operative routine for the application of EO data in water management.

***Keywords:*** lai estimation, radiative transfer model, water management

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# Comparison of satellite derived snow products with ground observations over the mountainous terrain in TURKEY

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Turkey can be described as a country with abundant snow cover on mountainous regions on the eastern part of the country where Euphrates River basin is located. This basin is largely fed from snow precipitation whereby nearly two-thirds occur in winter and may remain in the form of snow for half of the year. The concentration of discharge mainly from snowmelt during spring and early summer months causes not only extensive flooding, inundating large areas, but also the loss of much needed water required for irrigation and power generation purposes during the summer season. Accordingly, modeling of snow-covered area in the mountainous regions of Eastern Turkey, as being one of the major headwaters of EuphratesTigris basin, has significant importance in order to forecast snowmelt discharge especially for energy production, flood control, irrigation and reservoir operation optimization. There is not yet a well established operational snow monitoring system. Therefore comparison of satellite derived snow maps and snow course ground measurements is vital for improvement of the existing mapping algorithms. Distributed snow models require the following spatially distributed parameters: snow-covered area, grain size, albedo, snow water equivalent, snow temperature profile and meteorological conditions, including radiation. The paper present here the critical issues for the comparison of the parameters that optical remote sensing can deliver (snow-covered area and albedo as MODIS products) with snow course and lately established automated weather observation stations (AWOS). The snow cover area validation was performed by Tekeli et al. (2005) using the moderate-resolution imaging spectroradiometer (MODIS) images during the accumulation and ablation periods of 2002-2003 water year and as well during the winter period of 2003-2004. Over the ablation period of 2004, daily snow albedo values retrieved from MODIS Terra were compared with ground-based albedo measurements (Tekeli et al., 2006). The discussion on comparison of MODIS snow and albedo images with ground data is presented in this study. The use of EO satellite images and products in hydrological application for mountainous terrain, where scaricity of the ground data is the main problem, is discussed. The snowmelt runoff hydrograph shape is affected by the elevation bias of the MODIS snow-mapping algorithms, underestimate the area in lower altitudes and over estimate the area in the higher elevation regions. This difficultly may be overcome in further studies determining the fractional snow covered area using multi-sensor data (SEVIRI, NOAA , MODIS as optical and AMSR-E, SSM/I as microwave), which should be the basic task for future studies as satellite Application Facilities on hydrology (H-SAF) project, which is financially supported by EUMETSAT. The first findings of H-SAF project are discussed in this paper.

***Keywords:*** snowcover, satellitedata, mountain

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# Spatial and seasonal patterns of diurnal differences in ERS Scatterometer soil moisture data in the Volta Basin, West Africa

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Soil moisture is the key variable in the hydrological cycle. In the Volta Basin, West Africa where rainfed agriculture forms the main source of income for the majority of the population productivity relies on available soil moisture or green water. Progress there will depend on good management of green water, and will be strongly based on monitoring results. Data scarcity in these remote regions emphasizes the necessity for remotely sensed soil moisture estimates that allow for more stable monitoring techniques. New soil moisture satellites such as SMOS and MetOp provide improved technical means for soil moisture monitoring. In preparation for these new sensors, historical ERS Scatterometer data over the Volta Basin provided by the Global Soil Moisture Archive have been analyzed. The basin area is subject to a natural 1000 km long moisture gradient from the southern tropical rain forest to the northern sahelian grass savanna. Vegetation, rainfall, and soil moisture fields generated from ERS Scatterometer data show the same this north-south gradient. Our study investigated an anomaly in the day and night overpass data. Maps generated from the difference between day and night overpass data reveal significant spatial and seasonal patterns that differ from the moisture gradient driven by the local climatology. Spatial patterns emerge over dense rainforest, and sahelian savanna that show low diurnal differences in the ERS Scatterometer dB signal. Over central, and forested savanna areas high diurnal differences prevail. In addition the detected patterns shift temporally in accordance with the transition from dry to wet seasons. Regional and seasonal deviations from the natural moisture gradient are identified. Patterns suggest a close link between vegetation and satellite signals that remains to be investigated in more detail.

***Keywords:*** soil moisture, remote sensing, west africa

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# Contribution of earth observation data supplied by the new satellite sensors to flood risk mapping

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The risk of flooding due to runoff is a major concern in many areas around the globe and especially in Romania. In the latest years river flooding and accompanying landslides, occurred quit frequently in Romania, some of which isolated, others-affecting wide areas of the country's territory. An important contribution of Earth Observation (EO) derived information in the topic of managing flooding connected phenomena could be envisaged at the level of mapping aspects. The paper presents the specific methods, developed in the framework of the NATO Science for Peace project Monitoring of extreme flood events in Romania and Hungary using EO data for deriving satellite-based applications and products for flood risk mapping. NOAA/AVHRR satellite data, microwave data from U.S. DMSP and Quikscat and follow-on satellites, and the high resolution images supplied by the orbital platforms (SPOT, IRS, LANDSAT7, RADARSAT, QUIKSCAT, EOS-AM TERRA and EOSPM AQUA), substantially contributed to flood related products. A series of specific processing operations for the images were performed, using the ERDAS Imagine software: geometric correction and geo-referencing in the UTM or STEREO 70 map projection system, image improvement, statistic analyses etc. The information provided by the new satellite sensors is of a higher quality than previously possible, and especially given the need for frequent repeat coverage while floods are underway. The data issues from the optical and radar images have been used for the elaboration of certain spatial products necessary to monitor flooding: hydrographic network, water accumulation, size of flood-prone area, land cover/land use features, mask of flooded areas, multi-temporal maps of the flood dynamics and hazard maps with the extent of the flooded areas and the affected zones, etc. In order to obtain high-level thematic products the data extracted from the EO images have been integrated with other non-space ancillary data and hydrologic/hydraulic models outputs. This approach may be used in different phases of establishing the sensitive areas such as: the management of the database - built up from the ensemble of the spatially geo-referenced information; the elaboration of the risk indices from morpho-hydrographical, meteorological and hydrological data; the interfacing with the models in order to improve their compatibility with input data; recovery of results and the possibility to work out scenarios; presentation of results as synthesis maps easy to access and interpret, additionally adequate to be combined with other information layouts resulted from the GIS database. The distribution of the satellite-based spatial data to different end-users is provided by an Internet Web-based network. The presented applications will contribute to preventive consideration of the extreme flood events by planning more judiciously land-use development, by elaborating plans for food mitigation, including infrastructure construction in the flood-prone areas and by optimization of the flood - related spatial information distribution facilities to end users.

***Keywords:*** flood, satellite, mapping

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# Evaluating actual evapotranspiration by means of Multi-Platform remote sensing data: a case study in Sicily

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During the last the two decades, the scientific community developed detailed mathematical models for simulating land surface energy fluxes and crop evapotranspiration rates by means of a energy balance approach. These models can be applied in large areas and with a spatial distributed approach using surface brightness temperature and some ancillary data retrieved from satellite/airborne remote sensed imagery. In this paper a district scale application in combination with multispectral satellite and airborne data has been carried out to test the potentialities of two different energy balance models to estimate evapotranspiration fluxes from a set of typical Mediterranean crops (wine, olive, citrus). The impact of different spatial resolutions on models-derived fluxes has been investigated in order to understand the roles and the main conceptual differences between the two models which respectively use a single-layer (SEBAL) and a two-layer(TSM) schematisation.

***Keywords:*** actual evapotranspiration, remote sensing, surface energy balance

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**HS3007** **Oral Presentation** **4389**

# Change Detection and Hydrological Implication in Lower Ogun Floodplain, SW Nigeria

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Information on land use and land cover forms the basis on which the past and present human interaction with and their impacts on the natural resources and the environment can be understood. Land use and land cover are linked to hydro-climatic fluxes in complex ways. In addition to being a driver of Earth system processes affecting climate, the carbon cycle and the ecosystem, land use and land cover change has a significant impact on the feedback of the hydro- climatic processes on the surface hydrology. The need for proper understanding of the immediate and future consequences of the processes taking place in the ecologically fragile coastal floodplain of lower Ogun river basin necessitated this research, especially as the basin hosts the northern and north eastern part of the ever sprawling megalopolis of Lagos. Panchromatic aerial photography and landsat multi-spectral satellite imagery using the visible and near infrared were used to assess the land use land cover of the lower Ogun basin as it was in 1965 and 2005 respectively. Using the image elements such as colour, association, site, size, and pattern as well as the local knowledge of the environment, the landuse and land cover of the lower Ogun river basin for both dates were interpreted and vectorized using on-screen digitization in the multi source image data. Two major analyses were carried out on GIS to accomplish the landuse change detection. These are (I) area calculation of the landuse and landcover for the two scenarios (II) overlay of the generated landuse of two different years for change detection. While the first procedure provides aerial analysis that highlights the trend and rate of land use changes over the period of analysis (1965-2004), the second provides information in matrix format on specific (point by point) change detection procedure that generate the nature location and magnitude of changes. The change matrix was used to assess the extent of degradation and decreasing functional role of the flood plain as well as well as its consequence on human activities and habitation. This was achieved by combining field observation with different types of land use and land cover change and their correlation with the occurrence of land processes. The statistic land cover of the lower Ogun flood plain in 1965 was 38.001x 106 ha. The ecologically fragile wetland covers 31.338 x 106 ha (82.45 %). This decreases to 13x106 ha. (36.31%) in 2005 at an average rate of 0.438 x 106 ha .per annum. Conversion of the flood plain wetland to built up area especially for the residential purpose constitute about (40%) of the loss. Increasing flooding and erosion, sedimentation, loss of flora, fauna as well as valuable aquatic creatures were identified as major implications of the losses of the changes. Although agricultural activities and production recorded some appreciable increase on the flood plain the massive expansion of built up area further limit the use of the floodplain for agricultural purpose and created slum environment along the flood plain. A conservation management approach is proposed to redirect present trend of unsustainable and disaster prone development approach in order to rescue the fragile ecosystem of the lower Ogun from complete destruction.

***Keywords:*** remotesensing, gis, floodplainchangedetection

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**HS3007** **Oral Presentation** **4390**

# Mapping land degradation and forest resource loss from fused LANDSAT TM and NIGERIASAT-1 images in some parts of the southwest coast of Nigeria

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Abstract The coastal environment in Nigeria is facing increasing pressure which is reducing the volume of ecological goods and services it can deliver. evidences of increased influence of natural and anthropogenic drivers of environmental change is all pervading, leading to rapid transition of ?good? coastal lands to degraded wastelands. Increased perturbation of formerly undisturbed forests is now a common occurrence. The diversity and characteristics of forests can be an indication of its richness in biodiversity and potentials to foster national economic development. This research work quantifies forest resources and describes its spatial pattern, configuration and arrangement in the midst of changing environmental and human scenario. The methodological framework encompasses the integration of remote sensing, GIS and landscape ecology techniques to analyze NigeriaSat-1 and Landsat TM imageries for some parts of southwest coast of Nigeria. Selected bands of Landsat TM imagery were fused with selected bands of NigeriaSat-1 imagery to generate a new image that combines the superior spatial resolution of Landsat TM and the vegetation discrimination advantage of the NigeriaSat-1 image. NDVI and other band combinations describing vegetation and forest richness are derived from the hybrid image. Image classification is carried out and derivation of indices of degradation and landscape fragmentation is carried out within a GIS. The results of the analysis give pointer to the level of anthropogenic influences on environmental change, reflect the state and fragmentation of the forests, describe its richness in biodiversity, and suggest tourism potentials and conservation strategies for sustainable development in the study area.

***Keywords:*** land degradation, image fusion, nigeriasat 1

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# Application of GIS in Landuse Study in Osse-Ossiomo River Basin, Nigeria

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The Osse-Ossiomo River Basin of Edo State, Nigeria was investigated in terms of landuse changes from 1970 to 2000 using the Geographic Information System (GIS). The landuse classes investigated include built-up areas, other settlements, vegetation, agriculture, transportation network and water bodies. The topographic map of 1965, Landsat ETM images of 1987 and 2000 were used to investigate these changes. The AutoCAD 2000, Archview GIS 3.2 and Erdas Imagine 7.1 softwares were also used. Results obtained show that landuse in Osse-Ossiomo River Basin has changed between 1970 and 2000. The built-up area is principally Benin City. As at 1965, the areal extent was about 25 sq km or 2500 hectares, which increased to 645 sq km or 64500 hectares in 1987 and 804 sq km or 80400 hectares by 2000. The other settlements which included very many villages of different sizes (ranging from 5km to 10km) have merged with Benin City Metropolis. The number of roads has increased and the original tropical rainforest vegetation has changed to a more open Guinea Savanna vegetation type. The very many rubber plantations that existed in the 1970s have been drastically converted to built-up areas and farm lands. These changes are occasioned by rapid population growth and have impacted seriously on the basin hydrology, leading to turbid water, increased flood magnitudes and serious gullying. Appropriate landuse laws are recommended to check the eventual destruction of the natural ecosystem and the dynamic modification of the basin hydrology.

***Keywords:*** gis, landuse, changes

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**HS3007** **Oral Presentation** **4392**

# Evaluating urbanization and its impacts on local hydrologically environmental change in Shijiazhuang, China

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Urbanization is an important aspect of human activities in changing the environmental system. During the process of urbanization, the reflectivity of land surface is violently changed when large amount of natural or agricultural lands are converted to built-up surfaces. These changes strongly affect the atmosphere/land surface energy exchange and local weather and micro-climate regimes. As for the context of hydrological cycle, most of the processes between land and atmosphere, surface and subsurface are completely influenced by urbanization. In recent 2 decades, China experienced a rapid economic development. Accompanying with the significant growth in economy, the landscape of China is largely changed due to urbanization. In North China Plain, where water shortage is becoming the most important environmental problem, the change associated with urbanization accelerated the degradation of vulnerable water resources system (Shen et al. 2005). Together with detecting urban expansion and associated land cover/use change, using thermal- infrared remote sensing data can also help to analysis the thermal environmental change since remote sensing can provide frequent observations on the land surface by the identical instruments. Here, we will illustrate our recent work of the urbanization in Shijiazhuang region, China and its impacts on local micro-climatic and hydrological environments change using the remote sensing data and hydrological model. Firstly, a pair of Landsat TM images of the study area in 1987 and 2001 is used for detecting urban expansion and associated land cover/use change. Then, the change in thermal environment is analyzed by using the thermal infrared remote sensing data. In order to evaluate the impacts on hydrological cycle, we calculated and compared the water balances in 1985-1989 and 1999-2003. The results suggest the change in water balance due to urbanization is significant. The connections between micro-climatic change and water balance change are discussed too. Besides the physical environmental change, a range of long-term water quality records are employed to illustrate the deterioration of hydrological environments in chemical aspect. The detailed analysis and discussions will be introduced in the full paper. We hope these analyses help understanding the mechanism of local environmental change due to urbanization.

***Keywords:*** urbanization, hudrologicalchange, shijiazhuang

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# Sequential assimilation of microwave remote sensing information in flood inundation models

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Model developments are increasingly shaped by the societal demand for integrated watershed models. The individual components of a forecasting system (i.e. rainfall-runoff, flood inundation and damage assessment) all benefit from the availability of spatially distributed Earth Observation data. The hydrologically and hydraulically relevant variables (e.g. soil moisture, flood extent) and basin characteristics (e.g. topography, surface roughness) that can be obtained from radar remote sensing have a large potential for improving hydrological and hydraulic models. To achieve a time continuity that is crucial in monitoring applications but cannot be obtained by the sole use of remote sensing observations, the information extracted from the discrete earth observation data should be used as parametric input and as time-varying state and flux in coupled hydrological and hydraulic models. By obtaining systematic spatially distributed information over river basins and by integrating this information routinely in flood forecasting systems, the development of a Space-borne Solution, which may replace or supplement the use of ground data, shows high potential of becoming an important asset for flood management applications, especially in ungauged catchments. Assimilation of remotely sensed soil moisture in hydrological models, although not yet used operationally, has given promising results in several studies. However, methodologies to assimilate remote sensing data in flood inundation models still need further development. This presentation focuses on the assimilation of remotely sensed inundation depths into a 1D flood inundation model (HEC-RAS). Through the fusion of radar imagery and high precision digital elevation models, inundation depths can be extracted from remote sensing observations. The water surface line simulated by the hydraulic model is updated whenever a remote sensing estimation of water stage becomes available. The usefulness of the metholodolgy is illustrated by a well-documented flood event of the Alzette River (Grand-Duchy of Luxembourg). The flood area was monitored by two radar remote sensing images acquired at distinctive moments of the flood. It will be shown that for this case study the assimilation of remotely sensed observations of river stage lead to a more robust forecast of river inundation, thereby demonstrating the often-debated capability of SAR (Synthetic Aperture Radar) to aid in the calibration and updating of hydraulic models. The ongoing research focuses on the development of a data assimilation system for a coupled hydrological/hydraulic model, taking into account a variety of remote sensing and in-situ observed data sets.

***Keywords:*** sar, modelling, assimilation

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS3007** **Oral Presentation** **4394**

# Soil moisture retrieval over the Mackenzie River Basin using AMSR-E 6.9 GHZ brightness temperature

***Mrs. Naira Chaouch***
*civil ingeneering teledetectcion, hydrology IAHS*

***Marouane Temimi, Ramata Magagi, Robert Leconte***

An approach is proposed for estimating soil moisture and monitoring its change using AMSR-E 6.9 GHz passive microwave data over a large northern basin. Study sites located within the Mackenzie River Basin, northwest Canada, have been selected for the analysis. The lack of in-situ direct measurements is a major issue to be resolved to reach the aim of this work. Therefore, external ancillary data were used in addition to, and as a surrogate for, available measurements. Meteorological data for the study area were imported from the North American Regional Reanalyses (NARR) database. Leaf area index (LAI) values were retrieved from MODIS leaf area index data to take into account the spatial variation of the vegetation. The methodology is based on inverting the dual polarizations - model. The values of the geophysical parameters, h, , and soil moisture were adjusted iteratively to minimize the sum of the squared difference between observed and computed brightness temperatures. A sequential method based on the sensitivity of the signal to those parameters was applied to calibrate the model. The roughness parameter was determined from AMSR-E data acquired under dry (i.e. low soil wetness) watershed conditions. The vegetation parameters were estimated under wet conditions. The method was first applied in the Peace-Athabasca Delta area, located in the south-east portion of the Mackenzie basin and the estimated geophysical parameters were then used to retrieve soil moisture estimates for regions having similar LAI values. This allows validating the method in other areas and to generate maps of surface soil moisture. It was also noted that the variations of the estimated soil moisture compared well with soil moisture imported from NARR data. A satisfactory agreement was obtained between soil moisture, precipitation and temperature. It can be concluded that the sequential method is adequate to retrieve soil moisture variation when in situ observations are scarce.

***Keywords:*** hydrology, microwave radiometry, soil moisture

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**HS3007** **Oral Presentation** **4395**

# Probabilistic estimation of precipitation combining geostationary and TRMM satellite data

***Dr. Carlo De Marchi***
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***Aris P. Georgakakos, Christa Peters-Lidard***

Environmental satellites represent an economic and easily accessible monitoring means for a plethora of environmental variables, the most important of which is arguably precipitation. While precipitation can also be measured by conventional rain gages and radar, in most world regions, satellites provide the only reliable and sustainable monitoring system. This paper presents a methodology for estimating precipitation using information from the satellite-borne precipitation radar of the Tropical Rainfall Measurement Mission (TRMM). The methodology combines the precise, but infrequent, TRMM data with the infrared (IR) and visible (VIS) images continuously produced by geostationary satellites to provide precipitation estimates at a variety of temporal and spatial scales. The method is based on detecting IR patterns associated with convective storms and characterizing their evolution phases. Precipitation rates are then estimated for each phase based on IR, VIS, and terrain information. This approach improves the integration of TRMM precipitation rates and IR/VIS data by differentiating major storms from smaller events and noise, and by separating the distinct precipitation regimes associated with each storm phase. Further, the methodology explicitly quantifies the uncertainty of the precipitation estimates by computing their full probability distributions instead of just single optimal values. Temporal and spatial autocorrelation of precipitation are fully accounted for by using spatially optimal estimator methods (kriging), allowing to correctly assess precipitation uncertainty over different spatial and temporal scales. This approach is tested in the Lake Victoria basin over the period 1996-1998 against precipitation data from more than one hundred rain gages representing a variety of precipitation regimes. The precipitation estimates were shown to exhibit much lower bias and better correlation with ground data than commonly used methods. Furthermore, the approach reliably reproduced the variability of precipitation over a range of temporal and spatial scales.

***Keywords:*** precipitation uncertainty, convective storms, lake victoria

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**HS3007** **Oral Presentation** **4396**

# Validating Gravimetry Measurements in Canada with a Continental Scale Hydrological Database

***Prof. Caterina Valeo***
*ICRS ICRS IAHS*

***Alex Braun, Georgia Fotopoulos***

Water balance simulation is a basic but essential part of large-scale hydrological modelling. Gravity data provided by GRACE presents an alternative to insitu data for verifying and supporting hydrological and glacier mass balance studies on a continental scale. This work attempts to determine the utility of GRACE data for use in large-scale mass balance calculations by developing a hydrological database that supports hydrological mass balance calculations for major drainage basins within Canada. The development of the database is constrained by the spatial and temporal scale of the GRACE data. A variety of observed hydrological data including snow water equivalent, discharge, soil moisture and other elements important in hydrological mass balance modelling are collected for 2003, 2004 and 2005 for the three primary drainage regions of Canada. GRACE estimates are also assembled for this period and a statistical analysis is conducted to determine the correlation between GRACE estimates and mass balance simulations of changes in water storage for the drainage regions.

***Keywords:*** gravimetry, hydrology, continental

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**HS3007** **Oral Presentation** **4397**

# Satellite Observations of the Land Surface Emissivity in the 8 - 12 Micrometer Window: Effect of Soil Moisture

***Dr. Thomas Schmugge***
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***Kenta Ogawa, Patricia De Rosnay***

The land surface emissivity is often overlooked when considering surface properties that effect the energy balance. However, knowledge of the emissivity in the window region is important for determining the longwave radiation balance and it subsequent effect on surface temperature . The longwave radiation balance is strongly affected by the difference between the temperature of the emitting surface and the sky brightness temperature, this difference will be the greatest in the window region. The emissivity variability is typically greatest in arid regions where the exposed soil and rock surfaces display the widest range of emissivity. For example the dune regions of the Sahara have emissivities of 0.7 or less in the 8 to 9 micrometer wavelength region due to the quartz sands of the region. The multispectral thermal infrared data obtained from the Advanced Spaceborne Thermal Emission and Reflection (ASTER) radiometer and MODerate resolution Imaging Spectrometer (MODIS) sensor on NASA's Terra satellite have been shown to be of good quality and provide a unique new tool for studying the emissivity of the land surface. Two years of monthly composites of thermal infrared (TIR) surface emissivity data from the MODerate resolution Imaging Spectrometer (MODIS) sensor on NASAs Terra satellite were analysed for temporal variations over North Africa and the Arabian peninsula. It was found that the emissivity of the 8.6 micrometer band (MODIS band 29) increased by about 0.1 each July/August in southwestern Sahara (17 N, 1.5W). To understand this increase, the emissivity variation was compared with the normalized difference vegetation index (ndvi) also derived from MODIS and with soil moisture estimates from the Advanced Microwave Scanning Radiometer (AMSR-E) microwave sensor on NASAs Aqua satellite in eight regions. No correspondence was found with ndvi in these areas, however the TIR emissivity increase was found to be qualitatively correlated with an increase in AMSR derived soil moisture in some regions. This increase in TIR emissivity with soil moisture is in agreement with the lab measurements. The soil moisture dependence was studied further with ground data from the African Monsoon Multidisciplinary Analysis site in Mali (15 - 18 N and 1 - 2 W). This site will be ground validation site for the Soil Moisture and Ocean Salinity (SMOS) satellite to be launched in 2007.

***Keywords:*** thermal infrared, emissivity, soil moisture

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**HS3007** **Oral Presentation** **4398**

# Mapping and monitoring wetlands using airborne multispectral imagery

***Dr. Christopher Neale***
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***Dennis Wenger***

Wetland areas in the semi-arid west of the United States play an important eco-hydrological role. The size, location and function of wetlands are affected by numerous factors such as variations in water availability, water quality, geomorphic characteristics and anthropogenic factors such as runoff from irrigation systems, or discharge of urban effluents. Typically, wetland vegetation occurs in patches of variable size, requiring high resolution imagery to accurately identify distribution and extent of the different vegetation species. Airborne multispectral digital imaging offers several advantages, including cost-effectiveness and ability to resolve wetland features ranging in size from a few meters to thousands of hectares. This paper describes monitoring and mapping of wetland areas within the Great Salt Lake Ecosystem using high resolution multispectral imagery (1-meter pixels). Innovative aspects of image acquisition and processing techniques will be described. Image classification was based on supervised signature extraction supported by ground truth field data. An error analysis was conducted using independent ground truth data, and the resulting classification accuracy for the final wetland resource map was greater than 90%.

***Keywords:*** wetlands, multispectral, classification

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**HS3007** **Oral Presentation** **4399**

# Study of vegetation evolution in Sicily by means of time series analysis of remote sensing and climatic data

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***Capodici Fulvio, La Loggia Goffredo, Maltese Antonino, Noto Leonardo V., Bono Enrico***

During last ten years several studies confirmed that desertification phenomena are affecting southern Mediterranean areas. In some of these areas, the soil is degrading and, as a consequence, the productivity is compromised. The causes of this phenomenon are both natural (change in rainfall regime) and human (deforestations, agricultural activities) induced. One of the effects of the desertification is a modification of the vegetation cover and biomass. The aim our research is to investigate and monitor the evolution of this phenomenon in Sicily using remote sensing techniques. To do this, a dataset of NOAA-AVHRR multispectral images, acquired monthly from 1988 to 2005, have been processed. The satellite images were geocorrected, calibrated and corrected from the atmospheric influence and then the NDVI vegetation index distribution has been calculated from each image. A principal component analysis (PCA) has been applied on the NDVI time series in order to study the main characteristics of vegetation distribution during the period under investigation (first component) and the seasonal and interannual fluctuations (higher order components). A comparison with monthly rainfall distribution, measured from the gauge stations of Regional Hydrographic Office, has been also performed in order to investigate the correlation between the rainfall distribution temporal trends and the NDVI fluctuations. Results confirm the strong correlation (with a time lag) between climate oscillations (drought periods and rainy periods) and the vegetation answer in term of NDVI.

***Keywords:*** time series analysis, vegetation index, desertification

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**HS3007** **Poster presentation** **4400**

# Early warning system for landslides. The combined usage of Geoindicators and remote sensing

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*Geoecology engineer IAHS*

As every person in this world knows that landslides are very dangerous and if not to predict the landslide in time it could become a real danger for local citizens and destroy a lot of local houses. For predicting the landslide danger for every geological structure government and geological organizations uses the geoindicators which makes the monitoring on sites and tells scientist that "in ... place ... become a dangerous situation " or "The earth movement was made in ... place", all that is done with help of Geological indicators and some factors for current geological earth structure. The methods of measurements are done with help of special equipment on site, which transfers information with GPS or mail , or etc.. methods of information transfer. And also every scientist in the world knows the helpful usage of Remote sensing , that the whole world uses the Black bird satellites or other which makes the images of the surface of the world, and can see the changes which happened in the ... place that it scanned. The changes, and the difference of places we can see on different light spectra's , also we can see with help of remote sensing the changes in the earth which happened in 4-5 hours. The method I want to offer is the combined usage of Geoindicators(Humidity of ground, quantity of deposits lately, shifts in ground and other) and Remote sensing – monitoring from the satellites so we can have a one center in the world – which has the databases with all geoindicators of the structure of the ground of the world. Some people can say that's its impossible to watch after the ground from satellites , they say that all the work must be done in the current place, but we have never tried to do such work , we don't have an experience . Can you imagine how much of money will b saved if to use the current technology - Geoindicators and Remote sensing. The greatest improvement in this case will be that every government don't need to buy a new satellites , or some expensive equipment - the government just need to pay some fee every month (which will be much cheaper than to buy expensive equipment) . The information center which will be only one in the earth will process all the date from satellites and will compare with geoindicators and will tell to us where are the dangerous places and will show the model what will happen , and if its needed to evacuate local citizens .

***Keywords:*** landslides, geoindicators

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HS3007** **Poster presentation** **4401**

# Remoted sensing monitoring of long-term regime of the Pamirs glaciation

***Prof. Vladimir Konovalov***
*Commission of Cryospheric Sciences institute of geography IAHS*

Unexpected and rapid advances of glaciers are the most known and dangerous demonstrations of mountainous glaciers regime. The increment of glaciers length varies in Pamirs from several tenths of meters till 4-5 kilometers during such events. Photo-survey of high mountain areas from satellite and orbital apparatus have done for Pamirs glaciers from 1972 till 1999 using space images obtained from Russian space systems Resurs-F, Salut and Mir. Eighty temporal cuts of monitoring Pamirs glaciers having spatial resolution 5-10 meters were obtained during this time. The results of remotely sensed monitoring of glacier surges presented in Catalog of surging glaciers within Pamirs and in other publications. Started from 2001 the routine monitoring of glaciers state was included into the Uragan program performing on Russian segment of International Space Station. Once more important source of information on current state of Pamirs glaciers are digital images obtained from LANDSAT and TERRA satellites in frameworks of the international project GLIMS launched in 2000. The listed volume of space information was used for description glacier surges during of 1992-2006 in the Pamirs river basins. The period between surges was defined for several glaciers. Synchronism of surges for the most active glaciers located on southern slopes of the Lenins Peak was revealed also. The same phenomenon have take place there in 70-thies. Grouping of surged glaciers on activity rating and data on glaciers area within those groups in 1966, 1980 and 2000 were used for estimation effect of surges on general trend of shortage Pamirs glaciers. It was revealed that surges have local influence on glaciers size and does not impact essentially on background trend of glaciers evolution within of large river basins. This long term trend characterizes stable degradation of Pamir glaciers. Average velocity of this process increased in 1980-2000 in comparison with previous time interval.

***Keywords:*** remote sensing monitoring, glacier surges in pamirs, glaciers evolution

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**HS3007** **Poster presentation** **4402**

# Dynamics of water resources and land use in Mainstream of the Tarim River

***Dr. Yan Dou***
*HS3006 Water and water security in developing countries IAHS*

Based on the topographic map data and MSSATM data of the Tarim River in the 1960sAthe 1970sAthe 1990s and the 2000, this paper calculates the changing amplitude, changing rate and integrated dynamic degree of land use and land coverGand analyzes the relationship between the land use changes and the dynamics of runoff and groundwater resource and their exploitation . The results shows that: (1) Farmland area expanded distinctly 6.35~104hm2 , and most of them are dryland. Woodland are decreased fast, in the near 40 years decreased 48.85~104hm2,and also grassland;(2)the aspect of water resource, the differences of water quantity in the upper and middle reaches to that in low reaches are mall, but in the 2000 years the differences are bigger than ever before. The water contradictory problem becoming serious, the decreased of water flow makes desertification aggravate in downstream; (3) Groundwater exploitation develops progressively, and the density of water-supply wells increases remarkably, and the groundwater table drops obviously.

***Keywords:*** land use, water resource, dynamics

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**HS3007** **Poster presentation** **4403**

# Modis-Derived estimates of the regional evapotranspiration based on energy balance in Huai River Basin

***Mr. Ronglin Tang***
*Wuhan Wuhan University IAHS*

Evapotranspiration is a primary component in hydorlogical cycly, hydroclimatory and meteorology. The spatial distribution of the regional Modis-derived evapotranspiration based on surface energy balance and DEM(Digital Elevation Model) and limited weather data is presented in this paper. MODIS data include Land Surface Temperature(LST),16-day Albedo, 16-day Normalized Vegetation Index(NDVI). The spatial resolution is nominally 1km. A clear sky day was selected in April in 2001 in the Huai River Basin in China. The net sun radiation, soil heat flux, sensible heat flux, latent heat flux in the study area are calculated respectively and the spatial distribution maps and histograms of the aforementioned four fluxes are outlined. Considering the remote-sensed sun radiation is higher than actual sun radiation, two calibration factors are introduced with the measured evapotranspiration and the results are validated when the instantaneous evapotranspiration is converted to the diurnal evapotranspiration. In the process of calibration and validation, the mean value of 3 3 pixels including the observed point value is calculated as the pixel value to fit the remotely sensed pixel value so as to improve the representation of the observed point data. At the end of this paper, some common existing concerns are considered and analysed and some suggestions are put forward.

***Keywords:*** modisdata surfaceenergybalanc, evapotranspiration, calibrationfactorshuairiver

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**HW1001** **4404 - 4446**

## Workshop
## Isotope Tracing of Water Balance, Hydrodynamics and Hydrological Processes (Sponsor ICT)

**Convener :** Prof. John Gibson

Isotopic and geochemical tracers are increasingly being applied at the watershed to basin scale to study water cycling processes including evaluation of runoff generation mechanisms, flowpaths, water residence times, water yields and partitioning of water sources and sinks. This workshop explores the application of tracers as an integrated approach for improving the understanding of hydrology in ungauged or under-monitored areas, and as a fundamental contribution to the challenge of "Prediction in Ungauged Basins (PUB). Discussion will include application of isotope tracers for the evaluation of hydrological and hydro-climatic models and the organization of regional, national and global networks that serve to build scientific capacity for tracer-based research.

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**HW1001** **Oral Presentation** **4404**

# Identifying dominant processes of groundwater recharge using characteristical patterns of CFCs and SF6 in conjunction with analyses of stable isotopes 180 and 2H

***Dr. Christoph Kuells***
*Institute of Hydrology University of Freiburg IAHS*

***Marc Haering***

Groundwater recharge in semi-arid and arid regions results from complex interactions between runoff-generation, transmission losses and storage capacity in the alluvial aquifer. A proper understanding of dominant recharge processes usually demands a longtime monitoring within the investigated catchment. In this study we propose an integrated approach for ungauged and under-monitored regions, using characteristical patterns of CFCs and SF6 in conjunction with analyses of stable isotopes 18O and 2H. The chemically inert noble gases, as well as some anthropogenic produced gases are increasingly being used for reconstruction of groundwater transport processes. Within the project WADE FloodWater Recharge of Alluvial Aquifers in Dryland Environments (GOCE-CT-2003-506680-WADE) the alluvial aquifers of Rio Andarax Basin, Spain (Almeria) were investigated by evaluating characteristical patterns of CFCs and SF6 together with information gained from stable isotopes 18O and 2H. Groundwater of the different aquifers below and besides the ephemeral stream was characterized in terms of origin, recharge altitude, mean residence times and dominant processes. Analyses of stable isotopes reveal an altitude shift for most groundwaters, meaning that rainfall occurs at elevations higher than the actual sampling point. This shift is most pronounced for groundwater in the alluvium below the ephemeral stream. The temporal behavior of stable isotopes gives evidence that the shallow detritic aquifer below the river bed is recharged by floods. CFC-analyses determine three major ranges of mean residence times in groundwater of Rio Andarx basin. Young groundwater with mean residence times around 15 years are found in the active channel of Rio Andarax. Groundwaters originating in Pre-Cenozoic basement aquifers shows mean residence times around 30 years. Finally a groundwater with no trace of recent recharge is found in a molasse aquifer. CFC-analyses determine groundwater with intermediate and long mean residence times to be mixing waters composed of young and old water. Groundwaters from aquifers below the river bed of Rio Andarax points to a piston-type flow distribution, indicating focused direct recharge. For some samples, analyses of SF6 reveal a potential presence of high excess air concentrations in fissured aquifers and aquifers with rapid, focused recharge. The measurements of CFC-11, CFC-12, CFC-113 and SF6 concentrations in groundwater from different aquifers within the under-monitored Rio Andarax basin demonstrate that a determination of mean residence times in groundwater bodies is possible with a relatively high precision. If all CFCs and SF6 are measured, additional information on dominant processes in aquifers, such as presence of excess air, detection of anaerobic environments and identification of relevant mass transport processes, can be obtained as well. Nevertheless, information gained from stable isotopes 18O and 2H remains crucial to reliably interpret CFC and SF6 measurements and to avoid misinterpretation.

***Keywords:*** chlorofluorocarbons, groundwater recharge, age dating

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW1001** **Oral Presentation** **4405**

# Mathematical modeling of environmental deuterium transport through the unsaturated zone and the estimation of the soil heterogeneity

***Prof. Piotr Maloszewski***
*ICT Vice-president IAHS*

***Christine Stumpp, Willibald Stichler***

This study presents an approach, which enables to quantify in integrative form the preferential and matrix flow and the heterogeneity in water transport through the unsaturated zone under natural atmospheric conditions. For these purposes during 1984-1991 weekly measurements of precipitation and discharge amounts as well deuterium (2H) contents in precipitation and water flowing out were analysed in seven lysimeters (length of 2 m; cross-section area of 0.125 m) filled with different soil materials. Deuterium transport through the sediment materials was estimated by applying the conceptual model, which consists of preferential and matrix flow-paths for each using the lumped parameter approach. For preferential and matrix flow-paths the Piston Flow and Dispersion transit time distribution functions were assumed, respectively. Weekly 2H data measured in precipitation over eight years (1984-1991) were taken as input function. Combined modelling of isotope and hydrological data enabled the preferential and matrix flow rates to be quantified. The fraction of preferential flow in the total outflow, which appeared directly in the outflow within one week, varied between 7% and 37% regarding the yearly runoff data and in the mean between 17% and 30% considering the whole observation period. The fraction of the preferential flow was practically independent from the soil grain size parameters and flow rates. The crucial parameter influencing the fraction of direct flow was found to be the saturated hydraulic conductivity of the sediment material (Ks). In the matrix flow it was found that the apparent dispersion parameter (PD)* is indirectly proportional to the mean water content in the sediment material ( ). This relationship shows that the heterogeneity of the water flux in the matrix is higher by the lower water content. The transit time distribution functions with their parameters found for both flow-paths and the fractions of preferential flow were finally used to construct the vulnerability diagrams. Such a diagram for each soil material gives the amounts of the tracer mass (conservative pollutant), which appear every week in the outflow during the period of between 0 and 60 weeks. It was found that these diagrams show different patterns for different soils, depending on saturated conductivity and soil water content. Coarser material with low mean water content and high saturation conductivity showed a short mean transit time for the matrix flow (about 10 weeks) and mean preferential flow equal to or higher than 20%. Finer sand with lower Ks and higher water content resulted in mean transit times of approximately 30 weeks and a preferential flow of 17 to 21%. These diagrams can be used to estimate the vulnerability of groundwater due to pollution for different soil materials of the unsaturated zone.

***Keywords:*** environmental deuterium, mathematical modelling, unsaturated zone

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**HW1001** **Oral Presentation** **4406**

# Sulphate stable isotopes - a reliable tracer for hydrograph separation at catchment scale ?

***Dr. Karsten Osenbrueck***
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***Kay Knller, Stephan M. Weise***

Long term time series of stable sulphur isotopes (S-34, O-18) and sulphur content have been measured in stream water at different sites within the Saale catchment, Germany. The sampling sites include the Saale river before and after the confluence with the Weisse Elster, the Weisse Elster river just before its inflow into the Saale, and the Parthe river, a small tributary of the Weisse Elster. The size of the respective subcatchments range from 3.0 and 81 km2 for the Parthe, 5 150 km2 for the Weisse Elster to 17 979 km2 for the Saale. The main sources of sulphur in stream and groundwater of the investigation area include sulphate from Triassic evaporites, which dominates the middle part of the Saale catchment, sulphur from soil organic matter, which dominates the catchment of the Weisse Elster, and in general minor contributions of sulphate from oxidation of sulphides and from atmospheric deposition. Despite the numerous sources and expected spatial heterogeneities, 34S of sulphate in conjunction with sulphate contents indicate that dissolved sulphate in stream water can reasonably well be explained by a simple two component mixing for the majority of sampling sites. According to the isotopic composition of sulphate, the low SO4 endmember can be attributed to sulphate from atmospheric deposition as measured in rainfall at the nearby monitoring station in Leipzig. The second endmember is in good agreement with the expected terrestrial sulphate sources. Provided that the source of sulphate is related to the source of water, the observed correlation can potentially be used for separation of event water (atmospheric sulphur) and pre-event water (terrestrial sulphur). The influence of more than one dominating terrestrial sulphate source in the catchment and the uncertainty introduced by this, have been investigated by comparing the data record after the confluence of the Saale and Weisse Elster rivers with data from each subcatchment.

***Keywords:*** s 34 so4, hydrograph separation

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**HW1001** **Oral Presentation** **4407**

# Sensitivity of lake Mar Chiquita (Argentina) to climate change: a modeling and isotopic approach.

***Prof. Christine Vallet-Coulomb***
*CEREGE UPCAM Universit Paul Czanne Aix-Marseille IAHS*

***Florence Sylvestre, Eduardo Piovano, Corinne Sonzogni***

Laguna Mar Chiquita (3054S-6251W), a highly variable closed saline lake located in the Pampean plains of central Argentina, has clearly undergone the 20th century hydrological changes in SE South America, by marked water-level variations. This lake, located at the lowermost end of an endorheic basin, has a large catchment area covering 37,570 km2 and is a part of the Chaco-Pampean plain, an extensive area of forests and grassland, located at the west of the Parana-La Plata basin. Historical and instrumental data, combined with sediment core studies (sedimentological, isotopic, and diatom analysis) show that this lake is a good recorder of high- and low-frequency changes in hydrological budget. Therefore, Laguna Mar Chiquita can be considered as a regional and temporal integrator of its catchment water balance. In this study, stable isotopes will be used for different purposes. Firstly, combined with water chemical composition, the water isotopic compositions will help to characterize the hydrological functioning and the lake water balance, including partitioning surface and groundwater inflows. Secondly, a modelling approach will be applied to simulate water flows in the catchment in response to climate and environmental changes. The model will include isotopic processes that modify the isotopic signal from meteoric water until lake water, and a special attention will be paid to the isotopic enrichment that occurs in the intermediate evaporative saline zones of the catchment and on the lake Mar Chiquita itself.

***Keywords:*** lake, climate change, evaporation

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW1001** **Oral Presentation** **4408**

# Radon in the Gran Sasso spring waters (central Apennines) to investigate karst aquifer

***Prof. Marco Tallini***
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***Vanessa Di Sabatino, Donato Sciannamblo, Michele Spizzico***

The results of nine hydrochemical surveys (April 2002, January 2003, July and October 2005 and March, April, May, July and October 2006) of radon, main elements concentrations with T, E.C. and pH of more than 20 springs of Gran Sasso groundwater is shown. The improvement of calibration of radon tracer technique to characterize groundwater flowpaths and processes of water-rock interaction of complex karst aquifer was the goal of this study. It is known that amount in groundwater of 222Rn, noble, inert and radioactive gas with half-life time equal to 3.82 days, is by now applied to seek the mechanisms of influencing karst groundwater flowpaths. So this technique is a powerful tool to assess the vulnerability to pollution levels of karst aquifer in which groundwater circuit can develop along karst conduits responsible of pollution migration coming from local infiltration points on the surface. The Gran Sasso hydrogeological system was chosen as a case-study area on which the radon tracer technique was applied because of i) the aquifer is particularly complex from the geological point of view; ii) the hydrogeological framework is well defined and, finally, iii) vulnerability to pollution impact is quite important for the interaction of highway tunnels and underground nuclear physics laboratories with regional groundwater which is taken for drinkable purposes. The results of spatial and temporal analysis of 222Rn amount in the Gran Sasso integrated with the other chemical and physico-chemical parameters were encouraging: in spite of their periodic variability, 222Rn concentration was proved to be a good indicator of Gran Sasso aquifer giving also information on karst development level.

***Keywords:*** radon, environmental tracer, karst aquifer

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**HW1001** **Oral Presentation** **4409**

# Stable water isotope peak of temporal variations is a good indicator to split wet and dry season at site

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***Jiyang Wang***

Yangtze River is the largest river in China, and the third longest around the world. The isotope compositions of deuterium and oxygen-18 in river water are very useful tools for interpreting hydrological processes and hydrological cycle related to climate changes and anthropic activities in large-scale river basin. Since 2003, 170 water samples recovered from the 1st water campaign and 1-year regular sampling at 4-station are analyzed for D and 18O composition. From upstream to downstream, isotopic composition D and 18O are gradually increased. The trend line of the first campaign is just situated in the medium of LMWL and the trend line of 1-year river water sampled at 4 regular stations. The relationship of isotopic D and 18O at the 4-station is in good accordance with the LMWL. New water body from the tributaries coming to the main stem of Yangtze River is one of the main reasons of spatial isotopic variations in river waters. The results revealed that temporal and spatial variations in the oxygen- and hydrogen-isotope of water samples along the main stem of the Yangtze River strongly relies on the isotope pattern of the regional precipitation. Furthermore, signatures derived from influx of evaporatively enriched waters through the several reservoirs or lakes along the system will be resulted in d-excess values increasing. From the beginning to the end of the low water standing period, isotopic compositions (D and 18O) are expressed as progressively increasing. The peak of the river water isotopic temporal variations is good corresponding to the boundary point of the beginning or ending for annual flooding period at site. The peak and valley of the river water temporal isotopic variations is a good indicator to split flooding or low water standing period at a given location for a water year.

***Keywords:*** stable isotope, temporal variation, flooding period

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**HW1001** **Oral Presentation** **4410**

# Tracking stream nitrate sources and flow paths using isotopes on a basin with mixed land-uses and karst terrain

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Use of isotopes for tracking stream nitrate sources and flow paths was studied in a large mixed land-use watershed with karst valleys and sandstone uplands typical of the Ridge and Valley Provence of Pennsylvania. Baseflow sampling at the mouths of nested sub-basins dominated by urban, agricultural, forest and mixed land-uses showed that 15N-NO3 was better than 18O-NO3 for characterizing land use impacts. Both nitrate isotopes varied only slightly in baseflow throughout the year at each site, suggesting that relatively few repeated samples are needed at baseflow to characterize land-use effects on groundwater. Precipitation nitrate isotopes could be easily detected in peakflow during six rainfall events on an urbanizing sub-basin where a major flow path was overland flow on impermeable surfaces. However, precipitation nitrate tracing was complicated by isotope variations during some rainfall events. Peakflow nitrate on the steeper forested uplands with shallow subsurface stormflows could also be partially attributed to precipitation using isotopes. In contrast, nitrate isotopes at three karst valley sites with mixed land uses varied little from baseflow to peakflow for these events, indicating that recharge by rain water caused a piston-flow type delivery of nitrate from the karst aquifer at peakflow similar to nitrate found at baseflow. Change in nitrate isotopes from baseflow to peakflow in streams during events was found to be a sensitive indicator of nitrate flow paths on watersheds.

***Keywords:*** karst, baseflow, peakflow

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**HW1001** **Oral Presentation** **4411**

# Radon as natural tracer to separate event and pre-event water

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While many studies over the past several decades have documented the importance of subsurface stormflow (SSF) in hillslopes, its formation is still not well understood. Therefore, estimates of SSF intensity remain difficult in terms of flow rate and lag time until onset of flow. The ongoing debate on the "old water paradox" highlights the limited understanding of SSF formation, as it is not clear, how rapid pre-event ("old") water contributions to stormflow might originate from SSF. Therefore, we studied SSF formation in the vadose soil zone at four different hillslopes during controlled sprinkling experiments and natural rainfall events. Radon (222Rn), a decay product of 238U, was used as natural tracer to derive the fraction of pre-event water in SSF. Several problems are associated with the measurement of Radon. For instance, degassing of dissolved Radon has to be avoided during sampling. With a specialized installation, we were able to monitor the Radon-concentration in SSF continuously over a longer period during rainfall events with a temporal resolution of about 30 minutes. During sprinkling experiments, pre-event water fractions were determined with Radon as well as with artificially traced sprinkling water. The results of the two methods agreed well. Radon concentration as well as SSF intensity varied substantially at the different test slopes. The measurements showed that substantial amounts of pre-event water can be contained in fast subsurface storm flow and also in overland flow. The findings helped to understand SSF formation and might explain part of the "old water paradox".

***Keywords:*** radon 222, pre event water, subsurface storm flow

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**HW1001** **Oral Presentation** **4412**

# Application of isotope data to evaluate catchment rainfall-runoff models

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***Fabrizio Fenicia, Jeffrey J. Mcdonnell, Hubert H. G. Savenije, Laurent Pfister***

The use of isotope data in catchment model development and testing has been minimal to date. In this work, we develop a conceptual model for the well-studied Maimai catchment in New Zealand and evolve the complexity in the model structure as different sources of information are introduced. We evaluate the model first with discharge alone, then discharge plus groundwater and then discharge plus groundwater plus stream isotope data. The use of additional information allows defining new process components as it reveals new aspects of the catchment behaviour. Moreover, the representation of the catchment in an evolving, flexible structure enables us to evaluate the relative contribution of complementary information in a learning process, and to analyze the consequence of different hypotheses on our conclusions on the catchment behaviour. In particular, the effect of considering a system under dynamic conditions and the result of different mixing hypotheses on the simulated isotope signal are analyzed, illustrating the impact of alternative assumptions on the interpretation of the catchment behaviour. We argue that these results can be useful to guide field research in poorly gauged areas, as they help to understand the potential value of complementary data in revealing different aspects of the catchment behaviour.

***Keywords:*** modelling, isotopes

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**HW1001** **Oral Presentation** **4413**

# Fluctuations in lake and wetland water budgets in 50 lakes on the Boreal Plain: evidence from five years of isotope measurements

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A stable isotope mass balance technique for estimating water yield is applied to a five year isotopic time-series from fifty lakes in hydrologically complex, wetland-rich terrain of northeastern Alberta, Canada. The dataset, gathered as part of CEMA-sponsored research in the oil sands region, is designed to improve baseline understanding of hydrologic response at undisturbed sites in the area, as well as to constrain water yield estimates to lakes as part of a dynamic critical loadings assessment. The approach uses readily obtainable physical and climatological data combined with analysis of evaporative isotopic enrichment of deuterium and oxygen-18 in lake water as a quantitative tracer of throughflow, lake residency and runoff. The results illustrate practical limitations of working in ungauged basins, but also provide an indication of added value to be gained by incorporating such site-specific measurements within water quality networks. Implications for the role of lakes and wetlands in the regional runoff are discussed.

***Keywords:*** isotopes, water balance, lakes

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**HW1001** **Oral Presentation** **4414**

# Late holocene changes in european climate revealed by records of noble gas temperature, excess air and deuterium excess in groundwater from the Fontainebleau sands aquifer, South of Paris (France)

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Temporal variations of the noble gas temperature, the excess air component and the deuterium excess in groundwater from the Fontainebleau Sands Aquifer (south of Paris, France) revealed changes in European climate during the past five hundred years. The noble gas temperatures consistently indicate a cooling of up to 1 oC in the recharge area of the aquifer for the XIX century, which is in conformity with reconstructions of European temperatures for this period. Changes in the precipitation seasonality and in its intensity are responsible for the variations observed in the deuterium excess in groundwater. The lower deuterium excess in groundwater recharged in the XIX century compared to groundwater recharged in previous centuries is a consequence of a higher amount of summer precipitation lower d-excess than winter precipitation in recharge. This result agrees with reconstructions of the precipitation seasonality for Paris and Rennes (France), which have indicated higher summer precipitation rates in the XIX century. Finally, slightly lower values of excess air are observed in groundwater recharged between 1800 and 1900 despite the higher precipitation rate, and consequently higher recharge rate expected. This apparent contradiction is explained by a more homogeneously distributed recharge along the seasons which in turns produce a lower net variation of the water table than in previous centuries where recharge was more concentrated in cooler mothns (October to March). This result suggest that the excess air in groundwater, in this aquifer, is more related to the oscillations of the water table produced by the variability of recharge along the year than to the total amount of recharge. The present work provides new important data for a better understanding of the interrelationships between the climate prevailing in the recharge area and some groundwater parameters like the deuterium excess and recharge temperature.

***Keywords:*** groundwater, climate, tracers

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**HW1001** **Oral Presentation** **4415**

# Isotope Ratios of Rainfall and Water Vapor observed in Typhoon Shanshan

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Isotope ratios of rainfall and water vapor during the passage of Typhoon Shanshan were observed in Ishigaki Island, southwestern part of Japan, on 1516 September 2006. High-resolution samples of 1-ml rainfall allow a more quantitative understanding of detail water circulation of typhoon system. Observational results show that the isotope ratios of rainfall in rainband accompanying Shanshan decrease radially inward, but appear to be anomalously high in the eye wall. We speculate that the inward decrease in the isotope ratios of rainfall is due to the recycling process, diffusive isotope exchange between rainfall and converging vapor in the boundary layer. On the other hand, the anomalously high isotope ratios of the eye-wall rainfall is a consequence of their local cycling process which is a major source of the precipitating vapor for the typhoons inner region. We also collected the water vapor in the eye of the typhoon where rainfall and storm ceased rapidly. The isotope ratios of water vapor in the eye are markedly higher than that of water vapor near the rainband. In addition, a quite decrease in the deuterium excess from the eye wall to eye (d = 37.8 to 10.9 permil) appears, which is attributed to the difference in the water vapor source area. These findings indicate that the water circulation of the typhoons core is significantly different from that in the outer region.

***Keywords:*** water circulation, typhoon, recycling process

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**HW1001** **Oral Presentation** **4416**

# Isotope hydrological and hydro chemical characterization of base flow at the Mica Creek experimental watershed, Northern Idaho

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An isotope hydrological and hydro chemical characterization of base flow was carried out to determine water age and storage characteristics in a mesoscale (30 km2), mountainous watershed under different canopy characteristics (clear-cut, thinned, intact forest). A base flow sampling campaign was conducted during minimum annual flow conditions in September 2006, at the Mica Creek Experimental Watershed (MCEW) in northern Idaho, USA. Discharge was measured (salt dilution method) concurrently with water sample collection at 30 sites within the catchment. Water samples were analyzed for oxygen-18, deuterium, deuterium excess, tritium, carbon-13 and nitrogen-15, as well as for basic water chemistry (sodium, potassium, calcium, magnesium, chloride, sulfate, nitrate, carbonate and silica). Meteorological observations were available from a SNOTEL site located within the study site (measurements since 1991) and seven meteorological sites (since 2002). Discharge data is available for seven flume sites (continuous stream flow data 1991-2007). Flow data at the 30 sites ranged between 0.5 l/s (headwater spring) and 54 l/s at the lowest point of the stream network (Flume-7). Over a 15-year period (10/1991 to 9/2005) observed lowest, mean and highest daily discharge values at the Flume-7 were 17, 195 and 3690 l/s respectively. Isotope concentrations of 15.3 to 16.0 and 109 to 115 were found for d18O and d2H, respectively and deuterium excess (DE) values ranged from 9 to 15 . The base flow values in general reflect isotopic concentrations of winter precipitation and therefore indicate soil water storage of up to 6 months. Distinct patterns were found for the clear-cut, thinned and unimpacted forest sites. Tritium concentrations vary between 3 and 5 TU indicating young water components (<5 years) and forest treatments coupled with seasonal patterns of tritium input data (Portland / OR, GNIP) help to explain observed tritium variability. Hydro chemical data indicate a Ca-HCO3 dominated system and relative low ion contents (conductivities range between 25 and 200 micro S / cm). The patterns in conductivity for forest treatments are related to NO3 and probably TOC contents. N-15 and 13C data provide additional information on background geology, nutrient influence and forest treatments impacts. We discuss isotope hydro chemical characteristics of base flow derived from an intensive field campaign and discuss its applicability to interpret residence times and storage behavior in comparison with available hydro meteorological data. This approach may be useful for pilot studies in ungauged basins as a rapid assessment method to characterize water storage and residence times.

***Keywords:*** isotopes, base flow, mica creek

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**HW1001** **Oral Presentation** **4417**

# High frequent isotope monitoring of precipitation and river water in Siberia

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The high frequent (every 12 hours) isotope monitoring of precipitation, which includes 9 stations over Siberia region, and every two weeks river water sampling in the three major river (Ob, Enisei, and Lena) was launched from September 2004. Previous monthly basis monitoring activity, called as SNIP, exhibited clear spatial distribution, which gradually decreases toward the inland and the remarkable seasonal cycle similar to air temperature variation. However more intensive monitoring data needs to be clear the factors controlling of monthly mean values, because event to event isotopic variability is very large in this region. Here, we show the results of new high-resolution time series of isotopes in Siberia region and discuss the relationship between river discharge and precipitation over the basin. ?The results show that the largest daily isotopic variability occurred in early spring and late autumn. In these periods, the spatial isotopic variability is also the largest. During summer time, although the range of variation is small, the lowest isotopic value of precipitation occurred when the synoptical scale disturbances migrated from west and passed through the observed region, On the other hand, the convective rain due to local circulation showed the relatively high isotope values. These results suggest that the temporal large isotopic variation seems to be closely related with the atmospheric circulation. The seasonal isotopic variation of river water is characterized by the suddenly seasonal minimum in spring due to the thaw water contribution, and then gradually increases due to the input of summer precipitation. Although the seasonal change of isotopes is similar in three rivers, the ? D of base flow in Lena River is lower about 30 permil than in Enisei River. Because the spatial isotopic distribution of summer precipitation is small in Siberia, the difference of snow contribution to base flow might result in these difference.

***Keywords:*** siberia, monitoring, isotope

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**HW1001** **Oral Presentation** **4418**

# Implementing residence times of environmental isotopes into a rainfallrunoff model to document catchment scale drought effects

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We used the modelling framework of the conceptual rainfall-runoff model HBV to simulate catchment scale isotope concentrations in two mountainous catchments (18 and 40 km2) in the Black Forest, Southwest Germany. Additionally to modelling water fluxes by a combination of soil and groundwater reservoirs as given by HBV, an adjustable, exponentially shaped residence time distribution for isotopes was implemented into the model reservoirs. As such, the shape of the residence time distributions served as calibration parameter for observed O-18 concentrations in streamflow. Additionally to simulated O-18, the enlarged HBV-model produced theoretical mean residence times for every time step. The model was applied to 7 years of daily hydrometric and weekly isotope data including a major drought event in summer 2003. Model results revealed a clear increase of simulated mean transit times following the 2003 drought which had already been expected observing measured isotope concentrations. Uncertainty tests suggested that the absolute transit times were highly uncertain due to limited parameter identifiability, while the relative increase following the 2003 drought event turned out to be more certain.

***Keywords:*** residence time, rainfall runoff modelling, hbv

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**HW1001** **Oral Presentation** **4419**

# Isotope tracing of groundwater salinization process in a semi-arid region of Brazilian Northeast (Lagoa Real, Bahia State)

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The semi-arid region of the Northeast of Brazil is characterized by a lack of superficial waters due to the low pluviometric precipitation and high evaporation rates. In addition to this, the precipitation events are irregular in time causing long periods of dryness with catastrophic consequences. Owing to these adverse climatic conditions, intense pressure is being put on the use of groundwater resources. However, there is still insufficient knowledge of the basic aquifers characteristics leading to an over exploitation of the water resources. Groundwater occurrence on its turn depends on a series of geological and climatological characteristics that are very variable in the region. The prevailance of crystaline rocks is connected to a fracture aquifer type of low productivity, where wells show, generally, yield rates lower than 3 m3.h-1. In aquifers where vegetation cover is scarce like Caatinga and the discharge is mainly controlled by evaporation process, soil salinization and low recharge rates often produce hyper saline waters not suitable for human consumption. Thus, salinization is usually seemed to be caused by old waters coming from the discharge through deep faults orbythe large residence time of the aquiferrelated toits degree of confinement. This work was developed in a semi-aridarea located in the center-south region of Bahia State at900 metres a.s.l., where werediscoveredseveral radioactive anomalies byaerogeophysical surveys performedduring 70's decade,that allowed to set theuranium province named Lagoa Real. There were performed isotopic and geochemical analysis of groundwater sampled fromtwenty-five wellsplaced incrystaline rocks areas (granite or gneiss) often covered by shortlayers of residual soil or alluvial sediments.The sampleswere analysed in a mass spectrometer for stable isotopic ratios, like d 2H, d 18O, d 13C andalso measured for radiocarbon activity concentration (14C)tocalculate the percentage of moderncarbon(pMC) by AMS. The values of d2H andd 18O defined a local evaporation line (LEL) with slope equal to4,6 against the value of 7,4 for the Local Meteoric Water Line (Salvador station from 1972 to 1976). The radiocarbon ages, corrected by carbonate dissolution (through d 13C and DIC), showed veryyoung waters for most of the wells that were recharged recently, perhapsduringthe last few years to several months.These results seem to be in disagreement with theusual explanation for high salinity in fractured aquifers from semi-arid regions, which is based inmajor residence times or regional flow of paleogroundwaterthrough faults. Thus, we must conclude that salinization is mostly taking place from another source, probably due to evaporation during the infiltration in the vadose zone, chiefly controlled by the soil permeability. The salinization takes place during percolation time, probably caused by the concentration ofsalts in theremaining soil solution that, aftersome rainfall events,reachesthe satured zone. Ongoing analysis of uranium activity ratio (234U/238U) will give us further information about water-rock interaction and weathering that could allow to estimate possible mixing between different groundwater sources.

***Keywords:*** isotopes, recharge, salinization

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**HW1001** **Oral Presentation** **4420**

# Identifying groundwater contribution to the Darling River (SE-Australia) during drought conditions using stable water isotopes and geochemical tracers.

***Dr. Suzanne Hollins***

***Karina Meredith, Dioni Cendon, John Gibson***

The Darling River is a relatively under-monitored major river in the Murray-Darling Basin, Australias most significant agricultural region. The river is in poor health due to high user demands and the current drought being experienced in . Diversions for irrigation in low rainfall periods have seen the river cease to flow for years at a time. The highly regulated nature of the Darling River has made it more susceptible to degradation due to the enormous pressure placed on river water resources to supplement pre-existing multi-user demands.The current drought in has opened a window of opportunity for important research into surface water/groundwater interaction in this dryland river system. Stable isotopes of water (δ18O, and δ2H) and hydrochemical tracers have been particularly useful in identifying different input waters into the Darling River . As the drought has worsened and the rainfall has decreased, the isotopic signature of rainfall in the river water has decreased. By using various isotopic and hydrochemical methods, partitioning of the groundwater and evaporation components influencing surface waters in the Darling River has been accomplished. In a system where potential evaporation far outweighs the average precipitation, stagnant semi-isolated water systems have developed along the river system.Stable isotope and hydrochemical data of surface waters for the Darling River from July 2002 to January 2007 have been collected by ANSTO as part of the IAEA Global Network for Isotopes in Rivers (GNIR) project. Previous investigations have identified that evaporation is the major mechanism producing the observed isotopic signatures of river water samples. The presented work focuses on results from a surface water sampling regime conducted on a 1000 kilometre stretch of the Darling River system, starting in Mungindi located approximately 1050 km from the mouth of the river, to Burtundy which is located approximately 70 km from the mouth of the Darling River. Run-of-river results for 2002 to 2006 show sharp peaks in Cl- concentrations between Bourke (~690 km from the mouth) and Wilcannia (~370 km from the mouth). The influx of Cl- appears to be correlated with a decrease in δ2H and δ18O values and an increase in major ion concentrations. The distinctive evaporation signatures of surface waters from this stretch of the river are also muted. Subsequently, groundwaters high in Cl- and depleted in stable isotopes (relative to background waters) are dominating the geochemical signature of surface waters between Bourke and Wilcannia. Due to prevailing drought conditions, the lack of rainfall input to the system enhances the groundwater input signature in the surface waters. Partitioning of the different water components in the Darling River system is usually difficult to accomplish because the isotopic and hydrochemical signatures of the input groundwaters are subdued by rainfall dilution and distorted by evaporation processes along the river system, however, during drought conditions differentiation of these input waters has made conditions acceptable for this to occur.

***Keywords:*** isotope tracers, hydrochemistry, surface water

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**HW1001** **Oral Presentation** **4421**

# Combining isotopes and hydrometric observations to inform process based modelling of afforested catchments in eastern headwaters of South Africa

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Extensive afforestation on Molteno and Clarens geological formations in the Eastern Cape region of South Africa is likely to impact the dynamics of the hydrological responses in the region. In order to assess this impact, it is important to quantify the sources, pathways and travel times of components of flow emanating from the watersheds. The geological formations are characterised by horizontally bedded mudstone and sandstone layers which regulate the discharge of subsurface water which could be accessed by the deep rooted trees. Dominant hillslope responses have therefore been studied in a small research catchment (1.5km2) in which stable isotopes of water, natural chloride and silica tracer sampling has been combined with hydrometric and geophysical observations to define dominant response mechanisms during high and low flows. This information has been used to derive response functions for a process based model in which soil-water-plant-atmosphere water budgeting is linked to components of discharge, including: overland flow and rapid subsurface water; subsurface water perched on bedrock and deep groundwater responses. The model is then applied over a large scale catchment of 150km2 in which isotope sampling has been sparse and a single stream gauge monitors the catchment outlet response. The results demonstrate the merits of applying the dominant process mechanisms, derived through detailed tracer and hydrometric observations, in simulating the large catchment response, where both observed discharge and tracer dynamics are predicted.

***Keywords:*** stable istopes, process model, scaling

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**HW1001** **Oral Presentation** **4422**

# Use of δ18O in the interpretation of hydrological dynamics in alpine lakes

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During recent limnological investigations in Trentino (Italy) the δ18O content of water was introduced as an innovative parameter towards a better understanding of hydrological processes in some alpine lakes. Some small to medium sized lakes were sampled at various depths and times and isotopic data were reported. For three lakes in particular, Serraia, Lavarone and Tovel the δ18O values of lake water and influent water together with more traditional parameters, permitted a better understanding of the hydrological processes specifically tied to each lake. For example, we were able to confirm i) the absence of mixing between the epi and hypolimnion in summer for L. Serraia, ii) the presence of significant sources of underground water inputs for L. Lavarone and iii) a complete spring turnover for L. Tovel, a lake usually considered meromittic. This study underlined the importance of a capillary and regular spatial and temporal distribution of the measurements to accurately define water movements by means of the IRMS analysis of δ18O content of water. This parameter, because of its conservative nature, was confirmed to be an useful indicator of water renewal, summer/winter stratification and spring/autumn turnover for lakes hydrological cycle.

***Keywords:*** δ(18)o, lake, hydro dynamics

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**HW1001** **Oral Presentation** **4423**

# Combined use of environmental isotopes and artificial tracers for numerical process modelling in a small central european basin of fractured paleozoic bedrock

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***Willibald Stichler, Matthias Schniger, Sybille Schumann, Raphael Thies***

Environmental isotopes have contributed to quantify direct runoff proportions, mean transit times of soil and ground water, and other hydraulic features in small research basins distributed over many ecozones. Based on these experiences, a new integrated methodical basin approach was developed which combines analytical and numerical study methods. The concept is based on variable surface/groundwater relationships focusing on groundwater fluxes, which are the dominant component for flood hydrograph generation in the majority of studied cases. For this purpose, origin, age and pathways of groundwater that cause channel inflow would be required in sufficient resolution. Numerical treatment of hydrological and hydraulic data with coupled FEFLOW and MIKE11 software packages intends to simulate the groundwater exfiltration rates channel section-wise with sufficient accuracy. The proposed concept is realised in Lange Bramke research basin, Harz Mountains, which covers an area of 0.76 km. The unsaturated zone (UZ) is made of forest soils on silty materials which are of solifluidal origin, rich in skeleton and cover the weathered and fractured/fissured bedrock. Saturated zones (SZ) consist of fractured Lower Devonian sandstone, quartzite and slates (fractured rock aquifer), and of boulders, debris and gravels in the valley filling of the basin centre (porous aquifer). The following former experimental findings were pointing the way: Lateral interflow is almost zero; direct runoff is only 10% of total on the average as determined with oxygen-18; UZ and SZ are short-cut by distinct preferential flow paths, which enable fast percolation of the infiltration water that was traced with dyes; recharge of groundwater is a permanent process throughout a year, thus its mean transit time of about 2 years as calculated from tritium is quite short. Another finding from use of artificial tracers (dyes, deuterium, potassium bromide) was that major cross-faults play an important role for ground water transfer towards channels with flow velocities of up to more than 10 m/h which means turbulent flow. The paper picks up the role which play isotopic hydrograph separation and combined tracings of groundwater with O-18, H-2, H-3, eosin and naphthionate, (and of seepage from melting snow covers with uranine and potassium bromide) during the spring melt season March-April 2006 process studies, modelling and model calibration in small basins. A long-term goal is to meet the requirements of PUB (Prediction in Ungauged Basins) for this type of ecohydrological system. Taking Lange Bramke as an example means to profit from almost 60 years of hydrological data series, the extended isotope hydrological knowledge, and a relatively dense experimental network. The synchronous breakthrough curves of stables isotopes and dyes in both aquifers and discharge during high melt clearly indicate basin-wide transmission of pressure followed by that of water, thus mobilising groundwater which generates the snowmelt plus rain flood hydrograph. Accordingly, direct flow is less than 5% of total discharge, corresponding to less than 1% of the present input volume. In consideration of the huge groundwater proportions leaving the basin during single events, groundwater flow through several major cross-faults, which according to several tracer experiments function as principal subsurface drain channels, contributes considerably to flood formation as also confirmed by flow simulations with FEFLOW. As a result, groundwater recharge is about three times higher than assessed with traditional methods.

***Keywords:*** isotope tracing of water bala, hydrodynamics, hydrological processes

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**HW1001** **Oral Presentation** **4424**

# The Application of Stable Isotopes for the detailed Assessment of Meromictic Lakes - New Advances in Isotope Water Balance Models

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***Kay Knller***

Widespread surface mining activities in the Lusatian Mining District in Germany caused significant changes to the aquatic system. In association with the flooding of former opencast pit areas, the occurrence of pyrite oxidation in dump sediments subjected the lakes to continuous acidification. Against this background, the mixing dynamics of meromictic mining lakes ought to be researched. The application of stable oxygen and hydrogen isotopes is to help understand the interactions between groundwater and lake water and the isotope exchange within the lake. The purpose of the isotope mass balance approach has been well proven within the last decades estimating water balances of lakes and catchments all over the world. The combination of diverse conventional attempts (e.g. chemical mass balance) with the isotope water balance may help evaluate both water budgets and environmental disturbance like the acifidation of water bodies. Nevertheless, for all that, there are still limitations to the isotope mass balance model in particular of determining the isotopic composition of atmospheric water vapour. Up to now, the evaporation flux as the most important parameter of the isotope water balance only can be obtained with an equation derived from the resistance model of the evaporation process introduced by Craig & Gordon in 1965. The improvement of these frame conditions for estimating water budgets is the main target of the presented investigations. Therefore, the preparation of field sampling systems for water vapour combined with in-lake evaporation pans shall improve the accurate determination of net evaporation fluxes. For this reason, two study sites within the Lusatian Lignite Mining District had been chosen to investigate lake water groundwater interactions and mixing dynamics of meromictic acidic mining lakes. A two-year data set of lake water, precipitation and air moisture sampled 10 cm and 100 cm above lake surface will be calibrated with pan evaporation and linked to meteorological data and groundwater samples of the lake?s catchment area. In addition to that, investigations of isotope exchange via chemoclines tracing the vertical transport in stratified lakes will be driven ahead by the application of dialysis pore water sampler (DPS). The DPS has been well proven as a capable tool recording the isotope signatures over high-resolution profiles in the chemocline areas of the lakes. First attempts adopting the pore water sampler for isotope analysis obtained valuable results.

***Keywords:*** isotope water balance, lake evaporation, dialysis pore water sampler

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW1001** **Oral Presentation** **4425**

# Identifying groundwater contribution to the Darling River (SE-Australia) during drought conditions using stable water isotopes and geochemical tracers.

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The Darling River is a relatively under-monitored major river in the Murray-Darling Basin, Australias most significant agricultural region. The river is in poor health due to high user demands and the current drought being experienced in . Diversions for irrigation in low rainfall periods have seen the river cease to flow for years at a time. The highly regulated nature of the Darling River has made it more susceptible to degradation due to the enormous pressure placed on river water resources to supplement pre-existing multi-user demands.The current drought in has opened a window of opportunity for important research into surface water/groundwater interaction in this dryland river system. Stable isotopes of water (δ18O, and δ2H) and hydrochemical tracers have been particularly useful in identifying different input waters into the Darling River . As the drought has worsened and the rainfall has decreased, the isotopic signature of rainfall in the river water has decreased. By using various isotopic and hydrochemical methods, partitioning of the groundwater and evaporation components influencing surface waters in the Darling River has been accomplished. In a system where potential evaporation far outweighs the average precipitation, stagnant semi-isolated water systems have developed along the river system.Stable isotope and hydrochemical data of surface waters for the Darling River from July 2002 to January 2007 have been collected by ANSTO as part of the IAEA Global Network for Isotopes in Rivers (GNIR) project. Previous investigations have identified that evaporation is the major mechanism producing the observed isotopic signatures of river water samples. The presented work focuses on results from a surface water sampling regime conducted on a 1000 kilometre stretch of the Darling River system, starting in Mungindi located approximately 1050 km from the mouth of the river, to Burtundy which is located approximately 70 km from the mouth of the Darling River. Run-of-river results for 2002 to 2006 show sharp peaks in Cl- concentrations between Bourke (~690 km from the mouth) and Wilcannia (~370 km from the mouth). The influx of Cl- appears to be correlated with a decrease in δ2H and δ18O values and an increase in major ion concentrations. The distinctive evaporation signatures of surface waters from this stretch of the river are also muted. Subsequently, groundwaters high in Cl- and depleted in stable isotopes (relative to background waters) are dominating the geochemical signature of surface waters between Bourke and Wilcannia. Due to prevailing drought conditions, the lack of rainfall input to the system enhances the groundwater input signature in the surface waters. Partitioning of the different water components in the Darling River system is usually difficult to accomplish because the isotopic and hydrochemical signatures of the input groundwaters are subdued by rainfall dilution and distorted by evaporation processes along the river system, however, during drought conditions differentiation of these input waters has made conditions acceptable for this to occur.

***Keywords:*** isotope, tracershydrochemistry, surface water

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**HW1001** **Oral Presentation** **4426**

# Modelling the Isotopic composition of precipitation

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It is generally admitted that the isotopic composition of precipitation obeys a relation of the type 2H = a 18O + b, where at the global scale a = 8 and b = 10 ‰ (Craig, 1961). Subsequent investigations showed that a and b exhibit slight variations in certain geographical environments and seasons. Thus, another parameter, called deuterium excess d = 2H – 8 18O, was defined (Dansgaard, 1964) to assess the deviation of the combined hydrogen and oxygen isotopic compositions of natural waters from Craig's relation. The deuterium excess helps to understand local features of precipitation and identify processes (e.g. evaporation) affecting the isotopic composition of water (as for instance for summer rains exposed to evaporation during the fall). We explore how the 2H- 18O relation behaves in the adiabatic condensation of atmospheric vapour on the basis of a Rayleigh model and compare the results of numerical simulations with the experimental data. The model, derived from that used by Gonfiantini et al. (2001), enables to predict the isotopic composition of precipitation as a function of the formation temperature assuming that the vapour condensation process occurs at the isotopic equilibrium. The occurrence of a condensed phase (liquid water or ice) in the clouds and advection of new vapour masses can be included in the computations. Liquid water remaining in clouds is assumed to continuously re-equilibrate with the residual vapour, while for ice crystals this may be questionable. Our computations confirm that Craig's equation practically holds within a rather wide range of -values and indicate that the effects on deuterium excess are limited. This agrees with the assumption that the deuterium excess is mainly determined by the evaporation conditions. Thus, higher deuterium excess often observed in winter rains is probably associated with the moisture deficit of cold winter air coming into contact with warmer ocean water. When very negative -values are attained (as in Antarctic snow), a deviation from Craig's relationship associated with an increased deuterium excess must be expected. This is due to the faster removal by rainout of deuterium from the atmospheric vapour pool with respect to oxygen-18, because of the higher fractionation factor of the first (Gonfiantini & Gherardi, 2006). The isotopic gradients with temperature may appear reasonably constant for liquid precipitations, also because of re-equilibration between vapour and water present in clouds. The gradients increase steadily with decreasing temperature for snow precipitation, but for deuterium they reach a maximum and then decrease when temperatures below –50°C occur. Mixing of snow formed over a wide temperature range determines a decrease of the apparent isotopic gradients and the derived mean temperature of formation (Gonfiantini & Gherardi, 2006). Thus, snow mixing significantly affects the relationship between the isotopic signal and temperature.

***Keywords:*** precipitation isotope comp, deuterium excess modelling

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**HW1001** **Poster presentation** **4427**

# Observation of groundwater in arid Turpan Basin, Central Asia

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Water scarcity is most acute in arid and semi arid regions that cover almost one third of the Earths land surface. Moreover, limited fresh water resources available in these regions are also threatened with deterioration in quality due to man induced hydrological changes. The available water resources in arid regions are often restricted to groundwater. Analysis of stable isotope in groundwater and surface water in Turpan Basin, West China was carried out to identify the groundwater origin. Turpan Basin is hydrogeologically divided two parts, which is a North Basin and South Basin. The analysis data of stable isotope δD and δ18O in groundwater shows a systematic decrease identified from mountain hill to the basin along the groundwater flow direction. The δ18O value ranged from 9.5 ~ 11.8 and ranged about 2.3. The isotope variation is consistent with higher altitude recharge following flow paths along north south trending rivers in the upper basin and systematic decreased in the lower basin. All of the water samples besides the lake water were plotted above the global meteoric water line with high deuterium excess. It indicates that, the groundwater in the basin is different with the meteoric water. The groundwater in Turpan Basin recharges from melting of glaciers in high alpine area. There is no direct local rain infiltration to the aquifer.

***Keywords:*** stableisotope, groundwater, aridregion

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**HW1001** **Poster presentation** **4428**

# Isotope studies for groundwater characterization of Bakreswar and Tantloi geothermal area, Easren India

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***Nabendu Majumdar, Ajoylal Mukherjee***

The Bakreswar and Tantloi geothermal areas are located in the Birbhum district of West Bengal and Santhal Parganas district of Bihar respectively. They belong to several groups of geothermal areas occurring in an E-W belt along trend of Gondwana sedimentary basin in the central part of the Precambrian Chotanagpur Gneissic Complex( CGC).Geothermal activity in Bakreswar is represented by a cluster of seven thermal springs(44.5-71 Degree Centrigrade) scattered in an area of 3500m2. The emergence of the springs is mainly controlled by a nearly N-S trending fault (Majumdar et al 2000) .Two thermal springs (48 and 70 DegreeCentrigrade ) at Tantloi are associated with an ENE-WSW fault connected to a NNW-SSE trending one ( Nagar et al.1996). d18O and d D values of nonthermal and thermal waters from Bakreswar and Tantloi geothermal areas indicate a meteoric origin for thermal springs. Both nonthermal and thermal waters undergo seasonal isotope variations,being enriched in 18O and D in the winter relative to rainy Season. For nonthermal water this is due to a higher rate of evaporation in winter as a consequence of depleting atmospheric humidity,the effect is more observed for surface water than groundwater.Tritum content in the thermal water ranges between 0.6 +_ 0.5 TU and 1.6 +- 0.5 TU wheres that of surface water and adjoining ground water varies considerably (6.0 +- 0.5 to 10.9 + - 0.5 TU). Remarkably low T content in the thermal spring water in comparison with local meteoric water is indicative of little participation of local nonthermal water in the spring system and long residence time (55 years) of the water recharging the spring.

***Keywords:*** geothermal area, tritium, spring

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**HW1001** **Poster presentation** **4429**

# Estimation of Groundwater Recharge dependency in granitic terrain of Southern India.

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***Dr. Dewashish Kumar, Dr. Shakeel Ahmed***

Recharge is the process by which water percolates down the soil and reaches the water table. Quantification of the recharge is a pre-requisite for efficient ground water resource management. It is particularly important in regions with large demands for ground water supplies, where such resources are the keys to economic development. However, estimation of aquifer recharge is one of the most difficult factors to measure in the evaluation of ground water resources. An attempt has been taken into consideration in a granitic hard rock terrain of southern India. The most commonly used surface resistivity survey data sets have been used here to estimate recharge parameter. Resistivity of the top unsaturated zone has been used from 86 vertical electrical resistivity-sounding measurements. Fourteen sites have been selected for the tritium injection. A dependency between resistivity of top unsaturated zone and rechargehas been observed.

***Keywords:*** recharge, tritium injection, resistivity

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**HW1001** **Poster presentation** **4430**

# Groundwater recharge mechanism in the hyper-arid Gobi desert, Northwestern China

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Whether a groundwater recharge mechanism even exists that would induce groundwater recharge in hyper-arid areas is not well understood because of the extreme difficulties of taking measurements in such an environment. Using combined physical and tracer-based approaches, we have verified a hypothesis that high-intensity precipitation must induce groundwater recharge even in hyper-arid areas, taking into account other potential water sources such as paleowater and river water. We conducted hydrological and meteorological observations as well as water sampling in the Gobi desert in the lower reaches of the Heihe River basin, Northwestern China with annual precipitation less than 50 mm and annual potential evapotransipiration over 3500 mm. Our findings demonstrated that all the results observed in the present study were supportive of the hypothesis. We showed that 29% of a high-intensity precipitation infiltrated rapidly and remained in the vadose zone without being affected by evaporation due to a dry surface layer. We concluded that nothing but high-intensity precipitation infiltrated rapidly enough without being affected by evaporation to qualify as a source of groundwater in the hyper-arid environment of the Gobi desert. Our study is the first to demonstrate the possibility of groundwater recharge due to precipitation in a hyper-arid environment.

***Keywords:*** stable isotope, groundwater recharge, water balance

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**HW1001** **Poster presentation** **4431**

# Radio-isotopes for tracing, mixing and transport studies in Australia

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By combining radio-isotopes of carbon and chlorine with mass balance evaluations of the carrier ions, we can quantify the effects of mixing that limits the confidence and accuracy of groundwater dating. Thus, it is vital that we understand the chemistry of the groundwaters we are analysing and the chemical and isotopic history of the waters from recharge through to discharge. For chlorine isotopes this is relatively straightforward, but the ubiquitous and conservative nature of the chloride ion means that multiple sources need to be evaluated. Stable isotopes of chlorine can help, but fractionation is slight, except where a strong diffusion gradient exists. For radiocarbon, the reactive nature of bicarbonate and dependence on the acidity of the water, means careful correction needs to be made for mixing, precipitation and dissolution and fractionation as recharge waters transit through soils, the regolith and aquifers. Fortunately, stable isotopic analyses can be performed to help evaluate these processes and make correction. By combining radioisotope determinations with simple chemical transport models we can generate mixing envelopes, and constrain the contributions from different groundwater and surface water sources at any given location. Thus, using 14C and bicarbonate concentrations in ground and surface waters in Hodgson Creek, in the Queensland Murray-Darling Basin, we can estimate the relative contributions to salt export from the catchment. Alternatively, following flow-lines within the Great Artesian Basin, gradual incorporation of formational chloride with that introduced via rainfall recharge, can be modelled and revised estimates of groundwater flow dynamics can be given greater confidence. In addition, the variability in Darcy velocity through the system can be determined and revised maps of through-flow generated. Recent introduction of elevated levels of these radio-isotopes through the nuclear bomb tests of the 1950s and 1960s also gave a precise modern time marker that can be used to determine recharge rates and flow rates in modern and fast flowing systems. This is particularly evident in shallow aquifers of Central Australia, where distinction can be made between bypass and through flow of recharging waters.

***Keywords:*** radiocarbon, chlorine 36, groundwater dynamics

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**HW1001** **Poster presentation** **4432**

# Determination of groundwater - surface water relation by using environmental isotopes at Sultansazligi wetland-Turkey

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***Ebru Yildiz, Nail Unsal***

Sultansazl Wetland is placed in Develi Closed Basin in Turkey. Sultansazl Wetland is one of the seven important wetlands of Turkey and the second important bird habitat of Turkey. It is also known as one of the most important wetlands of the Eastern Europe and the Middle East. There are Yay Lake, l Lake, North and South reedfield areas in Sultansazligi Wetland Region. This wetland area is a conservation area protected by International Ramsar Agreement. Water level of Sultansazl Wetland had been decreased in the recent years and also there is an irrigation water supply problem in Develi Closed Basin. There are many illegally opened wells in Develi Closed Basin. In order to find out the effects of water scarcity in Sultansazl Wetland; environmental isotopes are used to determine surface water of wetland and groundwater intrusion. In this study tritium (H3), deuterium (H2), oxygen18 (O18) are used as environmental isotopes. Total 44 bottles of water samples had been taken from groundwater (from springs and wells) and surface water of Sultansazl Wetland (from Egri and Sap Lake) during 2003-2005 time period. Oxygen 18, deuterium and tritium analysis of these water samples had been made at the isotope laboratory of State of Hydraulic Works (DSI). According to the isotope analysis, it is found out that there is no direct relationship between the surface water of Sultansazl Wetland and groundwater under the wetland.

***Keywords:*** sultansazligi, isotope, interaction

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**HW1001** **Poster presentation** **4433**

# Study of the water recharge problematic in a semi-arid zone (climatic and anthropic impacts): The case of the Essouira aquifers system (Mogador, Morocco)

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The piezometric map of the Essaouira synclinal basin (Morocco) was realized. Different water samples have been collected from drillings, sources and wells belonging to the plioquaternary and turonian aquifers of the studied region. Their electric conductivity as well as 18O, 2H and 3H concentrations were measured. A meteoric local line was determined and compared to the world meteoric line. The radiocarbon ages of the studied aquifers were evaluated. The recharge of the main aquifers of the studied region was investigated. It has been shown by this study that the recharge rate of the deep turonian aquifer is too low. This may cause a lack of water for supplying the Essaouira city and its region. Nevertheless, if we return to the drought context of the past years as prevented by the present world tendency, Moroccan authorities must envisage to build small dams on the Ksob river for a better management of flooding waters which are presently thrown in the Atlantic ocean

***Keywords:*** plioquaternary turonian aquif, 18o 2h 3h 14c isotopes, aquifer recharge

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**HW1001** **Poster presentation** **4434**

# Can radon tracer technique improve karst groundwater vulnerability assessment?

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Among karst aquifers of central Italy the Gran Sasso certainly shows remarkable characteristics mainly the interaction of underground works (highway tunnels and nuclear physics lab) with a wide regional groundwater used for drinkable purpose. Therefore it is clear how in this case groundwater vulnerability is without doubt a focal point. With the goal to evaluate the groundwater vulnerability of the Rio Arno spring group located nearby and by the side of the Gran Sasso tunnels an integrated study of hydrochemistry and radon in spring water, used as environmental tracer, was carried out. The Rio Arno spring group (total average discharge of about 100 L/s) is generated by the outflow of the top of the regional groundwater due to the presence in the northern Gran Sasso slope of the permeability boundary caused by the overthrusting of Mesozoic and Tertiary limestone (i.e. regional aquifer) on to miocenic terrigenous unit (i.e. regional aquiclude).The study was based on two survey campaigns (August and September 2005) of 15 Rio Arno group springs. The major elements and several trace ones (F, Br, Sr, Li) together with T, pH and El. Cond. were measured in situ and in lab. The analysis of hydrochemical and radon data permitted to establish the relationship of shallow groundwater flowpath in the Quaternary clastic deposits laid on the carbonatic bedrock with respect to the regional groundwater one. The radon and hydrochemical data furnished some indications on the groundwater recharge process. High values of radon (60-80 Bq/L) were found on groundwater coming from the regional groundwater outflow, while shallow groundwater had low values of radon (nearby 20 Bq/L). Average values suggested a mixing between shallow and regional groundwater. Moreover radon values, above all of the outflow spring, seemed also to be influenced by seasonal phenomena.

***Keywords:*** radon, environmental tracer, karst vulnerability

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**HW1001** **Poster presentation** **4435**

# The Cl--RICH groundwater in the Kanto Plain, Central Japan: its isotopic characteristics and dating

***Dr. Masaya Yasuhara***
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In the Kanto plain, the largest Quaternary groundwater basin in Japan, water samples were obtained from 144 water supply boreholes with pumps installed to characterize the groundwater system. The spatial variation in chloride (Cl-) concentration indicates that in its central part there exists groundwater with Cl- concentrations of more than 100 mg/l (up to 216 mg/l) between 150 m and 430 m depth below ground surface. This 8 km wide, 35 km long Cl--rich area, spreading from the northwest to the southeast, corresponds with the so-called Motoarakawa tectonic zone bounded by the faults on its long sides. We have found the Cl--rich groundwater is also characterized by low dD, low d18O, and high d13C values. Both the chemical and isotopic evidence strongly suggests the Motoarakawa tectonic zone divides the regional groundwater system in the Kanto plain into three distinct hydrologic subareas. Two faults bordering the Motoarakawa tectonic zone act as barriers to the southward and northeastward regional movements of groundwater. Radiocarbon (14C) data suggest that the retention time of groundwater in the tectonic zone is long in comparison with that outside the tectonic zone. In conclusion, the Motoarakawa tectonic zone groundwater is assumed to have been recharged by either precipitation under cooler climate condition than the present, or groundwater and/or river water originated from precipitation on high altitude areas around the Kanto plain. It had been put under an isolated hydrologic environment for a long period of time with respect to the regional groundwater system, resulting in highly-evolved water chemistry with an elevated Cl- concentration. Contribution of pore water (formation water) squeezed out of the adjacent aquitards and/or deep-seated groundwater can be cited as another possible sources of water and Cl- for this tectonic zone groundwater.

***Keywords:*** cl rich groundwater, multi isotopes, groundwater flow

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**HW1001** **Poster presentation** **4436**

# Variations of stable isotopes in rainfall over Indonesia related to the MJO

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Daily rainfall and stable isotopes of water (Oxygen-18 and Deuterium) were observed from 2001 to 2003 at 5 stations over Indonesia. Pentad mean rainfall and Oxygen-18 variations from November 2002 and May 2003 were compared with the MJO indices from CPC/NOAA. Time series in Oxygen-18 of rainfall were clearly corresponded to the MJO indices at 100E at 2 stations in Sumatra Island, but not corresponded to the MJO indices at 120E at 3stations in Bali and Sulawesi Islands. This result shows that the MJO related convection activities can reach to the Sumatra Island, but cannot to the Bali and Sulawesi Islands. However, rainfall variations at all stations were not corresponded to the MJO indices. These results show only stable isotopes can catch the MJO-related activities over Indonesia. Using both Rayleigh-type Isotope Circulation Model and Colored Moisture Analysis (Yoshimura et al., 2003; 2004), origins of rainfall were estimated at all stations. The Indian Ocean and Java Sea origins were larger than other origins at 2 stations in Sumatra Island and 3 stations in Bali and Sulawesi Islands, respectively. Also, pentad mean rainfall and Oxygen-18 variations during 2001 at 2 stations in Sumatra Island were compared with the MJO indices. Time-series in Oxygen-18 of rainfall at 2 stations showed low (high) values when MJO activities were active (inactive). It means that water vapor which has low isotopic values by large-scale transportation were more (less) than water vapor which has high isotopic values by local circulation during the MJO active (inactive) phase.

***Keywords:*** stableisotopesofwater, indonesiamaritimecontinent, mjo

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**HW1001** **Poster presentation** **4437**

# Isotope tracing of hydrological processes in the upper Motueka River Valley, New Zealand

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***Tim Davie, Joseph Thomas, Timothy Hong***

Isotope tracing (oxygen-18, tritium) has been used to investigate water sources and residence times, and groundwater/surface water interaction in a riverine valley setting. The study area encloses about 50% river valley with inflowing and outflowing rivers, and 50% steep hill country between the valleys. Bedrock is low-permeability Moutere Gravel of Pleistocene age derived from greywacke, which underlies the valleys and forms the hills. Shallow permeable river gravel terraces of late Quaternary and Holocene age have infilled the valleys, and are tapped for groundwater supplies. The isotope measurements show that the groundwater is predominantly derived from the main stem river systems. Mean residence times of water in the river were 1-4 months, while those of groundwater in the river terraces were 2-14 months. No significant regional flow contribution from the underlying Moutere Gravel to either the rivers or groundwaters was observed. The work supports concurrent groundwater/surface water hydraulic interaction modelling in the valley.

***Keywords:*** gw sw interaction, residence times, water sources

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**HW1001** **Poster presentation** **4438**

# Comparing event-based observed and estimated mean response times at the catchment scale

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A characteristic response function (CRF) is a hydrograph recession occurring after a catchment achieves steady-state storage. Such a conditions may not occur very often (if ever) in nature. In the summer of 2006, six days of successive monsoon storm events occurred in the Santa Catalina Mountains located north Tucson, Arizona, USA leading to extremely wet conditions and some of the highest stream flows ever observed for this semi-arid environment. These conditions might provide a good approximation for a CRF making it possible to estimate the catchments mean response time using hydrological observations. Concurrent to these events, stable isotopes (18O and 2H) were measured in stream flow and rainfall at high temporal resolution at two catchment scales (8 km2 and 91 km2). Rainfall isotope values were highly variable both between and during storm events. This variability, in addition to the high temporal resolution of sampling, allowed for estimation of event-based mean response times through the two catchments. These isotopically determined event-based mean response times are compared with hydrologically determined mean response times estimated using the storm recession hydrographs. Through this comparison, it is possible to gage how readily a critical response function might occur in nature. In addition, relations between these CRFs and existing similarity indices, such as the hillslope Pe number, will be explored.

***Keywords:*** mean response time, cathment

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**HW1001** **Poster presentation** **4439**

# Study on runoff mechanism of baseflow in a small forested catchment with a thick weathered layer

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In East Asia, where the origins of precipitation water vapours change seasonally, the fluctuation in deuterium excess (d = δD-8δ18O) of precipitation is large (Kondoh and Shimada, 1997). Kabeya et al (2007) estimated MRT (mean residence time) of subsurface water using seasonal variation in deuterium excess in a small granite headwater catchment, Japan. In order to check the validity as a MRT estimation tracer of d value, it retested at the catcthment having another geology and subsurface structure (Tsukuba Experimental Watershed). This study watershed is underlain by gneiss. The annual precipitation and runoff from 1979-1990 except 1988 were 1429.1 mm and 641.6 mm, respectively. Stream water and spring water were collected at the time of the baseflow on a fine weather day. The MRTs of stream water and spring waters were about 1 or 2 years. As for the shapes of system response functions, there is almost no contribution of the rain which fell in the past 100 days. This is considered to originate in it taking time that rain water has permeated thick soil layer and reaches a groundwater table. The MRT of stream water from whole catchment was 1.3 years by the DM and 2.2 years by the EPM, which correspond to mobile water storage volumes of 834.1 and 1411.5 mm, respectively (i.e. Vm=tQ, where Q is annual runoff). These values are within the limits of the amount of effective porosities of forest soil & loam and heavily weathered gneiss layers (1746 mm; effective porosity of forest soil & loam and forest soil & loam was set to 0.3 and 0.2 from the soil moisture retention curve, respectively).

***Keywords:*** baseflow, mean residence time, gneiss catchment

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**HW1001** **Poster presentation** **4440**

# Stable isotopes as a tool to estimate the evaporation under an arid to semi-arid climate: Case of the Euphrates and Orontes Rivers, Syria

***Dr. Zuhair Kattan***
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Surface water resources in Syria are primarily linked with two main important rivers, the Euphrates and the Orontes Rivers . The Euphrates River (entire length of about 2900 km, and basin lands rounded 350,000 km2), is not only the largest river in the country, but also the largest fluvial axe in western Asia. This river takes its resources from the mountainous regions of eastern Turkey, and flows southward within lands belong to Syria and Iraq, until joining the Gulf. The annual average discharge of the Euphrates River at the Syrian-Turkish border is ≈750 m3/s, and approximately 94% of the river flow is originated from Turkey. The large lake, so-called "Al-Assad" (long about 80 km, and volume ≈11.9 billion m3) is the biggest artificial reservoir, being formed in country as a consequence of the Euphrates Dam construction across the course of this large river. The Orontes River, with its total long rounded 487 km, is the second important river in the country. This river takes its resources from northern Lebanon at an altitude of 910 m above sea level, and flows northward within Syrian lands in a narrow valley. Before joining the Mediterranean Sea, the river changes its direction from north to west. Qattineh and Al-Rastan Lakes (average volume rounded 215 and 250 million m3, respectively) are the main artificial reservoirs, being exist on the course of this river. The purpose of this study is to present the estimates of water losses by evaporation from the Qattineh and Al-Assad Lakes. Stable isotope ratios of the Orontes River waters were periodically (4 times) measured during the period 1997-1999 at eleven upstream stations, including two sites each on both the Qattineh and Al-Rastan Lakes. In the case of the Euphrates River, the isotopic composition of the river waters were monitored on a monthly basis at twelve sites along the river course, from the Syrian-Turkish border until the Syrian-Iraqi border during the period 2004-2005. Analyses of stable isotopes (18O and 2H), were determined in the Geology Department at the Syrian Atomic Energy Commission, using a Finnigan Mat Deltaplus mass spectrometer, where the measurement accuracy for 18O and 2H are 0.1 and 1.0 , respectively. The spatial distributions of the isotopic composition of the Orontes River along the selected sites show generally depleted values and neglected variation in the upper three stations. Cornerwise, as the river enters the Qattineh Lake a considerable shift of the isotopic composition (≈5 for 18O) can be seen at the exit of this lake (site no. 5), simply because of fractionation by evaporation. The special evolution of the deuterium excess, as an indicator of evaporation, permits to observe that the lowest values (below 8) are linked with the Qattineh and Al-Rastan Lake waters, proving hence the important role of evaporation under such a semi-arid climate. Noting that the d-excess value of local rainfall is normally about 20-22. Similarly, it can be observed in the case of the Euphrates River that the river water of two upstream stations was isotopically depleted, and latter become more enriched by evaporation as the water is stored in the Al-Assad Lake. In parallel, the spatial evolution of the d-excess values along the river course permits the distinction between the above two water groups: (1) the less evaporated waters of the two upstream stations, having low d-excess values (d-excess>12) and (2) and the evaporated waters of the remaining stations, distinctly of lower d-excess values (9-11). The enrichment of heavy stable isotopes by evaporation from the surface waters of the Euphrates and Orontes Rivers was used, as a direct indicator, to estimate the magnitude of water losses from the Qattineh and Al-Assad Lakes. Thus, an experimental evaporation study was conducted by collecting a water sample of 1 liter volume from the Euphrates River at the Syrian-Turkish border, and keeping it evaporated under natural condition. After different evaporation stages, analyses of 18O and 2H concentration were determined for this sample, together with measuring the water loss at each stage. The relationships

between the stable isotope compositions and the fraction of evaporated water (f) shows that as the isotopic composition of evaporated water approaches 0 for both 18O and 2H, the fraction of water loss by evaporation (f) becomes close to about 50 % of the initial water volume, and a good linear regression (R2 > 0.99) exists between the f values and the isotopic compositions within this range. However, as the evaporation process progresses towards higher values (0.5

***Keywords:*** hydrologystableisotope

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**HW1001** **Poster presentation** **4441**

# Managing Aquifer Recharge (MAR): assessment of groundwater resources in the sand dune coastal area of Binh Thuan, Southeast Viet Nam

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This paper presents the results obtained within the project Fighting against desertification; Groundwater Artificial Recharge in Binh Thuan Province, Viet Nam during the period 2004-2006. The objectives of the project are a) to built up an experimental pilot project in the sand dune area of Binh Thuan Province, as an example of artificial recharge in Southeast Asia, b) to assess methodologies and effectiveness of groundwater management through groundwater recharge technologies, c) to transfer knowledge and experience of augmenting groundwater resources by artificial recharge to scientists, d) to inform governments, donors and stakeholders on the role of artificial recharge in water supply and groundwater management, e) to supply with good quality water the communities periodically affected by longstanding droughts. The pilot project area is located in the Binh Thuan Province along the coastal plain in the lower part of Central Eastern Viet Nam, 200 km East of Ho Chi Minh City. Due to an uneven rainfall distribution and a four months period (from December to March) characterized by very little precipitation, the area suffers considerable water shortage during the dry season. The geological setting of the area is characterized by a ryo-dacitic bedrock (aquiclude), which forms steep isolated hills overlain by Pleistocene-Holocene sand dunes (up to 200 m a. s. l.) of marine and continental origin. Extensive geophysical, hydrological and isotopic investigations, including drilling campaigns, long term pumping tests and continuous monitoring of ground water levels in 4 monitoring wells, show that the sand dunes formation is characterized by the occurrence of an unconfined porous aquifer, of variable thickness (40 to 60 m), emerging at ground level in depressed morphological areas (20 to 30 m a.s.l.) where it forms intradune wetlands or natural reservoirs (lakes), and discharging directly to the sea through single springs (up to 200 l/s), linear springs and mostly by diffuse seepage along the shoreline (approximate discharge equal to 30 l/s per km). Hydrochemical and isotopic characterization of surface and groundwater in different periods, shows that the sand dunes aquifers, with electrical conductivity ranging from 50 to 500 µS/cm, are composed of different water types, characterized by complex mixing processes. The site chosen for the artificial recharge, where a 162 days pumping test has been carried out, proved that the use of the bank filtration technique has considerably improved the quality of water, originally highly contaminated by colibacteria. The well field developed within the present project is now capable of supplying 220 m3/day of good water quality to the Hong Phong community, recurrently affected by severe droughts. This project is part of UNESCO-IHP (International Hydrological Programme) and IMET (Italian Ministry for the Environment and Territory) Water Programme for Africa, Arid and Water Scarce zone - Viet Nam component funded by IMET. Funds for the Viet Nam project were also made available from the Vietnamese Government, and from ICSU, the International Council for Science and UNESCO Office Jakarta.

***Keywords:*** water stable isotopes, groundwater resources, sand dune aquifer

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**HW1001** **Poster presentation** **4442**

# Influence of irrigation canals on groundwater discharge into a coastal lagoon from southern Brazil: Evidence from geochemical tracers (radon, methane, and radium isotopes)

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We investigate the distribution of naturally-occurring geochemical tracers (222Rn, CH4, 223Ra, 224Ra) in the water column and groundwater of Mangueira Lagoon, Southern Brazil, as proxies of groundwater discharge. Mangueira Lagoon is a shallow water body and part of the largest coastal lagoon system in the world (the Patos-Mirim-Mangueira system). Sampling was carried out in August 2006 after a period of high precipitation. While the activities of 222Rn in shallow groundwater of Mangueira Lagoon basin were 2-3 orders of magnitude higher than in surface water, CH4 and radium isotopes were only 1 order of magnitude higher. Therefore 222Rn is the preferred groundwater tracer in this system. The relatively small enrichment of radium and CH4 in groundwater is because the aquifer is fresh and oxic. In fresh water, radium is highly particle reactive and becomes much less so with an increase in salinity. Methane, in turn, is found in high concentrations in reducing systems, where conditions are favorable for methanogenesis. Tracer concentrations did not show any clear covariance with conductivity, pH, or Eh. This implies multiple sources that are a function of the little known underlying local geology. Shore perpendicular transects were sampled from the pump house of selected irrigation canals to nearly 1000m offshore. Groundwater tracer and nutrient concentrations were higher near the pump house, consistent with a nearshore source. Decreasing radon concentration in the offshore direction can be modeled as a combination of mixing with low activity lagoon waters, radioactive decay, and emanation of radon into the atmosphere. The radon inventories, after making appropriate allowances for inputs and losses were used to estimate fluxes into the lagoon. We found that advection rates in the canals are nearly 2 orders of magnitude higher than along the beaches. This happens because the surface confining layer was removed from the irrigation canals during dredging, which may have serious implications for the management of coastal water resources. The irrigation channels may represent an important source of nutrients and other dissolved chemical elements and thus should be considered priority areas in future investigations in coastal lagoons from southern Brazil.

***Keywords:*** radon, groundwater, brazil

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**HW1001** **Poster presentation** **4443**

# The stable isotope composition of nitrate in the soil water at Ljubljansko Polje aquifer natural background

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Alluvial aquifer of Ljubljansko polje represents the main source of drinking water for the Municipality of Ljubljana. The purpose of our research was to determine the natural background concentrations and stable isotope composition of nitrogen in nitrate in the percolated water at Kleče Lysimeter station. The soil water was collected weekly in a lysimeter in the unsaturated zone at a sampling station located in the unpolluted grassland within the water protection area of the water field Kleče at the northern edge of the urbanized area of Ljubljana city during 3 years (2003-2005). The wider area around the station hasnt been fertilized or otherwise affected by anthropogenic activities during last few decades. The precipitation water percolates through a 4 m thick profile, consisting of pebble covered by an approx. 20 cm thick soil layer. The results were consequently compared with the concentration and isotopic composition of nitrate nitrogen in rainfall water. Weve got the information about nitrate input by precipitation, concentration gradient and isotope concentration changes thru the soil profile where due to microbiological processes the vast majority of transformations are taking place within. The δ15N values of nitrate varied between -0,5 and +11 and generally followed the trends of the nitrate concentration variations, although with some delay. The δ15N between 0 and +2, while the nitrate leached from the unpolluted vadose zone has δ15N between +4 and +8. A period of intensive denitrification was observed at the end of the dry and warm 2003 season, while during the following two years, denitrification didnt play a significant role in the observed system, or was masked by more intensive nitrate leaching from the soil profile.

***Keywords:*** nitratestableisotope, percolatedwater, naturalbackground

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**HW1001** **Poster presentation** **4444**

# Defining flowpaths and connections between lakes and wetlands: evidence from physical and isotope hydrology

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***John Gibson***

This paper presents first hydrology results from 5-year study of aquatic sensitivity to acid deposition in the oil sands region of northeast Alberta, sponsored by the NOxSOx Management Working Group of the Cumulative Environmental Management Association (CEMA). Two lake basins were selected for detailed study in the vicinity of Fort McMurray in areas typified by extensive wetland cover, very low topographic relief (<20 m), and poorly developed drainage patterns. This study aims to describe the surface and shallow groundwater hydrology of two basins, and to quantify the vertical water balance for each, to identify dominant flow pathways and areas of significant depression storage, and to apply isotope and geochemical tracers to label water as it moves through the hydrologic cycle.. Soil and vegetation surveys performed throughout the two watershed areas are used to classify the landscape into terrain types and assist in the selection of suitable sites for the establishing of a groundwater monitoring network. Two climate stations were established in each catchment (one in the lake and one on land) to quantify climate variability at the local scale and for application in estimating evaporation using several energy balance methods (e.g. Priestley-Taylor, Penman combination methods). Continuous shallow water table and periodic (biweekly) deep piezometer water level measurements are used to calculate a vertical water balance. Discussion will include LiDAR/GIS applications used to delineate catchment boundaries, surface flow paths, and describe morphological characteristics of the catchment areas, vertical water budgets for the shallow water table and vertical and lateral hydraulic gradient estimates of hydraulic conductivity for piezometers, and identification of isotopic and geochemical gradients in this system. Implications for acid sensitivity modelling will also be introduced.

***Keywords:*** wetlands, flowpaths, isotopes

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**HW1001** **Poster presentation** **4445**

# Seasonal and spatial variations of water stable isotopes along the main stem of Yangtze River, China

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The isotope compositions of hydrogen- and oxygen-isotope in river water are very useful tools for tracing hydrological processes and hydrological cycle related to climate changes and anthropic activities in large-scale river basin. Since 2003, recovered 170 water samples from the 1st water campaign and 1-year regular monitored at 4-station along the main stem of Yangtze River are analyzed. As expected, the isotopic compositions (hydrogen- and oxygen-isotope) are progressively increased from upstream to downstream. New water body coming to the main stem of Yangtze River from different tributaries, evaporation, farming are the main reasons of isotopic spatial variations in river waters. The results revealed that temporal and spatial variations in the oxygen- and hydrogen-isotope of water sampled along the main stem of the Yangtze River strongly relies on the isotopic patterns of the regional precipitation. Moreover, signatures derived from influx of evaporatively enriched waters through the several reservoirs or lakes along the system will be resulted in d-excess values increasing. Furthermore, a very interested behavior of the river water isotopic temporal variations that the isotopic compositions are expressed as gradually increasing from the beginning to the end of the low water standing period at site can be observed. The increase or decrease of isotopic compositions depends on the river water is dominant by the ground water or surface water. The peak of the river water isotopic temporal variations is good corresponding to the boundary of the beginning for annual flooding period or of the ending for low water standing period at site. Obviously, the peak and valley of the river water temporal isotopic variations can be used to determine the length of flooding period or low water standing period, and it is a good indicator to split wet and dry season at a given location for a water year.

***Keywords:*** anthropic activities, flooding period, isotope

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**HW1001** **Poster presentation** **4446**

# Application of 222RN for the assessment of groundwater / surface water interactions of Meromictic lakes

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The exchange of water between lakes or rivers and hydraulically connected aquifers provides a major pathway for chemical transfer between the respective water bodies. For instance, the migration of dissolved carbon, oxygen, and/or nutrients coupled to such exchange processes has to be considered a main driver for biogeochemical processes on both sides of the surface water/groundwater interface. Furthermore, dissolved contaminants, such as pharmaceuticals or heavy metals, are not only influential on the aquatic life and the biological properties of the affected water body, but also on its overall water quality. Generally speaking, if the status of a surface water or groundwater resource is to be assessed or its fate to be predicted it cannot be looked at as a separate aquatic system but interactions at the surface water/groundwater interface have to be taken into account. A particular problem in this field of research is groundwater exfiltration into open-pit lignite mining lakes. It was shown by many authors that the special geochemical situation given in such cases is likely to trigger significant degradation of the lake water quality (Knöller and Strauch, 2002; Knöller et al., 2004). Lake water acidification due to oxidation of sedimentary iron sulfides (pyrite, FeS2) can be named as one of the hydrochemical problems typically connected to such aquatic systems. Here the precipitation of dissolved iron, entering the lake via groundwater exfiltration, triggers the release of protons, i.e. the drop in pH in the lake water. Poor ecological properties of the lake and a resulting negative impact on the general economic value of the respective post mining area are the consequence. Hence, qualitative and quantitative understanding of groundwater/lake water interactions and tracing of pathways between aquifers and hydrologically connected surface water bodies are essential to the prediction of the development of the respective (drinking) water resources. The quantification of groundwater fluxes into a meromictic lignite mining lake (Lusatia Mining District, Germany) was assessed by means of a geochemical tracer technique using the naturally occurring radio isotope 222Rn. The noble gas makes an ideal environmental tracer because of its chemically inert behavior and its ubiquitous presence in groundwater, where it appears in concentrations well above the concentrations found in surface waters (Nazaroff & Nero, 1988). In a long-term project radon concentrations in the water of the studied mining lake and in the groundwater of surrounding monitoring wells were determined every moth over a two-year period. Evaluation and interpretation of the data set allowed for assessing the dynamics of the groundwater / surface water exchange processes. It could be shown that there is a high variability in the groundwater / surface water interaction rate, depending on changes of the (seasonal) precipitation rate, even within very short time scales. References: Knöller, K., Strauch, G., 2002. The application of stable isotopes for assessing the hydrological, sulfur, and iron balances of acidic mining lake ML111 (Lusatia, Germany) as a basis for biotechnological remediation. Water Air Soil Pollut. Focus 2, 3-14. Knöller, K., Fauville, A., Mayer, B., Strauch, G., Friese, K., Veizer, J., 2004. Sulfur cycling in an acid mining lake and its vicinity in Lusatia, Germany. Chemical Geology 204, 303-323. Nazaroff W.W., Nero A.V. jr. (1988). Radon and its Decay Products in Indoor Air. John Wiley & Sons, New York/NY/USA.

***Keywords:*** lakewater groundwater, interaction, 222 radon

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**HW1002** **4447 - 4491**

**Workshop**
**Patterns, thresholds and non-linearities: Towards a new theory of catchment hydrology (Sponsor PUB)**

**Convener :** Prof. Peter Troch

Catchment hydrology is presently operating under an essentially reductionist paradigm, dominated by small-scale process theories. Yet, hydrology is full of examples of highly complex behavior, including strong nonlinearities and thresholds, and paradoxes that defy causal explanation through these small-scale process theories. There are strong interactions and feedbacks between processes, leading to apparent simplicities in the overall catchment response, yet the laws governing these feedbacks are not well understood. Routine measurements and specialized field experiments have been valuable for observing catchment responses and understanding the underlying process controls, but there has been little progress in extrapolating the local knowledge and understanding gained from these well studied (or gauged) catchments to ungauged catchments. Efforts at generalization are hampered by the lack of an appropriate quantitative framework, for example, a classification system, to help identify interesting and useful patterns in the observations. There are many theories governing different elements of catchment hydrology, but not a unified theory that connects these seemingly disparate elements. This session solicits contributions that address how multi-scale heterogeneities, nonlinear dynamics and feedback mechanisms affect the predictability of hydrological dynamics at multiple scales in different biomes and explore new ideas of multi-scaling, nonlinear systems, self-organisation, pattern dynamics, etc. for developing a radically new theory of catchment hydrology.

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**HW1002** **Oral Presentation** **4447**

# Patterns of predictability in hydrological threshold systems

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Observations of hydrological response often exhibit considerable scatter that is difficult to interpret. In this paper, we examine runoff production of 53 sprinkling experiments on the water-repellent soils in the Ticina, Switzerland; simulated plot scale tracer transport in the macroporous soils at the Weiherbach site, Germany; and runoff generation data from the 2.3 km Tannhausen catchment, Germany, that has cracking soils. The response at the three sites is highly dependent on the initial soil moisture state as a result of the threshold dynamics of the systems. A simple statistical model of threshold behavior is proposed to help interpret the scatter in the observations. Specifically, the model portrays how the inherent macro state uncertainty of initial soil moisture translates into the scatter of the observed system response. The statistical model is then used to explore the asymptotic pattern of predictability when increasing the number of observations, which is normally not possible in a field study. Even though the physical and chemical mechanisms of the processes at the three sites are different, the predictability patterns are remarkably similar. Predictability is smallest when the system state is close to the threshold and increases as the system state moves away from it. There is inherent uncertainty in the response data that is not measurement error but related to the observability of the initial conditions.

***Keywords:*** threshold, predictability, initial conditions

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**HW1002** **Oral Presentation** **4448**

# The feasibility of the models of everywhere concept

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***Keith Beven***

Beven 2006 [Beven, K.J., 2006. Working towards integrated environmental models of everywhere: uncertainty, data, and modelling as a learning process. Hydrology and Earth System Sciences, in press.] introduced the concept of models of everywhere. The paper discusses a new philosophical framework for hydrological models, where catchments (or places in a more general sense) are treated as flexible and interrelated objects embedded in a distributed modelling environment. Here, more practical implications of how such a model could be implemented are discussed as well as existing efforts such as HarmonIT. First, the concept of models of everywhere relies to an extreme extent on (most likely distant) communication between data sources (and sinks), model objects and model structures. It is thus necessary to develop communication protocols, as well as standards for the storage of any type of hydrological and more generally environmental data. A second important aspect of the models of everywhere concept is the possibility of parallel implementation of model structures. Such a parallel implementation is necessary to deal with the uniqueness of place problem, but it also allows for a more flexible framework to evaluate, update and possibly reject particular model structures. In current computer technology and software techniques, many different solutions for this problem are available, but the advantages and disadvantages of each solution should be carefully balanced. As an example, new versions of both topmodel and dynamic topmodel are presented. These versions are written as generic dynamic libraries and as such are computer computer platform independent. It is shown how they are easily wrapped as functions in a high level mathematical environment such as R or Matlab, allowing for fast and convenient model comparison, visualisation, updating and bayesian averaging.

***Keywords:*** hydrological modelling, modelling frameworks, distributed modelling

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**HW1002** **Oral Presentation** **4449**

# Effects of Topography on Vegetation-Hydrology Interactions in a Semiarid Grass Ecosystem

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It is commonly observed that topography strongly affects the state and distribution of vegetation. This topographic effect is normally considered to operate through the regulation of the incoming solar radiation and lateral redistribution of water and elements. Nevertheless, largely unexplored questions are how plants adjust to terrain effects relative to their location in a landscape, what the implications are for the spatial distribution of the water balance, and whether catchment vegetation-hydrology dynamics can be generalized in the form of terrain indices. In this study, we address vegetation-water-energy dynamics in a semiarid area characteristic of central New Mexico by constructing a dynamic coupled model based on physical, biochemical, or mechanistic representation of individual processes. The modeling system, tRIBS+VEGGIE, considers essential water and energy feedbacks over the river basin and links them to the basic plant life regulatory processes. In a set of numerical experiments, we examine linkages between terrain attributes, patterns of vegetation productivity, and water balance components. For different imposed regimes of lateral water transfer, we identify regions of relative vegetation

***Keywords:*** ecohydrology, topographic control, vegetation water energy

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**HW1002** **Oral Presentation** **4450**

# Advances to Catchment Theory from Ecohydrological Patterns and Feedbacks in Complex Terrain

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One of the major challenges in catchment hydrology is identifying the interrelated spatial patterns in landscape properties that control basin response. In semiarid regions, terrain attributes, such as elevation, aspect and curvature, exert a strong control on water availability through subtle variations in the surface energy and water balance. These differences can lead to dramatic changes in ecosystem structure and composition with subsequent long-term effects on soil development and geomorphic processes in opposing hillslopes. In this study, we present field observations in a series of first order basins in central New Mexico which exhibit banded vegetation and soil patterns that closely follow topographic position. We utilize these field observations to present a conceptual model of the interactions and feedbacks between vegetation, soil properties and landscape attributes. This conceptual model is utilized to formulate theoretical arguments on the role played by vegetation in semiarid regions characterized by complex terrain. The strong topographic control on vegetation and soil distribution is used as an organizing principle for catchment hydrology in semiarid regions across a range of scales.

***Keywords:*** ecohydrology, topography, semiarid

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**HW1002** **Oral Presentation** **4451**

# Predicting the daily streamflow of ungauged catchments by regionalising rainfall-runoff model parameters

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A methodology has been derived which allows an estimate to be made of the daily streamflow at any point within the Burdekin catchment in the dry tropics of Australia. The input data requirements are daily rainfall (to drive the rainfall-runoff model), and mean average wet season rainfall, total length of streams, percent cropping and percent forest in the catchment (to regionalise the parameters of the rainfall-runoff model). The method is based on the use of a simple, lumped parameter rainfall-runoff model, IHACRES. Of the five parameters in the model, three have been set to constants to reflect regional conditions, while the other two have been related to physio-climatic attributes of the catchment under consideration. These relationships have been shown to be applicable over a range of scales from 68 km2 to 130,146 km2, The invariance of the relationships with scale indicates that the dominant processes may be similar across a range of scales, while the fact that different relationships were required for each of the three major physiographic regions of the Burdekin indicates the geographic limitations of this regionalisation approach. For most of the 24 gauged catchments within the Burdekin the regionalised rainfall-runoff models were nearly as good as or better than the models calibrated to the observed streamflow. In addition, many models performed better over the simulation period than the calibration period. This indicates that future improvements in regionalisation may come through improving the quality of input data and rainfall-runoff model conceptualisation rather than on the regionalisation procedure per se.

***Keywords:*** hydrologic regionalisation, rainfall runoff model, top down modelling

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**HW1002** **Oral Presentation** **4452**

# Application of a non-metric and non-parametric classification scheme to catchment hydrology

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Catchments Classification (CC) has been considered a fundamental step to improve the science of catchment hydrology. Classification has been traditionally carried out via Linnaeus-type cluster analysis, mainly represented by hierarchical approaches and methods based on partitioning of hydrological data set. This paper proposes a new scheme where the classification procedure is based on similarity interpreted as distances between catchments. The similarity or distance is defined under the following premises: 1. similar catchments behave similarly; 2. similarity can be described with catchments characteristics; and 3. hydrological models are able to capture catchments similarity. In other words, if many sets of model parameters lead to similar model performance for two catchments, they are considered as similar catchments. To implement the proposed scheme, two algorithms, namely multidimensional scaling and local variance reduction are tested. They are both non-metric and non-parametric approaches to construct a configuration of n catchments characteristics in Euclidean space using information about similarity between the catchments. The classification is established by searching for a transformation matrix through optimization towards a globally optimal objective function. The scheme avoids the idea of parametric regression-based regionalization approaches where a regression function is pre-defined between model parameters and catchment characteristics. In the regression-based approach, the function that is selected is usually subjective and arbitrary and one can also argue that a priori function is neither able to represent highly non-linear hydrological processes nor consider the interdependences amongst model parameters. The proposed scheme is initially tested with a research version of the HBV-IWS model on a number of catchments within the Rhine Basin. Additionally a modified Xinanjiang model is applied to the same catchments to check if the assumption of invariant catchment similarity holds true. Invariant catchment similarity here assumes the catchments genuinely carry their similarities independent of the model used for simulation. This test is also a backstop measure to determine if the models under consideration are capturing the underlying simplified hydrological processes in a rational manner. The scheme will be extended to regional calibration of rainfall runoff models as well as regional drought or flood studies once similarity within catchments has been established.

***Keywords:*** catchment classification, multivariate analysis, regional calibration

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**HW1002** **Oral Presentation** **4453**

# Patterns, thresholds and non-linearities at the hillslope scale: testing the fill and spill hypothesis

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Work at the Panola Mountain Experimental Watershed trenched hillslope (Atlanta, GA) and elsewhere has shown that formation of transient groundwater in bedrock depressions and connectedness of these patches during storm events is a precondition for the generation of subsurface stormflow. This fill and spill hypothesis has been proposed as a macroscale theory of sorts for observed patterns, thresholds and non-linearities at the hillslope scale. While there are clear threshold relations between subsurface stormflow and storm total precipitation, resolving the linkages between rainfall input, soil water recharge, transient groundwater formation and resulting subsurface stormflow has been difficult. Part of the problem is that we lack observational capabilities to interrogate the distributed internal slope response to storm rainfall. Even more problematic is our inability to quantify key boundary conditions like the permeability contrast at the soil-bedrock interface and its spatial variability. These challenges stand it the way of the further development of this macroscale theory. This paper uses a 3-D physically-based distributed model of the Panola hillslope (the TOUGH2 simulator) to model and visualize the linkages between storm rainfall, soil water recharge, transient groundwater development and resulting subsurface stormflow. We explore the effect of the bedrock permeability on the development of fill and spill behavior for observed storm events. Preliminary results indicate that an increase in the estimated characteristic bedrock permeability at the Panola hillslope can deteriorate and even eliminate the connected patterns of transient saturation developed during a storm event that result in subsurface storm runoff. Our 3-D visualizations and virtual experiments with different bedrock permeability values provide insight into how bedrock permeability, antecedent soil moisture and storm conditions conspire to create the patterns of transient groundwater and the resulting subsurface stormflow. We describe how these results affect the generality of the fill and spill hypothesis and how simple rule-based approaches may be used to predict fill and spill in ungauged catchments.

***Keywords:*** subsurface stormflow, connectivity, bedrock

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**HW1002** **Oral Presentation** **4454**

# Behavioral Modeling: A New Theoretical Framework for Hydrological Predictions

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***Bettina Schaefli, Ciaran Harman***

Watersheds are dynamical systems maintained by coupled biotic and abiotic processes, constrained by their evolutionary history, as reflected in certain organizing principles, as well as shaped by the unique historical circumstances of a given place. We present a new theoretical framework called "behavioral modeling" not just to describe and to understand watershed behavior but also to make hydrologic predictions. In this respect we view predictions in terms of making probabilistic statements about future system states (behaviors) given the current and past observed state and our understanding of how nature works. From this perspective, limits to predictability include: (a) system identification (boundary conditions, driving forces); (b) characterization of initial state based on all available information, (c) translation of our understanding of how nature works into a model of the system (dominant processes, process coupling); (d) appropriate mathematical representation (parameter, model structure uncertainty) to produce probablistic statements. The key to behavioral modeling is then to acknowledge the existence of the most probable system behavior conditioned by system evolution and inferable (in a Bayesian sense) at different moments, places and scales based on organizing principles (as expressed in a likelihood function) and observed behavior. The relative importance of local uniqueness as compared to (possibly universal) organizing principle(s) ultimately governs predictability. Behavioral modeling presents a whole new language: behavior includes both system structure, and system response that is conditioned by structure, which in turn governs the evolution of structure. Structure refers to the spatial or temporal arrangement of mass and energy within the system, and response refers to changes in time and in space. Behavior is observed at given points of the time-space-scale domain. Part of system behavior is unobserved; prediction is really about making probabilistic statements about unobserved system behavior either explicitly, or implicitly (encoding of system behavior in hydrologic models) on the basis of observed behavior and the identified organizing principle(s). We will discuss candidates for useful organizing principles and how to identify them, provide an outline of the steps involved in implementing behavioral models, illustrating how they combine with, and complete, existing models. We finally discuss the benefits of behavioral modeling for hydrologic predictions and for the design of new observation networks.

***Keywords:*** predictions, structure, response

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**HW1002** **Oral Presentation** **4455**

# Automatic evaluation of dominant runoff processes - a tool to estimate flood runoff for gauged and ungauged catchments

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The Allenbach (14 km2), a steep alpine catchment in Switzerland, reacts fast and intense to thunderstorms, whereas a neighbouring catchment of similar size (15 km2) and topography reacts delayed. This difference can be explained by different runoff formation. To assess the reaction of a catchment to heavy rainfall, it is thus essential to understand the occuring dominant runoff processes. A decision scheme was developed to determine the dominant runoff processes like Hortonian Overland Flow (HOF), Saturated Overland Flow (SOF), Sub Surface Flow (SSF) or Deep Percolation (DP) on the plot scale. The decision scheme was implemented in a GIS, using high resolution data of soils, geology, land use and topography and applied for an area of 1730m2, covering a wide range of topography, geology and flood producing precipitation regimes. With the resulting map, process based rainfall runoff models could be applied successfully in gauged and ungauged catchments. To determine the DRP automatically with the above described method, high resolution soil maps are required. If not available, the required hydrological soil parameters like soil depth, grain size distribution and soil water regime can be derived from geological and topographical information. This is well feasible in alpine catchments, where soil formation depends strongly on topography and geology. In the Swiss Plateau, soil formation is more complex and depends on different factors, which are not easily recognisable. Soil forming factors were identified in areas, where high resolution geological and soil maps and soil profile samples are available. A decision scheme is under development, using this knowledge together with a high resolution laser scanned DEM, to determine the required hydrological soil parameters. The potential of this approach is also discussed.

***Keywords:*** runoff process mapping, rainfall runoff modeling, gis models

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**HW1002** **Oral Presentation** **4456**

# On catchment classification, hydrologic similarity and predictions in ungauged basins

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Hydrology does not yet posses a generally agreed upon catchment classification system. Such a classification framework should provide a mapping of landscape form and hydro-climatic conditions on catchment function (including partition, storage and release of water, ecosystem services etc.), while explicitly accounting for uncertainty and variability in temporal and spatial scales. This framework would provide an organizing principle, create a common language, guide modeling and measurement efforts, and provide constraints on predictions in ungauged basins as well as on estimates of environmental change impacts. Achieving this objective requires that we can collapse the vast complexity of the catchment system into simple parsimonious representations, e.g. using dimensional analysis, and relate them to hydrologically relevant signatures which represent the function of interest. In this paper we [1] review existing approaches to define hydrologic similarity and to catchment classification; [2] discuss outstanding components or characteristics that should be included in a classification scheme; and [3] provide a basic framework for catchment classification as starting point for further analysis. Possible metrics to describe form, hydro-climate and function are suggested and discussed. We close the discussion with a list of requirements for the classification framework and open questions that require addressing in order to fully implement it. Open questions include: How can we best represent characteristics of form and hydro-climatic conditions? How does this representation change with spatial and temporal scale? What functions (partition, storage and release) are relevant at what spatial and temporal scale? At what scale do internal structure and heterogeneity become important and need to be considered?

***Keywords:*** catchments, classification, similarity

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**HW1002** **Oral Presentation** **4457**

# Hydrologic Cycle in a Changing World: A Complex System Perspective

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The pathways through which the water moves in the global water cycle are changing, often rapidly, in response to anthropogenic influences such as climate change, land use/land cover change, and urban and agricultural expansions. While on the one hand the pathways through which water moves have been shaped by its own movement such as stream networks, changes in these pathways significantly impact the water cycle, both its variability and magnitude. This strong dynamic coupling between the flow of water and the medium of the flow introduces changes in the variability of the water cycle itself if the properties of the medium are altered, for example through anthropogenic influences. Examples included build up of reservoirs across the globe over the past two centuries at scales that affect the water cycle, or alteration of vegetation patterns through deforestation resulting in changes in moisture in the atmospheric column locally or in downwind regions which may result in further changes in streamflows, groundwater recharge, or ecosystem functions. Such linkages are only beginning to be acknowledged in contemporary hydrologic thinking. Indeed, hydrologic science is still broken up across the boundaries of the medium as reflected through the prevailing paradigms of surface water hydrology, ground water hydrology, wetland hydrology, etc. Although this paradigm is changing with the emergence of cross-disciplinary focus such as ecohydrology, hydropedology, hydrogeomorphology, etc., it merely creates new boundaries rather than recognizing the fundamental characteristics of the water cycle as a vehicle that enables interaction across all the global systems. The purpose of thispresentation is to articulate how the understanding generated from the recent developments in the complex systems theory can enable us to overcome this barrier and see the global hydrologic cycle from a holistic perspective as a connected system where each component can potentially impact another component. My proposed framework is based on the following propositions: P1. Water is both a medium and a driver of interaction for a variety of natural processes. The two roles are fundamentally different. As medium water provides habitat and life support system to all types of living systems. However, the flow of water, particularly its variability, is a very important driver for both ecological as well as biogeochemical functions. The role of water cycle variability as a driver has emerged as an important component of contemporary thinking while traditional approaches only recognize the former role. P2. Water cycle consists of a network of cycles that interact with each other, that is, the water cycle is a hypercycle. The interaction between these cycles provides a mechanism for the dynamic stability of the water cycle in the presence of a balance between positive and negative feedback cycles. Rapid changes occur when negative feedbacks are suppressed and the positive feedback cycle becomes dominant due to changes, gradual or rapid, that exceed a threshold. This results in establishment of new dynamic regimes that arise from new balances that are established between the positive and negative feedbacks. P3. Water cycle connects systems that are dissipative. Dissipative systems are thermodynamically open systems operating far from equilibrium and exchange energy, matter, and entropy with their environment. They are characterized by time irreversibility, contraction of phase-space volume, and the ability to possess attractors. The flow of water, particularly its variability, is an important agent for communication of information across the connected dissipative systems which in turn determine the evolutionary course of these systems through self-organization. In the presentation, I will first establish that hydrologic variability is fundamental to the existence of ecosystems and rapid changes to this have significant consequences. I will then argue that the framework of cycle of cycles, or hypercycle, rather than an input-output systems approach is the best way to understand the consequences of change through the lens of the hydrologic cycle. I will then argue that hydrologic cycle should be viewed not

merely as characterizing the flow of water, but more broadly to include its function as a driver of connected dissipative systems as the variability of these connected systems in turn modifies the variability of the water flow. Implication for sustainability and prediction will be then discussed.

***Keywords:*** complexity, hypercycle, dissipative

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**HW1002** **Oral Presentation** **4458**

# Global Application of Similarity Indices for Hydrology

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When hydrological similarity indices are derived from theoretical considerations and appropriate simplifications, they can provide guidance in the development of new hydrological theory. By starting at the climatological timescale, and assuming that the dominant features of the hydrological cycle are strongly affected by the form of water storage (i.e., frozen water, pore water, open water), new similarity indices are derivedwhich can be usedinsimple predictive models. Examples of the inputs variables for the pore water component include an aridity index, a cliamte seasonailty index, a rootzone storage index, and a scaled transmissivity. These are used as inputs to an analytical model, which predicts, for example, the average annual water balance of a soil column. A similar approach is used for other types of water storage. This paper presents quantitative tests of the predictive power of this new collection of similarity indices, which are used to predict average annual water balance, and average annual snow storage and meltcharacteristics. Global datasets are used to calculate the input similarity indices, and comparisons are made with globaldata sets. The sources of uncertainty in predictions are discussed, and quantified where currently possible.

***Keywords:*** global, hydrology, similarity

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**HW1002** **Oral Presentation** **4459**

# Understanding the water balance pattern using a water-energy coupled model

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Many regions in the world are facing serious water shortage and this situation will be more chaotic due to the climate and landuse change. It is desired to understand the climate and landuse change impacts on hydrological cycle and water resources. Using the data of northern in the last second half century, it will explain the changes in water balances and vegetation, and the inside mechanism from a coupled water-energy balance perspective. And this top-down methodology will be useful for prediction in ungauged basins. Increase in air temperature and decrease in pan evaporation was found to be common worldwide during the past half century. This results in controversy in view of the changes to the hydrological cycle. Increases in precipitation have been expected and the hydrologic cycle is expected to be intensified (or accelerated) with global warming. However, the decreased pan evaporation is found to be well related to the global dimming, i.e., the decreased solar radiation induced by the pollution increasing, thus evaporation should be steadily decreasing from the energy balance perspective. Many researchers explained that the potential evaporation (usually measured by pan) is decreased with increasing of precipitation; however, the increased soil moisture (due to precipitation increasing) can be evaporated because of extra energy available. Therefore, the actual and potential evaporation are in complementary relationship, which is expected to unify the controversy between global warming and dimming. This means that pan evaporation decrease implicates acceleration of the global hydrologic cycle, i.e., increase in the terrestrial evaporation. Based on the complementary theory, many operational formulae have been introduced to estimated actual evaporation from the potential evaporation. Our recent water balance analysis of 108 catchments in non-humid regions of China has shown that there are no general opposite trends between potential and actual evaporation in the same period. A novel phenomenon has been found that the complementary relationships in evaporation are distinctly confirmed when the annual actual and potential evaporation are plotted against annual precipitation; However, complementary relationships disappear in many catchments when actual and potential evaporations are plotted against the time (year) during the same period. This means that complementary idea cannot provide universally correct predictions on the trend of actual evaporation only from the potential one. In this research, we examine the coupled water-energy balance based on Budyko hypothesis and proposed a conceptual model for predicting the inter-annual variability of annual water balance, and the change trends of water balances due to climate changes.

***Keywords:*** water balance, climate change, budyko hypothesis

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**HW1002** **Oral Presentation** **4460**

# Soil Moisture Spatial-Temporal Patterns, Threshold Behaviors, and Their Relations to Subsurface Flow Network at the Shale Hills Catchment

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***Xiaobo Zhou***

Understanding complex subsurface heterogeneity and their relations to soil moisture spatial-temporal patterns and preferential flow dynamics are fundamental to catchment hydrology. Despite significant progress made in the past decades, our ability to predict preferential flow patterns, thresholds, and pathways in the subsurface across space and time remains limited. It appears that an internal network structure exists in the subsurface of many hillslopes, which governs vertical and lateral preferential flow dynamics and a threshold-like hydrologic response under different precipitation inputs, soil types, and antecedent wetness conditions. We investigated soil moisture spatial-temporal patterns, heterogeneity of soil moisture response to varying rainfalls, trigger of soil moisture jumps, subsurface network-like behaviors, and their relationships to varying precipitation-soil-landform-bedrock conditions in the Shale Hills, a humid forested catchment in central Pennsylvania, . We developed an integrated framework to understand the complex landscape-soil-hydrology relationships across scales, and to use the iterative cycle of mapping, monitoring, and modeling for understanding catchment hydrology. An integrated approach of soil-landscape mapping, geophysics, hydropedology, hydrometry, and real-time monitoring of soil moisture, precipitation, and stream discharge was used to investigate soil moisture from the surface down to bedrock throughout the catchment, as well as subsurface flow networks and their critical nodes (i.e., important junctions of flow networks in the subsurface that control the threshold behavior of subsurface stormflow). Based on our extensive soil hydrologic monitoring data collected, different soil hydrologic response groups that show contrasting wetting-drying patterns in response to rainfall events are proposed, which can help understand first-order controls of subsurface preferential flow at the pedon-, hillslope-, and catchment scales. Threshold behavior of soil moisture jumps has been observed in many situations. This study demonstrates the benefits of integrating pedological and hydrological expertise within the framework of hydropedology to enhance the monitoring and modeling of subsurface preferential flow patterns and its connection to soil-landscape conditions.

***Keywords:*** soil hydrology, preferential flow, subsurface network

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**HW1002** **Oral Presentation** **4461**

# Model lumping preserving the processes non-linearities and retaining the physically meaningfull parameters

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Presently, physically based distributed models are recognized to be the most successful and fertile way of simulating and investigating hydrological processes. Nevertheless the power of synthesis of the lumped models makes them scientifically very attractive. The interest in lumped models not only lays in the practical aim of using simpler models but even more in the theoretical implications involved in finding the dominant processes, namely the essential hydrological features, to be preserved in the lumping process. Historically, the evolution of hydrological models proceeded from the simple conceptual models to the more complex physically based ones, gradually introducing more complicated and comprehensive equations in the efforts of better reproducing reality. An interesting question is whether or not it is possible to directly set up a lumped hydrological model encapsulating the physical meanings and processes, without the need of setting up a distributed model. This would allow the direct transfer of the model to ungauged catchments. Starting from a distributed model, the present work follows two lumping procedures: (1) a structural lumping of the catchment, (2) an empirical lumping of the dominant processes. The first structural lumping aims at aggregating all the grid cells composing the catchment in just one single cell with equivalent hydrological properties. This requires a non trivial aggregation, of the distributed model parameters, defined in each single cell, into a unique lumped parameter value. The empirical lumping exploits the diagnostic skills of the distributed model to infer internal relations (such as the water volume saturated area relationship or the exfiltration) representing the dominant processes that are now based on average quantities. This empirical lumping, which allows to correctly preserve the description of the internal dynamics at the lumped scale, is achieved by deriving a set of functions via simulation with distributed model. An interesting phenomenon highlighted by this lumping gives is the hysteretic dependency of the saturated area on the mean soil water volume, which was also found by other authors. Following this approach one has to realize that only the distributed model can be exported on physical grounds to ungauged catchments, while its lumped version will again be derived with the proposed approach. An example of application to a real catchment will complement the theoretical description.

***Keywords:*** lumping, non linearity, physically based

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**HW1002** **Oral Presentation** **4462**

# Inference of runoff-generation spatial distribution using time-series data

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Time-series of stream stage and precipitation are shown to contain (implicitly) information on the spatial distribution of runoff-generation across catchments. We present a non-parametric approach to the estimation of the marginal probability distribution of runoff-producing areas within a basin. The method is demonstrated to be robust based on tests with synthetic data. The approach is then applied to several watersheds within a basin in Oklahoma. The estimated probability distributions based on time-series observations of precipitation and discharge reflect expected physiographic factors. Hillslope recharge-discharge patterns, surface water-groundwater interaction, and the emergence of riparian zones are examples of processes that contribute to the shape of the probability density functions. Finally a scalar and non-dimensional measure of Hydrologic Complexity is introduced to characterize the spatial variability of basin rainfall-runoff response behavior.

***Keywords:*** run off, time series

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**HW1002** **Poster presentation** **4463**

# Extraction of basin characteristics based on Dem and RS image

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Extracting basin characteristics from geographic information, especially from digital elevation model (DEM), is very important for hydrologic simulation. The limitation of spatial resolution of DEM results in a large error for basin characteristics extraction, especially in the depressions and plat areas. As a result, employing more amount of information is adopted for attempting to increase the precision of extracted properties. In this study, remote sensor (RS) images are employed to increase accuracy of DEM-based basin characteristics extraction. Water surface information, such as river channels and lakes, from RS image is overlapped on the DEM, and thus the combining information can be used for basin characteristics extraction. A grid-based watershed is produced on the basis of following procedures: (1) river flow direction is derived from elevation of channel-grids by the process called vectorization of gridded channels; (2) channel-grids are also looked as outlet of flow in other grids as edges of study area, flow direction within a non-channel grid is determined by using D8 and depression filled methods; (3) flow routing network is then produced after integrating all grid flow routes; (4) basin properties, such as flow route, water system and subbasins, are extracted from flow routing network. The essential difference between this method and others extracting properties by increasing information source is that elevation of each grid has not been changed in this method, which is beneficial to keep the information of DEM. This method is applied in the Sanmenxia-Huayuankou region of the Yellow River. The DEM used here is USGS GTOPO30. Comparison of watershed characteristics from the combining RS images and DEM and from solely DEM demonstrates that information from RS image reduces the effect of DEM-generated error, increases the precision of watershed properties extraction, especially in the depression and plain regions. For distributed hydrological modeling in a large region, this method offers a reliable way for watershed properties extraction.

***Keywords:*** basin properties extraction, remote sensor images, digital elevation model

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**HW1002** **Poster presentation** **4464**

# Catchment-based the genetic hydrology application

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*na IAHS IAHS*

***Eugen Gopchenko***

The genetic hydrology of Befani [1958, 1977, 2003] proposes detailed mathematical des-cription for overland flow generation and further surface runoff transformation processes unlike black box approaches. It is basing on watershed isochrones theory with using inner catchments inflow functions, and well applicable for contemporary hydrology as a generator of computer-based simulation procedures and computation approaches sensitive enough for reflecting both impacts on a watershed: human activity and the climate change. Hydrological system would be considered as a set of numerous spatial elements of two kinds - homogenous and unitary [Chebanov, 2004]. First kind elements represent spacious enough structures, considering as homogeneous (e.g., monolithic soil layers and continuous surface covers, structured drainage network fragments and river channels lengths). Unitary elements represent (under differential considering) elementary measures of properties of the heterogeneous spatial structures: intrusion a soil series in the complicated massif, a cavity as fragment of surface retention system, etc. Assessment of such structures common properties requires stochastic analysis. Peculiarities like distribution proportion and character of hydrologic interaction between the spatial elements during rainfall or snow-melting events it is switching the runoff process between a number of specific runoff generation mechanisms [by Befani, 1958]: suspended or Hortons mechanism; subsurface runoff mechanism; surface retention or accumulation mechanism; or other probable mechanisms. Appropriate watershed runoff model it might be composed as a set of procedures for simulation runoff mechanisms and their interactions. Simulation parameters and characteristics (of infiltration, subsurface delaying the runoff, surface retention, etc.) spatial localization might be connected with the runoff mechanisms expansion catchments [following Befani, 1977, Chebanov, 2004]. In this case, the lateral inflow catchments are serving as smallest objects of the simulation and as cells in the runoff mechanisms expansion areas. Those areas vary together with changes of covers and climate, and land use options. Transformation procedures of the catchments inflow into channel flow use isochrones method and consideration sections of flood-plane flow, alluvial flow and common flow [Befani, 1958]. Simplified genetic approach is developed as a formula for computations flood flow extremes [Gopchenko & Romanchuk, 2002]. The formula components are maximum overland flow modulus and transformation function of the overland inflow hydrograph subsidence; also it is using parameter of flood subsidence by flowing lakes and reservoirs in the watershed (impoundment) and factor of riverbed and flood-plane influence on the outlet hydrograph subsidence. All the formula parameters are definable for ungauged watersheds with processing of maps or GIS layers, and water gauges data in the local and regional network. Proposed formula real advantage lies in the fact that it takes into consideration most of overland and channel flows factors. Testing on gauged and ungauged watersheds of Ukraine indicate good precision in comparison with regular schemes. LIST OF REFERENCES Befani, A.N. (1958) Basics of the theory of rainfall runoff, part 2. In: Proc. Hydrometeorological Inst., Odessa, vol. XIV, 1-310. Gidrometeoizdat, Leningrad. Befani, A.N. (2003) Objectives and methods for the scientific hydrology further progress. In: Proc. Conf. 'Hydrometeorology and environmental protection - 2002', vol. 2 (ISBN 966-7654-81-8), 7-13. State Environmental University, Odessa. Befani, N.F. (1977) Forecasting of rainfall floods based on territorially-generalized dependences. Gidrometeoizdat, Leningrad. Chebanov, O.Yu. (2004) Grounding rainfall-runoff model for the San-Francisquito Creeck Watershed. Environment ecology and safety of life activity (ISSN 1726-5428), 1, 74-84. Gopchenko, E.D. & Romanchuk, M.E. (2002) Unification the computations schemes for

extreme flood flow of rivers. In: Hydrometeorology and environmental protection (ISBN 966-7654-65-6), 20-21. State Environmental University, Odessa.

***Keywords:*** genetic hydrology, runoff mechanism, inflow catchment

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**HW1002** **Poster presentation** **4465**

# Simulating hydrologic responses with Representative Elementary Watershed approach in a mountainous basin

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***Liliang Ren***

The approach of representative elementary watershed (REW) which is an integrated hydrological modeling approach based on the discretization of a watershed into spatial units (REW) has been introduced in earlier publication. The REW approach is not so as the approach of general distributed models which use square-grids. The separation of a watershed based on square-grids is not consistent with the situation of actual physical processes and sometimes severs the hydrologic contact in a watershed. In contrast to the shortcomings of square-grids, the REW approach not only maintains the natural spatial characteristics to represent the physical processes, but also preserves the integration and connection of whole watershed. Based on these characteristics, the REWs can be treated just like points. But the independence on the chosen spatial and temporal scale is the feature that makes REWs different with points. Except for the above content, the governing equations for hydrologic responses in hydrologic systems are constituted by the REW-scale balance laws. Also, global balance laws had been formulated at the spatial scale of a REW by integrating the point-scale conservation equations at particular control volumes. Meanwhile, some applications of the REW approach recently show that this approach which is established for synthetic cases can be applied to real-world situations. In order to researching deeply on the REW approach, a rainfall-runoff model based on the REW approach has been developed and used for simulating hydrologic responses in a mountainous basin of China in this research. The approach takes into account several dominant hydrological processes. The entire basin is descritized into a finite number of sub-catchments, or REWs. To describe these processes, several flow zones within each REW are distinguished. Within each zone, averaged values for state variables and model parameters are used. Also, some approaches about generation, processing and calculation of REW are introduced in this paper. The formulation of appropriate closure schemes for mass, momentum and energy fluxes at the REW scale is one of the most valuable and significant point in this research. The simulated results show that the calculated data are identical with the observed data basically which indicates that the REW approach is an appropriate tool to investigate rainfall runoff relations. At the end of this paper, advantages as well as the points that need to improved of the REW approach are analyzed as a more comprehensive and scale-independent modeling philosophy for hydrological systems.

***Keywords:*** rew, hydrologic responses, mountainous basin

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**HW1002** **Poster presentation** **4466**

# Effects of explicit landscape representation in land surface hydrological models

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Land surface hydrological (LSH) models have focussed on providing reliable large scale surface states and vertical fluxes to the atmosphere and hydrological inputs to continental-scale river systems. This approach has meant that small scale horizontal processes and landscape heterogeneity are either ignored or aggregated. Because the atmospheric coupling can provide driving meteorological variables, considerable interest has developed in applying LSH models to smaller scales to provide runoff prediction in remote locations where meteorological stations and streamflow gauges are unavailable. In the sub-arctic, the spatial variability of snow accumulation and ablation has been found to be strongly influenced by slope, aspect, elevation, vegetation, and wind redistribution of snow. The primary runoff producing areas for large northern basins such as the Mackenzie, Yukon, Lena etc are the mountainous boreal and sub-arctic environments. The objective of this study is to examine the influence of including effects due to slope, aspect, elevation, and vegetation on the prediction of snowmelt runoff generation for a small basin in the mountainous subarctic. The study was conducted in Granger basin within Wolf Creek Research Basin, an 8 km2 in the Yukon Territory, Canada. Sparse and shrub tundra cover the basin, permafrost is discontinuous and all soils are fully frozen at the time of snowmelt. Snowmelt is normally the major hydrological event of the year. The basin has been subject to hydrological process research for several years and so a combined modelling approach that included the incorporation of both detailed process understanding and inputs along with information gained from observations of basin-wide streamflow phenomenon was applied. Hydrological processes such as snow accumulation, ablation and runoff generation were conceptualised from the process understanding, whereas a model sensitivity analysis was used to disaggregate the basin into the minimum number of spatial modelling units required for estimation of snow cover depletion and streamflow. To assess the importance of vegetation, slope and aspect in the calculation of basin hydrological response the LSH model was driven with radiation and snow accumulation as controlled by topography, pre-calculated using physically-based algorithms from a small-scale hydrological model. The LSH model already incorporated detailed canopy, hillslope and soil moisture movement algorithms. LSH model simulations using this explicit representation of the landscape heterogeneity were contrasted with those assuming spatial uniformity within the model grid. A sensitivity analysis further determined the importance of vegetation, soil and hillslope parameters within the LSH model. Results were compared to distributed observations of snow water equivalent and spring streamflow. The comparisons suggest that in order to estimate both snow covered area and streamflow in this environment, a LSH model must not only include hillslope processes but incorporate the effect of slope, aspect and basic vegetation cover on radiation and turbulent transfer.

***Keywords:*** lsh models, landscape heterogeneity, topographic effects

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**HW1002** **Poster presentation** **4467**

# The maximum low flow parameters depending on assumed threshold level

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The threshold level method is most frequently applied to determine the beginning and the end of a drought defining drought events. The threshold Q0 is fairly frequent introduced as the percentile (Q70, Q95) from flow duration curve (FDC). Assuming different values of threshold levels result in changes of the events number, their deficit volumes and their times of duration. In this paper an effort has been made to establish the threshold value which does not influence low flow periods separation; specification of deficit volume, time duration and its probability. To estimate extreme quantiles of drought duration and deficit volume (Jakubowski 2006) two dimensional Bivariate General-ized Pareto Distribution (BGPD) of Tajvidi (1996) was used. Eight parameters BGPD depends on two Univariate Generalized Pareto Distributions (UGPD). Each of these three parameter UGPDs describes the probability of the one of low flow indices. To estimate the unknown parameters the mixed (maximum likelihood and moment) method was applied. The estimations were carried out for the different thresholds level starting from the Q60 value. Results expressed as the probabilities of observed maximal event and estimated expected value of the drought intensity were analysed for every assumed threshold value. As the study area Nysa Klodzka river basin was chosen. The Nysa Klodzka River is the left side tributary of the Odra River and therefore it plays an important role in the water management of the Odra River ba-sin. Recognition of water resources during drought conditions, when groundwater yield is the only source of river supply, is very significant given the great diversity of basin morphometry, geological structures and climatic. The upper part of Nysa Klodzka basin is mountainous whereas the rest part has foothill and lowland character.

***Keywords:*** low flow, threshold level, distribution of extemes

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**HW1002** **Poster presentation** **4468**

# A journey through the hydrological cycle from a white to a brown noise

***Dr. Danijela Markovic***
*Analysis of Variability in Hydrological Data Serie No IAHS*

***Manfred Koch***

Differences in both the spectral properties and of the Hurst parameter estimates H from the discharge and precipitation time series in the Elbe River Basin are analyzed through deterministic precipitation-runoff and groundwater modeling. The Soil and Water Assessment Tool (SWAT) is used for the precipitation-runoff modeling in the Striegis River basin. The results show that the baseflow is the main component which shapes the low- frequency stream response to the basin's precipitation. The SWAT model is then applied to compute the recharge to a hypothetic phreatic stream-connected aquifer system consisting of various soils (sand, loamy sand and silt). The groundwater flow equation is solved for fluctuation of the hydraulic heads in response to the transient changes of the recharge using the PMWIN-MODFLOW package. The results show that a power shift towards lower frequencies and, consequently, an increase in H takes place for the modeled heads as the aquifer's lateral dimension increase and its hydraulic conductivity decreases, all of which appears to be well in agreement with theoretical predictions of stochastic groundwater theory. For very large and low-pervious aquifers the limiting value of 1.5 for H of the groundwater head could be reached which corresponds to a process called brown noise.

***Keywords:*** baseflow, hurst parameter, brown noise

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**HW1002** **Poster presentation** **4469**

# Analysis of hysteretic behaviour of a hillslope-storage kinematic wave model for subsurface flow

***Prof. Marco Borga***
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***Daniele Norbiato***

The objective of this works is to explore the hysteretic behaviour of a simplified model for subsurface fow processes based on kinematic wave. Hysteresis has long been known to exist in the relationship between pore water matric potential and water content, which is generally not unique for a given soil texture. This relation is evidenced during the wetting and drying of a soil sample, yielding a continuous curve, however the two pathways are not identical. This type of relationship has also been found to exist in many natural systems, including subsurface stormflow. We focus here on the hysteretic behaviour arising in the relation between hillslope average soil water content and both subsurface flow at the hillslope outlet and the areal-extent of saturated areas. The subsurface flow dynamics is analysed by means of a simplified model based on kinematic wave and using a method proposed by Fan and Bras to transfer the three-dimensional soil mantle into a one-dimensional profile. Continuity and a kinematic form of Darcy s law lead to quasi-linear wave equations for subsurface flow, solvable with the method of characteristics. Analytical relationships are found between hillslope average soil water content and subsurface flow for the wetting and drying phase, indicating hysteretic behaviour. The basic pattern in a storage-discharge plot is of anticlockwise hysteretic loops. We demonstrate that the hysteresis patterns change markedly with the hillslope shape.

***Keywords:*** hysteresis, subsurface flow, kinematic wave

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**HW1002** **Poster presentation** **4470**

# Do shrinkage and swelling of soils govern runoff generation in temperate regions?

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***Erwin Zehe, Jan Wienhfer, Jrgen Ihringer***

The runoff generation process in the small 2.3 km Tannhausen catchment is strongly influenced by cracking soils. Though located in southern Germany with moderate annual rainfall and evapotranspiration rates, the shrinking soils govern the runoff processes enhancing runoff coefficients in winter and lowering those in summer months. We also investigated runoff generation in the small Ebnit catchment in the Vorarlberg Alps with extreme precipitation conditions of annual sums of 2100 mm. Despite a moist mountainous climate, considerable shrinking cracks were found which enhance fast infiltration and preferential flow in the heavy clay soils altering the overall runoff generation. Physically based approaches used for small catchment modeling like unsaturated flow equations and soil hydraulic functions are not feasible to exactly simulate subsurface hydraulics in clay soil catchments as changing water contents alter the size of the porous media as well as it influences preferential flow through shrinking cracks. With this presentation we would like to deepen the insight towards cracking of clay soils and its influence on threshold patterns in hydrology. We want to develop a concept to better integrate shrinkage processes into catchment response and find a conceptual model to scale up the plot scale processes towards catchment scales.

***Keywords:*** soil shrinkage, runoff generation, preferential flow

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**HW1002** **Poster presentation** **4471**

# Towards a coalgebraic theory of catchment hydrology

***Mr. Michael Hauhs***

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Over the last decade, increasing computational power has been devoted to catchment models. However, the results are systematically disappointing; no non-trivial predictive capability has been gained for the relevant class of living systems. We conjecture that these modelling problems represent more than a technical difficulty; rather, the lack of significant progress in predictive models points to an anomaly in the underlying theory. Typically runoff generation is posed as a physical problem, where the system structure shapes the function (dynamics). Living parts of the system are of minor importance. In a complementary approach, we conclude on structural features based on documented behaviour. This direction of entailment is key to a coalgebraic representation of dynamical systems as used in computer science. Rather than inferring mechanistic processes and their invariants from observed states, the new framework infers computational processes and their constraints from documented behaviour. This provides a shift of focus towards biological aspects within catchments. Abiotic aspects of the system play a minor role. The new framework provides an arena for testable hypotheses on the failure of process-based models on one hand, and sheds light on the classification of runoff behaviour on the other.

***Keywords:*** catchment theory, coalgebra, runoff behaviour

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**HW1002** **Poster presentation** **4472**

# Classification of hydrological behaviour with complexity measures

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***Michael Hauhs***

There is a vast literature on modelling runoff from watersheds using either process-oriented or empirical approaches. However, there is a mismatch between model complexity and the observed simplicity of output behaviour (runoff). We seek to characterize and classify this simplicity in an information-theoretic framework (symbolic dynamics). Information content and complexity of time series is quantified for a large set of long-term runoff records. It is shown that on one hand the runoff data share a simple property making them uniquely identifiable: they are located on a parametrizable one-dimensional curve. On the other hand, they exhibit differences in complexity attributable to system properties from geology, climate, and land use. Thus, these measures provide a classification system for catchments. Conventional rainfall-runoff model outputs are not able to reproduce this behaviour. In particular, they lack the mentioned universality. However, rule substitution in context-dependent grammars from symbolic dynamics and Markov chains are successfully reproducing information content and complexity in a controlled fashion. These rules are best described as statistical avoidance of behavioural patterns. We try to establish a link between this behaviour of catchments and the influence of living systems on them.

***Keywords:*** catchment theory, runoff classification, complexity measures

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**HW1002** **Poster presentation** **4473**

# Limiatations of Darcys Law in exploration and development of groundwater resources in Hindu Kush Himalayan mountain regions

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The present paper is based on the data from more then 15000 borewells drilled in different hydrostratigraphic zones identified by Arya (1996) in the entire Hindukush Himalayan regions. Prior to these studies mountains in general and high altitude cold mountain deserts in particular were considered to be devoid of significant groundwater resources. Groundwater was only considered to be concentrated in the inter mountain valley regions. The main reason for this assumption was the limited application of Darcys Law in the mountain regions. Hence this led to non explaination of occurance of springs/wells on the peaks of mountain regions on one hand and non development of groundwater resources in these regions on the other. Based on the conceptual model proposed by Arya(1998) to show the occurance and movement of groundwater resources in mountain regions in a non linear manner by using simple principles of geology(lithology,structural, geomorphology),hydrology and physics(siphon,isostacy) it is possible to explain the occurance and movement of groundwater resources in a non linear manner specially in the mountian regions. The application of this model has led to development of groundwater resources in the mountain regions. Specially the high altitude cold mountain deserts of Ladakh, India which is located in extreme climatic and geological conditions. Based on the Non- Darcys, non linear model proposed by Arya in this paper it is now possible to extract groundwater resources in all the peaks which are below 8848 meters above the mean sea level provided certain lithological and structural conditions are met. Successful exploration and exploitationof groundwater resources in different hydrostratigraphic zones identified by Arya and occurance of artesian conditions at an altitude of 14263 feet at Chushul India is an example showing the success of the model proposed by Arya in this paper

***Keywords:*** groundwater model, himalayas, non darcylaw

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**HW1002** **Poster presentation** **4474**

# On the Relation Between Dynamic Storage and Runoff

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Recent hydrological process research implies that hillslope and small catchment runoff generation can be likened to flow from a series of storage reservoirs. Unit hydrograph theory as derived by Nash, Dooge and Wooding provides a foundation for evaluating the function controlling such runoff. This transfer function, k at the sub-basin scale and K at the basin scale, was derived using nested measurements of surface storage and runoff in a Canadian Prairie research catchment. The research objective is to evaluate the nature of k; how it behaves and what it indicates about hydrological processes, patterns and functions. The change in runoff relative to the change in storage indicates the hydrological function of a sub-basin, and k is indicative of the efficiency of this functioning. The size of the largest store in the watershed will control K when k is constant among sub-basins. Spatial variation in k is the cause of the commonly observed variability in runoff response at the basin scale. The role of k in dictating basin runoff response is tempered by the influence of storage thresholds at sub-catchment scales, which control when the transfer function can begin influencing runoff production. There is temporal variability in storage thresholds, but the storage threshold of a drainage area will be dictated by the size of the store located at its bottom.

***Keywords:*** storage, runoff, thresholds

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**HW1002** **Poster presentation** **4475**

# A New Focus on Integrated Analysis of Groundwater/Surface-Water Systems: Process Understanding, Conceptualisation and Modelling.

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The knowledge of induced infiltration from the river to the aquifer helps one to evaluate the extent of contamination of groundwater. In this paper, critical pumping rates that would avoid invasion of contaminated water from rivers to adjacent aquifers were determined by way of computer simulation using the Wilson and Newsom (1991) model. The procedure saves fertile agricultural lands from getting invaded by polluted river waters. The spatial distribution of flow induced from the river to the production well is denominated as zone of capture of the well, while the groundwater that flows from the river to aquifer and vice versa is denoted as the zone of direct induced flow. Each of these zones of capture are distinctly identified to facilitate rapid determination of the respective limits of these zones of capture. The pumping rate as adopted by the State Organ in Paraiba, Brazil was designated as the design discharge, Q which was simulated to higher pumping rates, in multiples of Q. The dimensionless pumping rate, is a function of three parameters, namely the pumping rate of the production well, regional (or natural) flow in the aquifer that is unaffected by pumping, and the distance of the river from the well. The critical pumping rate c, is a function of induced infiltration as fraction of well discharge. The area of study (520m x 320m) is in the semi-arid region of Paraiba State, Brazil with hydraulic deficiency of over 800mm/year. The unconfined aquifer has an extension 38.400 Km2, representing different types of configurations and drainage patterns (Radambrasil, 1981).. The model adopted has a sound theory behind it for the evaluation of the critical pumping rates, above which the polluted waters from the river invade the aquifer. Two-D hydraulic heads were used in the computer simulation, the central head in model simulation having been expressed as h(8,8) in the fictitious network of15x15 adopted. The Piranhas River at the time of study was a gaining river and the test pumping rates adopted varied from 20.9 m3/h to 80.8 m3/h. The model can be safely used for angles varying from 0 to 90o, even if the river direction is inclined to the direction of flow in the aquifer at any angle. Graphs and tables presented showing the hydrodynamic parameters of the aquifer and the formation of the three capture zones in the study area are self-explanatory.

***Keywords:*** river aquifer system, induced infiltration, capture zone concept

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**HW1002** **Poster presentation** **4476**

# Using Groundwater Flow Model for the potentiality of the Sustainable Aquifer Management

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***Adel Zghibi, Jamila Tarhouni***

Case Study Oriental Coastal aquifer (Cap Bon in the North of Tunisia) This study relates to the determination of various origins of the underground water pollution by using tools hydrochimic and hydrogeologic in order to better include understand the chemical interactions which can exist between the aquifer of the Eastern coast of Cap-Bon and the environment medium, aiming at an optimal management of its potentialities. Initially, one sought to as well identify the degradation of the state of the tablecloth on the quantitative level as qualitative. Consequently, one is interested in the identification of the origin of the salinisation of this tablecloth. For this end one proceeded to: - the cartography as well of the piezometric data as of salinity, - the interpretation of the results of the cartography, - identification of the origin of the localised deterioration of the quality of the water of the tablecloth. The analysis of the results showed that: - the state piezometric of the tablecloth nothing but does be degraded with time, - the tablecloth is prone to a salinisation at a quite advanced stage and, in certain places, too pushed, - this salinisation is due primarily to the inversion of the hydraulic gradient supporting an intrusion marinates close to the coast. In the light of these results, SEAWAT, model of flow and undergrounds transport taking of account the density of water, is used to simulate the dynamics of the marine intrusion. Its application within the framework of this work is made in the objectives following: - determination of the hydrodynamic characteristics of the aquifer in question, - quantification of the quantity of the water which enters the field of discretization (natural, artificial refill...) and that which leaves it (exploitation, drainage...), - determination of the direction of the flows of subsoil water in the aquifer, - simulation of the advance of the salt particles and the transport of dissolved body.

***Keywords:*** aquifer coastal; pizomtrie;

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**HW1002** **Poster presentation** **4477**

# Dynamics of soil water storage and Hurst effect

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***Valentina I. Shveikina***

A simple mathematical model of the hydrological process with the Hurst effect is constructed. Basic components of the land hydrological cycle such as precipitation and dynamics of soil water storage are used. We assume that the number of rains for the interval [t0, t0 + T] obeys the law of seldom events Poisson law. We develop a water balance nonlinear equation for the upper layer of soil including soil water storage and porosity, soil water content at the plant wilting point, water filtration coefficient in saturated soil, the ratio of evaporation speed to infiltration one. Integration of this equation results in the pulse process whose spectrum diverges at low frequencies. This fact is explained by a strong power dependence of the water conductivity coefficient on soil water storage. Due to that the relaxation of soil water stores after rainfall to equilibrium occurs very slowly. This attenuation demonstrates long memory of process. In the constructed model of water transport the nonlinear infiltration process provides the Hurst effect. The intensification of the dependence of water conductivity factor on soil water stores results in delay relaxation soil water storage, weak attenuation of the stochastic process correlation function that in turn, promotes growth of the Hurst index.

***Keywords:*** hurst effect, soil water storage, non linearity

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**HW1002** **Poster presentation** **4478**

# Nonlinear dynamics of a river runoff

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It was established by the up-to-date statistical methods for stochastic processes that there are several steady states in the river runoff observation series. This fact evidences the possibility of inducing chaotic oscillations in hydrological systems including oscillations of river runoff, soil water storage, and close water body level. In this connection methods of detecting chaotic regimes were developed and algorithms were constructed for such chaotic characteristics as the correlation and information dimensions, Kolmogorov information entropy and Lyapunov index. The method for obtaining the Poincar map for investigation of chaotic oscillations was elaborated. The Poincar map obtained and values of the quantitative characteristics evidence the existence of chaotic dynamics in the river runoff observation series. Three river runoff models were analyzed: 1) the model including differential equations for water balance and river runoff dynamics; 2) a version of the first model derived by the expansion in a Tailor series up to the third order terms; 3) the second model with a periodic perturbation force. It was shown that all the three models have chaotic solutions. The first two models lead to self-oscillations whose mathematical expression is a limit cycle. The third model has a chaotic mode. Based on the first model authors have obtained a non-linear oscillator of long-term fluctuations of soil water contents explaining the emergence of low-water and high-water phases in the hydrologic regime of a river catchment.

***Keywords:*** river runoff, chaiotic regim, oscillator

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**HW1002** **Poster presentation** **4479**

# A runoff generation process transfer tool developed for a tropical headwater catchment with scarce data

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***Denis Salas Gonzalez***

Runoff generation processes have been subjectively studied by observations in a tropical headwater catchment in the Costa Rican central volcanic mountains to empirically derive a hydrological response unit (HRU) map, which is considered the adequate tool to improve hydrological modelling approaches implementing maximum process knowledge with a minimum of data and measurement input at the ungauged or data scarce site. GIS methods, remote sensing and extensive fieldwork were utilized to develop an automized process transfer tool to compute the HRU map connecting physiographical characteristics with the subjective process knowledge and the results of a semi-distributed conceptual model applied to the study basin. This transfer tool might be regionalized to other application sites taking into account typical process indicators. In a tropical environment such as Costa Rica, among these can be mentioned the highly variable topography (slopes), tropical cloud forests as a particularity of land use, deep volcanic soils and aquifer systems and a typical geomorphology characterized by differently scaled landslides, which can be associated to fast, delayed and slow hydrological process patterns. These parameters were derived by photointerpretation, field control and model output, classified after its process affiliation and computed by a weighting superposition procedure to finally obtain a process transfer tool, which can be translated to a runoff generation routine in a distributed hydrological modelling approach and therefore, offers the opportunity for regionalization to other drainage basins and even to other climatic regions across the world. Slopes over 30 % were categorized to produce fast superficial flow (includes Hortonian overland flow and saturation excess), which was studied by semi-randomly installed overland flow detectors (OFD). This low cost methodology qualitatively identified fast runoff generation zones associated to land use and hydrogeology. Furthermore, the different processes could be distinguished due to infiltration measurements and soil properties analyzed in the laboratory, and by air photo interpretation to detect macro and micro morphodynamic processes. The slope category from 15 - 30 % is considered to consist of fast runoff generation zones, primarily according to land use (urban and mixed use), and of delayed flow due to soil properties. Moderate slopes (< 15 %) produce delayed and slow runoff reactions triggered by hydrogeology and soils with low influence from land use. The application of the conceptual semi-distributed model confirms the importance of quickly moved and concentrated fast runoff components for stormflow generation and delayed and slow runoff generation for streamflow recession.

***Keywords:*** runoffgeneration, ungaugedbasin, processtransfertool

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**HW1002** **Poster presentation** **4480**

# Self-organized simulation of overland flow generation in small catchment by cellular automata

***Dr. Xiang Zhang***
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***Xingyuan Song, Liping Zhang***

Soil Moisture is a key component and has a major influence on the generation of overland flow. The space-time self-organizations of soil moisture and overland flow generation in Tarrawarra experimental catchment in Australian are analyzed here. The A-K Network, which is the combination of ART neural network and Kohonen neural network, was used to identify the spatial pattern of soil moisture. The semivariograms were calculated for the clustering center of each identified pattern in order to find the structures of variance. The variety of overland flow generating area in catchment was analyzed by using a cellular automata model which models the self-organizing incorporation in soil water balance including infiltration, rainfall and evaporation. In this paper, our goal is to find the possible occurrence of self-organization in hydrological process. Some initial results tend to approve the hypothesis.

***Keywords:*** self organization, overland flow generation, cellular automata

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**HW1002** **Poster presentation** **4481**

# Evaluating an ambivalent effect of slope length on runoff generation using a water storage index

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A trench observation on runoff at the bottom of a short hillslope within a small study catchment including many longer hillslopes demonstrated that the specific discharge from this slope had higher storm peaks than that from the entire study catchment whereas the rising of hydrograph from the former delayed compared to that from the latter (Tani, J. Hydrol 200, 1997). Generally speaking, a long slope tends to have a relatively wide source area where saturation overland flow is easily produced, suggesting an earlier initiation of storm runoff. When storm responses are produced by subsurface flow, however, specific discharge from a short slope must have a higher peak than a long slope because of its shorter propagation time. Such an ambivalent effect of slope length on runoff generation can be comprehensively assessed by an application of water storage index. This index is defined as the difference of water volume on a slope between two steady states given by low and high rainfall supplies, and its high value indicates a large mitigation effect of storm runoff responses. Analyses of runoff responses using two-dimensional Richards equation show that the index increases with increasing of slope length for a steep mountain although the index decreases with its increasing for a gentle hill. It is concluded that a topographic influence on storm runoff may be distinguished according to differences of runoff generation mechanisms derived from the steep and gentle landscapes.

***Keywords:*** hillslope hydrology, water storage index, rnoff generation

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**HW1002** **Poster presentation** **4482**

# On LMBP-ANN algorithm network model and application to hydrological forecasting

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***Zhongbo Yu, Zhenchun Hao, Changjun Zhu, Qin Ju, Lei Zhu***

Conventional multilayer feedforward network and its some improved algorithms have defects on parameter estimation and convergence performance. So a back-propagation algorithm based on Levenberg-Marquardt algorithm, a quasi-Newtons method with better optimization performance, is developed. This method is used in regional flood forecast modeling. The results shows that LMBP algorithm have better system identification capacity and it is fit for network which performance index is mean-square error. The flood forecast result modeled is compared well with observed data. According to criterion, the model can be used as a favorable method. And it can be popularized in other nonlinear system identification.

***Keywords:*** flood forecast, system identification, neural network

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**HW1002** **Poster presentation** **4483**

# Thresholds and non-linearities in hillslope-scale subsurface stormflow: Describing lateral preferential flow networks experimentally

***Mr. Christopher Graham***
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***Jeff Mcdonnell***

The relationship between precipitation and subsurface flow at the hillslope scale is highly nonlinear. Numerous studies have documented precipitation amount thresholds for subsurface stormflow commencement. This nonlinear behavior has been attributed to a number of factors, including heterogeneities in soil properties, spatial variations in soil depth, soil matrix conductivity, antecedent soil moisture, bedrock permeability and spatial variations in throughfall. Paramount among the factors affecting subsurface stormflow is lateral preferential flow. Lateral preferential flow through discrete soil pipes and zones of high conductivity mesoporosity has been shown to account for the majority of subsurface stormflow in many catchments. Parameterizing these effects remains very difficult given the lack of field experiments aimed at quantifying this behavior. We conducted new hillslope-scale irrigation and dye tracing tests at two well-studied experimental hillslopes: the Panola Mountain experimental hillslope in Georgia, USA and the Maimai experimental hillslope on the South island of New Zealand. We addressed the following questions: (1) What is the length and continuity of the macropores? (2) Are there more soil pipes in different geomorphic positions? (3) How does the soil vs. the bedrock route water? (4) What is the microtopography of the bedrock surface? (5) How does the soil matrix hydraulic conductivity affect travel velocities? (6) What is the relationship between soil K and pipeflow percentage, and (7) What is the bedrock permeability and how does it vary spatially? At both field sites we irrigated in line and point sources between 2 -14 meters upslope of the subsurface flow trenches that captured lateral subsurface flow. At Panola, the upslope extent of macropore contribution and the permeability of the subsurface bedrock were measured by line source sprinkling and plumbing of macropores and soil matrix at the trench. At Maimai, extensive excavation following irrigation allowed us to determine the spatial extent and distribution of lateral subsurface flow paths as well as the microtopography of the bedrock. The spatial distribution of the macropore network and the bedrock microtopography were a major control of small scale water routing. The Maimai experiments were repeated at different geomorphologic positions. Preliminary results suggest that both soil properties and macropore density and typology varied, greatly affecting lateral subsurface flow dynamics.

***Keywords:*** hydrology, hillslope, experiments

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**HW1002** **Poster presentation** **4484**

# To a question on nonlinear dependence of evapotranspiration on the climatic factors

***Dr. Yusup Rysbekov***
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Water-balance accounts (WBA) are a basis for hydrological processes understanding, and one of major practical aspects of the catchment hydrology and river basin management. In the theory of WBA the empirical equations describing dependence of evapotranspiration (E) from climatic factors was found the wide application. As a whole, in the theory it is established that the dependence E from climatic parameters (solar radiation, temperature and humidity of air, etc.) is proportional (linear or quasi-linear). Practice of WBA operates with concept of maximal possible evaporation (MPE), which is accepted for a basis of WBA too, and the actual E is calculated as a share from MPE. In most cases water evaporation is accepted as MPE. Now concept of MPE has changed, and it is defined as MPE at optimum soil moisture for vegetation culture completely covering a soil's surface. But a new concept of MPE is closely adhered to the climatic factors also and is a water equivalent of heat (solar) resources. Therefore in majority of the methods of plants water needs definition are reduced to reception dependence such as E = f (Emax), where E is function of MPE (Emax) for the certain time period. For example, for WBA in Central Asia the following dependence is applied: E = (Emax)1.58/31.62, where Emax - water evaporation according to the formula by Ivanov-Molchanov: Emax = 0.00144 ( T+ 25)2 (100 - A), where T and A are monthly average temperature and relative humidity of air. At the same time, the long-term researches, which have been carried out on largest lysymeters of former USSR (area everyone is equaled 25 m2, vegetation culture - cotton, Chirchik river basin, Tashkent oasis, Uzbekistan) have shown that the linear dependence E = f (Emax) is a special case. If connection E = f (Emax) to construct for the monthly data in coordinates E (ordinate), Emax (abscissa), we will receive a hysteresis loop, and a curve of dependence E = f (Emax) for the period April-October is necessary is to divided into two curves - for the period April-July and August-October, as they have various character. Accordingly, use of common curve E = f (Emax) for evapotranspiration's accounts will have by a consequence to overestimate of its volume for the period April-July and reduction of its volume for the period August - October. For the separate summer periods a paradoxical connection between E and Emax is observed, namely - evaporation from a water surface (Emax) is reduced, but E continues to be increased. Given fact is not taken into account in the theory of WBA. Account of a hysteresis of water consumption by plants (delay in time of E concerning MPE) considerably raises accuracy of WBA for river basins and its separate parts, especially - for irrirgated territories.

***Keywords:*** hydrological accounts, evapotranspiration, hysteresis effect

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**HW1002** **Poster presentation** **4485**

# From the micro- to the meso-scale, the MAGS tile approach.

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***Frank Seglenieks***

Zero-order catchments are often considered the fundamental building blocks of hydrological models. It is argued that they are the smallest domains for which the closure of the water and energy balances is at all practical. They are, however, too complex and have defied attempts to be described generally. This paper demonstrates a more fundamental approach. There are often characteristic elements within a catchment that facilitate its parameterization. For example, many watersheds are mixtures of upland forest areas that shed water rapidly and lowland wet areas that provide long-term storage. Both release water to a local channel system that deliver it to a main stream network. This approach considers the catchment to be a interconnected collection of such sub-catchment elements. To emphasize that slope is a major determinant of their hydrological response we refer to the elements as TIlted Landscape ElementS (TILES). Tiles are nevertheless dynamically complex because of a wide range of initial conditions, partitioning mechanisms, and flow pathways. This paper describes a method for deriving the drainage characteristic curve for a tile from soil properties and element topography. A control-volume approach is used in combination with Richard's equation for a shallow aquifer to estimate the soil moisture distribution from bulk properties. Boundary values of soil moisture are used to calculate seepage and recharge. The result is a parameterization connecting storage to flow. The approach was developed for the Canadian MAckenzie GEWEX Study (MAGS) to model the 1.8 million square kilometre Mackenzie basin. With the many hydrologically unusual terrain types in the watershed, characteristic TILES were used to analyze research basin results and to construct the meso-scale model elements used in the basin domain model. This approach is implemented in WATCLASS. Both research basin results and Mackenzie simulations are presented.

***Keywords:*** mags tile approach, catchment hydrology, drainage characteristic curve

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**HW1002** **Poster presentation** **4486**

# Observations of soil water dynamics around a tree on a hillslope

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***Kenichirou Kosugi, Takahisa Mizuyama***

Precipitation in a forest is intercepted by the canopy and partitioned into throughfall and stemflow, leading to heterogeneous water inputs that affect soil water dynamics. To clarify the effects of a tree stand on rainfall infiltration processes on a steep forested hillslope, we conducted detailed and long-term observations of throughfall, stemflow, soil water content, and pore water pressure at high spatial resolution. Observations began in August 2005 on a hillslope at the Kamigamo experimental station of Kyoto University, located in southern Kyoto Prefecture, central Japan. The hillslope has a mean gradient of 28 degrees, with brown forest soil underlain by sandstone and slate. It is predominantly covered with tall stewartia (Stewartia monadelpha), planted in 1956. To monitor the soil water dynamics around a tree, we selected a tall stewartia and delineated a longitudinal observation line from upslope to downslope of this tree. We installed a capacitance meter (Sentek, EasyAG-5p) at each of 10 points upslope and downslope from the tree stem. Each capacitance meter consisted of five sensors to measure soil water content at depths of 10, 20, 30, 40, and 50 cm. Additionally, we installed tensiometers at the soilbedrock interface at the same 10 points to measure pore water pressure. For throughfall and stemflow measurements, we selected another tall stewartia, located at a similar point on the slope. To measure throughfall distribution, we installed a tipping bucket rain gauge at each of 6 points upslope from and downslope from the tree stem. We used two tubes cut longitudinally and wrapped spirally around the upslope and downslope sides of the trunk to collect separately the stemflow along the upslope and downslope sides of the trunk of the tree. The results showed that the soil water content increased rapidly and greatly in the region downslope from the tree stem, especially at points close to the tree stem. At these points, maximal soil water storage was more than 100 to 200% of the cumulative open-area rainfall, and occurrences of bypass flow were recognized. Moreover, the pore water pressure at the soilbedrock interface increased more rapidly and to a greater degree in the region downslope from the tree stem than in the upslope region. For a heavy storm event, the cumulative infiltration height of the stemflow along the downslope sides of the tree trunk was 18.9 times the cumulative height of the open-area rainfall. Locally concentrated rainwater input attributable to the stemflow on the downslope side of the tree trunk probably caused the large and rapid increases of water content and pore water pressure in the downslope region, resulting in the development of an asymmetric saturated zone around the tree.

***Keywords:*** bypass flow, infiltration, stemflow

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**HW1002** **Poster presentation** **4487**

# Buffer function of soil layer controlling flood and baseflow discharges from headwater catchment underlain by permeable bedrock

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***Shinya Katsura, Makoto Tani***

Recent studies have suggested that bedrock groundwater can exert considerable influence on runoff generation, water chemistry, and occurrence of landslides in headwater catchments. Consequently, accumulation of knowledge on infiltration and redistribution processes at the soil-bedrock interface is indispensable for accurate modeling of storm discharge, solute transport, and slope failure. In this study, we conducted hydrometric observations using soil and bedrock tensiometers combined with hydrochemical measurements and water budget analyses at three different spatial scales in a small headwater catchment underlain by weathered granite. Results showed that, in an unchanneled 0.024-ha headwater catchment, saturated and unsaturated infiltration from soil to bedrock is a dominant hydrological process at the soil-bedrock interface. Annual bedrock infiltration ranged from 35 to 55% of annual precipitation and increased as precipitation increased, suggesting a high level of potential bedrock infiltration. In the middle- and up- slope regions in the catchment, large water-holding capacity of soil layer, because of its thickness and unsaturated hydraulic properties, resulted in a large capacity to act as a buffer, making waveform of infiltration intensity gentle at the soil-bedrock interface. Consequently, all the rainwater infiltrated into the bedrock. In this way, middle- and up-slope regions never became contributing areas for water discharge, but contributed to the large potential water loss from bedrock infiltration. Thus, we found that the soil layer and the permeable bedrock layer generated feedback system resulting in nonlinear dynamics of water flow at the soil-bedrock interface, which can be one of the key factors in controlling hydrological processes in headwater catchments. In a 0.086-ha watershed including the unchanneled headwater catchment, exfiltration from the bedrock towards the soil layer composed more than half the annual discharge. Based on these results, numerical simulations for saturated and unsaturated water flow were conducted for analyzing rainwater infiltration and discharge processes in forested hillslopes underlain by permeable bedrock. Two-dimensional Richards' equation was solved numerically by using the finite element method assuming triangle elements. An observed storm hyetograph was supplied to the soil surface, and discharge hydrographs as well as infiltration amount across the soil-bedrock interface were computed. Results showed that, while an exfiltration from the bedrock sustains base flow discharge, storm hydrographs are characterized by saturated throughflow formed over the soil-bedrock interface. As the water-holding capacity of soil layer increases, the buffer function of the soil layer is enlarged, resulting in increased amount of rainwater infiltration into the permeable bedrock. We also found that this buffer function of soil layer is nonlinearly related to rainfall intensity, bedrock permeability, and topography. Thus, we conclude that analyses of the buffer function of soil layer, which reflects feedback mechanisms between soil and permeable bedrock layers, can shed new light on the modeling of hydrological processes in headwater catchments.

***Keywords:*** bedrock, infiltration, non linear process

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**HW1002** **Poster presentation** **4488**

# Surface temperature from remote sensing observations and energy budget hydrological model for soil moisture retrieving

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*D.I.I.A.R. Politecnico di Milano IAHS*

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At this moment the remote sensing estimates of the surface temperature (Ts) in the infrared band seem to be a very promising research field also for the new available technologies (e.g., Gillespie et al., 1998; Schmugge et al., 2002). However we have to remember that the soil water content may be derived through the mass and energy balance equations of the LSMs and not directly through the remote sensing estimates of Ts.Operative sensors are available for Ts estimates: some of these sensors, like ASTER mounted on the Terra satellite, provide high spatial resolution (90 m) estimate of Ts maps, but with low temporal resolution (16 days), other sensors, like AVHHR on NOAA and SEVIRI on METEOSAT, provide maps of Ts at lower spatial resolution (1100 m and 3000 m), but with higher temporal resolution (every day and every 15 minutes, respectively).Unfortunately, the remote sensing estimates of Ts are not directly comparable with the predictions of the LSMs and the ground observations. Indeed, there is the problem of the representativeness of the remote sensing observation, which is related to the instrument radiometric characteristics, to the spatial variability of the vegetation cover, soil properties and soil moisture inside the pixel (Detto et al., 2004; Kustas et al., 2004). Indeed, the vegetation cover fraction over the pixel, and the vegetation height and density play a critical role on the energy balance in the pixel (Gillies et al., 1997). On these topics many attempts in similar hydrology fields have been made with the objective to identify the representative elementary area (Koster and Suarez, 1992; Famiglietti and Wood; 1994; Wood, 1995; Giorgi and Avissar, 1997; Montaldo and Albertson, 2003b).Nowadays, new sensors, such as Aster or Quickbird, characterized by extremely high spatial resolutions (from 15 to 2.8 m) in the range of visible radiation wavelengths, allow to estimate accurately maps of fraction of vegetation cover in basins at our latitudes characterized by high spatial variability.One of the most popular vegetation cover index is the leaf area index (LAI), used also in the Penman-Monteith equation for the evapotranspiration estimate. LAI may be estimated from visible and near-infrared band data (Clevers, 1989; Baret e Guyot, 1991; Qi et al., 2000). It may be obtained from VIS-NIR radiometric data through complex physical models able to interpret the interactions between reflectance properties and vegetation physiology, spectral characteristics of the soil and observation geometry (Baret and Guyot, 1991). In practical applications simplified approaches that estimate empirical relationships between LAI and vegetation indexes are commonly used (Hall et al., 1995).The work presented investigate the potentiality of the use of remote sensing observations of Ts in hydrologic models for the soil moisture estimation. Hence, the project try to identify the proper spatial, radiometric and temporal resolutions of these state variables in relation to the hydrologic basin dynamics.For achieving these objectives, field campaigns for the measurements of Ts with radiometric instruments are an important step, which allow testing the accuracy of both the remote sensing estimates and the hydrologic models (e.g.,Jackson, 1997b; Giacomelli ed al., 1995; Montaldo et al., 2003).Two cases of study are presented, the Mulargia River basinthat is a water limited case and the Landriano corn-field.

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**HW1002** **Poster presentation** **4489**

# The effects of introducing non-native vegetation on hydrological partitioning in a tropical catchment

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Current global population growth and economical development accelerates the land cover conversion in many parts of the world and compromises the natural environment. The impacts on the hydrologic cycle at local to regional scales are poorly understood. The present study investigates the hydrologic implications of land use conversion from native vegetation to rubber (hevea brasiliensis) in Southeast Asia. Rubber was introduced in in the mid 1950s, and since then, native vegetation (mainly primary and secondary forest) has been substituted by rubber plantations at a breathtaking rate. Rubber is not native in , and therefore is not adapted to the local climatic conditions, resulting in distinct rates and timing of water consumption than the native vegetation it replaces. Introduction of non-native species with different water consumption possibly affects the partitioning of hydrological fluxes and regional water balance. In this paper, we propose a novel approach to understand and predict changes in the hydrologic cycle due to the introduction of rubber in an experimental catchment (69 km2) in Southwest China. The study area is divided into four dominant land covers: tea, secondary forest, grassland and rubber. Continuous records of soil moisture profiles (up to 2m deep) in each of these land covers and surface radiation data in tea and rubber canopies, help understanding vegetation phenology and timing of water demand. Results show that the water demand of most of the native vegetation is controlled by water availability (adapted to distinct wet and dry seasons), whereas rubber water demand is controlled by the increase in day-length. Flushing of rubber leaves with the subsequent root water uptake happens during the spring equinox, weeks before the first precipitation events. In contrast, native vegetation mostly activates with the arrival of the first monsoon rainfall. These observations and field measurements are used to better describe the root zone, surface and subsurface flow characteristics for these four land covers. Furthermore, a root zone water balance model is derived from these observations for each of the main land covers in the basin. The water and energy balance models are applied to single hillslopes and their integrated hydrologic response compared for different land covers. Finally, the response of individual hillslopes is routed through the channel network to represent the basin. Results from the model are compared to measured catchment-scale water and energy fluxes.

***Keywords:*** phenology, evaporation, non native

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**HW1002** **Poster presentation** **4490**

# Soil moisture variability along a hillslope transect on the Fiumarella of Corleto experimental Basin (South of Italy)

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The study of the soil moisture variability represents an important instrument for understanding the main flow dynamics on the basis of the rainfall-runoff transformations. A soil moisture data series were collected, with a sample dimension of about 300 days, by means of indirect measurements of a time domain reflectometer (TDR). The study area is located on a hillslope of the experimental basin of Fiumarella of Corleto, monitored since different years by three hydro-meteorological stations. Soil moisture is measured along a transect of 11 sample site at two depths (30 and 60 cm), with a total of 22 probe that covered a length of about 60 m. The datalogger acquires in continuous at hourly scale and transmits the data in real time by GSM network.The purpose of this study was to analyze, from a statistical point of view, the acquired data highlighting the different behaviour between the temporal variations of the water contents measurements at 30 cm and 60 cm of depth. The precipitation registered from a raingauge, sited near the TDR station, were taken in consideration to define the site wetness condition. Further investigations were conducted on the soil moisture spatial variability with particular emphasis to the morphological parameters influence: the topographic attributes, in fact, show their influence on the soil moisture spatial distribution in different way according to the wetter or drier climate conditions.

***Keywords:*** soil moisture, topography

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**HW1002** **Poster presentation** **4491**

# Identification of characteristic basin descriptors for flood frequency curves behaviour

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The estimation of flood frequency curves in ungauged basins is a crucial issue for practical and technical applications. In this field, a significant contribution may come from the use of theoretically derived probability distributions where parameters have a physical meaning that may be related to the basin features. The challenge is to define synthetic indices able to interpret and classify the main characteristics of flood probability distribution.In the present work, a variant of the theoretical model proposed by Iacobellis and Fiorentino [2000] has been adopted with the purpose to describe and classify the model according to the hydrological processes underlying the flood generation mechanisms. The model has been modified including a two flood generation mechanisms accounting for the nonlinear behaviour of soil response. Climatic and physiographic basin features are investigated through synthetic indices in order to predict the statistical moments of the flood probability distributions. The analyses are carried out over a wide area of Southern Italy that includes 33-gauged basins belonging to the Regions of Basilicata, Calabria and Puglia. Results allow a better understanding the role played by the climate, soil permeability and basin morphology in flood statistics.

***Keywords:*** floods, climate soil vegetation, probability distributions

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**HW2003** **4492 - 4578**

## Workshop
## Analysis of Variability in Hydrological Data Series

**Convener :** Prof. Salvatore Grimaldi

Statistical and other mathematical methods have been widely used in hydrology. In the last twenty years many different approaches have been developed for extreme values analysis, rainfall simulation in time and space, and runoff forecasting and management. In addition to classical linear parametrical models and univariate inference statistical procedures, a variety of procedures have been developed. This session collects presentations describing theory, procedures and applications related to following approaches: - Linear and non-linear time series modeling; - Neural network methods; - Space-time simulation procedures; - Multivariate distribution analysis; - Analysis of extremes; - Stochastic processes; - Analysis of long time series; - Long range dependence; - Trend and multiple scale fluctuation analyses; - Hypothesis testing. Presentations on theoretical innovative approaches and advanced statistical and mathematical methods, and poster contributions with applications of such procedures are encouraged. One of the expected results of the session is an assessment and comparison of different methods applied to all hydrological data types (rainfall, runoff, temperature, wind, waves, soil moisture, etc.), in univariate and multivariate settings, as well as in a multiple time scale setting (e.g. disaggregation/downscaling). Particular emphasis will be given to contributions on the analysis of reconstructed records of the past using isotopes, pollen analysis, tree rings, manuscripts, journals and newspapers and other proxy methods that can provide knowledge of previous hydrological conditions with the aim of assessing whether these methods can help to better understand hydroclimatic changes and predict future conditions.

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**HW2003** **Oral Presentation** **4492**

# Depth Duration Frequency curves with copulas

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***Assia Chebchoub***

A storm can be characterised by its depth and its duration. These hydrological variables can be assumed independent or dependent random variables. The main advantage of multivariate analysis versus univariate analysis is to study the possible correlations between the variables. In this study, we analyse the dependence structure of depth and duration of rain . We use rainfall data of the Saddine1: small catchment area located beside Makthar in Tunisia, in a mountainous zone. Instantaneous recorded rainfall depth data, collected by rain gauge, are available from a period of 8 years, from 1992 to 1999. We consider a dry period equal to 20 minutes to separate different storms and a depth larger than 2 millimeters. The choice is motivated by the known of the behaviour of the meteorology of the region. Thus, the number of events recorded for the period of observation is 245. The dependence of the pair depth duration is identified and measured by the correlation coefficient: Kendall's tau. The joint distribution of couple is built using Archimedean copula. The main advantage of theory of copula is to estimate the dependence function and the marginals separately; this gives a large freedom in choosing univariate marginal distributions. Three Archimedean copulas are tested: Gumbel, Frank and Clayton. The choice of best copula is based on five functions graphical analysis (K, J, M, R and L). These functions are respectively, distribution of copulas variable, cumulative tau function, cumulative conditional average and extreme values functions. The Gumbels copula seems to fit better the joint distribution of couple rain depth duration. On other hand, the durations are fitted by GEV distribution and the depths by extended three-parameter Burr XII. For adequacy of Burr XII, the test of Anderson Darling is used. In the end, for adequacy of the couple (depth - duration), the bivariate chi-square test is adopted. The approach by copulas allows simulating depth duration of rain. We find that the observed sample is integrated in the cloud of the simulated points (15000 simulations) as well for small values as for large ones. This technique can be used for generating samples of coupless depth duration. In addition, and this approach permits the determination of the level curves depthduration frequency which is used in hydrological practice to predict design storm. These two models are useful for many design procedures of water resources.

***Keywords:*** archimedean copulas, burrxii gev adequacy, bivariate chi square ddf

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**HW2003** **Oral Presentation** **4493**

# Statistical Experiment Study of Design Annual Runoff Estimated by Curve-Fitting Method for Pearson Type- III Distribution

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The curve-fitting method is a common way to estimate design annual runoff values under different high probabilities in water resource assessment. However, theres nearly no theoretical analyses done about exactitude of the design values calculated under different curve-fitting criterion. Therefore, its still a question that how these different criterion influence results. Meanwhile whether we should use all the collected data to do the curve-fitting or not is also a question. In the paper, the above questions are discussed by Monte-Carlo experiments with consideration Pearson-III as population distribution. The criteria for evaluation are the un-biasness and efficiency of the parameter and design value with given probability, Many calculations show that the estimation result is better when the proportion of data for curve-fitting from 50% to 60% than that when the proportion less than 20%, even slightly better than traditional curve-fitting method which we used all the data, and the curve-fitting by absolute criterion is better than that of square criterion. Key words: curve-fitting method; criterion of curve-fitting; partial data curve-fitting; un-biasness; efficiency; annual runoff ; P-III distribution

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**HW2003** **Oral Presentation** **4494**

# Classification-based Flood Forecasting Model by Artificial Neural Networks

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***Xia Jun, Zhang Xiang***

Flood forecasting takes a vital role for flood control and water resources managements of catchments. However, it is generally accepted that the relationship of rainfall and runoff is highly complicated, and for a basin, the under-lying mechanisms of streamflow generation in rain periods are quite different from those in non-rain periods. So we can decomposed the flow hydrograph to several segments, then establish the rainfall-runoff relationship separately. In this study, we employ two methods to divide flow hydrograph to several segments. One is Fuzzy C Means(FCM) method, and the other is the Self-Organizing Feature Map (SOFM). Based on the two clustering results, multi-layer Feedforward Networks(MFN) are used to simulate the rainfall-runoff relationship of each segement. In this way two hybrid artificial neural networks (FCMMFN & SOMMFN) are established. The methods mentioned above are applied to Wangjiachang Reservoir inflow forecasting, in Hunan province of China, for three-hour-header flood forecasting. Forty-five historical flood processes from 11 years (1982a-1992a) are applied for calibration whilst 14 flood processes happening in recent 3 years (1994a-1996a) are utilized for validation. Antecedent precipitation and streamflow data is input into FCM and SOM for flow hydrograph decomposing and clustering. The result shows that FCM and SOM are both able to find out the potential knowledge of flow, and that its easy to find that flow hydrographs as corresponding output is classifed into four different stages: (1) low flow, (2) rising flow, (3) flood peak, (4) recession. Then, for each segment, a MFN is applied to simulate its rainfall-runoff relationship. Results show FCMMFN and SOMMFN are both superior to MFN, which explains the two hybrid models can simulate precisely the rainfall-runoff relationship simultaneity in low flow, middle flow and high flow. Moreover, FCMMFN and SOMMFN are investigated and compared, and FCMMFN appears to be better.

***Keywords:*** artificialneuralnetworks, fuzzycmean, self organizingfeaturemap

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**HW2003** **Oral Presentation** **4495**

# A simple method of evaluating variogram through cross-validation test for sparse data

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***Pagadala D. Sreedevi, Kshatriya Devi, Shazrah Owais, Shakeel Ahmed***

Rainfall measurement is of prime importance to assess the water resources and estimation of groundwater recharge that is an extremely crucial component for groundwater planning and management. But high variability of this parameter and the erratic Monsoon rains forces a dense measurement of this parameter. Thus in a special drive, about 20 measurements of rainfall have been made with the help of local public in Maheshwaram Madal, Ranga Reddy district, A.P. India, a small watershed of granitic aquifers covering an area of 57 Km2. However, due to lack of awareness only few number of measurements could be made at all the time periods only and calculating their variogram has been a difficult task through graphical method. The main aim of this paper is to present a simple method for evaluating a variogram that represents the average variability of the rainfall event, within the limits imposed by the resolution and sampling window of the network. Measurements were made at scattered places in the area. Although the measurement points were made scattered uniformly in space but they were constrained with the villages of the volunteers. The data were analyzed for their accuracy of measurement and the suspicious data were discarded from the data set thus limiting the number of measurements further. Among the data, rainfall were taken for two time periods having 16 and 15 number of measurements respectively. Experimental variograms were calculated using graphical methods but it was extremely ambiguous to fit a theoretical model for estimating their variability. Thus cross-validation test using the method of Ordinary Kriging was directly employed to evaluate the representative variogram. The variance of the data were taken as initial sill and range was varied from a reasonable starting value to the maximum distance possible in the area. The range proving the minimum average squared difference between the observed and estimated values was taken the range of the variogram and then the sill value or a combination of sill and nugget effect was calibrated against the satisfactory value of the reduced error. This exercise was also repeated for a few possible variogram model before finalizing the variogram. The result obtained on the basis of the theoretical variogram proved to be more reliable and representative as the same is able to reproduce the known values satisfactorily. Although the Cross-validation test is pretty lengthy procedure but is proved to be more reliable in case of sparse data or rather the only way of determining the variogram than the graphical method that could produce severe errors.

***Keywords:*** variogram, cross validation, ordinary kriging

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**HW2003** **Oral Presentation** **4496**

# Homogeneity testing for pooling-groups of cross-correlated sites

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***Donald H. Burn***

The homogeneity of the flood frequency regime for a given pooling-group of sites is a fundamental assumption for many regional flood frequency analysis techniques. Assessing regional homogeneity is a critical step, which may be complicated by the presence of cross-correlation among flood sequences. The scientific literature proposes a number of statistical homogeneity tests and documents that inter-site correlation of floods is normally not negligible, but does not specifically address the impact of cross-correlation on such statistical tests. This paper focuses on homogeneity tests and spatial correlation and presents the preliminary outcomes of a twofold analysis. First, the study considers the well-known homogeneity test proposed by Hosking & Wallis [WRR, 1993] and assesses its effectiveness in the presence of cross-correlation through a series of Monte Carlo experiments by repeatedly testing the homogeneity of synthetic cross-correlated and heterogeneous regions. The results of the Monte Carlo experiments enable us to develop an empirical correction that accounts for the impact of inter-site cross-correlation of floods. Second, the study presents an alternative homogeneity test that accounts for the spatial correlation in the existing data. Instead of generating a number of synthetic uncorrelated regions from a given distribution (e.g., the Hosking & Wallis test adopts the 4-parameter kappa distribution), the alternative test uses a balanced vector resampling procedure to generate synthetic samples. The balanced vector resampling procedure does not require assumptions, in contrast to conventional approaches that typically involve a distributional assumption. Also, the procedure resamples on years so that the spatial correlation in the existing data is (on average) correctly reproduced, while the use of a computationally intensive algorithm is avoided.

***Keywords:*** regional frequency analysis, ungauged basins, annual flood sequences

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**HW2003** **Oral Presentation** **4497**

# Regionalization of the russian river runoff based on statistical analysis of long time series

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Research of spatial and temporal changes of a river runoff is actual as it allows to solve important economic and ecological problems. The river runoff is characterized by the large non-uniformity of distribution in time and space. Extreme hydrological events, such as flooding and low water-level are quite often observed in many regions. With the purpose of reduction of the possible negative consequences caused by the extreme hydrological events, the runoff forecasting and management is necessary. However, supervision over a runoff covers all spectrum of a hydrological regime of the rivers insufficiently, and hydrological look-out stations are located non-uniformly. Besides, long time series of monthly flow quantity have a length which is insufficient for researches because of the short period of supervision and are characterized by significant errors of measurements and presence of missing values. All this complicates the application of settlement and forecasting methods according to the supervision on separate hydrological look-out stations. The extension of the information due to the joint (group) analysis by groups of hydrological homogeneous objects enables to avoid many random errors. In this connection, in the present work it is offered for the improvement of forecasting and management of a river runoff to carry out hydrological regionalization. The object of the researches is the territory of Russia. The approach to hydrological regionalization suggested in this work is based on the analysis of annual distribution of the river runoff by means of extracting features of its seasonal variability and grouping time series of the average monthly water flow with the help of cluster procedures. As characteristics of seasonal variability of the river runoff we used the set of features received during the transformation of initial long time series of the average monthly water flow. Such parameters, in particularly, are seasonal indexes, characteristics of spectral density functions, and also the parameters of the low-flow periods - their durations, skewness and variability coefficients. For this aim, more than 1700 objects on the territory of Russia (hydrological look-out stations which satisfy some criteria of the fullness and the duration of supervising) have been selected and processed from the hydrological archive. The extracted sets of parameters served as the basis for the hydrological regionalization. The regionalization is performed on the basis of the cluster analysis with the help of the program system TeleStat which is intended for the statistical analysis of multivariate data and time processes. As cluster procedures we used k-means and a new method based on regression approach to clustering which uses radial basis functions (RBF). The employment of such a RBF regression-based procedure gives a possibility to find group centers and to evaluate the number of groups. The result of clustering in both cases depends vitally on the specified distance between objects. In the work the weighted Euclidian distance was used. When k-means approach was performed, variable weights were adjusted in such a way that ensured both the geographic proximity of objects (hydrologic points) and their criteria proximity. The basic criterion for evaluation of classification quality is Eta-coefficient or the correlation ratio coefficient between the source variables and the grouping variable, obtained in a result of cluster analysis. The multiple calculations carried out with the use of the above described cluster procedures have allowed to allocate on the territory of Russia statistically homogeneous areas according to the character of seasonal variability of a river runoff. The analysis of various variants of classification has enabled us to track the dynamics of the association of objects, to define the number of groups, to estimate the quality of the grouping statistically and to select the optimum variant for a further use in the solution of water-economic problems. Thus, the modelling of the river runoff by its generalized

characteristics (within the limits of the homogeneous areas) allows to improve the forecasting and management of Russian river runoff.

***Keywords:*** regionalization, long time series, river runoff

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**HW2003** **Oral Presentation** **4498**

# Frequency analysis of extremes in a large river basin Impact of climate and/or land use change?

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Global changes may lead to increasing hydrological extremes (floods and droughts) and, thus, highlights the importance of incorporating management of extremes in land use management to reduce the vulnerability. Moreover, the land development in upstream regions is often blamed for aggravating floods and low flows in the downstream and hence has to be brought into the integrated river basin management. This paper concentrates on the large Meuse river basin (21,000 km2) with a particular concern of the observed trends for floods and low flows and the impact of land use change. Statistical investigation based on the observation data (since 1911) demonstrates a climate-induced increase in the (winter) flood peak discharge of the Meuse river (at Borgharen) since 1984. The effect of historical land use changes in the upstream basin is, however, hardly detectable. Many precipitation parameters and the frequency of circulation patterns also showed a significant increase since the 1980s (Pettitt test; trend analysis), thus the observed changes in the discharge parameters and the rainfall/runoff relation are attributed to climatic changes. The findings of this study have a practical implication to flood risk management and land use planning in the Meuse basin, that will also briefly discussed in this paper.

***Keywords:*** floods, climate change, landuse change

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**HW2003** **Oral Presentation** **4499**

# Temporal scaling of hydrological and climate time series and the low frequency variability

***Dr. Danijela Markovic***
*Analysis of Variability in Hydrological Data Serie No IAHS*

***Manfred Koch, Holger Lange***

Sources of interannual to interdecadal variations in the structure of mean monthly hydro-meteorological time series from the German part of the Elbe River Basin are analyzed. Statistically significant correlations between the 2-15 yr. scale averaged wavelet spectra of the mean monthly climate variables and the North Atlantic Oscillation (NAO)- and Arctic Oscillation (AO)- Index are found, which provides evidence that such low-frequency patterns in climate time series are externally forced. Application of Singular Spectrum Analysis (SSA) results in major low-frequency modes for the basin precipitation of the Striegis, Ohre and the Elbe River that coincide with those detected also in the discharge time series. The percentage of the variance explained by the annual cycle and low frequency components is clearly larger for the discharge than for precipitation. This finding manifests itself also through higher DFA (Detrended Fluctuation Analysis) Hurst parameter (H) estimates for discharge than for precipitation. Upon subtraction of the annual-and the major low frequency SSA- signal from the raw time series data, the DFA H parameter estimates suggest a short-range memory structure of the residuals for both precipitation and discharge. For the Elbe- and Este-River flows at gauges Dresden and Emmen we show additionally that their low frequency variability modes can be predicted by the SSA recurrent algorithm.

***Keywords:*** singular spectrum analysis, low frequency variability, hydrometeorology

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**HW2003** **Oral Presentation** **4500**

# Stochastic forecasting of drought using exhogenous variables

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***Antonino Cancelliere, Brunella Bonaccorso, Giuseppe Di Mauro, Giuseppe Rossi***

Unlike other natural disasters, drought events evolve slowly in time and their impacts generally span a long period of time. Such features do make possible an effective mitigation of the most adverse effects, provided a timely monitoring of an incoming drought is available, based on a proper selection of indices for drought identification and forecasting. Among the several proposed drought monitoring indices, the Standardized Precipitation Index (SPI) has found widespread application for describing and comparing droughts among different time periods and regions with different climatic conditions. However, limited efforts have been made to analyze the role of the SPI for drought forecasting. Recently, many authors have investigated the influence of large-scale climatic patterns on hydrologic variables at local scale such as precipitation and streamflow, and their possible impacts on drought. In principle, use of such patterns to forecast droughts, should allow for an improved forecasting ability of the models, as well as for an longer time horizon of prediction. In the paper, a preliminary attempt to include information from large scale climatic patterns within stochatic models oriented to forecast drought indices is presented, with particular reference to Sicily. First, the correlation between climatic indices such as El Nino Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), European Blocking (EB) and precipitation in Sicily is investigated, considering the seasonality of the processes, as well as different aggregation time scales. Then, stochastic models that make use of climatic patterns indices as exhogenous variables are developed, able to forecast SPI values at different time horizons. Such models are then applied to SPI series in Sicily, and their forecasting performances are assessed also with reference to previous results obtained without exhogenous variables. Preliminary results of the applications seem to indicate that the inclusion of information from large scale climatic patterns into forecasting models can effectively increase the forecasting performance of the models, and therefore further efforts should be pursued in this direction.

***Keywords:*** spi, forecasting models, large scale climatic patterns

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**HW2003** **Oral Presentation** **4501**

# Regional dry spell frequency analysis of Isfahan Province, Iran, using L-Moments

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Dry spells are considered as one of the important index for drought risk analysis. However, the lack of sufficient data in desired places limits the hydrologist and managers to estimate drought risk. In this study, the annual maximum dry spells of Isfahan Province in center of Iran were used to estimate regional dry spell quantiles. We applied the method of L-moments to test the existence of discordant stations, test the homogeneity of the region and finding the best regional distribution for annual maximum dry spells. The results showed no discordant station except for one station. The test for homogeneity also showed that Isfahan Province is a homogeneous region. According to goodness of fit test, ZDIST, Generalized Logistic distribution was found to be the best regional frequency distribution. The map of dry spells in different return periods also showed that the eastern part of the province has higher risk of dry spells than the center and western regions

***Keywords:*** dryspells, l moments, regionalization

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**HW2003** **Oral Presentation** **4502**

# Seasonal Flood Frequency Analysis Based on Bivariate Joint Distribution

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***Guo Shenglian, Liu Pan, Xiao Yi***

Von Mises distribution and Pearson Type III distribution were used to describe the dates and quantities of seasonal maximum flood respectively. A bivariate joint distribution with Von Mises distribution and Pearson Type III distribution margins was developed based on Gumbel Archimedean Copula and used to describe seasonal maximum flood series. The approaches for calculating conditional frequency and bivariate return period were presented. Case study shows that bivariate joint distribution of seasonal maximum flood can optimally estimate design flood, explore more information and provide a new way for seasonal flood frequency analysis.

***Keywords:*** seasonal flood, bivariate joint distribution, frequency

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**HW2003** **Oral Presentation** **4503**

# Empirical validation of a Bayesian combination method of local and regional information in flood frequency analyses

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In a previous paper (Seidou et al. (2006), A parametric Bayesian combination of local and regional information in flood frequency analysis, Water Resour. Res., 42, W11408, doi:10.1029/2005WR004397), the authors proposed a parametric Bayesian (PB) approach for combining local and regional information in flood frequency analyses, under the assumption that annual flood peaks are GEV-distributed. They used generated regional data sets to validate the PB method and found that it is the better than the local (L), regional (R) and empirical Bayes estimators (EB) quantiles and/or parameters estimators in most cases. However, since their data generation algorithm is able to reproduce only part of the complex characteristics of regional streamflows data series, validation on real streamflows data is desirable. In this paper, the L, R, PB and EB estimators are compared on short 20-year and 40-year series extracted from the historic data of the Harricana river (84 years of data), the Beaurivage river (76 years of data) and the Matane river (74 years of data) located in the province of Quebec, Canada. It was found that the conclusions drawn in Seidou et al. [2006] hold in the case of real regional streamflows data. The results show the stabilizing effect of the proposed method on the parameters of the GEV distribution when estimated with the short data series. Furthermore, at sites where the GEV shape parameter is not very different from the regional average, the estimators obtained with the proposed method give values that are closer to the quantiles estimated with the total series of available data.

***Keywords:*** regionalization, distribution, bayesian

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**HW2003** **Oral Presentation** **4504**

# The AR metric for short and long memory time series: an application to hydrological data

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Statistical techniques for time series clustering and classification can provide useful information in order to improve planning and management of water resources. For instance, criteria for time series comparison are used for clustering-based streamflow prediction models (such as artificial neural network based on genetic algorithms), for characterizing different river flows across wide regions, for achieving an objective grouping of flow series into similar dynamics, for monitoring changes in the dynamic pattern, and so on. In this study, a metric between linear processes is presented. In particular, the AR metric between ARFIMA processes, that is the Euclidean distance between the weights of the pure AR formulation of two ARFIMA processes, is discussed and the statistical properties of the asymptotic distribution of this distance criterion are investigated. Moreover, an approximation which is computationally efficient is given. These results locate the problem of time series comparison in an inferential framework which implies that the comparison of hydrologic phenomena observed in time can be performed in terms of their data generating mechanism. The extension of the AR metric to long memory processes constitutes an effective attempt to produce a more comprehensive tool useful for hydrologic data clustering. The performance of the proposed criterion is illustrated by means of simulated and empirical applications. Specifically, we will apply the proposed criterion to classify river streamflow series recorded by U.S.G.S. National Water Information System in different basins.

***Keywords:*** classification, long memory, ar metric

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**HW2003** **Oral Presentation** **4505**

# Climate impacts on runoff and evaporation in the Mackenzie River Basin

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The research described in this paper examines how the hydrological cycle is affected by changing climate in the Mackenzie River Basin in northern Canada. The study focuses on four hydro-meteorological variables; runoff, evaporation, temperature and precipitation. Two different data sets are used in this study. In both data sets, runoff and evaporation are modelled using the WATFLOOD hydrological model. In the first data set, WATFLOOD is driven by gridded daily observed temperature and precipitation data obtained from Environment Canada. In the second data set, the WATFLOOD hydrological model is driven by the European Center for Medium range Weather Forecasting (ECMWF) Re-Analysis climate data (ERA-40). Trends are examined for each variable on a monthly and annual basis for the analysis period of 1960 to 2001 using the Mann-Kendall non-parametric trend test with a correction to reduce the effect of serial correlation. To account for cross-correlation, the global (or field) significance is assessed using a bootstrap resampling approach. It was found that all variables, in both data sets, have generally increasing trends during the analysis period. For the ECMWF data, when a trend is detected, 99.9% of the trends are increasing while the Environment Canada data set exhibits an increasing trend in 75% of the cases where a trend is detected.

***Keywords:*** trends, climate change, variability

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**HW2003** **Oral Presentation** **4506**

# Application of bivariate and multivariate data analysis to runoff prediction depending on the antecedent soil moisture in a small catchment in Germany

***Dr. Peter Chifflard***

***Harald Zepp***

In the small catchment Obere Brachtpe (2,5 km), Sauerland, central west Germany, runoff generation processes have been investigated since 2000 with a hydrometric, hydrochemical and soil physical approach. The experimental investigations have been focused on the analysis of the influence of soil moisture dynamics, relief and soil on the discharge processes at the plot, hillslope and catchment scale. A very significant aim was to evaluate statistically the relationship between rainfall and runoff on the basis of a multitude of events and especially to quantify the influence of antecedent soil moisture on the runoff dynamic. This paper demonstrates how common statistical methods like the bivariate and multivariate data analysis can used for prediction runoff especially the peak runoff. Therefore four soil hydrology measurement locations are installed in the catchment Obere Brachtpe in the year 2000. The measurement locations are arranged in a gently convergent slope ranging from the upper slope to the riparian zone. They are equipped with several tensiometers installed in different depths (20 to 200 cm). The soil water potential is registered automatically every 10 minutes and is used as an indicator for the soil moisture. Moreover the precipitation and the runoff are measured at the catchment outlet in a 10 min- respectively 15 min-interval. For the statistical analysis of the hydrological dataset the following methods were used: the correlation analysis, the multiple regression, the cluster analysis and the discriminant analysis. The results of the relationship between soil water potential of every measurement location and of every depth with the runoff measured at the catchment outlet based on a dataset of one year with an interval of 30 minutes show an distinct influence of the soil moisture on the runoff dynamic and a nonlinear behaviour of this influence. There exists a significant threshold which divides high runoff and low runoff depending on the soil moisture. If there are dry conditions (low soil water potential) the discharge keeps constant whereas there is a significant increase of the discharge at wet conditions. To evaluate statistically the relationship between rainfall and runoff depending on the antecedent soil moisture more than 130 rainfall-runoff-events (recorded over a period of 3 years (2001 till 2003)) have been distinguished and described by several variables i.e. total rainfall amount, median of the rainfall amount, ration of total rainfall amount and median, rainfall duration, rainfall intensity, peak runoff or initial runoff. Additionally for every event the antecedent soil moisture was determinated by using the soil water potential in the upper soil of every measurement location. With the cluster analysis this 130 rainfall runoff events were subdivided in six cluster whereas the antecedent soil moisture of each event were used as objects. The six cluster describe different soil moisture conditions of the convergent hillslope reaching from wet to dry conditions. In every cluster a multiple regression model was derived to predict the peak runoff of the different rainfall-runoff-events. The independent variables of the regressions are changing with the soil moisture conditions. The validation of the regression model shows a good correlation between predicted and measured values of peak runoff (correlation coefficient = 0,88). Summarized, the using of different statistical methods helped to analyse and especially to quantify the influence of antecedent soil moisture in the runoff dynamic. Moreover based on soil moisture measurements in the point scale the peak runoff in the catchment scale could be predicted.

***Keywords:*** soil moisture, runoff prediction

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# The key role of intermittency in rainfall disaggregation schemes

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The rainfall process is the result of a complex framework of non-linear dynamical interactions between the different components of the atmosphere. It preserves the complexity and the intermittent features of the generating system in space and time as well as the strong dependence of these properties on the scale of observation. The different intermittency features which characterize the process at various scales (from the climatological to the drop size scale) represent in their turn one of the principal obstacles in the development of reliable simulation/disaggregation models. The purpose of this work is the identification of a consistent probability structure for the intermittency process within rainfall events through the analysis of time series observed at very high resolution. The extracted statistical intermittence patterns are compared with the one obtained from a few commonly used disaggregation models (Random cascades and Iterated random Pulse process).

***Keywords:*** rainfall, intermittency, disaggregation

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**HW2003** **Oral Presentation** **4508**

# Advanced tool for statistical testing and its application for detecting impacts of climate change on evaporation

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Change and Trend Problem Analysis (CTPA) computer program has been developed by Czech Hydrometeorological Institute as a contribution of the Institute to the Hydrological Operational Multipurpose System (HOMS) established by the World Meteorological Organization for the transfer of technology in hydrology and water resources. The CTPA program provides tools for analysis of data with respect to the distribution properties and covariance structure. Its main purpose is however to provide a tool for detecting point and gradual changes in the analysed time series. Mean value and variance of the analysed series are the main tested parameters but the program includes also tests for detecting changes in spectral density, autoregressive parameters and parameters of bi-variate linear regression model. For correct application of the change tests, the CTPA program incorporates tests of normality and tests of statistical independence, and for each of the tests, assumptions with respect to the normality and independence are specified. T.G. Masaryk Water Research Institute operates Hlasivo evaporation station (station located in vicinity of Hlasivo municipality in the Czech Republic), which was established in 1957. The observed variables include air temperature, relative air humidity, precipitation, wind speed, solar radiation and also evaporation from free water surface. The evaporation has been observed by using a special large-area evaporimeter (5 m in diameter, area of 19.635 m2) and several types of open pan evaporimeters, including GGI-3000 evaporimeter and Class A pan. In 2006, the research activities of the Institute included statistical analyses of the observed series and the main attention was paid to the rare monthly evaporation series, which is available for months from May to September since 1957, i.e. the length of the series is 49 years. The intention was to identify and test statistically possible changes in the series that could be attributable to climate change or natural climate variability. The statistical analysis was therefore focused on testing the mean of the analysed series in terms of its possible gradual change, time occurrence of this change and possible change in the parameters of the detected change. For this purpose, the tools in the CTPA program include test of trend existence, test of trend appearance, test for change in trend slope and test for change in trend. The results of the analysis identified a statistically significant increasing trend in the annual series (series calculated as a sum of monthly values in each year) since the middle of the eighties, which is in approximate harmony with assumed beginning of climate change. The gradient of the trend line shows that the rate of the evaporation increase is 5 mm in a year. In terms of seasonal distribution of the increase, it occurs mainly in May and September. For the other months, the change is not statistically significant.

***Keywords:*** evaporation, climate change, statistical testing

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**HW2003** **Oral Presentation** **4509**

# Long time series segmentation with regression-by-constant

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Analysis of measured data sets has always been important in hydrological studies. Therefore, although they are substantially costly, measurement or gauging stations are installed and continuous monitoring systems are developed in hydrological watersheds. However having such a system in hand is not enough in order to make decision on how to design, construct or produce an engineering facility. Due to the complexity of the earth and also unknown structure in environmetrics, non-homogeneous, non-random, but trend- or jump-including data with a predefined probability mass or density function are observed. Because of that reason, data records are highly subject to preliminary analysis before deeper investigations take place and the design and construction (or production) of engineering facilities start. One among these is the jump analysis. The unknown behavior in data reflected by trends or sudden changes (jumps) is due to inconsistency (systematic errors) or nonhomogeneity. A trend in a time series can result from gradual natural and human induced disruptive and evolutionary changes in the environment whereas a jump may result from sudden catastrophic natural events. Without looking if it is gradual or sudden, nonhomogeneity and inconsistency in a time series should be identified or detected, be described, and removed. Any change in the time series is most reliable if it is detected by statistical tests and also has physical and historical evidences. Projections for future cannot be made without having this information in hand. Jump analysis is a change point detection problem for which statistical tests such as the Pettitt and Alexandersson tests are available. It can also be termed as segmentation of a time series simply aiming at dividing a given number of observations into subseries (subsegments) with statistical characteristics that are similar within each subsegment and different between subsegments. The simplest case is the segmentation with regression-by-constant which is the case considered in this study. The usual criterion to decide if a change point exists is based on the segmentation cost defined as the sum of squared deviation of the data from the means of their respective segments. Various techniques including the classical parametric or nonparametric tests are available to compare the average of subsegments, and test if they are different from each other by checking the hypothesis that the mean values of successive subsegments are equal. In addition to the classical tests, recent segmentation procedures are available in literature. A progress has been achieved in the segmentation algorithm of Hubert (2000) by using the newly introduced remaining cost concept, and the AUG segmentation algorithm has been developed (Gedikli et al., 2007). In this study, an application of the AUG segmentation algorithm that is performed for 661 year-long annual mean streamflow data from 1304 to 1964, of Jeffrey Pine at Tioga Pass, California, USA, is presented. The time series looked stable for centuries until mid 19th century except for a few upward and downward jumps with short duration. A negative jump was located for the period from 1841 to 1865 after which a positive jump was observed for 54 years from 1866 to 1919. Another negative jump has started in 1920 to continue till the end of the data set (1964). When results obtained through this application were combined to previous experience on segmentation, it is concluded that the AUG algorithm is fast and capable to segment long time series of hundreds (even thousands) of items and hence is advised for use of earth-related researchers as well as practicing engineers. References 1. Gedikli, A., Aksoy, H., Unal, N.E. (2007) Segmentation algorithm for long time series analysis, Stochastic Environmental Research and Risk Assessment, (accepted for publication). 2. Hubert, P. (2000) The segmentation procedure as a tool for discrete modeling of hydrometeorological regimes, Stochastic Environmental Research and Risk Assessment, 14, 297-304.

***Keywords:*** long time series, segmentation, jump analysis

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# Copulas: A Novel Method for Describing Spatial Dependence Structures and for Spatial Interpolation

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The magnitude of any hydrologic parameter, for example rainfall intensity, is changing in space. Geostatistical methods are commonly used to describe the variation of such parameters in space, specifically methods based on the analysis of variograms such as Kriging. These traditional geostatistical methods describe spatial variability with linear covariance functions and express spatial dependence as an integral over the whole distribution of parameter values. Copulas, on the other hand, are standardized multivariate distributions with uniform marginal distributions. A copula can exhibit different dependence structures for extreme values (high or low percentiles) and for central values, departing from the assumption of Gaussian dependence. Thus, using copulas, the spatial dependence structure can be defined without a parametric distribution. This presentation demonstrates how copulas can be used to improve the description of the spatial dependence structure of multivariate distributions independently from univariate marginal distributions. It will also be shown how theoretical copulas, based on this improved description of spatial variability, can be used for enhanced interpolation results, including a better uncertainty estimate of the interpolation. The purpose of interpolation is to estimate the value of a parameter at a location without observation. Ordinary Kriging and Indicator Kriging use linear estimation methods to provide a best estimator for interpolation. Copulas within a stochastic interpolation framework can, in addition to providing the best estimator, also provide the quality of the estimator which may be defined by a simple estimation error or a full distribution function. Multivariate copulas enable the calculation of the conditional marginal distribution corresponding to the point for which the interpolation is performed. The conditional distribution can then be used to estimate confidence intervals for the estimator. Using copulas, the width and location of the confidence intervals depend on the spatial dependence structure, the spatial configuration of the observation points, and the magnitude of the values measured at the observation points. In traditional interpolation methods the confidence intervals are measures of the spatial configuration of the data alone. The fact that, by using copulas, the same estimated value can occur from the same spatial configuration with different confidence intervals is a substantial improvement compared to Kriging. Preliminary cross validation results show that copulas can perform spatial interpolation better than traditional geostatistical approaches such as Ordinary Kriging or Indicator Kriging. The enhanced quantification of interpolation-uncertainty can have significant impacts in any application of a spatially distributed environment.

***Keywords:*** copula, multivariate analysis, spatial variability

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**HW2003** **Oral Presentation** **4511**

# The extreme peak flow series of the Tiber River in Rome

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The probability distribution of the annual maxima peak flows on the Tiber River in the town of Rome (Ripetta) can be evaluated using the information available since the XV century. The systematic stage measurements began at the end of the XVIII century, and the record of the peak stages of the inundations of the town of Rome goes back to the Renaissance. This last record is a left censored sample of the peak stages exceeding the threshold of 16 m at the Ripetta landing, below which the floods were not recorded before the year 1782. In order to use all this information, the stage discharge relationships were required for periods where only few discharge measurements were made, if any, and only in low flow conditions. In this paper we will give, first, a brief synthesis of the methods used to develop the stage discharge relationships, in order to highlight the nature of the data. Second, the probability distribution of three samples of annual maxima peak flows are analysed: the modern sample, including the observed data since the beginning of the systematic flow record in 1921, the complete sample, including the observed data since the beginning of the systematic stage record in 1782 and the censored sample of the exceptional floods, that starting from the XV century have flooded the town of Rome. The probability distributions fitted on the complete sample and on censored samples, truncated following two different criteria, are compared. Thus the problem of choosing a distribution law representing the high return period quantile arises. We propose the use of an index that takes into account both the quantile estimation accuracy and uncertainty.

***Keywords:*** flooding events, historical information, flood frequency analysis

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**HW2003** **Oral Presentation** **4512**

# Modeling episode peak and duration for eco-hydro-climatic applications

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Long series of observations on environmental processes provide a baseline record to better gauge recent episodes relative to prior ones. In this context, episodes are consecutive observations either above or below a reference level. Such episodes can be quantified in terms of three random variables: duration (the number of time intervals in the episode), magnitude (the sum of all process values for a given duration), and peak value (the absolute maximum reached by the process within a given episode). In this paper we present a new stochastic model for the bivariate distribution of episode duration and maxima (peak values). The model follows naturally (in the mathematical sense) from the definition of episodes, it properly reflects the randomness of duration, and it answers an explicit call made by several authors for a theoretical (rather than empirical) modeling of episode parameters. The model, which is based on the stochastic theory of random maxima, is called BTLG because it is Bivariate and has Truncated Logistic and Geometric marginals. Such mixture of discrete and continuous components reflects the discrete nature of duration and the continuous nature of the peak value. A similar approach was used for our previously published bivariate stochastic model of episode duration and magnitude (Biondi et al., 2005; Kozubowski and Panorska, 2005). The BTLG model was applied to a 2300-year long dendroclimatic record from the eastern Sierra Nevada headwaters of the Walker River, between California and Nevada. After testing the sensitivity of this proxy record as a moisture (water-year precipitation) indicator, positive (wet) and negative (dry) episodes (467 each) were stochastically modeled. Maximum likelihood estimates of model parameters, as well as expected and observed distributions, were computed, showing an overall good fit. The practical use of the model was illustrated by computing the likelihood of extended dry and wet episodes, including the 1930s drought and the early 1900s pluvial. Our results show that the chance of an extreme dry period is much greater than the chance of an extreme wet spell.

***Keywords:*** dendrochronology, paleoclimatology

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**HW2003** **Oral Presentation** **4513**

# Fitting parametric distributions to roughly rounded off records

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Daily rainfall time series were mainly collected in the past, and still nowadays, using nonrecording standard rain gauges that store the water volume fallen in a standard orifice (usually 0.1 m2) into a receiver tank. The daily volume of stored water is then converted in rainfall depths that should be discretized at a standard resolution of 0.1 mm. Nevertheless, a deep analysis conducted on a wide database of daily rainfall time series revealed the presence of anomalous percentages of measures that have been rounded off at some resolutions (such as 1 mm and 5 mm) different from the standard one (0.1 mm). The talk will focus on the following topics: i) An hypothesis on the origin of records rounded off at large resolutions, such as 1 mm and 5 mm. ii) An overview of the problems and errors arising when fitting parametric distributions and applying goodness of fit tests on samples containing roughly rounded off measurements. iii) The presentation of the Rounding off Rule Estimator (RRE), an original method that allows the estimation of the percentages of rainfall measurements that have been rounded at some potential resolutions. iv) The evaluation of performances (Bias and RMSE) of the RRE on distributions that can reliably describe daily rainfall time series. v) The discussion of results of the RRE application on a wide database containing 340 time daily rainfall time series. vi) An illustration of methods to manage and reduce errors driven by the presence of rounded off records.

***Keywords:*** precipitation, monitoring networks

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**HW2003** **Oral Presentation** **4514**

# Application of multivariate logistic model to estimate effective rainfall for an event and comparison with SCS method

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Multivariate logistic models, which are widely used in biological, medical, and social sciences, allow one to predict a discrete variable, from a set of non-normally distributed variables that may be continuous, discrete, or dichotomous. A logistic function behaves linear in the mid range and tends to be non-linear as it approaches to the extremes, hence it is more flexible than a linear function and capable of dealing with skew-distributed variables. Dependent variable of a logistic function is essentially a Bernoulli-distributed, thus unreasonable values of dependent variable (e.g. runoff coefficient > 1.0) can be avoided. Moreover, it is also very convenient to incorporate a priori knowledge of physical dependencies among different variables, consequently, can be regarded as data-plus-knowledge driven approach. Although logistic models are seldom applied to hydrological problems, they seem to bear good potential to handle asymmetrically distributed hydrological variables of extreme occurrence. In the following work, logistic regression approach is implemented to derive a multivariate logistic function for effective rainfall; in the process runoff coefficient is assumed to be a Bernoulli-distributed dependent variable. A backward stepwise logistic regression procedure was performed to derive the logistic transfer function between runoff coefficient and catchment as well as event variables (e.g. drainage density, soil moisture etc). The investigation was carried out using data base for 244 rainfall-runoff events from 42 mesoscale catchments located in south-west Germany. The performance of the derived logistic transfer function was compared with that of SCS method for estimation of effective rainfall. The methodology, outcome of the investigation and comparison between the logistic approach and the well established SCS approach will be presented.

***Keywords:*** logistic model, effective rainfall, data plus knowledge

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**HW2003** **Oral Presentation** **4515**

# Use of Aggregated Rainfall Radar Measurements in Rainfall-Runoff Modeling by Artificial Neural Networks

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The performance of rainfall-runoff modeling in hydrology is often affected by many uncertainties in the input selection phase as well as in the parameter estimation phase. The rainfall process in particular exhibits a high degree of spatial and temporal variability, which is obviously only partially considered by using traditional rain gauge data. Not only by physically based model, but also by more empirical linear and non-linear modeling techniques, like ARMAX models and Artificial Neural Networks (ANNs), a physical understanding of the hydrological processes under consideration and a correct definition of input data is required. Particularly in mountainous regions, real-time quantitative precipitation estimation is of high practical use in river-flow and lake-level forecasting, hydrological risk and water resources management. In the recent years new analysis and correction algorithms in the radar research field have resulted in a significant reduction of bias and scatter problems and in improved quantitative precipitation estimates. Taking advantage of these recent developments, different ANNs have been defined to simulate the inflow to the Lake Lugano, Southern Switzerland. Standard rain gauge data and innovative aggregated radar measurements have been used as input and the performance of the different ANNs are compared and critically discussed. This study is part of a more comprehensive water management research project, dealing with the analysis of the actual international management policy of the Lake Lugano, which is presently carried out by the cantonal authorities of Canton Ticino and by the Politecnico of Milan.

***Keywords:*** artificial neural network, radar rainfall measurements, rainfall runoff modeling

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**HW2003** **Oral Presentation** **4516**

# What drives high flow events in the Swiss Alps? On the use of wavelet spectral analysis for the analysis of hydrological time series

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Wavelet and cross wavelet spectral analysis offers a framework to analyze observed time series with respect to time and scale (~ 1/frequency) and has therefore become popular in water resources research to characterize the temporal or spatial variability of hydrometeorological time series. Current applications in the area of hydrology as well as in other fields of geosciences show however a certain lack of statistical rigor. We therefore briefly review state-of-the-art methods in wavelet spectral analysis, highlight the subtleties and potential pitfalls and discuss the use of recently developed solutions to overcome them. The presented methods are applied to a hydrological case study in the Swiss Alps to investigate the dominant driving processes during high flow events in an alpine catchment. The wavelet coherence analysis of temperature and precipitation shows that in this catchment, most of the observed high flow events over the last 25 years have been induced by coherent oscillations of temperature and precipitation at temporal scales up to a few days. Part of these typical flood producing weather situations however did not result in significant high flows. The identification of these periods being also of prime importance for good flood predictions, this underlines that wavelet spectral analysis offers powerful tools for hydrological process understanding and modelling: If applied in a statistically rigorous framework, it has the potential to substantially contribute to the analysis of hydrological processes, especially to the identification of the dominant driving processes and their encoding in hydrological models. The gained insights could form the basis of a new methodology to assess the performance of extreme event simulation frameworks, by focusing on the hydrological models ability to explain the occurrence and the non-occurrence of floods during potentially flood producing situations and by testing whether the coherence of the simulated time series differ significantly from the observed pattern of coherence.

***Keywords:*** continuous wavelet transform, hydrological modelling, wavelet coherence

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**HW2003** **Oral Presentation** **4517**

# A multisite stochastic daily rainfall generator for representation of low-frequency variability

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***Raj Mehrotra***

A stochastic modeling framework for multisite generation of daily rainfall is developed with an aim of representing both short and higher time scale dependence in the generated rainfall sequences. The framework simulates rainfall at individual locations using separate models for rainfall occurrences and rainfall amounts on the simulated wet days. The spatial correlations in the generated occurrences and amounts are induced using spatially correlated yet serially independent random numbers. The rainfall occurrence model is based on a modification of the transition probabilities of the traditional Markov model through an analytically derived factor that represents the influence of rainfall aggregated over long time periods in an attempt to incorporate low frequency variability in simulations. The rainfall amounts on the wet days are generated using a nonparametric conditional simulation approach. The utility of the proposed method is illustrated by applying the model on a network of 30 raingauge stations aroundSydney, Australia, and comparing a range of statistics describing daily and higher time scale distribution and dependence attributes. The analyses of the results show that the method adequately captures daily as well as aggregated higher time scale rainfall characteristics at individual locations including the spatial distribution of rainfall over the region.

***Keywords:*** rainfall, stochastic, long term memory

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**HW2003** **Oral Presentation** **4518**

# ARCH effects in rainfall processes

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***Xi Chen***

There are a several approaches for the modelling of precipitation series, many of which are based on ARMA (AutoRegressive Moving Average) techniques, or multivariate autoregressive models, or Markov models. ARMA models operate under the assumption of constant variance. However, with McLeod-Li test and Engles Lagrange Multiplier test, clear evidences are found for the existence of AutoRegressive Conditional Heteroskedasticity, i.e. the ARCH effect, a nonlinear phenomenon of the variance behaviour, in the residual series from linear AR models fitted to daily rainfall processes. ARCH-type models have been widely used to model the ARCH effect for economic and financial time series. An ARMA-ARCH error model is proposed to capture the ARCH effect present in daily rainfall series. The ARMA-ARCH error model combines an ARMA model for modelling the mean behaviour and an ARCH model for modelling the variance behaviour of the residuals from the ARMA model.

***Keywords:*** rainfall, arch, model

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**HW2003** **Oral Presentation** **4519**

# Probability weighted moments techniques applied to heavy-tailed distributed samples deprived of largest element

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Extremes of the stream flow are usually modelled by heavy-tailed distributions. While scrutinising annual flow maxima or the peaks over threshold, the largest elements in a sample are often suspected to be low quality data, outliers or values corresponding to much longer return periods than the observation period. Since, in the case of floods, the interest is focused mainly on the estimation of the right-hand tail of a distribution function, sensitivity of large quantiles to extreme elements of a series arises to the problem of special concern. This study investigated the sensitivity problem using the log-Gumbel distribution by generating samples of different sizes (n) and different values of the coefficient of L-variation by Monte Carlo experiments. Parameters were estimated by the probability weighted moments (PWM) method, both for complete samples and the samples by the same method. The PWMs method extended by Hosking for upper censored data and named as A-type and B-type, was applied for parameter estimation. For each type the value of the second largest element T=xn-1:n and its probability of non-exceedance FT is used alternatively as the population threshold. The effect of the FT value on the performance of the quantile estimates is then examined. It is shown that the value (n-1)/n adopted by Hosking and Wang as the FT estimate is too low. Moreover in the contrary to Hoskings recommendation, his A-type appears preferable. Experimental results show that omission of the largest sample element need not result in a decrease in the accuracy of PWMs large quantile estimation. Although censoring in ML method results in a loss of estimation efficiency, the ML estimates under type II censoring are still more accurate than those of PWMs method. Similar properties are noted for Log-logistic and Pareto samples if PWMs method is applied to right censored data.

***Keywords:*** censoreddata, floodfrequencyanalysis, probabilityweightedmoments

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**HW2003** **Oral Presentation** **4520**

# Initial study of two-shape-parameter flood frequency distributions

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The primary objective of flood frequency analysis (FFA) is the estimation of upper quantiles of probability distribution. Many natural events, river flows in particular, have a physical lower bound at zero and, therefore, it is doubtful whether the lower bound is the best third parameter for flood frequency models. Fixing the lower bound at zero and introducing the second shape parameter one may obtain greater flexibility of the distribution function. Here, the background and arguments for using two shape parameters instead of the lower bound parameter are presented. Three ways of introducing the second shape parameter are considered in respect to the commonly used flood frequency models. The gamma distribution serves as an example. A new selection procedure of the best fitted probability distribution model for the two competing models: (1) a three-parameter distribution with a lower bound and (2) a two-shape-parameter model has been also outlined.

***Keywords:*** floodfrequencyanalysis, two shape parametermodels, lowerbound

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**HW2003** **Oral Presentation** **4521**

# Statistical modeling of the discharge level in the Danube lower basin

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First of all, the internal structure of monthly time series of the discharge level at Orsova situated in the Danube lower basin for 166 years (1840-2005) has been analyzed. Statistical non-parametric tests have been applied for the emphasis the climate change points. Also, the signal-to-noise ratio has been estimated for testing the statistical significance of change points. The periodicities from 2 to 40 years have been found. Signal of Quasi-Biennial Oscillation - QBO is present in the discharge level during the spring and summer time, while periodicity of 40 years appears in autumn months. In the second part of this study the extreme value theory is applied for studying daily maximum discharges incorporating some covariates. Two methods are applied for fitting the data to an extreme - value distribution: block maxima and peaks over thresholds (POT). From the Generalized Extreme Values (GEV) analysis of the maximum daily discharges for one year, month or season, it resulted that these ones are fitted best to a Weibull distribution. By testing through different methods the exceeding threshold (POT) for the daily annual discharges over the period 1900-2005, a value of 10000 mc/s was found. The values exceeding this threshold analyzed through Generalized Pareto Distribution (GPD) are well fitted by using a beta-type distribution. In order to find the atmospheric circulation over Atlantic European region influence on the occurrence of extreme events in the lower Danube basin the period 1958-2001 was analyzed (ERA-40). The atmospheric circulation was fitted to the low frequency components of the decomposition in Multivariate Empirical Orthogonal Functions (MEOF). Then its influence was tested through incorporating in the GEV distribution parameters of the first 10 PCs of the MEOF decomposition simultaneously and with different month lags. The model presented the most significant improvement through introducing in the location parameter the first 10 MEOFs PCs of the atmospheric fields considered with one month prior to the occurrence of the maximum values in the discharge time series. Therefore, incorporating the signal components of the atmospheric general circulation in the statistics of extreme events of discharges in the Danube lower basin led to an essential improvement of the statistical modeling of these events. From this study we can conclude on the impact of climate change in the hydrological regime in Balkans zone, taking into account the capacity of Danube as pluviometry integrator in Europe . The results obtained in this study represent a background for the estimation of climate change emphasis by the different scenarios model in comparison with observed data.

***Keywords:*** extremes, multivariate, analysis

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**HW2003** **Oral Presentation** **4522**

# Space-Time Analysis of the Variability of Flood Magnitude and Occurrence in Germany

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This contribution analyses the variability of flood magnitude and flood occurrence in Germany. The analyses are based on discharge time series (annual maximum series and peak over threshold) of 40 gauges, distributed all over Germany, with observation periods longer than, at least 70 years. Fluctuations in flood magnitude and occurrence are identified by filtering methods, correlation analyses and wavelet transformation. It is shown that there is a distinct variability from the interannual to the interdecadal time scale, and that floods in Germany cluster in time. Periods with higher floods alternate with lower-floods periods. These fluctuations are spatially coherent, for example, subbasins in the Danube catchment show a similar spectral behaviour as subbasins in the Rhine, Elbe or Weser catchment. These flood variations are correlated with large (European) scale climate variables like mean sea level pressure, 500hPa geopotential and surface temperature. A significant part of the flood variability depends on large scale oscillation patterns like the North Atlantic Oscillation (NAO) or rather its global scale circumpolar component, the Arctic Oscillation (AO). Thus, the flood probability is fluctuating with time.

***Keywords:*** floods, space time variability, climate variability

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**HW2003** **Oral Presentation** **4523**

# Threshold Uncertainty in Modelling Extreme Values by the Generalised Pareto Distribution

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The analysis of hydrological data is often performed by assuming a Generalised Pareto Distribution (GPD) for the exceedances over a high threshold (Davison and Smith, 1990). This approach is often preferred to the modelling of block maxima because it allows for a more efficient use of the available data. As the GPD results as the limiting distribution of exceedances, a major issue with the former approach is the selection of an appropriate threshold over which such an approximation is deemed satisfactory. Standard approaches to threshold selection for the GPD are checking the mean residual life plot or the estimates of the shape parameter csi over a range of thresholds. Once the most appropriate threshold u is selected, the (final) model is estimated for a fixed threshold value and in so doing the uncertainty associated with the threshold is neglected. This can result in an underestimation of the uncertainty of the resulting inferences, especially if prediction ( i.e. return levels) is the main goal of the analysis. We propose a bayesian mixture model approach that accounts for threshold uncertainty by considering the threshold level as an unknown. The non extreme and extreme portions of the data are therefore modelled separately and both contribute to threshold and tail estimation. The work is a modification of the proposal by Tancredi, Anderson and O'Hagan (2006) along the lines of work by Shennach (2005). In particular a form of Bayesian exponentially tilted empirical likelihood approach is proposed for modelling the data below the (unknown) threshold. In this context threshold selection arises as an aspect of the estimation procedure and uncertainty in this process is embedded in inferences about return levels.

***Keywords:*** extreme value theory, threshold uncertainty

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**HW2003** **Oral Presentation** **4524**

# Generation of synthetic rainfall time series under instationary climate conditions

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Many applications in hydraulic engineering, for example the flood risk assessment or the dimensioning of hydraulic structures, require long time-series of high resolution precipitation values. Hydraulic models often work on 5-minute rainfall values; for an accurate estimation of flood events with high return periods, time series of several decades can be necessary. However, for most locations, such data series do not exist and the rainfall values have to be estimated from the observations and properties of the surrounding rainfall measurement stations. A simple interpolation (e. g. kriging) of the measured precipitation values does not work in this context as it can only reproduce the average values at the target site but in the same time modifies many other statistical characteristics like the autocorrelation or the extreme-value behaviour of the time series. Interpolated precipitation series do not look like real measured series and are of little use for risk assessment and dimensioning. With a more complex generation scheme, these problems can be managed. Instead of kriging the rainfall values directly, only the statistical parameters of the surrounding stations are regionalized, namely the yearly sum of the precipitation, the distribution function of the rainfall values and the extreme value distribution. Then a random time series is created corresponding to these parameters. In the next step, the temporal order of this series is optimized by simultaneous annealing. Stepwise, the positions of randomly selected value-pairs are switched and the statistical characteristics, e. g. the autocorrelation, of the modified time series are evaluated. The optimum is attained when the differences between the characteristics of the generated series and the regionalized characteristics of surrounding rainfall stations are minimal. Such a generation scheme is implemented in a programme unit called NiedSim that is able to create several decade long time series at any given point in Southwest Germany with a 5 minute time resolution. However, NiedSim needs adjustments due to the observed climatic change in the region. All the statistical characteristics that are used for the regionalization are calculated on the basis of data from the years 1958 to 2001. The NiedSim setup therefore implicitly makes the assumption that the climate of this period is preserved. Two modifications are promising for the adaptation to instationary climate conditions. First, the regionalized extreme value distribution can be modified by replacing its parameters by time dependent functions. The estimation of the function parameters seems nevertheless difficult as the variability of rainfall extreme values is very high in comparison to the underlying trends. Second, the simulation can be conditioned by atmospheric circulation patterns (CPs), so that the climatic trend can be represented by an evaluation of the CP-composition. An automated method based on fuzzy logic to find a suitable CP classification will be introduced. The challenging task in this attempt is to find the CP classification with the most significant differences in the rainfall regimes of the individual CP classes. The definition and properties of such a CP classification will be presented.

***Keywords:*** rainfall simulation, time series

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**HW2003** **Oral Presentation** **4525**

# Managing critic condition for small power station using artificial neural networks and support vector machines as powerful tools

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In this paper three different procedures of streamflow modelling starting only from rainfall and temperature data, are compared for River Nervia, located in Liguria , at Isolabona section. Daily rainfall and temperature input data, available from 1957 to 1973 are used to simulate streamflows at one day ahead. Our intent is to compare two empirical approaches (neural networks and support vector machines) to the lumped conceptual/metric model IHACRES for water management purposes when only basic input variables are available and when physical models would be too complex for practical application. For instance, the basin under study (123 km2), has been characterized during past years by the activity of several power stations able to guarantee supply for domestic and ordinary demands. Nowadays, with the aim to restore those sources of alternative energy both for Nervia and nearby catchments (e.g. Argentina) we propose the comparison between Artificial Neural Networks, Support vector machines and Ihacres considering that those models should be able to provide a powerful tools to simulate daily streamflow series in order to prevent critic or noxious conditions for the operation of the aforementioned systems. It can , furthermore, be noticed that support vector machines exhibit computational advantages respect Neural Networks which allow them to reach a unique optimal and global solution without being incurring the risk to be stucked in local minima.

***Keywords:*** support vector machines, simulating daily stream flows

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**HW2003** **Oral Presentation** **4526**

# A probabilistic model for flood frequency analysis based on a large space scale approach

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The estimation of peak discharges to be assumed for flood protection planning is usually performed on the basis of return periods much longer with respect to the historical series that are usually available. For instance, in Italy the above mentioned return periods range from 100-500 years up to 1000 years for the design of dam spillways. Moreover, in the judicial proceedings for the assessment of the liabilities regarding the damage caused by floods, it is required to establish whether the event causing the damage has to be considered exceptional or unpredictable, according to the meaning of these terms in common speech. The problems stated above can be faced by means of regional statistical techniques based on the analysis of the flood flows recorded at as many gauging stations as possible and on the formulation of a suitable methodology to render homogeneous data referring to natural systems that can vary from each other with respect to dimensions, climate, and physical characteristics. The present paper describes the results of a regional analysis of peak flood flows based on the data recorded in nearly 9000 gauging stations belonging to different geographical areas of Europe (Italy, Switzerland, Austria, Great Britain and EIRE, Portugal), North America (USA, Canada), Oceania (Australia, New Zealand) and to other sites of Africa, Asia and South America. The regionalization procedure is based on the definition of the dimensionless variable Y=(Q/m-1)/CV1.33 where m and CV are the average and the coefficient of variation of the annual maximum peak discharge Q whose probability distribution can be assumed constant for all the considered sites. The probabilistic model (MG model) obtained by interpolation of the empirical non exceedance frequencies of the maximum values of Y observed at each gauged site gives the probability distribution of peak discharges for return periods ranging from 30-50 years (nearly equal to the average length of the considered series) up to about 4000 years. The results of the analysis show that the MG model can describe the statistical behaviour of the data recorded in all the considered geographical areas, despite of the variability of climates and catchment characteristics. With respect to other probability distributions that are currently used for the same purpose, the MG model provides a better interpolation of the empirical non exceedance frequencies of peak discharges, especially for long return periods. The value Y=7 corresponding to about a 4000 year return period is the upper bound for which the interpolation of the frequency distribution of Y provided by the MG model can be considered reliable; the value Y=9 is the absolute maximum of the observed values of Y. These values can be assumed both to define the predictability bound of flood events and to estimate the design peak discharges in cases of particularly high risk levels.

***Keywords:*** peak flood discharge, regional statistical analysis, absolute maximum flood

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**HW2003** **Oral Presentation** **4527**

# A daily to hourly rainfall disaggregation method based on the K-nearest neighbors method

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In the article a rainfall disaggregating method from daily to hourly intensities is presented. The problem is stated as follows: disaggregate daily rainfall into hourly values at several stations when a historical database with hourly values at all stations is available. This methodology allows the replacement of missing hourly data at a given station when daily values are available. The first step consists of a previous identification of homogeneous regions of a given zone. For this purpose the k-nearest neighbor method was used to group rainfall stations. A station was described by the overall yearly average rain, monthly average rain and coordinates. Rainfall disaggregation is performed over a region, by considering that in each region there is at least one station (named as reference station) with hourly rainfall data available. The second step in our approach is the identification of rainfall event types for each rain-gauge station. A rainfall event is described by the hourly rainfall intensity variations, that is, by the inter-dependence of hourly intensities. Considering local characteristics of the rain events, nine hourly intensities are considered, where the maximum hourly intensity is in the fifth place. By identifying groups of similar rainfall events in the historical database, we characterize a station by the identified types of rains, where the type of rain corresponds to a particular set of nine intensity values. The disaggregation algorithm considers the daily rainfall values (at all stations of the homogeneous region) at a given date together with the hourly maximum intensity at the reference station and searches the historical database for similar patterns of data. The similarity is computed as the Euclidian distance between data vectors. For each pair of stations (reference and interest station) a local search is done through the above identified set of data in order to identify the most similar events at the two stations. Based on the identified historical events, the maximum intensity at the interest station is computed as the average of them. In order to identify the intensity during the rest of the hours, the rain event type at the interest station is established based on the maximum intensity. The start hour of a rain event at the interest station is computed as the difference between the start hour at the reference station and the average bias calculated from the historical events. The method was evaluated on 40 rain events from a test period. The results confirm that the internal structure of the rainfall events is well respected with an average correlation coefficient between real and simulated values above of 85 at all stations. Results on start hour are also satisfactory, fact that underlines the utility of the established homogeneous regions.

***Keywords:*** rainfall disaggregation, non parametric method

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**HW2003** **Oral Presentation** **4528**

# Changes in hydrological processes detection and attribution

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Hydrological processes are subject to natural variability and change in different time scales. On top of this, there have been several man-induced changes. Therefore, the study of changes has been an important track of hydrological activities, despite the, occasionally expressed, views that systems are naturally trendy and that long-term persistence may dominate. The term naturally trendy may be misleading, because the Earths system does not behave entirely naturally any more. There are several human activities, that induce considerable changes in hydrological processes. Land-use and land-cover changes (e.g., deforestation, urbanization) influence the rainfall-runoff relations. So do construction projects of water engineering, such as dams, dikes, and large-scale water withdrawals for irrigated agriculture.Besides direct change effects on water systems, one can also observe indirect changes. There has been a visible increase in anthropogenic emissions of greenhouse gases into the atmosphere, leading to dramatic, and unprecedented, strengthening of the greenhouse effect. This results in global warming and drives changes in hydrological processes. Hence, detection and attribution of changes in time series of hydrological data (such as precipitation, river discharge, river stage, lake level, lake surface area, ice break-up / freeze-up dates), both in terms of central tendency asnd variability, remains an area of considerable interest. The issue is difficult, since typically there are multiple factors - climate is only one of the drivers. Time series of observations are not very long, may contain errors and gaps. Moreover, if a change is weak and lasts for a short time, it may not be detectable amidst the strong natural variability. If a change is stronger and lasts longer, the likelihood of detection grows. A critical review of the area of detection and attribution of changes in hydrological processes will be undertaken, in particular reference to climate change. In particular, the following issues will be dealt with: Can global change impact be detected in hydrological time series? Why dont we have a Mauna Loa or a hockey-stick curve in hydrological processes. When will it be possible to detect a significant climate change track? Detection is understood as demonstrating that an observed change is significantly different (in a statistical sense) from situation that can be explained by natural internal variability. Once a significant change is detected, attribution may require two stages: demonstration that the detected change is consistent with a combination of external forcing and natural internal variability; and demonstration that it is not consistent with alternative, physically-plausible explanations.

***Keywords:*** non stationarity detection, time series, climate change

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**HW2003** **Oral Presentation** **4529**

# Extremes in hydrology: an approach using copulas

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In many hydrologic problems several are the random variables that play a significant role, and such variates are generally not independent. The following examples are paradigmatic: (i) different combinations of rainfall intensity and storm duration may generate storms showing quite different characteristics; (ii) the river management may strongly depend upon the joint features of flood peak and flood volume; (iii) the characterization of droughts requires the joint analysis of duration-magnitude-intensity, (iv) the accuracy of flood frequency regionalization estimates is influenced by the presence or not of the spatial dependence among maximum annual flood peaks. Therefore, it is often of fundamental importance to be able to link the marginal distributions of different variables in order to obtain a joint law describing the main features of natural events. In general, the development of multivariate probability models (and, in particular, of multivariate Extreme Value distributions) has been limited by mathematical difficulties in generating consistent joint laws with ad hoc marginals. Recently, the advent of Copulas has solved many of these problems. In this work we present some recent advances in hydrological modeling which exploit copulas. An application to hydrological data is given. As a global reference, both on the theoretical and the practical side, the reader is invited to consult.

***Keywords:*** copulas, extremes, multivariate distributions

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**HW2003** **Oral Presentation** **4530**

# The omnipresence of scaling behaviour in hydrometeorological time series and its implications in climatic change assessments

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It is demonstrated by examples that long hydrometeorological time series exhibit scaling in time, a behaviour equivalent to the Hurst phenomenon. The example time series investigated range from high temporal resolution (10 seconds) rainfall measurements for rainfall events lasting a few hours to proxy time series of temperature for a period over 400 thousand years. The scaling behaviour may reflect a multi-timescale variability of several factors and, thus, can support a more complete physical understanding and uncertainty characterization of hydroclimatic processes. The implications of this behaviour in statistical analyses of hydrometeorological time series is substantial, particularly at large (climatic) time scales, but appear to be not fully understood or recognized as they have been neglected in most climatological studies. To offer insights on these implications, we demonstrate using analytical methods that the characteristics of several temperature proxy series, which appear to exhibit scaling behaviour, imply a dramatic increase of uncertainty in statistical estimation and reduction of significance in statistical testing, in comparison with classical statistics. Therefore, we maintain that statistical analysis in hydroclimatic research should be revisited, in order not to derive misleading results.

***Keywords:*** hurst effect, long term persistence, climate change

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**HW2003** **Oral Presentation** **4531**

# An unorthodox physically-based stochastic treatment of tree rings

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Some practical lessons learned from a 40-year involvement in stochastic hydrology

***Keywords:*** special, lecture

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**HW2003** **Oral Presentation** **4532**

# Report of Poster Session Coordinator

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Report of Poster Session Cordinator

***Keywords:*** report, poster, session

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**HW2003** **Poster presentation** **4533**

# Application of a New Flood Stochastic Simulation Model Developed by a Russian Hydrologist in China

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Application of a new flood stochastic simulation model developed recently by a Russian hydrologist Samborsky in China is studied in the paper. The Quxian station in Qujiang river in the basin of Qiantang river in the southern region of China was selected as a case study. In the paper, the method to determine model parameters by using observed flood data during flood season is proposed and the assumption of these parameters distributions was tested. A lot of stochastic tests have been made for the simulated flood process by the new model, including the short series test and long series test of different durations of flood volumes and flood peak. The results show that simulated flood process may pass all tests and they can describe the characteristics of real flood process well. Meanwhile, the new model is also compared with the conventional models, including seasonal AR(1) model and the Disaggregation model by statistical test for simulation flood process. The results show that the new model is better than the other two models in this basin, not only in simulation flood process, but also in relatively smaller parameters number. So its said that the new model is feasible to simulate the flood process for the basin. Key words: flood stochastic simulation; Russia; disaggregation model; seasonal AR model; Qiantang river; application; statistical test

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**HW2003** **Poster presentation** **4534**

# The Proportion of Water Usable Distribution for Sustainable Development in Haihe River Basins

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Sustainable development means that socio-economic development and ecological environments is reciprocally harmonious. The proportion of water usable distributed rationally in industry, agriculture, life and ecology is the key to the sustainable development of a river basin. Since 1970s, large amount of water usable of ecology is occupied by industry, agriculture and life because of over-fast society and economy development, and thus many serious eco-environmental problems are produced, such as water and soil loss, channel flow-breaking, wet-lands shrinking, water contamination and the annual water volume reaching to sea outfall decreasing, etc in Haihe river basins. At the same time, serious water pollution is caused by a large amount of contamination discharged from society and economy activities in the river basins. These serious eco-environmental problems and water resources shortage has blocked the sustainable development of Haihe river basins. In order to resolve the water resources shortage and serious eco-environmental problems, some water will be diverted into Haihe river basins by the South-to-North Transfer Project that from 2010 on, 79.9108 m3/year of water in Yangtse River will be diverted into haihe river basins by Easter Route, and from 2030 on, 108.4108 m3/year of water in Yangtse River will be diverted into Haihe river basins by Eastern Route and Middle Route, and at the same time eco-environmental restoration program will be done and the eco-environments is predicted to be ameliorated to a good state about 2040 or so. The rational distribution of water resources usable is the key to resolve the contradiction between water use of ecology and that of agriculture, industry and life, especially is the key to reach the aim of eco-environments restoration is being reached about 2040 or so. So, multi-objectives optimization and time series analysis is used to calculation the rational proportion of water usable distribution from 2003 to 2040 in Haihe river basins under the conditions of sustainable development, the plan of society and economy normal development, the water supply of South-to-North Water Transfer Project and eco-environments gradually meliorating of the river basins. This will not only supply a scientific basis to the eco-environmental restoration of Haihe river basins but also supply a scientific method to the eco-environmental restoration of other river basins. Keywords: Rational proportion of water usable distribution; multi-objectives optimization; time series analysis; sustainable development; Haiher river basins.

***Keywords:*** haihe rriver basins, multi objectives optimization, time series analysis

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**HW2003** **Poster presentation** **4535**

# Originating extreme volumes of glaciers runoff in Amudarya River Basin

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Relative contribution of glaciers runoff and their total melting into feeding of Central Asia rivers increases in low water years and decreases in high water ones. Mean value and limits of this parameter vary depending on the water yield of year. For example, by authors data for Pyandzh River basin it equals to: 18.2% (limits 14.1-20.5%) in minimal; 33.2% (limits 29.1-36.7%) in average; and 46.8% (limits 40.4-54.6%) in maximal years. Similar data were obtained for Vakhsh River basin. Analysis of climate characteristics when glaciers runoff was formed should be done for understanding noticeable differences between extreme and average values and this is of practical interest for river runoff forecasting and improvement projects of utilization water resources. Long term ranges (1935-1994) measured volumes of monthly runoff Wb for Vakhsh and Pyandzh rivers in May-October and computed volumes of glaciers melting Vm during the same time were used for solving the outlined problem. Total number of glaciers within Vakhsh and Pyandzh river basins were divided on 127 their groups for calculations melted output from ice and snow. This output consists of volumes Wgl (melted firn, open ice, ice under moraine) and Wsn melted winter and summer snow. Spatial and temporal variability of Vm and Wgl within Vakhsh and Pyandzh river basins was studied in average and extreme years on statistical probability P(Vm). Years when 7%>=P(Vm)>=93% were related to extreme and when 45%<=P(Vm)<=55% were considered as average. Statistical probabilities of precipitation and mean air temperature measured on high mountain meteostations were calculated for the years chosen by above method. Analysis revealed that spatial variability of Vm and Wgl is essentially less in high water years than in low water ones. Intra-seasonal distribution of total melting, snow and ice feeding from glacier areas and relationship between these volumes are definitely connected with type of year on water yield. Specifically, glaciers feeding for Vakhsh and Pyandzh rivers in maximal and average years concentrated in July-August when winter-spring accumulation of snow have exhausted outside of glaciers area. Statistical probabilities of seasonal air temperature in average and extreme years entirely correspond to its role as ablation and runoff formation. Also, low water vegetation season is consequence of cool summer and vice versa. The described relation may be used for studying influence of climate change on water resources of glaciers.

***Keywords:*** statistical probability, extreme runoff, climate factors

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**HW2003** **Poster presentation** **4536**

# Impact of large-scale reservoir operation on flow regime in the Chao Phraya River Basin, Thailand

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The Chao Phraya River basin, the largest basin in Thailand, is located in the central and northern part of Thailand. This basin has two large-scale dams: the Bhumibol Dam in the Ping River and the Sirikit Dam in the Nan River. Analysis of comparing the annual and monthly flow regimes downstream of the dams before and after dam construction shows a constant increase in low flow and a drastic decrease, about 60%, in high flow. The spectrum of flow was analyzed by using the fast Fourier Transform for daily discharges in Nakhon Sawan city and immediately downstream of the Bhumibol Dam after the Bhumibol Dam construction. Flow in Nakhon Sawan city has a periodic characteristic of 7-days, and the released water from the Bhumibol Dam at P.12 has a periodic characteristic of 7-days. We can detect human activities using spectrum analysis of historical recorded discharge data. The reservoir operations affected the hydrological cycles considerably.

***Keywords:*** powerspectrum, regime, data

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**HW2003** **Poster presentation** **4537**

# Using neural network models to forecast the inflow of Doroudzan dam Iran

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One of the methods to have optimum exploitation of the water resources is forecasting the amount of available water in these resources. Doroudzan dam with 993 MCM reservoir capacity which is located in a dry area in south of Iran is a great water resource in region to use for irrigation, industry and generation hydroelectric power. Saving water in the reservoir to have the best use of it is a priority. In case of good forecast of inflow to the reservoir, discharging water through spillway could be minimized by an appropriate schematization of outflows and amount of excess water could be conducted to generate electricity. For this purpose 3 neural network models were created to forecast the amount of seasonal inflow, monthly inflow and weekly inflow to the reservoir. In seasonal model the data of last year rainfall, cumulative rainfall until last season, atmospheric forecast for specific duration and the amount of inflow in last season and last year were used. In monthly model neural network model the seasonal forecast, last year inflow amount and the cumulative inflow amount until last month were used. In weekly model, out puts of monthly model, the inflow in up stream branches, cumulative rainfall in the year till last week, last week rainfall and the inflow rate in last week were used. The models was used for simulation of the reservoir during 2000-2005 and during this years 500 MCM was saved in the reservoir and used to generate more electricity.

***Keywords:*** neural network, doroudzan dam, inflow

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**HW2003** **Poster presentation** **4538**

# Statistical study of extreme monsoon rainfall events over South India

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Winter Monsoon Rainfall (WMR) during October through December is one of the key parameters of local hydrological cycle over south India. In this stochastic study datasets relating to rainfall, global recognized pressure oscillations and Sea Surface Temperatures (SST) for a period of 127 (1876-2003) years are used primarily to examine the extreme rainfall events. The combined effect of El-Nino and Southern Oscillation (ENSO) exercises profound influence on the future weather over northern hemisphere in general and monsoon regions over southeast Asia in particular. In the present study an inverse relationship (0.1% level) exists between Southern Oscillation Index (SOI) in April and May and WMR, while there is a striking significantly direct relationship between Effective Strength Index (ESI) during April and May and WMR in the recent four and half decades. Similarly on examining the relationships between SST indices over the Pacific and WMR, it is interesting to note that SST indices over Nino-3.4 and Nino-4 regions during April and May and March through May respectively show a significant positive correlation with WMR. Next, the combined effect of above pressure and temperature indices in the form of Multivariate ENSO Index (MEI) during June and July is also related with the WMR and the positive relationship between them is highly significant at 0.1% level. To know the consistency of the above relationships between each parameter against WMR, 20-year sliding window test is performed and it shows that relationships between above five predictors with WMR are very consistent in the recent four and half decades. An extreme event of rainfall depends upon both frequency and intensity of synoptic/sub synoptic systems from the Bay of Bengal crossing the east coast of India south of 190N. The frequency of these systems relating to the extreme events of above five indices of pressure and temperature over the Pacific and Atlantic Oceans is examined. Further to study extreme positive and negative episodes of rainfall a non-parametric Mann-Whitney Rank statistics test is applied by using the influence of above predictors. For the episodes of extreme positive indices of SSTs and ESI over Pacific, Atlantic Oceans and negative SOI, the frequency as well as intensity of cyclonic systems, which cause much rain during winter monsoon season through synoptic systems is greater than normal and vice-versa. Finally, to substantiate above extreme events the NCEP/NCAR Reanalysis datasets are used to study the vertical cross section of mean monthly Walker cell in November (mean zonal winds) near the equator covering North Indian and Pacific Oceans for the period of 1962-2001. The composite anomaly Walker cell circulation patterns in the troposphere associated with extreme negative and positive episodes of MEI are analysed. Results indicate that the strength of Walker circulation in the Indo-Pacific region is strong/weak during extreme negative/positive episodes of MEI. Thus this study helps for the better understanding of hydro climatic change and to predict future conditions.

***Keywords:*** raifallpressuresst

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**HW2003** **Poster presentation** **4539**

# Flow regime variability: capturing the extent of the natural fluctuations around the mean seasonal runoff distribution. A suggested statistic, results from a regime-type specific analysis for Switzerland and possible fields of applications

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The present paper addresses the fluctuations of single-year runoff patterns around the long-term mean flow regime. The extent of the interannual variability of monthly discharges has been analysed on the grounds of observed flow data from Switzerland. A statistic able of capturing this variability is introduced which has been used for the analyses. A classification of the results shows that the established Swiss flow regime types do well differentiate among varying variability behaviour. Investigating in more detail the relative contribution for the total variability from fluctuations of the seasonal patterns (periodicity) on the one hand and from the variance of the annual discharges (the absolute level of the flows) on the other hand revealed, that the first is responsible for the major part, even though it is varying according to the flow regime type. It is also shown that the suggested statistic is suitable for trend analyses, since instationarity does not only imply changes of means but also of variances. We also demonstrate that the proposed statistic is able to capture the effects from human activity impacts on the flow regime variability. Finally we point to an important potential field of application: the gained information about the differing flow regime variability depending on the flow regime type constitutes a valuable basis for an ecological assessment methodology for anthropogenically induced changes as required for example by the European Water Framework Directive. We show the case how this is implemented in a Swiss assessment method.

***Keywords:*** flow regime, variability, switzerland

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**HW2003** **Poster presentation** **4540**

# Analysis of streamflow trends and hydrological response to climatic change in Tarim headwater Basin

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The Tarim River is the typical continental river in China, which runoff-feeding regions has located upper mountain reaches. The Tarim River Basin covers the entire southern part of Xinjiang in western China that is characterized by both rich natural resources and fragile environments. This paper has studies the change of streamflow and the impact of climatic variability conditions on regional hydrological cycle in the headwater of the Tarim River Basin. The debate on climate variability and climate change relies heavily on the detection of trends (or lack thereof) in instrumental records of hydro-climatic variables such as air temperature, precipitation and stream ow. This paper investigates possible causes of observed trends in stream ow in an environment which is highly variable in terms of atmospheric conditions, and where snow and ice melt play an important role in the natural hydrological regime. The discharge trends of three head streams have a significant increase trend from1957 to 2002 with the Mann-Kendall test. The annual mean discharges totally are observed increasing from 186.17w108m3 (1957-1970) to 203.7w108m3(1991-2002). It has an increase of 6.5% during 1990s compared with the mean discharge from 1956 to 2002. Complex time-frequency distributions in the streamflow regime are demonstrated especially by Morlet wavelet analysis over 40 years. The annual runoff time frequency distribution shows a significantly uprising trend of all of mean discharge series signal since 1990s at the time scale of 15-20 years. The purpose is to ascertain the nature of climatic factors spatial and temporal distribution, involved the use of EOF (Empirical Orthogonal Function) to compare the dominant temperature, precipitation and evaporation patterns from normally climatic rainfall records over the Tarims headwater basin. It shows that the first principal component was dominated since 1990s for temperature and precipitation, which identifies the significant ascending trend of spatial and temporal pattern characteristics under the condition of the global warming. An exponential correlation is highlighted between surface air temperature and mean river discharge monthly, so the regional runoff increases by 10-16% when surface air temperature rises by 1. These relationships suggest that the most vulnerable environments and also point to the fact that mountain basins are the most vulnerable environments from the point view of climate change, because of their watershed properties that promote runoff feeding by glacier and snow melt water and owing to their fundamental vulnerability to temperature changes that affect rainfall, snowfall, and glacier and ice melt.

***Keywords:*** tarim, streamflow, climatic change

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**HW2003** **Poster presentation** **4541**

# Modelisation des debits maximaux annuels de crue par la loi Burr XII tendue trois paramètres

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Parmi les lois de probabilit modlisant la distribution des valeurs extrmes nous citons la loi de Burr XII tendue trois paramtres (Shao & al., 2004), loi rarement utilise en hydrologie ; les lois Pareto et Weibull tant des cas limites de celle ci. Dans ce travail 13 stations du rseau hydromtrique tunisien sont considres, les superficies des bassins versant varient de 102 km 16483 km et la taille des sries de 29 96 ans. La modlisation de la distribution des dbits maximaux annuels de crue seffectuera par la loi de Burr XII. Lobjet ici est ltude du comportement dchelle travers les paramtres issus de cette modlisation, et ainsi pouvoir justifier dune approche rgionale. Les premiers rsultats montrent que le paramtre dchelle estim station par station a un comportement traduisant un effet dchelle en fonction de la superficie de drainage (ce paramtre varie linairement en coordonnes log-log en fonction de la surface) ; par contre, les deux autres paramtres de forme varient de faon alatoire en fonction de la superficie, ce qui justifie une estimation rgionale de ces derniers. Ce comportement dchelle observ sur ces dbits maximaux annuels est en cohrence avec les rsultats obtenus par lapproche multifractale (Bargaoui & Chebchoub, 2004) o il a t montr une loi dinvariance dchelle pour les valeurs extrmes permettant de relier moments statistiques et chelle. Ceci nous conduit considrer les moments dordre r de la loi de Burr XII et dessayer didentifier le facteur dchelle dans la relation moments dordre r chelle. Rfrences Bargaoui Z. & Chebchoub A., 2004. Investigations du caractre multifractal des dbits maximaux annuels de crue. Journal des Sciences Hydrologiques. 49(4), p. 549-562. Shao Q., Wong H., Xia J. & IP W-C., 2004. Models for extremes using the extended tree-parameter Burr XII system with application to flood frequency analysis. Hydrological Science Journal. 49(4), 685-702.

***Keywords:*** loi de burr, debits maximaux de crue, echelle

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**HW2003** **Poster presentation** **4542**

# Variability in Paraguay River flow associated with Southern Hemisphere Circulation

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***Carlos E. M. Tucci, Cintia Bertacchi Uvo, Pedro L. S Dias, Robin Thomas Clarke, Walter Collischonn***

Over recent decades, climate has varied markedly over the central region of South America, with an extremely dry period during the 1960s and a very wet period beginning in the 1970s. More recently, a period in which river flows have been very low has been observed since 1998. Here we present results obtained from analysis of long hydrological records in the basin of the Rio Paraguay. The purpose of this research is to explore the relation between the Southern Hemisphere Annular Modes (SAM) and river flow in the Upper Paraguay, and to establish whether SAM may be used to predict river flow and water level variations in the basin. Significant correlation has been found between Upper Paraguay flows and the SAM, which helps to explain the long term variations in flow patterns observed in the past, and may also improve the seasonal precipitation predictability of the region.

***Keywords:*** upper paraguay, sam aao

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**HW2003** **Poster presentation** **4543**

# Reconstructing an hyperconcentrated flash flood event using historical data and sediment TRAPP information

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***Jordi Tuset, Ramon J. Batalla***

Historical floods records are valuable resource of hydrological data that can be of great use for current planning in flood-prone areas. In catchments experiencing hyperconcentrated flows (5 to 40% in volume) there is the need to separate water and sediment loads, since flow hydraulics (i.e. depth, velocity) do not follow Newtonian flow laws. Within this context, we have studied the historical flood of september 1874 in the Ondara River (Ebro Depression, NE Spain). There exist the chronological description of the event, several flood level marks and sediment deposits accumulated over the course of the flood. With this information the peak discharge of the hyperconcentrated flow and the clear water discharge can be estimated. Using a global hydrometeorological model, the range of rainfall intensity can be obtained. Results show an event whose characteristics could not be well predicted by statistical laws of extreme events typically fitted using the local series of daily maximum precipitation.

***Keywords:*** flash flood, hyperconcetrated flow, prediction

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**HW2003** **Poster presentation** **4544**

# Inflow Forecasting by ARIMA Models on Karaj River

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Stream flow forecasting is a major point in applied hydrology. Knowing about river inflow and input water to surface water storage, capable us to do better decision making, planning and operation for water resources. This helps us for optimum allocating surface water resources to water demands. One of the best and useful forecasting models for long term prediction, is Autoregressive integrated Moving average method. Autoregressive Moving average is a stochastic model base method. Forecasting principal of this method is base on autocorrelation relation between data series components. This relation shows the data series effectiveness from their past components. Current values are followed their past pattern. Moving average process describes relation between residuals. Calculation methods of this forecasting model are Youl-Walker equation system and Kalman filter equation. These processes are done by Generalized Least Square and Exact Maximum Likelihood method. Generally statistic forecasting methods, use inflow historical records, to produce prediction values. Using ARIMA models needs the data series to be stationary and time series followed a normal probability distribution. To identify this condition we use ACF and PACF plots. To conquer the non stationary and reach to stability we should use differencing and Box-Cox normality transformation. For applying this approach, we do a case study on a monthly river flow data series. We select Karaj River, located in north of Tehran and its basin area is 850 square kilometer, which is one of the main water resources suppliers for great Tehran. Its annual average is about 13 CMS. For supplying different kind of Tehran water demand such as consumption, agricultural and industrial demands, we use more than 60 percent from surface water resources and the rest from ground water sources. Thus it is so important to be aware of the surface water availability. Use monthly records of about 30 years; we do the mentioned process on this data series. It is necessary to say that, we do especial grouping on time series while doing Box-Cox normality transformation according to statistical characteristic of monthly data series and choose the best grouping helping from Kolmogrove-Sminerove test error. Our calculation engine is X12-ARIMA from US Census Bureau. Search on all seasonal and non-seasonal ARIMA (p,d,q)(P,D,Q)orders form (0 0 0 ) (0 0 0 ) to (2 1 2 ) (2 1 2 ) and choose the best model according to Chi-square probability test and Akiake information criterion that describes data series character. Automatically updating parameters do the forecast from one to six months which means long term prediction. Finally to check the model correctness and accuracy does verification test in a five years period.

***Keywords:*** streamflow, forecasting, arima model

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**HW2003** **Poster presentation** **4545**

# Study of the rainfall spatial distribution as base to weather forecast models the case of a hydrological distributed model

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Nowadays, the researches are looking for new technologies in order to forecast rainfall data. These data are the main the input of hydrological models. In the case of developing countries, specially countries with semi-arid regions, discharge daily data are almost always difficult to be found. On the other hand, rainfall daily data are available. In this way, the use of hydrological models which transform rainfall data into discharge data is needed. A study of the monthly rainfall data, considering the spatial-temporal issues, in a semi-arid region in the Northeast of Brazil was carried out. The research area is located in a hybrid region, in other words in semi-arid located in the shore area of Paraba State. It means that the rainfall phenomena is strongly dependent of the ocean conditions. In this study area a rainfall gradient from East to West is about 100 mm/km. In order to understand better this condition, this research has been carrying out. This gradient must be better understood not only with hydrological models but also with a improvement of the rainfall monitoring network. At same time, the water resources management agencies in Brazil has not given the proper attention to the rainfall spatial distribution in this hybrid region. In Brazil, most of the studies about spatial and temporal rainfall distribution has been carried out to the semi-arid regions as well as the improvement spatial distribution of rainfall monitoring network. This occurs because of the drought phenomena. Thus, the rainfall monitoring network has a better density in the semi-arid region and poorly implemented in this hybrid region. Thus the study of spatial temporal rainfall distribution is not easy to be carried out for hybrid regions. The main aim of this study was try to understand better the spatial-temporal rainfall distribution. For this purpose, the distributed hydrologic rainfall runoff model AUMOD (Passerat de Silans, 2001) was used. This model has a Geographic Information System in its composition, which provides tools for the understand of the spatial rainfall distribution. With this model different sceneries were defined in order to achieve the study aim. These sceneries considered the rainfall gauges location in different positions and in different quantity. The results in terms of runoff series were monitored and these pointed out the necessity of a growth of the rainfall monitoring network density, in order to better represent the rainfall spatial distribution. These results were also import to show that the use of lumped models in hybrid regions, where rainfall gradient are great, can leads to considerable mistakes. These mistakes can be reduced with use of distributed models.

***Keywords:*** rainfall, spatial distribution, analysis

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**HW2003** **Poster presentation** **4546**

# Use of historical information to estimate flood quantiles and the return period of Salado River Flood 2003, Santa F - Argentine

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*FUNCEME SECITECE*

***Eduardo Svio Passos Rodrigues Martins, Dirceu Silveira Reis Junior, Juan Carlos Bertoni, Carlos G. Catalini***

The challenge for flood frequency analysis is to use all information available to obtain the best estimates of flood risk that is possible. Systematic records are in general either too short or even not available for the sites of interest to provide highly reliable flood risk estimates. Therefore it is important that hydrologists employ efficient estimation methods for quantiles and parameters, and as well as that combine all information available for the site and/or region of interest. In this context, regional information, and paleoflood and historical information can often be used to augment systematic streamflow and peak-flow records. This paper describes the approach that was used in order to estimate the return period of flood 2003 in Salado River at Santa F-Argentine. The main objective of this paper is bring a comprehensive view of this extreme event, which lasted 36 hours, flooded 35% of Santa F City, affected 27400 households and it was responsible for the evacuation of 134500 people. Much of this paper focuses on the use of the GEV distribution as a model of flood risk. This distribution has been the subject of many papers on at-site flood frequency analysis and regionalization. It is also used as a model of flood risk around the world. Additional information was also incorporated in the analysis in order to obtain better estimates. The historical information was surveyed from reports, newspapers, and other accounts. The value historical information can be tremendous depending on the threshold level and the historical record length. Comparison with Monte Carlo results is also carried out.

***Keywords:*** frequency analysis, historical information, gev

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**HW2003** **Poster presentation** **4547**

# Analysis of Rainfall Variability and its Extremes over India

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India the seventh largest country in the world and the second largest in Asia is situated in the monsoon climate zone of South Asia. Due to the monsoon circulation about 80-90 % of the total annual rainfall over various regions of the country occurs during the summer monsoon season between June and September. The average annual rainfall of the country based on the observations from 1871 to 1990 has been estimated at 109.0 cm with a standard deviation (SD) of 10.4 cm and a CV of 9.5 % (IITM, 1995) .Obviously, the rainfall is not the same every year and the total annual rainfall varies significantly from year to year. For instance, the frequency distribution of annual rainfall averaged over the whole of India for the 120 year period from 1871 to 1990 tabulated below shows that the rainfall of India exhibits considerable inter annual variability. The table shows that in Range (cm) 76-85 86-95 96-105 106-115 115-125 126-135 Frequency 2 7 32 96 27 6 India where the average annual rainfall is around 109 cm in very low rainfall or dry years, the annual rainfall may be reduced to around 76-85 cm while in very high rainfall or wet years, it may exceed 126-135 cm. This variability in rainfall over India affects the management and conservation of its fresh water resources for food production as well as for domestic requirements. Associated possible weather systems responsible for substantial rainfall variability are the frequency of tropical disturbances traversing the country in different years, an early or late onset of monsoon during monsoon season and the impact of the ENSO. In this paper, based on rainfall data from 1871 to 1990, the variability in rainfall in India associated with the above mentioned weather systems has been investigated.

***Keywords:*** monsoon

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**HW2003** **Poster presentation** **4548**

# Statistical analysis of hydrogeological data series (Stiffe cave, central Italy) to fine-tune the conceptual model of mixed karst system

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In a research project with the goal to estimate karst aquifer vulnerability, a long term (94-99) high frequency monitoring of physico-chemical (groundwater and underground air) and hydrological (discharge and rain) parameters were acquired by means of an environmental sensor network located in the Stiffe cave, peculiar of Mediterranean climate. Stiffe karst is a perched vadose system characterized by an outflow 3 Km long cave located in lower Cretaceous fissured mud-supported limestone. It connects two independent catchment areas which have a difference in height of 600 m (the upper one, Rocche Plateau, at 1,200 m a.s.l., and the lower one, Aterno River Valley). Stiffe karst aquifer is fed by a diffuse recharge with a share of about 30%, while the 70% remaining one is fed through point recharge sinkholes by Rio Gamberale stream located in Rocche Plateau. The vadose stream of Stiffe cave has a torrential flow regime and hydrographs show flood peaks which are superposed to seasonal base flow. The aim of this study was to improve the conceptual model of how a mixed-type karst aquifer works through time series and multivariate distribution analysis starting from the cross correlating comparison of hydrographs and chemographs. Moreover this step would be preliminary to the following numerical modelling.

***Keywords:*** multivariate analysis, time series analysis, karst monitoring system

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**HW2003** **Poster presentation** **4549**

# Predictability of univariate daily streamflow processes

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***Xi Chen, Wu-Cheng Xu***

Predictability is an important aspect of the dynamics of hydrological processes. But the predictability of hydrological processes has not attracted much attention by the hydrology community until recent several years. Some examples of the studies on predictability include those based on the multiple explanatory variables (e.g., Maurer et al., 2003; Maurer et al., 2004) and those based on univariate hydrological time series (e.g., Wang et al., 2004). Because the research on predictability is still on its early stage, there is a lack of well-established methods on how to estimate the predictability of hydrological processes. Two approaches may be distinguished in literature: univariate approach and multivariate approach. The former one measures the predictability based on univariate time series analysis techniques, whereas the latter one estimates the predictability based on the knowledge of the rainfall-runoff generation mechanism and/or the tele-connections between global geophysical quantities and streamflow processes of interest. A univariate time series based approach is proposed to measure the predictability of hydrologic time series in this study. We define the predictability as the predictable horizon for which the prediction is no better than the mean value for a stationary process or the seasonal mean value for a seasonal process. At the same time, for practical purposes, different levels of predictability are defined as the predictable horizons for each of which the prediction accuracy is larger than a given level. The model used in measuring predictability is the autoregressive (AR) model. With such a definition, the predictability is easily comparable among different hydrological processes. Based on this univariate approach, 31 streamflow series with different drainage areas in 8 river basins in Europe and northern America are investigated for establishing the relationship between the predictability and the intensity of autocorrelation, long-memory, and the watershed scale. The results show that, in general, the predictability is, as expected, closely related to the intensity of autocorrelation; similar but less clear relationship could be found between the predictability and the intensity of long-memory; the larger the watershed scale, the better the predictability of the streamflow process.

***Keywords:*** predictability, time series, long memory

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**HW2003** **Poster presentation** **4550**

# Nonidentical Model for Seasonal Flood Frequency Analysis

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The importance of seasonal flood frequency analysis and the advantages of considering seasonal design floods in the deriving of reservoir planning and operating rules are introduced. Acknowledge that seasonal flood frequency models already have been in use for over 30 years. This paper aims at building a seasonal flood frequency analysis model and estimating seasonal design floods. A set of nonidentical model with nonconstant parameters is proposed and developed to describe flows for reflecting seasonal flood variation. The POT sampling method was used since it is considered to provide significantly more information on flood seasonality than AM sampling and has better performance in flood seasonality estimation. The number of exceedances is assumed to follow the Poisson distribution (Po), while the peak exceedances are described by Exponential (Ex), Generalized Pareto (GP) distributions, respectively and alternatively. As a result, three models viz. Po-Ex, Po-GP and Po-Ex/GP, are constituted, whose performances are analyzed and compared. The Geheyan and the Baiyunshan reservoirs were chosen for case study. The application and statistical experiment results show that each model has its merits and the Po-Ex/GP model performs best. It is recommended to use Po-Ex/GP model in seasonal flood frequency analysis for the purpose of deriving reservoir operation rules.

***Keywords:*** seasonal flood, frequency analysis, nonidentical model

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**HW2003** **Poster presentation** **4551**

# Exploring Patterns of Hydrological Drought from Proxy Data in Wabi Shebele river basin, East Africa

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***Gerd Foerch, Ute Sass-Klaassen***

Quite often, in developing countries,many watersheds are totally ungauged or havestreamflow records for a short period of time. This problem may be compounded with inconsistency in hydrometric measurement and storage thatimpairs the quality of data retrieved.In time series analysis short lengthdata is not much different than none, thus precluding a clear understanding of the temporal hydrological phenomenon. Hence most conclusions drawn from such a data suffer a similar unreliability. Signature of water stress can be identified in tree rings. This investigation attempts to explore the potential of this proxy data for hydrological drought reconstruction in Wabi Shebele basin, a transboudary river basin in East Africa. Using Incremental corer and disk sampler, 31 cored and 17 disk samples of tree rings were collected at various sites and from different species in the riparian environment. The residual tree ring series has a good correlation with historical streamflow in the dry season. A long term seasonal hydrological drought series is reconstructed from the proxy record and temporally disaggregated. Possible improvement of the reconstructed series due to supplementary attributes from climatic and remotely sensed vegetation characteristics of the catchment is also analysed. The reconstructed series mimics well the hydrological drought series established from gauged historical flows. Patterns of drought in the study area are investigated by cross wavelet analysis.

***Keywords:*** dendrohydrology, disaggregation, hydrological drought

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**HW2003** **Poster presentation** **4552**

# Analysis of Long-term Trends in Groundwater Levels in Connecticut, USA

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***Dr. Gary Robbins***

Based on a study of precipitation records in Connecticut, in the Northeast US, Miller et al. [2002] suggested that precipitation in the state has been increasing over the last hundred years. To further test this finding, a study of well records was undertaken. Owing to porosity, groundwater level rise would make a more sensitive barometer to an increase in precipitation than surface-based precipitation data. Long-term trends in groundwater levels in Connecticut were analyzed using both parametric and non-parametric methods. Well records maintained by the U.S. Geological Survey as far back as 1940 were collected and processed to produce monthly and annual averages. Trends for each well were analyzed with least-squares (LS) regression and Mann-Kendall (MK) regression. Of the 20 wells examined, half showed significant trends at the 90% confidence level. Seven of the ten were increasing trends, ranging from 0.3 to 7.6 mm/yr. Two wells for which the LS and MK regressions gave opposite trends were considered inconclusive. For wells with significant trends, their spatial distribution and other properties (type of terrain, population density changes, well construction) were examined to explain the observed trends. These findings lend support for increasing precipitation, perhaps related to trends in the global climate.

***Keywords:*** groundwater, mann kendall

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**HW2003** **Poster presentation** **4553**

# Paired Watershed Analysis with a Continuous Water Quality Model as a Pseudo Control Site

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Assessing best management practice (BMP) effectiveness in large basins is complicated by hydrologic variability, ecosystem complexity, and issues of scaling. In smaller catchments, these challenges can be addressed using paired watershed analysis. In larger basins, however, it may be impossible to find a control watershed of adequate size. The authors propose that a continuous water quality model may be used as a pseudo-control site in paired watershed analyses in order to determine BMP effectiveness in large basins. Preliminary results from a simple univariate paired analysis confirm that agricultural BMPs have reduced dissolved phosphorus loads to the Cannonsville Reservoir, which is located at the outlet of a 1,200 km2 watershed in Upstate New York. Future work will involve the implementation of more sophisticated multivariate analyses to further confirm and quantify the statistical significance of reductions in dissolved phosphorus loads to the reservoir.

***Keywords:*** hydrology, phosphorus, statistics

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**HW2003** **Poster presentation** **4554**

# Nonlinear analysis of hydrodynamic time series based on minimal attractor embedding estimation with usage of matrix decomposition

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The behavior of nonlinear dynamical system (NDS) including hydrodynamic one can be described on the basis of reconstruction of an attractor in m-dimensional Euclidean state-space R**m . In this connection it is important to select the state-space with the minimal dimension m0 because the value m0 is an upper limit of the degrees of freedom for a NDS and, hence, m0 defines the minimal number of differential equations for the NDS modeling. Many correlative-topological methods have been used to computing m0, among them the Grassberger-Procaccia algorithm [1] is most conventional. However, such methods have large computational complexity and require significant volume of experimental data [1]. A new locally topological method for m0 determination has been developed in [2]. According to this method on the subset of chaotic attractor in Euclidean space R**m a function z(m) is constructed. It defines a measure of topological instability of the attractor when state-space dimension is enlarging: R**m -->R**(m+1 ). Using the matrix decomposition method [3] in state-space it has been shown in [2] that the value of z(m) changes monotonously when enlarging m, but if m = m0, then z(m) = const and does not depend on m . Thus, m0 is minimal embedding dimension for an investigating attractor of NDS. The proposed method requires much less experimental data, moreover, it is stable to changing m and thus decreases the lacks of correlative-topological methods[2]. This work develops a nonlinear analysis of hydrodynamic flows into the boundary layers based on the minimal attractor embedding estimation with usage of matrix decomposition and fractal-topological methods [2]. Instability of flow appears in boundary layer of concave wall when the velocity of external flow (e.g. and Reynolds number) tends to certain value. The originated perturbations are similar to the Grtler whirlwinds [4]. This report shows how the system of partial differential equations (describing hydrodynamic processes in the boundary layers) is reduced to the system of ordinary differential equations based on the Galerkin's method. In result the attractor of this system is obtained (the similar has been considered in [5]). Then the characteristic parameters a , b and c of this attractor are investigated using matrix decomposition methods [3]. The nonlinear analysis of the obtained attractor shows that the stationary solution of this model (for a=2sqrt(b) ) corresponds to double vortices rotating opposite to each other [6]. When a> 2sqrt(b) a non-stationary flow is appeared and, therefore, the corresponding attractor becomes chaotic [6]. The obtained results of analysis are in accord with the computational simulation of hydrodynamic flows into the boundary layers by means of program package STAR-CD. According to this computational approach, the calculated time series of the component velocity and pressure of hydrodynamic flow are processed into the state- space. The reconstructed attractors are investigated by means of estimations of their fractal-topological characteristics (the minimal attractor embedding dimension, Lyapunov exponents, control parameter, etc). The proposed methods can be used for analysis of hydrodynamic conditions for better understanding of hydroclimatic variations. References: [1] P.Grassberger and I.Procaccia, Characterization of strange attractor, Phys. Rev. Lett., vol.50, pp.346-349, 1983. [2] A.M.Krot and H.B.Minervina, Minimal attractor embedding estimation based on matrix decomposition for analysis of dynamical systems, Nonlinear Phenomena in Complex Systems, vol.5, no.2, pp.161-172, 2002. [3] A.M.Krot, Matrix decompositions of vector functions and shift operators on the trajectories of a nonlinear dynamical system, Nonlinear Phenomena in Complex Systems, vol. 4, no. 2, pp. 106-115, 2001. [4] H.Schlichting, Grenzschicht-Theorie. Verlag G Braun, Karlsruhe, 1970. [5] V.A.Baldin, A.M.Krot and H.B.Minervina, The development of model for boundary layers past a concave wall with usage of nonlinear dynamics methods, Advances in Space Research,

vol.37, no. 3, pp. 501-506, 2006 (Elsevier Publ. Co.). [6] V.A. Baldin, A.M. Krot and H.B. Minervina, The attractor model for finite length Grtler whirlwinds, Electromagnetic Waves and Electronic Systems, vol.11, no. 2-3, pp. 33-40, 2006.

***Keywords:*** hydrodynamic time series, nonlinear dynamic analysis, matrix decomposition method

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**HW2003** **Poster presentation** **4555**

# Study on the hydrologic simulation with artificial neural networks

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A back-propagation (BP) neural networks model is used for simulating daily streamflows in the upper area of Nangao Reservoir at Shanwei City, Guangdong Province in China. Daily rainfall, streamflow, and evaporation data are available from the four stations in the area for a 16-year period of 1988 to 2003. Approaches and techniques of applying the BP model in runoff simulation are presented in this paper. A comparison of the BP model to the Xinanjiang model was conducted to evaluate the performance of the BP model. The simulated results indicate a satisfactory performance in the streamflow forecasting with the BP model. The study concludes that the BP model has the high practicability and accurate ability for describing complex nonlinear hydrologic processes.

***Keywords:*** hydrological simulation, bp neural networks model, xin an jiang model

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**HW2003** **Poster presentation** **4556**

# Spatiotemporal drought assessment in the lower rio bravo/grande basin using the drought frequency index

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Water management under drought conditions is a critical issue for the future of the communities settled in the Lower Rio Grande/Bravo basin (LRGB). Concerns about the impact that water rationings would have on the economy of the valley have led to initiatives for developing methods of evaluating droughts in terms of both their spatial distribution and temporal persistence. In this context, the authors explore the performance of the Drought Frequency Index (DFI) for local and regional drought assessment applied to the LRGB. The DFI is a stochastic index that characterizes the persistent deviation of a variable, i.e. precipitation, towards the lower-tail of its probability density function. The result is a retrospective, sequential measure of the persistence of low values that is equivalent to the concept of return period. Therefore, the index offers an integrated measure of the severity, duration or intensity of a drought in each time step relative to its probability of occurrence, being the mean return period its scale of frequency. To assess the spatial distribution, severity and temporal persistence of droughts in the LRGB, point DFI values calculated in a cell-by-cell basis are grouped in several categories depending on their return periods using an iterative clustering algorithm that produces maps in which the occurrence of local and regional droughts can be traced at any particular time step. Values of DFI under certain threshold are considered normal while values above are considered part of a drought episode. As a drought becomes more severe in the region, the resulting DFI values increase accordingly, highlighting the effect in the map during consecutive periods. The index proved to be coherent at describing spatial and temporal drought conditions in the basin. Since a drought is defined by how long the precipitation values have been in the lower tail of their distribution function in a particular sequence, the index is able to detect droughts only after some consecutive low values have already occurred. Once a drought episode has been identified, however, the index is able to keep track of the event in many successive periods, recognizing sustained drought situations. The DFI shows that abnormally dry conditions in the LRGB are likely to occur and persist both locally and at a regional scale. These results in turn will be valuable to link the differential impacts of droughts over the communities in the basin.

***Keywords:*** drough index, extreme values, spatiotemporal analysis

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**HW2003** **Poster presentation** **4557**

# Recent shrinkage of water resources in Lake Chad Basin: A normal Hydrologic Noise or Climate Change Impacts

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A change in climate will certainly have major impacts on water resources availability of a place, through the hydrologic cycle; because changes in runoff or stream flow; water levels of water bodies are the direct result of changes in precipitation and evapotranspiration that are strongly influenced by temperature. This study investigates the evidence of climate change or variability and its impacts on the water resources of Lake Chad Basin in the northeastern, Nigeria. Analyzes of the trend and variability of water level and climatic data (annual rainfalls, evaporations and temperatures) from Nigerian Meteorological Stations in the basin, covering the period of 1940-2003; shows that what the basin is experiencing is not a normal hydrologic noise or fluctuations, but an evidence of climate change that appears as climatic cycles of wet and dry years every 15 to 20 years. An increasing trend of temperature was observed from 1970s, rising at a rate of 0.40C / decade; while rainfall and the water level of the lake have been on the downward trend. This rising air temperature creates a very high evaporative demand on water resources of the basin; thereby ensuing in the decline of the surface area and the volume of the lake. Further results show a southward shift in the isohyets and resultant encroachment of desertification over the area. The concomitant effects of the prolonged drought situation is seen on the satellite imageries by the shrinking of the Lake size from 25,000km2 in the 1960s to presently barely 2,000km2, with an average depth of 4m and dependent population of over 20 million people, out of which 12 millions are Nigerians.

***Keywords:*** lake chad and isohyets, climate change, satellite imagery

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**HW2003** **Poster presentation** **4558**

# Trend analysis of climatic indexes in Sicily

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***Bono Enrico, La Loggia Goffredo, Liuzzo Lorena***

Climate change during the last century are widely discussed by many researchers. The IPCC predicted that several dramatic climatic changes could occur as consequences of the increasing concentration of greenhouse gases. One of the most known consequences is confirmed by the evidence of the increase in mean global temperature. On the global scale this evidence has a great influence on the structure and the evolution of atmospheric circulation. For these reasons the detection of trends in climatologic data has become central to the discussion on climate change due to the increase in greenhouse gases concentration. Many studies have been carried out to investigate the existence of some tendency in temperature with regard to different geographic domain. In order to verify the hypothesis of temperature increase associated with global climate change, temperature data from weather stations, spatially distributed in Sicily, have been analyzed. In this study trend of annual, seasonal, and monthly temperature time series have been examined for about 80 weather stations in Sicily for the period 1930-2000 to search possible evidences of climate changes in this region. The Mann-Kendall non-parametric statistical test has been used to identify trends in temperature time series data. The test has been applied at local and areal scale for three different level of confidence. The field significance of the areal results has been evaluated using a bootstrap technique of resampling, that allows to eliminate the influence of data spatial correlation on Mann-Kendall test. The existence of a correlation increases the probability that the Mann-Kendall test detects trend when no trend exists. The application of Mann-Kendall test on temperature data provides the evidence of a general warming in Sicily during the analyzed period. In order to determine the spatial distribution of temperature patterns and identify areas with a similar temperature evolution, the detected trends have been spatially interpolated using GIS techniques. A previous study analyzed the presence of local and areal trend in precipitation data in Sicily, showing the existence of a general reduction of precipitation. The observed positive trends in temperature seem to be in relationship with negative trends of precipitation detected in the same region. Finally using temperature and precipitation data, some aridity indexes time series have been derived in order to confirm the presence of a relation between climate change and aridity in Sicily. Most of these aridity indices are based on a relationship between precipitation and temperature, or evapotranspiration. In this work the existence of trend in aridity indexes has been investigated and linked with trend in temperature data. Maps are created showing the results of Mann-Kendall test for each index.

***Keywords:*** climate change, trend analysis, aridity index

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**HW2003** **Poster presentation** **4559**

# Hourly long-term runoff analysis for snowy mountainous basins in Japan

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Water resources in Japan are depending on mountains and hills area that occupy about 70 % of the country area. The accurate prediction of reservoir inflow is required for the relevant management of water resources. As a basic study for this subject, the long-term runoff model analyzed by 1 hour time series is presented and applied for several snowy mountainous basins located in the northern part of Japan. The hourly long-term runoff model presented in this study is developed from the daily hydrological model presented by Ando, Musiake, and Takahasi (J. Hydrol., 64, 1983, and 68, 1984). Therefore the model comprises the hydrological processes, such as precipitation, snowmelt, infiltration, evapotranspiration, groundwater recharge, and groundwater runoff. In order to improve and adapt the original model to the recent progress of measurements and computer technology, modeling process of infiltration and direct runoff is completely changed for 1 hour time series analysis and the use of the GIS elevation data. The procedures for performing the model are as follows: (a) the basin is divided into a number of grids using GIS, (b) precipitation at each grid is estimated by considering the seasonal precipitation - elevation relationship, (c) snow water equivalent and snowmelt are also estimated at each grid, (d) the Diskin-Nazimov infiltration model, which can estimate the infiltration rate considering the rainfall intensity variation, is used to determine excess rainfall and infiltration into the ground, (e) excess runoff at each grid is integrated to the rate of the basin and direct runoff (flood runoff) is calculated using by the storage function method, and (e) infiltration into the ground is also integrated and the groundwater recharge and groundwater runoff are calculated by using the original hydrological model method. The basic time series data for the model are only temperature and precipitation. A grid size of this study is 100 m. Two of four study basins are the Shirakawa Dam basin (area: 205 km2) and the Sagae Dam basin (area: 231 km2), which are located in the upstream of the Mogami River one of the heaviest snowy region in Japan. Another two basins are the Iwaonai Dam basin (area: 331 km2) and the Taisetsu Dam basin (area: 292 km2), which are located in the Hokkaido region and have severe cold temperature in winter season. Especially in these basins, because of the cold temperature most raingauges are not available in winter but only at the Dam site could measure the precipitation but its rate is incorrect. Thus a simple assumption of precipitation at the Dam sites is settled and calibrated for the basin. The analysis is carried out for these 4 basins between Jun 2002 and December 2006, 4 years 7 month. The results showed that the calculated hydrograph approximately agree with the observed hydrograph. The model can also display the series distributions of snow water equivalent of the basin.

***Keywords:*** snowy mountainous basin, long term runoff, 1 hour time series

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**HW2003** **Poster presentation** **4560**

# Analyse de la variabilité temporelle des données hydro-pluviomtriques de la Medjerda Ghardimaou, influence de l'oscillation Nord Atlantique et l'oscillation Mediterranenne de l'Ouest: approche par ondelettes croises

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La variabilit temporelle long terme des ressources en eaux de loued Medjerda dans le bassin mditerranen est examine dans le contexte de la Circulation Atmosphrique sur lOcan Atlantique, reprsente par lindice NAO et un indice sur la Mditerrane WeMOI (Martin-Vide and Lopez-Bustins, 2004). Lapproche par ondelettes croises entre indice climatique et pluie ou dbit, est dveloppe. La base de donnes concerne la station hydromtrique et la station pluviomtrique de Ghardimaou, sur la frontire algrienne, situes la rive gauche de loued Medjerda et en amont du barrage de Sidi Salem (pice matresse dans la gestion des eaux en Tunisie). Les sries chronologiques d'coulement observes sont sparment tudies comme sries dcoulement (1) moyen annuel (2) moyen mensuel et (3) moyen journalier maximal sur toute lanne. Ces variables sont choisies afin de fournir des infrences sur l'impact de la variabilit du climat sur certaines inondations et scheresses et sur le bilan annuel en eau. Les chelles mensuelles et annuelles sont prises en considration afin de focaliser ltude sur la variabilit long terme du climat et son influence sur l'hydrologie du site. Cette approche nous a permis d'analyser les modes dominants de la variabilit et d'extraire des phnomnes de localisation en temps et en frquence. Lanalyse par ondelettes des sries mensuelles indique en effet que les composants de la variabilit sur des chelles de 3 6 ans de lindice mditerranen de louest (WeMOI) ont une trs grande influence sur le dbit de la Medjerda Ghardimaou. Ces rsultats sont soutenus par ceux de la pluviomtrie o la variabilit est lie celle de loscillation mditerranenne de louest aux petites chelles comme aux grandes chelles. Plus particulirement, aux alentours de 1953 1957, 1996 1999 et lanne 2003, considres des annes trs humides, une variabilit trs significative est observe aux chelles annuelles comme aux chelles de 2 ans. Mais la plus grande variabilit observe pour le dbit est autour des annes 90 sur une chelle de 8 ans. Ces rsultats sont galement appuys par ltude de lindice NAO, crois avec la pluviomtrie, qui montre une importante variabilit aux mmes chelles et aux mmes priodes que prcdemment. En effet, en utilisant la srie des dbits moyens journaliers maximaux annuels, on constate quun fort indice NAO hivernal a engendr des vnements extrmes sur les priodes 1974 1986 aux chelles de 8 ans. Par opposition, le dbit moyen annuel ne donne pas de rsultat significatif confront avec les deux indices. Ces rsultats mettent en vidence lintrt dexplorer le WeMOI et le NAO comme prdicteurs sur le long terme des ressources en eaux de la Medjerda.

***Keywords:*** variabilite temporelle, ondelettes croises, nao

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**HW2003** **Poster presentation** **4561**

# Analytical Derivation of steady state soil water probability density function using cumulant expansion theory

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***Mijin Ahn***

In this study a new stochastic model for the propagation analysis of fluctuations in rainfall to soil water dynamics is proposed. Based on a zero-dimensional soil water dynamics model with the rainfall forcing, the proposed model is derived by using cumulant expansion theory from a stochastic differential equation and has the advantage of providing the probabilistic solution in the form of a probability density function (PDF), from which one can find the ensemble average behavior of the system. Steady state PDF of soil water is obtained analytically and analyzed for different climate, soil and vegetation conditions. One sites (Daegue in Korea), representing the driest parts of the Korean Peninsula, is considered for applications. As a result, it is shown that the analytically derived steady state soil water PDF can make a good agreement to the numerically obtained steady state PDF from a zero-dimensional soil water dynamics model. From this agreement, the steady state analysis is thought to be appropriate for the study of soil water dynamics where the seasonality of rainfall is not very significant. As expected, the existence of fluctuations in rainfall tends to increase the variance of soil water dynamics, while the change of rainfall amount can shift the mode of PDF. General features for the PDFs as a function of different loss and soil characteristics are the decrease of soil water with loss rate and soil water storage capacity. The major conclusion, however, is that the proposed simplified stochastic soil water dynamic model for dry growing seasons in the Korean Peninsular can provide quite a sensible explanation of the main soil water probabilistic properties even if only accounting for rainfall variability.

***Keywords:*** cumulant expansion theory, rainfall fluctuation, soil water dynamics

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**HW2003** **Poster presentation** **4562**

# Rainfall index interpolation with objective analysis of the interactions between climate and morphology

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Rainfall index (RI) characterization in regional rainfall frequency analysis represents an open issue. Studies on the relations between RI and climatic and morphological parameters have been carried out using several techniques (e.g. principal component analysis of Digital Elevation Models, linear regression on representative local morphological parameters) but generally the methods can be hardly exported outside the study area. This work makes an attempt to find a general methodology for RI evaluation in mountainous areas, defining the physical variables that affects RI spatial variability from the analysis of the interactions between rainfall climate and morphology. The variables are extracted by a 2-D Fourier Series analysis of a DEM. Spectral analysis is carried out in order to single out the components that have the higher morphologic information content and to mimic a representation of orography as seen by the large scale atmospheric flow during rainfall events. Climatic analyses of extreme rainfall events are used to define and quantify large scale flux parameters that can interact with orography producing high intensity rainfall. The method has been tested in the area of the western italian Alps and Apennines. Here the relationship between RI and the topographical deors is, in general, quite strong and the proposed method supplies a direct estimation in space of this parameter. The application of the mapping method to an Alpine region with complex orography (Valle dAosta) is shown.

***Keywords:*** rainfall index, regional frequency analysis, rainfall climate

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**HW2003** **Poster presentation** **4563**

# Analysis of rainfall data of long series

***Prof. Tokuo Kishii***
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It is very important to analyze the rainfall data of long time series not only the planning the river improvement works but also the prediction of the future change in the changing environment due to the global warming.Fortunately the daily rainfall data from long time series were acquired by the submission of the Korean engineer. Its data had been observed from 1770 to 1907 in the Seoul of Korea. The minimum value of the rainfall was 316 mm/year and that of the maximum was the 2,582 mm/year. Further more, the long period data were analyzed by trend, average, moving average etc.In this analysis the trend of the rainfall through the long period became clear.

***Keywords:*** rainfall data, historical data, daily data

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**HW2003** **Poster presentation** **4564**

# Trend and correlation analysis of groundwater levels in Konya closed Basin

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Konya Closed Basin, which is located at the central Anatolia, covers 7% of Turkish territory and is of outstanding importance for preservation of biodiversity and the sustainable use of its water resources. The basin has been central of agricultural production areas of Turkey. In the last decades, a significant decrease for the groundwater levels measured in the wells has been shown. According to the linear trend analysis of 24 well data, the average rate of the decrease reaches almost 1 m per year over the basin. The monthly time series data of the groundwater level have been collected in various time periods for 24 wells. In order to extract a valuable finding about the expected behaviour of groundwater resources in future, before trend analysis of time series, data set should be carefully handled against systematical errors and outliers. And also, a correlation analysis is needed to verify the consistencies among time series data to each well. In this presented study, such a procedure has been implemented for the time series of 24 wells. For the trend analysis, a linear and a quadratic model are used to determine the change rate of the groundwater level over the relevant time period. The overall rate for the basin is computed after the correlation analysis of the wells. The correlation analysis reveal that the time series data of two wells are independent from the others.

***Keywords:*** groundwater level, time series, trend analysis

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**HW2003** **Poster presentation** **4565**

# Testing the consistency hypothesis of the ensemble members forecasted by a statistical model for precipitation downscaling by means of the verification rank histogram.

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Statistical models for precipitation downscaling start from information at coarse spatial and temporal scales and provide ensemble of precipitation fields at high resolution with minimal effort in terms of both number of model parameters and computational time. Nevertheless, verification of ensemble forecasts provided by downscaling models is still challenging because of the high dimensionality of the problem. In this study, we propose a generalization of the Verification Rank Histogram for testing the consistency hypothesis (i.e. observation and forecasts are drawn from the same distribution) for the ensemble precipitation fields predicted by statistical downscaling models. The verification procedure is applied and tested using a multifractal downscaling model based on a Log-Poisson generator with 2 parameters (c and b). In order to have more control on how the verification procedure works as well as to evaluate its performances, we set up two series of experiments based on controlled synthetic samples. In a first group of tests, we generate several precipitation events, that we consider as the truth, using the multifractal model with fixed parameters values c* and b*. Due to the sampling variability, the parameters estimated on each of these observations are different from their initial values c* and b*. We show that when ensemble members are generated using the values of model parameters estimated on each observed event, the shape of the resulting rank histograms is affected by overdispersion (i.e. the middle ranks are more populated than the extreme ones). The results of the first tests are then used to perform a second class of tests, where we apply the verification procedure to evaluate the reliability of downscaling models when calibration relations are used to estimate model parameters from meteorological observable at the coarse scale, such as coarse precipitation volume. We demonstrate that the adoption of such calibration relations allows the sampling variability to be better taken into account and the consistency condition to be respected leading to uniform rank histograms.

***Keywords:*** ensemble forecasting, downscaling models, rank histograms

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**HW2003** **Poster presentation** **4566**

# A predictive multidimensional model for remote sensing of vegetation

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***Fabio Castelli***

Many geophysical fields relevant to hydrological analysis are characterised by significant autoregressive components and spatial correlations. Several evidences exist about structural dependencies among the temporal and spatial variability of many of such fields, such as the indices of vegetation dynamics. The wealth of multi-year long sequences of satellite imagery provides an unprecedented source of data for the investigation and quantification of the space-time stochastic structure of such parameters, which in turn may play a crucial role in many hydrological and meteorological prediction problems sensitive to the vegetation evolution. In this study we use a two-step approach to the space-time modelling of vegetation indices obtained from remote sensing: the first step describes the deterministic component of the vegetation dynamics and related parameters with an additive model that includes seasonal components, interannual trends and jump discontinuities due to either climatic stresses or changes in sensor performance. The spatial dependencies are neglected in this first step. The second steps represents the dynamics of the random residuals with a predictive multidimensional (STAR) model which accounts for the autoregressive characteristics and the spatial correlations of the imagery sequences. The model is tested using spatial time series of MODIS vegetation indices (EVI and NDVI) from March 2000 through February 2007 over . Each spatial field in the series is a composite of several images over a 16-days averaging window, for a total of 161 samples over the study period. The nominal spatial resolution of the original product is 250m, which may make the use of the STAR model prohibitive for too large areas. Hence the model performance is studied for different aggregation scales up to 4 km, and the scale dependence of model structure, parameters and errors is analysed.

***Keywords:*** spatial time series, star model, vegetation dynamics

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**HW2003** **Poster presentation** **4567**

# Controlling meteorological factor for inter-annual variability of NDVI

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Soil moisture is one of initial and boundary condition for atmosphere and it controls partition of surface heat fluxes. Understanding the state of soil moisture is effective to enhance climate predictability on inter-seasonal or annual time scales. However, it is difficult to obtain global distribution of soil moisture with in-situ measurements only. Thus, the Global Soil Wetness Project (GSWP) has been implemented as an environmental modeling research activity initiated by the Global Energy and Water Cycle Experiment (GEWEX). The SiBUC (Simple Biosphere including Urban Canopy) land surface scheme is one of the participants of the 2nd GSWP, and it uses mosaic approach to incorporate all kind of land-use. In order to estimate the global soil moisture field as accurately as possible and to utilize the products of GSWP2 simulation more efficiently for water resources application, SiBUC is run with irrigation scheme activated. The basic concept of irrigation scheme is to maintain the water depth or soil moisture within appropriate ranges for optimal crop growth. In this scheme, Irrigation Water Requirement (IWR) can be calculated as amount of water that must be applied to achieve optimal crop growth without considering irrigation capacities. To understand inter-annual variability of IWR, adequately cultivated and irrigated grids are selected and aggregated for nation or sub-nation unit. In these regions, two correlation coefficients are calculated. One shows correlation coefficient between precipitation and IWR (hereafter CC-PI) and another shows correlation coefficient between precipitation and Normalized Difference Vegetation Index (NDVI) (hereafter CC-PV). From the analysis of two correlation coefficients, it was found that not only regions where CC-PI is negative and CC-PV is neutral but also regions where both CC-PI and CC-PV are positive exist. It can be implied that this difference of correlation expresses whether the irrigation facilities are adequate or not. Moreover, it can be pointed out where agricultural productivity is tolerant or vulnerable to precipitation variability. Not only using satellite remote sensing data set but also combining model outputs from the land surface scheme and satellite data leads to these suggestions. From these useful results, it is found that agricultural productivity can be tolerant where precipitation has little correlation with NDVI and agricultural productivity can be vulnerable where precipitation has positive correlation with NDVI. However, not only precipitation, but also other meteorological elements such as temperature and sunshine can be a controlling factor of crop growth. So, using precipitation, short wave radiation and temperature, other correlation coefficients with NDVI are calculated. In addition, target regions are expanded to all vegetation area. Especially in the grids where variation coefficient of NDVI is relatively high, from the analysis of these correlation coefficients, it is found that precipitation is generally controlling factor of vegetation growth. The relationship between meteorological variables and NDVI can imply tolerance and vulnerability of vegetation growth, especially agricultural productivity.

***Keywords:*** inter annual variability, controlling factor, vegetation growth

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**HW2003** **Poster presentation** **4568**

# Stochastic modeling of skewed data exhibiting long-range dependence

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Time series with long-range dependence appear in many fields including hydrology and there are several studies that have provided evidence of long autocorrelation tails. Provided that the intensity of the long-range dependence in time series of a certain process, quantified by the self-similarity parameter, also known as the Hurst exponent H, could not be falsified, it is then essential that the variable of interest is modelled by a model reproducing long-range dependence. Common models of this category that have been widely used are the fractional Gaussian noise (FGN) and the fractional ARIMA (FARIMA). In case of a variable exhibiting skewness, the previous models can not be implemented in a direct manner. In order to preserve skewness in the simulated series, a normalizing transformation is typically applied in the real-life data at first. The models are then fitted to the normalized data and the produced synthetic series are finally de-normalized. In this paper, a different method is proposed, consisting of two parts. The first one regards the approximation of the long-range dependence by an autoregressive model of high order p AR(p), while the second one regards the direct calculation of the main statistical properties of the random component, that is mean, variance and skewness coefficient. The skewness coefficient calculation of the random component is done using joint sample moments. The advantage of the method is its efficiency and simplicity and the analytical solution.

***Keywords:*** long range, dependence, skewed data

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**HW2003** **Poster presentation** **4569**

# Analysis of miscible displacement experiments in the frequency domain

***Prof. Angelo Sommella***

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SummaryIn the present paper two distinct approaches to the estimation of solute transport parameters in soils are considered. The first is based on the moments method, and it is by far the most used. The second requires that the solute transport parameters are determined by optimizing the quadratic differences between the theoretical frequency response, namely the Fourier transform of the breakthrough curve, and the one estimated from the experimental data. Both the methods have been used to analyze a plot scale solute transport experiment. With respect the calibration of the advective transport component u, both the methods leads to the same estimate. This is because u is very less sensitive to the experimental noise as it is related to the centre of gravity (and therefore to the first order moment) of the breakthrough curve. Instead, the dispersivity λ (which regulates the dispersion phenomenon) obtained by the aid the frequency domain response was better than that obtained by the moments method. Such a difference is attributed to the build up of the distortion effect due to the experimental errors in the estimation of higher moments.

***Keywords:*** solutetransport

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**HW2003** **Poster presentation** **4570**

# Scaling properties of rainfall time series

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Rainfall strongly affects our everyday life, very often in terms of fatalities, unfortunately. Therefore, it is crucial to examine closely the rainfall characteristics, such as the rainfall statistical structure at different time scales, that is a key issue in many Hydrological problems. The large amount of literature produced in the last twenty years about this issue deals with the validation of a power law dependence of all statistical moments on the scale of aggregation (scale invariance). This paper focuses on the analysis of the scale invariance properties of rainfall time series from a high density rain gauge network covering the Romes urban area. The network consists of 24 sites, and the gauge record at each site has 10-minute time resolution and about 12-year length. The aim of our work is that of determining the eventual existence of scale invariance regimes and their intervals of validity.

***Keywords:*** rainfall, scaling

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**HW2003** **Poster presentation** **4571**

# A comparison of models in return levels calculating

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The level of a phenomenon like precipitation fallen in a day, number of dry days, minimum (maximum) temperature in a day, height of a river flood, etc. expected to be reached in 100 or, generally, in N years time is called return level. As an alternative, it is possible to consider the return period for a determined events level on the basis of the same probability. In many fields and particularly in engineering ones, the Generalized Extreme Value (Gumbel) distribution (GEV/Gumbel) model is usually adopted for return levels calculating. Results in return levels strongly depend on the theoretical model adopted. Here we show that the prediction of time to be waited before a new event like the most severe would occur again might be significantly different if the Generalized Pareto Distribution (GPD) seasonal-trend incorporated model would be considered. The analysis is performed on 38 time series of daily precipitation data, derived from AM and ex-SIMN meteorological stations network. Time period is from 1951 to 2004 and datas availability is over 90%. Return period for the maximum level of daily precipitation registered between 1951 and 2004 is calculated on the basis of 3 different models: GEV/Gumbel-annual, GEV/Gumbel-seasonal and GPD seasonal-trend incorporated. The GEV/Gumbel model is based only on the maximum daily precipitation of each year whilst the GPD model describes the whole of events over a set threshold per each year. Besides, the latter takes into account both seasonal features of precipitation and time-varying component, which might affect the computation of predicting values. We use the Nadaraya-Watson non parametric estimator with a gaussian filter and a plug in method for bandwidth choice for detecting trend and the Cox-Stuart test for testing it. As a consequence of change over time, we replace GPDs threshold (location parameter) with a floating one according to theoretical values of Nadaraya-Watson trend. Results show that predicted return period is postponed in a percentage equal to 70% of cases comparing GEV-seasonal to GEV-annual model, that is the event is less probable to occur. On the other hand, we find out that predicted return period is anticipated of an average number of years equal to 102 adopting GPD seasonal-trend incorporated instead of GEV-seasonal model.

***Keywords:*** precipitation, gpd, trend

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**HW2003** **Poster presentation** **4572**

# Drougt identification using a stochastic approach: a comparison between hydrometeorogical and hydrological indexes

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Water resources management under shortage conditions due to drought is a rather complicated task: in particular, there is no general agreement neither regarding drought definitions, the analytical techniques for drought risk assessment and the proper mitigation measures. Following the well-known literature, it may distinguish between drought, which is a natural temporary condition of consistent reduction in precipitation and water availability with respect to normal values, spanning along a significant period of time and covering a wide region, and aridity, which is a natural permanent climatic condition with very low average annual or seasonal precipitation.Since 60s, several drought indexes were proposed, each with reference to a particular definition. Some indices referring to meteorological droughts are based on the rainfall series, such as the Standard Precipitation Index (SPI) (McKee et al., 1993); other indices describe hydrological or agricultural droughts, such as the Surface Water Supply Index (SWSI) (Gibbs e Maher, 1967).The aim of the present study is to investigate the potential of SPI index as a proxy for monitoring hydrological droughts, by coupling a stochastic model for generating daily rainfall series (based on a two-state Markov process) with a lumped conceptual daily rainfall-runoff model (IHACRES). More specifically, droughts are identified and characterized first by means of SPI series at a proper aggregation time scale k (i.e. 6 months) computed on synthetic rainfall series, and then by computing SWSI index or by applying the run method directly on runoff series. Then a statistical comparison between the characteristics of the identified drought events is made in order to determine the level of agreement of the derived results, potentially stating the capability of SPI index to monitor also hydrological droughts.Application of the proposed methodology is carried out with reference to the river basin in Sicily, Italy.

***Keywords:*** drought indexes, water resources management, stochastic hydrology

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**HW2003** **Poster presentation** **4573**

# On multi-variate flood scenario simulations

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Flooding hazard has a very deep impact on society, influencing both territorial planning and economic choices. This is emphasized in mountainous regions, where the extremely fast response of small basins to rainfall inputs calls for a civil protection use of extreme events forecasts. In this context, flooding risk prediction in terms of flood scenarios identification play an important role. Nowadays, hydrologic and hydraulic models allow the identification of flood prone areas, and their characterization in terms of return time. The resulting maps, which represent the envelope of the entire flood sets for assigned return times, are used to direct structural and non structural interventions in order to minimize the flooding risk. At present, minor attention has been devoted to the evaluation of the frequency of occurrence of flooding scenarios. In the present work, a spatial model for flood scenario frequency assessment is proposed for the Italian study area. First, the study area has been divided into homogeneous regions according to their hydrologic, orographic and meteo-climatic characteristics. Then, by using i) a historical flood events dataset; ii) a homogeneous regions correlation matrix; iii) an auxiliary variables data set; and iv) a return time matrix, a statistical model for flood scenarios simulation has been carried out throughout a conditional approach.

***Keywords:*** flood scenarios, multivariate simulations

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**HW2003** **Poster presentation** **4574**

# Long rainfall time series trend analysis in Campania Region, Southern Italy

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There is an increasing concern for the potential impact of environmental change and a number of papers appeared in the literature, in the recent past, confirming or denying a worldwide climate change. According to some recent studies the Italian territory is suffering a precipitation decrease, especially in the last fifty years, and the southern areas seems to be the more affected. The aim of the present study is to analyse long rainfall time series, detecting potential trends and assessing their significance. For this purpose over 200 stations, mainly located within the Campania region, southern , have been analysed for the period 1919 1999. The study initially started dealing with an analysis of data quality, including data missing and time series homogeneity, the latter performed by the t test of Student and also supported by the identification of changing points, that is of one or multiple abrupt changes occurring in the time series. Homogeneous rainfall time series have then been aggregated both at the annual and seasonal time scale. At first, trends detection analysis has been performed fitting a linear regression to the data assessing whether the slope coefficient is significantly different from zero, indicating in this case the presence of a linear trend. The slope coefficient sign would also indicates a positive or negative trend. The Mann-Kendall nonparametric test has also been performed confirming the existence of a positive or negative trend for a given confidence level. Detected trend appears to be predominantly negative both at the annual scale and at the seasonal scale, except for the summer period when it appear to be positive, that means an increase of rainfall amount during the summer period. They are however not significant for a given 90% confidence level, denying an important change in rainfall amounts. A similar analysis undertaken over three overlapping periods of 30 years, shows instead that, for the same confidence level, the negative trend is rather significant in the last 30 years.

***Keywords:*** long time series, rainfall, trend analysis

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**HW2003** **Poster presentation** **4575**

# A 2300-year hydro-climatic reconstruction for the Walker River Basin, California and Nevada, USA

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Tree-ring samples from western juniper (Juniperus occidentalis) trees located at two sites within the headwaters of the Walker River, near the boundary between California and Nevada were used to develop a 2300-year, annually resolved, hydroclimatic reconstruction. The tree-ring chronology was built from a total of 92 ring-width series comprising 34,034 measurements distributed over the period 300 BC to AD 2001. Average interseries correlation was 0.7, and signal strength was greater than 0.75 for the period AD 250-2001. Mean segment length was 370 years, which allows for the accurate identification of interdecadal to intercentennial patterns Climatic data used for calibration/validation tests were October through September (i.e., water year) precipitation totals in California Climate Division 3, which includes the headwaters of a few eastern Sierra Nevada/western Great Basin lake and river basins. Statistical tests indicated significant skill for reconstructing climate. We then used the tree-ring chronology, expressed in standard deviation units (sdu), as our proxy record of moisture. Maxima and durations were computed for all positive and negative episodes, each with 467 observations. The longest episodes were AD 791-811 (a 21-year dry spell), followed by AD 1449-'68 (a 20-year drought) and AD 1900-'19 (a 20-year wet period). The highest (absolute) peaks occurred in AD 1051 (wet) and AD 1782 (dry). We also computed episode magnitude, which was greatest for the 1900-'19 pluvial and for the 1449-'68 drought. A score was then assigned to every episode by (1) ranking episodes separately by duration, absolute magnitude, and absolute maximum (with increasing ranks for increasing parameter values); (2) adding the three ranks of each episode to obtain the final score (the higher the score, the stronger the episode). According to this numerical classification scheme, the most remarkable episode was the mid-1800s drought (1840-'51), followed by two pluvials, at the end of the 7th century (682-692) and at the beginning of the 20th one (1900-'19); the Dust Bowl drought (1927-'36 in this record) was in 73rd position. An alternative reconstruction was produced by using the model denoted as REXTN (Record Extension with Noise), which was proposed to extend short records in hydrology while maintaining the mean, variance, and the lag-1 autocorrelation of the short record, as well as the lag-0 cross-correlation between the short and longer record. Because the REXTN approach also produces an ensemble of reconstructions (through the randomly generated noise term), a formal and quantitative way is described to select one record from this ensemble. Results produced from the two approaches are compared and discussed.

***Keywords:*** dendrochronology, paleoclimatology

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**HW2003** **Poster presentation** **4576**

# On the development and testing of a soil moisture-based drought index

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Continuous simulations with the LISFLOOD model within the European Flood Alert System produce daily soil moisture maps of Europe . This information provides an instantaneous image of the current situation of the soil water content as modelled by LISFLOOD. The LISFLOOD model is a distributed hydrological model that is run within the EFAS on a 5 km spatial resolution. It comprises modules for the modelling of vegetation, soil, groundwater, snow cover, runoff generation, and stream routing in major European rivers. The soil compartment of LISFLOOD consists of a two-layer soil model. Infiltration of effective precipitation, soil evaporation and plant water uptake take place from the upper soil layer, while the lower soil layer represents essentially a storage term that produces a slow runoff component and recharges the groundwater compartment. Accordingly the soil moisture content of the upper soil layer mirrors the balance of water between precipitation supply and climate and vegetation demand. The soil water content represented as soil suction (pF), its normalized value and the seven days trend maps, as well as time series for some selected regions are updated on a daily basis on the http://natural-hazards.jrc.it website. The modelled soil moisture has been validated by comparison with the ERS Scatterometer derived Soil Water Index. In order to understand if it is possible to obtain valuable information for drought detection purposes, we evaluated the temporal behaviour of the soil moisture series and the relations with well known drought indices. First we assessed the possibility of adapting any statistical probability distribution to the pF series for the two modelled soil layers for standardization purposes. We considered the Gamma, Normal and Log-Normal probability distributions. Then we calculated from the input rainfall data the Standardized Precipitation Index (SPI) for different time scales (averaging periods) and we investigated its relations with the standardized pF series. The correlation coefficients between the standardized pF series for the two modelled soil layers and the SPI at different time scales have shown on average higher values for the four months (layer one) and eleven months (layer two) time scales. The relations between the maximum correlation time scales and basic information on soils and climate have been investigated. The soil moisture development for selected drought events is presented.

***Keywords:*** drought index, soil moisture

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**HW2003** **Poster presentation** **4577**

# Copula based regression methods applied to hydrological data

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***Salvatore Grimaldi***

A regression method based on copula functions is described and analyzed in this paper. This approach, recently introduced and not yet widely applied in hydrology, defines the regression function as the conditional expectation or conditional median, using the statistical information provided by the joint distribution of the variables. Schemes like this are called structural, since the regression pattern is completely defined when the conditional distribution or the joint distribution is known. The copula function procedure described here is essential because it allows to easily define the joint distribution of the variables by separately studying the marginal behavior and the dependence structure. Indeed, the flexibility in building bivariate distributions with arbitrary marginals is the reason that copula is becoming more and more popular in literature. Some simulations are performed to evaluate if the copula based regression approach is able to analyze non-linearly correlated pairs of data and to highlight the differences with the well known linear regression approach. The described method is further tested in a case study as regards the much often encountered problem of filling in missing data. Results suggest that copula based methods provide more correct information about the regression uncertainty, and that pseudo random series, drawn from copula based conditional distribution, keep main statistical properties of the observed sequences.

***Keywords:*** copula, regression, missing data filling in

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**HW2003** **Poster presentation** **4578**

# State-space approach to spatial variability of soil water status

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The spatial structures of soil water status, in terms of soil water content q and hydraulic potential h, had been examined on a bare volcanic soil in Ponticelli, Naples(Italy). Measurements were made in situ at 0.3 m depth on two transects consisting of 50 positions 1 m apart. The ACF and the PACF were used to identify the univariate ARMA(1,1) model for the analyzed series and the AR(1) model for the extracted signals . Relations with a state-space model are investigated and a bivariate AR(1) model fitted. The simultaneous relations between q and h are considered and estimated. ESSENTIAL REFERENCES Nielsen, D. R., Biggar J. W., Erh K. T., 1973. Spatial variability of field measured soil-water properties. Hilgardia. Vol. 42, 215-259. Anderson, S. H., Cassel D. K., 1986. Statistical and autoregressive analysis of soil properties of Portsmouth sandy loam. Soil. Sci. Soc. Am. J., 50, 1096-1104. Wu, L., Jury W. A., Chang A. C., 1997. Time-series analysis of field measured soil water content. Soil Sci. Soc. Am. J., 61, 736-742. Webster R., 2000. Is soil variation random? Geoderma, 97, 147:163

***Keywords:*** spatial structure, soil hydraulic parameters, arma state space

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**HW2004** **4579 - 4661**

## Workshop
## Towards Improved Evaluation of Hydrological Models: The Need to Understand and Characterize Uncertainties in the Modelling Process (Sponsor ICCLAS, PUB)

**Convener :** Dr. Jim Freer, Dr. Erwin Zehe
**Co-Convener :** Dr. Thorsten Wagener

To increase our knowledge about hydrological systems and to develop better models we have to be able to effectively evaluate models and predictions against observations of watershed responses. In doing so we have to be pragmatic about the limitations of our knowledge, our data collection techniques and our ability to characterize all sources of uncertainty in the modelling process, including the assumptions within our uncertainty analysis methodologies. Contributions are invited that explore novel ways in which we directly incorporate data (e.g., site parameterization) uncertainties (both temporal and spatial) in the evaluation and analysis of hydrological models. Papers are invited that characterise uncertainties in data at all spatial scales, from the 'effective model grid' scale for localised processes, to small headwater catchments and flood inundation experiments, through to the regionalisation of catchment characteristics at large scales. In addition, contributions are also invited on research that identifies new uncertainty analysis procedures for model evaluation and the quantification of prediction uncertainties. Issues to be explored include, but are not limited to: (a) the propagation of uncertainties in input data through hydrologic models to output prediction uncertainties; (b) techniques for assessing the data uncertainties in comparison with model simulated output; (c) novel ways to define data uncertainties so as to characterise directly the error properties, where such error structures may have non-stationary properties; (d) uncertainty analysis methods that try to understand more explicitly model structure errors and the identification of competing process descriptions; (e) techniques for incorporating extreme events, which typically have large measurement uncertainties; and (g) novel field experiments designed to understand better the dominant processes as well as the uncertainties in observations at a range of scales that are useful for modelling applications. Both oral and poster contributions addressing one or more of the above mentioned issues are solicited.

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**HW2004** **Oral Presentation** **4579**

# Influence of rainfall spatial variability on runoff modelling in a small Mediterranean research catchment (Vallcebre, Eastern Pyrenees)

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Rainfall spatial variability and its influence on runoff modelling have been investigated in a small Mediterranean catchment. Rainfall spatio-temporal variability was measured in the Cal Rod (4.17 km2) research catchment, during a 2 years period, with 7 rainfall recorders. Rainfall recorders were of tipping bucket type, connected to a small data logger that collects increments of 0.2 mm of rainfall with a time resolution of 1 s. Results showed that rainfall spatial variability was generally low within the catchment, except during summer. In these conditions high differences were observed among the different rainfall recorders, during short intensive rainstorms. The effect of this spatial variability of rainfall on runoff modelling was investigated with Topmodel. Using alternatively different patterns of catchment scale rainfall, the consequences of event scale rainfall variability on model parameterization and on the uncertainty associated with prediction were explored, using the model within a Generalized Likelihood Uncertainty Estimation framework.

***Keywords:*** rainfall, parameterization, topmodel

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**HW2004** **Oral Presentation** **4580**

# Uncertainty propagation in a hydrological conceptual model for water quality asessment

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Water quality impacts due to non-point source pollution can be significant particularly in environmentally sensitive areas. They may, however, be difficult to quantify, since the magnitude is heavily influenced by climatic, geomorphologic, lithologic and pedologic characteristics. A conceptual model for continuous daily simulation is proposed to reproduce the quali-quantitative response of a Sicilian catchment. Short-term water quality monitoring is necessary to assess the hydrological response of catchments characterised by hot dry summers and rainfalls with short duration and high intensity. The quantitative sub-model comprises two modules: a non linear loss model, to transform total rainfall in effective rainfall, which involves calculation of an index of catchment storage based upon a non-linear triggered exponentially decreasing weighting of precipitation and temperature; a linear convolution of effective rainfall with the total unit hydrograph with a configuration of one parallel channel and reservoir, corresponding to quick and slow components of runoff. The qualitative sub-model here presented deals with a conceptual form of the unit-mass response function of non-point source pollutants runoff. It connects flow discharges to concentrations of pollutants, as nitrates and orthophosphates by means of components of IUH (Instantaneous Unit Hydrograph) describing the quantitative response of the system. This paper explores how the limitations inherent in the modelling processes can be reflected in the estimation of predictive uncertainty. The Generalised Likelihood Uncertainty Estimation (GLUE) approach is used here in the estimation of predictive uncertainty of both, quantitative and qualitative, sub-models with an particular eye on propagation of predictive uncertainty within the two sub models to final predictions.

***Keywords:*** water quality, hydrological models, glue

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**HW2004** **Oral Presentation** **4581**

# Regional Hydrologic Analyses Using GLS Regression

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***Jery R. Stedinger***

To estimate flood quantiles and other statistics at ungauged sites, an iterative generalized least squares (GLS) regression procedure is commonly employed to estimate the parameters of a model of the statistic of interest as a function of basin characteristics. The GLS procedure accounts for differences in available record lengths and spatial correlation in concurrent events by using an estimator of the sampling covariance matrix of available flood quantiles. In a regional flood study with 162 sites from South Carolina (U.S.), the performance of a pooled regression model is compared with that of separate models for each hydrologic region: statistical tests recommend an interesting hybrid of the two which is both surprising and hydrologically reasonable. The statistical analysis is augmented with new diagnostic metrics including a condition number to check for multicollinearity, a new pseudo- appropriate for use with GLS regression, and error variance ratios. GLS regression for the standard deviation demonstrates that again a hybrid model is attractive, and that GLS rather than a weighted least squares analysis is clearly appropriate for the development of regional standard deviation models.

***Keywords:*** flood frequency, gls regression

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**HW2004** **Oral Presentation** **4582**

# Integrating alternative calibration strategies to set-up, evaluate, and compare hydrological models

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***Hubert H.G. Savenije, Patrick Matgen, Laurent Pfister***

The aim of this research is to compare different calibration approaches and to integrate their strengths in order to set-up, evaluate, and compare hydrological models. Two alternative calibration approaches are considered: the first refers to multi-objective optimization and develops a set of optimal solutions with respect to a number of calibration objectives; the second is a stepped calibration approach which reproduces in an automated fashion the steps that are followed by operational hydrologists during manual calibration. This approach develops a single parameter set. The comparison is performed considering the same set of objectives and two model versions of a different level of complexity. The results of the research show that the multi-objective approach is useful to evaluate the merits of individual models, and to track changes in model performance as the model structures are modified. However, it can produce solutions that, while being all optimal and equally important from a multi-objective optimization perspective, might be sensibly different one from the other and not all equally acceptable from a calibration perspective. The stepped calibration approach develops a solution that, even if not optimal, represents a balance of calibration objectives according to the operational needs. Such a balance can also be used to eliminate unrealistic results from the optimal set of solutions developed through multi-objective optimization. This way, the two approaches can be used in an integrated manner that exploits the strengths of each. The two approaches are tested with the data of an experimental catchment of the Alzette river basin, Grand Duchy of Luxembourg.

***Keywords:*** calibration, evaluation, comparison

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**HW2004** **Oral Presentation** **4583**

# Understanding uncertainties in hydrologic models: relationships between parameter uncertainty and model structure

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An outstanding research challenge in hydrology is quantifying the uncertainty in hydrologic model simulations. Uncertainties in hydrologic model simulations stem from uncertainties in model inputs, uncertainties in model parameters, and weaknesses in model structure. These different sources of model error are strongly inter-related, meaning that uncertainty estimates may be untrustworthy if the different sources of error are modeled independently. This paper presents an analytical framework to evaluate relationships between parameter uncertainty and mode structure, whereby four existing hydrologic models are re-configured as two-layer soil models that share many of the same model parameters. This framework provides scope to diagnose the control of model parameters in different model structures, as well as the relative importance (and interplay) between uncertainties in model parameters and the details of model structure. The fou re-configured models are used to simulate streamflow in two of the basins used in the MOdel Parameter Estimation eXperiment (MOPEX) in the southeastern United States of America. The analysis shows that the identifiability of model parameters depends on the particular mode structuredifferent parameters are more clearly identifiable in different models, and the values of parameter sets with the lowest error can vary markedly between different model structures However, most model parameters examined in this study are poorly identifiable. Poorly identifiable parameters mean that equally accurate streamflow simulations can be obtained in a number of different ways. When the different parameter sets represent different dominant flow processes, streamflow simulations produced using multiple parameter sets from a single mode can produce as much diversity in simulated streamflow that is produced by simulations from multiple models.

***Keywords:*** uncertainty, identifiability, parameterisation

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**HW2004** **Oral Presentation** **4584**

# Towards analytical assessment of model structure suitability and model comparison

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***Markus Casper***

Because of the broad variety of rainfall-runoff models available today, in most cases at least always a few appear equally suitable to meet the requirements of a specific modelling task, i.e. the models are able to produce the desired output variable with the input data and calibration data provided. Depending on the catchment under investigation the simulation of its system response requires the reproduction of different levels of process complexity by the model structure and the available data. In view of numerous examples that have shown that in general model performance is more likely to be dependent on the model structure than on model complexity it becomes relevant for practical model evaluation to assess whether the process complexity of the natural system can be satisfactorily met by the inherent structural capabilities of competing model structures. Powerful methods exist to evaluate parameter and structural uncertainties. However a method to facilitate insight into the suitability of different models by comparing their capabilities to cover the system stages and dynamic range of the observed system and to reveal model structural inadequacies is yet to be established. This contribution aims to explore a solution for this problem.

***Keywords:*** model evaluation, structural uncertainty, visualization techniques

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**HW2004** **Oral Presentation** **4585**

# Uncertainty analisys in water quality modelling parameters

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***Carlos Eduardo Morelli Tucci, Walter Collischonn***

Water quality models are useful tools for integrated water resources and environmental management. Applications of this kind of models goes from simply extending and completing observed time series of water quality parameters to predict the impacts of changes in water quality due to changes in land use, sewage treatment or hydrologic and climatic conditions. However, water quality modelling outputs carry out a high degree of uncertainty due to the usual lack of data for parameter identification at all simulated scenarios. Many parameters related to the pollution loads frequently need to be estimated based upon literature values, extracted from basins with different features of climate, soil and agricultural systems. Moreover, model outputs are biased by its structure, which reflects users knowledge, or lack of knowledge, of the processes involved in pollution sources and water quality parameter interactions. Each day practice suggests that representing natural processes with accuracy through mathematical models, especially in the case of water quality aspects, is at least pretentious and ingenuous. The water quality model outputs should be presented in combination with its respective uncertainties. This paper presents an analysis over the uncertainties due to both the process of non-point and point load generation and the kinetic process of source and sink in streams, performed in the water quality modelling of the Taquari-Antas river basin (~ 25.000 Km), in the south of Brazil. The model applied was a water quality model combined to a large-scale distributed hydrological rainfall-runoff model. The watersheds non-point load is estimated by the Event Mean Concentrations (EMC) coefficients as a function of the land coverage and use based on literature value ranges. The urban sewage point loads are estimated by means of typical average values of pollutant concentrations. The water quality model performs the kinetic processes and the advective transport of the constituents. The methodology applied to assess the uncertainties took the following steps: (a) adoption of ranges for the parameters and input variables analyzed; (b) generation of n random values in the parameters defined range (a sensibility analysis was performed to obtain the n value) by the Monte Carlo method; (c) running of the model for the different n group of parameters; (d) estimation of the 95% confidence bounds. Results from the uncertainty analysis throughout the confidence bounds were confronted with the ones obtained from manual model fitting, based on a 10-year series of water quality variables, and with the monitoring data itself. The model estimated errors for the 95% confidence level, regarding to the monitored data, showed the methodology potentialities in the river water quality assessment, and as a possible alternative for ungauged basins.

***Keywords:*** water quality modelling, uncertainty analisys

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**HW2004** **Oral Presentation** **4586**

# Partitioning river flow data to better understand and characterize uncertainties in hydrological modelling

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Different processes dominate catchment behaviour as moisture status and meteorological forcing change over time, particularly in semi-arid catchments which are characterized by substantial seasonal differences in rainfall and river flow. Some investigators have argued that conditioning models or evaluating model performance in these catchments on the basis of an objective function that aggregates performance over an entire calibration period, result in a loss of information. Ensemble predictions using multiple parameter sets may mitigate multiple sources of predictive uncertainty by characterizing the behaviour of the catchment as an average from a distribution of potential responses. The hypothesis tested in this study was that uncertainty in daily river flow predictions in semi-arid catchments will be reduced if an ensemble (single structure, multiple parameter sets) is formulated to represent different hydrological responses in wet and dry seasons or high and low flows. This hypothesis was tested using data from the Santa Cruz catchment located near Santa Barbara, California. Three ensemble formulations were developed using a parsimonious, lumped-conceptual model structure (IHACRES). The first ensemble included the top 25 ranked parameter sets from each of the wet and dry season calibrations. The Nash-Sutcliffe coefficient of efficiency (E) was used as the measure of model performance. The second ensemble included parameter sets identified as the Pareto optimal sets from the wet and dry seasons using E and the absolute bias (ABIAS) as the objective functions. For the third ensemble, the root-mean-squared error was calculated separately for high flows and low flows using the 95th percentile flow as the partitioning threshold. The Pareto optimal set was used to identify the parameter sets for this ensemble. The use of Pareto optimal sets to derive parameter sets for ensemble predictions of daily river flow resulted in predictions that were generally more accurate than those based on other ensemble formulations or the best single parameter set. The improved ensemble predictions using Pareto optimal sets and partitioned data seemed to be more a consequence of identifying robust parameter sets using multiple objective functions than the added information accessed by partitioning the data. The rainfall characteristics of the calibration period are shown to have a marked effect on the relative predictive performance of the different ensembles during model verification. Using an objective function that included the absolute values of residuals and seasonal averages as the baseline (rather than the overall average for the record), helped reveal predictive uncertainties that were not evident using E.

***Keywords:*** ensemble, objective functions, pareto set

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**HW2004** **Oral Presentation** **4587**

# Spatial discretization and uncertainties in distributed hydrological modelling

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For hydrological models, numerous studies have shown that model performance depends on spatial discretization (grid cell size or definition and size of hydrological response units). Especially the dependence of the performance of TOPMODEL on spatial discretization of the topographic index has been thoroughly investigated. All of these studies are looking at the change of parameter values and model performance in terms of different performance criteria with a change of spatial scale, but not at the uncertainties associated with the model results. Therefore the objective of this paper is to show how additional investigations of model uncertainties can help to assess the overall performance and associated predictive uncertainties of hydrological models and how the predictive uncertainty changes with grid size in grid based hydrological model. In our study we applied the distributed hydrological Model WaSIM-ETH in a meso-scale catchment Zeulenroda (99.5 km) in the lower mountain range of Thuringia, Germany. We distinguished five spatial discretizations according to the grid sizes of 25, 50, 100, 300 and 500 m. The calibration tool PEST was used and compared with the result of the Bayesian Monte Carlo Marcov Chain (MCMC) method, which uses a statistical likelihood function for the simulation error and the Gibbs within the Metropolis algorithm as the searching method. The MCMC method not only allows calibrating the model but also estimates parameter and the total uncertainty. The PEST calibration led to similar goodness of fit for all selected grid sizes and did not allow distinguishing the predictive uncertainties of the selected spatial model structures. The Nash and Sutcliffe criterion ranged between 0.721 and 0.822 in the calibration period and between 0.549 and 0.573 in the validation period. The MCMC analysis indicated that course grid sizes of 500 m had the widest total uncertainty bounds. Comparing the model uncertainties of the 500 m with the 300 m and the 100 m with the 50 m grid size, it could be shown that the differences between them were small. However, comparing the 100 m with the 300 m grid size, a significant difference was observed. This indicates a discretization threshold or a grid size threshold. The suggested methodology was proven to be very useful in selecting an appropriate spatial discretization of the selected hydrological model. It can be used to further investigate the effect of the model complexity and catchment characteristic on model performance and associated parameter and total uncertainties.

***Keywords:*** spatial uncertainty, distributed modelling, mcmc

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# Model transferability within an uncertainty framework: how to deal with parameter drift

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Transferability of hydrological model structures is important for many practical applications, ranging from predicting the hydrological reponse of ungauged basins (PUB) to predicting the effect of environmental changes such as land use change or climate change on a water quality and quantity. However, very few theoretical frameworks exist to deal with model structure transferability, in particular when uncertainty is taken into account. We explain how parameter drift can be incorporated within an uncertainty framework to transfer model structures. The conceptual framework allows for the use of different transformations of model parameters while dealing with parameter (set) likelihoods and equifinality. In an exemplatory case study, a modified TOPMODEL is used within the GLUE methodology to predict the effect of afforestation of small mountainous catchments in the pramo of the Ecuadorian Andes. Using data from a natural grassland catchment, parameter set likelihoods are calculated. A simple linear transformation of the parameter sets is used based on information in the literature about the impact of pine afforestation. This transformation is applied to the behavioural parameter sets, which are then used to calculate prediction limits for the discharge of a nearby afforested catchment. Despite considerable uncertainty in the boundary conditions, especially precipitation, and the simple parameter transformation technique, the model provides confidence intervals for the predicted hydrological response that bound the observations in this case.

***Keywords:*** hydrological modelling, land use changes, uncertainty

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**HW2004** **Oral Presentation** **4589**

# Uncertainty reduction in multi-variable hydrological modelling

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The increasing complexity of hydro-chemical rainfall-runoff models poses new challenges for parameter estimation. Calibration against a single variable may not provide enough information to determine model parameters. Research indicates that parameter uncertainties can be reduced by combining multiple objectives. A problem specific to water quality modelling, however, is the lack of reliable observation data. Measurement errors on water quality variables are generally large, leading to high uncertainty on model parameters. Combining such erroneous water quality data with more accurate stream discharge observations in simultaneous calibration may further introduce unknown bias in the parameter optimisation. This paper compares a sequential and a simultaneous automatic approach for the multi-objective calibration of the semi-distributed Soil and Water Assessment Tool (SWAT). The watershed under consideration is that of the Grote Laak, a small river in the north-east of Belgium. Model parameters are identified by means of observed stream discharge, nitrate and nitrite calibration data series. In total, 21 parameters are included in the optimisation, of which 16 are associated with stream discharge and five with nitrogen compounds. The effect of measurement errors of NO3 and NO2 data on parameter uncertainty and model prediction output in a multi-objective calibration frame is explored. Sequential and simultaneous calibrations of respectively stream discharge, NO3 and NO2 at different levels of aggregation and measurement error are performed. The Shuffled Complex Evolution Metropolis algorithm (SCEM-UA) is implemented for the optimization of model parameters. This is a Markov Chain Monte Carlo method that utilises Bayesian inference to estimate parameter uncertainties. SCEM-UA retrieves the best parameter sets along with the posterior probability density functions of the model parameters. From these functions, uncertainty intervals of parameters are inferred, thus allowing for the estimation of the uncertainty on model prediction. Results show that the sequential calibration against NO3 or NO2 does not allow for an effective confinement of the nitrogen parameters. Especially for NO3, large parameter uncertainties are translated into high model prediction uncertainty. The simultaneous calibration of stream discharge, NO3 and NO2 is more able to manage parameter uncertainties. Using all the information contained in the observation data simultaneously improves the confinement of most of the parameters associated with nitrogen. Increasing levels of measurement errors did not introduce important bias into the calibration process: stream discharge predictions and corresponding uncertainty remained unaltered and no major change in the hydrological balance was observed. Increasing the level of variable aggregation in the simultaneous calibration had positive effects on parameter confinement and model prediction performance, even at high measurement error. The findings also suggest that errors on point source pollution are more likely to introduce biases in estimation of model parameters than measurement errors on in-stream water quality variables.

***Keywords:*** multi objective calibration, parameter uncertainty, markov chain monte carlo

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**HW2004** **Oral Presentation** **4590**

# Reducing the uncertainty of streamflow simulation by accounting explicitly for the spatial variability of rainfall in a lumped rainfall-runoff model

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Spatial rainfall variability is often considered as a major source of uncertainty for streamflow simulation. In lumped rainfall runoff models, where only mean areal precipitation is available to the model as input, this is most likely a source of uncertainty in parameter estimation, as well as a source of error in runoff simulation. But the relations between rainfall spatial variability and error in runoff simulation are considered as a conundrum by most hydrologists [Smith et al, 2004]. What are the part of incertainties due to the rainfall variability that may implicate erroneous inputs? Is the information of precipitation spatial variability useful for lumped rainfall-runoff models? How can it be taken account in these models? How can the model benefit from information available on individual raingauge? In this study, we test and compare three methods that allow taking into account precipitation heterogeneity in a lumped model, based on a set of 200 French catchments: X a first method based on the introduction in the model structure of a rainfall variability index derived from observed data; X a second method consisting in feeding the model with a weighted precipitation input accounting explicitly for rainfall variability; X a third method based on multi-model principles, consisting in feeding each model with data from a specific raingauge, and combining the streamflow simulations at the end. We discuss the results and their implications for reducing the uncertainties in streamflow simulations as well as in model parameter estimation.

***Keywords:*** rainfall variability, rainfall runoff modeling

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**HW2004** **Oral Presentation** **4591**

# Hydrological model evaluation by extended information criteria

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Generally complexity of hydrological model works as an advantage for the accuracy of simulated variables. For instance, the number of parameters of rainfall-runoff model increases, the number of degrees of freedom and flexibility of model also increase, the goodness of fit between simulated discharge and observed one increases. However, excessive degrees of freedom leads to the problem of overfitting to the fluctuation caused from various uncertainty. Therefore, it is necessary to choose a model having the proper complexity balanced with the amount of information comprised in observation data. In this study, we use extended information criterion (EIC) to evaluate the balance between the complexity of hydrological model and the amount of information. EIC is regarded as an extension of Akaikes information criterion (AIC), and constructed by employing the bootstrap method to simulate the data fluctuation. At first, we define the statistical error model of simulation error, and define the likelihood function based on the error model as to respect the rules of Bayesian inference. Next, bootstrap samples needed to calculate EIC are generated. When the error model is given, parametric bootstrap method is usually used. However, in case of popular hydrological models, time series of simulation error shows strong autocorrelation, and parametric bootstrap method does not work properly. Therefore we adapt nonparametric bootstrap method. The third, maximum log likelihood of all bootstrap samples and observation data are computed by particle swarm optimization (PSO) algorithm, and EIC is calculated from these likelihood. Then popular conceptual lumped models are evaluated and compared based on EIC. This allows us to select the proper model balanced to the observation period and to reduce prediction uncertainty. Finally, posterior distributions of model parameters for all bootstrap samples and its statistical characteristics are calculated with Markov Chain Monte Carlo (MCMC) algorism, and parameter uncertainty is discussed.

***Keywords:*** eic, extended information criteria, model evaluation

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**HW2004** **Oral Presentation** **4592**

# Modifying NSGA-II in order to reflect multi-objective parametric uncertainty of conceptual rainfall-runoff models

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NSGA-II has been proven as a fast and reliable evolutionary multi-objective algorithm. This algorithm has been recently used in the context of rainfall-runoff model calibration in order to assign a set of pareto-optimal parametric values reflecting all considered objective functions. In this paper, it has been tried to incorporate the Bayesian information about the objective functions into the algorithm in order to consider parametric uncertainty in the search process. In this juncture, the crowding distance operator in NSGA-II which is used to select the potential solutions for the next generation is substituted by another module which considers Bayesian information about the potential solutions rather than their distance from each other. As a result the potential solution with higher overall likelihood measure has more chance to be selected in the next generation. Three different scenarios for estimating overall likelihood measure are compared together. The modified algorithm is used for calibration of two different conceptual rainfall-runoff models and the results are compared with the calibration performed by MOSCEM and original NSGA-II.

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**HW2004** **Oral Presentation** **4593**

# Dual polarization radar-based rainfall uncertainties and streamflow sensitivity in a distributed hydrological model

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The application of weather radar in hydrological modeling has demonstrated the prospect of improving the accuracy of rainfall inputs on which the accuracy of the streamflow prediction from a hydrological model is heavily dependent. To investigate the effect of temporal and spatial resolution of precipitation data provided by the Thurmham radar (a new C-band dual polarization radar in Kent, England) on the accuracy of short-term and long-term rainfall-runoff simulation as well as estimating the precipitation uncertainty during real-time flood forecasting, the MIKE-SHE/MIKE-11, fully physics-based distributed coupled modeling system has been applied to the UpperMedway basin (307km2). The study uses different radar algorithms with various space time resolutions to produce rainfall comparable to the precipitation gauge measurements. The model after it was calibrated and validated based on historical evens was utilized to investigate various aspects of uncertainty in relation to distributed modeling of catchment behavior. The impact of uncertainties in the quantitative precipitation estimate (QPE) on the streamflow simulation was also analyzed using Monte Carlo sensitivity methodology. Ensemble simulations were used to evaluate the accuracy of different radar-based rainfall algorithms under different resolutions at the scale of a headwater basin. The performance of the radar and further research on this approach is addressed and comments provided on the problems associated with characterizing the uncertainties of space-time hydrological processes.

***Keywords:*** distributed hydrological mode, dual polarization radar, rainfall uncertainty

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**HW2004** **Oral Presentation** **4594**

# Analysis of data and model uncertainty in hydrological modelling using bayesian hierarchical methods

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Calibration and prediction in conceptual rainfall-runoff (CRR) modelling is affected by the sampling and measurement uncertainty in the forcing/response data and by the structural error of the model conceptualisation. This study presents a robust Bayesian Total Error Analysis methodology (BATEA) for dealing with these multiple sources of uncertainty. The core idea is to pose the CRR model calibration as a Bayesian hierarchical model with latent variables describing uncertainties in the data and the CRR model. This provides the opportunity to directly and comprehensively address all sources of uncertainty. A critical challenge is to characterize model error. In the past this has been thwarted by the convenient but indefensible treatment of CRR models as deterministic descriptions of catchment dynamics. Here it is argued that CRR models are fundamentally stochastic because sub-grid variability of catchment processes in time and space cannot be uniquely described by models operating at hillslope or larger scales. Acceptance that CRR models are intrinsically stochastic paves the way for a more rational description of model error. We advance the hypothesis that CRR model error can be characterized by storm-dependent random variation of one or more CRR model parameters. BATEA requires the estimation of a large number of latent variables (realisations of stormdependent model parameters). This yields high dimensional optimisation and sampling problems to estimate the most likely parameter sets and to characterise their uncertainty. Optimisation strategies using Newton-type methods are presented, along with practical implementations of Metropolis and Gibbs samplers to elicit the full posterior distribution of model parameters. Diagnostic tests guiding the selection of the distributions of latent variables are discussed. Case studies are presented illustrating the BATEA approach and the insights it generates about predictive uncertainty in CRR models.

***Keywords:*** model and data uncertainty, bayesian hierarchical models

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**HW2004** **Oral Presentation** **4595**

# Reducing Uncertainty in Streamflow Simulations using a Coupled Modeling System

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Estuarine regions in the Tar-Pamlico river basin on the E. Coast of the U.S. are susceptible to flooding due to oceanic influences as well as impacts from cloud and land surface water. A probabilistic hydrologic prediction system is developed from an ensemble of precipitation inputs and perturbations of model parameter settings. The intention of the system is to estimate the total prediction uncertainty by assuming the model physics adequately represent the natural system being modeled. This study first assesses the skill of the ensemble of hydrologic simulations. Then, skill scores are recomputed after the hydrologic model is coupled with a hydrodynamic ocean model that considers storm surges emanating from tropical cyclones. A case study involving the passage of a hurricane is used to determine if the incorporation of more complex model structures improves simulated river discharges.

***Keywords:*** hydrologic, modelling, uncertainty

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# The role of uncertainty in design of objective functions

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Commonly used objective functions comparing observed and modelled flows (e.g. the Nash-Sutcliffe efficiency- NSE) do not explicitly take into account the uncertainties in the model input, or in the observed flows. However, all objective functions assume a particular distribution of uncertainties in the quantities being compared. For example, the NSE assumes that the amplitude of the uncertainties is independent of the values being compared. As a result, very high weight is given to high flow events, which are often the most uncertain. There have been several attempts to overcome this limitation, from not using the highest n% of observed flows, to transforming the flow prior to calculating the NSE. Transforming the flow still assumes a particular distribution of uncertainties (for example, when using the logarithm of flows, the uncertainties are assumed to be a constant multiple of the flow). While this is better than the linear form of the NSE, the relative uncertainties in the high flow values are likely to be underestimated (e.g. assuming the rating curve is a power law, then the log transformed NSE assumes negligible uncertainty in the power). If the uncertainties in the inputs (including flow) are not adequately represented in the objective function/s, then the evaluation of the models performance may be biased, resulting in sub-optimal parameter sets (tracking the errors in the data rather than the catchment response), and increased uncertainty in any regionalisation scheme. This strongly suggests that all datasets need to include a realistic estimate of their uncertainty, and that this uncertainty needs to be taken into account when designing an objective function. This is particularly the case for stream gauges that do not have good control structures a common problem in parts of Australia as well as in developing countries. The uncertainties in the inputs can be included into objective functions either analytically (by modifying the functional form of the objective function) or stochastically. Analytical approaches require the distributions of the uncertainties to be well known and able to be expressed in equation form. This is likely to be only possible for observed streamflow, and even then depends on the nature of the gauge.

***Keywords:*** rainfall runoff, uncertainty, objective functions

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**HW2004** **Oral Presentation** **4597**

# Inclusion of Potential Vorticity uncertainties into hydro-meteorological chain predictions: Application to a flash-flood event over Catalonia, Spain

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In the early morning on 10 June 2000, the Catalonian region was affected by a hazardous mesoscale convective system which produced an intense rainfall episode with a large increase on flow regimes in many internal catchments of the region. The present modeling study is focussed upon the Llobregat basin, the biggest internal catchment with a drainage area of 5040 km2. The characterization of the hydrological response of this catchment to the flash-flood event was assessed in a previous study using rain-gauge data and the HEC-HMS rainfall-runoff model. In the framework of the Spanish project PRECIOSO devoted to improve the short and mid-range numerical forecasts of cyclones, an ensemble prediction system (EPS) based on perturbed initial and boundary conditions has been designed. A Potential Vorticity (PV) Inversion technique has been used to perturb the initial state and boundary forcing of the MM5 mesoscale model. MM5 has been nested in the ECMWF forecast large-scale fields in a set of 54 h simulation period simulations. In order to introduce realistic perturbations in the EPS, a previous PV error climatology has been derived. Therefore, this climatology allows introducing the perturbations on the ECMWF forecast PV fields in the appropriate error range. The derived precipitation fields have been used to drive the hydrological model in order to test the performance of the mesoscale model for the Llobregat medium-size basin. That is, the set of MM5 driven runoff simulations are compared against the stream-flow observations, thus employing the one-way coupling between the meteorological and hydrological models as a validation tool. Furthermore, the value of this ensemble strategy for obtaining suitable driven runoff forecasts can also be assessed. The results can be potentially useful to expand the lead-times associated with the prediction of similar future flash-flood episodes, helping to alleviate its possible hazardous consequences.

***Keywords:*** flash flood, uncertainties, ensembles

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**HW2004** **Oral Presentation** **4598**

# Evaluation of hydrologic models in ungauged basins using regionalized watershed response characteristics

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An important problem in hydrologic analysis is the prediction of the hydrologic response (e.g. streamflow) of ungauged locations. Typically we approach this problem by either parameterizing a hydrologic model from a priori knowledge (soil type, vegetation cover etc.) or by regionalizing model parameters in a statistical framework. In both approaches it is common to assume that no information is available to evaluate the value or credibility of the predictions at the ungauged site. Here we present a new approach in which different hydrologic response behavioral characteristics of the watershed, quantified through model independent streamflow indices, are estimated at gauged locations and subsequently regionalized in an uncertainty framework. This results in expected ranges of streamflow indices in ungauged watersheds. We will show how this regionalized information about watershed behavior can be used to evaluate model behavior, credibility and reliability at ungauged locations. A main advantage of the proposed approach is its applicability to any hydrologic model, spatially distributed as well as lumped.

***Keywords:*** evaluation, regionalization, prediction in ungauged basins

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**HW2004** **Oral Presentation** **4599**

# Model Structure Identification and Correction through Data Assimilation

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The physical laws governing water movement at small scales have been understood for decades. What we dont understand well is how to apply these physical laws to systems that are complex and heterogeneous on all scales. To date, most physically based models of hydrologic systems are based on an implicit up-scaling premise that the behavior at the model scale can be described by the small scale governing equations by spatial averaging of the state variables and by use of effective parameters. Of course, the up-scaling assumption may be wrong, and the effective large scale governing equations for a heterogeneous system may be different in form, not just different in parameters, from the equations derived from small-scale physics. We suppose that there is a conceptual model of a hydrologic system; i.e. the major processes and their interconnections have been identified. We wish to know if it is possible to construct the mathematical relationships in question (or correct them) via data assimilation, using measurements made on the system inputs and outputs. Our approach is based upon the construction of a posterior joint probability density functions for the relationships in question, in such a way that data assimilation helps to correct prior belief about the dependences. In regions where no data are available the prior knowledge dominates. The approach permits a representation of, and discrimination between, all three sources of uncertainty: initial conditions, input and structure uncertainty, and is illustrated using case studies.

***Keywords:*** uncertainty, model structure, data assimilation

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**HW2004** **Oral Presentation** **4600**

# From sensitivity analysis to uncertainty estimation quantifying process uncertainties in a new generic error model

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Many calibration techniques rely on least squares optimization or derivatives thereof although the underlying assumptions are often not fulfilled. Input errors are significant; model residuals are seldom normally distributed and are affected by heteroskedasticity as different processes are dominant at different times. Uncertainty estimation methods which do not incorporate these features can be significantly biased. Therefore, a generic error model is proposed which considers temporally variable input and processes uncertainty. It is used in calibration to normalize the model residuals and leads to more realistic uncertainty estimates than simple additive or multiplicative error models. In this error model, the uncertainty is quantified using a combined procedure. A stochastic simulation method is used for the uncertainty of discharge due to meteorological input. To quantify the effect of process representation and parameterization, a sensitivity analysis is carried out. It is assumed that the model error due to process uncertainty is proportional to the sensitivity. The final model error variance can thus be calculated from the stochastic errors and the process sensitivities. The coefficients used for the quantification are estimated simultaneously with the model parameters. The presented methodology produces a gaussian error series which is representative of the varying importance of different processes in time. It is based on a scaled composition of plausible error contributions from several uncertainty sources which represents the temporally varying importance of different processes. This uncertainty time series can be used as a weighting factor to normalize the model residuals during calibration such that the assumptions of least squares optimization are fulfilled. Calibration and uncertainty estimation are demonstrated by an example application to a distributed HBV model of three watersheds of the Neckar basin. The model residual distributions are presented and compared to a standard calibration method. Further, it is shown that the new methodology leads to more realistic confidence intervals for model simulations. Although applied to the HBV model as an example, the method is general and can be applied to any model also in conjunction with other uncertainty estimation techniques. This contribution is focussing on the assessment of the process uncertainties. Their quantification from sensitivity analysis is derived and demonstrated.

***Keywords:*** error model, sensitivity, input parameter uncertainty

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**HW2004** **Oral Presentation** **4601**

# Hydrological model inter-comparison for understanding the predictable uncertainty

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For hydrological prediction in ungauged basins, it is desired to understanding predictable uncertainty of the hydrological model. In this study, a physically based distributed hydrological model (the GBHM model) and a conceptual hydrological model (the Xinanjiang model) are applied for both long-term and short-term simulation of annual runoff and flood in several catchments located in different climate zone in China. By using a normal calibration approach (i.e., optimizing the model parameters), the results show that both models can simulate the flood well, and the distributed model has better simulation of annual runoff. But the question is how to evaluate the model predictability for application to the ungauged basins. Here we firstly simulate the uncertainty of the physical parameters related to the target catchment using Monte Carlo simulation technique. It yields the characteristic values of the physical parameter, such as mean and standard variance. Then, substituting these characteristic values of the physical parameters into the hydrological models, we obtain the predictable uncertainty of the catchment hydrological responses. Finally, by comparing the optimized (by normal calibration) parameters with the Monte Carlo simulated characteristic values, it helps us to understand the physical meaning of the model parameters and to improve the hydrological model. In addition, we also examine the spatial distribution of rainfall affects on the flood simulations. This is used for determining the appropriate catchment size for the lumped hydrological model with respect to the meteorological input.

***Keywords:*** model inter comparison, predictable uncertainty, monte carlo simulation

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**HW2004** **Oral Presentation** **4602**

# MEDUSA: MEthodology for the Definition of the Uncertainty associated to event ScenArios

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In order to quantify the uncertainty associated to flood events scenarios we need a complete toolset for the management of uncertainties at each level of the hydrometeorological forecasting chain. This toolset should eventually aim to forecast predictive cumulative distribution functions (PCDF) for peek flows. Here we present an application of the MEDUSA methodology developed in recent years at CIMA for mountainous environments and experimentally used by the Italian Civil protection Agency. The chain includes a stochastic component and is based on a sequence that links numerical weather prediction models, meteorological ensemble prediction systems, stochastic rainfall downscaling procedures and rainfall-runoff models. The most innovative application does not concentrates on single targeted prediction sates but considers the extension of results to regions with homogeneous hydrological response to extreme events, in order to strengthen the robustness of the PCDF evaluations. In this work we test the methodology on case studies in the Mediterranean area by using LAMI (Limited Area Model Italy) forecasts, the recently introduced downscaling procedure RainFARM, and the semi-distributed rainfall-runoff model DriFt. In particular we present an example of the application of the methodology to small scale mountainous basins.

***Keywords:*** hydrometeorology, flood prediction, uncertainty

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**HW2004** **Oral Presentation** **4603**

# Importance of input data quality for transfer of model parameters

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Hydro-meteorological data in mountainous regions are scarce and regionalisation of these variables is difficult because their variability in space is large. Although many studies illustrate these facts, it seems that investigations on discharge simulations for ungauged areas focus much more on model type that shall be used. It is often argued that physical models should be better for such a task because many parameters are measurable. But, this is only partly true and many parameters must still be calibrated so that some other authors consider physically and conceptual hydrological models to be equivalent. The discussion, either physical or conceptual models are better for modelling discharge in ungauged catchments is still going on but only few investigation focus on the role of hydro-meteorological data quality for such simulations. It is the goal of this study to analyse this role when models are used in catchments without calibration. In this work a conceptual model is used because five catchments under investigation located in East-Styria Austria are very similar on the one hand in morphology, and topographic conditions, on the other hand in geological, soil and land use structures. Thus it can be expected that calibrated parameters should not vary that much from one hydrological unit to the other. The model is based on a linear reservoir approach and belongs to lumped model family. However rainfall as well as air temperature are distributed using an altitudinal gradient. The total area covers 569km whereas the largest catchment covers 159km (Gosdorf), the smallest 78km (Gerbersdorf). Input data from 13 rainfall and temperature stations are exploited and regionalised using simple Thiessen Polygon method. All stations present similar annual sums during calibration period (mean annual precipitation 1998-2002: 703  843mm). In a first step the model has been calibrated separately for three gauged unit using an auto-calibration tool incorporated in the model. In a second step each set of calibrated parameters has been transferred without modification to the other two gauged catchments. Finally, the three parameter sets have been transferred without modification to the two ungauged catchment areas (Gosdorf, Unterpurkla) and a quantification of differences on daily discharge was accomplished. Results confirm the quality of hydro-meteorological data playing a fundamental role when simulating discharge in ungauged areas. First, it cannot be expected to obtain good simulations if input data needed in the model dont represent natural process variability in space. Second, and certainly more importantly, a good set of hydro-meteorological data permits a good model calibration and therefore a good simulation of natural hydrological processes so that runoff generation dynamic is now captured by the model structure and the model parameters. Such a model performs reasonably well when transferred to ungauged areas.

***Keywords:*** hydrometeorological data, conceptual modelling, ungauged catchments

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**HW2004** **Oral Presentation** **4604**

# Uncertainty assessment of a hydrometeorological ensemble forecasting chain coupling a precipitation downscaling model and a distributed hydrological model

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Ensemble forecasting is a well-established technique that allows the uncertainty due to initial conditions and processes not fully explained by the models to be taken into account and evaluated, by hypothesizing that observations are equally likely members of ensemble forecasts (i.e. consistency hypothesis). In this study we quantify the propagation of uncertainty of the ensemble output provided by a hydrometeorological forecasting chain that couples a space-time multifractal model for precipitation downscaling and a fully-distributed hydrological model known as the TIN-based Real-time Integrated Basin Simulator (tRIBS). Our approach relies on downscaling a coarse precipitation product, such as a satellite observation or a meteorological model output, for which no uncertainty is assumed, by generating an ensemble of precipitation fields at high resolution. These synthetic fields are used to force the distributed hydrological model for flood prediction. The precipitation data used to calibrate the multifractal downscaling model have been collected by the NEXRAD radar network in the Arkansas-Red River Basin for the 1997-2003 summer months, while the target watershed is Baron Fork basin (808 km2) in Oklahoma. We develop a procedure based on the Verification Rank Histogram to test the consistency of the ensemble downscaling products with respect to the correspondent observed precipitation fields and to detect the presence of errors in the ensemble mean and spread. We then apply scalar and non-scalar metrics for the verification of the ensembles of synthetic hourly hydrographs, in order to evaluate forecast reliability, resolution, sharpness and bias. To conclude, we summarize how ensemble forecast metrics can be used to quantify propagation of uncertainty from downscaled precipitation products to distributed flood forecasts.

***Keywords:*** ensemble forecasting, downscaling models, distributed models

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**HW2004** **Oral Presentation** **4605**

# Dynamic Multi-Criteria Evaluation of Conceptual Hydrological Models

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Accurate and reliable simulation of river streamflows is crucial for successful management of water resources and for dealing with the consequences of hydrological extremes such as floods and droughts. Conceptual rainfallrunoff models like the HBV approach nowadays are the most popular in rainfall-runoff modeling. However, the calibration and evaluation of such approaches is often oversimplified by the use of a single performance criterion. This research aims to find novel ways of model calibration and uncertainty assessment by identifying periods of similar hydrological conditions and customizing the evaluation within each of these identified periods using multiple criteria. A combination of traditional criteria and a novel criterion that focuses on the shape of the hydrograph was used. Since the use of a single performance measure signifies a loss of information, the Pareto front that represents equally viable model realizations in terms of multiple criteria can be identified using a multi-criteria algorithm (e.g., NSGA-II). However, not every Pareto solution is equally viable at a certain point in time in the simulation period. This leads to a dynamic view on model evaluation, calibration and parameter identifiability. The goal of this research therefore is to divide the simulation period according to various hydrological conditions and to find appropriate combinations of criteria for each of the periods. The identification of periods of similar hydrological conditions is done by using clustering algorithms (e.g., Self-Organizing Map, Fuzzy C-means algorithm). The results show that the classification algorithms define categories that reflect hydrological process understanding: dry/wet conditions, rising/falling hydrograph limbs, precipitation-driven/non-driven periods, etc. The calibration results of the HBV model show that a dynamic, multi-criteria approach is able to find appropriate solutions, and to give a more realistic assessment of model parameter uncertainty. Moreover, the differences between parameter values and state variables between the various periods are quantitative indicators of model structural shortcomings.

***Keywords:*** calibration, hydrology, simulation

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2004** **Oral Presentation** **4606**

# Effect of Radar-Rainfall Uncertainties on Simulation of Different Runoff Processes

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Recently, it became possible to have spatial and temporal resolution of rainfall measurement as well as their areal coverage using remote sensing. Next Generation Weather Radar (NEXRAD) system is one of the remote sensing techniques. However, rainfall estimations from radar measurements are subject to uncertainties caused by both instrumental effects and lack of unique relation between radar rainfall estimations and the surface rainfall quantities. The interaction between uncertainties and errors of radar-rainfall estimations lead us to study and analyze the effect of these uncertainties on the hydrologic models and the flood prediction process. Issac Verot is an experimental watershed in Lafayette, Louisiana, which has a network of rain gauges and there is the NEXRAD Radar site at Lake Charles.This study is based on hydrological model GSSHA (Gridded Surface Subsurface Hydrologic Analysis). The model is physically based distributed model which has been used successfully in Hortonian and non-Hortonian watersheds. The model will be calibrated using the rain gauges rainfall data and the runoff estimation results will be compared to runoff estimations simulated using radars rainfall estimations. Using some statistical assessment, an evaluation to know to what extent we can relay on the radar-rainfall estimations will be conducted.

***Keywords:*** rainfall, remote sensing, hydrological modeling

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**HW2004** **Oral Presentation** **4607**

# Analyzing hydrological model performance in the wavelet spectral domain

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Observed hydrological processes result from the joint action of different hydro-meteorological processes, the dominance of which varies through time. This interplay can be supposed to be imprinted in the temporal evolution of the frequency content of observed processes such as discharge. Quantifying how well a simulated time series reproduces this temporal evolution is, therefore, an essential step to judge whether the behavior of a hydrological model is really equivalent to the behavior of the observed natural system a prerequisite to make good hydrological predictions. Wavelet spectra have enough discriminant power to distinguish between apparently very similar time series; based on these results we believe that wavelet spectral analysis has the potential to help to detect process or measurement error induced differences between time series that cannot be seen in the original data. Ultimately, this could enable us to develop new model diagnosis tools that capture and explain the similarity (or dissimilarity) of observed and simulated time series and to assess the value of different observed system input time series.

***Keywords:*** continuous wavelet transform, model calibration, hydrological modelling

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**HW2004** **Oral Presentation** **4608**

# A simulation based approach for mitigating parameter bias in hydrological models due to uncertainty in inputs

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The uncertainty in hydrological model inputs, if ignored, introduces systematic bias in the parameters estimated. We introduce here a method to determine the true value of parameters given uncertainty in model inputs. This method, known as SIMulation EXtrapolation (SIMEX) operates on the basis of an empirical relationship between parameters and the level of input noise (or uncertainty). The method starts by generating a series of alternate model inputs by artificially adding white noise in increasing multiples of the known error variance. The resulting parameter sets allow us to formulate an empirical relationship between their values and the level of noise present. SIMEX is based on theory that the trend in alternate parameters can be extrapolated back to the notional error free zone.We illustrate the utility of SIMEX using a synthetic rainfall-runoff time series where rainfall uncertainty is multiplicative and temporally invariant. We further test the strength of SIMEX in improving skills of predictive models that use uncertain distributed sea surface temperature anomalies (SSTA) as predictors. Our hypothesis is that the higher magnitude of noise in the pre-1960 data period introduces bias to model parameters where SSTA is the input variable. The relatively error invariant Southern Oscillation Index (SOI) is regressed over SSTA and calibrated using a subset of the series from 1900 to 1960. We validate the resulting models using the less erroneous 1960 to 2003 data period. Overall the application of SIMEX is found to reduce the residual predictive errors during the validation period.

***Keywords:*** input uncertainty, parameter bias, simex

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**HW2004** **Oral Presentation** **4609**

# Modelling the ungauged catchment - how far can we go with limited streamflow measurements and soft data?

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The long-standing issue of hydrological predictions for ungauged basins has received increased attention thanks to the PUB imitative. Given all the problems on making predictions in totally ungauged catchments one might argue that the best thing to do in an ungauged basin is to actually take a few runoff measurements. In this study we explored how implementing such a procedure might support predictions in an ungauged basin. We used the well-studied Maimai watershed as a hypothetical ungauged basin where we pretend to start with no runoff data and add different sub-sets of the available data to constrain a simple catchment model. These sub-sets were single runoff events or a limited number of point values; in other words these data represent what could be measured with limited efforts in an ungauged basin. Besides these runoff data we used different types of soft data to constrain the model. We recently presented 'soft data' as a general framework to facilitate communication between experimentalist and modeler for new ways to test models and quantify uncertainty, parameter identifiabilty and parameter uncertainty. The model simulations were then validated using the available runoff data from different years. We found that surprisingly little runoff data was necessary to derive model parameterizations which provided good results for the validation periods, especially when these runoff data were combined with soft data. We argue that the improved dialog between experimentalist and modeler may be a necessary next step within the PUB movement for moving from calibration-reliant models to ones grounded in understanding and applicability to ungauged basins.

***Keywords:*** pub, streamflow, soft data

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**HW2004** **Oral Presentation** **4610**

# Introduction of ancillary information to filter out non-physical parameter sets under equi-finality

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An efficient technique to narrow down the range of reliable parameter sets is to utilize ancillary information that imposes physical constraints on the calibrated model parameters. In this study, we illustrate an example of equi-finality in a physically-based distributed hydrological model; then propose a new reduction methodology of parameter uncertainty, which is physically based sorting procedure (post-calibration process) using additional useful information to filter out non-physical parameter sets among the plausible ones. An adopted auxiliary physical constraint is set by a spatiotemporal-recorded matrix (Sayama et al., 2007) which enables to trace spatiotemporal aspects of runoff variation in distributed grid cells. The tracer method makes it possible to analyze internal behaviors of a distributed hydrologic model used here. The method is used to understand the model structure and reject erroneous parameter sets. An example is demonstrated to narrow down the range of reliable parameter sets in distributed rainfall-runoff modeling. T. Sayama, K. Tatsumi, Y. Tachikawa and K. Takara, Journal of Japan Society of Hydrology & Water Resourses, in press (2007).

***Keywords:*** distributed hydrologic model, equi finality, parameter uncertainty

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**HW2004** **Oral Presentation** **4611**

# On the use of comparative evaluations of competing models to investigate the uncertainties arising from model structure errors

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Different procedures for model evaluation and the quantification of prediction uncertainties have been developed in recent years. The abilities of these methods to discriminate the effects of different sources of uncertainty are very limited. The imperfect model representation arising from incompatibilities between the structures represented by the model and the structures present in the hydrological system introduces a degree of uncertainty to the model predictions, which is difficult to quantify. Needless to say, the detection of structural inadequacies and the estimation of the uncertainty conditioned on them would be helpful to improve model structures. Detailed observations concerning the runoff generating processes could be used to identify the failures in a model structure. Unfortunately, this information is only available for small scale field study sites. Considering this there has been an augmented discussion in the past years of model inter-comparisons as a less data-intensive approach to evaluate model uncertainties.This contribution presents the comparative evaluation of competing models to investigate the uncertainties arising from model structure errors. The different model structures investigated were implemented following the well-known HBV concept. The variants differ in terms of spatial discretization, vertical model structure (number of runoff components) and process descriptions. The basic idea of this comparative model evaluation is that a model structure, that is compatible with the hydrological functioning of a landscape will allow less uncertain predictions than non-appropriate model structures. In the latter case the parameter values have to compensate the structural model error, which is reflected in a higher parameter uncertainty. The General Likelihood Uncertainty Estimation (GLUE) method, along with a multi-objective parameter identifiability analysis (based on objective functions conditioned on different sections of the flow range) was used for model evaluation. The study has been carried out within a mesoscale catchment located in Mid-East Germany. Important results concerning the relationship of structural errors and parameter uncertainty have been found: i) parameter uncertainties, i.e. poor parameter identifiability, are conditioned on failures in the model structure (e.g. inadequate spatial averaging, over-simplified process descriptions) ii) advancement of the discretization scheme led to a better identifiability of parameters related to discrimination of runoff components as well as their routing iii) interactions between different process models reveal that errors in the description of one process can lead to an uncertain parameterisation of another process model and iv) the analysis of the multi-dimensional objective space confirmed the assumption that a model structure, which is supposed to exhibit less structural inadequacies, offers a stronger potential to meet all objectives simultaneously with the same parameter, set, i.e. the distance between the optimum values is less.

***Keywords:*** prediction, uncertainty, evaluation

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**HW2004** **Oral Presentation** **4612**

# A stochastical Approach to assess the Reliability of Parameter Calibration in a complex, heavily stressed multi-Aquifer System

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***Phatsaratsak Arlai***

Effective assessment of reasonable calibrated aquifer parameters can be mainly divided into three categories; firstly, the conventional analysis of the misfit-error between observed and calculated heads, secondly, the calculation of sensitivity- and correlation coefficients and, finally, the pure stochastical approach applying well-known formulae of stochastic groundwater flow theory (cf. Gelhar, 1993 ). As part of an exhaustive numerical study of flow and solute transport processes in the heavily stressed coastal Bangkok multi-aquifer system (Arlai, 2007)we have employed these three approaches during the initial calibration process. In the present contribution we focus on the third, the stochastical calibration approach to set bounds on the uncertainties of the calibrated aquifers transmissivity field (the model space), given the uncertainties in the observed heads (the data space) and explain the source of non-zero model residuals. For that purpose, stochastic realizations of a transmissivity field Y=lnT of different variances σY2 and correlation lengths λx, λy are generated for the aquifer system and its responses on the head data is simulated in a series of Monte-Carlo (MC) simulations using a standard 3D groundwater flow model. We then investigate how σY2 contributes to the variance σH2 of the head and/or the residual head and are able to verify some predictions of analytical stochastic groundwater flow theory and show, namely, that it is a fruitless exercise in a groundwater calibration job to attempt to overfit the observed response data (the hydraulic heads). We then extend the study to include further uncertainties in the observed model parameters, such as the pumping rates of this heavily stressed aquifer system. The results of the MC simulations show that pumping plays a smaller but still significant role for the estimation of the residual model error, as the residual head variances obtained from stochastic pumping are lower than those obtained from the stochastic transmissivity field .References:Arlai, P., Numerical Modeling of possible Saltwater Intrusion Mechanisms in theMultiple-Layer Coastal Aquifer System of the Gulf of Thailand, Ph.D. Thesis, University of Kassel, Germany, 2007.Gelhar, L.W., Stochastic Subsurface Hydrology, Prentice Hall, Englewood Cliffs, NJ, 1993.

***Keywords:*** aquifer calibration, stochastic theory, monte carlo simulations

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**HW2004** **Oral Presentation** **4613**

# USe of geostatistical methods to assess the impact of rainfall estimation uncertainties on flood hydrograph simulations with rainfall-runoff models

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The efficiency of flood forecasts on small watersheds appears to be limited, in particular by the accuracy of Rainfall-Runoff (RR) simulations. In fact, many flood forecasting services do not consider hydrological models to be reliable enough for use in a real-time operational context. Many authors suggest that the uncertainties associated with spatial rainfall estimation are probably one of the major factors limiting the accuracy of the RR simulations. Most of the previous studies on the assessment of the impact of rainfall estimation uncertainties consisted of propagating into RR models either empirical rainfall estimation errors (obtained through under-samplings of rain gauges in an existing network) or purely theoretical errors (use of un-calibrated rainfall error models). The originality here is the proposal of a rainfall estimation error model calibrated on observed rainfall data. The proposed model is composed of two components: (i) an error model for the hourly point and mean areal rainfall estimates based on geostatistics (kriging), (ii) an autoregressive model to account for the temporal dependence of the estimation errors. The proposed approach is developed and applied to a given case study: the application of lumped conceptual RR models for the simulation of the floods in eleven watersheds exposed to flash floods, located in the upper Loire region (France) with areas ranging from 20 to 3230 km2. First, the proposed error model and results of its validation will be presented. A cross-validation procedure has been used: the statistical distributions of empirical spatial interpolation errors and modelled interpolation errors have been compared for various rain gages of the network and various rainfall durations. Second, Monte Carlo simulations have been used to generate corrupted rainfall scenarii which were propagated into two lumped hydrological models (TOPMODEL and GR4). The obtained results confirm the major impact of the areal rainfall estimation uncertainties on RR simulation results despite a relatively dense hourly rain gage network (1/80 km2 on average over the region). For the smallest watersheds the observed discharges generally lie in the uncertainty range of the simulated discharges: i.e. the rainfall estimation errors alone can explain the differences between simulated and observed discharges. This is not the case for the largest tested watershed, where the spatial pattern of the rainfall events appears to play an important role and the use of at least semi-distributed RR models seems to be necessary. In any case, the awareness of the uncertainty level associated to any RR simulation, which probably will remain non-negligible even if the rainfall observation networks and techniques are improved, should lead to the use of ensemble simulations rather than the standard deterministic RR simulations. The proposed procedure can be used to produce such ensemble simulations.

***Keywords:*** kriging, rainfall, uncertainties

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**HW2004** **Oral Presentation** **4614**

# Predictive probability assessment in hydrological modelling using empirical likelihood based Bayesian inference

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Predictive probability assessment in hydrological modelling and forecasting is still an open problem. While several attempts have been made to overcome the problems generated by the complex nature and structure of the various types of errors (model, parameters, observations, boundary conditions) embedded in hydrological forecasts, only recently the problem has been thoroughly tackled due to its implication in the decision process. Beven and Binley, (1992) suggested a procedure (GLUE), which was supposed to overcome these problems, while, unfortunately it was shown (Mantovan and Todini, 2006) that GLUE is not capable of efficiently extracting information from the observations. Moreover, the definition of predictive uncertainty in GLUE does not correspond to the widely accepted definition of predictive uncertainty (de Finetti, 1975). In particular, Krzysztofowicz (1999) clarified the difference between predictive probability, defined as the uncertainty of a true, albeit unknown quantity of interest (such as the water stage or discharge), conditional to the model forecast, as opposed to the model forecast uncertainty, which, unfortunately, is commonly used by hydrologists to represent it instead. Following the work of Krzysztofowicz (1999), this paper introduces an empirical likelihood based Bayesian approach to the predictive uncertainty assessment. It is in fact possible to transform both observations and model predictions into a space where their marginal distributions are Normal, and the distribution of errors can be effectively approximated by a multi-Normal distribution, by means of the Normal Quantile Transform. This allows to apply the formal Bayesian inferential approach without the need of making strong assumptions on the probability distribution of errors. In this approach, starting from a uniform prior on the model parameters, via Montecarlo sampling of parameters, one is able to obtain a posterior parameter density which is finally used to marginalise the parameter uncertainty from the predictive probability. Results are given for a simple test based on the a,b,c model (Fiering, 1967, Mantovan and Todini, 2006) and for a real world case based on a complex hydrological model (TOPKAPI) applied to real world catchments. The results of the approach will be shown in terms of reduction of predictive uncertainty with respect to the use of a parameter prior and in terms of consistency of predictive bounds opposed to what is produced by GLUE.

***Keywords:*** uncertainty, bayesian

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**HW2004** **Oral Presentation** **4615**

# A multi-scale hydrological experiment: insights into processes, data errors and model uncertainty

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A 12km2 catchment and a 1.3km2 catchmentin Wales, UK, have been instrumented as part of the UK Flood Risk Management Research Consortium, beginning in August 2004. The instrumentation includes 14 flow gauges, 4 tipping-bucket rainfall gauges, 93 tensiometers, and 1 weather station, all logging data at 15 minute intervals or less, plus additional time-series data on interception, soil mositure and groundwater levels. Spatial data include a soil survey, topography, land-cover and use, subsurface drainage, and a ditch network survey. Additional information about hydrological responses and land use was provided by farmers and other stakeholders.The objectives of the research are to: 1) understand the rainfall-runoff response in the catchments, especially flood response and its links to land management; 2) develop a set of models for predicting effects of change including evaluation of uncertainty. These objectives are pursued at each of three scales: the plot scale, field scale and small catchment scale. Upscaling techniques are being developed which assimilate the small-scale information into the field and then catchment models. The intensity of instrumentation, together with the significant stakeholder contribution and the close involement of modellers in the design and updating of the field programme and data quality control, make this a novel modelling experiment, presenting a unique opportunity to take better information from hydrological data.The field program and modelling methodology will be described, including examples of how the interactions between farmers, field experimentalists and modellers have allowed a fuller appreciation of the source and nature of data and model errors. A sample time-series of data and model results are used to demonstrateinsights gained, model uncertainty andthe challenge of predicting change.

***Keywords:*** experiment, land use, upscale

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**HW2004** **Oral Presentation** **4616**

# Evaluation of Hydrologic Model Uncertainty from Diverse Perspectives: Beauty is in the Eye of the Beholder

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How good is a hydrologic model? How accurate or uncertain are hydrologic model predictions? As modelers, we have a suite of traditional and innovative methods for evaluating model structure, parameterization, initialization, and forcing. However, hydrologic models are often ultimately applied for purposes other than scientific research, and by users without advanced scientific or statistical training. Consideration of the panoply of hydrologic model applications reveals the need for an expanded array of metrics for evaluating hydrologic models, their performance, and impacts of their application. While these user-centric evaluation metrics may not comprise the standards for hydrologic model development, they do constitute standards for acceptance by real-world decision makers. Further, probabilistic predictions pose complex challenges of interpretation and evaluation. Different concepts of uncertainty and accuracy are illustrated using seasonal climate predictions from the National Weather Service (NWS) Climate Prediction Center and ensemble streamflow predictions generated using NWS River Forecast Center procedures. For example, using the criteria of discrimination, predictions of seasonal streamflow volumes for Colorado River tributaries are shown to convey useable information, not revealed by other criteria, even with lead-times of several months. Some evaluation approaches are clearly inappropriate for probabilistic predictions, particularly application of traditional metrics of model performance used for deterministic predictions of continuous variables, to mean or median values of an ensemble distribution. Evaluation of operational probabilistic hydrologic predictions requires archiving different, and significantly more, information than for traditional deterministic predictions. In addition, presentation of prediction uncertainty to decision makers requires new product formats. User-centric tools (e.g., http://fet.hwr.arizona.edu/Forecast EvaluationTool/) for self-directed learning, customized evaluation of predictions, and placing predictions in context with supporting information offer a practical pathway for meeting the needs of diverse decision makers in deciding whether hydrologic models and predictions are'good' enough.

***Keywords:*** prediction, uncertainty, validation

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**HW2004** **Oral Presentation** **4617**

# Regionalisation of hydrological models via flow characteristics

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Regionalisation of hydrological models is a key methodology for estimating hydrological behaviour in ungauged catchments. Models are typically calibrated to multiple gauged sites and the variance in the resultant identified parameters is then related to physical characteristics of the gauged catchments. Previous studies have indicated that about 40% of the variance in model parameters can be explained using such approaches representing significant uncertainty associated with implementing such schemes. In this study, a novel approach at regionalization is demonstrated. Regionalisation relations are first found between flow characteristics of the gauged catchments and their physical properties. Using a GLUE approach, uncertain model realizations are then conditioned on the derived regionalized relationships. A key advantage of the approach is that the scheme is developed with respect to the modeling objective directly (i.e. the flow behaviour itself). This negates the need to specify a particular hydrological model which may be inappropriate for the catchments or may be overparameterised with the consequence of calibrated parameters of dubious relevance. An additional benefit is that uncertainty estimates are generated providing meaningful estimates in ungauged basins. It is shown that the developed approach performs well in application to eastern Australian catchments.

***Keywords:*** regionalisation, hydrological models, uncertainty

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**HW2004** **Poster presentation** **4618**

# Identification of equifinality zones of behavioral parameter sets of hydrological models using the fuzzy c-means clustering

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In assessing the parameter uncertainty of hydrological models, the Markov Chain Monte Carlo (MCMC) methods have become very popular as they are able to infer the implicit and very complex posterior joint probability distribution of the model parameters through controlled random sampling. In order to reveal the hidden structure of the posterior joint probability distribution of the model parameters, the fuzzy c-means clustering technique is suggested for use in identifying equifinality zones of the behavioral parameter sets. In this paper, a behavioral parameter set is defined as a set of parameter values such that the corresponding model objective function value or model efficiency value is greater than or equal to a selected threshold. The corresponding equifinality zone is then defined as a compact and well-separated space consisting only of the behavioral parameter sets. The proposed identification method comprises three main steps. Firstly, the Shuffled Complex Evolution Metropolis-University of Amsterdam/Arizona (SCEM-UA) sampler is chosen to generate the sequences of parameter set samples that approximately converge to the posterior joint probability distribution of the model parameters. Then, the behavioral parameter sets are selected from the parameter sample in accordance with the selected threshold of the models objective function value or efficiency requirement. Finally, the fuzzy c-means (FCM) clustering method is used to identify the number of the equifinality zones of the behavioral parameter sets and their domains. It is shown from case studies that the proposed framework is very effective in revealing the intrinsic structure of the posterior joint probability distribution of the model parameters as well as the major topological features of the response surface. In particular, it leads to a better understanding of the equifinality phenomenon encountered by hydrologists in hydrological modeling.

***Keywords:*** uncertainty analysis, hydrological models, fuzzy c means clustering

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**HW2004** **Poster presentation** **4619**

# Recharge effects on environmental tracer concentrations in the subsurface

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Environmental tracers are isotopic and chemical compounds which have been increasingly used in hydrological sciences to investigate the water cycle. Early studies in the '80s demonstrated the potential of environmental tracers' also in groundwater investigations. Dissolved in the water or being part of the water molecule, these tracers are present in the groundwater body, allowing the hydro-geologist to gain information about water movement in the subsurface (groundwater age, travel times, streamline information, ratio of fluxes and recharge rates). Compared to artificial tracer tests over short time scales, transient environmental tracers were released into the atmosphere since the early '50s, providing a tool to investigate the groundwater flow and transport over time scales from 0 to 50 years. Following a study from Cook and Solomon (1995), the presence of a thick unsaturated zone (>10m) above an aquifer is crucial to the fate of the tracers in the subsurface. The time-delay and the hydrodynamic dispersion occurring in the vadose zone significantly modify the tracer concentrations in time and in depth. For any meaningful modelling of tracer transport in the subsurface, these effects have to be properly accounted for deep groundwater tables. We present a case study for the environmental tracers 3H, 3He and 85Kr in a small catchment in Northern Switzerland , near Baltenswil. The site is chosen as test site for our environmental tracer modelling and sampling since it is hydro-geologically well known with well defined boundary conditions. The measured 3H, 3He and 85Kr concentrations during the years 2003-2005 in this aquifer system show significant variations on a seasonal timescale without an apparent trend. We investigate the transport of the tracers 3H, 3He (decay product of 3H), 85Kr in the unsaturated zone by means of a numerical solution to the vertical advection-dispersion equation. We use this solution to calculate a correct tracer input at the groundwater table. The groundwater flow model is assessed by means of Stochastic Inverse Modelling Technique in a transient regime. A number of equally likely realizations of the Transmissivity field, made conditional to both measured transmissivity and time-dependent heads, are generated. Selected transmissivity realizations are then used as input to deterministic transport model. The calculated tracer concentrations at observation locations show variations in time of the same magnitude of the measured ones, the fluctuations in concentrations being ruled by the amount of water which recharges the aquifer. We found a positive correlation between recharge and tracer concentrations in the groundwater, also detected by an extensive sampling campaign in the field. The chosen approach allows the modeller to gain insight into the subsurface transport mechanisms of environmental tracers, with a special attention to the impact of the unsaturated zone, and to combine hydraulic analysis with information coming from tracer data for an improved groundwater flow modelling. A combination of several tracers makes their application to groundwater investigations more reliable. The used stochastic approach has the considerable advantage of naturally including the quantification of uncertainty in the model predictions.

***Keywords:*** groundwater, environmental tracers, unsaturated zone

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**HW2004** **Poster presentation** **4620**

# Flood Risk Prediction in a Watershed by Using Statistical Models

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By occurrence of climate change phenomenon and increasing of human s interference on global climate, two natural disasters such as drought and flood have effected on different parts of the earth. In the recent years, our country was alternatively witness in occurring of floods and sever droughts in most of places, specially twice occurring of these natural disasters, improve each other as because of severe droughts, vegetative coverage and humidity of soil are spoiled that is facilitation agent for flowing destructive floods. On the other hand, occuring of severe floods have caused destroyed of agricultural lands and lynching fertile soils and has amplified the effective of drought in these places. In a watershed which has high submergible potential, with a alternative and correct management, we can reduce the effects and damages of flood and use of it for increasing of water potential in this place, for example increasing of soil moisture and discharging of aquifer and increasing of water resources of lake of dams. For succession in these actions, an alternative and optimum flood risk management in that watershed is neccessary. Kardeh watershed is located near of Mashhad, and it is considered as a case study. The risk of flown floods in this basin is modulated with three flowing types of statistical models: 1) probability Distribution Function, 2) Linear Regressive Model, 3) Auto Regressive Independent moving Average (ARIMA) Models. According the results of models testing, Probability Distribution Function couldnt be able to model the floods risk in basin. Regressive Model doesnt offer acceptable responses because it obeys from one general trend. ARIMA Time Series Models are tested in difference stages and finally, ARIMA (1,2,3) Model offer the best statistical fitness. According the conclusion from this research, by using of three statistical models, we can get a fit model for flood risk management for (Kardeh) basin, that It is usable into practical and conclusion of this research is expansible and usable for the other similar watershed basin.

***Keywords:*** flood risk management, statistical models, time series

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**HW2004** **Poster presentation** **4621**

# Estimation of saturated hydraulic conductivities in a large tank experiment by modelling of different pedotransfer functions

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Saturated hydraulic conductivity (Ks) is one of the key parameters for groundwater flow and transport models, but frequently an accurate reconstruction of Ks spatial variability is constrained by the cost and the time required. For this reason many studies address this topic via simple expressions, based on pedologic properties, to estimate Ks values. So far, none or few of these studies compared pedotransfer functions through groundwater flow modelling: for this reason we implement different scenarios to simulate different Ks distributions derived from the application of 8 pedotransfer functions on 70 samples collected on a semi-regular spaced grid from a large tank [8*4*1.4 m] filled with heterogeneous soil. The grain size distribution of the samples was intensively characterized via sedimentological analysis and the out coming Ks values were interpolated using Kriging approach. The resulting krigged fields were used as input values in a MODFLOW2000 numerical model. Outputs of every scenario are robust as boundary conditions can be finely tuned and controlled in a laboratory tank, excluding variable recharge rate and unsteady state flow typical of field conditions. But, comparing simulated piezometric heads distributions from different scenarios against observed ones, we find out that only the scenario using the Ks distribution derived from the Breyer (1967) pedotransfer function was validated providing a useful tool for prediction. So we conclude that for the class of fine heterogeneous soils considered in this experiment the Breyer (1967) pedotransfer function is the most suitable.

***Keywords:*** grain size, hydraulic conductivity, modelling

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**HW2004** **Poster presentation** **4622**

# Application and Parameters Sensitivity Analysis of BTOPMC Model in Small Catchment

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Distributed hydrological models have become the main tool which studies the hydrology natural law and solves the hydrology practice question, especially the ones that physically based. The block-wise use of the TOPMODEL with the MuskingumCunge routing method (BTOPMC) is a physically based distributed hydrological model developed for large river basins and has already been applied to many basins. It is a mixed model based on subdividing the entire basin into sub-basins (lumped) that consist of a number of grid cells (distributed) and consists of topographic sub-model, runoff generation sub-model, flow routing sub-model and parameter identification component. It can simulate river runoff using a stream network extracted from a digital elevation map (DEM) by an automatic stream network generation method and the resultant topographic indices in sloping land where stream network is uniquely formed and the topography is the main factor controlling flow generation as well as routing. In this study BTOPMC model will be used in a small catchment to investigate the model performance. Also investigated is the extent to which the model parameters are sensitivity to model output. Nowadays, estimation of parameters value is a bottleneck in operational applications of almost all distributed hydrological models. So, parameters sensitivity analysis is important and necessary in understanding the relative importance of parameters to the variation of runoff and calibrating. Sensitivity curve method is a simple but practical way of sensitivity analysis. It calculate and plot the relative changes of an input variable against the resultant relative change of the output variables as a curve, the corresponding relative change of the outcome can easily be read from the sensitivity curve for a certain relative change of the variable. This method has been used by many authors. Due to the high non-linear nature of hydrological models the simple sensitivity curve method is used in this study. The Huangnizhuang catchment with the area of 805 km2 is selected for this study which lies in Shiguan River Basin, the first-order southern tributary of the Huaihe River. A 8-year historical dataset of daily precipitation and discharge, monthly time series data of CRU TS2.1 climatic variables, DEM, IGBP land cover classification and NOAA-AVHRR NDVI etc. over the Huangnizhaung catchment was used in the analysis. Using the SCE-UA algorithm to automatic optimize model parameter values. Model performance is evaluated by the Nash-Sutcliffe Efficiency and the volume ratio of simulated to observed discharges. The application indicates that the model works successfully. And last, some model parameters that significantly affect model output are identified.

***Keywords:*** sensitivity, btopmc, parameters

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**HW2004** **Poster presentation** **4623**

# Evaluation of a conceptual rainfall-runoff model with automatic calibration approach

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A variety of conceptual rainfall-runoff (CRR) models used to simulate the internal subprocesses of watersheds and to provide on-line forecast of riverflows have been developed. The various subprocesses involved are represented by parametric functions known to reasonably describe the underlying physical systems. These functions require watershed-specific parameters, thus calibration (i.e. automatic optimization of an objective function) may be the most critical stage of the overall modeling process. The success of an automatic calibration procedure is highly dependent on the choice of the objective function and the nature (quantity and quality) of the data used. Reports in the literature indicate that it is typically difficult, if not impossible, to obtain unique optimal values for their parameters using automatic calibration methods. Sensitivity analysis of the models parameters to factors such as input and output data error, model error, quantity and quality of data, objective function used, etc., is not simple, leading to uncertainties on the forecast capability of the models. For this reason, the automatic calibration approach has been criticized by several specialists in the past. In this paper we deal with the uncertainties related to hydrologic model calibration. The paper first reviews the essential concepts of the mono-objective global optimization method SCE-UA (Shuffled Complex Evolution University of Arizona) and then presents the results of several experimental studies in which the IPH2 hydrologic model (seven parameters) commonly used for flood forecasting, was calibrated using several objective functions. The results show how different objective functions lead to different parameter sets. We later examine the shape of the response surfaces of the tested objective functions in the vicinity of each global minimum. Comparisons of the parameter set associated to the global minimum to those parameter sets corresponding to the local minimum points show that not always the former group provides more realistic results. We argue that part of the models unrealistic response can be explained by the input and/or output data error. The arguments are illustrated using results obtained from the San Antonio river basin (340 km2) located in the Province of Cordoba (Argentina). This basin is famous for violent floods that have produced many losses of human lives. Finally, we propose a calibration technique in which the automatic calibration is coupled to a user conceptual participation.

***Keywords:*** automatic calibration, objective function, runoff forecasting

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**HW2004** **Poster presentation** **4624**

# Evapotranspiration: Using a feedback approach to estimate the surface resistance term for vegetated surfaces.

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Correctly describing the evapotranspiration process is an important requirement in hydrological modeling; the evaporative process plays a major role in the partitioning of both energy and water at the surface. Most hydrological (and meteorological) modeling systems use a form of the Penman (1948) equation as the basis for describing the evaporative process. The Penman equation was developed for saturated surfaces; however, while consistent with the principles of conservation of energy and aerodynamic relationships, it does not adequately describe the evaporation (and transpiration) which occurs from vegetation whose surface is not saturated. Monteith (1965) first extended the Penman equation to the unsaturated case by introducing the concept of a stomatal or surface resistance, rs. The resultant Penman-Monteith equation is applied in most hydrological and climatological models to this date. Obtaining appropriate estimates of the surface resistance term remains a practical problem. Most predictive applications incorporate estimates of the resistance term that are based on laboratory-derived relationships between leaf water potential and parameters such as soil moisture, vegetation type (leaf area), humidity, temperature and response to solar radiation. Using direct evapotranspiration measurements obtained over a variety of natural vegetated surfaces, it is shown that the current formulations do not correctly represent the diurnal variation for the surface resistance, rs. Whereas in the laboratory it may have been possible to isolate the effects of air temperature, humidity and solar radiation on rs, in nature these effects are neither independent nor additive. The magnitude of the resultant errors in evapotranspiration estimates is demonstrated. An evapotranspiration model presented by Granger and Gray (1989) can be used to obtain further insight into the behavior of the resistance term. The method, which is also an extension of the Penman equation to the non-saturated case, characterizes the evaporation from a non-saturated surface using the ratio of the actual evaporation to the evaporation rate that would occur if the surface were saturated at the same temperature. Using a feed- back relationship, this relative evaporation, G, is related to the dimensionless relative drying power, D, which is a function of the air temperature, humidity and radiation. There is an analytical relationship between the surface resistance, rs, and the relative evaporation, G; the nature of this relationship is developed and demonstrated. Thus the surface resistance, rs, can be obtained from standard meteorological observations, through its relationship G.

***Keywords:*** eavapotranspiration, surface resistance, modelling

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**HW2004** **Poster presentation** **4625**

# Simulation error in groundwater models with rectangular and non rectangular discretization

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The error of groundwater numerical models depends on the boundary conditions, the hydraulic conditions of the aquifer, the geometry of the flow field, the parameterization used to describe the heterogeneity of hydraulic field, the distribution and quality of the measurements and the discretization resolution. In this study we focus on the dependence of the error to the type and resolution of the spatial discretization. Using a two-dimensional stochastic model with a hypothetical aquifer, we produced a synthetic field of 100x100 hydraulic conductivities and we used a finite differences model (MODFLOW) to obtain synthetic fields of hydraulic head. Hereupon we used 4 grids (100x100, 50x50, 20x20, 12x12) and a simple parameterization (6 zones of homogeneous conductivity), common for all grids, along with a parameter estimation algorithm based on a modified Gauss-Newton method. Moreover we used 3dkflow, a model based on finite volumes method with simplified integration that uses a non rectangular sparse discretization (43 cells) in conjunction with the Shuffled Complex Evolution optimization algorithm. In the latter model every cell had a unique conductivity resulting in 43 conductivity parameters. Finally we compared the accuracy of the simulation of the 4 rectangular grids and the sparse non rectangular discretization to investigate the deviation of estimated parameters from the true conductivities and the deviation of simulated hydraulic head from the true synthetic field. We concluded that to keep the model error low a reliable parameterization along with a rectangular grid of high resolution should be used. Alternatively a sparse non rectangular spatial discretization with a unique parameter for each cell can keep the error small and is more advantageous in the applications that require simulation speed.

***Keywords:*** numerical models error, non rectangular discretizat

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# Sensitivity analysis of rainfall uncertainties in rainfall runoff models in Weida catchment, Germany

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The objective of this paper is to assess the sensitivity (variability) in prediction of stream flow solely due to the errors (uncertainty) in rainfall data estimation. This study attempts to isolate this source of variability in the prediction from other uncertainty sources (i.e. model and model parameter). There are detailed measurement error studies on German precipitation standard gauging stations in the Weisse Elster catchment (HarmoniRib Data report). While these measurement errors were not fully considered in previous rainfall runoff modeling studies, these measurement errors of the gauging equipments and the quality assessment of each gauge station (e.g. influenced by degree of site sheltered) are implicitly considered to assess the effects on predicted stream flow. The headwater basin (Weida) in north-eastern Germany is used as study basin. The estimated input rainfall data includes errors in measurement and their spatial interpolations. The rainfall time series are prepared by using: a) measured data (two inside rain gauges and three gauges are outside of the catchment), b) corrected data (measured data plus the errors due to wind, wetting and evaporation), and c) spatially interpolated data from a) and b) (using inverse distance method). These estimated rainfall data are applied to two selected rainfall runoff models to assess the effects on predicted stream flow of input uncertainty: The PDM model is a type of lumped conceptual model, which uses averaged rainfall data over whole catchments. The WaSim model in this study is a fully distributed model (with 100m * 100m grid resolution), which is able to represent spatial rainfall distribution. All simulations of the stream flows are examined in Multi-objective schemes, such as high/low flow regime, and rising/decreasing flow regime in the hydrograph. Furthermore, the soil moisture states in the catchments of dry/wet year are considered for detailed model performances. Using WaSim with spatially interpolated rainfall data provides the best results and performs significantly better than the PDM model, especially for predicting high flows. In general, the simulations for high flow regimes are underestimated or miss their flow peaks especially in the summer of a dry year. This could be due to spatial difference in catchment state; as large soil moisture deficit is distributed unevenly in the catchment and these are dominant in hydrological processes especially in a dry year. The ensemble of all simulated stream flows provides an indication of the effects of rainfall input uncertainty, although this frequently fails to encompass flow peaks.

***Keywords:*** inpit uncertainty, rainfall runoff model

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**HW2004** **Poster presentation** **4627**

# Gravimetric 3D modelling and observation of time-dependent gravity variations to improve small-scale hydrological modelling.

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Hydrological variations and their underlying processes increasingly became a focus of scientific interest in the last years. On the one hand they represent a significant, broadband disturbance in geodynamic observations, particularly in recordings with superconducting gravimeters. They must be eliminated to detect small geodynamic signals like core modes or coseismic changes. On the other hand the distribution of water as well as its temporal and spatial variation is an essential factor in many processes. The parameters necessary for a water balance like precipitation, water table, evaporation and soil moisture are measured pointwise. Gravity observations, in particular areal gravity measurements, contain integrated information about hydrological mass shifts in the subsoil, for instance groundwater movement. Thus information is also won about areas, in which hydrological measurements are not or hardly possible. Hence, the gravity data can be a valuable supplement to meteorological and hydrological observations. They can help to improve the understanding of hydrological processes and can act as boundary condition in the parameterisation and validation of hydrological models. Investigations were carried out exemplarily for the surrounding of the Geodynamic Observatory Moxa, Germany, which is situated in a small headwater catchment in hilly topography. At Moxa significant hydrologically caused gravity variations are observed, e.g. in the data of the superconducting gravimeter in an order of magnitude of some ten nm/s. The observatory is well suited for the geophysical and hydrological investigations, because its noise level is one of the lowest worldwide, numerous environmental and hydrological parameters are observed and the subsoil is geologically well known. In addition to the recordings with a superconducting gravimeter, hydrologically induced gravity variations are significantly proved by repeated measurements with field gravimeters, with standard deviations of about 10 nm/s. To understand the gravity variations and to evaluate hydrological models, a gravimetric 3D model of the observatory surrounding was developed based on the free-air anomaly. Hydrologically induced gravity variations are caused by the movement of water masses which is associated with density variations in the subsoil. These density variations are simulated numerically by changing the densities of the bodies in the gravimetric 3D model. The applied density variations result from hydrological measurements and hydrological modelling. Thus hydrologically caused gravity variations are modelled in a complex geological context. The resulting gravity effect is compared to the results of the repeated gravity measurements as well as to the observations with the superconducting gravimeter. It turned out that in particular a steep slope next to the superconducting gravimeter has a crucial influence on the gravimeter recordings and on the hydrology of the area. By modification of the input of the gravimetric model it is shown, in which areas and with which amplitude hydrological variations ought to appear in order to explain the observed gravity variations. From the results of the modelling indications can be derived, in which areas and in what way the hydrological model should be modified. Therefore, gravity observations and gravimetric 3D modelling can be a good supplement in the evaluation of hydrological models.

***Keywords:*** gravity observations, gravimetric modelling, hydrological modelling

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**HW2004** **Poster presentation** **4628**

# Internal evaluation of TOPBAL, a TOPMODEL version developed for an improved simulation of the water balance of diverse vegetation types.

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***Jrme Latron, Rafael Poyatos, Carles Rubio, Javier Garca-Pintado, Aleksandra Muzylo***

TOPBAL has been developed within the semi-distributed structure of TOPMODEL to simulate the response of catchments with diverse vegetation types and high climatic seasonality. For these purposes an evapotranspiration subroutine allows the presence of several types of vegetation cover, distributed in patches, controlling the local soil water balance but not the overall shape of the water table. It explicitly considers rainfall interception by vegetation and two-way exchanges between the root-unsaturated store and the phreatic store. This version was tested and compared with the classical TOPMODEL using the GLUE methodology in the Can Vila small catchment (Vallcebre research area, NE Spain). Results indicate that for similar efficiency, TOPBAL improved the simulation of recession curves and provided a better simulation of water balance along the studied period than TOPMODEL. But, as a consequence of the two-way exchanges, TOPBAL parameters showed a large interdependence when constrained only on discharge. Discrete observations on semi-distributed soil moisture and depth to the water table, as well as evapotranspiration fluxes were used to evaluate and revise the model.

***Keywords:*** topmodel, water balance, internal evaluation

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**HW2004** **Poster presentation** **4629**

# Simulation on ungauged catchments based on upstream/downstream discharges assimilation within lumped model

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This paper introduces a novel approach to assimilate in a simple way the information provided by upstream or downstream flow measurements to simulate discharges on ungauged catchments. The simulations are based on a combination of a simple routing model to propagate an upstream or downstream hydrograph from a gauged site towards an ungauged location and a lumped rainfall-runoff model to generate the runoff on the intermediary basin between the two sites. This technique is an original alternative to the regionalisation of models parameters and permits to exploit efficiently the information provided by nearby gauged time-series. This approach is applied on a large set of 126 French catchments. For each site considered as ungauged, several upstream/downstream gauged sites are selected, the combined model is then applied and results are compared with the real observed data.

***Keywords:*** ungauged catchments, rainfall runoff modeling

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**HW2004** **Poster presentation** **4630**

# Using Sequential Self-Calibration Method to Integrate Tracer Test Data to Refine Hydraulic Conductivity Field

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***Bill X. Hu***

A three-dimensional gradient-based inverse method the Sequential Self-Calibrated method (SSC)is developed to update the hydraulic conductivity field generated by Geostatistical simulation methods. The SSC method can honor permeability measurements and also tracer test data, which is an important type of dynamic data related to the heterogeneity of permeability. By creating a synthetic aquifer and also hypothetic Packer test and tracer test, the present study demonstrates that by using the combination of SSC method and Geostatistical conditional simulation, the conductivity field can be inversed more efficiently and accurately than by the Geostatistical method only. The RMSE of the mean of SSC updated realizations is smaller than that of the Geostatistical realizations; after updating by SSC, the variance of breakthrough curves decreased drastically, and the mean of breakthrough curves matches the reference breakthrough curves. Consequently, the uncertainty of the SSC inversed hydraulic conductivity field is significantly reduced.

***Keywords:*** tracer test, sequential self calibration, uncertainty

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**HW2004** **Poster presentation** **4631**

# Rainfall-runoff model for flood forecasting in the catchment of The river Gambie, upstream Kedoudou: application of GR3J and GR4J

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***Malanda Nimy Edmond Nicaise, Mahe Gil***

Climate variability have occured in West and Central Africa, since the 1968s years with decreasing of rainfall. But during the last years, in 1999, 2003, and particularly 2005, we have experienced in Senegal severe events, resulting in impeting flooding in the Gambie river catchment upstream Kedougou. Modelling rainfall runoff process is one of the only way to prevent people from damages of these flooding In this paper we look for hydrological rainfall - runoff model for flood forecasting. According to quantity and reliability of the available inputs, we have selected conceptual global models: among these we have chosen the daily GR3J. and GR4J models of CEMAGREF. These models have few parameters, three for the first, four the second. As inputs, they need the area of the catchment, rainfall and potential evapotranspiration and as outputs runoff at the outlet of the catchment. Parameters are estimated and optimized using Nash criterion on a calibration sample and tested on the validation sample. Application of these two models is made on the catchment of Gambie river, upstream of gauge station of Kdougou. Hydrological models always generate errors. In our case, we try to explain these errors through the models structures: production function and transfert function. These two functions have to been modified and adapted to the river catchment we model. Another source of errors comes from the inputs. We have then tried to model the errors with a first order autoregressive process and alter the inputs before using them in the model.

***Keywords:*** rainfall runoff models, flood forecasting, gambie river catchment

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**HW2004** **Poster presentation** **4632**

# Comparative analysis between two automatic calibration algorithms aplied to a conceptual lumped model: Metropolis Montecarlo and SCE-UA

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***Facundo Alonso***

As is well know the hydrologic models represent a very important tool in engineering studies. However, in the developing countries the lack of hydrologic data frequently attempts against the success of the tasks of calibration and verification. As a consequence, its results are associated to a high level of uncertainties. In other hands, when an appropriated quantity of hydrological data is available, the lack of knowledge about the use of techniques of global optimization to adjust the parameters of the hydrologic models affects the results. As initial contributions to improve this scenario in Argentina, in this paper are revised the essential concepts of two mono-objective global optimization methods: the SCE-UA (Shuffled Complex Evolution University of Arizona) and the Metropolis-Montecarlo algorithms. Then, the results of some experimental studies in which the brazilian IPH2 hydrologic conceptual lumped model was calibrated by the both methods using different objective functions are presented. Finally, some conclusions respect to the advantages and disadvantages associated to their respective use are extracted.

***Keywords:*** automatic calibration, metropolis montecarlo, sce ua

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**HW2004** **Poster presentation** **4633**

# Online parameter update for conceptual rainfall-runoff models using data-driven systems

***Mr. Alireza Nazemi***

***Andrew H. Chan, Xin Yao***

All conceptual rainfall-runoff models contain number of free parameters that should be calibrated regarding to the observation. It has been proven that in most of the cases the model optimal parameters are changing during the low and high periods as well as quick and slow segments of the hydrograph. In this study, it has been tried to adjust models parameters regarding to each period of prediction. First the model is calibrated regarding to each segment of the hydrograph and corresponding optimal values are assigned by Shuffled Complex Evolution Metropolis (SCEM) algorithm. Then a data-driven system predicts the next state of the hydrograph based on the previous observations. Regarding to the predicted state the corresponding optimal values regarding to the state is feed to the conceptual model and the models output is calculated. Three different data-driven paradigms, i.e., feedforward neural networks, ANFIS neuro-fuzzy systems and genetic fuzzy systems are used to perform this update. The paper reports the performance of the resulted system and compares its efficiency with single and multi-objective calibrations.

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**HW2004** **Poster presentation** **4634**

# Comparison between MOSCEM and NSGA-II for multi-objective calibration of conceptual rainfall-runoff models

***Mr. Alireza Nazemi***

***X. Yao, Andrew. H. Chan***

There are several evidences proving that calibration of conceptual rainfall-runoff models, in many cases, is inherently multi-objective rather than single objective. In this study, the performances of two well known multi-objective algorithms in this context, i.e., MOSCEM and NSGA-II are compared together. In order to have an insight about the effect of internal parameters of each algorithm on the quality of calibration, several configurations of each algorithm have been applied for calibration of a conceptual model in Leaf River Basin. Then the best configurations of each algorithm are compared together in terms of objective function convergence, speed of convergence, parametric convergence, diversity of solutions, and robustness. Finally it is tried to address the results in another conceptual model as well as different catchments.

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**HW2004** **Poster presentation** **4635**

# GIS based distributed rainfall - runoff modeling of ungauged basins

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***Dr. N.V. Umamahesh***

Traditionally, assessment of productivity of land took priority over all other aspect of evaluating land use performance. Presently, the effects of land use on the quality of the environment and environmental sustainability of production system have become the major issues. In hills, the terrain conditions aggravate erosion-induced land degradation. Judicious allocation of available resources for sustainable production requires mapping, prioritization and monitoring the areas based on their susceptibility to degradation. Remote sensing and Geographical Information Systems (GIS) are effective tools for inventory, monitoring and management of spatially distributed resources. This is a case study of 358.307 km2 ungauged catchment near Station Ghanpur in Warangal district of Andhra Pradesh of South India. It includes development of distributed hydrologic models for runoff prediction and automation of process of hydrologic models. A procedure is developed to use the topographic analysis tools available within the ARC/Info GRID package. The procedure applies on elevations from the Digital Elevation Model (DEM) to obtain slope and in turn travel times useful in prediction of overland and sheet flow. Multi-spectral IRS 1D LISS III data acquired on June 2000 is used for preparation of the land use/land cover map. The catchment is classified into six land use classes; forest, agriculture, scrub, barren rocky, water bodies and settlement. Using U.S. soil conservation services (1972) curve number method, Nash model linked with GIS is used to predict the runoff potential of each delineated hydrological unit on grid-based analysis using ARC/INFO GIS. A GIS based procedure is developed to estimate time of concentration (Tc) and Instantaneous Unit Hydrograph (IUH) at user selected outlets.

***Keywords:*** gis, ungauged, iuh

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**HW2004** **Poster presentation** **4636**

# Instantaneous rainfall stream flow models for two Welsh catchments: is the concept more widely applicable?

***Dr. Ian Littlewood***
*IAHS*

For many decades in the UK, a triangular, 1-parameter, instantaneous unit hydrograph (IUH) has been central to systematic estimation of flood hydrographs from rainfall in ungauged (flow) basins, e.g. for engineering design hydrology. In this approach, a unit hydrograph (UH) parameter (its time-to-peak Tp the peak and basewidth of the triangle are constrained to be simple functions of Tp) is estimated from discrete time-step data for gauged basins and normalised to become essentially time-step-independent (i.e. giving Tp* for an IUH). Then, a statistical link between Tp* and catchment properties is established, e.g. by regression, to facilitate estimation of synthetic IUHs for ungauged basins. To estimate a hydrograph in an ungauged basin, Tp* is un-normalised to Tp corresponding to the time-step of the available rainfall data; placed after (in series with) a suitable loss module, this IUH is used to estimate a flood hydrograph from rainfall. The procedure acknowledges that (a) Tp varies with the data time-step used for model calibration and (b) statistical relationships between time-to-peak and catchment properties are likely to be better for Tp* than Tp. The paper investigates whether this time-independent-parameter approach can be applied using an established rainfallstreamflow model that allows continuous simulation of streamflow (not just flood hydrographs). This possibility appears to have been overlooked in many rainfallstreamflow model parameter regionalisation studies, and may provide a route towards reducing the typically large uncertainty in flows estimated for ungauged basins. For two catchments in Wales (10.6 km2 and 298 km2) a simple, spatially lumped, unit-hydrograph-based, rainfallstreamflow model is calibrated using 1-, 2-, 4-, 6-, 12- and 24-hourly data, over given periods of record for each catchment. For each basin, the model parameters change substantially over the range of modelling time-steps applied, e.g. by 50% or more. Furthermore, when plotted against the data time-step used for model calibration, each of the five model parameters for the smaller basin (a Plynlimon research catchment) describes a smooth curve that, at a time-step of 1 hour, reaches or approaches an asymptote. The asymptotes define the parameters of an instantaneous rainfallstreamflow (IRS) model. Results for the larger basin (a national network catchment) are not so well-behaved but nevertheless allow essentially time-independent model parameters (six for this basin) to be identified. It is argued that IRS models could be an important step in making progress with reducing uncertainty in rainfallstreamflow model parameter regionalisation schemes. To investigate this further it is proposed that, as a contribution to the PUB Decade by the Top-Down modelling Working Group (TDWG), other models and modelling techniques are similarly applied to the two catchments, and to many other basins.

***Keywords:*** unit hydrographs, rainfall streamflow models, uncertainty

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**HW2004** **Poster presentation** **4637**

# Modeling of nitrogen dynamics in soils of glacial and post glacial origins using numerical approach: Model development, Field Calibration and Model Prediction

***Mr. Jean Jolicoeur***
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A study was conducted in the Catatonk Creek watershed, in the headwaters of the Susquehanna River, Tioga County, NY, in order to determine the vulnerability of the valley-fill aquifers and the Catatonk Creek to nitrate contamination. The overall goal of this research was to evaluate nitrate transport and the retention mechanisms for different combination of soil of glacial and post glacial origins and agricultural land uses within the Catatonk watershed. In order to address the objectives, a combination of field data of hydrologic and chemical parameters (rainfall, infiltration, subsurface water movement) and nitrate transformation and migration in the shallow subsurface has lead to the development of a numerical model that can be adapted to use as a tool for predicting the long-term effect of fertilizer application as a source of nitrate loading to the underlying aquifer. The nitrogen module of the Leaching Estimation and Chemistry Model (LEACHM) was used to simulate nitrate distribution in the root zone. LEACHM was calibrated hydraulically and chemically using input parameters from a wet year (2004) and a dry year (2005). The calibration involved adjusting parameters describing the hydraulic properties of the soil layers such as the Campbells constant a, the Campbell exponent b, the saturated hydraulic conductivity and the nitrogen transformation rates such as mineralization, nitrification, and denitrification rates until the predicted soil moisture and soil moisture nitrate during the crop growing season of 2004 and 2005 match the observed ones on selected days. It was found that seasonal field weather condition displays a typical pattern of hysteresis associated with the wet (2004) and dry (2005) year on the watershed soils of glacial or post glacial origin. This paper recommends calibrate the model for the wet and the dry year separately using distinct moisture retention characteristics for each year and resulted in satisfactory predictions of soil moisture and soil nitrate when tested against 2004 and 2005 field data. The results indicate that it was necessary to hydraulically calibrate the model based on field data from each year separately in order to warrant good model hydraulic calibration. Furthermore results also indicate that the ratio of nitrate leached to the nitrate applied on the surface during the simulation periods is greater during a dry year than a wet year due to greater nitrate accumulation in the soil because of reduced crop update during the dry season.

***Keywords:*** watershed, modeling, nitrate

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**HW2004** **Poster presentation** **4638**

# Improving the Assessment of the Potential for Groundwater Contamination Using an Analytical Risk Factor Model

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***Martin M. Kaufman, Kent S. Murray***

To maintain a sustainable urban environment, a thorough understanding of soil and groundwater contaminant vulnerability and surface water interaction is crucial because of chemical and physical interactions that greatly affect the migration and persistence of contaminants released into the environment. An analytical risk model of contaminant transport across a region of varied soil types was developed to quantify potential impacts to soil, groundwater, and surface water quality resulting from urbanization within the Rouge River Watershed in southeastern Michigan, USA. The model developed combined the properties of toxicity, mobility, and persistence for specific contaminants with physical and chemical properties of soil and groundwater. The results indicate that chlorinated volatile organic compounds and hexavalent chromium have the highest risk factors for groundwater. Geographic Information System analysis also suggests there is an increased probability of transport of these contaminants into the Great Lakes due to the fluvial geomorphology of the watershed, which exhibits the highest surface water drainage density within its zones of sandy soil. This creates the potential for ecological and public health concerns at broad geographic regions because of the hydraulic connection between groundwater and surface water within the Rouge River Watershed.

***Keywords:*** groundwater, contaminant, risk assessment

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**HW2004** **Poster presentation** **4639**

# The application of self-adaptive artificial neural network in channel flood forecasting

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*IAHS IAHS IAHS*

***Xiang Zhang, Liping Zhang***

Because of the uncertainty and nonlinearity existing in the movement of streamflow, the traditional dynamic methods for channel streamflow routing are seldom used in channel flood forecasting, especially in the channel with the influence of branch between the stream sectors. In this paper, artificial neural networks model trained by self-adapt back-propagation(S-BP) algorithm is applied to build the complicated relationships between the inflow at the upstream sector and the outflow at the downstream sector, and the influence of the inflow of the branches between the two sectors is also considered. The self-adaptive back-propagation(S-BP) algorithm can avoid the phenomena of local optimum that often happens during the training of artificial neural networks and increase the training speed by using the momentum term and the self-adaptive learning rate. This model is used for the channel flood forecasting between the upstream sector, Luoshan, and the downstream, Hankou, at Yangtze River in China. Between Luoshan and Hankou, the inflow from the branches Hanjiang and Lushui is considered as the auxiliary input variables to improve the performance of the model. The results indicate that the suggested model can represent the impaction of inflow from branches on the discharge process of Hankou, and the accuracy of 4-day leading forecasting is satisfactory and better than the traditional BP networls.

***Keywords:*** self adaptive, artificial neural network, channel flood forecasting

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**HW2004** **Poster presentation** **4640**

# Derivation of unit hydrograph model considering spatial-temporal variation of rainfall by using artificial neural network

***Dr. Xiang Zhang***
*IAHS IAHS IAHS*

***Jun Xia, Wenhua Zhang, Xiaoni Wang***

For decades, the impactions of watershed morphologic and topographic structure and spatial-temporal variation of rainfall on unit hydrograph (UH) has been the key questions in the study of watershed flow routing. In this paper, a new method is proposed to derive UH considering the spatial-temporal variation of rainfall. The method is termed as S-curve based approach. S-curve is the cumulative curve of UH. A non-linear function with two parameters was used to fit the S-curve. The two parameters are found to be related with the barycenter of storm and the intensity of rainfall that represent the spatial-temporal variation. In order to build the relationship between the parameters of the S-curve function and the barycenter of storm graph and the intensity of rainfall, artificial neural networks are applied considering the underlying nonlinear relation among them. So the unit hydrograph with changing position of storm barycenter and intensity of rainfall can be derived by using this method, which has the characteristics of Sherman unit hydrograph and also consider the temporal-spatial variation of rainfall. A case study in Juhe catchment located in Yantze basin, China, shows that the suggested method is effective.

***Keywords:*** unit hydrograph, spatial temporal variation, artificial neural network

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**HW2004** **Poster presentation** **4641**

# Inter-comparison of calibration techniques for HBV hydrological model

***Mr. Nejc Pogacnik***

***Kay Suelj, Mira Kobold, Mojca Sunik, Janez Polajnar***

Three different calibration techniques: downhill simplex, scuffled complex algorithm and particle swarm optimization were used to calibrate the soil routine of the conceptual HBV rainfall-runoff model, which was developed by Swedish Meteorological and Hydrological Institute. The HBV model was calibrated on hourly time step in the upper catchment of Savinja river, with the basin area of about 460 km2. The catchment of Savinja river is mountainous and its discharge is characterized by frequent flash floods which are caused by intensive precipitation. The optimization techniques were used to find such sets of model parameters that the simulated discharge is as close as possible to the measured one. The Nash-Sutcliff criterion was used to estimate how close the time series of the measured and simulated discharge are. The optimization techniques were compared as if they are able to find the best parameters as well as the number of model runs they require before they converge.

***Keywords:*** optimization, rainfall runoff model, particle swarm optimization

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**HW2004** **Poster presentation** **4642**

# The Propagation of uncertainties in input data and model structure for estimation of minimum environmental flow with the wetted perimeter method

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*IAHS*

The wetted perimeter (WP) method/model is used to analyze the propagation of uncertainties in input data and model structure through the model to output prediction uncertainties of minimum environmental flow (EF). In WP, it is assumed that the discharge corresponding to the critical point with the maximum curvature on the relationship curve between wetted perimeter P and discharge Q is the minimum EF required by river ecosystem to maintain its ecological function. The considerations are made on the uncertainty in model structure (by using different types of power law function of the curve) and model input (by using three different scaling schemes to standardize the input variable, i.e., P and Q). It is shown that three different scaling schemes bring different solutions of EF. The solution of minimum EF based on original variables is independent of the data series (maximum wetted perimeter) and only related with channel geometries. The solution of minimum EF based on scaled variables is related with both input data series and channel geometries. This hints it seems that the solution based on scaling variables is more reasonable than that based on original variables as different rivers with different wetted perimeter-discharge relationship should have different values of minimum EF. However, the scaling schemes should be used in caution as they may bring very different results. For example, the maximum difference of minimum EF relative to Maximum scheme and Z-score scheme by summation scheme reaches 44%. When focusing on the structure of power law function, it is also shown that models with different structures produce different solution of minimum EF.

***Keywords:*** uncertainty, wetted perimeter method, environmental flow

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**HW2004** **Poster presentation** **4643**

# Modeling the partitioning of rainfall at land surfaces and identifying the model parameters

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The partitioning of rainfall into surface interception, surface runoff, and direct deep percolation was incorporated into the two-layer BBH (bucket with a bottom hole) model of soil hydrology (Iwanaga et al., 2005; Kobayashi et al., 2007) by introducing two additional parameters. If cumulative gross rainfall during a period is designated by Pr (mm), cumulative surface interception plus surface runoff is expressed asΨPr and direct deep percolation asΦPr for the same period. Although surface interception and surface runoff cannot be separated in this model, one is generally much smaller than the other and is negligible. For example, if rainfall is heavy, surface interception should be insignificant, while if rainfall is light, surface runoff should be negligible. These two model parameters can be obtained from the water balance terms of the two-layer BBH model. Water balance equations of the first layer (sub 1) with thickness D1 and the second layer (sub 2) with thickness D2 are as follows: W1(t+1)-W1(t)=Pr(t)-E1(t)-Gd1(t)-Rs(t) W2(t+1)-W2(t)=Gd1(t)-E2(t)-Gd2(t) where t indicates the day, and Wi(t) = daily mean amount of soil water contained in the ith layer (mm), Pr (t) = daily gross precipitation (mm/d), Ei(t) = daily evaporation from the ith layer (mm/d), Gdi(t) = daily internal flux expressing gravitational drainage plus capillary rise at the bottom of the ith layer (mm/d), and Rs(t) = daily surface runoff (mm/d)(i = 1,2). These water balance terms except for Pr can be obtained using the parameterization proposed by Kobayashi et al. (2001). Two parameters Ψ and Φ are determined for a period of half a month or longer using the estimates of the cumulative BBH water balance terms (mm) during the period. Their estimates for a cornfield (3853 m) in the Yellow River basin (D1 = 40 cm, D2 = 60 cm) were obtained for periods of half a month or longer as follows (Kobayashi et al., 2007): Ψ = Rs / Pr Φ = (E1 + E2 + Rs ET) / Pr where ET is the cumulative actual evapotranspiration during the period (mm). These relations were obtained based on a few assumptions, such as no surface runoff, which were realized in the cornfield. The results obtained by applying this model to the cornfield for two years will be given in the presentation. References: Kobayashi et al., IAHS Publication no. 270, 41-45 (2001) Iwanaga et al., J. Japan, Soc. Hydrol. & Water Resour. 18, 664-674 (2005) Kobayashi et al., J. Agric. Meteorol. 63, 1-10 (2007).

***Keywords:*** soil hydrology model, rainfall partitioning, cornfield

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**HW2004** **Poster presentation** **4644**

# Approche quantitative de calcul du deficit d'ecoulement dans le bassin hydrographique du Cotier-Cheliffzahrez en Algerie du Nord. Bnina Touaibia, Martin-Rosales Wenceslao & Gallego Juan M Gisbert . Laboratoire dHydrologie. ENSH. Blida. Algerie

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***Martin-Rosales Wenceslao, Gallego Juan M Gisbert***

A chaque fois que nous dcidions de faire un dimensionnement dun ouvrage hydrotechnique sur des petits bassins versants, nous nous heurtons labsence de la donne hydromtrique. La ncessit de construction des hydrogrammes de crues diffrentes priodes de retour nous oblige recourir des formules empiriques souvent tablies dans des conditions non similaires aux conditions algriennes ou des mthode utilisant au moins la prcipitation maximale journalire. La mthode de lhydrogramme synthtique appele aussi mthode des isochrones permet de construire les hydrogrammes de crues diffrences frquences. Son application ncessite trois paramtres importants : i. lexposant climatique issu dune tude des pluies de courtes dures, ii. la prcipitation maximale journalire, iii. et le dficit dcoulement. Si les deux premiers paramtres sont plus ou moins connus, le troisime pose problme. Cest dans ce contexte que ce travail est conu. Une approche de calcul simple du dficit dcoulement est propose, base sur le bilan hydrologique et la gostatistique, pour llaboration dune carte susceptible daider les dcideurs dans leur prise de dcision. Notre choix exprimental a port sur le bassin hydrographique du Ctier-Cheliff-Zarez, drainant une surface de plus de 55000 Km.

***Keywords:*** dficit dcoulement, cheliff

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**HW2004** **Poster presentation** **4645**

# Improvement to optimize the parameters of hydrologic tank model

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***Rudiyanto***

The hydrologic tank model is a simple lumped-model and commonly used to study rainfall, evapo-transparation and run-off relation whether during a rainfall event along periods of time. This model can be applied in a basin scale or even in a plot of a paddy field, and explains the presences of water surfaces, and water inflow to and outflow from the underlying reservoirs (tanks). This article describes another attempt to develop an effective and interactive tool to optimize the tank models parameters. Herewith, we replaced the discrete function with a continuous step function to calculate the outflows, introduced multi-optional objective error functions for error minimization process such as mean average error, root mean squared error, etc., and developed a procedure to approximate initial conditions of water level in each tank. The computer programs were developed using spreadsheet, visual basic editor and the solver in Microsoft Excel. All input and output data are placed in the spreadsheet and can be easily presented in any types of the available charts. The model was then used to find the parameters for Indonesian watersheds, and most of them resulted in better correlation coefficients between measured and observed discharges which were more than 0.8, and produced reasonable water level and water flow conditions in each reservoir.

***Keywords:*** hydrologic tank model, parameter optimization, indonesian watersheds

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**HW2004** **Poster presentation** **4646**

# Routing uncertainty of Muskingum-Cunge method and discretization on cell channel segment and time step in large river basin modeling

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By neglecting inertial terms, the full Saint Venant equations reduce to the diffusion wave equation. Since the Muskingum-Cunge (M-C) method is conceptually simple, easy to code and efficient to compute, it has been used extensively to approximate the diffusion wave equation and to solve the river routing problems. However, the hydrological behavior in a large basin is heterogeneous and scale-dependent. Furthermore, the schematic river channels are heavily used in the grid-based distributed hydrological models. The negative and/or inaccurate output cannot be avoided in the M-C method for every grid cell at every time step within available computation resources. Based on the accuracy criteria of M-C method, this paper applied the M-C method to basin runoff routing by further discretizing the cell channel segment and the simulation time step to adapt to the cell flow regime. This discretization on spatial and temporal steps is top-limited by a maximum number so that, one way, the problems of water loss and water creation can be mitigated and they generally compensate each other for a period over the upper drainage areas of the sites under consideration, and another way, the computation resources are allowable. The application on the daily simulation of Mekong River basin (drainage area: 805,600 km2) with 0.05 degree grid resolution (about 6 km) shows that, by selecting an appropriate maximum discretization on the spatial and temporal steps, the proposed adaptive M-C method can improve the routing output well. For example, when the maximum discretization on the spatial and temporal steps takes 6 times 6, compared to the case without further discretization (i.e. 1 times 1), the parameter values are calibrated in a more reasonable range. During model validation in 1988-1992, the cell local routing error (without accumulating upper basin) on the water creation reduces from 0.575% to 0.041% of the inflow water averaged over the basin, the accumulated upper basin routing error on the water creation at Pakse (drainage area: 578,160 km2) reduces from 2.6% to 0.5% of the total runoff, and the occurring frequency of cell negative routing output also reduces considerably. The Nash-Sutcliffe efficiency increased from 81.9% to 89.5%, averaged at Vientiane, Mukdahan and Pakse.

***Keywords:*** muskingum cunge, adaptive, mekong river

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**HW2004** **Poster presentation** **4647**

# Improvement of input data quality and reduction of parameters uncertainties in low flow modelling

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***Gille Emmanuel, Francois Didier***

The quality of model simulations depends both on data input quality and on the model parameter values. The main objective of this study is to reduce these two types of uncertainties. In this work a daily conceptual model is used in order to simulate and predict low flow discharges for 60 stations located in the East of France. The area covers 32320 km whereas the smallest basin covers 39 km and the largest 10700 km. First we have to focus on the role of the hydro-meteorological data quality in the model simulations. Among the input data, the rainfall has the most important influence in simulations. Thus the rainfall which evolves from 750 to 2200mm has been spatializated by a geostatistical method with a relief parametrisation. This method can only be applied for the monthly step. Thus a particular method based on the results of the monthly spatializated rainfall has been developed to calculate the daily spatializated rainfall. The quality of data discharges is also fundamental to validate the model. We show in this study the uncertainty associated to extreme values measurements especially for the lowest discharges. Several methods are used to evaluate and if necessary, to correct possible errors. The second uncertainty is associated to the model parameter values. To reduce it, the main parameters are pre-determinated by a previous hydrological analysis, in particular a recession analysis. Furthermore the model calibration follows a particular device which has really proved its efficiency in the reduction of parameter values uncertainties notably linked to equifinality problems. This approach permits with an accurate knowledge of rainfall to obtain satisfactory simulation in ungauged basins. Indeed parameters from basins with similar physical conditions are introduced in the model to adjust parameters for ungauged basins.

***Keywords:*** low flow prediction, input data uncertainties, parameters equifinality

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**HW2004** **Poster presentation** **4648**

# Bayesian Kriging and remote sensing applied to soil moisture mapping

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***Eric D. Soulis, Nicholas Kouwen***

Soil moisture plays a significant role in hydrological simulation, both for model initialization and in later time steps to control and to correct model performance. This work uses active microwave image to detect the soil moisture variability that occurs at the surface layer within a watershed. In particular, the spatial distribution of digital image data in a scene provided by remote sensing technology is addressed through a geostatistical framework using bayesian kriging methodology. More specifically, this paper explores the geostatistical approach applied to an approximately flat bare field located at Oxford County in the Big Otter Creek watershed, Ontario, Canada, which was exhaustively sampled for collecting a soil moisture ground-truth data set on October 14, 1992. Also added to the analysis is the ERS-1 SAR image collected on the same date. Firs, the intention is to examine the spatial variability in the ground-truth data set and the spatial variability in the image for the selected field. Second, the analysis investigates the possible relationship between the underlying physical phenomenon of soil moisture distribution and how it relates to or translates into the SAR image. The last section of the paper examine the feasibility of using a geostatistical methodology, such as bayesian kriging, for estimation of volumetric soil moisture at the field level. The Bayesian kriging results were compared to the regression approach for estimating average soil moisture and soil moisture distribution in the bare field analyzed. The results show improvements built upon regression models at the field scale. Finally, although the particular geostatistical method used in this research work might fulfill the needs of effectively deriving soil moisture maps at field scales and at watershed scales, much more work is still necessary for applications regarding rainfall-runoff models.

***Keywords:*** soil moisture, bayesian kriging, remote sensing

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**HW2004** **Poster presentation** **4649**

# Uncertainty in discharge data and hydraulic modelling within flood forecast chains.

***Prof. Giorgio Boni***
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***Elena Bertolotto, Luca Ferraris, Lauro Rossi, Cosimo Versace***

Usually, in flood forecast as well as in hydraulic modelling, forecasted peek flows are transformed into water levels in a deterministic way. Uncertainties in these relations are not usually taken into account. When forecasted or modelled values are used in the decision process for the emission of alerts or in the process of urban planning in flood prone areas, this can induce into the decision maker the false perception that levels below the critical level are deterministically safe. Missed alerts and higher risk exposure than expected are among the consequences of this deterministic approach. This study introduces a new probabilistic methodology which makes possible a quantitative evaluation of uncertainty in hydraulic computation for mountain catchments with relevant sediment transport. The methodology is based on the perturbations of those parameters which rule sediment transport and affect hydraulic behaviour. Ensemble simulations have been performed with different configurations of parameters generated from a variation of the original set, according to their probability distribution through a multivariate Monte Carlo method. An application of this methodology in the Alps Regions and its utilization within a flood prediction chain are presented here.

***Keywords:*** hydraulic modelling, sediment transport, mountainous catchments

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**HW2004** **Poster presentation** **4650**

# Uncertainty and Complexity in a Snow Hydrology Model

***Dr. Andrew Slater***
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***Martyn Clark***

Many and varied models of snow accumulation and ablation currently exist. However, questions still remain as to what level of complexity is justified for such a model given the many uncertainties in the streamflow prediction system. Model complexity can be defined in terms of both the processes that are explicitly included as well as the parameterization methods used to represent those processes. While complex models that include detailed physics may perform very well when provided with sufficiently accurate input and parameter data, such data is rarely available at the scale desired. Thus the additional complexity may introduce increased sensitivity and error. Using two snow dominated, but climatologically different, catchments in the western USA, we undertake a series of experiments in which the uncertainty of model input data is used as a form of penalty function in the process of model selection. In this sense, we select the model/s that are of justifiable complexity. Furthermore, because our model is hierarchical in nature (i.e. modeling of specific processes can be included or excluded while keeping the remainder of the model the same) we assess the compensatory abilities of different model structures. Model performance is assessed against a variety of ground based and satellite derived measures. Additional constraints on model selection, such as the requirement of physically realistic relationships among variables and parameters, are also explored.

***Keywords:*** snow, complexity, inputs

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**HW2004** **Poster presentation** **4651**

# Uncertainties in estimating total terrestrial water storage in major river basins in the world

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***Kei Yoshimura, Hyungjun Kim, Yanjun Shen, Ngo Duc Thanh, Shinta Seto, Shinjiro Kanae***

There are three ways to estimate the variation of the total terrestrial water storage which consist the changes in ground water, soil moisture, snow water equivalent, and water in rivers, lakes, ponds, etc. They are the combined atmospheric-river basin water balance using 4DDA data of the atmosphere, the remote sensing by GRACE, and off-line(or on-line) simulation by land surface models or hydrological models. In terms of the atmospheric-river basin water balance (AWB) method, the global distribution of water vapor flux convergence was estimated using the ECMWF global analysis data for the period from 1986 through 1995. The 10 year mean value of the atmospheric water vapor convergence was adjusted to match with the climatological mean value of river runoff for 1961-1990. Then the seasonal changes of the total terrestrial water storage were estimated by AWB method combining the atmospheric water vapor convergence for major river basins and the runoff from the area. GRACE data was regridded into the same spatial resolution as other estimates, namely 1 degree by 1 degree longitudinal and latitudinal grid boxes. For the estimates by numerical simulations, the components in the change of the total terrestrial water storage were investigated using the multi-model products forced by observed surface meteorology. Under the Global Land/Atmosphere Study (GLASS), the Phase 2 of the Global Soil Wetness Project (GSWP-2) produced the first global (excluding Antarctica) 1x1 degree Multi-Model Analysis (MMA) of land-surface variables and fluxes for the 10-year period of 19861995 at the daily time scale. Thirteen land-surface models (LSMs) were driven by the best possible forcing data of the atmospheric conditions, such as precipitation, downward radiation, wind speed, air humidity and air temperature with temporal resolution of 3-hourly or higher. Water balance in major continental scale river basins were post-processed and the seasonal changes in ground water, soil moisture, snow water equivalent, and the water in river channel were analyzed using the Total Runoff Integrating Pathways (TRIP) and a simple ground water model of linear reservoirs. The seasonal changes of the total water storage in river basins estimated by AWB method, GRACE, and GSWP MMA are compared, and basically they corresponded fairly well, but GRACE data used showed slightly lower than other estimates. It was found that in the case of the Amazon River basin, the storage term which appears in the runoff routing model plays a significant role in the seasonal change of the total water storage in the watershed. This result suggests that it is important to exclude the contribution of the changes of river water from the changes in the total terrestrial water storage in order to purely estimate the changes in ground water, and at the same time, this result is encouraging because it suggests that the storage term in the simple runoff routing scheme is not an imaginary term but a physically relevant variable.

***Keywords:*** groundwater, soilmoisture, riverwaterstorage

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**HW2004** **Poster presentation** **4652**

# Verification of the combined model of a geyser (periodic bubbling spring) by underground investigation of Kibedani geyser ☐

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We have proposed a mathematical model (a static model), a dynamical model and a modified dynamical model of a geyser (a periodic bubbling spring) based on observation of Hirogawara Geyser (Yamagata, Japan)and model experiments of the geyser and have also proposed a combined model combining above 2 models. And numerical simulations of the modified dynamical model or the combined model reappear dynamics of spouting of geysers (periodic bubbling springs) and it becomes possible that parameters (volume of the underground space, depth of spouting hole and so on) under a geyser are estimated due to comparison between results of simulation and those of observation. But above models were only qualitatively verified based on similarity of spouting dynamics of numerical simulations to one of real geysers (periodic bubbling spring) and had not been verified through geological investigation because of difficulty of underground observation. Then we tried indirect observational verification through geological exploration, analysis of hot spring water and radioactive prospecting around Kibedani Geyser ( Shimane, ) in March 2006. From results of geological exploration and analysis of hot spring water, it was suggested that underground caves (spaces) which were needed by above models could exist by summing gaps among pebbles and sand in talus deposit and hot spring water gushed from an underground deep spot. Then above results were reported in AOGS2006 and so on. But results of the radioactive prospecting there have not been reported yet. Then we will report results of the radioactive prospecting in this presentation. From the radioactive prospecting, positions of concrete dislocations through which hot spring water gushed from an underground deep spot were clarified. That is, we could estimate those from the distribution of quantity of radiant rays. Synthesizing above results of the radioactive prospecting and past results of geological exploration and analysis of hot spring water leads to support of a scenario of underground caves formation around Kibedani Geyser proposed by Kagami(2006). That is, it is the scenario that interaction between deposit which originates from hot spring water gushing through dislocations and talus deposit forms large-volume underground caves (spaces) which consist of a lot of small gaps among pebbles and sand in talus deposit. By the way, above models demand existences of underground caves (spaces) under a geyser (periodic bubbling spring). In this presentation, we will also refer to relation of values of various underground parameters estimated through numerical simulations of the combined model to results of above geological exploration, analysis of hot spring water and radioactive prospecting around Kibedani Geyser.

***Keywords:*** geyser, model, verification

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**HW2004** **Poster presentation** **4653**

# Characterization of water retention curves of a natural forested hillslope by using a scaling technique

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Describing heterogeneous water flow in soils requires information of spatial variability of water retention curves (WRCs). Most previous studies derived scaling factors from the microscopic characteristic length of soil, assuming the similar media concept that the microscopic structure of soils is identical, and the soils differ only by their microscopic length scale. However, it has been revealed that, in most cases, field soils do not strictly follow the similar media concept. In this study, we applied the scaling technique by considering that field soils do not necessarily have similar shapes, for the purpose of describing spatial variability in WRCs of a natural forested hillslope, which is covered with predominantly Chamaecyparis obtusa Endl (Japanese cypress) and Quercus glauca (oak), and underlined by granitic bedrock. Undisturbed samples were collected at five points distributed from downslope to upslope segments of the slope, and WRC for each sample was measured. The observed WRCs were fitted by the physically based model introduced by Kosugi (1996), which assumes that the log-transformed soil pore radius should be normally distributed. This model contains three parameters: the median of log-transformed pore radius, ym, the variance of log-transformed pore radius, s, and effective porosity, qe. In each scaling method, scaling factor is related to one of the three parameters. That is, in Method 1, ym was optimized for each soil, and s and qe were set to be common for whole data sets. In Methods 2 and 3, s and qe were optimized for each soil, respectively. Results showed that Method 3 produced the best description of spatial variability in WRCs observed on the studied forested hillslope. This result indicated that on the natural forested hillslope the variability in pore size distribution, which was affected by forest biological activities, was characterized by the variability in effective porosity, while variability in the median and the variance of the pore size distribution were relatively small. In practical aspects for determining scaling factors, it is important to suggest simple methods to estimate qe value of each soil. Although Method 3 produced the highest effect of scaling (90.8 %), the method was laborious and time consuming; undisturbed soil samples should be collected in the field by digging trenches, and WRCs should be measured for the entire matric potential range. In Method 3a, qe for each sample was calculated as a difference between the observed saturated water content and water content at y = -1000 cm. This method can save time because it does not require WRC measurements for the entire matric potential range. Moreover, we found that the scaling effect derived by Method 3a (86.0 %) was comparable to that derived by Method 3. In Method 3b, the values of qe were estimated from independently measured penetration resistances, which can be easily obtained by conducting a cone penetration test. Thus, Method 3b can greatly reduce time and labor for determining scaling factors. Although the effect of scaling derived by Method 3b was lower than those by Methods 3 and 3a, Method 3b still can explain 59.3 % of spatial variability in WRCs on the forested hillslope studied.

***Keywords:*** scaling, water retention curve, natural forested hillslope

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**HW2004** **Poster presentation** **4654**

# Assessing the seasonality in the hillslope response of a Mediterranean basin by sub-surface and surface-water monitoring

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The water balance partitioning and flows is under investigation in an experimental 100 km2 sub-humid catchment in Southern Italy, where surface and groundwater flows are conveyed into an artificial reservoir. The aim of the research project is to understand water dynamics across different landscape elements of the catchment. The catchment is a typical Mediterranean landscape, resulting from the co-evolution of climate-soil-vegetation interactions. It is characterized by large valley with braided channels and gravelly sediments, deriving from alluvial and colluvial fans at the foot of the surrounding steep hillslopes. Along the slopes landuse ranges from Mediterranean macchia, pasture, forest and heterogeneous agriculture landuse. At medium and large catchment scale, runoff is mainly generated by the saturation excess mechanism occurring in the coarse alluvial aquifer at the valley bottom, which in turn is fed by lateral surface and subsurface flows along the hillslopes. Intensive field campaigns have been conducted, covering both the dry and the wet seasons, aiming at understanding the dominant mechanisms controlling the hillslope response and their contribute to the water balance partitioning at the catchment scale. The experimental activities have been focused into two small catchments (drainage area of 5 and 18 ha, respectively). The former is mainly covered by Mediterranean macchia, whereas the latter is characterized by various agricultural landuses. Laboratory tests have been performed on undisturbed soil cores collected within the top 30 cm, to evaluate superficial hydraulic properties of soil. Meteorological data are monitored by a complete weather station. Surface flows are measured at the catchment closures with V-notch weirs. Superficial soil water content is measured on a regular grid across the catchments on a monthly base. Subsurface lateral flow dynamics is monitored by piezometric monitoring in numerous irrigation wells. Preliminary results show a strong seasonality of the hillslope response, with a clear switching from dry to wet seasons. During the dry season, rainfall is stored and redistributed locally, by vertical processes of infiltration and evapotranspiration. During the wet season, the response is mainly controlled by lateral subsurface flow within the top soil horizons, enhanced by vertical heterogeneity, with time-scales of a few days.

***Keywords:*** hillslope response, lateral flow, seasonality

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2004** **Poster presentation** **4655**

# Uncertainty in soil water budget modeling at the hillslope scale when soil hydraulic parameters are estimated with indirect methods

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Modeling soil hydrologic processes across different landscape elements is of prime importance for many studies applied to environmental and land-use planning problems. Nevertheless, the application of soil hydrological models at large spatial scales is often limited, chiefly because it requires the determination of soil hydraulic parameters that are difficult to assess by direct observations, especially over relatively large land areas. Pedotransfer functions (PTFs) are being developed as simplified methods to translate readily available soil data into parameters required by soil hydrological models. In this study we designed a general methodology for assessing the uncertainty in estimated soil hydraulic properties and simulated soil water budget resulting from the application of PTF at hillslope scale. The proposed procedure takes effects exerted by the spatial density of the available PTF input soil data also into account. Two sources of uncertainty are examined: (i) the error in estimated PTF input soil data and (ii) PTF model error. This methodology has been applied to an experimental hillslope in Southern Italy, where an intensive field campaign has been conducted to gather several PTF input soil data and soil hydraulic properties. A sequential Gaussian simulation algorithm is used to generate multiple equally probable images of PTF input soil data, consistent with the estimated spatial structure and conditioned to the measured soil core properties. Commonly used PTFs are then applied to evaluate the uncertainty in the predicted soil hydraulic properties. The predicted soil hydraulic properties are also employed into a soil-vegetation-atmosphere model to evaluate the uncertainty in the simulated evaporation, transpiration and soil water budget variation during a wet to dry transition season. With specific reference to practical directions when planning field campaigns, outcomes of this study suggest that the application of PTFs provide accurate and precise estimates of the soil water retention characteristic, transpiration flux and soil water storage variation at the hillslope scale even for a relatively coarse sampling resolution of basic soil hydraulic properties. The examined PTFs show worse level of performance when they are applied to predict the hydraulic conductivity and evaporation fluxes. In this case the PTF model error is much more significant than the input uncertainty, even at very high sample resolution. A major implication of the outcome obtained is that if one would reduce the prediction uncertainty of these quantities, the PTF model structure has to be improved prior of reducing the uncertainty in the PTF input soil data.

***Keywords:*** pedotransfer functions, soil hydraulic properties, soil water budget modelling

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2004** **Poster presentation** **4656**

# A Parameter Estimation Approach for the Groundwater Representation in the NCAR CLM (Community Land Model)

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Our previous study of coupling groundwater dynamics into the NCARCLM (Community Land Model) has successfully reproduced the observed monthly variations of regional hydrology in Illinois. However, when applying this coupled model to other regions in the world, the insufficient observations (water table depth and streamflow required for the determination of aquifer storage-discharge relationship) limit its global application at the climate model scale. Therefore, the development of a parameter estimation approach is a necessary step before its global implementation. In this study, a parameter calibration approach using only the daily streamflow data and baseflow separation technique was proposed. The practical application of this approach was demonstrated in several river basins in Illinois and Mississippi River Basins. Further, the critical issues of scale transition with this parameter calibration approach are addressed, because the watershed scale does not coincide with the typical grid scale of land surface models. A parameter aggregation scheme to average the calibrated parameters from the watershed scale to the model grid scale is suggested.

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**HW2004** **Poster presentation** **4657**

# Sensitivity Analysis of a Distributed Hydrologic Model for Uncertainty Reduction and Identification of Dominant Model Controls

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Hydrologic models become increasingly complex as we move towards a more complete representation of spatial heterogeneities and processes occurring within the watershed. The progression from spatially lumped to distributed models is also driven by the availability of high resolution hydrological data and the potential for improved predictions when the model accounts for spatial variability in precipitation and in runoff production. Much work has been done in recent years to develop new distributed watershed models, and improved evaluation and calibration strategies for these models have been proposed. If we consider calibration as the process of using observed inputoutput behavior to reduce the uncertainty on the model parameters, which is typically high in complex models, then our main task is to optimize the extraction of information from available time-series. However, dominant model controls are still not well understood when considering the (dynamically varying) impacts of distributed forcing and spatially distributed model response, as well as model parameters and states. Improved understanding of these dynamic model controls would allow for the development of more effective and appropriate methods for calibration of distributed models. In this study, we use sensitivity analysis to assess the impact of spatial precipitation distribution and spatial model element location in a distributed rainfall-runoff model. We use both observed data as well as virtual experiments to understand distributed model behavior to guide to new calibration strategies.

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**HW2004** **Poster presentation** **4658**

# Hydrograph separation method based on spatio-temporal record of stream flow by a distributed rainfall-runoff model

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Realistic representations of internal catchment processes by distributed rainfall-runoff models are essential to address various environmental problems. Many field observations have been conducted to identify runoff generation mechanisms. However, modelling the identified runoff processes may not always show distinct advantages in terms of the matching of simulated and observed hydrographs, although extrapolations of a model that includes large uncertainty tends to fail reasonable predictions. To reduce the model uncertainty by evaluating a model with field observations, the measurements and modelling should be compared with common representative properties that reflect rainfall-runoff responses at an appropriate scale.Hydrograph separation techniques in terms of temporal and spatial origins of rain water by using isotope and physicochemical tracers are becoming more common and more reliable. Mean residence time of stream flow is also getting widely recognized as a potential index to represent the characteristics of rainfall-runoff processes at a catchment scale. On the other hand, few modelling studies have addressed to validate if the simulated processes are reasonable against the above mentioned observations. Furthermore, not many methods have been proposed to extract the information including spatiotemporal origin ofstream flowand mean residential time from distributed rainfall-runoff models.This study proposes a hydrograph separation method based on spatio-temporal record ofstream flowwithin a distributed rainfall-runoff model. It traces virtual information representing the record of rain water at each unit slope and at each flow pathway defined in the model. The proposed method is able to decompose hydrographs by taking into account the effects of unsaturated, saturated subsurface and surface flows, and it is able to analyze the impact of model structures and parameters on the simulated stream flow compositions that can be compared by the observations to evaluate the model structures.

***Keywords:*** tracer, mean residential time, model uncertainty

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2004** **Poster presentation** **4659**

# How complex should a catchment scale phosphorus prediction model be?

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***Sarah Dean, Keith Beven, Andrew Wade, Daniel Butterfield***

There is a need to understand the mobilisation and transport of Phosphorus (P) from diffuse and point sources to the stream at the catchment scale. Despite there being many phosphorus models available for the prediction of phosphorus concentrations, there has been little effort to quantify the amount of uncertainty present in these predictions. Furthermore the modelling framework considered and the complexity of that approach should reflect the limitations in our ability to monitor appropriate phosphorus dynamics used to both drive and evaluate model predictions. Taking into account these key ingredients should ensure the end-user is provided with as much information as possible in order that they can make more informed management decisions within a risk based framework. In this paper an uncertainty analysis of the process-based model INCA-P within the Generalised Likelihood Uncertainty Estimation (GLUE) framework is presented. The framework is applied to a set of data describing the Lugg catchment (885km2) on the border between England and Wales. Daily flow for four catchments and monthly phosphorus (soluble reactive and total) for ten and eight catchments respectively are used to initially assess the uncertainty and sensitivity of 46 of the model parameters. We include estimates of observational errors in our analysis. These are introduced through an assessment of the errors in the non-perfect stage- discharge rating curves from three stations and from the analytical error and the representational level' of single point phosphorus measurement being used to define a daily concentration. We apply different assumptions to the assumed error characteristics and evaluate the impact that these assumption make on the prediction uncertainties. We finally discuss whether such process-based modelling approaches can be evaluated effectively and if the ability of the model to reproduce catchment behaviour is limited mainly by the model structural error and/or the limitations and errors in the observed datasets.

***Keywords:*** phosphorus, uncertainty, modelling

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**HW2004** **Poster presentation** **4660**

# Sensitivity analysis of hydrological predictions with regard to precipitation forecasting informativeness

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***Jos Eduardo Gonalves***

The article presents a sensitivity analysis for hydrological prediction of streamflow with regard to variations in the precipitation forecasting informativeness for multiple leading times. Hydrological prediction systems based on different techniques are analyzed: multiple linear regressive model, Kalman filter and rainfall-runoff model. The study site is the Iguau River Basin, in Parana State, , where flood control and energy generation constitute a permanent challenge for the reservoirs management. Comparisons are considered between measures of quality of streamflow predictions, with and without supplying precipitation forecasts to hydrological prediction systems. The precipitation forecasts generated with different informativenesses are supplied by class for a 24-hour lead time, split into 4 6-hour intervals. The results highlighted significative and moderate losses and earnings situations, with regard to accuracy and association, when the precipitation forecasting informativeness and the leading time vary. Then, to each type of model, it is possible to recognize situations when it is better to use precipitation forecasting and also situations when it is worse to use them. Moreover, it is possible to derive a measure of models resiliency with regard to precipitation forecasting errors. These results can provide us guidelines to improve the use of models of these types in the operational hydrological forecasting.

***Keywords:*** statistical informativeness, sensitivity analysis

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**HW2004** **Poster presentation** **4661**

# A new hydrologic land surface parameterization scheme with lateral soil water redistribution

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***Otto Corra Rotunno Filho, Isimar De Azevedo Santos, Luciano Xavier***

In the atmospheric models, the exchanges between the soil and the atmosphere are usually parameterized through a soil-vegetation-atmosphere transfer (SVAT) model. Most SVATs simulate reasonably well the vertical exchanges of heat and water. However, they do not model the hydrological processes appropriately, essentially neglecting lateral soil water transport and its effect on groundwater. At regional scales, neglecting these hydrological processes may result in inconsistent soil moisture fields, which influence the atmospheric model-derived structure of the atmospheric boundary-layer (ABL) and precipitation. In this way, a hydrologic land surface scheme containing an approach for lateral redistribution of the soil water and capable to be easily coupled to mesoscale atmospheric models is proposed. Taking the ISBA model as a starting point a third soil layer, the gravitational drainage and the vertical diffusion processes and the mechanism for subgrid-scale surface runoff generation were added. Finally, an approach for lateral redistribution based on topography gradients was implemented. The model reproduces quite well the vertical fluxes and the soil moisture state. The results obtained with the activation of the lateral redistribution showed consistency with the topography controls, which means that positive differences were verified at plane areas and negative differences at areas with more favorable gradients to runoff. However, the real impact of the lateral redistribution in the mesoscale atmospheric models still needs to be evaluated by a two-way coupling, jointly with the capacity of the model to generate consistent flows at the basin outlet.

***Keywords:*** hydrological parameterization, models coupling, atmosphere surface interactio

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**HW2005** **4662 - 4708**

## Workshop
## From Measurements and Calibration to Understanding and Predictions (Sponsor PUB with the support of ICWRS and ICGW)

**Convener :** Prof. Hubert Savenije

Because of equi-finality, calibrated hydrological models often suffer from poor predictability. One important reason for this problem is that models are often merely calibrated on the output signal at the downstream end of a catchment. The availability of additional orthogonal information on internal state variables could constrain the solution space considerably, leading to reduced predictive uncertainty of the model. Hence there is a clear need for more information. Partly this information can be provided by a denser network of discharge and groundwater observations within a catchment, but in poorly gauged catchments such information is not available. New observation techniques can provide crucial additional information on ungauged catchments to further constrain the modelling space. Such techniques may include: gravity observations from space to derive time series for water storage in a catchment; estimates of rainfall patterns from space at different temporal and spatial resolutions; radar altimetry to derive water levels in rivers and lakes; techniques to derive estimates of actual evaporation from remote sensing and ground observations; techniques to derive soil moisture estimates from remote sensing; isotope diagnostics; the combination of atmospheric and hydrological modelling. Effective predictions of water flow and quality in surface- and ground-water systems also require that system dynamics and reactions be well understood and modeled, and that uncertainty be properly assessed. A fundamental problem in the analysis of complex hydrologic systems is the interplay of data and modeling when testing fundamental theories, calibrating and testing models, and assessing prediction uncertainty. Improving how data and models are used has proven to be exceedingly difficult. One of the most difficult problems is that hydrologic model calibration methods frequently lack any rigorous method of relating models to the calibration data and the predictions of interest, and numerical problems and limitations of forward models make the problems more difficult. This session invites contributions on new measurement approaches and on calibration techniques to reduce predictive uncertainty of hydrological models, with a focus on poorly gauged catchments (PUB). Applications for and in developing countries are particularly welcome.

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**HW2005** **Oral Presentation** **4662**

# Enhancing flood forecasting with the help of transient model parameters.

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Due to the fact that the required input data are not always completely available and model structures are only a crude description of the underlying natural processes, model parameters need to be calibrated. Calibrated model parameters only reflect a small domain of the natural processes well. This imposes an obstacle on the accuracy of modelling a wide range of flood events, which, in turn is crucial for flood forecasting systems. Together with the rigid model structures of currently available rainfall-runoff models this presents a serious constraint to portraying the highly non-linear transformation of precipitation into runoff. Different model concepts (interflow, direct runoff), or rather the represented processes, such as infiltration, soil water movement etc. are more or less dominating different sections of the runoff spectrum. Most models do not account for such transient characteristics inherent to the hydrograph. In this paper we try to show a way out of the dilemma of limited model parameter validity. Exemplarily, we investigate on the model performance of WaSiM-ETH, focusing on the parameterisation strategy in the context of flood forecasting. In order to compensate for the non-transient parameters of the WaSiM model we propose a dynamic parameterisation strategy. This starts from a detailed analysis of the considered catchments rainfall-runoff characteristics. Based on a classification of events, WaSiM-ETH is calibrated and validated to describe all the event classes separately. These specific WaSiM-ETH event class models are then merged into one artificial intelligence based black box forecasting tool (PAI-OFF: Schmitz & al. 2005, Cullmann & al 2006). This is done with the help of a newly developed ANN fusing tool, which merges output from the different class models into the PAI-OFF training data base. PAI-OFF thus integrates all available information from the specially calibrated WaSiM-ETH class models, accounting for the different processes and dynamics governing the various event classes. E.g. PAI-OFF portrays the flood formation process with transient parameters according to the event class models. Implications arising from this study are demonstrated for a catchment in the Erzgebirge (Ore-mountains) in East Germany (1700km). Online flood forecasting of the Zschopau River at the gauge Kriebstein is validated using an unseen storm event, i.e. one that did not feature in the training process. The computational efficiency, together with the convincing agreement between the predicted and observed flood hydrographs underlines the potential of the new parameterisation strategy in the context of operational online forecasting. J. Cullmann, G.H. Schmitz, W. Grner (2006): A new strategy for online flood forecasting in mountainous catchments. IAHS red book 303. Schmitz, G.H., J. Cullmann, W. Grner, F. Lennartz, W. Drge. 2005 PAI-OFF: Eine neue Strategie zur Hochwasservorhersage in schnellreagierenden Einzugsgebieten, Hydrologie und Wasserbewirtschaftung, 49. 2005:.226-234.

***Keywords:*** forecasting, calibration strategy, transient parameters

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**HW2005** **Oral Presentation** **4663**

# Combining atmospheric model information, remote sensing and hydrological models to enhance knowledge in PUBs

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***Hubert Savenije, Nick Van De Giesen, Wim Bastiaanssen***

Hydrological models in data scarce regions suffer from poor predictability. The calibration issue in these regions is being addressed frequently by researchers. Often outlet discharge is used as a measure for the integrated response of a catchment or river basin on rainfall, while heterogeneity is disregarded. Sometimes the parameters of a model based on such time series are adopted in neighbouring ungauged catchments because there simply is no data available in the region of interest. These issues are all underlying sources of uncertainty and can only be solved by introducing and formation of new, alternative datasets. In this paper we address new data sources that can help lift the problem of PUB on several spatial and temporal scales. Past results and constraints on the use of atmospheric model information are evaluated and new results on all-sky evaporation estimates from remote sensing and possible applications in hydrological modelling are presented. Our application area is the Zambezi, a typical scarcely gauged catchment, where evaporation accounts for 90 percent of the outgoing fluxes. This region shows extremes in both floods and droughts and covers a spatially heterogeneous surface, which makes it an excellent target area for case studies.

***Keywords:*** pub, evaporation, atmosphere

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**HW2005** **Oral Presentation** **4664**

# The importance of independent data to constrain ground water model calibration in a complex aquifer

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A mathematical model simulating the ground water flow of the aquifer system in the alluvial basin of about 2500 square kilometers, bordered by the Adda, Po and Oglio rivers in Northern Italy, has been developed. The aquifer system is characterised by a dual flow regime. In shallow sediments, which constitute a phreatic aquifer with high conductivity and an average thickness of about 50 m, great fluxes are driven by the interaction between ground water and the network of surface water, by the infiltration of rain and irrigation water, and by the fluxes drained from depression springs and river valley terraces. The underlying semiconfined aquifers are discontinuous and characterised by minor fluxes driven by water abstraction from wells of the public Water Works. Moreover, most of the head and source data are related to the phreatic aquifer, whereas most of the estimates of transmissivity are obtained with field tests on deep wells pumping from the semiconfined aquifers, so that we cannot directly profit from this kind of prior information. In accordance with observations, most of the ground water occurs in the phreatic aquifer, as a first step toward full model calibration, we attempted to calibrate an equivalent single layer 2D steady state flow model. The model is based on a conservative finite difference scheme with grid size of 500 m. For the identification of the transmissivity field at the scale of the model the Comparison Model Method (CMM) has been used. This method permits also to recognise physical inconsistencies of the data set in a straightforward way. The reference data used for model calibration are: heads and sources and boundary conditions on heads. The results of the CMM also depend on the initial tentative transmissivity field, which fixes the water flow in the aquifer system. Therefore we performed a series of tests with different hypotheses about the initial configuration, i.e.: reference head, initial transmissivity field, values of the source terms. This study confirms that the choice of the best initial configuration cannot be based on head data only, but other data on the aquifer flow are necessary, e.g. river discharge, spring extraction, etc. In the study case this information was poor and we had to rely on weak constraints to select a limited number of initial configurations, which have been used to initialise the automatic inversion procedure.

***Keywords:*** groundwater, calibration, inversion

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2005** **Oral Presentation** **4665**

# Using discrete internal catchment observations for obtaining TOPMODEL parameter description in a small mediterranean mountain catchment.

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***Jrme Latron, Pilar Llorens, Keith Beven***

Discrete observations on recession flows, depth to the water table and the extent of saturated areas were used in a small research basin for obtaining the distribution functions of the TOPMODEL parameters that drive the behaviour of the saturated store. Using this parameter information within the GLUE method, the robustness of discharge simulations was improved and the uncertainty of flow separation between saturated overland flow and shallow groundwater flow was significantly reduced in comparison with the results obtained with the usual model constraining using continuous discharge records. Other advantages of the approach are that these observations do not need any permanent instrumentation in the catchment, and that it may be applied without running the whole model, and therefore precipitation and climate data are not needed. Conversely, local conditions near the piezometer and the determination of the topographic index may weaken the representativity of the water table observations, whereas recharge or capillary upwelling during recession periods may limit the identification of the recession parameter. The use of the extent of saturated areas provided the best results, although the simulated patterns of saturated areas do not match the observed ones, because the role of local controls not taken into account by the topographic index.

***Keywords:*** topmodel, glue, internal information

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**HW2005** **Oral Presentation** **4666**

# Potentiality to use ground geodesy data to constrain calibration of hydrological model

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In this work, we explore the possibility of using ground geodesy measurements as additional orthogonal data for hydrological models. Ground geodetic measurements are sensitive to the deformation of the earth crust under surface mass loading, they therefore estimate directly the water mass variations on the earth crust. As a consequence, geodesy allow to bring complementary information on the hydric state of the catchments. With similar goals but different methods, GRACE data have recently proved to be of great interest for hydrological modelling (see e.g. Schmidt et al., 2006). To this aim, a 100-meter base hydrostatic inclinometer has been set up in an old mine in the Vosges Mountains (France), and records the water mass variations of a 100-km catchment since December 2004 with a temporal sampling of 30 seconds and a resolution better than 10-9 degrees. The physical modelling of the tilt deformation induced by water mass variations in the catchment requires the investigation the mass balance equation. Results show that modelled short term fluctuations of stored water are in good agreement with inclinometer measurements during winter time, when the spatial distribution of water within the catchment can be considered as uniform (i.e. stable precipitation field). Conversely, large discrepencies exist during storms and snow accumulation periods because the inclinometer is also sensible to the position of water masses. As a consequence, we believe that geodesy could bring interesting information on both the quantification and the distribution of water stored within the catchment, and thus better calibrate hydrological models.

***Keywords:*** ground geodesy, mass balance, catchment hydrology

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**HW2005** **Oral Presentation** **4667**

# Calibration of a Land-surface Hydrology Scheme in an Arctic Environment

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***Bruce Davison, Alain Pietroniro, Bryan A. Tolson, Eric D. Soulis, Philip Marsh***

In arctic environments, snow cover prior to the snowmelt season show a non-uniform spatial pattern due to snow redistribution by wind, which is enhanced at small scales as a consequence of vegetation and topography effects. As melt progresses, a typical patchy snow cover develops resulting in a mosaic landscape where snow covered areas coexist with bare ground patches. This has proven to have significant implications on land-surface interactions and feedbacks on snowmelt and on runoff generation. The inclusion of subgrid variability of snow-cover during snowmelt in Land Surface Hydrological (LSH) models has been found to improve the simulated snow cover ablation and associated basin streamflow. Due to the large number of model parameters involved in LSH models, automatic calibration schemes are believed to be required to deal with parameterization. In our study, different calibration and sensitivity schemes are applied in order to further investigate the performance of LSH in arctic environments. The study area was Trail Valley Creek, a small (63 km2) research basin representative of the Canadian Arctic, located in the North West Territories. In particular, the possible combination of equally plausible parameter sets derived from single and multi-objective functions is explored. This is done using both the GLUE methodology and a multi-objective global optimisation algorithm knows as DDS (Tolson and Shoemaker, 2006). Analysis includes the evaluation of snow covered area (SCA) and streamflow runoff predictions and their effects on the multi-objective optimisation problem. The global optimisation algorithm used is based on a dynamically dimensional search which is ideally suitable for expensive optimisation problems. Furthermore, the importance of model parameters to snow covered area depletion, surface and atmospheric exchanges, and streamflow is investigated by a sensitivity analysis on parameter values.

***Keywords:*** arctic, multiobjective calibration, lsh model

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**HW2005** **Oral Presentation** **4668**

# Application of the surface energy balance methodology for estimating total evaporation using scintillation and remote sensing techniques in the Thukela River basin-S.Africa

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Hydro-meteorological parameters, including total evaporation exhibit high spatial and temporal variation. These results from highly variable drivers such as rainfall and solar radiation, as well as heterogeneity arising from differences in land use, land cover, soil physical properties and are also subject to rapid changes in time and space. , Total evaporation is the dominant component of the water balance in semi-arid and arid regions and is considered an important component in water resources planning. However, there are many challenges in determining its spatial and temporal variation over large areas of a river basin scale from ground measurement alone. In the past two decades, there has been significant progress in the development of satellite image processing algorithms for computing the amount and spatial distribution of total evaporation, most commonly as a residual of the surface energy balance. One such algorithm is the Surface Energy Balance Algorithm for Land (SEBAL). This approach was applied in the Thukela river basin, South Africa using the public domain Moderate Resolution Imaging Spectroradiometer (MODIS) data and minimum ground measured data. One of the intermediate outputs of the SEBAL computation procedure, the sensible heat flux over each pixel of the satellite image, was calibrated against measured sensible heat flux data obtained from a Large Aperture Scintillometer installed over a transect of 1.03km. Comparison was also made between the SEBAL estimates of total evaporation and the values obtained from the Large Aperture Scintillometer and a nearby weather station. It was observed that the SEBAL computational approach estimated with a reasonable/appreciable accuracy the total evaporation values obtained from the Large Aperture Scintillometer on both daily and monthly time steps. Such a comparative study highlights the potential of applying remote sensing techniques as a contribution to monitor the impact of lands use on catchment hydrology by quantifying total evaporation at various spatial and temporal scales from natural and managed landscapes in South Africa. Such a contribution is of great significance with regard to understanding system dynamics in ungauged river basins in Africa

***Keywords:*** ungauged basins, surface energy balance, total evaporation

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**HW2005** **Oral Presentation** **4669**

# On the use and misuse of semi-distributed rainfall-runoff models

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Recent advances in hydrological modelling have led to a variety of complex, distributed or semi-distributed schemes, aiming to describe the heterogeneity of physical processes across a river basin. These are useful for operational purposes, such as design of large hydraulic structures, sustainable management of water resources and flood forecasting. However, due to the large number of parameters involved and the need for extended measurements, a robust calibration, which ensures a satisfactory predictive capacity as well as a physical interpretation of parameters, is a very difficult task. Hence, the applicability of such models in real-world studies, employed by practitioners with moderate hydrological knowledge, is at least questionable. The paper aims to reveal some critical issues, regarding the entire procedure of selecting, configuring and fitting a hydrological model. These are discussed on the basis of four classification criteria: the expertise level of the user, the representation of processes, the parameterization concept and the calibration strategy. An inexperienced user focuses on just finding a good fitting between model outputs and observations, usually by activating more parameters than are supported by the data. In contrast, an expert hydrologist wishes to explain the entire spectrum of model results, giving emphasis on the reasonable representation of the processes and the consistency of the all output variables, even those not controlled by the calibration (e.g. real evapotranspiration, soil moisture and groundwater storage fluctuation, etc.). In terms of the processes representation, modelling approaches that are devised for uniform, undisturbed basins are misused if applied on complex systems, with multiple human interventions. The next criterion refers to the parameterization procedure. Some approaches assign parameter values on the basis of the schematization, i.e. the spatial discretization of the system under study (e.g. the sub-basins), thus leading to schemes with too many degrees of freedom, suffering from the well-known curse of dimensionality. On the other hand, more intelligent models assume different levels of parameterization and schematization, employing the concept of a hydrological response unit. Thus, they significantly reduce the number of control parameters, also ensuring consistency with the physical characteristics of the system under study. Finally, one may classify the calibration strategies from manual, one-criterion fitting to sophisticated automatic optimization methods, using evolutionary algorithms and multiple fitting criteria, both statistical (based on measurements) and empirical (based on the hydrological experience). The above spectrum of modelling options is explored by selecting representative cases which reveal problems of everyday hydrological practice. The test area is the Boeoticos Kephisos basin, Greece, where a conjunctive simulation model is employed to describe the surface and groundwater hydrological processes as well as the water management practices.

***Keywords:*** semi distributed models, multicriteria calibration, disturbed basins

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**HW2005** **Oral Presentation** **4670**

# Validation of large scale hydrological model with data fields retrieved from reflective and thermal optical remote sensing data a case study for the Upper Rhine Valley

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For the entire Upper Rhine Valley between Karlsruhe and Basel, a long term simulation (1985-2002) with the GWN_BW model (partly physically based 1-D water balance model) resulted in the retrieval of the following hydrological process variables: daily potential and actual evapotranspiration, surface runoff and groundwater recharge. Climatic data is interpolated from all available stations in France, Germany and Switzerland including the mountain regions (Vosges Mountains and Black Forest). The grid size of the model is 500m, but it takes into account the sub-grid variability of landuse. For the integration of remote sensing data in hydrological process models, a couple of approaches do exist (e.g. definition of spatial subsets for distributed modelling, assessment of variables for model initialization, driving the model by recalibration or applying techniques for model validation). In this study, Landsat TM data were used for the validation of the surface radiation budget and the actual evapotranspiration at a couple of different dates in the modelling period. For their integration, a detailed preprocessing of the Landsat data was necessary including both geometric and radiometric corrections. For the thermal channel, a one channel atmospheric correction approach using a radiative transfer code was performed and validated by additional information of climatic stations in the study region. In fact, the following fields of data were derived from the satellite data partly by integrating additional information (e.g. air temperature) to calculate the total net radiation: brightness temperatures, coefficients of emission and kinetic temperatures of the land surface (LST), albedo and longwave radiation fluxes; a digital evelvation model was used for the pixelwise estimation of incoming solar radiation. The surface energy balance was approximated assuming a single layer of the canopy-soil system. The pixelwise estimation of the vegetated fractions, which was performed by different approaches (spectral indices, Spectral Mixture Analysis), was used for the estimation of the soil heat fluxes and for partitioning sensible and latent heat fluxes. In the following, the data fields retrieved from the satellite data were compared to the model output quantitatively e.g. by correlation and geostatistical pattern analysis.

***Keywords:*** evapotranspiration, remote sensing, simulation

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**HW2005** **Oral Presentation** **4671**

# A call for the development of inexpensive extreme rainfall automatic gauge station

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Changes in the rain pattern in Southern Brazil cannot be better exemplified by the occurrence of Catarina, the first hurricane ever to be registered below equator line. Although the area is being monitored by a network of meteorological and hydrological stations, the reliability of data produced by the unmanned ones, in special those assembled with tipping buckets rain gauges, is a reason for concern. Experiments show the performance of rain gauges under severe rainfall conditions is poor, a fact that may have been overlooked by Brazilian scientists. Considering that Tipping Bucket rain gauges are still largely used they are the least expensive and instruments for precipitation measurement - this paper intends to discuss the use of this technology and highlight a call for the development of better instruments in order to meet the needs for reliable data in an environment that may become more extreme in the near future. The case study is based upon experiments on commercial equipments intensively used by Brazilian Water Resources entities.The results point out to random unpredicted errors that may undermine the real rainfall values.

***Keywords:*** tippin bucket, rain gauges, reliability

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**HW2005** **Oral Presentation** **4672**

# A hydrological model system for flood estimation in ungauged basins of Switzerland

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For successful flood protection, sound estimations of floods of different return period are required. It is especially difficult to meet this demand in ungauged catchments. So far, mainly empirical methods were used for this purpose. During the past years, a number of such approaches have been tested and developed, ensuring their applicability to Switzerland. Experience shows, however, that these procedures still bear large errors. In order to make further progress in flood estimation, the approach of deterministic long-term modelling is now tested in Switzerland. The hydrological modelling system PREVAH is used to simulate the discharge of a period of 20 years in hourly resolution. These simulations are then analysed by means of extreme value statistics, resulting in estimations for peak discharge and flood discharge volume. Main goal of this approach is to achieve information for any Swiss mesoscale catchment without measurement of discharge. PREVAH is a spatially distributed HBV-type linear storage model which uses hydrological response units (HRU) and has been adopted especially for use in alpine catchments. For the present application, the HRUs are assembled from 500m500m raster cells; invariant HRU properties are set using a digital elevation model and further digital maps (e.g., land use and soil properties). The model is then forced for the period 19842003 with data from the Swiss meteorological gauging network in hourly resolution. As a basis for model regionalisation, 140 meso-scale catchments (approx. 20 to 1000 km) in Switzerland were calibrated successfully using the following calibration scheme: In a first step, the respective parameter sets were optimised for standard runoff conditions. Then, as a second step, these parameter sets were further adjusted for peak flow conditions, resulting in two separate model parameterisations. The regionalisation of the 12 free model parameters is obtained through a combination of different approaches: Firstly, the nearest-neighbour-method is employed to search for donor catchments which are as similar as possible to the target catchment; the model parameter sets are then directly transferred from the target to the donor catchment. Secondly, model parameters are interpolated in space with the help of Kriging, using the catchment centroids as points of reference. Third, relationships between model parameters and catchment attributes are sought. These three independent approaches are then each used to simulate the target catchment's hydrograph and combined by utilisation of the median regionalised discharge. Results show that the approach of long-term simulation is indeed able to produce plausible flood estimations in ungauged Swiss catchments. For a hundred year return period flood, the median error from 49 regionalised test catchments is only -7%, while the error for half of these catchments ranges between -30% and +8%. This approach adds significant information to the already existing methods and is suitable to complement and extend flood estimation procedures in Switzerland.

***Keywords:*** flood estimation, regionalisation, hydrological modelling

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**HW2005** **Oral Presentation** **4673**

# Calibration of a Numerical Ground-Water Flow Model Using Shuttle Radar Topography Mission (SRTM) Elevations

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Remotely-sensed elevations are potentially useful for constructing regional scale ground-water models, particularly in regions where ground-based data are poor or sparse. In this study, surface-water elevations measured by the Shuttle Radar Topography Mission (SRTM) were used to develop a regional ground-water flow model by assuming that frozen surface waters reflect local water table potential. Drainage lakes (fed primarily by surface water) are designated as boundary conditions and seepage lakes and isolated wetlands (fed primarily by ground water) are used as observation points to calibrate a numerical flow model of the 900 square km study area in the Northern Highlands Lakes Region of Wisconsin, USA. Elevation data were utilized in a geographic information system (GIS) based ground-water modeling package that employs the Analytic Element Method (AEM). Calibration statistics indicate that lakes and wetlands had similar influence on the parameter estimation, suggesting that wetlands might be used as observations where open water elevations are unreliable or not available. Open water elevations are often difficult to resolve in radar interferometry because unfrozen water does not return off-nadir radar signal. Due to their charateristially shallow water table, open wetlands are a potentially useful source for calibration of ground-water models in un-instrumented basins.

***Keywords:*** groundwater, remote sensing, model

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**HW2005** **Oral Presentation** **4674**

# Constraining Hydrologic Simulations with Remote Sensing in a Large-Scale Semiarid Basin with Monsoonal Climate

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A promising development in the hydrological modeling of remote areas is the availability of satellite observations. In semiarid regions with monsoonal climates, dramatic changes in soil moisture, vegetation and albedo lead to time-varying land surface conditions that need to be captured in hydrologic simulations. Remote sensing from various platforms can provide precipitation, land cover and soil moisture estimates to force, parameterize and test distributed simulations. In this study, we present field and remote sensing observations of hydrological conditions in northern Sonora, Mexico during the North American Monsoon. We utilize the observations to constrain the simulations from a distributed hydrological model applied to the large-scale semiarid basin. High resolution data sets in the basin allow detailed study of the flood and soil moisture patterns after intense convective storms. Comparisons are made to daily discharge estimates and to internal soil moisture fields obtained from aircraft remote sensing. We discuss the impact of capturing time-varying vegetation conditions on the hydrological response. Further, we illustrated how remote sensing allows improved understanding and predictions in large semiarid basins experiencing monsoonal climates.

***Keywords:*** monsoon, remote sensing, distributed hydrologic model

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**HW2005** **Oral Presentation** **4675**

# Calibration strategy for hydrological distributed conceptual models

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In this study the hydrological distributed conceptual model selected was TETIS, which has been used satisfactorily in Spain and France during recent years. The available information in the Basque Country located in Northern Spain was used to perform a regional water resources study. Hydrological conceptual distributed modelling requires the calibration of a huge amount of data usually represented as parameter maps. In this sense, it is not an easy task, and sometimes it is not feasible, to calibrate such a large amount of parameters. Therefore, it is necessary to implement new strategies to calibrate parameter maps as best as possible. The parameter maps required by the TETIS model are the hydraulic properties of soil based on the field capacity, and the saturated hydraulic conductivities of soil and subsoil. The TETIS model requires calibrating only eight Correction Factors instead of eight maps of parameters because each Correction Factor multiplies the whole parameter map, increasing or decreasing the previously estimated map and preserving its spatial variability. Therefore, this strategy strongly simplifies the calibration process and defines the calibration strategy. The main idea of the proposed technique is to use automated calibration strategies combined with hydrologist experience, field observations and common sense. The SCE-UA methodology was selected as the automated procedure to obtain Correction Factors and was used at 20 basins in the Basque Country during the water resources management study. Then, the hydrologists were in charge of reviewing the mass balance and flow distribution. Then, it was decided in most cases to adjust some Correction Factors according to field observations, neighbour basin results and previous experience. In this sense, the second part of this calibration strategy can be seen as an expert system. Special attention was dedicated to the initial condition of soil moisture which was included during the calibration strategy as a spin-up period in most basins. The daily scale information of the past 50 years was used during the simulation process. These results were the baseline for the water resources analysis, where available recent year's data was used to calibrate the model and the validation process was performed at multiple sites and times using the remaining data. The final results confirm that it is feasible and efficient to use the automatic calibration strategy combined with hydrologist expertise in distributed conceptual models. The next research step is to implement a new methodology to quantify the uncertainty of the model and parameters, where data uncertainty is not included because it must be studied in a previous stage.

***Keywords:*** calibration, distributed models, water resources

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**HW2005** **Oral Presentation** **4676**

# Deducing reservoir operations from remote sensing in the absence of in-situ data

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Hydrologic modeling in basins with flow regulation structures is a major challenge because of the alteration of natural streamflow at the structures. With two major dams located along its main stem, the Zambezi River in southern Africa is an example of a poorly-gauged international basin with major control structures. Discharges from Kariba Dam eventually make their way into Cahora Bassa Dam which is located approximately 650 kilometers downstream. Discharge data from both dams are not readily accessible to either the scientific community or the general public. In the absence of in-situ dam discharge data, accurate reconstruction of streamflow in the basin using hydrologic models is very difficult, and model calibration algorithms are generally ineffective in characterizing the influence of the structures. We present a modeling approach using remotely sensed data from multiple sensors to deduce reservoir operations for incorporation into simulation models. Daily reservoir inflows are simulated with a rainfall-runoff model using satellite derived precipitation estimates and evapotranspiration data computed from Global Data Assimilation System fields. Reservoir storage changes are computed using satellite altimetry data from the TOPEX/POSEIDON mission. The primary source of this information is the water level anomaly data processed and distributed by the US Department of Agriculture through its Global Reservoir and Lakes Monitor. Reservoir discharges are deduced at each time step by comparing the simulated inflows and storage changes, and an analysis of a time series of such discharges provide useful insights into how an individual reservoir is operated. In the Zambezi basin, the modeling approach is implemented to estimate releases from Kariba Dam. The releases are verified at Cahora Bassa Dam by comparing simulated inflows with observed changes in reservoir storage. The results show that inflows to Cahora Bassa are better replicated when the deduced reservoir operations from Kariba are incorporated into model simulation than by unaltered natural flow simulations. The results highlight the potential of remotely sensing to contribute to improved understanding of the operation of control structures and prediction of streamflow in regulated basins, even in the absence of in-situ river gauge data and reservoir operations information.

***Keywords:*** reservoirs, remote sensing, streamflow

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**HW2005** **Oral Presentation** **4677**

# Use of soil moisture observations to reduce the calibration uncertainty of a rainfall-runoff model

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The National Weather Service (NWS) is responsible for providing river and flash flood forecasts for the US. To accomplish this mission, the NWS uses hydrologic and hydraulic models to forecast river flows and stages at over 4,000 points. Calibration is a critical component in the implementation of operational models for river forecasting. Calibration of watershed models has traditionally relied on minimizing the errors between simulated and observed basin outlet hydrographs. However, considering numerous sources of uncertainty and the complexity of recently-developed models, this approach frequently fails to reduce parameter uncertainties. One of the possibilities to reduce calibration uncertainty would be use of additional independent data in the model evaluation. Unfortunately, such data are limited and their quality is usually not well defined. This presentation reports on the potential use of soil moisture measurements in the model calibration process. While these data are not commonly available, there is potential for considerable expansion of soil moisture measurements in the near future. Comprehensive soil moisture measurements from the Oklahoma Mesonet are used in the analysis. The Sacramento Soil Moisture Accounting model with a new heat transfer component (SAC-HT) is applied to more than 20 watersheds of sizes ranging from 200 km2 to 4000 km2 to answer two main questions: a) does an outlet-based calibration provide the right result for the right reason; and b) can the use of soil moisture data improve calibration reliability without an unacceptable reduction in the accuracy of the simulated outlet hydrograph. Three cases of simulated soil moisture and hydrographs are analyzed: 1) a priori parameters with no calibration; 2) automatic calibration based on outlet hydrograph fit only; and 3) automatic calibration based on outlet hydrographs and basin average-soil moisture computed at two depths. Overall analysis suggests that calibration to fit outlet hydrographs (Case 2) improves the outlet hydrograph accuracy for most basins. While soil moisture dynamics and trends are reproduced reasonably well in Case 2, significant soil moisture biases can be seen. These biases in soil moisture can be larger than those generated from the a priori parameters in Case 1. Use of soil moisture measurements in the calibration process (Case 3) improves the accuracy of soil moisture states and maintains an acceptable level of hydrograph accuracy. Graphical plots and statistics of these simulations will be discussed.

***Keywords:*** soilmoisture, observations, calibration

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**HW2005** **Oral Presentation** **4678**

# Coupling of a regional atmospheric model with an Ensemble Kalman Filter based Land Data Assimilation System and its application to North-East Asia during the 2003 Monsoon Season

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A new ensemble Kalman filter based land data assimilation system is developed, which can be used to assimilate satellite-borne passive microwave brightness temperature data to update soil moisture and temperature. Fully driven by a regional atmospheric model, the assimilation system can provide new surface fluxes to the atmosphere and gets back its updated forcing. The system uses a new land surface model based on the Simple Biosphere Model, which is currently under development at the Japan Meteorological Agency. The observation operator is a radiative transfer model, which can estimate the land surface brightness temperature. Currently the Q/h model is used to estimate the soil brightness temperature. The data assimilation method employed is the ensemble Kalman filter technique, which is a Monte Carlo based sequential filter method. The atmospheric driver is the Advanced Regional Prediction System (ARPS) which is a 3-dimensional non-hydrostatic atmospheric model. The system was tested on a regional scale over North-East Asia (0 to 60 deg. North, 45 to165 deg. East) for a two weeks period during the 2003 Monsoon season using NCEP/GFS-FNL global data as boundary and initial conditions. Forcing from the atmospheric model drives the land surface model. Satellite brightness temperature observations from the Advanced Microwave Scanning Radiometer are compared to the simulated ones through the assimilation process to update the surface state and feed back the new simulated fluxes into the atmospheric model. A control run using only ARPS nested from the global model data without land surface assimilation is used for comparison. Furthermore the new land surface conditions and fluxes are compared to in-situ observation collected during the Coordinated Enhanced Observation Period. The results showed significant differences compared with standard regional atmospheric model outputs, and it is shown that the system can estimate land surface states more reasonable than uncontrolled modeling by merging the brightness temperature observations into land surface dynamics.

***Keywords:*** land data assimilation, regional atmospheric modeling, ensemble kalman filter

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**HW2005** **Oral Presentation** **4679**

# Diagnostic Evaluation of a Distributed Watershed Model: A Process-based Approach

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Spatially distributed hydrologic models, with their capability of simulating the spatio-temporal distribution of hydrologic processes within the watershed, are important tools for improving river forecasting capabilities. However, due to their complex structure, formulating proper identification strategies for such models are difficult and often their outputs suffer from significant predictive uncertainty. Here we present a process-based, multi-measure evaluation strategy for improved identification of the Hydrology Laboratory Research Modeling System (HL-DHMS) developed by the National Weather Service. The proposed evaluation strategy is based on analysis of the consistency between input-state-output behavior of the model and observed watershed dynamic response (in this study, streamflow). In the procedure, diagnostic signatures related to model functioning are formulated based on theoretical and empirical analyses of the model parameter-streamflow sensitivity relationships. Each signature, corresponding to a specific model function, is then used to identify parameter(s) related to that function. The parameter dimensionality of the HL-DHMS model is constrained using soils information (Koren et al., 2000). We will show how the proposed evaluation strategy can help to improve identification of spatially distributed HL-DHMS hydrologic model through its utility to diagnose problems with the model structure and to provide guidance for model correction.

***Keywords:*** distributed model, prediction, evaluation

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**HW2005** **Oral Presentation** **4680**

# Multifractal approach for rain simulation and forecasting in ungauged basins

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In the emergency situations, the hydrometeorological forecast and alert systems require more and more detailed space-time information and reliable forecasts. In addition, there is a large consensus among the hydrologists that one of the main sources of uncertainties in the flood modelling is the uncertainty in the rainfield forecast. The current weather forecasting models or the standard statistical methods of radar and satellite image processing cannot adequately model the rain: many parameterizations, long spin-up and computation time incompatible with short-term forecast. Generally these methods do not take into account the strongly nonlinear dynamics (e.g. for the displacement and deformation) of the stormy cells. The multifractal approach, physically based on the notion of the cascade processes of atmospheric dynamics and rain, can be regarded as an alternative to these methods. It takes into account the hierarchy of the structures and their nonlinear interactions over a wide range of space-time scales, as well as the scaling anisotropy between time and space. The advantage of this approach is that it requires a very limited number of parameters which have a physical significance. The interest of this methodology is that it can generate rains spatially distributed for PUB. In this presentation we will discuss the implementation of a multifractal procedure to simulate and forecast the rainfall with the help of radar data. We will discuss in details the predictability limits and uncertainties of this method, as well as its deterministic, stochastic and probabilistic forecast modes.

***Keywords:*** multifractal, rainfall, forecasting

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**HW2005** **Oral Presentation** **4681**

# An alternative approach to estimating heat fluxes over land surface

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Evaporation/evapotranspiration is central to the hydrological cycle. By evaporation water returns into the atmosphere, and the available energy is separated and transformed into latent heat and sensible heat over natural surfaces. Founded on the pioneering work of Penman [1948], the contemporary theory of evaporation has been developed quite comprehensively with the help of similarity theory [Obukhov, 1946], through theoretical and observational study in modeling water and heat transfer in the atmosphere boundary layer. Experimental technologies have also progressed including the invention of the eddy correlation method. Furthermore, many comprehensive field experiments such as FIFE, HAPEX-SAHEL, and SGP have been performed for studying water transport and the interaction between the land surface and the atmosphere. Yet, the contemporary theory remains as a diagnostic, and accurate predication of evaporation over the land surface still remains daunting tasks. The major uncertainty in estimating evaporation is from the parameterization method to partition the available energy into sensible and latent heat fluxes. Based on the principles of energy balance, equilibrium evaporation, and non-equilibrium thermodynamics, we proposed an alternative approach to estimating surface heat fluxes. The necessary inputs data are net radiation, soil heat flux, surface emissivity, land surface temperature, and surface air temperature. To verify the approach, we used available field data obtained on a flat, semiarid tableland in the mid-south of the Loess Plateau, China (35.2N, 107.7E). A flux and radiation observation system (FROS) was used to accurately measure radiation components and turbulent fluxes in the atmospheric surface layer. Our proposed approach reproduced the results agreed surprisingly well with that of field observation. Furthermore, uncertainty analysis revealed that the overall uncertainty in the estimates would be within 30W/m2, given an accuracy of land surface temperature within 2 degrees. Unlike surface resistance used in the contemporary theory of evaporation, all of the necessary input variables for the proposed approach have the rigorous physical meanings and can be measured in field easily. It is unnecessary for this approach to parameterize surface resistance, and thus avoid the uncertainty from the parameterization in the contemporary theory. The proposed approach is very simple but with firm physical basis and sounds very promising. Its simplicity makes it highly valuable to modeling, remote sensing, and other applications, in addition to fundamental theory of evaporation. With the development of the increased accuracy of satellite retrieval techniques for the necessary input variables, this method offers a practical way with a high accuracy for long-term monitoring of surface evaporation on either regional or global scales.

***Keywords:*** land surface evaporation, equilibrium evaporation, remote sensing

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**HW2005** **Oral Presentation** **4682**

# Inferring the spectral properties of river flows for hydrological model calibration in ungauged catchments

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***Alberto Montanari***

For gauged catchments, hydrological models can simply be calibrated by fitting the estimated spectrum of the simulated time series to the estimated spectrum of the observed time series. The calibration in the spectral domain, however, also offers new perspectives for the calibration of hydrological models for catchments with only very few observed data: The spectral properties of discharge can be obtained based on information provided by old, and sparse data that is difficult to include in a traditional calibration procedure or by regionalization or relevant parameters. Once an appropriate reference discharge spectrum has be estimated, the hydrological model can then be calibrated based on the spectral likelihood function proposed by Whittle. This estimator has nice statistical properties, it is namely asymptotically consistent and unbiased, and has been shown by preceding studies to satisfactorily perform for hydrological models. We illustrate the method and discuss new ways of identifying the spectral properties of discharge in ungauged or sparsely gauged catchments. A key question, herein, is the quantification of the prediction uncertainty induced by so calibrated models and we, therefore, also present our recent developments in this field.

***Keywords:*** rainfall runoff model, prediction in ungauged basins, whittle likelihood

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**HW2005** **Oral Presentation** **4683**

# Combining of Radar and laser altimetry, MODIS and GPS for the monitoring of flood events: application to the Diamantina river.

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A method of wetland mapping and flood event monitoring was developped on the basis of a satellite multi-sensor combination. The method has been tested on the Diamantina River, in central Australia, and which is the main tributary of the Lake Eyre. The river basin, located in a very arid zone, is affected every three-four years by flood due to extreme precipitation in the north-East of Queensland.The Diamantina river is an nearly ungauged basin. One such heavy rain occured in the beginning of 2004. The flood crossed the Diamantina river basin from upstram to the lake Eyre, hundreds of kilometers downstream in a period of less than two months. The Goyder Lagoon, located in the middle reach of the river, near the city of Birsdville, was chosen as a target to asses the potential of the method. This includes surface reflectance measurements from the MODIS Terra instrument to detect water on the area of study and monitor the spread of aquatic vegetation on a daily basis. A topography map of the Lagoon was obtained from the Icesat satellite. It has the capability to determine water level with high precision and high resolution along the satellite track, but on a flat, regular and dry surface, it can be also used to measure the vertical topography, which then can be derived as Pseudo digital Elevation model. To compute water level variations on continental surface, such lakes, rivers, or wetland, the radar altimetry is a usefull tool with time resolution ranging from 10 to 35 days depending on the satellite. Based on this different techniques it is hence possible to determine extent of water within a given area, as well as its volume of water evolution, which is a key parameter in the understanding of hydrological regime of big rivers, in particular in regions affected by large flood events. In ungauged basin this type of information may be used as input of hydrodynamical model.

***Keywords:*** flood, altimetry, modis

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**HW2005** **Oral Presentation** **4684**

# River Flow Simulation within Ungauged Catchments in Lebanon using Remote Sensing techniques

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Development of methodologies to achieve a priori parameter estimation of hydrological models is fundamental in ungauged basins, to reduce the number of parameters to be calibrated or to obtain parameter values where calibration is not possible. This study shows that a conceptual precipitation-runoff model can be applied to ungauged Lebanese watersheds and its parameters can be estimated using physical approach and remote sensing techniques. Most of the Lebanese coastal watersheds are affected by an important seasonal snow cover. The snowmelt contributes up to about two thirds of the total yearly discharge of the catchments. A conceptual model MEDOR, based on the snowmelt mechanisms using the standard energy balance approach and a degree-day melting module allows simulating the streamflow discharge of Nahr-el-Kelb catchment. The calibration of MEDOR is affected by the equifinality issue. The snowcover area and snowline were calculated by combining TM5 and TM7 satellite images, available over Lebanonevery eight days, with a digital elevation model, and field observations made every three days at altitude ranging from 1400 to 2300 m. The model is semi-distributed and divided into zones according to altitude. The snowline defines a variable surface versus time. Thus, it is possible to calibrate the model by comparing the simulated and calculated snowline. This approach was validated on two other Lebanese catchments considered as ungauged. The availability of the additional information of snowline altitude using remote sensing techniques constrain the solution space considerably, leading to reduced predictive uncertainty of the MEDOR model.

***Keywords:*** predictions, remote sensing, equifinality

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**HW2005** **Oral Presentation** **4685**

# Flood forecasting for ungauged locations: what approach is best?

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One of the most important and difficult challenges of hydrological science concerns modelling the river response to storm rainfall at ungauged locations for the purposes of flood forecasting. The choice of approach to pursue can vary from simple empirical transfer methods, through techniques using lumped model simplification combined with parameter association with catchment characteristics, to ones based on distributed physical-conceptual formulations specified through measurable spatial properties rather than catchment-integrated characteristics and parameters. Whilst the latter distributed approach is the more scientifically appealing, it is not straightforward to implement due to the complex nature of hydrological response, the question of how best to identify and represent the dominating processes, and the difficulty of using property measurements at the appropriate model scale. The presentation will critically review examples of the different approaches to flood forecasting at ungauged locations. It will then report on recent developments in pursuing the physical-conceptual modelling approach, developing formulations of only moderate complexity that have real operational value for flood warning. One form of the model links lateral soil water conveyance to terrain and soil properties and represents hillslope-channel interactions as a return flow from groundwater to surface water flow paths. The grid-based area-wide model formulation can be used for flood forecasting across a region of interest containing gauged and ungauged locations requiring warning of impending flooding. Future challenges for this type of modelling approach will be discussed in an operational flood watch and warning context.

***Keywords:*** flood, forecasting, ungauged

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**HW2005** **Oral Presentation** **4686**

# Development of a timestep-based performance measure for hydrological models

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The idea that a number of different models may model the observed data equally well is not a new one (see discussion in Beven, 2001 and Beven and Freer, 2001). This is the concept known as equifinality. This idea was developed into the Generalised Likelihood Uncertainty Estimation (GLUE) of Beven and Binley, (1992). Beven, (2006) commented on the need to improve the equifnality technique by defining levels of acceptability for model predictions; this issue is addressed in the present study. Traditionally models have been analysed using a performance measures, such as Root Mean Squared Error (RMSE). These measures only take into account the modelled output against the observed output for the entire data range. Whilst these measures can be very useful in giving an overall picture of modelled performance, they cannot give information about model performance at individual time steps or acknowledge observational error in a meaningful way. By contrast, a performance measure based on individual time steps will give information allowing the unknown observed values to be reconstructed from an ensemble of different model estimates. In this paper a model is used to give predictions of flow at a catchment gauge using real data. The results are then analysed using the method created in this paper, an extention of the GLUE procedure. The study area, data and model are presented as is anoutline of the methodology created. The paper suggests that we need to be more thoughtful about errors in our observations and be inclusive to these when we evaluate our models. K. Beven. A manifesto for the equifinality thesis. Journal of Hydrology, 320(1-2):18-36, 2006. K.J. Beven. Rainfall-Runoff Modelling: The Primer. John Wiley & Sons, Chichester, 2001 K.J. Beven and A.M. Binley. The future of distributed models - model calibration and uncertainty prediction. Hydrological Processes, 6(3):279-298, 1992. K. Beven and J. Freer. Equifinality, data assimilation, and uncertainty estimation in mechanistic modelling of complex environmental systems using the GLUE methodology. Journal of Hydrology, 249(1-4):11-29, 2001.

***Keywords:*** uncertainty, glue, hydrology

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2005** **Poster presentation** **4687**

# Estimation of regional parameter settings for ungauged regions of the Three Gorges Area (PR China) and application for operational flood forecasting

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Changjiang is the largest river in PR China as well as one of the biggest in the world. There are abundant rainfalls with uneven distribution in space and time. Floods are mainly produced from April to October by storm rains. Flooding disasters have been frequent. This study has been completed in the framework of Changjiang Flood Forecasting Assistance Project (2003-2007). The project aims to improve the current flood forecasting technology for the middle part of Changjiang River. The project is assisted by the Swiss government through the Swiss Agency for Development and Cooperation and by the Changjiang Water Resources Commission (CWRC). An operational spatially distributed flood forecasting system based on the HRU related model PREVAH has been developed and is installed for estimating discharge from poorly gauged contributing areas of the Three Gorges dam reservoir. This domain has an area of about 56000 km2. PREVAH is coupled in real time to the database of CWRC (data for now casting) and to the numerical weather prediction (NWP) model MM5 that provides operational 72h hour forecasts. The Daning River (2000 km) is the only reliable and representative gauged contributing basin within the investigated domain and served as pilot basin for calibration and sensitivity analysis of the tuneable model parameters. The results show that among 18 parameters, the model outputs show the significant sensitivity to the parameters controlling rainfall correction, infiltration and runoff generation. Due to reduced accumulation of snow in winter the parameters controlling snow cover modelling showed little sensitivity. An approximation of the contribution from the ungauged areas was obtained by subtracting the observed inflows from two large gauged upstream rivers (the main Changjiang River, gauge Chongqing, 866559 km and the Wujiang River, gauge Wulong 83035 km) to the observed value at the first gauge after the dam (Yichang, 1005501 km). For the six most sensitive tuneable parameters a simple test has been made in order to determine the range of values to be adopted for the more detailed analysis. 170 model runs with random allocation of the parameter values to each of the 34 sub-basins were then run. The 9 runs (5% of the total) with highest agreement to the approximated contribution of the ungauged area served for the assignment of the regional parameters to each basin (average of the 9 correspondent random values). This procedure was completed for the calibration period May 1st to September 30th 2005 (several minor floods) and verified for the corresponding periods in 2004 (major flood) and 2006 (hardly no flood up to September 4th). The application of this procedure to the parameter governing rainfall correction show that the Nash and Sutcliffe agreement between simulated contribution and estimated observed contribution from ungauged areas to the inflows of the Three Gorges Dam reservoir could be improved from 0.383 to 0.591 in the calibration period (2005) and from 0.315 to 0.429 in the verification period (2004) as compared to a simulation where the calibrated parameters from the Daning basin have been assigned without regionalization to all other 33 sub-basins. This paper will present the final results of this sub-basin regionalization for the proposed calibration and verification periods and present an analogue derivation of bias correction factors for the rainfall forecasts yielded by MM5 (flood season 2006). Comparisons have been made between model simulation (now-casting), observations and the one-day issued prediction (as there is no now-casting for the routine work) at Yichang station. The results shows that the model might be able to improve estimating the contribution of the inflows from ungauged areas

into the Three Gorges Dam reservoir, and consequently to benefit developing new strategies for the operational management of hydrological hazards at CWRC.

***Keywords:*** flood forecasting, ungauged basins, three gorges area

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**HW2005** **Poster presentation** **4688**

# Application of a fractal method in TOPMODEL based on downscaling

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Spatial resolution of digital elevation model (DEM) data usually has great effects on such topographic characteristics as slope, up-slope contributing area per unit contour length and topographic index (the logarithm of the up-slope contributing area divided by slope). This phenomenon is mainly attributed to terrain discretization effect that arising from dividing the terrain into different numbers of grid cells. The parameter calibration of TOPMODEL is influenced by DEM resolution because of the utilization of scale-dependent topographic index representing hydrologic similarity. In this study, the downscaled DEM from the coarse-resolution is used to compute the upslope area per unit contour length so as to remove the terrain-discretization effects by reducing the grid cell size. Meanwhile, a fractal method is introduced as an approach to account for the effect of DEM resolution on terrain slope. The variogram technique for the definition of fractal parameters is demonstrated to provide a relationship between slope and the spatial resolution of measurement. Standard deviation of elevation is found to be the most invariant property of different scale DEMs of the same area. A significant improvement on the slope estimated directly from the coarse resolution data is made by applying fractal parameters that are estimated from the standard deviation of elevation in a window of the DEM containing 3 rows and 3 columns to account for local variability in the surface. A case study of the Zishui watershed in China shows that the topographic index distribution derived from the DEM data at coarser resolution is similar to that calculated from finer DEM data and few effects of DEM resolution on model calibration is shown by applying this method. On the basis of the method above, the scale-invariant TOPMODEL is established and used to perform streamflow simulation in the context of different DEM resolutions. Results show that the calculated hydrograph based on the DEM data at 1800 m resolution is consistent with that based on the DEM data at 100 m resolution when the former uses the same parameter set as the latter. When TOPMODEL parameters are adjusted to optimize the model efficiency with applying the fractal topographic index calculated from the 1800 m resolution DEM in runoff simulation, the recalibrated parameters are little different from that calibrated with the DEM data at 100 m resolution.

***Keywords:*** topmodel, fractal, downscale

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**HW2005** **Poster presentation** **4689**

# Prediction of saturated areas in a mediterranean catchment finalized to flash-flood forecasting: ground observation vs. remote sensing techinques

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Initial soil moisture is the dominant control factors on flash flood development and, hence, its knowledge is the basis for a reliable and robust forecasting system. Derivation of soil moisture conditions both lumped and distributed approach can be performed by means of hydrological models which are calibrated against field data. Nevertheless, calibrated models suffer from uncertainty in predictions due to different sources as model structure, errors in measured data used for calibration, poor knowledge of parameter space. Model prediction uncertainty is, of course, higher in those catchments which are ungauged or poorly gauged. As matter of fact, in latter situations, hydrological prediction must be carried out using very simple hydrological models (hydrological parsimony, see Jakeman & Hornberger, 1993) using few pieces of reliable data, i.e. precipitation only. In this work results form the comparison of two methods for predicting soil moisture content and spatial extent of saturated areas are reported in order to explore their capabilities to reduce uncertainty and increase robustness in those predictions. The two methods presented here used, respectively, the SCS-CN approach in the modified form proposed by Mishra et al., (1998) and a remote sensing technique based on the well know Triangle Method (Gillies et al., 1997) are tailored for ungauged or poorly gauged catchments. The applied remote sensing technique provides map of the instantaneous distribution of a surface soil water content index by means of a comparison between a thermal band data and a vegetation index distribution. We used a dataset of NOAA-AVHRR multispectral images. The satellite images were geocorrected, calibrated and corrected from the atmospheric influence. The results were obtained by the application of the two methods to a semiarid ungauged catchments in the south-eastern part of Sicily, Italy.

***Keywords:*** soil moisture, remote sensing, flood prediction

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**HW2005** **Poster presentation** **4690**

# Efficient multiple sub-catchment calibration and validation of a distributed hydrological model

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The calibration of distributed hydrological models usually involves an estimation of a large number of parameters based upon the comparison between the simulated and observed streamflows sequentially at the sub-catchment outlet. However, these parameter values are usually unknown and non-unique, which leads to the uncertainty and equifinality problems and the sequential calibration of the parameters from upstream to downstream sub-catchments leads to the propagation of uncertainties. In this paper, we investigate the problem of calibration of distributed hydrological model in view of the parameter identification and computational time. The distributed hydrological model WaSiM-ETH based on the TOPMODEL approach is used for the study. The study is undertaken using the data from the Goeltzsch catchment in the North-Eastern Germany, which is a 150 km subcatchment of the Weisse Elster in the Elbe river basin. A simultaneous calibration of model parameters at all sub-catchments is undertaken so that the uncertainties do not get propagated between the sub-catchments. For the automatic identification of the model parameters, an extended gradient based search algorithm is used. The method is based upon the multiple start point search algorithm introducing a degree of randomness to the parameter search process so that it does not get trapped in a local minimum. In addition, uncertainty of the model parameters is investigation using Monte Carlo method. Different results of the study such as simultaneous and sequential calibration of sub-catchments, and single and multiple start point gradient based search algorithm are compared using the goodness of fit criteria. The optimised parameter sets are compared with the results of Monto Carlo analysis, which gives sensitivity and identifiability of the parameters as well as the associated uncertainty. The preliminary results of the study indicate that the multiple start point algorithm leads to better overall model performance compared to single start point method

***Keywords:*** distributed model, parameter identification, uncertainty analysis

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**HW2005** **Poster presentation** **4691**

# Investigation of the spatio-temporal patterns of soil-moisture in a headwater cachment with the spatial TDR-technology

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***Bronstert, Axel, Bauer, Andreas, Morgner, Markus, Reusser, Dominik***

The spatial distribution of soil moisture and its resolution in time is valuable information for soil science, agriculture and hydrology. However, estimation of spatial soil moisture patterns is often an unresolved problem specifically as the spatial scale increases: The integration volume of measuring device for soil moisture such as time domain reflectometry (TDR) probes is much smaller than the representative elementary volume (REV) soil moisture in heterogeneous soils. In addition, the TDR yields only single point measurements and thus averages along the wave-guide. Common ways to assess information on the space-time patterns of soil moisture for larger spatial scales using TDR are to perform either a distributed set of point observations using mobile sensors or a fixed set of TDR probes distributed in a catchment. The mobile system is restricted to field campaigns without continuous information, whereas the stationary one delivers high-resoluted temporal, data but the distance between the probes in the field is often too coarse to obtain any knowledge on the small-scale spatial pattern of the investigated area. The present study introduces an advanced TDR technology called Spatial TDR (STDR) which has the potential to overcome the above listed shortcomings of conventional TDR technology. STDR encompasses three components: a sampling three-rod-TDR, an appropriate wave-guide and an algorithm to reconstruct the soil moisture profile along the wave-guide. By connecting up to 40 STDR sensors via a multiplexer to a single sample, the representative soil moisture patterns may be observed at a scale of up to 900 m2 and at a time resolution of 10 min, which allows the determination of the geostatistical properties of soil moisture at the field scale. Within the scope of the experiment the STDR is tested in the headwater catchments of the upper Weisseritz in Saxony, Germany. One STDR clusters is installed in the meso-scale catchment at sites with different initial characteristics in regard to soil type, vegetation and topography, to produce a time series of soil moisture data for up to two years. We expect a better understanding of the governing processes on how different initial conditions of the sampling plot affect the probability density function of soil moisture. The thus measured soil moisture data sets of the network of STDR clusters, deliver the statistical and geostatistical properties as required for the interpolation of spatial patterns. The derived information can also be used to estimate as spatial ground truth data for the assessment of remote sensing imagery. We intend to introduce the technology of STDR as well as applications of STDR to assess soil moisture dynamics at different spatial scales ranging from the plot to the catchment scale. It is expected that the knowledge of the delivered soil patterns as derived by STDR technology helps to advance the ability of current hydrological models to forecast flood events with operational hydrological models.

***Keywords:*** soil moisture pattern, spatial tdr

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**HW2005** **Poster presentation** **4692**

# Comparing three hydrologic real-time correction methods

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The three hydrologic real-time correction methods: the combined method of recursive least square (RLS) and autoregressive (AR) model, ANN method (BP model) and wavelet neural networks (WNN) are used in this paper. Some comparisons are made among the three methods. Forecasting model is the core of a flood forecasting system. But forecasting errors always exist in such a system, because of the inaccuracy of the model and the errors in observation of input and output variables. Moreover, the parameters of a flood forecasting model is the average optimal values reflect the former measured data, so forecasting errors will appear when the practical situation deviates from the average situation. We can see that the accuracy of the model can be efficiently improved if the parameters of the model could be real-time corrected according to the new received information. There are mainly three conventional hydrologic real-time correction methods: AR model of errors, RLS method and Kalman filtering method. In practice, AR model is often combined with RLS method or Kalman filtering method in hydrologic real-time correction. In this paper, the combined method of RLS and AR model is utilized. In recent years, artificial neural networks(ANN) has come into use in the field of hydrologic real-time correction. This is largely depended on the ANNs powerful ability of self-teaching. A three-layer BP(Back Propagation)-ANN model is used in this paper. Wavelet neural network (WNN) is a new structure of ANN. It has both the advantage of wavelet and the ability of self-learning as ordinary ANN. Wavelet has the feature that the series of the wavelets decomposition after dilation and advection can approach a function precisely. In this structure, the conventional nonlinear function in the hidden layer of ordinary ANN is replaced by wavelet primary function, and the weights and thresholds from input layer to hidden layer are replaced respectively by dilation factors and advection factors of wavelet primary function. After proper training, a WNN based on a few of series of the decomposition of wavelet can get the optimum solution efficiently. Based on the theory of WNN, a three-layer wavelet-BP-ANN is utilized is this research. Calculations are made using the three hydrologic real-time correction methods respectively. Comparison is also carried out among those methods.

***Keywords:*** rls, ann, wnn

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**HW2005** **Poster presentation** **4693**

# Towards more Efficient Calibration Schema for HBV Model

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The calibration of a Rainfall Runoff Model may be remained to a global optimization problem of a function that calculates the distance between observed and calculated model outputs. The SCE-UA is one the most effective and efficient optimization method and is adequate to this problem which is characterized by well-known difficulties as interdependence between parameters, indifference of objective function, local optima, scale problems parameter. The objective of this work is to improve efficiency of the global optimization method SCE-UA (Duan et al. ,1992) applied for calibration of the HBV Rainfall runoff model in lumped case. Evaluation of the model predictive uncertainty is performed through the objective function RV = R - |RD|, where R2 is Nash Sutcliffe coefficient related to discharges, w weight and RD relative bias. Three techniques are tested: Parameter space transformation, the SCE-UA algorithm modification, include p-KNN approach to estimate the objective function. The Logarithmic transformation of the recession coefficients gives an improvement of the convergence speed of the optimization algorithm of about 20 %. This may be due to the effect of the smoothing of the objective function, as well as the better sampling of initial population by a better exploration of all decimal classes of parameter. We have chosen to use the modification of the SCE-UA algorithm by adding in Simplex Evolutionary Algorithm a shifting step of the reflected or contracted point to the best point (Mutill et al., 2004). This modification makes an improvement of effectiveness and efficiency of SCE-UA. Thus, the improvement of the convergence speed is about 30 %. We propose also, to apply the p-Knn technique to estimate the objective function. So, the objective function is calculated by an interpolation using nearest neighbors in the normalized parameter space with Euclidean distance. The use of these three techniques gives at the end an optimization algorithm 2 to 3 time faster then the initial SCE-UA. The modified algorithm is applied to theoretical and practical cases in several catchments under different climatic conditions: Rottweil (Germany) and Tessa, Barbra, and Sejnane (Tunisia).

***Keywords:*** calibration, hbv, sce ua

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**HW2005** **Poster presentation** **4694**

# Modelling the recession limb of the hydrograph development of the low flow forecasting models

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The Sava River runs 945 km from northwest to southeast beginning in Slovenia, continuing over Croatia and Bosnia and ending in Serbia and Montenegro at its confluence with the Danube in Belgrade. It contributes approximately 25% of the Danubes total discharge and has a drainage area of approximately 96400 km2 which presents 15% of the Danube River Basin. In Slovenia the Sava River Basin comprises the central part of the country. There are four in-stream hydropower stations situated on the Slovenian part of the Sava River. Good and accurate longterm low flow forecasts are especially important in the fields of sustainable water management, water rights, water supply management, industrial use of freshwater, optimization of the reservoir operations for the production of electric energy and other water-related disciplines in the Sava River Basin. Basic approach to studying low flows is to analyse the recession parts of the streamflow hydrographs. Within the streamflow hydrograph, recessions are a sequences of decreasing flows during periods of no or little precipitation. The dynamics of the flow rates on the recession part of the streamflow hydrograph is usually modelled as: $Q_{t+n} = Q_t \cdot e^{(-k \cdot n)}$ , where $Q_{t+n}$ is flow rate at n-days after the time of the forecast t, $Q_t$ is the flow rate at the time of the forecast, e is the base of the natural logarithm function, k is the recession constant and n is the number of days in advance for which the forecast is made. By using the decision trees machine learning method and analysis of the recorded recession streamflow data we modelled the recession 'constant' k as being a function of the flow rate at which the 7-day low flow forecast is made and the decrease of the flow rate from the previous day. Low flow forecasting models for most of the Sava River's Slovenian tributaries were developed and verification of the results show really good results and improved accuracy in comparison to low flow forecasting models in which a single numerical value is used as the recession 'constant'.

***Keywords:*** lowflow, machin elearning, forecast

**(H) - IAHS -** *International Association of Hydrological Sciences*

**HW2005** **Poster presentation** **4695**

# Results of the Mackenzie Basin runoff assessment project

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Various development projects are planned for the Canadian Arctic in the coming years, including a major pipeline to link the oil and gas fields of the Mackenzie Delta to southern Canada and the United States. The projected path for this pipeline is along the Mackenzie valley, this is a vast area with little current development and consequently very few climatological stations. The pipeline would cross many rivers, a majority of which have no streamflow gauging stations. Knowledge of the flow of these rivers will be crucial in not only the feasibility assessment stage of the project but also in the actual design of the pipeline should it be approved. Moreover, water quantity estimates are required for assessing potential water quality and wildlife habitat issues. This project focused on the simulation of distributed runoff within the Mackenzie basin with the goal of simulating the streamflow characteristics of the all rivers within the basin. The goals of this project fit in well with the International Association of Hydrological Sciences (IAHS) decade on Predictions in Ungauged basins (PUB). The Canadian arctic is a vast and largely ungauged area. In order to make estimates of hydrological variables in this region, the data that are collected must be used in the most efficient way. Two different hydrological models were used in this study the WATFLOOD distributed hydrological model and MESH the Modlisation Environnementale Communautaire Surface and Hydrology model from Environment Canada. Three forcing data sets were used to run the hydrological models: observational data, NCEP/NCAR reanalysis 1 data, and ECMWF ERA-40 reanalysis data. All of the forcing data sets were at a different scale than the hydrological models and thus had to be interpolated, this interpolation was done using both a simple inverse distance technique as well as more intensive technique based on regressions using physiographic parameters. The different methods for interpolation were evaluated using output from the hydrological models. The models were run for a 40 year period between 1960 and 2000 allowing for the maximum overlap between datasets. It was generally found that the larger basins had a higher Nash coefficient than smaller basins. The following distributed hydrological parameters were extracted from the runs: runoff, Evapotranspiration, soil moisture, soil temperature, and snow water equivalent. A trend analysis was then done for each grid of the model using a Man-Kendall analysis. This allowed for a distributed display of the trends for all the hydrological parameters using each of the input datasets. An uncertainly analysis was then carried out on the both the input data sets and the model parameter sets allowing the confidence in the model results to be determined. Finally, flow frequency diagrams, which included uncertainty, were created for the many ungauged rivers that flow into the Mackenzie. These diagrams as well as the other distributed hydrological parameters created during this study will aid in the environmental assessment of future projects in the Canadian arctic.

***Keywords:*** mackenzie, modelling, runoff

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**HW2005** **Poster presentation** **4696**

# Development of an observation strategy to mitigate flash flood forecasting uncertainty

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Lack of observations hamper advances on understanding the hydrological processes at work during flash floods, and, consequently, on forecasting the stream response to extreme precipitations. Observational limitations mainly stem from the fact that flash floods develop at space and time scales that conventional observation systems of rain and river discharges are not able to monitor. As these events are locally rare, they are also difficult to capture during classical field-based experimentation, designed to last a few months over a given region. In this sense, flash flood forecasting exemplifies the ungauged basin problem under extreme conditions. The roadmap to provide the observations needed to advance flash flood research is through the development of an observational strategy capable to provide high-resolution data on storm and stream/landscape response during flash floods. The main motivation of the strategy is to observe these locally rare events wherever they occur in a region and not only in places where refined observation system actually exist. The strategy develops on three pillars: availability of good quality radar data; availability of good quality and relatively dense conventional hydrometeorological data; execution of post-event field surveys to provide indirect estimates of event peak discharges. The paper provides feedback from the first applications of this observation strategy to some major flash flood events, occurred in Northern Italy. Data from these events are used to investigate the meteorological and hydrological processes at work during flash flood, to examine their inherent scales, and to identify their best use to reduce uncertainties in flash flood forecasting.

***Keywords:*** flash flood, pub, radar

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**HW2005** **Poster presentation** **4697**

# Choice of an appropriate objective function for optimisation and of performance evaluation criteria in hydrological modelling

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Automatic optimization is an important tool in identifying the best set of the parameters of a hydrological model for simulating the process of rainfall to runoff transformation whether the model is of the physically inspired conceptual type or has a parametric black-box structure. The success of such models in fulfilling their desired purpose depends on the choice of objective function used as well as on their structural adequacy. As regards the objective function, the conventional approach is based on the minimization of the global Mean Square Error (MSE). Modelling with such an objective function, while it may produce a good overall fit of the time-series of flow data, often fails in satisfactorily simulating the magnitude and the time-to-peak of the critical high flow values. If flood forecasting is the primary objective, then the use of a weighted least squares objective function emphasising the range of high flows may be more effective than its un-weighted counterpart. For water availability studies involving rainfall-runoff simulation, where volume conservation is the critical constraint, an objective function incorporating an Index of Volumetric Fit (IVF) may be more appropriate. Different objective functions are considered in this study and their suitability for various model requirements is outlined. Having calibrated and run the model with the selected objective function, its performance still needs to be evaluated for deciding on the extent to which the model fulfils its purpose. Some widely-used model performance evaluation criteria, i.e. efficiency indices or measures of goodness of fit, are reviewed. Their applicability in continuous flow simulation, event modelling, lead-time flow forecasting and regional analysis for flow prediction in ungauged catchments is discussed. For drawing inferences on some of the modelling aspects considered in this study, the lumped conceptual Soil Moisture Accounting and Routing (SMAR) model is applied to the Brosna catchment located in the centre of Ireland.

***Keywords:*** objective function, efficiency index, optimization

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**HW2005** **Poster presentation** **4698**

# Conceptual hydrological models calibration on pub conditions: regional characterization of extreme events in Argentina

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The basin of the Popopis river (8000 km) is in the west-center region of Argentina. The hydrological information available for this basin is mainly concentrated over the upper sector of the basin, where a remote rain gauge system is located. In addition, others hydrological data are available from information registered on four dams located throughout the main channel. The quantity and quality of the available information are not enough to characterize the meteorological and hydrological phenomena happened in the basin with similar conditions to those that characterize poorly gauged basins (PUB). In the last years, the Poppies River has caused severe floods events over the Argentinean central region, which presents great economic and social importance for the country. For that reason, a project is underway to build El Chaar attenuation floods dam in the lower portion of the basin. This article summarizes the actions completed in relation with the search and treatment of additional information to those provided by the remote rain gauge system, in order to model two severe hydrological events happened in January 2000 and March 2001, respectively. The final objective pursued in the analyses was to improve the understanding of the hydrological phenomenon happened in the basin in order to reduce the uncertainties associated with the project of El Chaar dam. The severe event happened in January 2000 was originated by a sequence of mild rainfall events which generated a significant saturation condition in the basin. The second severe event happened in March 2001 presented extraordinary characteristic at local level, with rainfall depth values on the order of the PMP value estimated by statistical methods (300 mm in 10 h). These conditions generated the highest flow peak registered in the basin (1140 m/s) since 1970. The analysis reported in this article also included the use of an artificial neuronal network that combined flow and precipitation data and the analysis of regional values of maximum specific flows.

***Keywords:*** pub, anns, simulation

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**HW2005** **Poster presentation** **4699**

# Effect of temporal resolution of NDVI on potential evapotranspiration estimation and hydrological model performance

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Evapotranspiration as one of key inputs to hydrological model is difficult to measure and predict. There are many evapotranspiration models have been developed, from the single climatic variable driven equations to the energy balance and aerodynamic principle combination methods. But these models, either estimation are poor or input data are difficult to collect. However, the ShuttleworthWallace (S-W) model (M.C. Zhou et al., 2006) is an exception which is physically based and all required data are publicly available, so it can be applied to the data-poor or ungauged basins. Normalized difference vegetation index (NDVI), one of important needed data to S-W model and obtained from remote sensing information, was demonstrated to be sensitive to changes in vegetation conditions and directly influenced by the chlorophyll absorption of the sun radiation. In this paper, monthly and 10-day NDVI data set were used respectively to estimate the potential evapotranspiration during from Jan 1985 to Dec 1987, analyzed the difference of two calculate results and compare with pan measurement. Also investigation is extent to evaluate the effect of two potential evapotranspiration on a physically based distributed hydrological model (BTOPMC) performance. The Huangnizhuang catchment is selected for this study which lies in Shiguan River Basin. A 3-year historical dataset of daily precipitation and discharge, monthly time series data of CRU TS2.1 climatic variables, DEM, IGBP land cover classification and two different temporal resolution NOAA-AVHRR NDVI etc. were used in the analysis. Model parameter values were manual calibrated and model performance was evaluated by the Nash-Sutcliffe efficiency and the volume ratio of simulated to observed discharges. The results show that: both annual and monthly PET which estimated by 10-day NDVI is smaller than ones by monthly NDVI. Annual PET relatively decreases 9.77-13.64% and most monthly PET decreases 3.28-17.44% over the whole basin. PET0 has the same trend with PET. The correlation between PET of estimated by 10-day NDVI and pan measurement, correlation coefficient (R2) is 0.835, is better than one by monthly NDVI calculate which R2 is 0.775. Two potential evapotranspiration drive BTOPMC model with the same group of parameter values get the different performance. But after calibrate respectively, model performance which using 10-day NDVI is no better than one using monthly NDVI. So, the temporal resolution of NDVI has significant effect on potential evapotranspiration estimation, but on hydrological model performance is trivial.

***Keywords:*** ndvi, evapotranspiration, hydrological

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**HW2005** **Poster presentation** **4700**

# Research of the features of formation of soils hydrological regime on the urban territory using experimental data

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Formation of water regime of the city territories is rather actual problem because the development of cities leads to radical restructuring of water balance of extensive parts of the land. As a consequence, it also leads to essential changes of all parameters of hydrological regime of the city territory. These changes are frequently accompanied by unfavorable engineering consequences, which demands the development of methods of the forecast of their development. So, for example, higher concentration of soil moisture on unpaved parts of the city in comparison with natural conditions causes the increase of infiltration, and then ground water level rise and flooding of the city territory, which are intensified due to outflow from water transfer communications. Absence of regular observational data about the formation of water regime on the urbanized territories, and also data of experimental researches, taking into account specificity of city territories, complicates the solution of forecast problems. Significant difficulties also deal with organization and carrying out of experimental researches in the cities. In recent years the authors carried out theoretical and experimental researches of formation of water regime on the territory of Rostov the Great City -monument of old Russian culture (Upper Volga basin), where negative aspects of urbanization worsened by natural features, such as city location on the lowest point of Rostov depression were revealed. Results in the field of modeling of surface runoff and characteristics of moisture transfer in unsaturated zone were obtained for built up part of the city. With this purpose continuous monitoring of water objects and environment was organized. Thus besides continous standard (meteorological) and special (hydrological) observations we carried out experimental researches on studying regularities of hydrophysical characteristics of soils of the cultural layer. Results of such researches on the city territories are practically absent. It was shown, that these characteristics possess spatial variability and can essentially differ for various objects. Experimental researches were performed on different types of city landscapes (monuments of ancient culture, city park, square in the city center, private inhabited sector (vegetable garden)) and in comparison in suburb (zonal soils). Significant range of fluctuations of hydrophysical characteristics of soils both on depth of soil profiles, and on the territory of the city was revealed. Within the city boundaries they change in spurts, to the contrary for zonal soils. Permeability of soils as a whole is insignificant. So it is possible to consider them as water permeable. This characteristic also significantly varies on depth of soil profiles and on the territory of the city. As a rule, the highest water permeability is character for surface layers. Due to essential cleavage of soils the curves of water-retaining ability, which reflect soil structure features and describe the energy of dependencies of different types of moisture in the soil are also various. Essential distinctions in soil hydrological constants (wilting moisture, total and least moisture holding capacity, etc.) for experimental soil profiles were found out. Obtained characteristics of soils allow to consider them as a new soil type, corresponding to the term

***Keywords:*** soil, water, urbanisation

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**HW2005** **Poster presentation** **4701**

# Critical Analysis of Water Quality Modelling Calibration using Genetic Algorithm Case Study of Iguau River at Metropolitan Area of Curitiba

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One of the most difficult phases in a water quality modelling project is its calibration. The calibration requires a better attempt to represent the physical, chemical and biological nature of a water body, just to assure a consistent representation for furture water quality forecast. This is not an obvious activity and can represent one difficult process to better assess the physical, chemical and biological characteristics of a river system, specially very polluted water systems. It relies on a better combination of field data (hydrology, hydraulics and water quality). Considering that these activities are time consuming and requiring structure for field and laboratorial activities, is not common a consistent representation and a clear explanation of these activities in the literature. In such a context, the water quality modelling strategy for The Iguau River has been based upon a calibration technique using genetic algorithm. This is a first serious attempt to calibrate a water quality model in a very polluted water system using this technique in described in Brazilian Rivers. This paper, presents a critical analysis of the experience at the Iguau River highlighting that distinct criteria can induce different results that can affect the decision support system model.

***Keywords:*** water quality, genetic algorithm

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**HW2005** **Poster presentation** **4702**

# Application and Comparison of YHyM Model and Xinanjiang Model in a Mountainous Watershed

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In this research, two models, YHyM model and Xinanjiang model, are applicated in Huangnizhuang which is a mountainous watershed and the performance of two models are compared. The Yamanashi Hydrological Model (YHyM) was developed to meet requirements such as calculating water balance in a watershed, improving simulation accuracy et al. to better practice the watershed management. The YHyM has already been applied to many large basins, for example, Mekong River Basin (795,500 km2) in Vietnam, Upper Minjiang Basin (20,000km2) in China and Kali Brantas Basin (11,800km2) in Indonesia, as well as mesorscale basins, for example, Fuji-kawa Basin (3,500km2) in Japan and Naka River Basin (3,270 km2) in Japan. YHyM maily has two parts: BTOPMC (Block-wise use of TOPMODEL and Muskingum-Cunge method) and the sub-models. BTOPMC includes following submodels: (1) Topographic model; (2) Runoff generation model; (3) Flow Routing model; (4) Parameter identification model. The sub-models include: (1) Meso-scale precipitation model; (2) Potential evapotranspiration model; (3) Snow and soil freezing model; (4) Sub-surface model; (5) Sediment movement model; (6) Inundation simulation model; (7) Water quality model; (8) Water use/control model. Xinanjiang model was developed by Professor Renjun ZHAO of Hohai University in China. It also includes following submodels: precipitation model, evapotranspiration model, runoff generation model, slope flow concentration model and channel concentration model. Huangnizhuang watershed lies in the south China. Data of 6 years are employed to simulate daily hydrological processes using two models, including DEM, precipitation, discharge, evaporation, normalized difference vegetation index, monthly average mean daily temperature, monthly average diurnal temperature range, monthly average actual vapor pressure, monthly average cloud cover, monthly average wind speed, monthly average extraterrestrial radiation, monthly average daylight duration. The comparison Index are and Nash%. The former reflects the water quantity of simulation and the later reflects the accuracy of flood peak simulation. The is from 0.90 to 1.04 of YHyM and 0.96 to 1.07 of Xinanjiang model. The Nash% is from 0.60 to 0.82 of YHyM and 0.66 to 0.88 of Xinanjiang model. From these results, it is found that the Xinanjiang model performs a little better than YHyM in Huangnizhuang watershed. But it is can not concluded that Xinanjiang model is absolutely better than YHyM. Xinanjiang model is a lumped model, while YHyM is a distributed model. Thus, YHyM dependents on the data accuracy more than Xinanjiang model does. That is one of reasons why the Nash% of YHyM is less than that of Xinanjiang model. The sensitivity analysis for parameters of YHyM is also carried out in this research.

***Keywords:*** yhym model, xinanjiang model, application and comparison

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**HW2005** **Poster presentation** **4703**

# Parameter optimization in flood routing mathematical models

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Mathematical flood routing models need to be calibrated before they can be applied to reproduce flood behavior in a river. This stage of the study is often tedious and sometimes complicated, as the river response to an input may vary according to the magnitude of flood and other flow characteristics, river properties and so on. The correct identification of the model parameters assure a reliable flood forecast along one or more river stretches. The first attempt to identify the parameter values is usually a trial and error procedure, regarding the flood peaks and their time of occurrence at several river cross sections. However, when one knows typical parameter values, it is possible to take a set of initial estimative and get into an automatic algorithm based on some kind of optimization technique. The calibration procedure is often carried with measured flood values along river stretches, allowing the following task of routing floods that have not yet occurred, or floods that have been predicted by some other approach. Of course, the boundary conditions are different in calibration and prediction stages. In this work, the influence coefficients algorithm for three parameters is developed and employed to optimize the evaluation of the hydraulic radius exponent and two parameters related to the variation of roughness coefficient with flow depth. A case study at Uruguay River in Brazil shows how this procedure can be used to perform an automatic calibration of an implicit finite differences flood routing mathematical model.

***Keywords:*** parameter, identification, optimization

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**HW2005** **Poster presentation** **4704**

# Reduction of uncertainty in urban catchment by physically based distributed flood runoff model using geographical feature data

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Urbanization has been a universal phenomenon since the later half of the 20th century. With the progress of urbanization, the water retention capacity of the land has declined because of the increased amount of impervious surface areas and the extension of sewage system. As a result, the flood reach hour is significantly shortened and the flood peak discharge is drastically increased in urban catchments. Urban catchments are formed as very complicated artificial structures, such as buildings, houses, roads, parking lots, parks, waterways, underground sewer system and so on. Mainly grid based distributed models are used as rainfall-runoff models not only in mountainous and rural catchments, but also in urban catchments due to their simplicity and the limitation of available information of the catchments. Grid based models, however, are not appropriate for urban catchment modeling, because those models greatly average the land use property into each grid cell ignoring individual land structure property of the urban catchment. Recently, with the progress of GIS (Geographical Information System) technology and the development of the related geographical data, digital information on road network, grid based land use, sewer and drainage system has been rather easily available. GIS information on geographical feature, such as individual building, house, parking lot, park etc., for rainfall runoff modeling has also been prepared in the large cities. Physically based distributed flood runoff model using geographical feature data can exactly trace the rainfall runoff process in urban catchment. The physically based distributed model presented here takes advantage of GIS information of geographical feature data to take precisely into account of impervious and pervious areas as individual structure or segment of the urban catchment. The physically based runoff model is simulated by one-dimensional hyrodynamic modeling incorporating the interaction between the sewage system with manholes, the river system, the streets, and the areas flooded with stagnant water. The model uses two types analytical models: hydrological models which simulates surface runoff from rainfall, and hydraulic models which describe river flow, sewer pipe flow, and the flow of storage water on the surface of streets and residential blocks. The computation of the surface runoff from rainfall is carried out by a standard kinematic wave model. A surface runoff hydrograph is computed for each single area. Runoff hydrographs from each single area are then used as input for the hydrodynamic model, simulating flows in the pipe and street systems. The distributed runoff model is applied to a flood-prone urban catchment in Tokyo with actual rainfall event. It is found that the model can simulate both the physical rainfall-runoff process as well as inundation in the basin in a satisfactory way. Then, the reduction degree of uncertainty by this model, in this case taking runoff prediction error as its index, is investigated compared with a grid based model.

***Keywords:*** gis information, urban flood runoff, reduction of uncertainty

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**HW2005** **Poster presentation** **4705**

# From the micro-topography organisation, via runoff modelling, to water reservoir management: the Male Basin in Mauritania as a case study

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We study the poorly gauged Male basin in Mauritania, which extends over 800 km.This basin is located in the Sahalian region with variable annual precipitation ranging between 150-350 mm/yr. It is a place for many semi-nomad populations that depend on the limited water resources for their basic agriculture-base economy. In the 1960's the local population built a dam on the main basin outlet forming a large seasonal reservoir, which is critical for their subsistence. In order to help the local people manage effectively their limited water resources, we study the hydrology of the basin by conducting in-situ measurements, analyzing remote sensing observations, and constructing a hydrological model. Our study includes two new techniques that significantly improve the model results in this poorly gauged basin. First, we introduce new remote sensing observations, both optical and radar, allowing us to better determine the details of the basin's morphology, which consists of many variable-scale depressions. Second we develop a new calibration-free production function, enabling us to produce more accurate models with the limited available measurements. This study holds two scientific objectives: i) obtain a general law of micro-basins size distribution, which assume to follow a simple statistical law; and ii) model the water flux, which discharges over the micro-basin thresholds towards the hydrographic network. This approach is particularly important in arid and semi-arid climates because of the great variability of both annual rainfall and precipitations intensities. It appears that for similar total annual rainfall in two successive years, a given dam reservoir can be filled depending on the intensity of main rain events. In most hydrological theories, water drainage is modelled by the combination of two functions: i) a production function, which transforms the total watershed rainfall into an effective rainfall; and ii) a transfer function, which transforms the effective rainfall falling at a given time, into a time distribution of the discharge at the outlet. In order to improve model accuracy, we develop a new calibration-free, topographically-based production function. The new production function takes into account both an infiltration law deduced from measurements and the watershed's micro-topographic organisation. In general, watershed morphology consists of a large number of micro-basins linked by superficial micro-talwegs, which form a hydrographic network following the topographic gradient. This new production function was successfully applied to a hydrological study in Indonesia, where there are only very small catchments (10 to 60 hectares) in tropical climate. In the current study of the Male basin in Mauritania, we expand the model to a larger watershed. The final technical goal is to simulate the discharge of rivers (vs. oueds) in function of time in order to manage the water reservoir.

***Keywords:*** micro topography, modelling, simulation

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**HW2005** **Poster presentation** **4706**

# Data error and highly parameterized models

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Methods to develop and calibrate highly parameterized models are now readily available to groundwater modelers. These methods are attractive because they often yield close fits to observations and the parameterized distributions often have an intuitive appeal. In ground-water models, they are most often used to represent hydraulic-conductivity distributions, but can be used to represent other spatially and temporally distributed characteristics. It can be argued that if the distributions vary spatially, methods that allow such variations should lead to better inference about them. However, a concern with highly parameterized models versus parsimonious methods, is whether the simulated variations reflect reality and, if not, whether they diminish, rather than enhance, the predictive capability of the model. They would not reflect reality, for example, if they were produced in response to observation error. This work investigates this issue by evaluating the effect of observation error in a synthetic model for which "truth" is known. In models of field and synthetic systems with local variations in the parameterized characteristic, the fitting of observation error can not easily be separated from the accurate representation of local variations. Here, the fitting of observation error is isolated by using a synthetic test case in which there are no local variations. Many of the results are consistent with the theory behind highly parameterized inverse methods. However, the results illustrate surprising occurrences and levels of (a) parameter error and (b) model fit to the single flow observation, as the highly parameterized model was instructed to match the regression observations first to a level consistent with the observation error, and then more closely by reducing the objective-function target. To help alleviate these problems, the following procedures are suggested: (1) regularly compare the resulting simulated variability with hydrogeologic evidence of variability, (2) check how highly parameterized models match influential observations, and (3) identify influential observations and correlated parameters using parsimonious overlays of highly parameterized models. Suggestion (1) allows knowledge about the continuity of the subsurface to be included in the regression results. Such "soft" knowledge is often available in the form of hydrogeologic investigations of the shallow subsurface typically of concern in ground-water investigations.

***Keywords:*** parsimonious models, higly parameterised models, mode calibration

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**HW2005** **Poster presentation** **4707**

# Hydrological modelling of an andean watershed in South-Central Chile: partial validation using the MODIS snow product

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***Patrick Debels, Francisco Romero, Hernn Alcayaga***

Water resources from the Biobo Basin (24.400 km2) are of high importance for the Chilean economy. Located in Central Chile between 3645 - 3849 S and 7100 - 7320 W, Biobo is the third-largest Chilean Basin and stretches from the continental divide in the E (Andes, Chilean-Argentinean border) to the Pacific Ocean in the W. The basin is influenced by the temperate climates of the South as well as by the Mediterranean climate of Central Chile. The flow regime of the Biobo River is pluvio-nival, with a very marked difference in discharge between dry and wet season. During the dry period, snowmelt from the high Andes constitutes an important contribution to river flow. The rainfall-runoff modelling application described in this paper focuses on the Lonquimay, a sub-basin of the Biobo located in the Andes between 880 and 2533 m.a.m.s.l. (3820 3841 S and 7113 - 7135 W). This sub-basin has a surface area of 455 km2, which corresponds to approximately 1.86% of the total area of Biobo. The selection of the sub-basin was based on: the strategic importance of nivo-pluvial sub-basins for regional water management; the availability of meteorological stations (precipitation and temperature) within or near to the sub-basin; the availability of limnimetric data at the outlet; and the absence of artificial flow modifications (e.g. irrigation abstractionsand reservoir operations) which would make model calibration & validation more difficult. The Soil and Water Assessment Tool (SWAT) was chosen for modeling the basin hydrology. Prior to model calibration, a sensitivity analysis was executed using the Latin Hypercube Sampling- One at A Time (LH-OAT) method: this was first done by considering 28 parameters, and then followed by an analysis which included only the parameters involved in the SWAT snow routine. The model was then calibrated for the period 1995 -1998, using the PARASOL automated calibration procedure implemented in SWAT2005. Validation took place using monthly output data from the period contained between 1999 2002, together with MODIS snow product data (MOD10A2) from March 2000 until December 2002. Calibration results show a good model performance for runoff data at the monthly level (Nash Sutcliffe of 0.81). However, during validation model performance is only satisfactory (Nash Sutcliffe of 0.56). In the absence of snow water equivalent measurements for the study area, the available MODIS snow products were used to evaluate how well the monthly presence/absence of snow cover in the models 45 analytical units is represented by the SWAT snow module. Results indicated that in average on a yearly basis, for 16% of the 45 * 12 analytical units the MODIS Image shows snow where the model does not, whereas in 5.3% of the cases MODIS does not show the snow modeled by SWAT.

***Keywords:*** swat, snow, modis

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**HW2005** **Poster presentation** **4708**

# Identification of model structure stability through comparison of hydrologic models

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An ideal hydrologic model with a reliable model structure should have an identical optimal parameter set without regard to any objective functions. Such hydrologic model with the proper model parameter set is expected to maintain high degree of accuracy for simulated hydrographs when applying various types and magnitudes of flood events. This means model structural stability is measured by means of influence of objective functions and magnitude of flood events on model parameter sets. From this point of view, model structure stability is measured for different kinds of hydrologic models. In the presentations, a framework to assess the model structural stability is presented. Three different kinds of objective functions, Simple Least Squares (SLS), Modified Index of Agreement (MIA), and Heteroscedastic Maximum Likelihood Estimator (HMLE) are adopted. At the catchment with 210 square kilometer, different magnitudes of five flood events are selected and model parameter sets are identified using Shuffled Complex Evolution (SCE) Algorithm for different kind of hydrologic model, a distributed hydrologic model and a lumped hydrologic model, those have the same number of parameters. The results reveal that the identified parameters set of a distributed model used here shows more stable than a lumped model used here. We emphasize the measurement method to access parameter stability is well utilized to evaluate the appropriateness for hydrologic model structure.

***Keywords:*** structure stability, parameter uncertainty, uncertainty measurement

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**HW2006** **4709 - 4755**

## Workshop
## New Avenues for Contemporary Water Resources Management (Sponsor ICWRS)

**Convener :** Dr. Joerg Dietrich
**Co-Convener :** Dr. Christos Makropoulos

Floods, droughts, water scarcity and water contamination are already prominent problems in many parts of the world, but will become even more so in the future. In the past, many different tools have been used for simulation and optimization of complex water resources systems in order to provide an improved basis for decision making. The continuing evolution of information technology (hardware and software) creates a good environment for the transition to new tools. Application of the systems approach to water resources planning, management and operations has been established as one of the most important advances made in the field of water resources engineering. Based on the lessons learned, this workshop provides an overview of the tools to be used in the future. Two paradigm shifts are shaping the future: the first focuses on the complexity of the water resources domain and the complexity of the modelling tools in an environment characterized by continuous rapid technological development; the second deals with water-related data availability and natural variability of domain variables in time and space affecting the uncertainty of water resources decision making. The workshop will address the role of new tools for the effective management of water resources. Contributions are invited on a wide spectrum of techniques from object oriented dynamic simulation to spatial optimization under uncertainty, including application case studies. In addition, there will be a focus on the utility of (a) system dynamics simulation tools; (b) evolutionary optimization tools; (c) integration of fuzzy analyses with simulation and optimization tools; and (d) spatial extension of simulation and optimization tools.

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**HW2006** **Oral Presentation** **4709**

# Impact of Water Pollution and Water Shortage on Economic Development of the Haihe River BasinDevelopment of the Haihe River Basin

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Haihe River Basin is one of the seven major river basins, which are of great ecological importance to China. On the one hand, Chinafs economy is developing rapidly; on the other hand, the ecological environment in that region is becoming increasingly worse, and the ecosystem there is getting extremely fragile, which is inconsistent with the countryfs rapid economic development. Originated from the general equilibrium theory of Walrus, CGE model (Computable General Equilibrium) can be applied to analyze impact of government policy on economic development. Environmental policies taken to reduce pollutant disposal and water consumption directly influence product price, production cost and even economic structure. Therefore, elements of environment and resource can be brought into CGE model so as to simulate general economic system of equilibrium and thus to identify the key elements. And those key elements will determine the overall mechanism of resource distribution and income distribution in market economy. In this paper, by building a simple CGE model, we analyze the impact of water pollution and water shortage on economic development in the basin region. And viewing water resource as one of the production factors and water pollution treatment as an independent entity, we also analyze the relationship between input and output of water resource, water pollution control and other economic activities. The analysis comes to the following points. First, through water pollution controlCthe traditional GDP decreases, but the green GDP increases; and moreover, the economy in the basin improves to a sustainable way. Second, compared to water shortage, water pollution crisis is more urgent. Through gdivert water from the south to the north projecth and technique index promotion, water shortage will get alleviated, but water pollution need further effort.

***Keywords:*** cge model, haihe river basin, water pollution

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**HW2006** **Oral Presentation** **4710**

# Neuro-Fuzzy Inference System for Operation of a Multi Purpose Reservoir

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Multipurpose reservoir operation involves various interactions and trade-offs between purposes, which are sometimes complementary but often competitive or conflicting. Reservoir operation may be based on the conflicting objectives of maximizing the amount of water available for conservation purposes and maximizing the amount of empty space for storing future flood waters to reduce the downstream damages. Studies of long-term storage reallocations and designing seasonal rule curves are two important types of reservoir system modeling and analysis applications. With the growing pressure on available supplies of water, the problem of conservation and allocation has assumed importance in recent decades. Water resources projects are managed in an environment characterized by varying degree of risk, often by relying on the managers judgment, experience, vision and intuition. Traditional techniques like optimization techniques have serious limitations because they may not be able to incorporate the managers experience and judgment, which are usually qualitative in nature. Hence there is a need for development of new techniques relying on advanced mathematical tools to model the expert opinion and experience and automate the management of complex water resources projects. In the recent years, there is an increasing interest in Neuro-Fuzzy modeling techniques. Neuro-Fuzzy techniques or Soft computing techniques, which mimic the human way of reasoning and decision making can supplement the conventional mathematical techniques in dealing with complex problems. The present paper presents a neuro-fuzzy inference systems for management of the Hirakud reservoir on river Mahanadi, in India with the objectives of efficient flood control, irrigation and power generation. The objectives are considered as vaguely defined and hence are treated as fuzzy. The neuro-fuzzy inferences system is used to capture the historical operation policy. The model developed is used to simulate the operation of reservoir and the performance of the reservoir is evaluated with reference to the identified fuzzy objectives. The performance of the model is found to be satisfactory and can be used as a rule curve for operating the reservoir.

***Keywords:*** reservoir, operation, neuro fuzzy

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**HW2006** **Oral Presentation** **4711**

# Good Water Governance For Water Security and Integrated Water Management: Bangladesh Case

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Water is central to the way of life in Bangladesh and the single-most important resource for the well being of its people. All facets of our life economic, socio-cultural, arts and literature, rural entertainment and sports are either controlled or at least influenced by water. It sustains an extremely fragile natural environment and provides livelihood for millions of people. Unfortunately, we have excess of water during a part of the year, while it is drought in another part of the year, which makes good water governance essential and indispensable to develop and manage water resources, and the delivery of water services, at different levels of society in Bangladesh. The paper briefly discusses the following major issues relevant to good governance in Bangladesh: Formalizing Water Rights and Allocation Management of Transboundary Rivers Ground Water and Arsenic Problem Decentralization of Water Governance Participatory Approach and Role Change Privatization of Water Services Awareness Raising and Dialogue Financing Good Governance and Cost Recovery Reforming Institutions, Redefining Roles and Capacity Building Updating the Legal Framework The paper also includes a case study of water governance on private initiative at farmers field level, and their (farmers) perspective on water governance. It is also recognized that governance requires change and new adaptations, which is often resisted, and by its nature it involves political debate. Achieving effective water governance cannot be undertaken hastily using blueprints; it needs to be developed to suit the conditions around and, taking the benefit of lessons learned from all over the world.

***Keywords:*** governing, reforming institutions, updating legislations

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**HW2006** **Oral Presentation** **4712**

# Towards a large-scale approach on groundwater management in stressed agricultural areas of the Mediterranean

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In the Mediterranean, natural water scarcity and the frequent occurrence of droughts on the one hand and high water demands for irrigation and consumption result in severe imbalances of available water resources and demands. Groundwater resources play a key role for water supply. Water quality problems arise from salinisation of irrigated areas and leaching to groundwater and sea-water intrusion due to overexploitation of groundwater bodies (, but also from intensive use of fertilizers and pesticides). To facilitate communication between EU policy makers and regional authorities (alt: To guide EU policies into local actions and river basin management and rural development plans), there is a need for a large-scale assessment of drivers, pressures, states, impacts and responses as well as for scenario analyses to evaluate the effects of management strategies and environmental change. Based on a review of major threats on groundwater resources and their relation to further environmental and socio-economic aspects, we outline the first concepts of a methodology for large-scale assessment and modelling of groundwater resources. This will include the definition of suitable indicator sets, the development of large-scale modelling approaches and the integration of data and models into a GIS framework. We will discuss various problems relevant in this context: Suitable indicators should be integrative measures at the level of the elementary units and be observed or derived at the scale of interest, facilitating comparison with modelling results. Modelling approaches at the intended scale can no longer reflect individual processes and require aggregation and conceptualisation. The potential to include nested models for relevant problems on smaller scales is evaluated. The availability and applicability of existing data sources may pose severe limitations to indicator based assessment or modelling. The methodological approaches will be evaluated with respect to their applicability within a test catchment (Guadalquivir basin in Spain) and for the extension to the entire Mediterranean.

***Keywords:*** large scale, modelling, groundwater

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**HW2006** **Oral Presentation** **4713**

# Influence of the decision makers importance weights on the final solution in group decision making

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Paper analyses sensitivity of the solution when the importance of decision makers (DMs) is varied in the group decision making context, characteristic for Analytic hierarchy process (AHP) applications. That is, the importance limits are assessed to identify possible preorder of ranked alternatives. Limits are analyzed and defined for the example of selecting most suitable irrigation technology. Starting assumption is that performance parameters of alternative irrigation technologies across given criteria set is known and given as standard decision matrix. The three experts: in irrigation technologies (DM1), in water resources economy (DM2) and water resources system analysis (DM3), are asked to assess only criteria by using standard AHP pair-wise comparisons. This way it was possible to compute related priority vectors for criteria for each decision maker and provide for their geometric aggregation. Assuming equal importance of DMs (alfa1 = alfa2 = alfa3; alfa1 + alfa2 + alfa3 = 1), aggregation and straightforward additive synthesis of data in the decision matrix led to the final priority vector for alternatives as there was only one (virtual) decision maker. By setting importance of the DM3 (alfa3) to a smaller level, because of its relatively lower competence in a given field, importance of the two other DMs is then varied accordingly, that is in the range of 0 (1-alfa3). Sensitivity analysis finds critical importance weights of DM1 and DM2 when the first ranked alternative is changed.

***Keywords:*** group decision making, ahp, decision makers importance

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**HW2006** **Oral Presentation** **4714**

# Information Technology enhancing a Global Monitoring of Groundwater Resources

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Assessment of the global groundwater resources is the core mission of International Groundwater Resources Assessment Centre (IGRAC). The change of groundwater in time makes the groundwater assessment a dynamical process and the groundwater monitoring a necessary precondition for the assessment. Groundwater is monitored in many parts of the world, mainly by measuring groundwater levels, groundwater abstraction, spring discharge and water quality. The results of these point measurements are sometimes interpolated and combined with other information to produce various groundwater (related) maps covering aquifers, regions or even countries. There is, however, no systematic monitoring and assessment of groundwater change on global scale. IGRAC intends to establish a sustainable global groundwater monitoring system and to use monitored data for a periodic assessment of the global groundwater resources. The term system, rather than network is used to avoid an impression of an apart, global network of monitoring wells. Further on, this new network does not imply any (re)design of existing groundwater monitoring networks world-wide. The global monitoring system network will use aggregated information on groundwater in order to assess a global change of groundwater resources. Aggregation of the point groundwater measurements need to be carried out by local experts, involving their knowledge of hydrogeological conditions, measurement practice, historical records, socio-economical setup, and other factors relevant for derivation of reliable figures. On its turn, IGRAC is developing a web-based tool to encourage and enhance the aggregation procedure and the process of global monitoring in general. A Global Groundwater Management tool will enable the local expert (a UNESCO/IGRAC representative) to regularly produce on-line maps showing the change of groundwater variables in time. Representative point measurements (from monitoring wells or springs) and proxy information (such as precipitation and demography) can be uploaded in the application to assist the aggregation procedure. Moreover, the uploaded point measurements can be automatically interpolated, making the basis for a fine aggregation by hand. Once the aggregation is completed, the information is stored in IGRAC database and combined with information from other monitoring regions. In this way the info on a global state of groundwater resources can be further processed and visualised. For the use of the Global Groundwater Management tool, the local representative needs only a browser and the access to the Internet. The user interface is completely map-based and very simple to use. Finally, a direct access to the database and a full control over own data is provided. All this facts will hopefully increase the motivation and the commitment of groundwater community to support and join the network. The application is being developed by using ArcGIS server and Java ADF.

***Keywords:*** web based, groundwater, monitoring

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**HW2006** **Oral Presentation** **4715**

# The UNH earth systems observatory and the white water-to-blue water analysis of regional ecosystem state

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The Northeast corridor of the US is emblematic of the many changes taking place across the nation's and indeed the world's watersheds. Because ecosystem and watershed change occurs over many scales and is so multifaceted, transferring scientific knowledge to applications as diverse as remediation of local ground water pollution, setting State-wide best practices for non-point source pollution control, enforcing regional carbon sequestration treaties, or creating public/private partnerships for protecting ecosystem services requires a new generation of integrative environmental surveillance systems, information technology, and information transfer to the user community. Geographically complex ecosystem interactions justify moving toward more integrative, regionally-based management strategies to deal with issues affecting land, inland waterways, and coastal waterways. A unified perspective that considers the full continuum of processes which link atmospheric forcings, terrestrial responses, watershed exports along drainage networks, and the final delivery to the coastal zone, nearshore, and off shore waters is required to adequately support the management challenge. A recent inventory of NOAA-supported environmental surveillance systems, IT resources, new sensor technologies, and management-relevant decision support systems shows the community poised to formulate an integrated and operational picture of the environment of New England. This paper presents the conceptual framework and early products of the newly-created UNH Earth Systems Observatory. The goal of the UNH Observatory is to serve as a regionally-focused yet nationally-prominent platform for observation-based, integrative science and management of the New England/Gulf of Maine's land, air, and ocean environmental systems. Development of the UNH Observatory is being guided by the principles set forth under the Global Earth Observation System of Systems and is cast as an end-to-end prototype for GEOSS, targeting the monitoring in near real time of regional ecosystem state. The UNH Earth Systems Observatory consists of five interacting components. These pillars include (1) the Observatory data holdings themselves, (2) IT informatics backbone with standards-compliant data and map services, (3) community engagement through User Working Groups (UWGs), (4) an Advisory Board (drawn from local, regional, and national entities), and (5) education and public outreach. The structure is designed to capitalize on

***Keywords:*** earth, systems, observatory

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**HW2006** **Oral Presentation** **4716**

# Participatory modelling for effective management of water resources

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Knowledge of complex hydrological and hydrochemical processes at the catchment scale is demanded for efficient water management and cost-effective strategies to reduce water pollution. Such knowledge is synthesised and made available through integrated dynamic catchment modelling. However, there is often limited input data available when applying the tools at the local scale, the models are not transparent for the user and large uncertainties are involved in water quality modelling of specific pathways, as they are difficult to validate. Nevertheless, it has been hypothesised that models can be a platform for stakeholders communication and practical implementation of measures. Hence, a participatory modelling process (DEMO) has been developed and applied in a 350 km2 catchment in southern Sweden. The study is focused on reducing nutrient load and on the development of a locally established plan of measures, which is requested by the European Water Framework Directive by 2009. The integrated dynamic catchment model HBV-NP was chosen as it can calculate effects and costs for different allocations of several combined measures in a catchment. The participatory modelling process includes (i) identification of stakeholder groups with an impact on water quality in the catchment; (ii) a dialogue of model assumptions, availability of input data, possibilities to deliver results in consistence with participants needs, and perceptions of prevailing local conditions; (iii) model setup and test against monitored data, including local participatory monitoring; (iv) discussion of results about causes to todays problems. If a consensus cannot be found, steps (i)-(iv) are repeated. When participants agree on a general description of todays environmental conditions, the next step is (v): a dialogue about local environmental and development goals and strategies to reach these goals followed by (vi) scenario modelling, and (vii) discussions of the scenario results, in order to establish a common view of appropriate measures. If such agreement is not found, earlier steps are repeated. Finally, when an agreement is established, a locally approved plan of measures can be designed and implemented. The presentation shows the impact of including local data in the modelling process vs. using more general data. It was found that modelled diffuse nutrient pollution was highly modified when including local know how, soft information and more detailed field investigations. Leaching from arable land was found to be 35% higher using more detailed information (on e.g. agricultural practices, crop and soil distribution), which is of major importance for the decision making of suitable measures. Moreover, the stakeholders acceptance of model results and reliance on experts was increased by applying the participatory process and involving stakeholders in the modelling procedure. From a modellers point of view, however, a more distributed model approach was desired and is thus under development.

***Keywords:*** participatory modelling, water quality, river basin management plan

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**HW2006** **Oral Presentation** **4717**

# System dynamics simulation tool to evaluate and predict lake salinization process

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The major hydrological variables that may cause long-term salinity changes in fresh water lakes are the volume of the lake, various streams and groundwater inflows, outflows, various levels of stream salinity and evaporation. Evaluation of the contribution of each component to the long-term salinity trends may be a difficult task. The objective of this work was to test and verify a system approach method to evaluate the causes of long-term salinization process. With this method we consider the lake as a natural integrator in space and time. As such, the long-term change of the chloride concentration in the lake (representing salinity), is subject to the linear mechanism of complete mixing, and reflects the long-term changes in each of the various past hydrological variables. The theory was tested against long-term measurements of hydrological variables and salinity in Lake Kinneret, Israel, and Lake Biwa, Japan. In the analysis of Lake Kinneret the measured inflows, outflows and lake salinity were used to verify that the salinization mechanism follows the theory of complete mixing. In Lake Biwa, the same approach, together with the known mechanism and the measured salinity of the lake was used to investigate the reasons for long-term salinity changes. In addition, since the system analysis is disturbed by uncertainties of the measured variables, a stochastic component was added, in order to take these uncertainties into account. The entire system (deterministic and stochastic components) is an efficient dynamics simulation tool to evaluate and predict lake salinization process.

***Keywords:*** lake salinity, complete mixing, stochastic model

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**HW2006** **Oral Presentation** **4718**

# Water resource management through partnership between public, private and civil society -case of Uttaranchal Himalaya, India

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Water resource management in a country like India is so diverse that it is necessary to establish and develop meaningful roles for, and fruitful partnerships between, the public, private and civil sectors through ENGO and NGO activities. The paper examines the roles of the three sectors in water management vis--vis the activities of local organizations like Rural Litigation and Entitlement Kendra (RLEK), Himalayan Consortium For Himalayan Conservation (HIMCON) and the NGO, Friends of the Trees (Dalyon Ka Dagrya). All of them have reinvigorated a strong volunteer base through small activist oriented projects. They have also involved the local people in maintaining plan implementation and participation in protection of local, cultural and environmental conditions. The 73rd and 74th Constitutional Amendments of the Government of India established community planning at the watershed level as a priority. These organizations recognized the opportunity to promote conservation of water and forest resources while improving livelihoods for poor households and traditional communities. Through utilizing PRA techniques, the study identified that water conservation was a critical need. In fact, they found that in some communities traditional springs were drying up. Working with local villagers projects were identified for improving water supplies that could be undertaken through locally available skills and resources. Project examples include rooftop rainwater harvesting with tanks made by local masons and the planting of trees around the source areas of springs. More recently water-harvesting structures are being established to cope with rapidly growing water stress. Utilizing both primary and secondary information the paper considers the successes and barriers to civil sector engagement in development activities. The study also demonstrates effective functioning of the NGO operated micro-hydro project in the region. The plant was partially funded by an NGO, Society for the Promotion of Wastelands Development (SPWD).The remaining fund came from the villagers and in the form of donated labour. No government agencies were involved in the development of this project. The success of the project has made Uttaranchal Renewable Energy Development Agency to incorporate aspects of public participation into their other future projects. The paper concludes that important linkages between ENGOs and the government sector need to be made. This requires further decentralization of decision making in water management and the encouragement of community organizations to represent the marginalized sections of society.

***Keywords:*** himalaya, integrated management, watershed management

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**HW2006** **Oral Presentation** **4719**

# Hierarchical optimization of a multireservoir system using the drought frequency index

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Multiple-reservoir operation, serving multiple purposes in regions threatened by persistent drought conditions, requires the application of new climate conditionals to modify operation rules while weighing the reliability of the system in terms of the available water and the expected performance during the occurrence of such extreme events. The Drought Frequency Index (DFI) was recently developed by two of the authors (Gonzalez and Valdes, 2006) to characterize droughts based on their return periods. The DFI makes use of probabilistic criteria that take into account the persistence of extreme low values to determine an integrated measure of magnitudes such as the severity, duration and frequency of a drought event. The Conchos River Basin (Mexico) was chosen to evaluate the effects of incorporating the DFI as a parameter to control the operation rules of five reservoirs in order to improve the rational allocation of water among the users and the reliability of the system under drought scenarios. The Conchos River is a major tributary of the Lower Rio Grande-Bravo Basin. The system includes three main irrigation districts, a city and a small hydropower station. Streamflows from the Conchos to the Rio Grande are also subjected to an international treaty between USA and Mexico that establishes an average quote to be fulfilled on 5-year cycles. The response with and without the index was studied through different optimization techniques widely used in reservoir operation (linear, nonlinear, dynamic stochastic programming). A hierarchical optimization process was developed to reduce deficits, maximize farmers? net benefits in each irrigation district and fulfill the requirements of the treaty in each time step. The DFI was considered as a drought trigger parameter in the definition of the reservoirs' operation rules and as a criterion for future water assignation to the irrigation districts. Results suggest that the inclusion of the DFI index may improve the long run reliability of the system, reducing the probability of high deficits and the corresponding high losses, while improving the fulfillment of the USA requirements under the current treaty.

***Keywords:*** drough index, reservoirs, optimization

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**HW2006** **Oral Presentation** **4720**

# Three strategies for contemporary water resources management

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Changing demographics and population movements; shifts in geopolitics; fast developing information and communication technologies; plus the impacts of climatic change and extreme weather conditions are all making contemporary water resources management more challenging. It is within this setting that the water managers must administer what is becoming an increasingly scarce and fluctuating resource. Presentation focuses on three strategies to provide response to the challenge of contemporary water resources management: Integrated Water Resources Management. It is increasingly recognized that an Integrated Water Resources Management (IWRM) approach is needed to consider natural, social and economical factors and issues simultaneously in order to secure the equitable and sustainable management of freshwater. A system dynamics simulation approach is presented as an appropriate tool for integrated water resources management. Partnership. Water resources management becomes more efficient in systems where governments, private firms and civil society work together in collaborative undertakings. A multi-objective decision modeling approach adapted for group decision making under uncertainty is presented as an appropriate tool for involvement of multiple stakeholders in the decision making process. Managing risks. Water is an essential component of security. In the last decade, 90 percent of natural disasters have been water-related events. Tsunamis, floods, droughts, pollution and storm surges are just a few examples of hazards that can constitute a risk for societies and communities. These are likely to increase in the changing environmental context. Hazards like these become disasters when risks are not managed with the objective of reducing human vulnerability. Proper tools for management of risks are still missing. I will present fuzzy reliability analysis as an approach capable of capturing both, objective and subjective risks in contemporary water resources management.

***Keywords:*** integration, participation, risk

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**HW2006** **Oral Presentation** **4721**

# Use of artificial neural networks to simulate urban wastewater systems: with an objective to integration with broad scale catchment models

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The EU Water Framework Directive stresses the importance of integrated water management at the level of the catchment basin, in order to achieve good ecological and chemical status in all water bodies by 2015. The urban water system and its subcomponents (for example, water supply, sewer and drainage system, and treatment plant) interact both between them and between them and the surrounding environment. Yet, more often than not, these subsystems are conventionally planned, designed, and operated in separation while the interaction between the entire urban water system and the surrounding catchment are mostly ignored in broad scale catchment models. Reasons of complexity and computational burden are mostly at the heart of this modelling gap. This paper describes the background, rationale, and scope for such integrated urban modes in a catchment scale, with focuses on (a) the development of integrated modelling of the entire urban wastewater systems, including the benefits in operation and control and limits in integration with broad scale catchment models; and (b) the approach to develop a surrogate model of the urban system using artificial neural networks (ANNs), which can be then embedded into catchment models to allow for a better integration of the urban areas in the wide scale modelling framework. As a case study, an integrated system consisting of combined sewers with overflows (CSOs) and treatment plant is optimised against a series of quality objectives using a control strategy. The optimal system is then perturbed against a series of inputs, including rainfall and dry weather flow, and its response in terms of both quantity and quality in CSOs and treatment effluent are captured and used to train a feed-forward back-propagation network. The comparison results of the integrated model and ANNs shows a good agreement for both water quantity and quality parameters. It is shown that the predictive performances of the ANNs enable their use as a surrogate in a wider scale water catchment management.

***Keywords:*** anns, wastewater, broad scale

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**HW2006** **Oral Presentation** **4722**

# The Complexity and Variability of Artificial Water Regulation on Modeling Hydrological System for Korean TMDL Management

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In this paper, we concentrated on modeling the hydrological system for characterizing the water balance for the whole watershed elements and the specific TMDL regulation flow in Nakdong river basin, which is the largest watershed in South Korea. Recently, the Korean TMDL management have been launched for all watersheds in South Korea for 4 years and producing several problems including defining the TMDL regulation flow, the water quality standard, the safety factors, the management rule etc. in the progress. In doing this, we met the several unexpected problems such as (1) the lack and variability of observed flow data for model calibration (prediction for ungauged basin), (2) the complexity due to artificial water regulation from large upstream dams and various water uses on the river flows (consideration of artificial water regulation), (3) the ambiguity to define the design flow for Korean TMDL management (definition of TMDL design flow). The problems above may be loaded on the hydrologist and water resources engineers dealing with the TMDL policy in the world. In this study, we made our efforts to solve those problems in three ways such as (1) confirming adequate and integrated watershed modeling based on USDA SWAT considering all hydrological elements and artificial regulation systems, (2) selecting the proper calibration sites for basin parameters and river flow properties, (3) performing the sensitivity and variability of artificial water regulations including the large dam operation and water uses on the flow properties for the sites of interest based on several senarios. In doing these, the effects of the complexity and variability of artificial water regulations was focused, and evaluated in terms of the TMDL management concerns.

***Keywords:*** korean tmdl management, swat nakdong river, dam water use regulation

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**HW2006** **Oral Presentation** **4723**

# A new approach to simulate runoff conditions under climate change constraints

***Prof. Ren Roy***
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Qubec (CANADA), has an installed electricity generation capacity of over 38,000 megawatts (MW), supplying more than 40 percent of its total energy requirements. More that 80 per cent of this originates from hydroelectric plants located north of the 50th parallel, in the Boreal region. In addition to this, Qubec has a remaining theoretical potential of 44,000 MW, much of which could be added to current generation. From the perspective of both economics and Quebeckers' energy security, it is clearly important to determine the impacts of climate change on the currently installed generation capacity. This must also be borne in mind when planning future facilities, since the time constants of climate change correspond closely with the planning horizon for large hydroelectricity stations. Thus, it is important to make the serious efforts required to better understand the physical conditions that determine runoff and to develop tools and models allowing for a finer spatial resolution of the various phenomena involved. These developments will improve the impact analyses of climate change on the hydrological regimes of Qubec's watersheds required to elaborate adequate adaptation strategies over the upcoming decades. This communication outlines the steps followed to construct hydro-climatic projections of basin-scale runoff and their associated uncertainties over the Qubec/Labrador peninsula by using an original method. First, we show that the physically-based Canadian RCM (Regional Climate Model) is able to reproduce basin-scale annual runoff within observational errors. The robustness of the CRCM at simulating annual runoff at the basin scale is studied through an analysis of the models intrinsic internal noise (e.g., internal variability related to the non-deterministic nature of the climate system), which we find to be small (with respect to observational errors and interannual variability of observed runoff). The CRCMs main advantage is that it is constructed with balanced land and atmosphere water and energy budgets, and includes feedbacks between the surface and the atmosphere; providing variables that are all internally consistent. Through land and atmospheric water balance equations computed over long periods, it is possible to directly link runoff to horizontal convergence of vertically-integrated atmospheric moisture flux. We can therefore use the horizontal convergence of atmospheric moisture flux as an interesting additional validation dataset for runoff averaged over long periods and large basins. Sensitivity experiments show that domain size has an important effect on simulated annual runoff, and that surface scheme and driving reanalyses have less influence but still remain significant. These findings imply that not only should the experimental configuration of a simulation be carefully defined according to the area of interest, but also that one must consider results from more than just a single RCM simulation (to account for the models internal variability). Following these basic steps, more trustworthy climate change data can be provided to water resource managers. Through the provision of an ensemble of regional climate projections, it is then possible to evaluate the climate change signal and the associated level of confidence.

***Keywords:*** runoff, climate change, simulation tool

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**HW2006** **Oral Presentation** **4724**

# A Nonparametric Stochastic Downscaling framework for Catchment Scale Climate Change Impact Assessment

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A nonparametric stochastic downscaling framework for generation of daily rainfall at multiple point locations for catchment scale climate change impact assessment under enhanced greenhouse conditions is presented. This framework aims to maintain the spatio-temporal structure associated with a continuous climatic "state" variable to form the basis of generating rainfall at multiple point locations in the catchment such that dominant spatio-temporal dependencies are well represented. Three formulations of the nonparametric downscaling framework are evaluated. In the first case, rainfall is downscaled using a system of variables that combine atmospheric circulation indicators (geopotential height, pressure and derived variables) with time lagged wetness indicators reflecting a continuous rainfall state. In the second and third cases, the above system of variables is augmented using indicators of atmospheric moisture found relevant in defining the downscaling relationship. The downscaling framework is specified using 43 years of daily rainfall observations at 30 locations nearSydney, Australia, with reanalysis data being used to represent observed atmospheric variables. A single ensemble member of the CSIRO Mark 3 GCM (corresponding to the SRES A2 emission scenario) is used to downscale the rainfall for year 2070 conditions. While all the downscaling formulations show an overall similarity in the downscaled rainfall for the current climate, marked differences are simulated for year 2070 conditions. Overall, use of only atmospheric circulation variables and atmospheric circulation and temperature depression datasets project a drier future climate whereas atmospheric circulation and precipitable water reverses the trend with expected increases in the frequency of wet days and total rainfall amount in the warmer climate, with most of the increase being confined to summer. Also, inland stations are found to be more sensitive to the expected future climate changes in comparison to the coastal ones.

***Keywords:*** climate change, stochastic downscaling, water resources management

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**HW2006** **Oral Presentation** **4725**

# Integrated Water Quality Management System INWAQ (Ialomita river basin Romania)

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The proposed research aims at developing and implementing the instruments required by a global and integrated approach to water quantity and quality management at the watershed scale, with an application to the Ialomita river basin.The main output of this research consists of providing an operational GIS-based integrated water management tool to be applied by the various river basin authorities of Romania (Water Directories and National Adminsitration Romanian Waters-ANAR) and to apply it to define short-, mid- and long term strategies to improve the overall water quantity and quality management, respectively to increase and maintain the water resources security in Ialomita river basin. In order to create the GIS instrument mentioned above, first a conceptual data model (CDM) of a geodatabase had to be developped. A CDM is a graphic model that shows in a synthetic and explicit way the objects and the relations between them that are taken into account in the realization of the management tool: spatial objects like river basins, rivers, aquifers, lakes, etc and nonspatial data like hydrographs, rating curves, quality parameters, etc. The CDM was organized in the following modules: river network, river network caracteristics, river basin, aquifers, indicators, pollution, works on the river network, settlements and documents. The next step was to create a geodatabase - GDB - (a GIS database that integrates spatial and non spatial data) and to fill it with all available data from the Water Directories. On this kernel, several functionalities were developped. These functionalities were devided on two main directions: quantity and quality. The quantitative functionalities refer to querries, reports, vizualizations using data from the GDB; the qualitative functionalities were grouped within an application called GESROM. GESROM proposes an automatic way of determining the rivers quality on the base of parameters mesured values. At present the application deals with the following aspects:chemical indicators, biological indicators,dangerous substances,drinking water,vulnerability to nitrates. GESROM application was programmed in Visual Basic technology under GIS and represents an extension of ArcMap functionality. This application is based on methodologies which are according to the WFD, adapted by ANAR and used at the moment to establish water quality categories: five classes (I-V) for chemical indicators, respectively five classes (bad, poor, moderate, good, very good) for biological indicators. This management tool will be used for identifying the areas where measures are needed in order to diminish the qualitative pressure upon water resources.

***Keywords:*** gis, geodatabase, integrated management

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**HW2006** **Oral Presentation** **4726**

# The NMPI network: a global platform for improving the development of numerical models through better end-user uptake for adaptive water resources use management and policy

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Although the application of environmental models is ubiquitous, there remain serious problems and issues with respect to their efficacy and the context within which they are developed and then applied. Models are often conceptualized, developed, applied and evaluated without proper reference to the policy and management context they are intended for. Applied to investigate sustainability at any geographic scale, this low level of care and interaction between model developers (e.g., scientists and engineers), model users (e.g., engineers, planners, and managers) and model stakeholders (e.g., affected living populations) is not only likely wasteful, but potentially harmful. The need for a thorough reassessment of the rational behind the development and use of environmental models is now more than ever an imperative.The latter is especially true in the implementation of integrated water resources management. This paper will present the outcome of two workshops of the Numerical Modelling-Policy Interface (NMPI) initiative organised under the auspice of the University of Stuttgart and the British Geological Survey. The first workshop will seek to analyse, define and document the gap between research results (especially but not restricted to numerical modelling) and policy / strategy implementation. Under the theme of "Operationalizing Adaptive Capacity", it will aim to develop an international network of multi-disciplinary scientists and practitioners to set an agenda for research to close the gap between the development of models and the uptake of their results by policy makers. A follow-up meeting in will seek to implement findings from the meeting in Stuttgart. In summary,both workshops aim: a. To develop a network of multidisciplinary scientists to systematically assess, define & document the gap between numerical modelling and policy development; b. To develop a research agenda driven by the findings from objective a; c. To develop international research consortia to actualize the research agenda set out in objective b. The NMPI Network will have a global reach with nodes in Europe, North America, Africa, Latin America andAsia. The workshops are a product of ongoing dialogue with the research directorate of the European Commission and similar organisations inNorth America.

***Keywords:*** numerical, modelling, policy

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**HW2006** **Poster presentation** **4727**

# General Principle for the Short-term Optimal Regulation of the Hydropower System-(1) Basic Concepts and Mathematic Models

***Dr. Senlin Chen***
*Theme II Prediction HW2006 IAHS*

A system of hydropower stations are generally made up of series cascade subsystems on a tributary, parallel station groups between cascades or a large-scale mixed connected system. Due to the strong coupling relationship between cascades, and the complexity of temporal - spatial relationship, of energy transfer and of time distribution, both of which lead to the high-dimension problem in optimization of short-term load allocation. Just these characteristics of the system of hydropower stations make the system can not full play its maximum potential. Aftereffect and solution technique of the model are the both key technologies for the short-term optimal regulation of the hydropower system. The aftereffect results from two factors. One is the short-term operation of the hydropower stations with better adjustability will inevitably lead to a long-term effect. The other is that time-lagging of the flow transfer between cascade hydropower stations results in the after-affectivity in energy transfer. The mathematical model for the short-term load allocation of hydropower stations is generally a large-scale non-linear planning problem, thus the effective way is to find out a solution method that can balance the solution time and solution precision of the model. To solve both of the key technology programs, this paper proposes the general principle that makes maximal the sum of the power generation of hydropower system within the load allocation period and the converted energy by the lagged flow. The general principle of short-term load optimal allocation of hydropower system can be described as follows: in a certain load allocation period, under the constraints of whole load chart of the system, make maximal the total electricity energy which can be generated by the given water consumption of the objective station in the system. The principle is the unification of the maximum power generation principle and the minimum water consumption principle in the traditional method. The principle can be applied in any time of the year, and it can also help the power dispatching personnel make reasonable decisions. According to the general principle proposed above, the objective function and the correlative constraint conditions of the mathematic model for the short-term optimal regulation of hydropower system are established in this paper. The correlative constraint conditions include power balance constraint of the system, water consumption constraint of the objective station, water balance restraint of each reservoir and so on. The performance index function of each station in the system is deduced according to the general principle and the established mathematic model. A solution can be drawn from the physical significance of the function: it can be sought that the optimal combination between the generation of each station in the current allocation period and the lagged energy of each station by using the performance index function, and then the inflow of the objective station in the current allocation period can be used most effectively though the optimal combination.

***Keywords:*** after affectivity, mathematic models, performance index function

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**HW2006** **Poster presentation** **4728**

# General Principle for the Short-term Optimal Regulation of the Hydropower System-(2) The optimal solution of the model and its application

***Dr. Senlin Chen***
*Theme II Prediction HW2006 IAHS*

With setting the general principle as the key to the performance index optimization of a hydropower system, when the load chart of the hydropower system and the water consumption of non-relevant station, namely objective station (that is the head cascade station or a single station with better regulation capacity) both are given, the available generation of the system will be made maximum with the water level of relevant input stations, namely load-balancing station (including daily regulation station and radial-flow regulation station) controlled at the end of the allocated period. On the basis of these, the optimization algorithm of general principle mathematical model in short-term optimization dispatching of hydroelectric system is proposed in this paper. In this paper, the complicated multi-function system of mixed-connected hydropower stations located on the basin of the Minjiang River in Fujian Province is set as an example, and the optimization algorithm is used for its short-term optimal regulation calculation to demonstrate the application effect of this optimization algorithm. According to the characteristic of high dimension of the system, in this paper, the large-scale decomposition and coordination principle is applied, and the whole system is decomposed into four interconnected and well-organized cascade subsystems to reduce the spatial dimension; the DDDP method and the successive approximation principle are used to seek optimal solution for each subsystem in turn to determine the optimal operation policy of the whole system. Because the input energy transfer caused by the flow connection in the cascade poses difficulty in the reduction of spatial dimension, in this paper, the method of electric equilibrium is introduced to reduce spatial dimension, and several improvements have been made to solve the problems appeared in the application of the method to the short-term load optimal allocation of hydropower system, the concept of the optimal input capacity is proposed at the same time. All of these measures not only make the load allocation tally with the features of cascade stations much better, but also keep down the spatial dimension. Due to the aftereffect of the optimization algorithm, in this paper, the permutation and combination method is used to find out a solution of the model, that is the optimal combination is sought for combinations of possibly input capacities of electric equilibrium of the cascade stations. The operated results of the model indicate that, the water consumption ratio is decreased and the water utilization ratio is increased by applying the optimization algorithm. The optimization effect is quite obvious.

***Keywords:*** decomposition and concordance, electric energy balancing, the best input capacity

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**HW2006** **Poster presentation** **4729**

# Degradation of cellulose film submerged into artificial wetland made for treatment of slightly polluted stream water.

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To define the operating property of artificial wetland (4 by 30 m) made for stream purification, the degradation rates of cellulose, major component of plant was investigated. Moreover the attached bacterial numbers and their beta-glucosidase activity of cellulose films were also measured. For this purpose, the cellulose films stained with Remazol Brilliant Blue R were submerged at Aug. 30, 2006 into target stream water, treated water and 3 observation holes in wetland. After retrieving the cellulose films weekly, the degradation rate of cellulose film was measured with remaining dye, attached bacterial number on film with Hoechst dye 33258 staining, and their enzymatic activity with MUF-glucose method. By these results of microbial properties related to cellulose film, the target water and wetland water can be discriminated. The films were perfectly degraded after 4 weeks in target water, while those in wetland and treated water were merely 35.5 - 60.6 %. Also the attached bacterial number on cellulose film submerged into target stream water was twice higher that those in wetland. Similar result was coming from beta-glucose activity of attached bacteria. These results suggest that the nutrients was eliminated by chemical precipitation and adsorption by macrophytes, and consequently the microbial proliferation and activity were lowering. These microbial activities and abundance can be applicable as indices for confirming the efficiency of artificial wetland.

***Keywords:*** artificial wetland, cellulose film, microbial properties

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**HW2006** **Poster presentation** **4730**

# Water resources management and policy in closing river basin: a literature review

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With growing human pressure and soaring economic development, the supply of natural water resources reaches capacity. During this course, the river basins surfer a change from

***Keywords:*** water resources management, water resources policy, closed river basin

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**HW2006** **Poster presentation** **4731**

# A water quantity-quality model for basin scale water management modelling

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A water quantity-quality model for water management at the watershed-scale level is described in this paper. The processes in and outside of the river are simulated respectively. The model includes three components: the first submodule estimates domestic consumption, industrial water consumption, and irrigation requirement and return water, and pollutants loading produced from these process using empirical models. Four types of pollutants (COD, NH3-N, TN, TP)are considered. The second submodule describes hydrologic process outside of the river. Land with different cover and use out side of the river is divided into five types according to runoff generation: water surface of reservoir, catchment of reservoir, grassland, farmland and dry land. The semi-distributed hydrological model and non-point source model are applied to each type land to simulate the rainfall-runoff and non-point source pollution loading. The third submodule describes water quantity-quality model in the river network, which employs the hydrodynamic equations, transfer-diffuse equation and node equation. The model is applied to Taizhou, Zhejiang Province, China, where almost all of the water supply (industry, domestic, irrigation .etc) depends on reservoirs. The whole catchment is divided into a series of sub-basin to each of which the water quantity-quality model is applied. The model is calibrated for the hydrologic response and validated for the water quality component. The calculated values show well agree with the observed data. Using the model, the water quality and quantity in the research area with various allocation schemes of water resource can be simulated and computed to choose the optimal scheme. This would be helpful for management of water resource.

***Keywords:*** water quantity, water quality, basin scale water management

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**HW2006** **Poster presentation** **4732**

# Network flow allocation model with hydrologic routing

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Conventional water resources allocation analysis assumed water could be transmitted to any location within the system during simulation time period. Flow in all river reaches and conduits was assumed steady too. However, it may not be true especially when the operation time period is short such that water could not reach target location within a single simulation time step. Thus a proper operation strategy must take the posterior water use demand in consideration. Another feature is that a reservoir installed with a hydropower plant. Daily discharge is always released within a few peak hours. The flow in downstream channels may not be regarded steady in a day. The flow released from downstream regulation pond can not be treated as steady also if its capacity is not sufficient to store the water released from hydropower plant. It may not be possible to withdraw the full amount of water which is released from hydropower plant and the water supply may be over-estimated. This paper developed a water allocation model with considering the flow routing based on network flow programming. It transformed a daily water spatially-allocating problem into an extended period dynamic allocation problem contained multi-hours within one day. Furthermore, a channel storage node was designed in this network flow model. The water flow into and out from a channel storage node was in accordance with Muskingum equation through iterative calculation. Hence this model could simulate the water allocation in the situation when the flows at the two ends of an arc are not equal. The Feitsui Reservoir system in northern Taiwan was chosen as case study. According to the operational experience of reservoir authority, this study assumed that the travel time of released water from Feitsui hydropower plant to Chihtan Weir is two hours. At the premise that daily total release remains the same for Feitsui Reservoir, different peak release hours were tested to probe how the downstream water usage would be affected. The result showed that under the water demands in year 2006, different release policies of Feitsui Reservoir within a day did not make a great change to downstream water supply, but the surplus water from each control point would increase as the time period of peak release extended. If it is expected to utilize the surplus water to improve the water supply capacity, reservoir authority should extend the hours of peak hydropower release and modify the electricity allocation strategy for Taipower Company; otherwise it would be necessary for Chihtan Weir to expand its storage capacity.

***Keywords:*** hydrogenation, routing, networkflow

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**HW2006** **Poster presentation** **4733**

# Accelerating human impacts on water resource in the Heihe River basin, Northwestern China

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The river discharge and groundwater level data were collected within the Heihe River basin in Northwestern China. The surface water-groundwater interaction particularly in the lower desert reaches was analyzed with the help of isotope data of collected water from the river. The river reached the terminus only when river flow was large at the upper mountainous reaches in summer. A flash-like flood scarcely contributed to groundwater recharge in the area where it is difficult for water to penetrate. In winter, the river water, in the lower desert reaches, was derived from the groundwater in the middle oases reaches, which recharges the river in the middle oases reaches. The river water stayed on the riverbed all winter long in the lower desert reaches, which recharges the groundwater there. Thus, most of groundwater, in the area where it is difficult for water to penetrate, was recharged by winter river water. Based on the results, various measures to improve environmental degradation would lead to a further degradation.

***Keywords:*** human activities, arid inland river basin, stable isotopes

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**HW2006** **Poster presentation** **4734**

# Distributed Hydrological and Dynamic Coordinated Models of the Balsas River Basin

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***Jorge Salgado-Rabadn***

The Balsas River Basin in Mexico covers 111,600 km2 and includes part of ten states with a population of 10.1 million. Two coordinated simulation models were implemented by request of the Mexican National Water Commission to support the River Basin Council in complex consensus building on the integrated water resources management. The Hydrotel distributed hydrological model generates multiyear daily runoff series in 2,348 relatively homogeneous hydrologic units (HU) averaging 47.5 km2. The physiography was processed with Physitel from a 90 m DEM, river network and reservoirs vector map, and land use and soil texture raster maps. The hydrological model simulates direct, subsurface and base flows through six processes: interpolation of daily precipitation and temperatures, snow accumulation and snowmelt, potential and actual evapotranspiration, vertical water balance in three soil layers, overland runoff, and river network and reservoir routing. The simulated runoff and interpolated precipitation series are fed into the second model. The dynamic integrated water resources management model simulates the surface and groundwater balance with a daily time step and a multiyear horizon. A friendly interface helps to analyse water management scenarios, including long term trends in: water demand for various uses, efficiency in water distribution and irrigation systems, water transfers, and hydropower generation. Water demand input data are detailed at municipal and irrigation district level. Output results are aggregated in time and space at different scales, including hydrologic and administrative divisions. This model was developed using Powersim linked with Excel. The application of both coordinated and highly detailed models means a gain of confidence among stakeholders for the flexibility and good fit to reality. This technology is applicable to transboundary watersheds where consensus building based on objective scenarios is challenging and crucial.

***Keywords:*** distributedhydrologicalmodel, systemsdynamicsforiwrm, mexicobalsasriverbasin

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**HW2006** **Poster presentation** **4735**

# Assessment of groundwater resources and aquifer recharge- a case study in low Barind area, Bangladesh

***Dr. Mohammad Azizur Raman***
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***Dr.Jackson Roehrig***

Agriculture has great importance on the economy of Bangladesh. Population growth poses pressures on agriculture and sustainable development and demands at the same time for more food production. For increasing the agricultural production and to reduce environmental impacts from agriculture, it is also necessary to investigate the interrelationship between rainfall, surface water and groundwater on one side and demand for irrigation water and crop production on the other side.The study area consists of eight upazilas of north-west region of Bangladesh. This is one of the driest parts of Bangladesh, normally less rain from November to April. The study area has been irrigated using about 2100 Deep Tubewells. It covers only about 80% of the total cultivable area. The remaining 20% area has been planned to cover by installation of additional Deep Tubewell under Bangladesh Multipurpose Development Authority (BMDA). To ensure the long term sustainability, the consequences of the groundwater development in the region need to be analyzed. This study tried to explore the appropriate modelling technique to increase agricultural production through sustainable utilisation of available water resources using Visual MODFLOW. From the study it can be seen that groundwater resources are inadequate in Raninagar, Durgapur and Puthia upazilas of the study area. Present withdrawals of groundwater to fulfil the requirement of Boro in excess of actual recharges and available resources have created the tendency of continuous lowering of groundwater level in these 3 upazilas. The deficit indicates a non-sustainable situation with increasing draw down. 80% coverage of Boro for all cultivable land of upazilas will incur an additional draw down, for which, quite a large number of shallow tubewells need to be replaced by deep tubewell. The river is in direct contact with the aquifer system, contributing to the aquifer recharge from March to November and receiving water from aquifers from December to February. The rivers contribute about 9% of the total recharge for the simulation period. Monitoring of groundwater level in these upazilas need to be carefully continued for future action. Vertical percolation of rainwater is the main source of groundwater; increasing duration of percolation time and area by construction of water control structures on the rivers and Kharies will increase groundwater recharge. There is a possibility of increase of groundwater recharge by conservation of surface water in rivers and kharies in the post monsoon by retention structures. Conjunctive use of surface water-groundwater irrigation should be promoted and a conjunctive water allocation plan must be implemented.

***Keywords:*** recharge, water management, bangladesh

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**HW2006** **Poster presentation** **4736**

# Method of planning structural countermeasures against water disasters: a case of check dams against debris flows

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An advance of technology has recently led to more competent countermeasures but lives and properties still continue to suffer from water-induced disasters such as floods, landslides, debris flows etc. Impact of such disasters can be reduced by the help of appropriate countermeasures and the efficiency of counter systems can be improved by proper planning and designing. Structural countermeasures are supposed to be effective if the systems are technically sound, economically viable, environment friendly and best fit to the local contexts. This paper describes a method of evaluating counter function of a series of check dams against debris flow in steep mountain torrents. As an example, debris flow-1999 in San Julian river, Venezuela is chosen for discussions and the method of evaluating control function of check dams as well as the criteria for the selection of sizes, numbers and locations are proposed. It is hoped that this practical tips will help engineers to workout better performances in advance.

***Keywords:*** debrisflow, checkdams, sanjulianriver

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**HW2006** **Poster presentation** **4737**

# System hydrology tools for the upper catchments of the Jordan River and Lake Kinneret, Israel

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Three studies on major hydrological and water management problems in the Upper Catchments of the Jordan River and Lake Kinneret, Israel, are reported. By application of system approach to each problem we learned the nature of each system and the major physical laws that govern its operation. The studies were focused on: 1. Identification of the hydrological system (precipitation stream flow relations) of the Jordan River sources, which originate from the karstic region of Mt. Hermon; 2. Detection of three unknown components: evaporation, saline springs discharge and salinity, of the monthly water-solute-heat balances of Lake Kinneret, and 3. Long-term predictions of Lake Kinneret salinity, in response to operational changes. Each system will be presented from the definition of the problem, through the system type, objectives, and system equations, to the main results, the potential application, and the required future research. In all three cases, the physical laws and the nature of the system are combined into a single concept of system operation. It is this concept that constitutes a so-called gray-box, the intermediate concept between detailed physical analysis, and the classic system approach, usually referred to as black box. All three systems are general, and have a potential use in other watersheds and freshwater lake management.

***Keywords:*** system hydrology, direct and inverse problems, watershed management

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**HW2006** **Poster presentation** **4738**

# Identification of wet and dry stremflow seasons based on peak over thrshold method

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In this study, the peak over threshold method was applied on daily streamflow data of 9 stations in semi arid region of south east Iran in order to identify dry and wet streamflow seasons in this region. Based on frequency analysis of daily streamflow, the 2-year return period streamflow was selected as the threshold of wet and dry seasons. Then, the wet and dry season for each station were determined based on the number of events, , over and lower than the selected threshold. The region was found to have two seasons. It was also found that the region can be divided into two homogeneous regions based on peak over threshold analysis. For each region, different methods can be carried out for water resources management based on the wet and dry seasons.

***Keywords:*** peak over threshold, seasonal stremflow, regionalization

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**HW2006** **Poster presentation** **4739**

# Water Market Transaction Game Model Study in Water Resources Optimal Allocation

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21 century, the shortage phenomenon of water resources in China is obvious day by day; the supply and demand pressure is more and more tense too. How to do a good job of optimizing allocation of water resources become the key issue of sustainable development of water resources in the whole society already. Using market mechanism to optimize water resources is one feasible way to solve this problem. In a certain valley, the users' water using benefit is unequal because the initial allocation for the users' water right and drainage right is different, utilization ratio of water resources, water saving cost and pollution control cost are different too in the course of using water, so a transaction scheme of unifying water right and drainage right in water market was proposed. the scheme founded dynamic game model of complete information taking the most optimal social income of water resources as the goal, then gained the optimum solutions of the sub-game refining Nash equilibrium of the model using backward induction and optimum transaction scheme for users in water market. This scheme considered not only water right but also drainage right, made the best of market mechanism to optimize allocation of water resources. The conclusion of example indicated the schemes realistic feasibility.

***Keywords:*** water, market, transaction

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**HW2006** **Poster presentation** **4740**

# Current Problems of Water Energy Resources of the Mountain Tajikistan

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Hydrographically the region of Central Asia (CA) is distinguished as the Aral Sea basin, which in its turn consists of two basins the Syrdarya and the Amudarya Rivers. The water-energy problems became even more acute after the collapse of the USSR and formation of new independent states when they obtained intergovernmental status.One of such problems is connected with contradiction between irrigation and hydroelectric engineering. Irrigated agriculture demands maximum use of water during vegetative period from April to October. And hydroelectric engineering is concerned with paramount use of river flowing in winter, the coldest period of a year when rivers contain little water, from October to April. Thus by the irrigative regime filling reservoirs is necessary in winter and their use in summer, and by the energy regime it is vice versa, filling reservoirs is necessary in summer and their use in winter. It is impossible to combine their interests within one reservoir. But such a situation just takes place in the Aral Sea basin today. The number of reservoirs is quite limited in the zone of flowing formation, where the principal regulation of flowing has to be carried out. There is only one such reservoir in Tajikistan in the Amudarya River upper reaches the Nurek reservoir. In the Syrdarya River basin there are three such reservoirs: the Tocktogul reservoir in Kyrgyzstan, the Kayrakkum reservoir in Tajikistan and the Andijan reservoir in Uzbekistan. But from the latter three the Tocktogul reservoir can only carry out long-term regulation of flowing. Besides, all of them are located in different states, and co-ordination of their work is in itself a problem. Until recent times Tajikistan improved the situation to some extent by changing the regulation of river flowing by the Kayrakkum reservoir in the interests of the irrigative complex of Kazakhstan and Uzbekistan. This is well shown in diagrams on Pictures 3 and 4. But first, in contrast to the Tocktogul reservoir the Kayrakkum reservoir can only carry out a seasonal but not a long-term regulation of flowing that is insufficient in a long-term section. Second, as it will be shown below, without getting sufficient compensation for its delivered services Tajikistan makes changes of a flowing regulation just by virtue of the developed tradition, displaying its good will. Such a scheme cannot work long in existing today market conditions. Today the positions of Uzbekistan, Kazakhstan and Turkmenistan in this question consist in the request to preserve the existing limits of water division and allocation of additional limits for the Aral Sea and the Aral Shore. The positions of Kyrgyzstan and Tajikistan consist in reconsideration of these limits with increase of their shares (not for today, in the perspective). At the same time Kyrgyzstan and Tajikistan demonstratively ground their requests on the increase of water resources limits by the fact that they were deprived by water division and did not get any compensation for this during the times of the USSR. As a consequence they possess now the least specific area of irrigated land per man in accordance with other republics, and they cannot even provide their population with the minimal level of consumption owing to their own agricultural production. Fairness of the requirements of the countries of lower stream on the necessity to increase water resources limits for the Aral Sea raises no doubts. Apropos Kyrgyzstan and Tajikistan were always concordant with them in this regard, as todays situation in the Aral Sea zone negatively impacts on them too. It is connected with dusty and salty winds from the territory of the former sea, which are spread up to glaciers and cause their intensive thawing. Separation of the Aral Shore as additional water user together with the Aral Sea itself causes objection. It is apparently simply an effort to increase its own limits. In order to exclude this and, besides, taking into consideration the fact that today there is not any reliable and objective control of water use inside separate republics, it may have sense not only to exclude the Aral Shore, but the Aral Sea itself too from the number of water users, and instead if this to set limits to Uzbekistan and Kazakhstan. And one, certainly, cannot agree with the equal

responsibility of all the states for the Aral Sea destruction and with their equal participation in allocation of water limits. Such limits must be created first of all at the expense of the republics, which sharply reduced flowing into the Aral Sea in the 60s 90s due to sharp increase of irrigated lands on their territory, i.e. owing to Kazakhstan, Turkmenistan and Uzbekistan. Both Kyrgyzstan and Tajikistan bear minimal relation to this.

***Keywords:*** aral, sea, asia

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**HW2006** **Poster presentation** **4741**

# Application of effective rainfall on flood and water resources estimation

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Flood hazard is one of the most harmful disasters in the world for over 40% of the natural hazard damages are caused by flood hazard every year. Focusing on the problem of forecasting flood, the goal of this study is to investigate Flood Index (FI) and Available Water Resources Index (AWRI) during flood events. Such a flood index based on effective precipitation is utilized to estimate flood index from floods over Tabass city from April 15 to May 15 in 1995 and over Birjand city from April 1 to April 30 in 1986. Daily precipitation on Tabass and Birjand stations from January 1975 to December 2002 is examined to calculate indices and to compare with result. FI is calculated by considering precipitation and produces the Available Water Resources Index (AWRI) by precipitation. Result showed that the FI was successfully represented the danger of flood and FI variation was different from precipitation because of calculation of available water resources. The big value of AWRI indicates plenty of water resource available and the small value its deficiency. Comparisons of validation results from FI and AWR with observed flood over events are purposes. This study reveals FI to be promising tool for warning flood. 1. HW2006 2. New Avenues for Contemporary Water Resources Management 3. "Flood" Index", "Available" Water" Resources" Index", "Flood" warning" 4. Department of Watershed Management, Faculty of Natural Resources, University of Tehran, Karaj, Iran, P.O.Box:31585/4314, Fax :( 0098)-261-2249313, Tel (0098)261-2223044, Email:msaravi@ut.ac.ir 5. O 6. Pc 7. Student Paper 8. Yes 9. None

***Keywords:*** floodindex, availablewaterresources, floodwarning

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**HW2006** **Poster presentation** **4742**

# Environmental water demand in water resources management

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One of the relatively recent trends in water resources management is the increasing attention to multiple aspects of river ecology and development of methods to estimate environmental water demand. The latter is often referred to as environmental flows and represents a hydrological regime designed to maintain a river in some agreed ecological condition. The above trend overlaps with both increasing water scarcity and variability due to climate change. At the same time, our knowledge about relationships between changes in river flow and their impacts on aquatic ecology remains limited. This makes it difficult to streamline the inclusion of environmental flows into river basin management. This is particularly true in developing world, which is under pressure to increase agricultural production for its growing population and, which at the same time remains mostly unexposed to the concepts of environmental flow management. This paper describes recent tools for preliminary environmental flow assessment based primarily on hydrological analyses. It is argued that such hydrology-based methods represent the necessary first step in planning for environmental allocations and in developing national capacity in this field. The core assessment method ensures that elements of natural flow variability are preserved in the estimated environmental flow time series, as required by the contemporary hydro-ecological theory. The method is based on the use of a flow duration curve a cumulative distribution function of monthly flow time series. The curve is calculated for several categories of aquatic ecosystem protection from largely natural to severely modified, and the required environmental flow volume and elements of flow variability are set to progressively reduce with the decreasing level of ecosystem protection. A simple spatial interpolation procedure is then used to convert environmental flow duration curve into a continuous monthly time series of environmental flows. Environmental flows corresponding to different environmental protection categories have been evaluated using several major river basins in India, including Krishna, Godavari, Narmada and Cauvery as examples. Illustration of environmental flow demand application in India is particularly relevant considering that the country is about to embark on major intrerbasin water transfers from Himalayan to Peninsular rivers. The paper further present a software package which allows the preliminary assessment of environmental flows to be carried out at any part of the world using the above method and default hydrological data (with a spatial resolution of 0.5 degree) simulated using a global hydrology model.

***Keywords:*** environmental flows, flow duration curve, india

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**HW2006** **Poster presentation** **4743**

# Coupling Approach of Distributed Hydrological Model and Lumped Water Allocation Model in Modern Water Resources Planning and Management

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***Chunmiao Han, Cunwen Niu***

This paper describes necessity, approach and a study case for coupling distributed hydrological model and lumped water allocation model in modern water resources planning and management. Under the impact of strong human activities, hydrological processes and water resources system have typical Nature-Human dualistic characteristic in all aspects of forcing, parameter and structure. However, the separate study and application status of distributed hydrological models and lumped water allocation models can not describe the dualistic characteristic and thus becomes a development obstacle of modern water resources planning and management. Traditional water allocation models are usually lumped ones, difficult to give distributed information for groundwater level and discharges at key river sections. Further, they only consider the runoff-typed water resources, lack of the function of balance analysis of all hydrological factors including evapotranspiration (ET). Whilst distributed hydrological models can do balance analysis of all hydrological factors , but limited to pure simulation, lack of the function of water allocation or regulation analysis. Therefore, only by coupling the two kinds of models, dynamic water resources assessment and realistic scenario analysis can be done in the water resources planning. The coupling approach of the two kinds of models is suggested by taking the distributed hydrological model WEP and the lumped water allocation model ROWAS as an example. The distributed hydrological model provides the lumped water allocation model with the inflow process and evaluates whether the water allocation scenarios can meet the requirement of water balance demand at main control sections by figuring spatial and temporal distribution of water resources. The lumped water resources allocation model provides the former with the water allocation scenarios by conducting joint operation of hydraulic engineering network. The result of distributed hydrological model is input of the water allocation model after reasonably aggregated in space and time and the result of water allocation model is input of the distributed hydrological model after reasonably distributed in space and time. The iterative process is repeated to realize the coupling of the two models. Based on the separation and coupling of the two models, the status of river basin water resources with and without artificial disturbance can be analyzed. Through changing condition of watershed and human water utilization, the historical series of river runoff, the natural water resources under historical watershed condition, under present watershed condition and under future watershed condition can be simulated, the evolutionary law of runoff-typed water resources, general water resources including ET from vegetation and detailed components of water resources can be simulated, and the effect of human activities on the evolution of water resources can be quantified. The suggested approach is successfully applied to the Yiluo river basin (18881 km2), one of first level sub-basins of the Yellow River. After validations of the WEP model (1149 computation units and one day time step) and the ROWAS model (6 lumped analysis regions and one month time step), the coupling of two models are carried out. Dynamic water resources assessment results are obtained by applying the coupled models, water allocation schemes are suggested, and various scenarios of cropping pattern adjustment and water savings are studied. It is concluded that the coupling of two kinds of models is quite successful and is very useful in water resources planning, though some further studies are expected.

***Keywords:*** model coupling, distributed hydrologic model, lumped water allocation model

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**HW2006** **Poster presentation** **4744**

# Role of dykes in the occurence and movement of groundwater in the Nandurbar District Maharashtra, India by using ground magnetic survey and VES methods

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The role of dykes in the occurrence and movement of groundwater is a topic of challenge to hydrogeologist. Dykes can act as pathways or barrier to the groundwater flow depending upon intensity of fracturing in the dyke rock. Whether the dykes act as water conduits or as barriers depends on their structure, location and orientation with respect to the groundwater flow. The Nandurbar district of Maharashtra, is known for occurrence of dykes and dyke swarms. A total of 33 dykes were demarcated in the area of Nandurbar district and four major dykes from these were chosen for the vertical electrical soundings (VES) and the ground magnetic data. The VES were taken for the two different periods of pre and post monsoon. Both these studies have indicated that dykes form potential aquifers, as they possess sufficient width, length and favorable hydrogeological structure. Hydrogeological and electrical resistivity investigations further revealed that dykes behave as a conduit for ground water flow provided porosity and permeability characteristics of dyke rocks are higher than the host rock basalt and their trends in relation to topography are suitable. The density of jointing, fracturing and weathering of dykes increases as hydraulic gradient decreases thereby favoring low-lying areas as loci of groundwater accumulation. The integrated studies have revealed that the blue colour zones are most promising for groundwater exploration and dug wells may be dug up to depths of 30 to 35 m.

***Keywords:*** dykes, hydrogeology, vertical electrical sounding

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**HW2006** **Poster presentation** **4745**

# Finite-volume 2d model of stormwater infiltration and focused recharge in a rain garden

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Source control is the fundamental principle behind sustainable management of stormwater. Rain gardens are an infiltration practice that provides volume and water quality control, recharge, and multiple landscape, ecological and economic potential benefits. The fulfillment of these objectives requires understanding their behavior during events as well as long term, and tools for their design. We have developed a model based on Richards equation coupled to a surface water balance, solved with a 2D finite volume Fortran code which allows alternating upper boundary conditions, including ponding, which is not present in available 2D models. Also, it can simulate heterogeneous soil (layered or more complex geometries) to estimate infiltration and recharge. The algorithm is conservative; being an advantage compared to available finite difference and finite element methods. We will present performance comparisons to known models; to experimental data from a bioretention cell, which receives roof water to its surface depression planted with native species in an organic-rich root zone soil layer (underlain by a high conductivity lower layer that, while providing inter-event storage, percolates water readily); and to controlled experiments, as well as a natural rainfall event occurred in October 2006.

***Keywords:*** groundwater recharge, raingarden, stormwater infiltration

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**HW2006** **Poster presentation** **4746**

**Lecturer, dr. eng. Andreea Galie**

***Dr. Andreea Galie***

***Director, Dr. Eng. Petru Serban***

The Reference Conditions for Water Quantitative Parameters. In the last years, a series of international documents such as EU Water Framework Directive 2000/60, Strategy and policy in water field of UNEP for 2007-2012 have mentioned the necessity to define the reference conditions for water quantitative parameters which should be the basis for: Defining a system for water quantitative classification; Water allocation among the states within transboundary river basins; Defining ecological discharges required for conservation of aquatic biodiversity. The paper shows the criteria for selection of reference parameters for hydrological regime and the method to asses them. In addition, the 5-classes classification system for quantitative water parameters in accordance to the recommendations of European Standard 14614/november 2004 Water Quality Guidance Standard for assessing the hydro-morphological features of rivers is shown. The paper ends with a case study for the Crisul Repede Transboundary Basin.

***Keywords:*** water quantitative parameters, water classification

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**HW2006** **Poster presentation** **4747**

# Groundwater assessment in Al Ain aquifer using remote sensing and GIS

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Groundwater resources play a vital role in the sustainable development of all countries located in arid and semi arid regions, where rainfall and surface water resources are almost absent. Despite the tremendous explanation in the development of desalinated water in the Gulf Cooperation Council (GGC) countries, including the United Arab Emirates (UAE), groundwater still represents the main resource for all the agriculture development in the region. On the other hand, more that 70% of the total water demands in the GCC countries is covered by groundwater. Therefore, the importance of the groundwater resources can not be overlooked. Geological and hydrogeological data are numerous, interrelated, complex and diverse. Remote sensing images capture important information that may not be accurately identified using traditional data collection techniques. Examples of such information include, among others, land use, surface geology and monitoring of agriculture development. The difficulty of analysis of such data is attributed to its large size and diversity. For example, a single monitoring well may result into hundreds and sometimes thousands of data points. Integration of remote sensing techniques and GIS provides an efficient and reliable tool for the assessment of groundwater resources. GIS has the ability to deal with huge datasets and remote sensing images, store, arrange, analyze and visualize a large number of diverse sets of geo-referenced data. In almost all GIS systems, data are separated and stored in a layered structure that allows combining and demonstrating selected information needed for a specific application. The process of data capture and the subsequent analysis can be viewed as open systems that allow for adding, modifying, updating and analyzing information in an effective manner. This paper is devoted to the assessment of the groundwater resources in Al Ain area, UAE using remote sensing techniques and GIS. The agriculture development in the area has been identified and analyzed using remote sensing images. The developed database included various information related to groundwater levels, groundwater quality and land use that might affect the groundwater quality. Contour maps for the groundwater levels and some selected quality parameters were developed using ARC-View. It is concluded that the groundwater level in the study area is declining with an average value of 2.5 m per decade. However, the aquifer is has a good potentiality for recharge from rainfall events. The agriculture development and its impact on the groundwater resources have been identified.

***Keywords:*** groundwater, remote sensing, gis

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**HW2006** **Poster presentation** **4748**

# Challenges in water management under extreme hydrological conditions in a humid tropical region

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Though water is a basic necessity of life, its availability in excess or deficiency results in natural disasters. Extreme hydrological events always have impact on all facets of life, especially in developing and underdeveloped world with insufficient economy for disaster mitigation measures. In the present study, an analysis of such extreme events in the State of Kerala in is made. Kerala lies in the south-western coast of . It is a north south oriented narrow landscape with a length of around 700km and average width of 80 km. Arabian Sea borders its western side and the mountain chains, the Western Ghats , the eastern side. Monsoons and thunderstorms produce more than 3000mm of annual rainfall here, creating 41 rivers, numerous tributaries and other water bodies. Steep slopes of the terrain allow the water to flow fast and join the Sea, before it could be effectively harnessed. This uncontrollable flow produces floods in the low lands. But, even with this heavy rainfall the state experiences periods of serious water shortage and droughts, owing to the improper spatial and temporal distribution of rainfall. In this study, the extremes in rainfall and runoff conditions in the major rivers of Kerala and occurrences of floods and droughts in the State during the last century have been analysed, using a modified hydrological model. Study shows the changing seasonality and wide variations in river runoff. Southwest monsoon shows wide interannual variability and the northeast monsoon which is decisive in maintaining water security is becoming highly erratic. Floods of varying intensities affected different parts of the State in almost every year and droughts of different categories occurred in 50% of the years of study. Lack of the spatial coherence of the droughts and their intensities reveals that most droughts in Kerala are due to local variations in rainfall, rather than the global anomalies. Extremes in the rainfall and water balance conditions even shift the local climate to a more or less humid category. Study on the proneness to floods and droughts, based on the criteria adopted by the India Meteorological Department shows that the State is not vulnerable to either. However, water crisis in Kerala is mainly because of failure in administration. There is no adequate water policy or implementing mechanism. Conservation and management practices are poor and the functioning of disaster management cell is very slow. Problems associated with extremes in Kerala can be effectively solved with a strong and impartial political will. Suggestions for the mitigation of the impacts of extremes in future have been provided. Guidelines for an appropriate water policy and its effective implementation have been provided, considering the environmental, social and economic conditions in the State.

***Keywords:*** hydrological extremes, water management, kerala

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**HW2006** **Poster presentation** **4749**

# The risk assessment and the geotechnologies as means to identifying sources of non point pollution without specific water quality data. the case of Descoberto Lake, Federal District, Brazil.

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***Nabil J. Eid, Jorge Enoch Furquim Werneck Lima***

The important population growth of the Federal District and of the municipalities located in its boundaries caused the degradation of the water quality of its water resources. From the point of view of sanitation, the Federal District is an exception in Brazil, as it is the only Federal Unit with almost 100% of domestic waste treated. The threat of impairment is due to non point pollution. In developing countries the resources for catchments management are poor and there is no way to establish a comprehensive monitoring system to evaluate the impact of non point pollution or to calibrate and validate sophisticated models. A methodology to trace the most probable sources of non point pollution, making use of available data of physical features (pedology, geomorphology, geology, drainage and precipitation) and land use data derived from SPOT satellite (2003), is presented. A multicriteria analysis is presented to assess the effect of the various pollutants in raw water and each pollutant is weighted. Geotechnogies (GIS, spatial data fuzzy analysis) were applied to diagnose the vulnerability of the area. Remote sensing and muticriteria analysis has been used in order to identify the magnitude of the impact of land use on water quality. By overlapping the information above, a final map of hazard from non point pollution is obtained, identifying probable critical source areas. The information obtained is of paramount importance in managing the basin within a sustainable development planning. The Descoberto reservoir is taken as a case study as it is the most important source of fresh water in the region and, although its basin is an environment protected area with no direct industrial or domestic waste discharges, is suffering a continuous degradation of its water quality and reduction of its volume.

***Keywords:*** water quality, risk analysis

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**HW2006** **Poster presentation** **4750**

# Establishing a New Approach for Recovering Water Quality in Critical Watersheds in South America The Case Study of Iguau River at The Metropolitan Area of Curitiba

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***Maria Cristina Frisch Carvalho Marin, Monica Ferreira Do Amaral Porto***

The Water Resource Plan is an important tool to assist in the implementation of the water resources policy and management. The formulation of the Plan is a responsibility of the Water Agencies. The decision process must be based on decision support instruments which will enable greater objectivity, measure the intended objectives and point out the best alternative to be implemented under financial, technological and physical restrictions. The decision for consolidating the strategy for recovering a river water quality, must be considered. In this context, an analysis of the economic benefits of pollution control measures, can act as an auxiliary instrument to formulate a Water Plan for a river basin. The proposed methodology is based upon the evaluation of benefits as a function of a decision parameter Z, which relates the degree of reduction of pollutants in the water body and the relative importance of the uses of the water resources and the water quality parameters. This methodology was used to evaluate the economic performance of the different projects, where the economic benefits were estimated using the acceptable water pollution level with its limits defined by law, and its associated cost of achievement as a reference. This is an original approach that will complement the required activities for decision support systems models. KEY-WORDS: pollution control, environmental benefits, hierarchal decision

***Keywords:*** pollution, benefits

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**HW2006** **Poster presentation** **4751**

# Methodologies for catchment behaviour analysis: shared experiences between Brazil and France

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***Flavie Cernesson, Marie-George Tournoud, Julien Burte, Pascal Kosuth***

A 4-year project was run on four study sites under different climatic and hydrologic conditions: in , a Mediterranean coastal catchment was selected, meanwhile in one semi-arid northeastern catchment and two tropical central and southeastern catchments are studied. The overall objective is to develop, compare and exchange methodologies and tools for understanding and managing water and pollutant transfer in rural catchments. Experiences were shared on in-situ observation protocols, spatial analysis methods and benefits, water quality modelling tools and risk analysis. Institutional water management contexts were detailed and compared for both countries. Then climatic and geomorphological aspects were analysed for the four basins. Characteristics and restrictions of the study areas are highlighted and specific water issues were detailed for each basin, in terms of water use and conflicts. Remote sensing tools were applied on the four catchments during the project, for different purposes, including the evaluation of morphological characteristics; evaluation of impacts of anthropogenic works on erosion and sediment loads in rivers; delineation of river networks. Collaborative methodologies and tools were developed for understanding hydrological functioning and pollutant transfers in the four study sites. Finally, various aspects of risk analyses were addresses for evaluating the benefits acquired from the use of models.

***Keywords:*** water quality, spatial analysis, hydrological functioning

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**HW2006** **Poster presentation** **4752**

# A bilevel model to assess the performance of a water system

***Dr. Carmen Gale***
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A usual situation facing water resource planners is to determine which additional reservoirs must be built, how big should they be and what channels must link them in order to supply the prescribed water in the required periods. In this situation, alternative configurations for the water system or alternative management plans are proposed and the problem is to determine the best one according to the goals established. On the one hand, difficulties arise to establish measures of the system performance from the point of view of water system users. What is common to the problems in this field is the existence of multiple measures of the quality of the feasible alternatives. These measures take into account the different interests of water system users. On the other hand, water resource planners can use their influence to modify the behavior of water system users favoring sustainable use of water by fixing prices, taxes or subsidies. Therefore, in order to analyze the impact of alternative configurations or management plans in the performance of the system, we are led to models which are able to deal with a hierarchical framework. Usually, water resource planners are on the top of the hierarchy and water system users are on the bottom. Bilevel programming has been proposed to deal with decision processes involving two decision makers with a hierarchical structure. The second level decision maker optimizes his/her objective function under the given parameters from the first level decision maker. This one, in return, with complete information on the possible reactions of the second level decision maker, selects the parameters so as to optimize his/her own objective function. Hence bilevel problems are characterized by the existence of two optimization problems in which the constraint region of the first level problem is implicitly determined by another optimization problem. The aim of this research is to develop a bilevel programming model to assess the performance of the above water system, which allows us to take into account the interaction between water resource planners and water system users.

***Keywords:*** bilevel programming, water system

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**HW2006** **Poster presentation** **4753**

# The challenge in managing water resources in the Cerrado Biome, Brazil

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***Euzebio Medrado Da Silva, Sergio Koide***

Brazil is the country with the largest water availability, detaining almost 19% (8,130 km.year-1) of the total water that flows in all rivers of the world (42,600 km.year-1). Despite this rather abundant availability of surface water, there are some areas of the country where water resources are overexploited. The Cerrado (Brazilian savannah) is the second largest Brazilian Biome in extension, with about 204 million hectares, which represents approximately 24% of the national territory. This Biome occurs in almost all the area of the Brazilian Central Plateau, playing an important role in terms of water production and distribution throughout the country, and even to other South-American countries. For example, in the special case of the So Francisco River Basin, where the Cerrado Biome encompasses only 47% of its total area, the Cerrado is responsible for more than 90% of the water that flows out to the Atlantic ocean. Besides its hydrological importance, the Cerrado ecosystem has an outstanding relevance in terms of both national and international agricultural scenery. It is responsible for more than 50% of the national soybean production, 70% of the cotton, 50% of the meat and other products, with a potential to easily surpass those numbers. Conflicts due to the overexploitation of water resources already exist in the Cerrado, demanding additional technical information in order to support a sound implementation of the suitable water management systems for this region. The objective of this paper is to present and discuss data and information about the importance and situation of the water resources of the Cerrado Biome, as well as some management actions, practices and tools that have been developed in order to improve the knowledge about the hydrological behavior and the productivity associated to the water use, mainly for agricultural purposes, aiming to reduce risk of conflicts and environmental damages.

***Keywords:*** water management, brazilian savannah, simulation tool

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**HW2006** **Poster presentation** **4754**

# Calculation of phreatic water reserves from MOSTISTEA plain using GIS Technology

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Phreatic water reserves means the quantity of phreatic water from a phreatic water-bearing stratum. The volume of phreatic water from a phreatic water-bearing stratum presents important variations in timp meaningful because of the drainage through springs and supplying through precipitations. The water loss and accretion are translated in the surface phreatic water stratum oscillations, oscillations which are staying on the basis of the calculation of phreatic water reserves from Mostistea Plain In this way, there have been evaluated the permanent reserves, the regularization reserves, the total reserves and the exploitable reserves of phreatic water on the basis of national phreatic monitoring network wells from NIHWM (National Institute of Hydrology and Water Management) administration. These reserves are correlated with the variation amplitudes of the phreatic level and they are meaningful influenced by the precipitations for the interstream area and by the rivers level for floodplain area. The main objective of using GIS technology consist in conciveing of a geospatial database for calculation of phreatic water reserves from Mostistea Plain which offers the automatization advantage of some operations which implies complicated mathematical algorithms, but also because the ease of the outcomes interpretations.

***Keywords:*** 3gis, phreatic water reserves

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**HW2006** **Poster presentation** **4755**

# The role of computing and information system in intergrated water resources management: examples from Africa.

***Dr. Olusegun Adeaga***
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Its complexity and lack of sound and appropriate methodology has greatly impended development in hydrological science prior to the computing and information technology era. This technology with its high processing speed and very large data storage capabilities marked the development of more reliable hydrological information system, complex mathematical and statistical modelling and simulation in hydrology which replaced the hitherto highly laborious and error-prone manual computation methods. The advent of global observing system initiative has necessitated the development of complex basin-wide conceptual and water resources planning models which was possible only through development in mathematics sciences which took advantage of computing technology. In this respect, the superior distributed models replaced the less efficient lumped models in conceptual modelling while the more adequate synthetic flow data sequence replaced the less efficient single sequence historical data as the basis for water resources planning for water projects where hitherto an approach to its study has proved very daunting. The poor presentation of hydrological processes in all cadres of models and the need for improvement on this coupled with the observed drastic decline in hydrometeorological network in developing countries since the 1980 has marked another major phase in the application of the computing and information systems to hydrological science in form of the PUB (Prediction of Unguaged Basins) initiative targeted at the generation of synthetic data for water resources planning and management. In this paper the imperative adopting of Prediction of Unguaged Basins (PUB) initiative in part of Yewa basin () using a terrain based technique in the generation of Geomorphologic Instantaneous Unit Hydrograph was discussed. The analysis involves automatic channel network extraction and processing from a digital elevation model (DEM). This is based on the D-8 drainage model of the DEM and the steepest descent (monodirectional) algorithm. Bocquillon method was used to establish the major topographical link between the main basin and its sub-basin as well as identifying the hydrological links between the upstream and downstream flow within the drainage system while the morphological transfer function technique was used to estimate the system-response to input (rainfall) analysis in the selected sub-basin. PUB approach is necessary for a better understanding of drainage basin dynamics in unguaged and poorly gauged basins is undoubtedly crucial for sustainable water resources management.

***Keywords:*** water resources assessment, dem, unit hydrograph

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**HW3007** **4756 - 4809**

## Workshop
## The Impact of Environmental Change on Sediment Sources and Sediment Delivery (Sponsor ICCE)

**Convener :** Prof. Desmond Walling
**Co-Convener :** Mr. Jim Bogen

There is increasing concern for the potential impact of environmental change, including both climate change and land use change, on sediment fluxes in catchments and river basins. Increased sediment loads and concentrations can result in significant environmental problems associated with sedimentation in river channels, reservoirs, canals and related hydraulic structures, increased water treatment costs and degradation of water quality and aquatic habitats. Such impacts relate to both the physical presence of the sediment and its biogeochemical impact. Any attempt to develop an improved understanding of the potential impact of climate and land use change on sediment fluxes must consider their interaction with both sediment sources and sediment delivery mechanisms. Sediment source exerts a key influence on the sensitivity of mobilisation and delivery processes to environmental change and on the biogeochemical properties of sediment (e.g. nutrient and contaminant content). Similarly, small changes in catchment hydrology could generate important changes in sediment delivery dynamics, which increase slope-channel connectivity and greatly increase the proportion of the sediment mobilised from the catchment surface that reaches the channel network. The workshop will review the existing understanding of sediment sources and sediment delivery in catchments and river basins and their likely sensitivity to the impacts of environmental change.

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**HW3007** **Oral Presentation** **4756**

# Spatiotemporal downscaling of Global Climate Model output for assessing soil erosion and crop production under climate change

***Dr. Xunchang John Zhang***
*IAHS*

Spatial and temporal mismatches between coarse resolution output of General Circulation Models (GCMs) and fine resolution data requirements of ecosystems models are the major obstacles for assessing the site-specific climatic impacts of climate change on natural resources and ecosystems. The objectives of this study were to (i) present a simple but elegant method for statistically downscaling GCM output of climate change at the native GCM grid scale to station-scale, and (ii) further disaggregate spatially downscaled monthly GCM projections to daily weather series for input to hydrologic and crop models using a stochastic weather generator (CLIGEN), and (iii) demonstrate the site-specific impact assessment of climate change on natural resources at the Changwu station, Shaanxi, China using the Water Erosion Prediction Project (WEPP) model. Monthly precipitation and temperature projected by the U.K. Hadley Centres GCM under the A2, B2, and GGa emissions scenario were downloaded for the periods of 1900-1999 and 2010-2039 for the grid box containing the Changwu station. Univariate transfer functions were derived by matching probability distributions between station-measured and GCM-projected monthly precipitation and temperature for the 1950-1999 period. The derived functions were used to spatially downscale the GCM monthly projections of 2010-2039 to the Changwu station. The downscaled monthly data were further disaggregated to daily weather series using a stochastic weather generator (CLIGEN). HadCM3 predicted that average annual precipitation during 2010-2039 would increase by 4 to 18% at Changwu. Simulated wheat and maize yields would increase in response to increases in precipitation. Due to the warming effects, frequency and intensity of large storms would also increase in the area. Under conventional tillage, percent increases under climate change, compared with the present climate, would be 49-112% for runoff and 31-167% for soil loss. It should be pointed out that the predicted runoff and soil loss using the proposed spatial downscaling method were several times greater than those predicted without an explicit spatial downscaling.

***Keywords:*** soilerosion, climatechange, impactassessment

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**HW3007** **Oral Presentation** **4757**

# Impacts of Farming Operations on Soil Erosion of Cropland in Purple Soil Hilly Region of Southwestern China

***Prof. Xiubin He***
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***Zhang Xinbao, Zheng Jinjun, Hua Lizhong***

Flow and sediment discharge responses of streams to basin-scale human activities such as urbanization, timber-harvesting or intensively agricultural operation, have been well documented. And recently, many references have reported field-scale tillage effects on soil erosion. Impacts of complicated farming operations on soil erosion and thereafter altering flow/sediment discharge of rivers, however, are not well understood. The present paper investigated how two traditional farming operations of Biangoubeigou and Tiaoshamiantu combined with water erosion effect soil redistribution of the slope land by using 137Cs tracing technique. Biangoubeigou is a tillage operation to develop a drainage system on slope land. Before crops planted, farmers prepare the land with level trenches every distance of 4 to 7 meters. The distance depends on the slope gradient, the steeper slope the shorter distance. The trenches are general 30 cm depth and connected with one end or both ends to the hill-side ditches or to runoff tanks. Those trenches are served to (1) divide a slope land into relatively homogenous units for an appropriate crop; (2) intercept surface runoff and lead it to hill-side ditches, water tanks or stream gullies; (3) stop rill erosion by shortening the slop length and reducing velocity of runoff; and (4) temporarily trap sediment in rainfall season, and sediment is returned into the field by Tiaoshamiantu operation, which means returning manually the deposited sediments in the level trenches and tanks back to the slope field. A field survey, interviews with farmers and local governors, and soil core sampling along the slope transect for 137Cs assessment of net soil loss were carried out in Jiajia Village. The field annual net soil loss estimated was about 24.15 t ha-1 yr-1 in the Tiaoshamiantu-and-Biangoubeigouapplying slope land. The net soil loss from the slope land was negligible as the rill erosion has been prevented by the farming system and the eroded soil was mainly trapped in the trenches within the field, and returned into the field manually. Compared with the highest on-site point soil loss of more than 105.80 t ha-1 yr-1 by the 137Cs technique in this study and field erosion rate of 42.21 t ha-1 yr-1 from other plot monitoring studies in the similar area, this traditional farming system has effectively prevented soil erosion on the slope land.

***Keywords:*** farming operation, soil erosion, cs 137

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**HW3007** **Oral Presentation** **4758**

# Trends in sediment fluxes and loads in the Athi drainage basin, Kenya.

***Dr. Shadrack Kithiia***
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The Athi River drainage basin is the second largest basin in Kenya after the Tana River. It is drained by the main Athi River and its various tributaries in the upper catchment areas. The river drains two important urban centers; Nairobi city, in the upper catchment areas and Malindi in the southern outlet. This paper tries to examine trends in sediment conveyance in amounts in relative to the volume of water conveyed in the river channel. In addition, the various land use systems are assessment in providing an insight into the sources and levels of sediments from the headwater areas to the outlet point of the river. In the upstream tributaries of Ngong, Nairobi and Mathare rivers, a total value of total suspended sediments (TSS) was measured at 1 019 mg l-1 translating to 13457 t yr-1 in the years 1998-2000. This was found to increase downstream reaching a value of 131,089 t yr-1 in the middle parts to over 2,057,487 t yr-1 at the outlet (mouth) near Malindi. The implication of this has been increasing sediment fluxes and loads, decreasing trends in water quality and pollution of the sand beaches near Malindi town. This is attributable to land use changes and activities in the upstream areas particularly increasing agricultural practices and urbanization. This paper therefore, examines changes in sediment yields within the basin and attempts to make mitigation recommendations against the increasing trends in sediment fluxes and other associated problems in the basin and in Kenya in general.

***Keywords:*** sediment fluxes, land usechangesandactivities, pollution mitigation strategy

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**HW3007** **Oral Presentation** **4759**

# Combining radionuclide tracers and conventional techniques for qualitative assessment of local sediment-retantion measure effectiveness on arable slopes

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In this study we have applied 3 independent techniques to evaluate sediment-retention and soil-protective effectiveness of forest belts with runoff-intercepting ditches on contour terraces. The techniques employed included 137Cs radionuclide tracer, soil profile comparison and USLE-based model modified for Russian conditions (Larionov, 1994). For our case study we have selected 3 pairs of slope transects within the territory of the Novosil Experimental Station (NES), where field-based studies of soil and gully erosion aimed at developing effective soil-protective measures have been carried out since late 1920s. Each pair of slopes is characterized by similar morphometry and aspect. One of slopes in each pair has few forest belts planted on contour terraces with runoff-intercepting ditches, located about 100 m from each other, while another is a uniform arable field with conventional cultivation. Soil profile morphology descriptions in pits and 137Cs soil sampling were carried out at the same points for all slope transects. Topography survey using DGPS technique provided us with slope DEMs for model inputs, while other parameters (precipitation, soil characteristics, crop rotations) were taken from the NES data, meteorological records from neighboring stations, our sampling and internal database available with the model. The model was run for the same slope transects, allowing direct comparison of results yielded by all the 3 different techniques. For slope transects with forest belts, two scenarios were considered by the modeling (with or without forest belts), providing us with potential predicted effectiveness of counter-erosion measures. Both 137Cs and soil profile techniques produced close patterns of soil redistribution rate downslope variation for all the transects. For all slope pairs both techniques showed 30-60% decrease of soil loss on slopes with forest belts, except for 3rd pair from soil profile technique. However, average soil redistribution rates from 137Cs (12.3-75.8 t ha-1 a-1) were 3 to 8 times higher than those from soil profile comparison (4.7-14.7 t ha-1 a-1). This high discrepancy obtained can be attributed to differences in temporal resolution of methods as well as to possible influence of individual extreme events soon after fallout on results yielded by the 137Cs method. On the other hand, more significant decrease of average soil degradation rates on slopes with soil conservation (up to 70-75%) was predicted by the model. Problems associated with different temporal resolution of methods as well as internal limitations of each technique will be discussed in details. It can be generally concluded that application of a few independent techniques allows acquiring much more detailed information on temporal and spatial variability of soil redistribution rates than for single method-based studies, as well as highlighting possible shortcomings and errors of the individual approaches employed.

***Keywords:*** sediment, redistribution, dynamic

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**HW3007** **Oral Presentation** **4760**

# The influences of quarrying activity on hydrology and suspended sediment load of the upper Pelarit River, Perlis, Malaysia.

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***Wan Ruslan Ismail***

Research on the influences of human activities on the environment has been a major theme for many years. Most studies of the human influences on hydrology and suspended sediment have been carried out in the west, only recently the focus has shifted to the tropics, usually related to the effects deforestation. Several studies on the effect of land use changes on hydrology and suspended sediment have been conducted in Malaysia. One of the activities that involve a large scale modification of the landscape is quarrying. Hence, the influence of quarrying activity on the hydrology and suspended sediment load of Upper Pelarit River, Perlis, Malaysia was investigated in 2001-02. Baseflow accounted 64.7% and 52.1% of the total discharge in 2001 and 2002, while stormflow comprised of 35.3% and 47.9% respectively. Suspended sediment concentration varied with an average concentration of 1.2 mg/l during lowflow and 1544 mg/l during storms. Suspended sediment load was highest in 2001 (13249.7 t) compared to 6439.2 t in 2002. Suspended sediment transport accounted as little as 0.02% of the total sediment transport in the driest month, but as much as 30% in the wet month. The behaviour of suspended sediment was examined for each storm (total of 46 storms) by plotting both storm hydrographs and hysteresis loops for discharge and suspended sediment concentration. Most of the hysteresis loops were an anti-clockwise loop, where a single rise in discharge with lag in suspended sediment concentration on the falling limb of the hydrograph. The behavioural pattern of suspended sediment and discharge suggested the influence of quarrying activity on the suspended sediment behaviour.

***Keywords:*** suspended sediment load, hysteresis, quaryying

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**HW3007** **Oral Presentation** **4761**

# Influence of land use changes on slope processes sediment flushing and total sediment budged - a case study from a southern Taiga Catchment in Russia

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Due to political influence and economic pressures the commercial agriculture in Russia is subject of dynamic changes. Major triggers are the modification of the property rights and consumer demands. However, the lack of investments often results in an unsustainable utilisation of natural resources with serious consequences for soil and water quality. This case study examines the impact of proposed or predicted land use changes for a typical catchment in Russia and its impact on connectivity aspects and sediment budged with catchment monitoring and model application. The 18.8 km2 Lubazhinkha catchment is located 100 km south of Moscow, Russia in a subhumid southern Taiga region. The valleys are deeply incised into the undulated flat interfluves where Greyzems are the dominant soil type. 55% of the area of the Lubazhikha catchment is used agriculturally by three co-operative farms. One-third of the catchment is covered by forest. Detailed recording of meteorological data, hydrological observations and estimation of sediment and nutrient loads are carried out since 2002. The observed sediment loads at the catchment outlet are characterised by a high variability and can reach up to 0.25 t ha-1 for the snowmelt period 2005. Maximum suspended sediment concentration range from 500 to 2000 mg l-1 during the years 2003, 2004 and 2005. A factor analysis of the data results in two significant different factor which are closely connected to different runoff generating mechanism. Hysteresis curves and parameter combination allow a further identification of interfluves areas and forest as important sediment and nutrient source areas. However, the connectivity of these source areas depends on the soil frost conditions and snowmelt dynamic of the individual years. There is evidence from the data that sediment deposition and remobilisation in the channel occur not only in consecutive years but also within on snowmelt period. The integrated winter erosion and nutrient load system (IWAN) was developed to characterise temporal and spatial aspects of runoff generation and snowmelt rill erosion at the catchment scale. It is a system of loosely coupled models that consist of three independent modules and pre- and post-processing procedures. The model system delivers satisfying results especially with respect to the alternation of slope erosion and sediment flushing in the channel. Simulated land use scenarios, that include increase of forest area or increase of cattle breeding pastures, prove the importance of slope and channel erosion processes. Aside erosion reduction on the arable fields, a detailed examination of connectivity lines and a management of areas with concentrated flow generation is of high importance for a proper catchment management.

***Keywords:*** sediment flushing, landuse change, russia

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**HW3007** **Oral Presentation** **4762**

# Modelling sediment production and delivery in the Xihanshui River Basin, Gansu, China

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***Ding, J***

This paper outlines a framework for assessment of the effects of changing land management practices and climatic regimes on the spatially-distributed production, delivery and yield of sediment from the Xihanshui River Basin, a 1.02104 km2 tributary of the Upper Yangtze River in Gansu Province, China. It is based on the evaluation of steady state production and routing of sediment, but under different land use and climate change scenarios, and in relation to the combination and interaction of these changes. The approach uses field, archive and remote sensing data as well as simple modelling within a GIS environment to analyse sediment production by surface wash and rill erosion, gully erosion, landslides, and river bank erosion. The whole basin is divided into sub-catchment spatial units, and the sediment budget for each of these is evaluated as the sum of the sediment input from the upstream unit, the internal production of sediment by the above-mentioned processes, and a depositional loss term; this is the model structure of SedNet (Prosser et al., 2001). For each sub-catchment spatial unit there is then a sediment delivery ratio, defined as the ratio of its yield (output) to the total supply. To evaluate the sediment yield at a downstream site, the model requires the summation of delivery from all sub-catchment units tributary to that location. However, the total sediment production in each sub-catchment unit must be multiplied by the product of all sub-catchment delivery ratios along the path from the unit to the downstream location, which progressively reduces the supply from that unit during the routing process. This model structure offers the possibility of defining the contribution made by sediment production in particular, spatially-distributed source locations to downstream sediment yield; of therefore evaluating the consequences of changes in sediment production as a result of different environmental conditions (land use and climate change); and of managing sediment production and delivery in large catchments in order to reduce sediment yield at downstream sites. This approach avoids the problem of routing sediment explicitly, with the attendant difficulties of representing travel times, but cannot deal with the short-term dynamic transients in sediment delivery. It offers a valuable strategy for both evaluating sediment delivery as a spatially-distributed phenomenon within a large catchment (rather than treating delivery as a lumped catchment-scale phenomenon); and of assessing the possible benefits of land management in different parts of a basin with different routing characteristics. Such a method could be an important tool for managing sediment problems in the Yangtze River above the Three Gorges Dam.

***Keywords:*** sediment delivery, steady state, land management

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**HW3007** **Oral Presentation** **4763**

# Impact of forest roads on subsurface flowpaths and shallow lansliding

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This study investigates how subsurface flowpaths are altered by forest roads and how these changes influence shallow landsliding susceptibility in steep, forested landscape. A simple conceptual model of the effect of forest roads on hillslope subsurface flow is developed. The model is incorporated into a hydro-geomechanical, threshold-based model for slope instability. In the model, the occurrence of shallow landsliding is evaluated in terms of drainage areas, ground slope and soil properties (i.e., hydraulic conductivity, bulk density, and friction angle). Model results allow to quantify the influence of roads on shallow landsliding hazard across a landscape and to generate hypotheses about the broader geomorphic effect of roads. Modelling results are compared with field data collected in a number of monitored sites located in north-eastern Italy, where accurate LIDAR data are available to represent both hillslope topography and road geometry. Observed landslide patterns are broadly consistent with model estimates, a finding that underscores the utility of this simple approach for predicting the geomorphic effects of forest roads constructed on steep slopes. The approach used in this study may be useful for defining criteria for road design that reduce the effects of roads on geomorphic processes.

***Keywords:*** forest roads, landsliding, subsurface flow

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**HW3007** **Oral Presentation** **4764**

# Beaver driven vertical accretion of sediment on floodplains and terraces

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We used the Colorado River valley in Rocky Mountain National Park, Colorado, USA as a model system to explain a process by which beaver can drive vertical accretion of sediment. An in-channel beaver dam triggered overbank flooding in the 4.3 ha study area, killing vegetation in areas deeply flooded during the beaver occupation. Only plants on hummocks survived the flooding. The beaver-created hydrologic connection between the Colorado River and the valley bottom permitted ~750 m3 of sediment to accumulate in a fragmented pattern on the floodplain and terrace while the dam was active (August 1997 May 2003). Sediment deposited on the terrace is protected from future re-mobilization by overbank flood events as the terrace is disconnected from the river unless another beaver dam reconnects it to the river. Although nutrients were deposited in association with the sediment, the deposited sediment did not have higher nutrient availability than the surrounding soils, likely because of its high sand content. While areas east of the river did not accumulate sediment, the drowning of plants meant that the mineral soil was exposed following de-watering of the area following the dam breach. Newly deposited sediment and exposed bare soil was quickly colonized by sedge-dominated communities on wet sites and early successional grass-dominated communities on dry sites, forming a heterogeneous patch on the landscape. Salix spp. and Populus tremuloides seedlings were found throughout the study area, suggesting that these beaver-created patches may succeed to a shrub-carr community, which would facilitate future reoccupation of the site by beaver. This study shows that beaver drive hydrologic processes that connect terraces to rivers, which leads to the accretion of sediment and plant establishment in different parts of the landscape than does flooding. These data have implications for valley development theory.

***Keywords:*** accretion, beaver, plant diversity

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**HW3007** **Oral Presentation** **4765**

# Changeability of intra-annual uneveness of runoff, erosion and suspended sediment yield in river basins of the East Europe

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The some spatial regularities of the intra-annual unevenness of runoff (R) and suspended sediment yield (SSY) (the natural zonality, dependences on a degree of agricultural activity (a portion of woodiness or cultivated areas), dependences on a river basin area and absolute mean height etc.) in river basins of East Europe (basins of Volga, Don and Ural) have been determined. They are based on analysis of the long-term series of observations (the 1940-1980s) for runoff and suspended sediment yield in 115 basins of small (with areas less 5 000 km2 azonal basins) and medium (with areas from 5 001 to 35 000 km2 zonal basins) rivers (on materials of Hydro-Meteorological Service of the former Soviet Union) with different landscape-climatic conditions (a zone of taiga and mixed forests (34 basins), a zone of broad-leaved forests (26 basins), a zone of forest-steppes (21 basins), a zone of steppes (25 basins), a zone of semi-deserts (9 basins)). Total area of all river basins is 777 956 km2. The average duration of observations for SSY is 18 years (76 basins 11-20 years, 33 basins 21-30 years, 6 basins 31-40 years). Main parameters of intra-annual unevenness were chosen: - the average long-term ratio between maximum and minimum monthly values of runoff (max/min(R)) and suspended sediment yield (max/min(SSY)); - the average long-term ratio between the maximum monthly value and annual norm value of runoff (max/N(R)) and suspended sediment yield (max/N(SSY)); - the average long-term ratio between annual norm value and minimum monthly value of runoff (N/min(R)) and suspended sediment yield (N/min(SSY)); - portions of maximum and minimum monthly values of runoff and suspended sediment yield in its total annual values (Pmax(R) and Pmin(R), Pmax(SSY) and Pmin(SSY) respectively). Dimensionless of these parameters allows uniform approach for characteristics of some spatial regularities of intra-annual unevenness of runoff and suspended sediment yield. Some geomorphic aspects of this changeability and approaches for improvement of eco-geomorphic situation in this region during XXI century are considered in the Paper.

***Keywords:*** intra annual unevenness, runoff, sediment

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**HW3007** **Oral Presentation** **4766**

# Degradation processes in river systems of Volyn-Podillia High Plain, Polissya lowland and Eastern Carpathians (Ukraine) as a reaction to economic activity

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Degradation processes in river systems are those, which cause the reduction of water discharges in rivers, mud depositions in their riverbeds, their overgrowth with hydrophilic plants, the transformation of rivers into interim streams or their complete drying out. These processes bring about the transformation of river systems structure (the lowering of their rank), the deterioration of their hydroecological state and the quality of water resources. They pervade mostly the upper links of river systems and are the consequences of the impacts of economic activities on watersheds, floodplain and valley landscapes, and also of climatic changes. The paper gives the assessment of the scales of degradation and transformation processes in river systems of different regions of Western Ukraine (Polissya, Podilla, Eastern Carpathians), taking place during the last 230, 150 and 80 years. The obtained results are based on the comparative analysis of maps (mostly of the same scale) for different time moments (1772, 1855, 1925, 1955, 2000 years), the results of field studies of geomorphological structure of fluvial systems, and stationary observations on the intensity of erosive processes, sediment transportation, and accumulation. The stationary observations encompass high plains (Western Podilla, Precarpathians), as well as mountains (Polonynskyi range of Eastern Carpathians). The tendency is discovered towards the increase in intensity of the development of erosion-accumulation processes in small river watersheds, in their floodplains, and riverbeds, which are explained by the impact of economic activities on basin landscapes (increase of areas of arable lands, deforestation, river alluvium extraction, melioration activities, etc.) The rates and directions of erosion-accumulation processes in riverbeds of Carpathian, Polissya, and Podilla rivers were assessed using the methods of repeated leveling, transverse river profiling on hydrological stations and the construction of different-time curves Q = f (H). As a result of research 3 variants of the development of erosion-accumulation processes were distinguished: 1) Cutting of streams and deepening of their channels, with the dominating bottom erosion; 2) Sediment accumulation in the riverbeds of small rivers, the accumulation of slime and overgrowth with vegetation, their transformation into interim streams; 3) Pulsating development of erosion-accumulation process, caused by a combination of climatic changes and the changes in economic activities. The models of the structure of river systems for different time periods were created using GIS technology. The scales of transformation processes and the influence of natural and socio-economical factors on their development were assessed, and the system of measures for the stabilization of ecological state was validated.

***Keywords:*** erosion, sediment, river system

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**HW3007** **Oral Presentation** **4767**

# Estimating the impact of projected change in farming by 2015 on the importance of the agricultural sector as a sediment source in England and Wales

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In association with a major initiative aimed at identifying policy packages for inclusion in the Programmes of Measures (POMs) comprising River Basin Management Plans (RBMPs), ADAS has recently been commissioned to evaluate the gap between current and compliant suspended sediment losses due to farming across England and Wales. The work required national scale sediment source apportionment to assess the current contributions of diffuse agricultural and urban sector losses, channel bank erosion and point source discharges to the total suspended sediment loads delivered to all rivers. Results suggested that the agricultural sector dominates present day (year 2000) sediment inputs to rivers (1929 kt = 76%) compared to eroding channel banks (394 kt = 15%), diffuse urban sources (147 kt = 6%) and point source discharges (76 kt = 3%). Projected change in farming by 2015, represented by the Business as Usual forecast of structural developments and predicted uptake of sediment mitigation methods, suggested a 9% reduction in sediment losses from the agricultural sector across England and Wales. Based on this analysis, further mitigation of diffuse agricultural sediment transfers to watercourses will be necessary under RBMPs to ensure good ecological status in some catchments.

***Keywords:*** change agriculture, suspended sediment sources, water framework directive

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**HW3007** **Oral Presentation** **4768**

# Changing floodplain states: unravelling changes in the depositional history of a large dryland floodplain system

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Floodplains are complex depositional features in the riverine landscape. The physical, chemical and biological character of floodplain sediments can be used to reconstruct their condition before and after the advent of human activities. Thus they can be used to benchmark river floodplain ecosystem functioning. This paper outlines the results of a palaeolimnological study of the lower Balonne floodplain, a large floodplain wetland complex in south west Queensland, Australia. A series of 18 sediment cores were extracted from a suite of different geomorphic units across the floodplain. Sediments in the individual cores exhibited a variety of textural forms and three broad stratigraphic patterns were identified: a general fining upward sequence, an episodic fining upward sequence, and a mud-dominated sequence. Within each pattern there was a notable and abrupt change in the nature of sediment deposition around the 1950s. The post 1950s sediment depositional pattern is chaotic in nature than the more regular and cyclic nature of sediments deposited prior to the 1950s. Moreover, the post 1950s sedimentation rates are over an order of magnitude greater in comparison to those established for the pre 1950s. The geochemistry of sediments associated with the two different time periods is also markedly different, with the post 1950s sediment being more homogeneous in its geochemical character. Given these changes it is suggested the lower Balonne floodplain wetland complex has undergone a metamorphosis of its sedimentary character.

***Keywords:*** palaeoecology

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**HW3007** **Oral Presentation** **4769**

# Environmental change: inferences from sediments in a terminal floodplain wetland complex

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***Martin Thoms***

The environmental history of a terminal floodplain wetland complex located in semi arid Australia is investigated. The stratigraphy, textural and geochemical character of sediments contained in 12 cores, ranging in length from 6-15 m, were determined and used to assess changes in sediment sources and sink conditions within the Narran floodplain wetland complex. Entropy analysis of the textural data provided seven sediment groups and the distribution of these highlight distinct textural sequences within the cores; an upper contemporary sequence, middle chaotic sequences and lower sequences. The nature of these sequences reflects possible changes in both catchment sediment sources and/or hydrological conditions within the study site. Multivariate analysis of the geochemical, data based on the a priori Entropy groups, note significant differences between the three main stratigraphic sequences. In particular, Mn and P clearly differentiate between the different vertical sequences. A geochemical mixing model using these elements suggest that there has been a shift in the dominant source of sediment derived from the two principal tributaries upstream of the study area over time. This study highlights the utility of integrating of standard sedimentological and multivariate techniques in unravelling complex environmental histories of depositional environments.

***Keywords:*** entropyanalysis, sedimentgeochemistry, sedimentcores

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**HW3007** **Oral Presentation** **4770**

# Effect of dam construction on streamflow and suspended sediment load of Beris River, Sik, Kedah (Malaysia)

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***Zullyadini A. Rahaman, Salleh Bakar***

A new Beris reservoir in Kedah State, north western part of Peninsula Malaysia, was recently completed and impoundment started in February 2004. A study was conducted to examine the impact of construction activities of the dam on the surrounding environment. This paper focus on the effect of water impoundment on the streamflow, TSS and sediment loads of Beris river, the major river supplying water to the dam. Water sampling and river gauging were carried out every month from April 2003 to January 2005. The period April 2003 to January 2004 represent the period before impoundment whilst February 2004 to January 2005 represent the period after impoundment. Sediment sources are readily available for transport during construction activities evidencing from our observed TSS concentration of up to 1500-1800 mg/l from silt trap and ditches around construction sites during a storm event. This has caused a lot of sediment to be washed down into the river and we have estimated the highest sediment loading for July-August 2003 was about 4700 tonnes. Sediment sources were from land clearing of the forest before impoundment and construction activities. The average flow of the outlet was reduced from about 6 cumecs before impoundment to about 0.9 cumecs after impoundment. The average suspended sediment concentrations were reduced from 51.9 to 27.1 mg/l and the sediment loading of Beris river downstream of the dam was reduced by almost 94%. Most of the sediment was trapped in the newly built reservoir. Further study will be carried out to monitor the progress of the dam.

***Keywords:*** sediment, streamflow, impoundment

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**HW3007** **Oral Presentation** **4771**

# Assessing the impact of improved land management on catchment sediment yields

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***Jean P.G. Minella, Gustavo H. Merten***

In many countries, in both the developed and the developing world, there is increasing concern for problems of on-site soil degradation and the off-site impacts of eroded soil within catchments and river basins. This has led to the implementation of improved land management practices, including no-till and other soil conservation measures. There is an important need to assess the effectiveness of such measures in reducing sediment mobilization and catchment sediment yields, in order to evaluate their cost-effectiveness and to plan future management strategies. This paper reports the results of a study undertaken in a small catchment in southern Brazil that was monitored before and after the implementation of improved land management practices. Although the traditional monitoring programme was able to demonstrate the impact of the improved management practices in reducing storm runoff amounts and storm-period sediment yields, the incorporation of sediment source fingerprinting investigations into the study provided a much clearer picture of the changing sediment dynamics of the catchment and the impact of the improved land management practices. The findings of the study have important implication for both designing monitoring programmes to assess the impact of improved land management on catchment sediment yields and understanding the nature of the changes.

***Keywords:*** soil erosion, sediment yield, management impacts

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**HW3007** **Oral Presentation** **4772**

# SOme impacts of environmental change on the sediment loads of the worlds rivers

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Current concern for the impacts of global change on the earth system have focused on many different facets of its functioning. Most attention has been given to climatic change and its wide-ranging implications. However, there are many other aspects of global change, including land cover and land use change and water resource development, which are now having important impacts on the system. This contribution considers the impacts of such changes in the sediment loads of the worlds rivers and land-ocean sediment transfer. The lack of reliable longer-tern time series of annual sediment load data for many of the worlds larger river precludes a definitive assessment of recent changes in the overall land-ocean sediment flux, but there is increasing evidence of significant changes in this flux which in turn permits some preliminary conclusions as to the likely magnitude of the changes involved.

***Keywords:*** world rivers, sediment loads, environmental change impacts

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**HW3007** **Oral Presentation** **4773**

# Use of landslides reservoir deposits and the pollen tracing technique to investigate the erosional response to land use changes of a small drainage basin during the later of the sixteen century on the Loess Plateau of China

***Prof. Xinbao Zhang***
*IAHS*

***Yi Long, Des Walling, Xiubin He, Yangchun Wang***

This paper reports the results of an investigation of the erosional response to land use changes of the 0.1-km2 Houxiaotan Gully catchment during the Ming dynasty in the rolling loess plateau region of Zizhou County, Shaanxi Province, China. The gully was dammed by a landslide in 1569 A.D, and then the delivering sediments from the catchment were trapped in the reservoir. Since the dam failed when the reservoir was filled up, a channel has incised into the reservoir deposits and reached the former gully bed. A profile of the reservoir deposits with a vertical length of 12.73m was investigated in April, 2006. According to variations of clay and pollen contents, 54 flood couplets were identified in the profile. The appearance of freeze-thaw textures in the clay layers of the couplets is used to identify the last flood couplet in a year and the 54 flood couplets occurred in 31 years. Specific sediment yields for the 31 years after 1569 A.D are estimated from the deposit volumes of the couplets. The specific sediment yields for a flood event range between 716 tkm-2 and 22525 tkm-2 with a mean value of 7245 tkm-2a-1 and for a year range between 968 tkm-2a-1 and 55579 tkm-2a-1 with a mean value of 12629.49 tkm-2a-1. Those values indicate that soil erosion in the Ming Dynasty was severe with similar extents to the present day. At that time, military reclaiming land for cultivation to supply army provisions in situ was extensive in the rolling Loess Plateau region of Shaanxi province on the southern side of the Great Wall. For the last five years, sediment yields, pollen concentrations and Artemisia pollen proportions in the sediment deposits increased rapidly. It implies that re-reclamation of the abandoned land in the catchment since the landslide disaster, where vegetation rehabilitated already, caused very sever soil erosion in the catchment.

***Keywords:*** reservoirdeposits, pollentracing, sedimentyields

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**HW3007** **Oral Presentation** **4774**

# Suspended Sediment Yield of the Amazon River : an increasing budget from 1995 to 2006, using river sampling and MODIS data

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*IRD IRD IAHS*

***Jean Michel Martinez, Naziano Filizola, Francis Sondag***

The Amazon River is the largest river of the world with a drainage basin of more than 6 106 km2, and a mean annual discharge estimated at 210 000 m3/s (Molinier et al., 1996). Surface suspended sediment are sampled, every 10 days since 1995, for 16 selected gauging stations in the basin, by the international HYBAM observatory (www.ore-hybam.org). At the bidos station the last gauged station before the Atlantic Ocean, a nine years (1995-2003) suspended sediment budget suggests a increasing sediment yield since 2001 (Guyot et al., 2005). In this study, using actualized HYBAM dataset (1995-2006) and surface suspended sediment calculated by MODIS reflectance inversion (Martinez et al., 2004) for the 2001-2006 period, we present new results that confirm this increasing sediment yield of the Amazon River. Guyot J.L., Filizola N., Laraque A. 2005. Rgime et bilan du flux sdimentaire de lAmazone bidos (Par, Brsil), de 1995 2003. Sediment budgets, IAHS Publ. 291 . 347-356. Martinez J.M., Maurice-Bourgoin L., Moreira-Turcq P., Seyler F. 2004. Amazon floodplain Water Quality Monitoring using MERIS and MODIS Data. Envisat symposium, Salzburg, Austria, 6-10 Septembre 2004. Molinier M., Guyot J.L., Oliveira E., Guimares V. 1996. Les rgimes hydrologiques de lAmazone et de ses affluents. Lhydrologie tropicale : goscience et outil pour le dveloppement (Ed. P. Chevallier & B. Pouyaud) (IAHS Symposium, Paris, 05/1995). IAHS Publ. 238 : 209-222.

***Keywords:*** amazon river, brazil, suspended sediment

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**HW3007** **Oral Presentation** **4775**

# Hill slope erosion and climate change in Hong Kong

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There is evidence that the climate of Hong Kong and the region is changing. During the period 1989 2002, annual mean temperature at two stations less affected by local urbanization rose by about 0.15C and 0.19C, slightly less than the global rate of 0.21C for the same period. In line with global climate change, southern China has experienced warming in the last fifty years and this will be continued till the end of this century. Trend analysis of rainfall for the period 1956 to 2005 over five different regions showed a rising trend from 34 to 103 mm per decade. The number of heavy rain days per year is projected to increase from the 1961 1990 normal of 5.6 to 6.5 in the period 2070 2099. Landslides are an important erosional process on undeveloped hill slopes in Hong Kong. Observations are presented illustrating erosion and sediment production by landslides in the territory. These include storm period observations made of suspended sediment concentration and C and N content of the suspended matter during two storm events (June, 2001 and May, 2003) in a small drainage basin. The June 2001 event generated very high maximum suspended sediment concentrations of around 2900 mg/L whilst both storms were characterized by a change in sediment colour and C and N content of the suspended matter. Wildland fires in Hong Kong are generally known as hillfires since most fires occur on hill slopes in the countryside of Hong Kong. There may be as many as 500 fires in one season covering more than 5% of the total land area. Hillfires can be an important cause of geomorphological change. However, little or no information is available on this for Hong Kong. Recent monitoring on hill slopes has provided some preliminary data. Splash pans and sediment traps installed on erosion plots have been used to compare the sediment production on hill slopes affected by fire. In December 2004, a fire occurred and in 2005 yield of mineral soil was 4.6 times and 135 times higher, for pans and traps respectively, at the sites that experienced fire compared to those sites that were not burnt. An understanding of the associations between climate and the occurrence of landslides and hillfires in Hong Kong may provide an insight into the influence of climate change upon hill slope erosion. It may also permit identification of important research gaps and problems. Evidence for linkages between landslides and rainfall and the influence of weather upon hillfires is reviewed. It is suggested that climate change may have implications for hill slope erosion.

***Keywords:*** landslide, hillfire

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**HW3007** **Oral Presentation** **4776**

# The effects of changing land use on soil erosion and sediment mobilisation in two small catchments in Southern Italy

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***Des E. Walling, Giovanni Callegari, Francesco Catona***

Soil erosion is a major concern for the sustainable management of agricultural land because it reduces soil productivity, degrades stream water quality and increases water pollution risk for humans and aquatic ecosystems. In Southern Italy, where soil loss can exceed 100-150 t ha-1 year-1, there is a drive to minimize erosion by implementing improved management practices and erosion control measures. Among these practices, a change in land use involving reafforestation of large areas aimed at providing increased protection of the soil from rainfall and runoff has proved to be highly effective in terms of reducing erosion risk. In order to devise meaningful land-use policies and to select effective soil conservation practices, it is important to evaluate the importance of forest cover in reducing soil erosion. In this context, the use of environmental radionuclides, and particularly 137Cs and excess 210Pb, to estimate soil erosion has proved to possess several important advantages over traditional techniques, if reliable conversion models are available for estimating soil redistribution rates. The study reported focuses on two small catchments (W2 and W3) located in Calabria, Southern Italy, for which measurements of suspended sediment yield are available. Both the catchments originally supported a rangeland vegetation cover and they are subsequently reafforested with Eucalyptus trees in 1968. Currently, only catchment W3 shows a continuous forest cover whereas catchment W2 shows some bare areas that preserve the natural vegetation. Within catchment W2 two additional erosion plots were established in 1994 in order to explore the effect of the tree cover on soil erosion. Measurements of sediment yield from the two catchments and the plots for several storm events and associated information on the 137Cs and excess 210Pb of the sediment have been used to evaluate the effects of the conversion from rangeland to forest cover on sediment mobilisation and soil loss. The analysis showed that the areas with the highest soil loss are associated with the slopes where the tree cover is discontinuous, emphasizing the importance of vegetation cover in influencing rates of soil loss in the study catchments. The results have also been used to validate some of the basic assumptions commonly associated with the use of mass balance models for estimating rates of soil loss from radionuclide measurements.

***Keywords:*** caesium 137, lead 210, soil erosion

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# Summary Statistics for Selected Major and Trace Element Concentrations Associated with Fine-Grained Fluvial Bed Sediments Based on Land Use, Rock Type, and Population Density, for the United States

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In 1991, the U. S. Geological Survey (USGS) began the first cycle of its multidisciplinary National Water Quality Assessment Program (NAWQA). The program encompasses 51 river basins that collectively account for more than 70% of the total water use (excluding power generation), and 50% of the drinking water supply in the U.S. The selected basins represent a wide variety of hydrologic settings, rock types, land-use categories, and population densities. Approximately one-third of the river basins are under active investigation for periods of 3 years at a time; hence, it took 9 years to complete the sampling program for the first cycle. One aspect of the first cycle included representative bed sediment sampling, and subsequent chemical analyses, within each of the river basins. Sampling sites were selected to represent the most important land-use categories (e.g., agriculture, undeveloped, urban) in each river basin. In total, over 1,000 bed sediment samples were collected. All samples were field-sieved to <63-m to facilitate spatial and/or temporal comparisons, and subsequently were analyzed for a wide variety of chemical constituents including major elements (e.g., Fe, Al, Ti), trace elements (e.g., Cu, Zn, Cd), nutrients (e.g., P), and organic carbon. The analytical procedures employed generated total (≥95% of the concentration present) rather than total recoverable chemical data; this also should simplify intercomparisons. Based on a wide variety of ancillary data, each site was categorized by (1) land use; (2) rock-type; and/or (3) population density, to facilitate the calculation of summary chemical statistics. Background summary statistics for the entire U.S. also were generated from a subset of all the samples, and are based on material collected from low population density forested, range, and agricultural areas. Because the bed sediment samples were grain size-limited (≤63-m), all the summary statistics are likely to be applicable to suspended sediment as well.

***Keywords:*** geochemistry, inorganics, sediment

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# The impact of environmental changes on the sediment load in Norwegian rivers

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The increase in the number of extreme precipitation events and other unusual weather events in Norway, strongly suggests that weather conditions are changing. An example given by the Norwegian RegClim research project report from observations of exceptionally high precipitation during the three months November to January during the last decades. The maximum of 1400 mm recorded in 2005 is 3.5 times the standard deviation of 615 mm for the period 1881-2005. The rainfall triggered a major debris slide inside the city of Bergen that resulted in loss of lives and extensive damage to houses. The seasonal distribution of runoff in several parts of the country has changed due to the increase in temperature and rainfloods in formerly cold and snowy winter months have become more common. A plot of the number of snowmelt floods vs rainfloods for the last 150 years revealed long term changes with the maximum number of rainfloods occuring during 2000-2005. Higher winter temperatures have also produced an increase in flood events caused by rainfall on frozen ground that may have led to unusually high erosion rates. In the river Leira I n Southeastern Norway, very high concentrations of 2500-5400 mg/l representing 90% of the annual transport were measured during during such a situation in February 1990. In the stream Vikka, a tributary to river Leira, the availability of sediments increased with the soil moisture content in a prolonged period of rain during September to December 2000. Suspended sediment concentrations during the initial phase of the wet period culminated at 1000 mg/l during a flood event of 700 l/s. As the ground became saturated, more active slope processes caused erosion rates to increase markedly; a concentration of 8000mg/l was attained in a flood event of similar magnitude two months later. The combined effects of climate change and human impacts on the sediment transport in rivers seems to enhance the downstream sediment delivery to the sea. The construction of flood protection works along river channels prevent sediment from being deposited on the floodplain. River channels that have been lowered in order to lower groundwater levels in agricultural floodplain areas will experience the same effect. Up to 25-30% of the total flood sediment input is estimated to be deposited on floodplains under natural conditions. During the last decade extensive ecological changes have taken place in the coastal areas of southern Norway. 90% of the sugar kelp forest has been lost from large areas along the Skagerak coast. This change has been attributed among other things to an increase in water temperature and the apparent increase in sediment delivery.

***Keywords:*** sedimenttransport, climatechange, humanimpacts

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**HW3007** **Oral Presentation** **4779**

# The impact of hydrological extremes on uses and functions in river basins

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A river catchment offers a number of environmental and societal services, such as nutrient regeneration, phytoplankton production, a variety of habitats, transport, recreation, agriculture (floodplains), drinking water production, and fishery. However, even though the water quality in most European rivers has improved a lot since the 70s, sediments below often carry the memory of an industrial history of the area and impair these functions if they are exposed. As sediments undergo a number of resuspension - sedimentation cycles during their transport to sea, they interact with the water phase enhancing the risk of remobilization of contaminants. Even at average annual flood events, the suspended matter in many rivers is contaminated. With exceptional flood events, old legacies can become re-introduced into the river, endangering not only the aquatic community, but also fish production and port activities, as well as use of agricultural products from flooded flood plains on which they may settle. This presentation is based on studies that have been prepared for the Elbe and the Rhine river in Germany, aiming at quantifying risks for services along the catchment due to resuspension of contaminated sediments. This quantification needs to consider that hydrological extremes can affect regions within a catchment differently, diluting or increasing the concentration of contaminated material in the main stream. Uncertainties need to be considered as measurements of suspended matter show a strong dependence on sampling procedures. Also effects of exposed sediment contamination on services and uses is often not clear due to missing standards. In the studies on Rhine and Elbe we looked into periods of exceptional high and low water discharges and the effects on suspended matter transport, sedimentation and use-impairment. We tried to trace the origin of the suspended matter back from places at risk in order to suggest measures to be taken in the catchment area. While in the Rhine basin, only 2 areas, the barrages in the Upper Rhine at HQ1-floods and the Ruhr area at HQ100-events, posed according to our calculations a high risk to downstream areas at different discharge levels, the number is expected to be higher in the more contaminated Elbe river. Climatological projections for the Elbe River show a 20 % increase of precipitation in the coastal area in winter, a 10 % decrease of precipitation in Northern federal states in summer, an increase of wet days in the Ore Mountains in the catchment area, and an increase of precipitation that will fall on a wet day and the number of those days in summer leading to the risk of flash floods. The importance of these developments on the transport of sediments within the Elbe catchment will be discussed.

***Keywords:*** contaminant transport, river basin, elbe river

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**HW3007** **Oral Presentation** **4780**

# Sediment Sources in the Mackenzie River Basin

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The Mackenzie River basin is Canadas largest drainage basin and occupies a total area of 1.8 x 106 km2 or approximately 20 % of Canadas landmass. The Mackenzie River is the fourth largest northern river in terms of freshwater discharge (after the Lena, Yenisei, and the Ob Rivers), with a mean annual discharge of 8980 m3/s, representing approximately 14% of all total freshwater discharged into the Arctic Ocean, and peak discharges as high as 34,000 m3/s during the spring freshet in May/June. The Mackenzie River officially begins at the outflow of Great Slave Lake. Sediment from the regions upstream of Great Slave Lake is deposited in the Peace-Athabasca delta in Lake Athabasca, and in the Slave delta in Great Slave Lake. The presence of the large lakes and associated deltas in the Mackenzie River basin results in discontinuous transport of sediment and associated contaminants in the Mackenzie River system. The sediment load of the Mackenzie River is very low at the outflow of Great Slave Lake, and the majority of its sediment load comes from the tributaries that drain the mountain ranges to the west, with smaller contributions from the tributaries that drain the shield areas to the east. Deposition of sediment in the Mackenzie delta is an important factor determining the sediment flux to the Beaufort Sea. The Mackenzie River is the largest single source of sediment for the Arctic Ocean, depositing approximately 128 Mt (107 Mt from the Mackenzie River and 21 Mt from the Peel River) of sediment each year, more than double that of all other rivers draining into the Arctic Ocean combined. A special feature of the Mackenzie River is that river ice break-up progresses from the south to the north, resulting in extensive ice jams as upstream regions provide water to areas further downstream to the north where the ice-cover is still intact. Associated with the break-up is a substantial increase in the concentrations of sediment and total metals. Because of its location, in particular its range in latitude from about 52N to 70N, the Mackenzie River basin is extremely sensitive to current and future changes in climate. Possible impacts of global warming are a change in river ice and break-up characteristics, melt of permafrost resulting in bank collapse and increased erosion rates, changes in sediment contributions from glacierized areas, and decreases in water level in the Athabasca delta as a result of lower discharges in the Athabasca River. In addition, resource development within the basin, for example associated with the proposed Mackenzie Gas Project, is likely to have an impact on sediment transport. As a result, the sediment dynamics of the Mackenzie River basin may dramatically change in the near future.

***Keywords:*** sediment, mackenzie, arctic

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# Determination of a river potential to recover (co)natural river habitats on the basis of sediment analysis

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***Matja Miko, Matej Padenik***

Consequence of regulations, flow pattern simplifications and reduced sediment supply due to hydroelectrical power plants are weakened stream channel morphology, river bed lowering, deterioration of groundwater table and lower soil wetness of flood areas on downdstream sections. In the Mura river in Slovenia, at the times of low and average discharges, water from the channel is not entering into side channels and oxbow lakes are not filled with groundwater. The processes of channel dynamics are therefore limited only to flood periods. The frequency and duration of high water events is decreasing. The river hydrology does not efficiently sustain diverse river ecosystems and high groundwater table. Nevertheless, the river ecosystems on the Mura river downstream of the hydropower chain in Austria, still have high nature protection value. To sustain existing habitats and to initiate formation of new channel forms, the habitat creativity potentail has been studied on the middle section of the Mura river in Slovenia. It has been found that slope adjustments through upstream degradation and downstream aggradation may mean that the long-profile is approaching a graded condition and that the processes in this section control the downstream sections and have the greatest impact to the flood dynamics in the riparian zone. For the estimation and prediction of the environmental effects of implementation of measures such are introduction of weirs, feeding of gravel, mobilisation of river banks gravel and river bank, revetment beyond optimal width, the study of river topography, hydrology and sediment transport have been further investigated. The paper presents results on sediment processes in the Mura river corridor in Slovenia and potential for creation of new habitats.

***Keywords:*** regulated river, sediment transport, riparian habitats

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**HW3007** **Oral Presentation** **4782**

# Impacts of wildfire on sediment and water quality in headwater regions of the Oldman River basin, Alberta

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***Uldis Silins, Monica Emelko***

In 2003, the Lost Creek fire burned 210 km2 of nearly contiguous crown land forests in the headwater regions of the Oldman River basin, Alberta. A total of 8 hydrometric stations were monitored during 4 main stages of a hydrograph: snowmelt, rising limb, peak and recessional limb (April 2004 to March 2005) to measure stream flow, sediment concentrations and water quality in burned and unburned catchments. Several differences in streamflow (increased yield, magnitude of peak flows, potential flood flows) and water quality (physical and chemical) were observed between burned and unburned catchments. The mean snow water equivalent was nearly 3 times greater (an additional 142 mm) in burned areas due to the near elimination of canopy snowpack interception losses after the fire. Stream discharges reflected runoff regimes consistent with high regional precipitation and high relief physiographic setting of the study area. Suspended sediment concentrations varied strongly with flow condition but sediment availability was much higher in burned catchments, particularly during the snowmelt freshet and high flow events. Differences in sediment concentrations were highest during storm flow events (27 fold) but also during the snowmelt period (22 fold). Higher sediment concentrations in combination with slightly higher water yield produced larger differences in overall sediment yield (57 and 22 fold differences between burned and unburned during stormflows and snowmelt, respectively). The highest mercury concentrations and yields were observed during storm flow events which produced the largest relative differences between burned and unburned watersheds (16 fold differences in mercury concentration and 21 fold differences in total mercury yield). During the snowmelt freshet relative differences were smaller (4 and 6.5 fold differences between burned/unburned for concentration and yield, respectively) but 2 to 3 fold differences in mercury concentration and yield were still evident during summer base flows.

***Keywords:*** widfires, sediment transport, water quality

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**HW3007** **Oral Presentation** **4783**

# The impact of the volcanic eruption on hydrological processes and sediment yield

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Volcanic eruptions can affect key components of the hydrological cycle. Explosive volcanic eruptions often emit enough volcanic ash to completely cover the land surface near the volcano. The previous studies have reported the dramatic increase in the sediment and water discharge from such a volcanically disturbed watersheds. In order to clarify the effect of volcanic ash deposits on hydrologic and erosional processes, the authors conducted field hydrologic measurements at the slope of the Miyakejima volcano having erupted in 2000 and the laboratory hydrologic tests of the volcanic ash. As a result of the survey and tests, the following were clarified: 1) The volcanic ash has dramatically reduced the hydrological conductivities. Hortonian overland flow is a dominant runoff processes of ash-mantled hillslopes. Less surface runoff is generated at slopes mantled by coarse ash, mantled less thickly, or covered with a litter layer or grasses; 2) Erosion rates measured at volcanically disturbed slopes are considerably high and depend on the water discharge from the slope; 3) In recovering processes, sediment yield from the revegetated slope has decreased substantially while that from the unvegetated slopes has not.

***Keywords:*** volcanic ash, erosion, infiltration capacity

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**HW3007** **Oral Presentation** **4784**

# Steepland gully initiation, development and closure in response to land use change, East Coast Region, North Island, New Zealand.

***Dr. Michael Marden***
*IAHS*

***Greg Arnold, Anne Seymour, Randolph Hambling***

The region-wide distribution of actively eroding gully and gully-mass movement complexes was mapped across 8355 km 2 of steepland hillcountry within the East Coast Region,North Island, . We used aerial photography taken between 1939 and 1957 to document the onset of gully erosion for the period following clearance of the indigenous forest (~1880s1920s) for conversion to pastoral farming and before reforestation (1960). The distribution of gullies was then remapped using photography flown in 1997, 37 years after reforestation for erosion control began.Since the turn of the 19th century 3356 gullies with a combined area of ~5600 ha were the major contributing source of sediment delivered to the river systems of this region. Following the establishment of ~153 000 ha of exotic forest (19601997), pole planting and indigenous reversion of on-farm gullies, 2356 active gullies have been treated and sediment generation from them closed-down. Over the same time frame the combined area of untreated gullies increased and 1131 new gullies were initiated. The majority of untreated and new gullies occur in areas of pastoral hill country; lesser numbers are associated with areas of regenerating scrub and mature indigenous forest. Despite extensive efforts over the past half century to curb the erosion problems of this region, the total combined gully area is today ~37% greater than it was before reforestation programmes began in the early 1960s.Logistic models were fitted to describe the relation between the odds of gully closure and a) gully size at the time of planting, b) geology, and c) length of time since planting. The results of this modelling are discussed in relation to the impacts of gully erosion on the on-site loss of productive farm land and the off-site damage to the regions river systems and infrastructure.Key words: steepland-gullies, reforestation, probability-of -closing.1. HW30072. The Impact of Environmental Change on Sediment Sources and Sediment Delivery.3. Gully erosion, land use change, reforestation.4.

***Keywords:*** steepland gullies, reforestation, probability of closing

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**HW3007** **Oral Presentation** **4785**

# The use of sedimentation in ancient dams as environmental tool. South Zaragoza, Spain.

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Temporal variability within the last centuries, sediment accumulation and storage loss in reservoirs is studied. Roman reservoir within the Huerva and Aguasvivas River, South of Zaragoza were selected in base of previous erosion rates investigations and the presence of several reservoirs since Romans times until the half of the XX century. A methodology was designed based in dating with 14C AMS, archeomagnetostratigraphy, GPR profiles combined with GIS to assess sediment yield in ancient reservoirs and try to relate temporal sediment yield variability to natural background and human impact during Roman times. The Muel dam is located in the Muel village over the Huerva River, a tributary of the Ebro River (NE Spain). The dam wall of 3m high and 60m long is very well preserved, and the reservoir is completely silted. A combination of geophysical, archaeomagnetostratigraphy, sedimentological techniques, 14C AMS dating and historical compilation allowed the reconstruction of the dam sedimentation history. Ground Penetrating Radar was applied in order to obtain the thickness of the sediments accumulated in the reservoir, and to decide the cores location. Sections were carried out using a 25 MHz antenna. Penetrating depths was up to 40m and allow the identification of the infill materials. A drill campaign was carried out close to the dam site and cores were recovered. The bottom of the dam infill provided an age of 202030 14C yr B.P indicating that the dam was constructed during the I century B.C. corresponding with the period of Augustus. A second sample located 4,25m over the first one, showed an age of 188030 14C yr B.P. Assuming a constant rate of sedimentation of 1.9 mm/year the dam would be completed silted during the VI century A.C. In 1770, a Catholic Hermitage was built over the Mosque ruins. The Almonacid de la Cuba dam is located in the Aguasvivas River (Fig. 5). Was the world biggest dam in the world before the construction of the Kurit dam building in Iran in the XIV century. Erosion rates from different period of times were estimated using previous bathymetric data, obtaining sediment yield values between 8 and 56 tnkm-2year-1 from period between 14 year BC and 174 year AC. Results show that sediment yield values calculated at the Muel and Almonacid de La Cuba Roman dams are lower (10 times) than those provided by present day reservoirs (Las Torcas y Moneva). Differences in sediment yield will be related to important change in climate or land use change. Ancient water reservoirs would provide interesting information about climate and land use changes in the selected catchments.

***Keywords:*** dams, sedimentation, erosion

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**HW3007** **Oral Presentation** **4786**

# Erosion, sediment transport, and reservoir siltation in drylands: experiments, modelling and scenarios

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***Ramon J. Batalla, Jos C. De Arajo, Till Francke, Andreas Gntner, George Mamede, Eva Mller***

About one-third of the global population currently lives in countries which experience conditions of water stress. Such regions, often located within dryland ecosystems, are exposed to the hazard that the available freshwater resources fail to meet the water demand in domestic, agricultural and industrial sectors. Water availability often relies on the retention of river runoff in artificial lakes and reservoirs. However, the water storage in reservoirs is often adversely affected by sedimentation as a result of soil erosion. Erosion of the land surface due to natural or anthropogenic reasons and deposition of the eroded material in reservoirs threatens the reliability of reservoirs as a source of water supply. To guarantee future water supply, a quantification of the sediment export from large dryland catchments becomes indispensable.The objective of this comprehensive research effort is the development of a model system to assess sediment production in catchments, sediment transport in river system and sediment retention in reservoirs for meso-scale catchments in semi-arid and sub-humid regions. The necessary data for model development and application are collected within experimental meso-scale catchments, dryland rivers, and reservoirs in Spain and North-East Brazil to characterise rainfall runoff characteristics and sediment production in such environments. A hydrological model was adapted to such environmental conditions of semi-arid areas and has been extended with components representing erosion and sediment transport processes at the hillslope to the basin scale.Selected results concerning a representation of erosion-prone landscape units, the role of sediment transport in the river system, and the sedimentation in reservoirs are presented. We also show some first simulation results ref. the efficiency of soil protection and areal sediment storage processes for reducing reservoir siltation.

***Keywords:*** dryland hydrology, sediment transport, reservoir sedimentation

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**HW3007** **Oral Presentation** **4787**

# Global Change and the generation of sediments on South America Continent

***Dr. Fernando Campagnoli***
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This paper proposes a digital model of the sediment production of the South America lands to evaluate the potential impacts of global changes on the sediment sources. It is based on geological, slope, kind of soils, land use and annual and monthly rain features. Using the software Arc Gis 9.2 and samples of the hydro-meteorology data, the author made a successive superposition themes, relating these features to evaluate the natural fragilities to erosion processes, how the debris flows, landslides, gullies, ice melt, and ridges, showing in a digital layer designed to help on the planning the land use, which layer was called “Natural fragility features to erosion evaluation - NAFE”. The second stage was used the layer NAFE and made relation with the land use, to evaluated the preservation or not of the fragilities of the lands, generate the second layer called “Potential Erosion of the Areas Evaluation - PEAE”. The third and last stage was to know the relations between the PEAE and the various aspects the rain on South America Continent, considering the actual scenarios of precipitation, based on average annual and monthly data observed and the potential global changes expected, showed on the layer called “Rates of production of sediments on South America Continent – RPS”. This layer show the rates expected to production of sediment on the different climate scenarios, and can be used to regional estimative on projects of the engineering.

***Keywords:*** sediment, global change, south america

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**HW3007** **Poster presentation** **4788**

# Comparing the real value of sediment load with the results of erosion models in Kor River Iran

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Performing the best procedure preventing the erosion and decreasing sediment load entering the dams reservoir, the integrated information about sediment load is needed. Therefore many experimental models have been offered to estimate sediment load for different regions by researchers. None of these models couldnt define the realities of watersheds so for accurate estimation, measuring the real amount of sediment load hydrometric stations is needed. Kor River in central south of Iran is one of the individual sources of water in region which are used to irrigate so many lands. In this article the experimental models such as MUSLE, SLEMSA, MPSIAC, PSIAC, EPM, and FAO have been applied to Kors basins and the results are compared to real amount of sediment load which has been measured in Chamriz station. Chamriz is a hydrometric station in Kor River which measures suspended load and bed load which transported by floods. The results show that MPSIAC model is more conform than other models with the realities of Kor River Basins region.

***Keywords:*** erosion models, kor river, sediment load

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**HW3007** **Poster presentation** **4789**

# Watershed management and its effect on sedimentation in Doroudzan dam Iran

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***Pouyan Keshtkaran***

Doroudzan dam which is located in south of Iran is an earth dam with the reservoir capacity of 993 MCM. It supplies the demand water for Shiraz city with 2000000 population and irrigation of 1100 Km2 down stream agricultural land as well. Due to the importance of this dam in regional development increasing the period of operation of it, is on priority. The large amount of sediment load entering the reservoir is the greatest factor threatens the useful life of this dam. Dead storage of dam is estimated about 133 MCM for 50 years. Decreasing the amount of sediment load, watershed management operations such as creating mechanical structures like check dams, terraces, and biomechanical operation like vegetation and training to residents has been applied to upstream lands since 1980. In this article the watershed management operations are investigated and to evaluating the results of these operations, the amount of sediment load entering the reservoir before and after the watershed management operations, has been considered by the data of Chamriz hydrometric station that is located in the upstream of the reservoir, and the results of hydrographic surveying that has been done in 1995 and 2003 in reservoir. At the end, the result of investigation showed that after the watershed management operations the sediment load entering the dam reservoir decrease 40% which causes 25 years increase in period of operation of doroudzan dam.

***Keywords:*** droudzan dam, watershed management, sedimentation

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**HW3007** **Poster presentation** **4790**

# River environment changes due to river bed degradation and beach changes in estuary

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*IAHS*

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In estuary of Muka-river of Hokkaido in Japan, there was a natural tidal flat that exceeds about thirty-five hectares until 1970s. Many migratory shorebirds such as plovers and snipes etc., which are registered in The East Asian - Australasian Shorebird Site Network, used to come flying there to prey foods such as sandworms or to take a rest. The number of species counted up to thirty or more. However, the area of the tidal flat has been decreased since 1980s and only five hectares remains now. Then the number of shorebirds species that come flying to the tidal flat has decreased no more than five as the decreasing of the area of tidal flat. On the left bank side of the river channel in estuary, there were point bars composed of gravel, where vegetations could not be seen at all until 1980s. Since 1990s, however, the vegetations such as maples began to grow even on the floodplain as well as on point bars. Thus the vegetation environment of the ground has changed greatly. At the same time, the right bank has been eroded approximately 400m due to transition of the river channel in a period of from 1978 to 2003. This erosion brought the decrease of the tidal flat. In this study we analyzed the causes of the above-mentioned river environment changes by topographic map reading, photo interpretation and quasi-three-dimensional numerical simulation of sediment transport and river hydrodynamics. The main conclusions are shown below. 1) River bed degradation due to sediment excavation on the bank and the riverbed since the latter half of 1960s caused water level fall and increase of flow speeds at low water channel in the downstream area. As a result, increase of the discharge capacity at low water channel and fall of the water level in river channel were brought. 2) The decrease of the frequency of floods on the flood channel due to water the level fall caused the change in the vegetation distribution. 3) The sediments discharged form the river have been carried farther offshore than before because of the increase of flow speeds at the river mouth. Therefore the discharged sediments with small grain size have been less likely to deposit around the river terrace, then this has prevented the tidal flat from being formed. 4) The bank erosion has been caused by the increase in the flow speeds that act on the rive bank, by the shift of the action point of secondary flow generated in the bulge, and by the changes of its strength. 5) The fishing port, which was constructed at about 2000m eastward (left side) of the river mouth in 1980s, has brought about shoreline retreat by blocking the long shore sand transport, and the tidal flat has been eroded by this process at the same time.

***Keywords:*** tidal flat, river bed degradation, beach changes

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**HW3007** **Poster presentation** **4791**

# Vertical distribution of Sulfate Reducing Bacteria (SRB) in sediment of Lake Sihwa and Soyang, Korea

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For scrutinizing the relationship between distribution of sulfate reducing bacteria (SRB) and pollution of lake, vertical profile of SRB in sediment of polluted Lake Sihwa and unpolluted Lake Soyang was investigated. Apart from the conventional methods, such as cultivation and MPN, fluorescent in situ hybridization(FISH) was used for detection of SRB. The SRB385 probe which is specific to Desulfovibrionaceae was chosen for FISH. The SRB numbers in sediment of Lake Sihwa ranged from 1.5x10^7 - 9.5x10^7cells/g and showed peak at 2cm. While at the Lake Soyang, those ranged from 7.1x10^5 - 7.6x10^6cells/g. In Lake Sihwa, the proportion of SRB was 9.1 - 25.3% of DAPI-stainded cells, while in Lake Soyang, those were 0.7 - 8.4%. SRB is more abundant in the sediment of polluted lake than that of unpolluted lake, so SRB could be used as an indicator of pollution.

***Keywords:*** sulfate reducing bacteria, fish, polluted and unpolluted lake

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**HW3007** **Poster presentation** **4792**

# Considerations about bedload transport in River Paglia (umbrian reach, Central Italy)

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The paper concerns the study of the bedload transport in the River Paglia (River Tiber watershed, central Italy). The stream has shown a progressive reduction in width of the active riverbed area coupled with a heavy downcutting of the riverbed itself. This trend is connected with some human actions which have strongly reduced the sediment supply and caused a sediment load deficit in the main stream (quarrying activity, hydraulic works, changes of soil use in the watershed). Assuming that the present hydrologic conditions (rain and its distributions) haven't significantly changed during last decades, we have estimated the bedload transport which has entered the study reach, during a fifty years period, in order to evaluate the stream capacity to recover a condition of sedimentary equilibrium. Therefore we applied the Schoklitsch formula (1962) three cross sections. The results show that, concerning the sediment transport capacity, in correspondence of the cross section located in the upstream part of the studied reach, only the fine sediments of a large longitudinal bar can be mobilised. The coarse materials, located in the channel, can't be entrained even during the higher flood events (Return period = 50 yr). Conversely, in the downstream part of the reach, due to the reduction of the flow area, the sediment transport capacity is much higher: the stream is able to entrain coarser sediments more frequently than in the upstream section. The computations indicate that, in this part of the reach, also hypothetical materials with grain-size as coarser as those observed at the the initial cross section could be entrained by the main flood events (Return period = 50 yr). Therefore, since all the sediments arriving to the downstream part of the river are quickly removed, the erosional processes and the connected downcutting will continue.

***Keywords:*** sediment supply, bedload, erosion

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**HW3007** **Poster presentation** **4793**

# The method for designing pipeline to transport the hyper-concentrated mud

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The method for designing pipeline has been put forward to transport the hyper-concentrated mud. The pipe mud resistance coefficient has been studied by the in-site experiment, selected typical silting-constructing engineering and device for mud piping. According to the measured data of pressure, discharge, concentration, etc., the resistance characteristic of hyper concentrated flow in the pipe has been analyzed. The relation between the resistance coefficient in rough transition region and Re. number, concentration, etc., has been pointed out. Further more, the relation between the resistance coefficient and synthesis sediment factor has been put forward, so as to the calculating method. Meanwhile, the local resistance of mud in the typical pipe has been analyzed, and the method for determining local resistance coefficient in mud transport pipe has been ascertained, taking the flow strength and sediment factor into account. The achievement can be used for hydraulic design and making quota for mud pipe constructing.

***Keywords:*** the hyperconcentrated flow, theresistance coefficient, local shear stress

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**HW3007** **Poster presentation** **4794**

# Application of Remote Sensing and GIS techniques on soil erosion prevention : A case study in Santos (Brazil)

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***Rossella Napolitano, Enrico Feoli***

Combination of erosion models as the Revised Universal Soil Loss Equation (RUSLE) and GIS/ArcMap techniques for soil erosion estimation and soil management has been successfully applied to elaborate erosion risk maps. Integration of information coming from different sources was necessary for the calculation of different erosion factors needed by RUSLE equation (A=R*K*LS*C*P), specifically landcover/landuse, slope, DEM, physiographic and soil maps were integrated for this purpose. The main aim of this paper is to show effectiveness of application of these techniques providing reliable erosion risk maps of the study area. Results obtained showed that Santos watershed (located at Sao Paulo State, Brazil) although being very much urbanized and severely influenced by anthropogenic activities does not suffer from severe erosion due to its vegetation coverage (Mata Atlantica). The soil loss rates varied from 0.15 t.ha-1 yr-1 in forest areas (Serra do Mar) and plain areas to more than 100 t.ha-1 yr-1 in areas located on very steep slopes. The erosion risk map obtained through RUSLE showed that 74.7% of the area is affected by a very low erosion and 1.1% by severe to very high erosion risk. These results are very interesting since most of the area seems to be stable regarding soil loss nevertheless the high anthropogenic impact which emphasize the importance of a good vegetation coverage to prevent erosion risks.

***Keywords:*** erosion, gis, usle

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**HW3007** **Poster presentation** **4795**

# Estimating suspended sediment yield in the Mellah catchment during storm events, Northeast Algeria

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Recent published studies of suspended sediment transport in the northeast of Algeria are extremely limited and those that have been carried out have focused on determining some overall transport rate on an annual basis using empirical formulas. Facing this situation, it seemed tempting to introduce more recent measured data of suspended concentration and water discharge to estimate sediment load in the Mellah catchment. Thus, this work examines suspended sediment yield and its response to catchment disturbance and factors of erosion in the study catchment. Information about the sediment yield estimation has implications for management strategies. Methodologies for establishing the relationships between land cover, climatic and topographic variables with sediment yield are introduced.The surveys of suspended sediment load and water discharge are carried out from the hydro-system outlet in the selected catchment. For the quantification of the sediment transport, it seemed judicious to propose a method that permits the estimation of the fluxes of sediments exported by wadi Mellah during storm events to give a better comprehension of the sediment transport phenomena and soil erosion. The used method, called the discharge class method (developed by Jansson), tries to reconstruct missing suspended sediment load sampled from recorded storm event surveys of the period series 1975/76 1996/97. This study may help by the analysis of the factors of erosion to understand the variations of suspended sediment transport and its relation to rainfall and runoff. Since many recorded floods show complete missing instantaneous suspended concentration data, due to a lack of continuous sampling, relationships between measured means of sediment concentration and water discharge are applied to develop sediment rating curves (using the above method). The use of the discharge class method and correction for bias in the estimation of the sediment load from storm events has provided good results where calculated values are very close to those predicted. During the period 1975/76-96/97, the mean annual sediment yield to the outlet of the Mellah wadi is equal to 387 T/km/year. The Mellah catchment is generally more distinguished by lithologic, climatic and hydrologic conditions to provide more sediment fluxes. Besides the later factors that are important, the catchment seems to be also affected by higher relief energy and a more extended culture practices and sparse grassland developed on clay and marl-rich slopes exceeding 12%. These factors have accentuated the erosion dynamics and soil entrainement during winter and spring seasons.

***Keywords:*** sediment, erosion, catchment

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**HW3007** **Poster presentation** **4796**

# River bed evolution downstream a bed sill

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Quantitative estimate of sediment transport processes is important, especially in river-control engineering and water management projects, because it determines the evolution of riverbeds, estuaries and coastlines. In particular, as far as the planning and execution of river valley projects is concerned and due to scientific purposes, it is very important to know the effects of man-made structures, such as a dam, on alluvial stream trasporting large sediment loads. In fact, when the equilibrium of a alluvial stream trasporting large sediment loads is disturbed by the construction of a dam, adjustment is needed itself to a new equilibrium condition and degradation occurs downstream of the dam. Furthermore, local scouring around the hydraulic structure could occur. It may undermine the stability of the structure itself creating the risk of failure. Consequently, designers are often required to take into account the scouring process and to include adequate protective measures against the local scour. The design of the protective measures, in turn, needs the knowledge of the mechanics, location and geometrical characteristics (maximum depth and length) of scour. The analyses of the erosion process and of the kinematic characteristics of flow downstream hydraulic structures is very complex and many interrelated phenomena have to be taken into account. As consequence, the investigations concerning local scour phenomena have been usually conducted in laboratory channels. Several empirical and semi-empirical relationships have been proposed to estimate the maximum depth of the scour hole downstream grade control structure and around bridge piers and abutments (Roshko, 1961; Roper e al., 1967; Franzetti et al., 1994; Graf e Istiarto, 2002; Pittalinga, 2004). The aim of the present work is to give a contribution for a better understanding of the scouring process downstream bed sills. The temporal evolution of the erosion process is analysed on the basis of data collected during an experimental work carried out in a straight channel constructed at the laboratory of the Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali - Palermos University (Italy). The variations of the bed profiles are measured by using a profile indicator by Delft Hydraulics. An empirical relation to estimate the local scour is proposed and tested by using data found in literature. Finally a numerical model to estimate the evolution of the river bed and the transported sediment load along an alluvial channel is applied.

***Keywords:*** river bedvariation, sediment, scouring

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**HW3007** **Poster presentation** **4797**

# A physically-based and distributed approach to analyze soil erosion and rainfall triggered landslides at a watershed scale.

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Soil erosion is one of the most important land degradation problems worldwide. It affects soil quality, in terms of agricultural productivity, water quality at catchment scales and also reduces the availability of water in reservoirs. Information about soil erosion is required at temporal and spatial scales that reflect the timing and pattern of sediment movement in response to different rainfall events. It is also recognized that possible changes in land use and climate can act as triggers for increases in hillslope soil erosion and catchment sediment yield. For these reasons, there is a need for tools that are able to predict, at the watershed scale, soil erosion and sediment yield and can be used to assess the impact of environmental change on these variables. A dynamic spatially-distributed model (tRIBS-SED) capable of simulating sediment transport, erosion, and deposition is proposed for these purposes. It is built on the existing physically-based hydrological model, tRIBS. tRIBS-SED can simulate soil erosion by a variety of mechanisms including raindrop impact, leaf drip and overland sheet flow.The transport of the eroded material is by overland flow at the hillslope scale. Diffusive processes such as biogenic activity (animal burrowing) rainsplash, tree throw, soil creep, and solifluction have also been included in the model. For channels, the model simulates the erosion of bed material and the downstream transport of this material together with that supplied by overland flow. In the channel sediment routing procedure it is assumed that the load is limited by the calculated capacity transport rate of the flow. Furthermore, a shallow landslide erosion component, applicable at the watershed scale, has been incorporated into the tRIBS-SED. The module determines when and where landslides occur in a watershed in response to time-varying rainfall. Information about soil moisture conditions simulated by the hydrologic model tRIBS is used to assesses the volume of material eroded and released for onward transport. The model has been applied to rainfall-induced sediment yield events at two watersheds of different dimensions and dominant scales. The first is the Reynolds Creek Experimental watershed (RCEW), a 239 sq. km watershed located in Idaho, USA. The second is a European watershed located in Belgium (Kinderveld watershed) with an area of 250 ha. The simulations in both of the watersheds show good reproductions of observed sediment discharge magnitudes.

***Keywords:*** soil erosion, landslides, hydrologic modeling

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**HW3007** **Poster presentation** **4798**

# Assessing erosion using WEPP model with GIS for an experimental basin in Northeastern Brazil

***Dr. Celso Santos***
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***Richarde Marques Da Silva***

Prediction of runoff and erosion in ungauged basins is one of the most challenging tasks anywhere and it is especially a very difficult one in developing countries where monitoring and continuous measurements of these quantities are carried out in very few basins either due to the costs involved or due to the lack of trained personnel in sufficient number. Predicting spatial patterns and intensity of soil erosion and sediment redistribution in landscapes can be problematic in areas where few experimental data are available. Moreover, it is in those data-scarce regions that the ability to extrapolate local field evidence could be most useful in practical applications. Conventionally, soil conservationists and policy makers look at the field scale to judge the on-site impacts of soil erosion on the basin. Water resource managers, in contrast, usually rely on sediment yield data of gauged basins to evaluate the off-site effects of erosion intensity and sediment yield. WEPP model (Water Erosion Predicting Project) is a process-based continuous simulation erosion model that can be applied to hillslope profiles and small watersheds. WEPP model erosion predictions have been compared in numerous studies to observed values for soil loss and sediment delivery from cropland plots, forest roads, irrigated lands and small watersheds. A number of different techniques for evaluating WEPP have been used, including one recently developed where the ability of WEPP to accurately predict soil erosion can be compared to the accuracy of replicated plots to predict soil erosion. The most basic watershed interface requires that the user enter information on the screen to delineate the channels, hillslope profiles, and impoundments that comprise the watershed. Background photographs (for example scanned from soil surveys) can be imported and used to assist in defining the watershed. Drawing tools allow orientation, scaling, and placement of polygons to match field areas.In the present paper, the WEPP modelwas applied to Guarara river experimental basin, located in northeastern Brazil. The model was calibrated with daily rainfall data from five raingauges for the period of 2003 to 2005. The obtained results showed the susceptible areas to the erosion process within Guarara river basin, and that the mean sediment yield could be in the order of 3.0 ton/ha/year (in an area of 574 ha). The present study reveals also that the use of WEPP model is viable to ungauged experimental basins and that its coupling to a GIS showed to be promising. Thus, the model could be considered as a promising tool for prediction of sediment yield in experimental basins at northeastern Brazil.

***Keywords:*** gis, wepp, erosion

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**HW3007** **Poster presentation** **4799**

# Particle morphology and size distribution of suspended solids in fire impacted and control catchments in the Rocky Mountains, southern Alberta

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Fires modify the physical and chemical properties of soil aggregates but little in known about the implications of aggregate modification on sediment and nutrient transport/storage in slope and channel environments. In 2003, the Lost Creek wildfire burned a 210 km2 area in the Crowsnest Pass region of southern Alberta, Canada. The subsequent removal of vegetation cover on slopes caused the redistribution of topsoil during snowmelt and rain events which increased the transfer of sediment to stream networks. This study examined the nature (morphology, particle size distribution, degree of flocculation) of suspended solids and deposited sediment in a series of burned and unburned watersheds in the Oldman basin, Alberta. Digital images of the particles deposited on filters were collected with an image analysis system and morphology of the particle populations for each sample were characterized using three fractal dimensions (D, D1, DK). Fractal dimensions were obtained from the regression coefficients of the slopes of log-log plots of selected aggregate properties. The fractal dimensions of suspended solids and river bed sediments were significantly different at two burned sites. Fractal data and photomicrographs show that fine-grained sediment deposits consist primarily of burned organic and inorganic aggregates which may represent important in-stream sources of sediment-associated contaminants resulting from the fire.

***Keywords:*** wildfire, sediment morphology, flocculation

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**HW3007** **Poster presentation** **4800**

# Geochimical composition of water and suspended river sediments: a tool for the environmental analysis of a hydrographic basin

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The preliminary results aimed to defining the environmental conditions of the hydrographic basin and based on geochemical and hydrological methods are presented. The discussed case study is represented by the Reno river, northern Italy, where its environmental conditions are initially determined with a geochemical analysis of the solid suspended material and of the water in 8 monitoring stations. In particular, the chemical analysis of the collected solid material by means of an X-rays method and of the waters by means of ICP-MS standard procedures allowed to define i) the principal mean concentrations of both water and sediments and their comparison with the Italian and European legislative limits; ii) the variations in ionic concentration of both sediments and water, therefore enabling to infer the degree of erodibility of the rocks outcropping within the hydrographic basins, their relation with the amount of precipitation and corrivation times of the water at the monitoring sections.

***Keywords:*** reno river, sediments, water

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**HW3007** **Poster presentation** **4801**

# Suspended sediments in Himalayan streams under monsoon regime: Overwhelming contribution from glaciers

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***Dr. J.T Gergan***

High sediment load of Himalayan Headwater Rivers is a major operational problem faced by many hydro-power stations in the region. In many rivers of western and central Himalaya , high sediment flux occurs along with highest seasonal discharge during the monsoon months of July and August. This lead to the general perception that the high sediment loads in these rivers are mainly contributed by the monsoon rains. Role of the glaciers, occupying higher altitudes of these headwater river catchments, in contributing sediment to these streams received little attention due to lack of data generated from these glaciers. Present study carried out in a micro scale Himalayan catchment attempted to evaluate the contribution of glaciers and monsoon in controlling the suspended sediment transfer in the upper reaches of a Himalayan river. Discharge and sediment concentrations were monitored close to the Dokriani glacier snout at 3800m a.s.l. and also along the stream progression at 3400 and 2360m a.s.l. in the Din Gad catchment. Data generated during the six months long ablation season (June- October) for four consecutive years since 1998 demonstrate overwhelming glacier contribution in the stream suspended sediment flux. Din Gad stream at 2360 m a.s.l. received contributions from 77.7 km2 area with around 13% glacier cover. Average monsoon rains in this catchment is 1250mm. On an average, suspended sediment contribution from the glacier was 59% at 2360m asl and 78% at 3400 m a.s.l compared to the average contribution of glacier discharge of 29% and 59% respectively. The suspended sediment yield of the glacier catchment ranged between 9611 - 2038 tonnes/km2/yr and it is 10 times higher than the yield from the deglaciated lower catchment under the influence of summer monsoon (465/Tonnes/km2/yr). This study demonstrates the dominant role of glaciers in determining the suspended sediment flux in the Himalayan Headwater Rivers.

***Keywords:*** himalayanglaciers, suspendedsediment, dokrianiglacier

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**HW3007** **Poster presentation** **4802**

# Comparison of the discharges and suspended sediment yields budget between one pacific and one amazonian watershed in Ecuador : the case of the Napo and the Esmeraldas Rivers.

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The Andean Cordillera, oriented North-South, divides into two areas (the Pacific and the Amazonian side). This topographic division between its Western and Eastern slopes forms the natural limit of division of the flows.The aim of this study is to compare discharges and suspended sediment yields for two basins located on both sides of the Ecuadorian Andean Cordillera: the Naporiver basin under Amazonian influence and the Esmeraldas river basin under influence of the Pacific Ocean. The three main rivers of the Eastern Ecuadorare that, by catchment areas order, of Napo, Santiagoand Pastaza. The two main rivers of the Western Ecuadorare that, by catchment areas order too, of Guayas and Esmeraldas. These basins are distributed between the Andean region, the piedmont (between 6000 and 200 meters of altitude) and the Amazonian plain (for the Naporiver) marked by an absence of relief and a dense drainage network and the Pacific coast plain (for the Esmeraldas river). The NapoRiverstarts in the Ecuadorian Andes at an altitude close to 5 000 m and leaves in Nuevo Rocafuerte and enters in until its junction with the Amazon river. At the Nuevo Rocafuerte hydrological station, Ecuadorian outlet of the Napo river watershed (27 400 km), we have calculated (for the 2001-2005 period) an annual mean dischargeof 2 160 m3/s, an annual mean suspended sediment yieldof 16millions ton/year, corresponding respectively with a annual mean specific dischargeof 79 l/s/km, and a annual mean specific suspended sediment yieldof 570 ton/km/year. At the D.J. Sade hydrological station, outlet of the Esmeraldas river watershed (19 700 km), we have calculated (for the same five years) an annual mean dischargeof 770 m3/s, an annual mean suspended sediment yieldof 4millions ton/year, corresponding respectively with a annual mean specific dischargeof 39 l/s/km, and a annual mean specific suspended sediment yieldof 206 ton/km/year. We thus highlighted a ratio of 2 between annual mean specific discharges and 2.75 between annual mean specific suspended sediment yields of the two basins in favour of the Naporiver basin (Amazonian basin). The morphological characteristics of these basins being close, this ratio is explained mainly by the existing ratio (1.6) between the annual average precipitations affecting these basins (3 228 mm/year for the Napo, 2 055 mm/year for the Esmeraldas). On the other hand, this ratio can change in a significant way in favour of the Esmeraldas basin for the years when the Ecuadorian Pacific coast is affected by a ENSO phenomenon (El-Nio phase), for example in 1997-1998, the ratio decrease to 1.15.

***Keywords:*** sediment, ecuador, nino

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**HW3007** **Poster presentation** **4803**

# Estimation of soil loss and sediment yield in a basin without sediment data through empirical and physically-based models

***Dr. Celso Santos***
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***Richarde Marques Da Silva, Jorge Flvio C. B. Da Costa Silva***

In this study, two hydrological models to estimate soil loss and sediment yield, due to sheet and channel erosion, at the basin outlet are presented. The models were applied to Guarara River Experimental Basin, located in Paraba State, northeastern . The soil erosion models are (a) the classical Universal Soil Loss Equation (USLE), used to simulate soil loss, that predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices; and (b) Kineros2 model, which was used to simulate sediment yield within the basin. Kineros2 model is a physically-based distributed model that uses a cascade of planes and channels to represent the basin and describes the processes of interception, infiltration, surface runoff and sediment yield for each described element. The USLE was also calculated for each element using digital maps of soil use and management, erodibility, rainfall erosivity, and topography factors. The soil use and management maps incorporated the temporal variability of the soil surface cover characteristics for each element according to its topography and vegetation cover homogeneity, as well to the water paths. The application of Kineros2 model included several steps: (a) rainfall data selection; (b) basin discretization into planes and channels; and (c) estimation of the basin physical parameters. The soil loss results simulated by the USLE showed that this loss within the basin is around 8.0 (ton/ha/year) and that the period from May to July presents the greatest losses while period from October to December shows the smallest ones. In general, the Guarara River Experimental Basin shows a soil loss potential which could be considered as very low for the studied period. The parameter values used in the Kineros simulations could be considered as a first attempt for this basin, and the results showed also that this model could be considered a promising tool for the runoff and erosion simulation in the Guarara River Experimental Basin . Its simulation results showed that the mean sediment yield could be in an order of 9.0 (ton/ha/year) in accordance with the USLE results. However, the sediment yield measurement campaigns in basins at northeastern Brazilian coastal area are necessary to accurate further studies.

***Keywords:*** soil loss, sediment yield, hydrologic models

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**HW3007** **Poster presentation** **4804**

# Sediment delivery from a small river basin

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The results of 25 years of sediment transport field observations (1982-2006) in a small basin in the Western Alps are presented. The watershed was instrumented in 1982 with three rainfall recorders. At the same time the main stream was equipped with one water stage recorder and a debris basin, in order to evaluating hydrological processes and drainage sediment erosion by sediment yield at the basin outlet. The Valle della Gallina catchment (1.08 km2) is located in North-western italy at the the foot of the alpine range. The region is rainy up to 1461 mm/year and is characterized by a continental-Mediterranean climate with two seasonal rainfall peaks (October and May) and heavy storms in summer, generally related to the highest amount of sediment yield. The main physiographical characters of the catchment in the period of the observations can be summarized: elevation max-min 522-330 m a.s.l.; basin average slope 49%; main stream length 1.57 km; basin elongation 1.35 km; average runoff 750 mm/year; maximum discharge 6.44 m3/s; mean temperature 11 C. Since 1982, at the outlet of the basin water stage data are recorded at a wide crest weir close to a 40 m3 sediment trap defined by means of concrete walls and bottom. Sediment yield is periodically measured surveying elevation at a grid of 0.50x0.20 m referred to bench marks. The trapped materials are mainly sand and gravel distributed between 0.06 and 128 mm. The catchment is characterized by a volcanic, homogeneous and impervious bedrock and by an azonal soil (regolith) no more tah 2 m thick. The dominant grain size of the fragmental rock is coarse sand followed by coarser fraction with up to 40% of gravel with a finer fraction down to 10% of clay. Data are derived from 127 samples out of 57 boreholes. The catchment slopes are unaffected by human activities and the land cover is represented by a uniform deciduos vegetation (77% coverage). A dendritic stream network is incised down to the bedrock with a density of 52 km/km2. Distances runned by gravel and sand tracers have been measured in the main stream. Results showed that elements 16-32 mm in size may be displaced by flow of at least 0.30 m3/s, while coarse sand (1-2 mm) is put into motion by flow of only 0.10 m3/s. Travelled distances have been related to the irregularities of the bed (pool-riffle sequences as well as protruding boulders or bedrock), while the volumes of the sediment trapped was related to the sediment feeding process along the channel, mainly due to moving bed forms. The average yield was computed as 35 m3/km2. Since the 90s, precipitation is lightly increasing, but no change was perceived in runoff and sediment yield. A likely explanation could be looked for in the increase of land coverage in the upper parts of the basin. Acknowledgements L. Bellino performed field soil studies; F. di Nunzio provided hydrometeorological data; F. Godone carried out topographic survey; F. Godone, R. Massobrio and G. Rivelli provided sediment yield data. (Cnr-IRPI).

***Keywords:*** stream erosion, bedload transport, italian alps

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**HW3007** **Poster presentation** **4805**

# Role of sewage fed fisheries for treatment of dry weather flow of Kolkata city maintaining the eco-toxicity balance

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Kolkata founded in the year 1690, has grown slowly in an uncontrolled manner along the eastern side of River Ganga and stretching more along the northern and southern direction. The eastern part of Kolkata was chosen by the city managers as a place to receive both liquid and solid waste. Kolkata Municipal area (KMA) has a combined drainage system. The Dry Weather Flow (DWF) is discharged in a dedicated DWF channel which starts from Topsia Point A and leads to the eastern direction. The dry weather flow comes mainly from Palmer Bridge Pumping Station and Ballygunge pumping station. Separate storm water channels are also existing for the city. The dry weather flow and major storm water flow of Kolkata discharge in Kulti-Bidhyadhari river at Ghusighata which is more than 30 km away from the city limit. The storm water channels and dry water flow channel are part of the drainage system of the city. At present dry weather flow amounting to approximately 1000 MLD leads to DWF channels as per Kolkata Municipal Corporation (KMC). Kolkata is unique as wetlands are situated in the eastern fringe of the city. Local fishermen use sewage conveyed through DWF channels in the wetlands (Bheri) for pisciculture. It is the largest sewage fed aquaculture in the world. Presently 3898.70 ha out of 5852.14 ha water areas are used for sewage fed fish farming. The maximum yield from this sewage fed fisheries is about 30000 MT per year. The sewage fed aquaculture system acts as an ecologically balanced waste water treatment for the city. The production of fish in sewage fed aquaculture system which is considered to be at least 4 times than the production of fish in normal surface water. A study has been carried out to assess the performance of existing sewage fed fishery under ecologically balanced waste water treatment system. The study also assessed the eco-toxicity of the ecologically balanced waste water system and detail auditing of heavy metals in the fish, sediments and waste water was also carried out. The sewage analysis result of DWF from Topsia point A to Ghushighata reveals that the BOD value of sewage is getting reduced while moving along more than 30 km stretch and also due to utilization of sewage in fish ponds including ecologically balanced treatment in the pond and then getting mixed again in the DWF. The study also indicates that presence of heavy metals in fish is within tolerable limit according to per capita per day consumption basis. In this context, it is to be mentioned that considerable quantum of metal are released out from fish during cutting, dressing and washing.

***Keywords:*** dry weather flow, wetland, pisciculture

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**HW3007** **Poster presentation** **4806**

# Computation of reservoir sedimentation as a consequence of soil erosion

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***M. Galani***

The present study aims to compute sedimentation in Yermasoyia Reservoir in terms of soil erosion in the corresponding basin. Yermasoyia Reservoir is located northeast of the town of Limassol, Cyprus. The storage capacity of the reservoir is 13x106 m3. Yermasoyia River feeds the reservoir with water. The basin area of Yermasoyia River, upstream of the reservoir, amounts to 122.5 km2.Two versions of a mathematical model are used for the computation of the mean annual reservoir sedimentation. The first version consists of three submodels: a rainfall-runoff submodel (Giakoumakis and Tsakiris, 1992), a soil erosion submodel (Poesen, 1985) and a sediment transport submodel for streams (Yang and Stall, 1976). In the first version, the calculations are performed on a monthly time basis. The second version consists of the same rainfall-runoff submodel and the same soil erosion submodel as the first version. However, instead of the sediment transport submodel for streams, the empirical concept of sediment delivery ratio is used. In the second version, the calculations are performed on a daily time basis.Daily rainfall data from three rainfall stations and other meteorological data from one meteorological station for three years (1987 - 1989) were available. For more precise calculations, the basin of the reservoir was divided into four natural sub-basins. The arithmetic results of the mean annual soil erosion rate, according to both versions of the mathematical model, are compared with erosion measurement data. Additionally, a comparison between the two model versions is made in relation to the arithmetic results of the mean annual sediment inflow into the reservoir and the mean annual reservoir sedimentation.

***Keywords:*** erosion, modeling

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**HW3007** **Poster presentation** **4807**

# Results of flooding: A study of habitation deposits along the Ajay River Basin in India

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Human habitations along the river valleys are often subjected to frequent flooding. Traces of such deserted villages are preserved in the river bank sediments. Do these markers of human presence can provide special information on fluvial activities? This study on such deposits has indicated that these are not only patterned but also indicative of different fluvial regimes. Fluvial impact on habitation deposits along the Ajay river basin, West Bengal, produce enormous varieties in any fixed temporal zone. This area experiences repeated floods of higher and lower degrees. The resultant deposits of a particular flood are often influenced by locational features. In the present paper the author has tried to interpret the habitation deposits of the area in the context of late Holocene fluvial activities.

***Keywords:*** floods

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**HW3007** **Poster presentation** **4808**

# Sediment transport modeling on large sandbed rivers: case study of Congo River.

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*IAHS IAHS IAHS*

The inner delta of Congo River s maritime reach has been surveyed intensively during the last 23 years in order to develop a method to predict its morphologic changes and to improve the dredging operations in the navigation channel giving access to the harbours of Boma and Matadi. Flow and sediment gauging form part of the tools of the prediction method; they produce interesting data for testing sediment transport theories. The paper presents results of the application of four theories or approaches: Schoklitsch, Shields, Meyer-Peter & Muller and Bagnold. Besides the calculation of the cross-sectional sediment transport rates for establishing the rating curves for the main-gauging sections, Bagnolds approach has been adapted for application in local stations in view of predicting morphologic changes. The calculations are in fairly good agreement with the measurements.

***Keywords:*** sediment transport, bed sand river, sediment model

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**HW3007** **Poster presentation** **4809**

# A flume experiment on jamming of Large Woody Debris

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***Rulli M.C, Rosso R.***

The dynamic of Large Woody Debris (henceforward, LWD) is a relevant topic, with many implications in channel morphology and ecology of rivers. Flow driven deposition/removal of LWD jams triggers sediment deposition, colonization of vegetation and even river island formation, leading to relatively stable (up to a decadal time scale or so) in channel structures. LWD plays a key role in the ecology of rivers as wood jams provides optimal habitat for fish and generally for riverine species and regulates water temperatures, water flows and nutrient fluxes. River management often requires planned introduction of LWD for fish bearing and river restoration. In first orders streams, lowland braided rivers, flood plains and diverted flow areas, such as meanders or estuaries, congested transport of LWD interacts with morphology and flow dynamics, resulting in entrainment of wood and eventually, in cyclical accumulation/release of wood jams. As a result, LWD shows accumulation patterns of tremendous complexity both in space and time. Here, based on some pioneering attempts in the recent literature, we design a flume experiment to explore the interaction of LWD with complex channel morphology in case of congested transport. Using proper scaling, we simulate the accumulation process taking place in a reach where LWD pieces are conveyed and complex channel morphology, leads to wood entrapment. Properly placed obstacles mimic the presence of in channel vegetation, boulders or complex terrain morphology in braided rivers. Consecutive insertion of properly scaled wood dowels lead to wood accumulation in the flume. We then identify the so formed jams and we classify them according to their size, (i.e. number of pieces), morphology and position. We use some deive statistics to provide a synthesis of the complex aggregation patterns of the jams, also depending on flow conditions and the geometry of the obstacles. Eventually, we provide some suggestions to predict jamming of LWD in rivers with considerable wood load, also viable for river management purposes.

***Keywords:*** geomorphology, large woody debris, river management

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**HW3008** **4810 - 4840**

## Workshop
## Changes to Hydrological Extremes and Water Quality (Sponsors ICWQ and ICSW)

**Convener :**
**Co-Convener :** Prof. Mikhail Bolgov, Dr. Hege Hisdal, Dr. Thomas Ternes, Dr. Peter Heininger, Prof. Siegfried Demuth, Dr. Alan Gustard

In many countries around the world a rapid alternation of floods and droughts is observed. A common question which has been posed is whether the change in frequency of hydrological extremes is a result of global warming or lies within the natural variability of climate. For water resources management water quantity aspects were important. But a key concern is the environmental impact of floods and droughts as a result of rapid change due to different flow conditions. The main purpose of the workshop is to bring together scientists from various fields of research (hydrologists, chemists, etc.) who have experience of interdisciplinary programmes on hydrology and water quality. Scientists who are not currently participating in large programmes but who have an experience in that scientific domain are also welcome. The workshop topics will cover several aspects: (1) point sources which will influence water quality (industry, waste water treatment plants, landfills); (2) diffuse sources (agricultural areas, groundwater and sediments); (3) fate and behaviour of pollutants under extreme hydrological conditions and their impact on water quality; (4) mobilisation models for different flow conditions (risk management); (5) indicator substances (which flow conditions trigger which substances); (6)techniques for estimating hydrological regimes at gauged and ungauged locations; (7) methods for detecting change in the frequency of hydrological extremes; and (8) evidence for global warming causing a change in the frequency of extremes. The workshop will provide an opportunity to establish a closer link between the water quantity and quality communities, especially with respect to hydrological extremes.

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**HW3008** **Oral Presentation** **4810**

# Diffuse source of high fluoride and the role of water- rock interaction on water quality in parts of India

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Fluoride problems are wide spread in India especially in nine States covering almost the entire country. In order to assess the water quality and the related health problems due to high fluoride content, water samples from nine States across India have been collected and analyzed. Analyses from surface, subsurface and thermal water samples had fluoride concentration that range from < 0.2 to 20 ppm. The probable source of high fluoride relates to the water-rock interaction within the sedimentary basins. During rock weathering and subsequent circulation of pore water through the soil and rock matrix, fluorine is leached out, mainly from the mineral fluorite (CaF2) and calcium difluoride, and dissolved in the ground water. Human health affects of high fluoride content in water are manifested in the form of endemic fluorosis causing tooth mottling and inducing the prevalence of osteoporosis and collapsed vertebrae. Fluorosis has no known treatment other than early detection and limiting the amount of fluoride ingested. It is considered to be a deadly disease. The fluoride content of ground water varies greatly depending on the type of rocks from which they originate. Among the various minerals responsible for high concentration of fluoride, the flour - apatite [3Ca 3 (PO 4) 2], calcium difluoride [CaF2] and fluorite, CaF2 are important. However, the most important being the Fluorite, CaF2 and the leaching of fluoride from the metamorphic rocks hornblende gneiss of Proterozoic age. Even with a sizeable atmospheric source, the mobility of the F - should, once it is deposited, be governed by the soil and rock conditions. Concentration of fluoride below 1.5 ppm according to World Health Organization (WHO) are helpful in prevention of tooth decay, and such level of fluoride also assists in the development of perfect bone structure in human and animals. Long term ingestion of drinking water having fluoride above a concentration of 1.5 ppm leads to dental and skeletal fluorosis as well as non skeletal manifestations. High fluoride consumption leads to the fluorosis of the bones which is generally found in Asian region but it is particularly acute in India. Reducing the high fluorine content of groundwater may be done by dilution or by defluorination process. Dilution with the surface water is one very simple technique but not very practical in water scarce India where high fluoride concentration are found. But the addition of Ca++ ions to the fluoride rich groundwater causes an appreciable decrease in fluoride concentration which appears to be the potential cost effective solution to high fluoride problem in an otherwise water scarce India.

***Keywords:*** fluoride, fluorosis, defluorination

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**HW3008** **Oral Presentation** **4811**

# The use of watershed macrophytes and storm water in river water quality management in a tropical river basin with reference to the Nairobi River Basin, Kenya.

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***Francis M. Mutua, Kenneth M. Mavuti***

This paper examines the usefulness of watershed macrophytes and storm water in the management of a polluted river system. The study focused on the Nairobi River drainage basin in Kenya. Water samples and riverine vegetation tissues were collected and analyzed in trying to assess the extent of water pollution and the use of the plant macrophytes in the restoration of the water quality status and reduce water pollution levels with a focus on heavy metals dissolved in the river water. The results from the study indicated that Heavy metal concentration in the tissue of riverine vegetation was found to be significant. Sphaeranthus napierae (spp 1), Commelina benghalensis (spp, 2) and Xanthium pungens (spp, 4) had the highest absorbed values of Zinc, Copper and Nickel and these varied with the part of the vegetation tissue. High Zinc concentration values were recorded in the root system with a value of 0.68ppm recorded in sampling point Njiru 2 (10) for plant species 1 (Sphaeranthus napierae) and 0.66ppm in species 2 (Commelina benghalensis) at Njiru 1 (9) and 0.55ppm for species 4 (Xanthium pungens). In Mathare River, Zinc values of 0.85ppm were recorded in the root system of species 1, 0.52ppm in species 2 and 0.53ppm in species 4. The stem and leaf had the least heavy metal concentration with some metal ions not being detected in the leaves. Generally, heavy metal concentration decreased upward the plant system (i.e.) from the roots to the leaf system. The study recommends the use of storm rain water (natural purification after heavy storm down fall) and Commelina benglensius, Sphaeranthus napierae and Xanthium pungens plant species in cleaning the heavily polluted river water and restore its aesthetic quality in the basins studied. Species 3 (Pennisetum purpureum-Napier grass) was commonly found along the river profiles where it is harvested as folder for cattle feeding in and around Nairobi. Generally, pollution and pollutant levels varied with season and distance away from the city in the three rivers. In addition, the streams were found to be less polluted chemically (less ionic concentration) away from the city due to dilution effect and self-purification of the river waters during the wet season. The study revealed that storm rainwater can be used to clean up the dirt, foul smelling and highly polluted waters of the rivers passing through the city. Riverine vegetation along the streams were found useful in reducing some of the heavy metal pollutants in the river water and therefore a useful tool in water quality restoration in the basin investigated.

***Keywords:*** macrophytes, heavy metal pollution, storm water

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**HW3008** **Oral Presentation** **4812**

# A quasi-2D modelling approach in simulating the hydrodynamics and substance transport in polder systems

***Dr. Karl-Erich Lindenschmidt***

*I do not understand, which department is meant! I do not understand, which affiliation is meant! IAHS*

In flood modelling, many one-dimensional (1D) hydrodynamic and water-quality models are too restricted in capturing the spatial differentiation of processes within a polder or system of polders and two-dimensional (2D) models are too demanding in data requirements and computational resources. The latter is an important consideration when uncertainty analyses using the Monte Carlo techniques are to complement the modelling exercises. This paper describes the development of a quasi-2D modelling approach which still calculates the dynamic wave in 1D but the discretisation of the computational units is in 2D, allowing a better spatial representation of the flow and substance transport processes in the polders without a large additional expenditure on data pre-processing and simulation processing. The models DYNHYD (1D hydrodynamics) and TOXI (sediment and micro-pollutant transport) from the WASP5 modelling package was used as a basis for the simulations. The models were extended to incorporate the quasi-2D approach and a Monte-Carlo Analysis was used to investigate the contribution of uncertainty from parameters and boundary conditions to the resulting substance concentrations. An extreme flood event on the Elbe River, Germany, with a proposed polder system variant was used as a test case. The results show a more realistic differentiation of suspended sediment and zinc concentrations within the polders. The results also show that for flood simulations, uncertainties in boundary conditions are higher and should be given more attention than uncertainties in model parameters.

***Keywords:*** polder, flooding, sediment

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**HW3008** **Oral Presentation** **4813**

# Coupling all water related historical data to predict possible future ecological conditions of the river corridor

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INTRODUCTION AND PROBLEM STATEMENT River channel and riparian morphology, surface water and sediment flow, groundwater flow and chemical status of water are parameters to describe basic abiotic parameters of the ecological conditions of the river corridors. Present state of a river and riparian morphological and chemical parameters are described by data collected in few sampling campaighn, but have also be interpreted with the use of all available historical data of water and sediment flow. Furthermore, the evaluation of possible future ecological conditions of the river corridor greatly depends on interpretation of how hydrological processes have been and are still greatly impacted by long lasting human interventions if not climate change. For that purpose, it is crucial to collect and interpret as much historical data and information as possible. We have coupled all available water related data to evaluate present and possible future ecological conditions of the Slovenian section of the Mura River. The Mura River (380 km), the tributary of the Drava River (Danube), is a transboundary river, flowing from Austria to Slovenia and Croatia. Historical development of hydro-electric power plants in Austria, channel straightening and other engineering of the channel for flood protection have altered the hydrological and sediment transport regimes in the Slovenian section of the river. METHODS Hydrology and river morphology are analysed from national monitoring data (period 1926-2000), past studies, aerophotos from 1954, 1987 and 2000 and field inspection. Riparian vegetation cover history is defined from 18th Century Austro-Hungarian military maps (1763 1787) and areophotos. Field inspections and aeropohotos are used to evaluate river corridor habitats. Fish composition history is reconstructed from literary data, information gathered by questioning fishermen, a fishery register and recent ichthyologic studies (1981- 1989 and 1992-1996). The information about groundwater surface water connections have been extended with on going field data collection. RESULTS The analysis shows there is no significant trend for change in the relationship between rainfall and river flows. Linear trends of annual average discharges and minimal discharges are negative. The excess carrying capacity from 1970 on of the river resulted in head-cutting of Austria- Slovenia border (average 33 cm, localy 1.2 m). The amount of bed degradation decreases downstream in the river section in Slovenia. Annually the groundwater fluctuates from 1.5 and 3.5 m under the surface, but a general decline is indicated of 20-25 cm in groundwater levels throughout the area. A decline of both water surfaces and riparian forests was perceived. Water surface has declined for 15% in 200 years, the biggest change happened in the last 40 years. Area of riparian forest has declined for 30%. Today 4 % of the area is covered by running water surface, the main stream of the Mura River. At this part a great proportion is still forested (65%), but among forest 10% is degraded by alien speices. Only 35% of an area is completely natural or nature-close stage. A reduction in natural tree species of flood forest is detected and a general decline in diversity of wetland habitats and flora species is noted. The ichthyofauna of the Mura is used to be a pronouncedly salmonoid-cyprinoid and the river with oxbows must have been permanently or periodically inhabited by 52 different species from 15 families. Nearly all trace has been lost of the indigenous representatives of the family Salmonidae and Thymallidae. In spite of an organic water pollution, a relatively small number of species has disappeared from the river during the last century due to its morphological diversity. CONCLUSION Though the river sustains high fish diversity, good ecological conditions are deteriorating due to water pollution, larger and more frequent drought periods, subsurface water storage decline, groundwater level drop and allien forest species expansion in the river corridor.

***Keywords:*** water sediment flow, hydroecology, riparia

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**HW3008** **Oral Presentation** **4814**

# Temporal patterns in hydrochemical export from drainage tiles in a first-order agricultural catchment in Southern Ontario, Canada

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Drainage tiles in agricultural areas are point sources of nutrients that allow drainage waters to bypass natural filtration pathways, thus permitting the delivery of solids and nutrients to receiving streams. The role of tiles in agrochemical export has been the focus of several studies but factors governing temporal variability in nutrient export from tiles are still poorly understood. Much of the current understanding of hydrochemical export patterns from tiles has been developed in warmer geographic regions and little is known about nutrient export from tiles during winter months. The objectives of this study are to demonstrate spatiotemporal variability (within-event, between-event, seasonal) in the contribution of drainage tiles to (1) basin hydrologic discharge; and (2) basin soluble reactive phosphorus (SRP), total phosphorus (TP) and nitrate (NO3-) export over a one-year period, and to discuss the factors controlling this variability. Considerable variability in tile discharge was observed at both moderate (wet versus dry periods) and smaller (within-event) temporal scales. Under dry conditions, tiles contributed very little to overall stream flow (<5%). In contrast, under wet conditions, there was a linear relationship between stream and tile discharge and tiles represented 60% of stream discharge. Under intermediate moisture conditions there was strong variability in the contribution of tiles to stream flow, with tiles contributing 0-90% of stream discharge. The hydrologic contribution of tiles to basin runoff also varied throughout and between events (30-90%), depending on antecedent wetness and storm magnitude. Correlations between high-frequency measurements of tile discharge and water table position were weak suggesting that suggesting that tiles were not fed by saturated groundwater flow alone. Significant spatiotemporal variability was also observed in nutrient export from drainage tiles within the study basin, and patterns observed for P and NO3- differed. Higher concentrations of SRP and TP were linked to fields receiving manure compared to fields receiving inorganic fertilizers whereas NO3- export was high from all tiles within the basin. During discrete sampling periods when tiles were flowing, SRP export from tiles often exceeded the SRP mass export from the basin (mean = 118%, range = 4-344%), suggesting that a portion of tile-derived SRP was buffered within the stream. On average, drainage tiles accounted for 43% of basin TP export but ranged from 0-200%, and 51% of basin NO3- export, ranging from 8-105%. This work has shown that tiles are highly variable in both their hydrologic and chemical export. Improving our understanding of the temporally dynamic role of tiles, and being able to quantify and predict this variability are areas where future research is necessary.

***Keywords:*** tile drainage, agriculture, nutrients

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**HW3008** **Oral Presentation** **4815**

# Effect of Floodwaters of hurricane Katrina and Rita from New Orleans on the Pontchartrain Water Quality

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Lake Pontchartrain is an estuarine lake in southeastern Louisiana, the second largest brackish-water lake in the United States with an area of 630 square miles. The Lake Pontchartrain and its basin is a vital resource of food and recreational activities. The lake water quality has always been a critical issue because of the various point and non-point sources of the Pontchartrain basin, and also the environmental factors. It has been a sink for the stream and rivers, which are identified as impaired water bodies by the provincial environmental quality department. The Pontchartrain water quality became more vulnerable to the pollution especially after floodwater discharges from the New Orleans city area during the hurricane Katrina and Rita. This study is an attempt to investigate the long-term environmental impact due to sediment discharge on the lake water quality. The spatial and temporal analysis is expected to reveal the effect of such an instantaneous and huge pollution discharge on the Pontchartrain water quality. The hydrodynamic and Plume dispersion modeling is done using Environmental Fluid Dynamics Code. The hydrodynamic and water quality model showed that flow-field and dispersion of pollutant under the major dominance of wind. Typically, two large circulation gyres east and west of the Lake with opposite rotation are observed. The plume dispersion model showed a prominent plume on the south-western side of the lake, this is the cumulative effect of the water currents and wind. The sediment plume spans over a stretch of 1 mile in north-south direction and 12 miles in east-west direction. The sudden change in the hydrologic regime of the lake Pontchartrain has threatened the estuarine ecology. This kind of study is very useful in the environmental planning and monitoring.

***Keywords:*** floodwater discharge, sediment dispersion, lake pontchartrain

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**HW3008** **Oral Presentation** **4816**

# Changes associated to hydrological extremes: the catastrophic flood of Santa Fe State, 2003, Argentina

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The Salado River originates in the west mountainous region of Argentina. The river travels 1500 km before ending in the Paran River, one of the main tributaries of the La Plata River basin, the 5th biggest basin of the world. The Salado River basin has an area of 247.000 km2. The lower portion of this basin (55950 km2) is developed integrally in the Santa Fe State and has characteristic of a large plain landscape. A sequence of intense rainfall events occurred during April and May of 2003 on the lower portion of the basin, generated the most important stream flood peak observed in the historical records (4000 m/s). This flood affected large rural sectors of the Santa Fe State and the Santa Fe city (located over the outlet of the basin), implying the loss of human lives and property damage estimated in US $1000 millions. This flood constituted the most important catastrophe associated to natural events of the history of Argentina, with several sanitary and socioeconomic consequences for the whole region. This article summarizes the analysis of some relevant aspects associated to this flood such as the changes that taken place in the basin and the techniques for estimate the frequency of extreme flows. The mentioned changes contributed to the catastrophic character to the flood. The systematic flows record of Salado River initially available corresponded to 1954-2005 period. However, the search of diverse historical information allowed an extension of the record to the 1875-2005. The analysis of historical events provided very interesting information to the characterization of the possible climatic change in the region. The Generalized Maximum Likelihood Estimation method (GMLE) was used to fit the GEV distribution to a combination of historical marks and systematic discharge series. The return period of the peak discharge was estimated in 800 years. The historical trends on the precipitation and discharge records are revised, as well as the evolution of the road and drainage channel network on the rural and urban sectors of the basin. The similarities are also identified between the flood of the Santa Fe city and the flood occurred in 2005 in New Orleans city, US. The lack of urban planning is obvious in the mentioned cases. The roll of the lateral protection against floods on urban areas is finally analyzed, with a remark over the false safe felling provided for these protections.

***Keywords:*** globalchanges, urbanandruralfloods, gmle gev

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**HW3008** **Oral Presentation** **4817**

# Spatial and temporal variations of water quality along a Mediterranean intermittent river: dry period and flash floods.

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Small Mediterranean rivers show a succession of long dry periods cut by flash flood events. Due to this specific regime, diffuse and point source pollution inputs associated with human activities have harmful effects on the river water quality. During the dry period, the river channel may dry up completely except in some reaches where anthropogenic inputs (mainly waste water treatment plant effluents) contribute to maintain some pools. Accumulation of pollutants is observed in these reaches, while, during floods, pollutants are flushed away from the same reaches. So, the evolution of the water quality, along the river, is related both to the importance of the inputs and to the river flow conditions. The existing monitoring networks are usually not representative enough to account for the variability of river flow and in-stream water quality and to assess the impacts as well as to identify the contribution of pollutant sources in such catchments. The lack of adequate monitoring networks originates partly from the general idea that these rivers are not "important" enough, despite the role they play as potential water resources in a water scarcity context or in the flashy pollution events that occur in coastal areas. This study addresses the water quality along the Vne River (67 km, south of France) during dry periods and flood events. Spatial variations were assessed by observations made during floods and in steady state conditions based on one-day field campaigns. Floods were sampled hourly at three gauging stations. During one-day campaigns water samples were collected and flow measurements were undertaken at eighteen sites: nine along the main river (from the spring to the outlet) and nine in its tributaries and direct inputs (storm sewers and treatment plants). Water quality was evaluated through the determination of nutrients (nitrogen and phosphorus species) and suspended solids concentrations as well as enteric bacteria (coliforms and streptococcus). On the basis of the observed data, the study has built a perceptual hydrological model of the Vne River and pollutant sources were ranked taking into account the flow conditions. During the dry season, retention of pollutants is observed in the reaches downstream from the direct inputs from sewage treatment works. These accumulations are due to sedimentation combined with co-precipitation and assimilation processes. High pollutant storage rates were highlighted in these reaches. Flash floods are essentially due to runoff on the urban areas; agricultural zones were shown to have a low contribution. The high loads of pollutants flushed away during these floods are mainly issued from the riverbed reservoir where pollutants were stored during the dry season.

***Keywords:*** water quality, intermittent river, flood

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**HW3008** **Oral Presentation** **4818**

# Comparison of three methods for detecting change in the drought frequency

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Climatic hazards - floods and droughts - have always been a primary matter of concern for human population. Severe floods cause damage to settlements, transport networks, and to arable land. Devastating droughts are harmful primarily for agriculture and terrestrial ecosystems, but they can lead to local water supply shortages, too. Despite significant achievements in science and technology and success stories in environmental management in the 20th century, people still continue to suffer the consequences of climate hazards worldwide. In view of the developing issue of climate change, floods and droughts may become more frequent. Climate change has the potential to increase the frequency of extreme events globally by increasing flood risk in some regions, increasing drought risk in others, and even increasing the occurrence of both floods and droughts in some parts of the world. Therefore methods for detecting change in the frequency of hydrological extreme events are needed along with climate change scenarios and climate impact studies. The paper presents a comparison study of three methods for evaluation trends in drought frequency: Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), and a new method for estimation of dry series based on average daily temperature and precipitation and taking into account the length of series. The methods were applied for the Elbe River basin using climate data from 450 stations for the period 1951-2003. After that statistical methods were used to evaluate significance of detected trends. The results of the study revealed statistically significant trend to increased frequency of droughts in the Central lowland part of the Elbe basin.

***Keywords:*** climatic hazards, drought frequency, drought trend

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**HW3008** **Oral Presentation** **4819**

# Development of an Analytical Risk Model to Assess the Potential for Groundwater Contamination

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*Urban Groundwater and Aquifer modeling International Association of Hydrogeologists IAHS*

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An analytical risk model of contaminant transport across a region of varied soil types was developed to quantify potential impacts to soil, groundwater, and surface water quality resulting from urbanization within the Rouge River Watershed in southeastern Michigan, USA. The model developed integrated the properties of toxicity, mobility, and persistence for specific contaminants with physical and chemical properties of soil and groundwater. The results indicate that chlorinated volatile organic compounds and hexavalent chromium have the highest risk factors for groundwater. Geographic Information System analysis also suggests there is an increased probability of transport of these contaminants into the Great Lakes due to the fluvial geomorphology of the watershed, which exhibits the highest surface water drainage density within its zones of sandy soil. This creates the potential for ecological and public health concerns at broad geographic regions because of the hydraulic connection between groundwater and surface water within the Rouge River Watershed.

***Keywords:*** groundwater, model, contaminant

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**HW3008** **Oral Presentation** **4820**

# The evaluation of water quality achievement on TMDL regulation using SWAT and LDC modeling in South Korea

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The major streams in South Korea have established the TMDL(Total Maximum Daily Loads) regulation for just 4 years. Traditional concepts in water quality management in South Korea are based upon the selection of a design streram flow which is 10-year averged flow exeedance probability 75%(Q275). That is, a single flow value based upon average long term flow conditions is chosen for application in dilution calculations, permit design, water quality modeling, etc. While these TMDLs seems to satisfy the requirement of the target water quality regulations, they have contributed little to any watershed/waterbody assessment and restoration plans. These types of TMDLs do little to characterize the problems the TMDLs are intended to address. For TMDLs to be more beneficial in the assessment and implementation process, TMDLs should reflect adequate water quality across flow conditions rather than at a single flow value such as average daily flow. In this paper, we developed LDC (load duration curve) methodology for the evaluation of Korean TMDL evaluation based on watershed scaled, physically based on SWAT(Soil and Water Assessment Tool) model. First, We developed FDC (flow duration curve) based upon the hydrograph of the recent 10-year period stream flow information using the calibrated SWAT model due to the lack of observed flow data for the sites of interest. Then, the LDC for each site was constructed by multiplying the stream flows by the TMDL water quality standard. In Korea, a 10% margin of safety(MOS) is applying to account for uncertainties in the gauging flow data and water quality modeling. In order to evaluate the water quality achievement for TMDL regulation, the observed flow and water quality data such as BOD and TP were plotted on the developed LDC for each site. In this process, the results show that the point values below LDC values indicate the satisfied water quality condition for TMDL regulation. Otherwise the point values above LDC values indicate the unsatisfied water quality condition. For a regulation year, we described the probability of the unsatisfied water quality condition in statistical manner. In real application, the Nakdong river basin which is the largest basin in Korea was implied to show the effectiveness of SWAT-LDC method suggested above. The LDC was developed for several river sites using the simulated stream flows for 10 years (1995-2004). Then the water quality status according to TMDL regulation for the recent years (2005 and 2006) have been evaluated based on annual and monthly bases. About 35% of measured sample data exceeded the water quality standard in Nakdong river basin, South Korea. Finally, we concluded that SWAT-LDC method might be useful for characterizing the water quality problems and providing a visual display for people to better understand the status of TMDL targets. Moreover, the result showed that the seasonal water quality effects might be possible to define the different standards between point source and non point source management.

***Keywords:*** tmdl water quality, swat ldc, evaluation

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# On nonstationary flood frequency analysis

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The L-moments are recommended for parameter estimation in stationary flood frequency analysis (FFA), both because of their computational simplicity and because of their good performance for small samples. Perhaps, even stronger but less known argument for using L-moments instead of ML method comes from evaluation of the resistance of moments and quantiles estimates with respect to the distributional choice. The L-moments technique has the disadvantage of not being able to readily incorporate covariates. It is why the ML technique is applied for nonstationary FFA (NFFA) and hence to hydrological design under nonstationary conditions. For instance, a simple candidate model for trends could involve linear trend linear trend in the mean and standard deviation while keeping the constant skewness. Since ML is specific distribution method, its estimates of trend in moments and upper quantiles strongly depend on the distribution choice. It has been shown by applying the ML NFFA package consisting of several distributions and several trend options to annual peak flow series of Polish rivers. Even the sign of linear trends may depend on distributional choice. Therefore a careful selection of a distribution by applying several discrimination procedures to stationarized time-series is crucial. Studies on model bias show that the estimates of upper quantiles got by the method of moments are more robust to the distribution choice then ML estimates. It is the reason for developing Weighted Least Squares (WLS) method to estimate the trend in the first two moments. Its applicability to NFFA is discussed. However the main interest in NSFA is a nonstationarity of heavy floods. Taking into account that they may have been generated by different mechanism then small floods, the Partial Duration Series method and ML estimation from left censored samples can be adjusted to estimate time-variant parameters of a distribution.

***Keywords:*** nonstationarity, floodfrequencyanalysis, maximumlikelihoodmethod

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**HW3008** **Oral Presentation** **4822**

# Impacts of hydrological extremes on water quality case Elbe River

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Compared to moderate flow conditions, in extreme hydrological situations water quality changes significantly. Under high flow conditions, among others, dissolution as well as the dysfunction of wastewater treatment plants may be crucial. In drought periods particularly the increasing portion of wastewater has to be considered. A degraded water quality may cause serious problems for water uses which have to be assured also under extreme conditions, e.g. drinking water supply. Therefore, it would be helpful for water managers to predict potential changes in the water quality under extreme conditions. In the last few years, the fate of pharmaceuticals in rivers has been a matter of interest. In these studies some pharmaceuticals have been proven to be retained in wastewater treatment plants (WWTPs) by more than 95% while others are not removed at all. Based on this different removal efficiency it was hypothesised that pharmaceuticals could be used as indicators of the wastewater portion in rivers (Ternes and Joss, 2006). To verify this theory an investigation programme at the River Elbe and selected tributaries was developed and operated 2005 and 2006. Chemical and hydrological data measured during flood events of the river Elbe in March 2005 and March/April 2006 were compared with data gained under normal and low discharge conditions. Two floods were investigated during a period of approximately 15 and 30 days covering the whole cycles of increasing, maximum and decreasing water levels. Discharges ranged between approximately 250 and 2500 m3/s. Mixed water samples (24h) were collected automatically in selected monitoring stations. In comparison to the high flow situations, measurements under moderate to low flow conditions of 250 to 400 m3/s were carried out in June 2005 and 2006. In these cases water sample were directly collected midstream from a ship. Pharmaceuticals such as antibiotics and X-ray contrast media were studied. In addition, the conventional parameter boron (B) was part of the monitoring programme. The antibiotics and the X-ray contrast media were detected by LC electrospray tandem MS in the positive ion mode after SPE enrichment. ICP-AES was used to analyse B in the filtrated water samples (< 0,45 m). First results are encouraging. Fluctuating concentrations of pharmaceutical-indicators can be explained by seasonal variations in their application (especially in the case of antibiotics) and by changing wastewater proportions. Highest concentrations were measured under low-flow to normal conditions and at the rising flood, respectively. The tributary Saale stands out with its specifically high share of wastewater and affects to a high extent the Elbe quality downstream.

***Keywords:*** extreme, pharmaceuticals, river

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**HW3008** **Oral Presentation** **4823**

# Influence of dry years on the baseflow formation in the upper part of the Nitra River catchment, Slovakia

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The influence of meteorological drought on the baseflow formation was investigated in the upper part of Nitra River catchment located in the central part of Slovakia. Time series (1983-2003) of discharges in four discharge gauging stations were studied. Two right-side tributaries Chvojnica and Tuzina represent natural conditions of streamflows formation, left-side tributary Handlovka is strongly influenced by mining activities. The lower-most assessed profile in Chalmova on Nitra River represents the resulting discharge. Gauging profiles represent different geological conditions. Meteorological data from Nitrianske Pravno, Handlova and Prievidza stations were used, being corrected on the average altitude of each sub-catchment. The Bilan model and BFI estimation procedure were used for baseflow calculation. The Bilan model (Kasparek and Novicky in Tallaksen and van Lanen Eds., 2004) has been developed for assessing water balance components of a catchment using a monthly step. The BFI model (Morawietz in Tallaksen and van Lanen Eds., 2004) performs separation of the base flow from the total stream flow and calculates the Base Flow Index (BFI). The whole period was classified according to yearly precipitation amounts; dry, normal and wet years were defined. Occurrence of very dry years reached 19 % for Handlovka and Chalmova gauging stations, 33 % of years were classified as dry and 33 % as normal. For Chvojnica and Tuzina gauging profiles, 9.5 % of years were classified as very dry, 19 % as dry and 47 % as normal. Streams in all gauging profiles can be characterized as streams with an unstable flow regime. The seasonal pattern of streamflows was quite distinct till 1995. Maximum values occurred in spring months (March, April), minimum values inthe late summer-autumn period (July-October). The seasonal pattern of discharges was less distinct after 1995. The strong influence of Handlovka tributary on the Nitra river flows (Chalmova gauging profile) was proved. The relation between surface runoff and baseflow was studied using Bilan model especially for dry years. The closest relation was proved for the Tuzina tributary and confirmed by the BFI procedure. The year 1993 was classified as adry year with the extremely low values of discharges and baseflow in all assessed gauging profiles. The proportion of the 1993 yearly baseflow on the long-term average was the lowest for the whole assessed period. Development of drought was studied for all gauging stations in very dry and dry years in a monthly step in more details.

***Keywords:*** drought, baseflow, model

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**HW3008** **Oral Presentation** **4824**

# Water retention in river headstream areas as an instrument of integrated flood protection and drought problem solving

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In context of catastrophic floods and extreme droughts in recent years there is an urgent need of solving of flood protection questions and measures leading to discharge increase in dry periods, not using just classical engineering methods but also untraditional practices. There is a new strategy focusing on gradual increase of river catchment retention capacity including the realization of measures as runoff retardation and water retention increase in headstream areas. To increase water retention in Vltava River headstream area (southwestern Czech Republic) the detailed analysis of peatbogs hydrological function and qualified reference of measures being implemented at present by the Bohemian Forest National Park Management in connection with former ameliorative channels (made during communist regime) dyking need to be done. The peatbogs influence on runoff conditions and other hydrographic and climatic characteristics is being assessed by detailed comparison of hydrological regimes in two subcatchments with very different peat land proportion. We can reason about the peatbog influence on hydrological process also with respect to its affecting of water quality, respectively to ionic structure of water in periods of high or low discharges. Very favourable conditions for realization of this project currently bear on existence of several water measure profiles with long time ranks (also more than 50 years) and on using modern equipment and methods including a number of automatic ultrasound water level gauges and shuttle precipitation gauges in the study area. Our department can also go upon first results of bog pools detailed research carried out in recent years. The first partial outcomes made by exact analysis of runoff ascending and descending phases show higher discharge variability of streams draining peatland localities. As well, detailed analysis of snow conditions in the study catchment as an important component of rainfall-runoff process has been carried out by means of aerial photographic surveying for monitoring of snow cover thickness and of hydrometers for water value determinations. One possible way how to improve hydrological regime of streams, concretely to lower its maximum discharge values during floods and to increase low discharges in dry periods, is to drain off and to ameliorate peatbog bed in order to lower groundwater level and consequently to extend the depth of peatbog surface layer for capturing causal rainfall totals. In addition to considering the renewal respectively dyking of former channels draining peatbogs we should consider also evaluation of possible former accumulative reservoirs (being used for wood floating) restoration which could function for example as dry (green) polders. Using complex system of hydrological models (rainfall-runoff and routing models) with semi-distributed approach we are able to simulate the runoff process in the source area and to assess the effectiveness of these small accumulation reservoirs. By implementation of these unforceable measures we could contribute to reduction of flood wave peaks and to increase of water resources during extreme droughts in future.

***Keywords:*** water retention capacity, peatbog hydrological function, dry polder

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**HW3008** **Oral Presentation** **4825**

# Hydrological extremes in Bulgaria current and coming

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At the beginning of the XXI century, the sustainable use of water is not only a priority question for water scarce regions but for almost all sectors and regions. Imbalances between availability and demand, degradation of water quality, regional and internal conflicts, all bring water issues to foreground. In parallel climate is changing gradually as a result of the increase greenhouse effect. The objective of this study is to present the response of the Bulgarian rivers to the changing of the main flow-generating factors and also to detect changes in the frequency of hydrological extremes. Long series with 105 yearly observations of precipitation and 70 yearly series with discharge values have been utilized in process of assessing. Analyzing 104 years precipitation series, nine annual maximum sums over 800 mm (mean is 650 mm) were select. Five of them occurred during the last fifteen years, i.e. their frequency has increased drastically to 34 %. After a long drought period of about twenty years (since 1982) a few very heavy floods occurred between February and August 2005 and during the spring of 2006, which caused massive losses of livestock and immense damages to the infrastructure and economic activities. The 24-hour precipitation fallen with exceptional depth have a probability of occurrence once in 1000 years. Summer and winter low flow in 2006 and 2007 were contiguous which suppose a new drought period. There is no compelling evidence change in frequency of drought. The changes in droughts events are pronounced in their duration and severe. The assessment of the coming hydrological extreme has been achieved using observed data for the period 1961-1990 and also results from regional climate change scenarios for the Balkan Peninsula developed by the MGICC/ SCENGEN package in A2 and B2 storylines, especially HadCM2 and ECHAM4 models as the most suitable for Europe. Multi-regression models, a water balance model, and the HBV model have been used to simulate low flow and maximum monthly flow in climate changed conditions. The reduction in precipitation and increase in temperature results in a decrease of runoff according to both the Water Balance and the HBV models. The size of decrease of low flow will be greater according to the HadCM4 scenario. The decrease magnitude of flow tower 2025 is alike to this during the previous long drought period (1982-2000).The degree of stream flow decrease varies with the assumed time horizons and exhibits an acceleration of the decrease towards 2100. Second order tributaries will be dry towards 2050, 2100.

***Keywords:*** low flow, drought floods, climate change impact

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**HW3008** **Poster presentation** **4826**

# Climate Change Impacts: A Case Study of Flooding in Benin River Basin, Nigeria

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A study of flooding in Benin River Basin, Nigeria was carried out using rainfall and temperature data from 1961 to 2000, and flooding data from 1990 to 2000. The climatic data indicated large variation in annual rainfall between 1961-2000. The temperature regime showed a gradual warming of the environment. Increasing temperature and fluctuating sporadic rainfall attenuated the incidences of flooding in the drainage basin. Adaptation strategies adopted by the communitities are highlighted.

***Keywords:*** climate change, flooding, benin river basin

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**HW3008** **Poster presentation** **4827**

# Analysis of long time series of discharges as tool for hydrological management of wide basins: the case of the Po River

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***Mario Tomasino, Pietro Traverso***

The hydrological management gains big benefits from any improvement in the understanding of the physical processes which drive the hydrology in specific areas. This contribution deals with the possible insights and potential improvements provided by the analysis of the 200-year time series of daily Po River discharge, in the fields of hydrological risk assessment and hydrological management of the Po River basin. Emphasis is given to the assessment of the natural causes which have originated the recently observed increase in hydrological extremes (both in the intensity and in the frequency of occurrence) through the coupled analyses of Po River discharge, rainfalls and evapotranspiration data and indices of large-scale climatic structures. In particular, it is discussed: - the knowledge of the natural variability within a temporal window as wide as possible, as a prerequisite for the assessment of the significance of any extreme event; - the changes in the last two centuries which occurred both in precipitation patterns and in the processes of conversion of precipitation to discharges; - the role of large-scale climate fluctuations described through the North Atlantic Oscillation and El Nio Southern Oscillation phenomena, as forcing factors of the Po River regime, in order to improve the consciousness when return rates or other usual hydrological analyses are used by managers and Authorities to determine the mitigation strategies.

***Keywords:*** hydrological extremes, po river, natural variability

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**HW3008** **Poster presentation** **4828**

# Solubility of carbonate system in groundwater of Granitic terrain, India.

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***Dr. J.M. Gandolfi, Dr. Shakeel Ahmed***

The problem of high fluoride concentration in groundwater resources has now become one of the most important toxicological and geo-environmental issues in India. A total of 25 wells were monitored for the fluoride variation in the Maheshwaram watershed, Ranga Reddy District, Andhra Pradesh, India. Geologically, the area comprises crystalline archean granites with intrusions of pegmatite, dolerite and quartz vein. Apart from that various anthropogenic sources such as the brick kiln, poultry farms and fertilizers are in common practice. High concentration of fluoride (>1.5 mg/l) is observed at number of places. The groundwater of watershed is mainly CaHCO3Cl and CaHCO3 type. A systematic monitoring of fluoride content in the groundwater with a function of space and time has been carried out. A correlation study was performed with the hydrological and meteorological parameters viz water level and rainfall. It has been found that with the emergence of monsoon, the concentration of fluoride has been lowered many fold, in the post monsoon compared to the pre monsoon fluoride content in groundwater. However fluoride highs are again noticed during the next cycle of pre monsoon. Ion activity product and saturation index of fluoride and carbonate system has been calculated using the geochemical program PHREEQC. Results of Saturation index have shown that the high fluoride bearing wells are oversaturated with calcite and undersaturated with fluoride in the general. Binary plot of S.Icalcite and S.Ifluoride shows a shift of the water samples to more undersaturated field in postmonsoon. Although, both group of samples shows undersaturation of fluoride. Saturation index of calcite shows the variation from marginally undersaturated to undersaturated field of the plot in premonsoon and postmonsoon respectively. Calculated S.I of fluoride shows positive linear correlation with log EC, while this trend could not be clearly seen with the S.I of calcite indicating the possibility of the additional of fluoride in groundwater with some other source except the mineral fluorite.

***Keywords:*** fluorosis, solubiliy index, andrapradesh

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**HW3008** **Poster presentation** **4829**

# Evaluation of relationship between climate change and monthly rainfall, temperature in the city of Fukuoka Japan, using self-organizing map

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Self-Organizing Map (SOM) has been developed by Kohonen as a clustering algorithm. SOM is a quite useful method to classify data depending on their geometric similarities. One of the advantages of SOM is that SOM can visualize the classification results on the 2-Dimensional map. Many studies have been conducted to identify the relationships between climate change and its influence on hydro-meteorological variables. Most of the studies carried out in this area use linear correlation method to identify the relationships between the variables. However, what linear correlation method is able to do is to identify linear relationship between the variables, and therefore how to identify the significant variable has been one of the important issues in this area. This study utilizes SOM to evaluate relationships between climate indices and monthly rainfall, temperature in Fukuoka, Japan. The procedures used in this study are as follows. As the first step, SOM was employed in order to classify 5 kinds of climate indices, which are Southern Oscillation Index (SOI), Pacific Decadal Oscillation Index (PDOI), North Pacific Index (NPI), Dipole Mode Index (DMI) and Arctic Oscillation Index (AOI). Each of those indices characterizes climate in wide area. As the results of SOM application for those climate indices, past climate represented by the indices were classified on the 2-Dimentional map. As the next step, we selected each of the climate pattern classified by SOM, and examined corresponding 1 to 12 months lagged monthly rainfall and temperature in Fukuoka, Japan against the climate pattern. By doing this analysis, we examined the connections between specific climate pattern and occurrence of extreme rainfall and temperature in Fukuoka.

***Keywords:*** som, climate change, rainfall

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**HW3008** **Poster presentation** **4830**

# Frequency analysis of Nyanyadzi River flow floods

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This paper presents results of a study carried in Zimbabwe aimed at analysing the frequency of Nyanyadzi River floods using the Gumbel distribution. Extreme floods over recent years had washed away fields, destroyed infrastructure and killed animals. It was hypothesised that Nyanyadzi flood flows obey the Gumbel distribution. The scale and shape parameters of the distribution were estimated using method of moments. Maximum instantaneous flow data covering 30 water years (1969-1999) for station E119 on Nyanyadzi River were collected from the Zimbabwe National Water Authority (ZINWA). A Chi-square 2 test revealed no significant (p = 1.000) differences between recorded and predicted flood flows. Due to goodness of fit of the Gumbel distribution, it was assumed to be appropriate for modelling frequency of Nyanyadzi River floods. The magnitudes of the 100- and 200-year floods were estimated to be 276 and 310 m3/s respectively.

***Keywords:*** flood, frequency, gumbel distribution

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**HW3008** **Poster presentation** **4831**

# The fate and transport of radionuclides in aquatic ecosystems within the Chernobyl accident exclusion zone

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The studies of radionuclide distributions in basic components of lake ecosystems, located at dam-fenced site of Krasnensky flood plain (with highest density of radioactive contamination within the Chernobyl accident exclusion zone) indicated depositing of the main quantity of radionuclides to bottom sediments. Hence, concentrations of radionuclides equalled as follows: by Sr-90 - 89-95%, respectively; by Cs-137 - 99%; by TUE (transuranic elements Pu-238, 239, 240 and Am-241) - almost 100% of total content in ecosystems. The difference in Sr-90 contribution to bottom sediments of the lakes and contents of other radionuclides is stipulated by elevated migration activity of Sr-90 compared with Cs-137 and TUE. This is the determining reason for higher concentration of dissolved Sr-90 in waters of lakes (4.3-10.2%) compared with Cs-137 (0.5-0.6%) and TUE (0.03-0.04%) and, vice versa, lower Cs-137 concentration in seston (0.15-0.16%) compared with Cs-137 (0.25-0.30%), respectively. The content of TUE in biotic components of ecosystems was minimal 0.07-0.16%, respectively; for Cs137 it equals 0.14-0.47%, and for Sr-90 - 0.25-0.61%. Within the period of investigation (1989-2005), dynamics of radionuclide concentrations in tissues of the aquatic organisms from river ecosystems indicated a decrease of Sr-90 and Cs-137 content. So far as concerns closed or low flowage water bodies, the measurements have shown that since the late 1990-s the hydrobionts are indicating a frank tendency to Sr-90 content increase in tissues. It is suggested that Sr-90 specific activity in tissues of aquatic organisms from Krasnensky flood plain increases due to dynamics of radionuclide transformation in soils of water catchment areas and bottom sediments of water bodies. Since after the Chernobyl accident Krasnensky flood plain appeared one of the most radionuclide-contaminated areas of the exclusion zone, in 1991-93 a complex of flood control dams were constructed here, which changed the hydrological regime of flood plain flows during floods and preventing radioactive substance washing off the soils of contaminated areas. In its turn, this became the reason for intensification of waterlogging and swamping of dam-locked areas. As a result, at the background of general tendencies of Sr-90 mobile form increase in the soils of water catchment areas and bottom sediments of the Exclusion Zone water bodies; in swamped soils of Krasnensky flood plain fulvic and humic acid concentration increases, that decreases pH-value in water and intensifies a denuding of water-soluble forms of Sr-90 forming soluble complexes with fulvic acids. Hence, an increase of concentrations of mobile forms of the radionuclide and their inclusion to biotic turnover of aquatic ecosystems are observed. This also confirms the increase of Sr-90 specific activity, observed in recent years in Krasnensky flood plain lakes at the background of stabilisation of this index for Cs-137.

***Keywords:*** biohydrocenoce, radionuclides, chernobyl

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**HW3008** **Poster presentation** **4832**

# The Tuo Jiang River Cloud Seeding Programme for Waters Pollution Mitigation

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This study provides an introduction to the Tuo Jiang River Cloud Seeding Programme (TJRCSP) that was conducted in 2004 in Sichuan Province in China. In February 2004, waters in the upper reaches of the Tuo Jiang River were greatly polluted because of industrial sewerage leakage by the sudden damage of cleansing systems of a large chemical plant. A great many of fishes were killed and the people resident by the Tuo Jiang River banks were in danger. The pollution accident took place in early spring, in which natural precipitation is a little there. The Tuo Jiang River lacked waters at that time and ran at 600 m per hour. Then the Tuo Jiang River Cloud Seeding Programme was commenced on urgent demand. Liquid nitrogen was chosen as the seeding agent. Operations were conducted on a fifty-seat airplane. From March 19 to April 7, eight flights were conducted in the air of the upper reaches of the Tuo Jiang River, in which five flights were conducted at night. Three skillful pilots and three or four engineers were boarded every flight. An air-motion GPS temperature and humidity measuring system, polarization radars, satellites, and raingauge networks were employed in the programme. Every flight lasted around two or three hours. Clouds were seeded at the height within 4200 m to 5200 m. In and after every flight, the raingauge networks showed that the target region gained enhanced rainfall, radars tracked larger and stronger echoes as well. The people were relieved at the news of the programme. And waters were depurated by enhanced rainfall. Soon after the programme, waters from the Tuo Jiang River were used as drink waters again. It shows that the programme had considerable socio-economic benefits. Furthermore, it is recommended that further development of the cloud seeding technology and more detailed measurements should be greatly emphasized.

***Keywords:*** water, pollution, cloud seeding

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**HW3008** **Poster presentation** **4833**

# Hydroclimatic variability in the andean region of the Amazon Basin

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The current hydroloclimatology variability in Andean region of the Amazon basin is analyzed from Madeira river (Porto Velho station, 954400 Km2, Peru Bolivia Brazil) and Peruvian Amazon River (Tamshiyacu station, 726400 Km2, Peru Ecuador). Rainfall and discharge interannual variability show a decreasing trend in both cases for the period 1975 2004. In the Andean region as well as in the whole basin, an increase in the ranges flow values, which intensify from the beginning of the 90s to the present for the three basins analyzed. The lowest ranges flow values in the last 40 years recorded in the Peruvian Amazon region and in the Madeira River in 2005, as well as the major floods of 1997 in Porto Velho and 1999 in Tamshiyacu, show this intensification. Climatic global phenomena and/or regional impacts such as deforestation may be the cause of decrease in rainfall and increase in the extremes values.

***Keywords:*** amazonas, andes, hydroclimatologie

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**HW3008** **Poster presentation** **4834**

# Analysis of first flash load from urban watershed in Isfahan, Iran

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Large amount of raining water is transferred to reception resources in urban areas due to the increased impermeable surfaces. Urban catchments water is that produced by precipitating or snow melting considered as one the most important non-point source pollutants. Good management of treatment works requires an understanding of the First- Flush phenomenon of wet weather in urban drainage systems. In this study, having discrete sampled the output drainage of 13 precipitation events in one of Isfahan catchments during autumn/winter, 2002/2003, 10 qualitative/quantitative parameters were measured assessing general quality and the First- Flash curves were drown for each pollutant parameters. The results showed that primary elution much occurred for nitrates, biological oxygen demand and chemical oxygen demand in comparison to other pollutants and the major pollution amount can be eradicated through controlling the primary drainage volume.

***Keywords:*** first flash, urban runoff, non point source pollutant

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**HW3008** **Poster presentation** **4835**

# Evaluation of Groundwater Potential Zones and Zones of groundwater quality Using Remote Sensing and GIS in the Hilly Terrains around (Devak-Rui) Watersheds, Jammu District, J&K State, India

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***Rajinder Singh***

In the present study various thematic layers were prepared from remotely sensed data and data collected by conventional methods that directly influence the terrain for evaluation of groundwater prospects and groundwater quality mapping. Lithology, the study areas have been divided into Upper Murree, Lower, Middle and Upper Siwaliks Subgroups and Alluvium of Jammu formation. Geomorphologic the study areas have been divided into Structural Hills, Low Dissected Structural Hills, Highly Dissected Structural Hills, Residual Hills, Piedmont Alluvial Plain, Valley Fill Deposits, Active Flood Plain, River Terrace, and Braided Bar. Structurally the area comes under Suruin- Mastgarh anticline in which Krishanpur-Mandli Thrust passes in the north eastern portion. Hydromorphogeologic map of Devak-Rui watersheds has been prepared by integrating the lithological, structural and geomorphological maps. GIS technique has been used to integrate and analyse the thematic maps and to prepare a map showing groundwater potential zones. The groundwater prospect map has been prepared by integrating the hydromorphogeological, land cover, slope, drainage frequency, soil, depth to water table (pre-and post-monsoon), water table fluctuation, static water table, discharge, drawdown, specific capacity, transmissivity and hydraulic conductivity maps by using Index Overlay Method in the GIS environment. GIS based groundwater quality mapping for drinking and irrigation purposes were carried out with the help of hydrochemical data. Integrating groundwater quality for drinking and irrigation purposes pictorial representation shows groundwater quality zones favorable for drinking purposes, irrigation purposes, zones of both drinking and irrigation purpose, zones not favorable for either drinking or irrigation purposes.

***Keywords:*** groundwater potential zones

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**HW3008** **Poster presentation** **4836**

# Climatic and anthropogenic impact on underground water quality: an example from Agrigento province (Sicily, Italy)

***Dr. Dimitra Rapti-Caputo***
*department of earth sciences university of ferrara IAHS*

***Dimitra Rapti-Caputo***

The alluvial plain of Licata (southern Sicily, Agrigento province) has been investigated to evaluate the influence of the human activities and that of the climatic changes in the hydrological cycle in terms of qualitative and quantitative impact on the groundwater resources. In this area, the evolution of the Salso river (in Italian 'salty river') and the coastal dynamics, characterised by consecutive transgresions and retreats of the coast-line, qualitatively and quantitatively influenced the underground water resources. In this complex geological contest, also the anthropogenic activities played a crucial role, especially the farming activity as largely testified by the occurrence of numerous greenhouses that cover most of the plain. The analysis of thermopluviometric data concerning the last 75 year allowed to obtain inferences on the climatic evolution of this region characterised by a mean annual temperature of about 18 C and mean annual precipitations of only 454 mm. In particular, during the last 24 years a 12 % decrease of the precipitation with respect the previous period of observation is observed together with the increase of the temperature of the air about 1C. The research was focused on the unconfined, mainly sandy, aquifer developed in the Quaternary deposits of the Licata plain. The water depth of this aquifer is between to 0.3 to locally 5 m from the surface and the principal alimentation occurs via infiltration from precipitations and lateral outflow from the Salso river. The high salinity of the river especially during Summer periods and the intense farming activities played a crucial role for the quality degradation of the aquifer.

***Keywords:*** climaticchanges, hydrogeochemistry, agriculturalactivities

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**HW3008** **Poster presentation** **4837**

# Coupling water related historical data to predict possible future ecological conditions of the Mura River corridor, Slovenia

***Dr. Lidija Globevnik***
*IAHS IAHS IAHS*

***Meta Pov, Mitja Kaligarič***

The evaluation of possible future ecological conditions of the river corridor greatly depends on interpretation of how hydrological processes have been and are still greatly impacted by long lasting human interventions if not climate change. Riparian hydro-morphological parameters for the 90 km long river corridor of the Mura river in are described by data collected in few sampling campaighn and interpreted with the use of all available historical data. Results show that linear trends of annual average discharges and minimal discharges are negative, but maximal discharges are positive. The ground water retention capacity has fallen for half in the last 40 year. The excess carrying capacity from 1970 on of the river resulted in head-cutting of Austria- Slovenia border. The amount of bed degradation decreases downstream in the river section in. Annually the groundwater fluctuates from 1.5 and 3.5 m under the surface, but a general decline is indicated of 20-25 cm in groundwater levels throughout the area. Water surface area has declined for 15% in 200 years, the biggest change happened in the last 40 years. Area of riparian forest has declined for 30%. Among forest 10% is degraded by alien species. Only 35% of the area is completely natural or nature-close stage. The ichthyofauna of the Mura is used to be a pronouncedly salmonoid-cyprinoid and the river with oxbows must have been permanently or periodically inhabited by 52 different species from 15 families. In spite of a remarkable changes of river ecology, a relatively small number of fish species has disappeared during the last century. Though the river sustains high fish diversity, good ecological conditions are deteriorating due to water pollution, larger and more frequent drought periods, subsurface water storage decline, groundwater level drop and allien forest species expansion in the river corridor.

***Keywords:*** river ecology, hydrological trends, mura

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**HW3008** **Poster presentation** **4838**

# Managing models for Tevere River water quality related to on stream lakes restoration (Italy)

***Mr. Angiolo Martinelli***
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***Alessandra Cingolani, Giacomo Rapi, Alessandra Santucci, Giuseppe Patrizi***

The Umbria Region Water Safeguard Plan interests the northern and central part of the Tiber River basin in Central Italy, where are present two on stream lakes, Corbara and Alviano, different for environmental and morphological conditions. Both lakes are in bad quality status, according to the Directive 2000/60/Ec, and their qualitative restoration will ask a considerable effort on whole upstream watershed (aprox. 8.000 km2), more significant than that necessary for the objective of good ecological status of river itself. According to climate and anthropic hydrological evolution, the definition of maximum acceptable trophic loads for the lakes, especially of phosphorus, could represent the key to address the restoration policies of the local authorities. Every safeguard action in the Plan has been defined according to legislative, technical and economical analysis, and its impact on river reaches is quantified using specific emission and transfer factors for each sub-basin, to evaluate the improvements in terms of trophic pollutants concentrations. In order to estimate the pollutant loads carried by the river and to simulate the effects of general planning and the impact of interventions of the Umbria Region Water Safeguard Plan, a mathematical quality model of Tiber River and its lakes has been developed. Moreover, the GIS interface provides useful representation of the various scenarios simulated by the model; this could allow local authorities to simply choose the best configuration of actions, in term of priorities for each specific sub-basin. The quality model will be used to evaluate the implementation of planned measures also and to redefine actions, in order to achieve the good ecological status of water bodies in 2015.

***Keywords:*** water quality, river, prediction models

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**HW3008** **Poster presentation** **4839**

# Impact of diffuse pollution from agriculture on quality of the great Backa Canal Dunav-Tisa-Dunav

***Prof. Andelka Belic***
*Department for Water Management Associate Professor IAHS*

***Sima Belic***

Intensive development of the agriculture in the area of South Backa not followed by adequate and sufficient protection of agroecosystem resulted in deterioration of the water quality in the Canal DTD. This Canal runs through the most fertile soil of Vojvodina with very intensive agricultural practice, which includes usage of a wide-range agrochemicals. As the fertilizer and pesticide application to agricultural land are not always rational and adequate, there is a possibility of diffues losses of nutrients (nitrogen and phosphorous) and pesticides to surface and groundwater. Furthmore, since the water from the Canal is used for irrigation of crops it may happen that agricultural products do not meet the regular quality standards. In the previous period no systematic research has been done and there are no many data regarding the impact of agriculture on the water and soil quality in Vojvodina. The aim of this project is to assess the impact of agriculture on the water quality in Crvenka-Kula-Vrbas part of the Canal, i.e. to make an estimation of agriculture contribution to general pollution of the Canal. Based on the results of this investigation certain actions shall be recommended that should result in reduction of agricultural pollution. With the aim of estimating the influence of pollutants from agricultural production in the overall pollution of the Bezdan-Bečej (Great Backa) Canal an analysis was carried out of mass load parameters which characterize agricultural production (BOD5, ammonium, nitrates, nitrites, and phosphorus) and their comparison for the Canal I-61 and the Great Canal. Analyses were carried out for minimal and maximal discharge for the Canal I-61, and compared with the available data for the discharges as well as for the quality. Having in mind that the available data give the characteristics in a time instant, the obtained results should be understood as such. By analyzing the percents of contribution of particular mass loads from the Canal I-61 to the mass loads of the Great Canal it is possible to notice high variations from one parameter to another, whereby the proportions of ammonium and phosphates are very high at minimal discharge, while at maximal discharge the nitrates percentage prevails in the overall pollution. Having this in mind, the difficulties still remain in the establishing of the exact contribution of agriculture to the overall quality of the recipient water, and highest precision in this domain can be achieved by analyzing every quality parameter separately and in a longer period of time. Complex measures for protecting the channel water quality assume a series of synchronized activities that are to be performed in the frame of these two parallel groups, viz.: selecting best procedures of managing agricultural production and monitoring of water quality.

***Keywords:*** chanal water quality, agriculture, diffuse pollutants

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**HW3008** **Poster presentation** **4840**

# Excess precipitation influence in 2005 upon the phreatique aquifer from Banat Region (Romania)

***Dr. Doina Dragusin***
*GIS Data Processing Laboratory National Institute of Hydrology and Water Manageme*

***Mihai Radescu***

In different periods of 2005, all over the romanian teritory a great amount of precipitation fell. This caused important increases of the river levels, producing socio-economical negative effects. In Banat region, situated in west part of Romania there are lower areas such as Beregsau or Bega Plains; here, the phenomena with great precipitations were significantly in the month of April and are reflected in higher values of the phreatic levels and a hydrochemical degradation of the groundwater. The influence of those great quantities of precipitation upon the phreatique aquifer was studied using specific stored data, collected from the National Hydrogeological and Hydrological Networks. The study results are: Graphic correlation between the phreatic levels, rivers levels and the cumulative precipitation quantities; Graphic variations of the maximum piezometric levels in 2005 and 2004, in comparison with the multiannual mean parameter. Maps, using GIS technique, ilustrating the minimum depht level and the spatial dstribution of some chemical parameters related to level variations.

***Keywords:*** phreatic level, monitoring wells, hydrometric station

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**HW3009** **4841 - 4847**

**Workshop**
**Loss of Knowledge (with support of WMO and UNITAR)**

**Convener :** Dr. Arthur Askew

Over many decades concern has been expressed throughout Africa at the deterioration of hydrological records, the inadequate support for hydrological research and the loss of trained hydrologists to other careers, particularly in private business. This same phenomena is now becoming apparent in many of the former Soviet republics and, if one looks with care, there is a similar tendency, though less dramatic, throughout the world. If we are to reverse this trend and save the practice of hydrological science in many regions, we need to learn from those close to the problem how and why it has arisen and seek together for possible solutions. New technologies certainly hold promise, but they need the very expertise that is lacking if they are to be applied effectively. Papers are invited from those with experience of these problems to join an open debate on the current situation and means of resolving the difficulties faced.

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**HW3009** **Oral Presentation** **4841**

# The deterioration in hydrometric data collection in Africa; what can be done about it ?

***Mr. Frank Farquharson***
*Centre for Ecology and Hydrology IAHS*

Few hydrologists who work in Africa would deny that both the quantity and quality of hydrometric data collected in the majority of African countries has declined over the past 20-30 years. A number of authors have documented this decline (Rodda (??), World Bank, (1984)), and it is becoming increasingly difficult for hydrologists and engineers to plan and manage water resources systems in Africa. There are many reasons behind this decline, but the major cause of the deterioration is often the institutional failures in countries, where hydrological data collection is not recognised as important, and a general reluctance by governments to allocate sufficient staff and funding for this task. Many countries have become over-reliant upon external donor funds for this vital activity, with the inevitable short-term solutions to the problem, and breaks in record collection as one donor project ends and the start of another is delayed. Even where donors allocate funds for the activity, the author has seen numerous examples of where expensive new four-wheel drive field vehicles, intended for the hydrology department, have been commandeered by senior politicians in the Ministry of Agriculture/Water/Natural Resources to transport their children to and from school, or their wives to shops etc. Similarly, staff training is either neglected, or when staff are trained in new techniques, particularly modern computer based data processing, they often subsequently leave poorly paid government service for the private sector. One approach to this problem is the WMOs WHYCOS Project (World HYdrological Cycle Observation System), initiated in the SADC region, and now extended to West Africa and parts of the Nile basin. The aim was to establish a series of good quality benchmark stations on international rivers equipped with data transmission facilities via Meteosat, reporting data back every three hours. However, the projects have not always been successful due to lack of commitment by participating countries, and by the difficulties of maintaining this hi-tech equipment: solar panels and batteries are frequently stolen, and even where spare parts are available (as they were for the SADC-HYCOS project) deployment of these spares is often difficult. An alternative approach has been adopted by the World Bank in India, where the Hydrology Project has forced government agencies in India to take hydrology seriously, and where relatively low-tech, traditional methods of data collection have been employed. The initial first five year phase of the project has involved upgrading equipment at over one thousand stations, and more than 25,000 staff, at levels ranging up from field technicians through data processing staff at regional offices to managers at State and national level have been trained to date. The project has invested hugely in development of a well-trained pool of staff, and has even attempted to get round the problem of low government salaries. The author will talk of his experiences and will suggest how hydrometry in Africa might be improved.

***Keywords:*** hydrometric data, training, developing countries

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**HW3009** **Oral Presentation** **4842**

# Hydrological service in Bosnia and Herzegovina

***Mrs. Esena Kupusovic***
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Changing organizational environment in which National Hydrological Services operate reflects strongly to Hydrological Service (HS) in Bosnia and Herzegovina (BiH). After hydrological stations network system in Bosnia and Herzegovina suffered complete collapse during the war 92-95, consequences are still present in miscellaneous modes, too. Institutions in charge of water management in BiH rely on a long central European tradition from the end of XIX century, including strong cooperation of HS with World Meteorological Organization (WMO) concerning hydro-meteorological monitoring. The combination of local competence and donor hardware support has resulted in the monitoring network being re-established. However, together with the key issues globally recognized, HS in BiH faces with gaps in hydro-meteorological observation during nineties and reflection by overall complexity of national administrative, territorial and socio-economic situation. Nowadays, missing information during last 15 years are lost knowledge. Only adequate, scientific filling in gaps can bridge long data series. There is a strong need to clearly define the role of HS in institutional set up of water and environment sector in BiH

***Keywords:*** hydrology, service

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**HW3009** **Oral Presentation** **4843**

# Streamflow monitoring in Australia - Typical of worlwide neglect?

***Dr. Ian Cordery***
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Modern streamflow monitoring began in Australia in 1865. The number of active stations increased slowly until about 1960 and then station installation accelerated during the International Hydrological Decade (1965 - 1975). After 1975 overall station numbers remained fairly static, with severe decline in numbers in 3 of Australia's 7 states and Northern Territory, and modest increases in three others. Where station numbers declined or were static attention to station operation and particularly calibration (stage - discharge relationship) also declined, to the point where discharges at mediun and high flows could only be estimated approximately. Australian stream flows are highly variable with more than 50% of flow volumes typically occurring in just a few (much less than 10) high flow events per year. This low level of attention to development of accurate stage - discharge relations implies that most medium and high flows cannot be estimated to better than between 33% and 300% of the real values. Therefore even at the few places where monitoring occurs our water resources assets cannot be known more accurately than within +/-50% and the planning and design of engineering infrastructure such as reservoir capacities, waterway crossings, flood protection, spillways, urban storm drains etc has a very uncertain basis. A few years ago it was shown that for the most populous State the annual economic benefits of streamflow data for engineering infrastructure works alone were more than nine times the annual costs of all activities associated with streamflow monitoring. Streamflow data provide far more benefits to the community than the the engineering design of infrastructure! Some examples of the infrastructure benefits, or costs of insufficient data. For a small water supply dam a few years of recorded data could have provided a basis for reducing uncertainties, which could not be ignored, and which added $2M to the best estimate cost of $5M. In another case two additional hydrological studies were required to overcome data deficiencies. In both cases collection of data for perhaps 10 years with a total cost in each case of less than $200,000 would have saved significantly on the project and could have added considerably to the perceived reliability of the eventual designs. In spillway flood studies for two dams on catchments of about 100 sq. km methods developed for estimating floods for ungauged catchments showed huge uncertainty (and potentially large cost to reduce risk) of having no streamflow data. One had recorded flood data and analysis of the recorded data suggested a spillway twice the size of that indicated by a regional flood estimation method. In the second case the uncertainty in the flood estimate from a regional method (no data on the catchment of interest) suggested the existing spillway could fail on occurrence of a flood of recurrence interval between 400 years and 15,000 years. For the safety of the population downstream this spillway either needed urgent attention (population at risk too large to accept failure once in 400 years) or could acceptably be left unmodified. What would be the potential value of a few years of data for the making of this decision? Why do we have these dilemmas and uncertainties when the cost of collecting reliable streamflow data is much less than $20,000 pa per station? Perhaps it is because resources professionals have dismally failed to communicate the essential nature of streamflow monitoring to those who frame government budgets.

***Keywords:*** stream discharge monitoring, economics of flow measurement, benefits ofstreamflow data

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**HW3009** **Oral Presentation** **4844**

***Mr. Chidi Francis***
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The quality of a hydrological prediction and forecasting is connected at a fundamental level to the quality of the hydrometeorological data used both in developing the prediction method (modelling) and during its operational use. Hydrometeorological data and information are veritable resources that are essential in all ranks of decision-making, in the planning and design of water resource mobilization and development projects and to the effective management of future infrastructure and installations. The issue of inadequate hydrometeorological data acquisition in River Basins of Nigeria in the last few decades has been observed and studied. Perceptive analysis is being used to assess the current status of hydrometeorological network of stations in the country. This involved a survey by questionnaires and responses from 8 River basins Development Authorities (RBDAs) spread across the 6 geo-political zones. Unfortunately, despite the encouraging conclusions of the Sub-Saharan hydrological appraisal conducted between 1990 and 1992, current findings indicate that the gauging networks in the majority of the River Basins have suffered continual deterioration since the late 1980s, in the absence of the large-scale funding needed by the meteorological and Hydrological Services to properly monitor these gauging networks. Further results show that 85% of the responses from the survey confirm that the data collection and dissemination are relatively poor in terms of quality, quantity and reliability. Over 65% of the hydrological data equipment and facilities in the basins lacked maintenance and as well as being outdated. 80% also Show that new hydrological stations has not been established since the last decade. Inability of the decision-makers to view hydrometeorological data as resources that has economic value, resulting in poor budgetary allocations explains the reasons for the degradable state of data acquisition in the country. The implications and consequences of these inadequate institutional provisions to meet the sustainability of data handling and management in RBDAs have continuously made it difficult for acquisition of adequate data necessary for climate change, floods and drought monitoring. Necessary future reforms to address these problems and bring about the sustainability of data handling and management have also been discussed.

***Keywords:*** hydrometeorological data, river basins, data acquisition

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**HW3009** **Oral Presentation** **4845**

# Improving Knowledge for water resource management for sustainable hill agriculture in foothills of Shivaliks, India

***Dr. Sanjay Arora***

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The drought prone zone locally known as kandi region of Jammu province of Jammu and Kashmir state of is characterized by low to medium rainfall, deep water table, undulating topography, poor soil fertility with land surface full of sand stones, soil moisture stress, frequent droughts and acute scarcity of water for domestic use and crop production. The kandi zone has two major river basins viz. Chenab and Tawi, which pass through deep gorges and undulating terrain, draining entire Jammu region. About 3.5 to 5.0 km3 of water is received as annual rainfall, mostly during July and August. Rest of the period during the year remains dry except few showers during winter. Rains are generally with high intensity, resulting in over flowing of seasonal streams, soil erosion and degradation. The entire zone has agriculture-based economy but is always deficient in food grains. Though, the farmers are hardworking, working most of the time in the field along with their spouse and children, they do not produce as much as to feed their family. In absence of optimum soil moisture and irrigation facilities; application of fertilizers, good crop seed and other inputs have little impact on crop productivity. It is difficult to derive any benefit from the water from two rivers as they flow in hilly terrain and cost involved in lifting the water and construction of canals would be two high compared to the area available for irrigation in the immediate vicinity. The farmers have less technical knowledge and know-how for in-situ and ex-situ water management. An attempt was made in 2004 to prepare the resource inventory of the farmers and their agricultural practice and on the basis trainings and demonstrations were employed to aware the farmers regarding the need, methods and benefits of the water management for sustainable agriculture in the hilly regions. The indigenous knowldege of the farmers were evalauted in respect of improved practices on scietific basis which includes along the slope tillage and mulching with local material for growing summer crops. The results are now visible as there is about 23 per cent increase in the adoption rate for improved practices and rainwater is being managed by the farmers.This study shows that there is need to re-adopt the indigenous water managementpractices in tandem with modern scientific techniques

***Keywords:*** rainfed, knowldege, agriculture

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**HW3009** **Oral Presentation** **4846**

# Constraints and prospects of hydrological science practices in Sub-Saharan Africa

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Strategic water resources development and management, in the 21st century and beyond within the Sub-Saharan Africa region depends on improved knowledge of global, regional and local water resources availability, consumption and withdrawal. Such knowledge is indispensable, if reliable information on the state and trends of water resources and substantial economic development is to be accomplished under the present global change challenges. Unfortunately, water resources assessment in Africa has been greatly affected by pressure of economic stringency through insufficient budget allocation and varied neglect of water resources assessment infrastructure provision and research development. Cases of station neglect are also common with the status of gauging of the various basins still far from satisfactory and in many cases, worse than it was two decades ago while the consistency of available hydro-climatological and auxiliary datasets and its accuracy for detailed water resources assessment is doubtful. The prospect of hydrological science practices in Sub-Saharan Africa as suggested in this paper lies in the integration of water resources data within and between an effective institutional, organizational, procedural and information quality scheme. Such scheme needs to adopt both horizontal and vertical approach as well as incorporate digital and space technology Fully improved water governance in the area of financial and technical support mechanisms for water assessment infrastructure at local, regional and sub-regional level should also be encouraged. And a science-based data recovery and compilation scheme of the different organizations at both local and international level needs to be well structured, in order to strengthen and improve the resolution scale of water data and information systems. Also, the adoption of a a policy relevant science like the Prediction of Unguaged basin (PUB) initiative should also be encouraged, in order to resolve the ubiquitous Ungauged basin incidence in a technical-scientific way. PUB initiative is one of the benefits derivable from advancement in hydrological sciences. International cooperation in the area of networking, finance, man-power development, exchange programs as well as data acquisition, dissemination, manipulation in addition to equipment standardization and calibration will also go a long way in promoting a worthwhile hydrological science practices in Sub-Saharan Africa.

***Keywords:*** water resources assessment, ungauged basin, hydro climatological data set

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**HW3009** **Oral Presentation** **4847**

# Combiniing modern and traditional knowledge bases for integrated water resources development in Africa

***Dr. Kodwo Andah***
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***Christine Young***

Knowledge is the engine that drives economic growth, and Africa cannot eliminate poverty without first increasing and nurturing its intellectual capital. The history of water and land management in Africa dates as far back as the early empires on the continent which left in their stead the very large expanse of the Sahara desert which can be attributed to uncontrolled land use practices. Local knowledge bases in Africa comprise accumulated cultural knowledge, modified knowledge through intercultural exchanges and progressive learning of the environment. Traditional knowledge in most African societies have been applied through indigenous customary laws and regulations aimed at the proper use or conservation of land and water resources, mainly through observance of cultural and spiritual values attached to water bodies. Some of these included protection of grove yards on the headwaters of rivers and streams, the ban on entry into streams or water bodies at certain times of the week and for certain periods and the regulation concerning washing, bathing, and blocking of streams. Indiscriminate degradation of watersheds including headwaters occurred with the breakdown of taboos and myths through modern formal education and changes in religious beliefs. Some recent studies indicate that institutionalised memory on land and water resources management, including hazards can provide detailed and accurate knowledge which sometimes is comparable with formal science. It is possible to make adequate diagnostic assessment of land and water resources if scientific knowledge can be combined with traditional sources, especially when quick decision is required but data is lacking. In fact, there are already ongoing projects in Africa involving local and indigenous knowledge systems supported by some United Nations agencies and also by some African academic and research institutions. Some of the projects focus on soil and water conservation with emphasis on local techniques and also on information research on knowledge and management systems used mainly by African herders. These are based on the identification of indigenous farming systems and to determine whether and how these conservation techniques can be used as starting points or building blocks for more scientifically based programmes in order to improve their efficiency. It must however be emphasised that the complexity of the hydrological cycle and its interactions with the environment and societal needs calls for modern scientific and technological tools for the analysis and development of Africas water and land resources in a holistic framework. Ensuring the knowledge base, for Africa s water resources development and management, boils down to knowledge and information transfer within the general framework of technology transfer. Technology transfer to African countries, for it to be effective, must be accompanied by a long term process of human and institutional capacity building within an enabling environment with the necessary general infrastructure and conducive professional climate and incentives. It is not only sufficient to adopt and adapt knowledge bases developed in other physical and climatic regions to Africas needs but such knowledge must be infused into local knowledge and experiences within Africa in order to take full advantage of traditional wisdom.

***Keywords:*** knowledge, water, africa

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**HW1011** **4848 - 4896**

## Workshop
## Cryosphere: Observations, processes, and future evolution (UCCS and IGS Workshop hosted by IAHS) (Merges JPSCCS004 and JPSCCS005)

**Convener :** Prof. David Holland, Dr. G Hilmar Gudmundsson
**Co-Convener :** Prof. Georg Kaser

The cryosphere is currently undergoing rapid changes in response to both natural and human-influenced processes. A challenged posed to the scientific community is to differentiate between changes reflecting the natural variability of the cryosphere and those derived from human activities. Cryosphere is a prime example where nonlinear self-sustained oscillations can give rise to changes in volume and geometry of ice masses that are not, or only weakly, related to external forcing. At the same time Cryospheric components are also very sensitive indicators of climatic change. This session invites papers addressing the important and challenging task of both understanding what changes are taking place, and why. We encourage papers reporting observations of ongoing cryospheric change, and modelling papers focusing on processes and future evolution of iice masses. This session focuses on Glaciers, ice streams, ice sheets and shelf ice but welcomes also papers on other components of the cryosphere. It aims to be complementary to the more specialized sessions of the program.

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**HW1011** **Oral Presentation** **4848**

# Sea ice extent extremes on intraseasonal time-scale in the Amundsen-Bellingshausen oceans and associations with large-scale circulation

***Mr. Fabio Ullmann Furtado De Lima***
*Atmospherics Sciences So Paulo University - USP IAHS*

***Leila Maria Vspoli De Carvalho***

The goal of the present work is to understand possible atmospheric mechanisms related to intra-seasonal (20-100days) anomalies in the Amundsen-Bellingshausen sea ice extent (SIE). Amundsen-Bellingshausen sector SIE is obtained from satellite with daily resolution and covering the period 1979-2004. Spectral analysis of SIE showed significant peaks on intra-seasonal time-scales. Previous studies suggest that intra-seasonal variations in the SIE are related to responses of the sea ice to atmospheric circulation and sea surface temperature. The relationships between extreme intra-seasonal anomalies of the SIE and the propagation of intra-seasonal (20-100 days) mid-latitudes wave trains were investigated. Atmospheric circulation and sea surface temperature were strongly related to distinct phases of the subtropical wave trains such that each phase modulates distinct SIE extreme anomalies, particularly stronger in the winter.

***Keywords:*** extreme sea ice extent, intra seasonal, subtropical wave trains

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**HW1011** **Oral Presentation** **4849**

# An analysis of 200 glacier length records

***Prof. Johannes Oerlemans***
*IMAU Utrecht University IAPSO*

Glacier length is a quantity that can be measured relatively easy and can be inferred indirectly from maps, drawings, and, more recently, satellite images. Although in modern glaciology one wants to know much more about a glacier than just its length, length provides the connection with the past. In this contribution, 200 glacier length records from around the world are studied. The mean starting year of the records is 1865, the mean end year 1997. After a brief description of the nature of the data set, an overview is given of the glacier length signal from different continents. As is well known, the majority of glaciers has retreated. With the dataset the dependence of glacier retreat on factors like glacier size, mean elevation, latitude, etc. has been studied. Results of such an analysis will be discussed. Finally, the global glacier length record has been used to estimate the contribution of glaciers and small ice caps to sea level rise. The best estimate for the period 1850-2000 is 5.51 cm, which is significantly larger than assumed so far.

***Keywords:*** glaciers

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**HW1011** **Oral Presentation** **4850**

# Mass-balance modeling of Keqicar Glacier in the Tarim River Basin, Northwestern China

***Mr. Zhang Yong***
*Chinese acodemy of Sciences CAREER IAG*

***Yong Zhang, Shiyin Liu, Yongjian Ding***

The Tarim River basin, a river system formed by the convergence of nine tributaries, is the most heavily glacierized watershed in arid northwest China. In the basin there are 11665 glaciers with a total area of 19878 km2 and a volume of 2313 km3. These glaciers represent important water resources to the Tarim River Basin, contributing significantly to streamflow. With the global warming, there is a step change in both temperature and precipitation around 1986 in the Tarim River Basin, northwestern China. Under the ongoing warming and increasing in precipitation in the Tarim River Basin, however, little is known about the variation of glacier mass balance in the Tarim River Basin, northwestern China, where very few such data and studies exist. In this study, a degree-day mass-balance model is applied to Keqicar Glacier, a Turkistan glacier in the Tarim River Basin, where detailed mass-balance measurements are available for the period 2003-2005. There is a good agreement between simulated and observed variation in the mass balance with elevation over the study period. Recently, although precipitation increases, there was still a strong mass loss on Keqicar Glacier due to the dramatic warming. Over the period 1977-2005 the equilibrium line altitude (ELA) rose at a rate of 11 m a-1 on Keqicar Glacier. An experiment indicates that the debris layer covering most of ablation area exerts a considerable effect on the glacier mass balance, and protects the glacier from much more rapid mass loss.

***Keywords:*** mass balance, modeling

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**HW1011** **Oral Presentation** **4851**

# Melt water retention across the southern Greenland ice sheet

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The high focus on the fate and the climate sensitivity of the Greenland ice sheet has facilitated new research particularly in the field of climate - ice sheet interaction. One of the major unknowns regarding climate sensitivity is the fraction of melt water retention to the total melt water generation. Passive microwave brightness temperatures reveal a steady increase in surface melt area in the interior of the ice sheet, particularly the southern part of the ice sheet has experienced an increase in melt area. The present study is focusing on an east-west transect around 66 degrees north - in an area where significant melt water refreezing is occurring. We combine ice core information i.e. ice layer distribution, chemical indicators of refreezing and meteorological data from AWS for modelling of melt water generation in an effort to gain insight and possibly predict where and how in the snow pack melt water retention is taking place. We use ground penetrating radar (GPR) to interconnect the cores and spatially extend the information between the core sites. The depth and vertical distribution of refreezing in the interior is critical for the future evolution of the ice sheet because much of the climate-runoff sensitivity is related to the depth of the near-surface melt water refreezing. A scenario which favour melt water runoff from the ice sheet is to be expected under conditions with predominant preferential water flow and deep percolation of the melt water, to a depth beyond the seasonal freezing depth.

***Keywords:*** refreezing, icecores, modelling

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**HW1011** **Oral Presentation** **4852**

# Tree-ring based, Little Ice Age mass balance estimates along a subarctic to arctic transect in Alaska

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Glacier mass balance records provide an ideal means of assessing fluctuations in a glacier mass in response to both high and low frequency modes of climatic variability. In North America, however, most instrumental records of mass balance are limited to the last 40 to 50 years and provide only a narrow window of glacial behavior over an interval of pronounced warming and ablation. In this study, temperature and precipitation sensitive tree-ring series from Alaska, British Columbia, and Washington were used to provide nested, annual mass balance estimates at Taku Glacier, tidewater, southern Alaska, 1605-1983 A.D., Wolverine Glacier, land-based maritime, Gulf of Alaska, 1554-1987 A.D, and Gulkana Glacier, interior Alaska, 1559-1992 A.D. The success of these models relies on the temperature and precipitation sensitivity of the tree-ring chronologies and on teleconnection patterns in the North Pacific. Reconstructions are limited by the length of the tree-ring record and a loss of climatic sensitivity at some tree-ring sites. The three study glaciers reflect distinct climate regimes and glacier dynamics. Reconstructed mass balance estimates extend through the middle and latter portions of the LIA and highlight the role of decadal and secular-scale change in the North Pacific in forcing positive or negative mass balance regimes. The estimated mean mass balance of Gulkana Glacier is positive prior to 1910, reflecting prominent cooling throughout the LIA and negative after 1910, corresponding with secular warming over the last century. Reconstructed mean mass balance of Wolverine Glacier is positive prior to 1900, and generally negative throughout much of the 1900s with the exception of a brief recovery period related to an interval of heavy winter precipitation between 1976-1988. Four pronounced periods of positive (negative) mass balance reflect prominent glacier advances (recession) that correspond with regional tree-ring based temperature reconstructions and with PDO regime shifts in the North Pacific. Mass balance estimates for Taku glacier reflect positive mass balance regimes, but steady retreat after 1700, up until the early 1900s. Since 1900, Taku glacier has re-advanced in response to local precipitation and calving glacier dynamics. All models are consistent with dated moraine complexes, which provide a means of independent model verification. Ongoing analyses will concentrate on evaluating the role of climatic variability in the North Pacific on tidewater, maritime, and interior glaciers in the context of LIA cooling and contemporary warming.

***Keywords:*** mass balance, tree ring, alaska

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**HW1011** **Oral Presentation** **4853**

# Mass balance of Austfonna Ice cap, Svalbard

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Austfonna (8200 km2) is the largest ice cap in the Svalbard archipelago. However, there is considerable uncertainty about its current state of balance and its possible response to climate change. The geometry changes of the ice cap have been measured by airborne laser and ground-based GPS profiling in order to obtain indications of the mass changes. Repeated airborne laser profiles carried out by NASA in 1996 and 2002 indicated a clear thickening of the upper central part of the ice cap with as much as up to 3.5 m over the six year period; a change of about 0.6 m a-1, and a peripheral thinning. This indicated a positive mass balance of the ice cap. The net balance derived form shallow cores from the period 1986-1999 indicated, however, a balance close to zero of the ice cap, and a shallow ice core drilled in 2004 at the same location as the 1999 core gave the same net accumulation in 1986-2004 of 0,47 0,03 m water eq., or the same as the long term trend of the period 1963-1999. We have conducted ground-based, repeated, differential GPS profiles in 1999, 2004, 2005 and 2006. The GPS profiles indicate less pronounced thickening and less thinning compared to the NASA-profiles but confirms the general pattern of thinning in lower elevations and thickening in the interior. The GPS-profiles also show that different parts of the ice cap can develop differently and that there are large annual variations. It is, however, clear from all the different data sets that we need extensive data to be able to make reliable assessments of the mass balance, covering different parts of the ice cap in which the dynamic effect must be considered.

***Keywords:*** arctic, massbalance

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**HW1011** **Oral Presentation** **4854**

# Global glacier mass losses and mass balance sensitivities assessed from observations and gridded climate data

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***Mattias De Woul, Valentina Radic***

Glaciers have generally experienced mass loss in the last couple of decades with strongly accelerated ice wastage during the last decade. We study regional differences in mass balance sensitivities in response to climate warming with special emphasis on the Arctic and present a methodology for global assessment of glacier mass loss of all glaciers outside the ice sheets in Greenland and Antarctica during the last decades. Annual and seasonal mass balance sensitivities are computed for >100 glaciers based on calibration of a simple temperature-index regression model to observations of seasonal mass balances using ERA-40 re-analysis data as climate input. The mass balance sensitivities are then regionalized by means of a continentality index and precipitation as derived for each grid cell of the ERA-40 grid. Regional estimates of glacier mass loss are computed from regionalized mass balance sensitivities, observed temperature trends and glacier area. Results indicate that previous global assessments based on extrapolation of measured mass balances may have underestimated glacier mass loss during the last 40 years due to underestimation of high sensitivities in areas were measurements are scarce. We also compare mass loss estimates for the Arctic compared to global estimates.

***Keywords:*** mass balance, volume changes, era 40

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**HW1011** **Oral Presentation** **4855**

# Glacier changes in the Polar Urals during XX century from historical data, ASTER and Landsat

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***Glazovsky Andrey, Tsvetkov Dmitri, Osipova Galina***

Historical data on the glaciers of the Polar Urals have been collected and integrated, including data of glaciological, geodetical and photogammetrical studies of reference glaciers from 1953 to 1981. The procedure of combined application of heterogeneous historical data and multispectral imagery in visible range collected by ASTER and Landsat system has been developed using modern geoinformation technologies for quantitative assessment of the glacier dynamics in the Urals. The assessments obtained have been validated by direct field observations of reference glaciers in 2005. The field studies were held on the glaciers of Khadata massif in the Polar Urals in July-August 2005. After 25-year break in observations the dynamics of the margins and factors of accumulation and ablation have been studied on reference glaciers IGAN, MGU, Obruchev, Chernov and etc. GPS-survey allowed to build a network of reference points that will be used for geometric rectification of space images with their further transformation into cartographic projection that allows to make measurements required. For the first time the procedure developed has been used to assess the current state of the glaciers in the Polar Urals and their change in the last 50 years. Results show the general and stable trend of glacier recession in the region. The range of recession of some cirque-valley glaciers reaches 56 per cent from their area that indicates substantial rise of climatic equilibrium line in the last semi-centennial period. Analysis of meteorological conditions reveals that the summer air temperature rise by 3C in 1946-2005 is not compensated by increase of winter precipitation, and the glacier mass balance values are negative. Glacier recession proves the unfavorable combination of climatic factors for glacier health in the region.

***Keywords:*** glaciers, space images, recession

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**HW1011** **Oral Presentation** **4856**

# Variations of the Grosser Aletschgletscher

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***Matthias Huss***

The state (length, area, volume, flow velocity) and the temporal evolution of glaciers reflect ongoing climate change. Long-term glacier observations have been carried out to document glacier variations of the Grosser Aletschgletscher, the largest glacier in the Alps. Starting in the second half of the 19th century, important time-series of length variation, mass balance and volume change have been achieved. Ice volume changes of high spatial resolution were calculated by comparing two consecutive surveys of the surface topography. The mass change for four decadal periods since 1880 is the result. In order to increase to seasonal (winter and summer) temporal resolution of the mass change, a distributed temperature-index model is used. The model calculates the snow accumulation and ice melt with air-temperature and precipitation data from weather stations. The model is calibrated with the independently evaluated volume changes and verified with more than 1000 direct point-observations of the accumulation or melt and discharge measurements, collected during the last 80 years. We summarize the major glacier variations with the unique datasets of one of the best documented glacier in the Alps. The glacier lost about 55 m in mean ice thickness since 1880. The retreat of the glacier tongue did not respond on two decadal periods of mass gain. The volume is estimated of 17% of the total ice volume remaining in Switzerland.

***Keywords:*** glacier fluctuations, in situ measurements, long time serie

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**HW1011** **Oral Presentation** **4857**

# Modelling Ice Cap Evolution and Mass Balance in the Canadian Arctic Islands

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Arctic Canada is the most heavily glaciated region in the world outside of Antarctica and Greenland. The icefields of the Queen Elizabeth Islands are still adjusting to the last Pleistocene deglaciation, with responses to Holocene and recent climate variability superimposed on the longterm evolution of these icefields. To examine the recent and future changes in these icefields, we employ a modelling strategy that includes a regional-scale glacier model (ca. 4 km resolution) nested within a continental-scale ice sheet model for the Holocene period. The continental-scale model provides the initial and boundary conditions for the regional Arctic icefield model. Mass balance forcing is based on ice-core climate reconstructions from the Devon and Agassiz ice caps, along with present-day observations that relate regional climate conditions to historical mass balance data. We have found that low and variable surface-temperature lapse rates are needed to give realistic simulations of seasonal snowmelt at these sites. I present our climate downscaling strategy along with preliminary results from the Holocene simulations, with a focus on reconstructions of the present-day icefields.

***Keywords:*** holocene, ellesmereisland, downscaling

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**HW1011** **Oral Presentation** **4858**

# The effect of anisotropy in flow near an ice divide: bumps, dips and shoulders in radar layers and in near-divide surface topography

***Dr. Carlos Martin Garcia***
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***G. Hilmar Gudmundsson, Hamish Pritchard***

Polycrystalline ice within an ice sheet develops a crystal orientation fabric that leads to macroscopically anisotropic behaviour. This has been observed in several ice cores located at divides and is known to affect ice flow and therefore the shape of both isochrones and the ice surface topography. The Raymond effect also operates near ice divides, it has a strong influence on the age-depth relation in ice cores and it causes upwarping of the radar layers as a consequence of the nonlinear rheology of ice. The detailed geometry of these layers is known to produce a record of change in the cryosphere: of accumulation, of local thinning and of the age of formation of the divide. Employing a nonlinear extension of an orthotropic flow law, we study the effect of anisotropy on the operation of the Raymond effect. The detailed evolution of anisotropy and its dependence on past properties of ice remains poorly understood but by exploring simplified orientation distribution functions of the crystal fabric, several qualitative features emerge. We show that anisotropy amplifies the Raymond effect and changes the shape of the radar layers near the ice divide: the amplitude and width of the Raymond bumps are increased; dips appear in the radar layers and in the surface topography; and under certain circumstances the Raymond bumps can develop into double-rooted bumps. These features, that can only been explained by considering anisotropy or assuming unrealistic rheologies, are compared with field examples from Roosevelt Island, Fuchs Ice Piedmont, Kealy Ice Rise and Fletcher Promontory, Antarctica.

***Keywords:*** ice anisotropy, radar layers, raymond effect

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**HW1011** **Oral Presentation** **4859**

# An alternative reconstruction of ice history on Kibo, Kilimanjaro

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The age of the ice table on the summit plateau of Kibo, Kilimanjaro, was suggested to be 11,700 years and mass balance history from ice cores was assigned to the history of wet and dry periods in East Africa (Thompson et al., 2002). Yet, analyses, interpretation, and conclusions give reason to question the ice core determined mass balance and glacier history. Present day ice shrinkage on Kibo is dominated by the retreat of the steep cliffs that delimit the ice bodies on the summit plateau of the volcanic cone. Measurements and modelling suggest that these cliffs have been a persistent feature during present climate conditions and most probably throughout the entire Holocene. The steepness of the walls hinders snow to accumulate, thus, the cliffs can only retreat. The observed present day retreat rates suggest that the lifetime of the summit ice table is about 150 years and is widely independent from the mass balance of the horizontal surfaces. Only major accumulation phases can start a new glacier cycle or interrupt an ongoing one. Based on this understanding and on lake level records in East Africa, a history of the Kibo plateau ice is set against the one interpreted from the ice cores, without violating the data evidence from that. Reference: Thompson, L.G. et al., 2002. Kilimanjaro ice core records: Evidence of Holocene climate change in tropical Africa. Science, 298: 589593.

***Keywords:*** glaciers, climate, eastafrica

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**HW1011** **Oral Presentation** **4860**

# On the effects of divide migration, along-ridge flow and basal sliding on isochrones near an ice divide

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Radar layer geometry in divide areas is strongly influenced by the operation of the Raymond effect, which causes upwarping of the layers as a consequence of the nonlinear rheology of ice. The detailed geometry of these layers is known to produce a record of change in the cryosphere: of local thinning, of the age of formation of the divide, and has been surmised to provide information about lateral motion of divides. Such lateral motion can be caused by changes in flanking ice-streams, and the divide area thereby contains a record of ice-stream dynamics. It has also been suggested that large perturbation of divide position will obliterate the cumulative effects of the operation of the Raymond mechanism, leading to the disappearance of Raymond bumps. Since the Raymond effect has a strong influence on the age depth relation in ice cores, knowledge of whether its operation is localised (leading to strong bump formation) or distributed is crucial in the interpretation of ice cores.The detailed evolution of ice divide radar layer geometry remains poorly understood. Employing a full thermomechanically coupled transient model, we qualitatively explore the effect of divide migration on radar layer geometry. Certain qualitative features emerge which are compared with field examples from Roosevelt Island and Siple Dome. These can be used to infer history of cryosphere change, in particular in areas distant from the usual sites of geological dating. There remains uncertainty about the influence of sliding on the operation of the Raymond effect. Under certain conditions, the existence of sliding can damp or eliminate the operation of the Raymond effect. If this is generally true, then dating of ice divides may simply be a date for the freezing of the divide bottom. We show that sliding does not necessarily eliminate the formation of bumps, and dates of divide formation are likely to be dates for the location of the ridge at a particular spot.

***Keywords:*** radar layers, divide migration, basal sliding

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**HW1011** **Oral Presentation** **4861**

# Radio-echo sounding and ice volume changes of Ariebreen, Hornsund, Spitsbergen

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Ariebreen (Lat. 77° 01' N, Long. 15° 29' E) is a small valley glacier located at Hornsund, Spitsbergen, Svalbard. Its area, as determined from an ortophotomap based on aerial photos taken in August 1990, was 0.52 km2, while that determined from a satellite image (L1B ASTER) taken in August 2004 was 0.40 km2, showing that Ariebreen has experienced a significant retreat during the recent years. Ablation and accumulation rate measurements are underway, thus mass balance is still not determined. At the end of 2006 ablation season, the glacier was almost totally free of snow cover, even in the uppermost area. Ariebreen surface is steep and is orientated to the South. Therefore it is well exposed to solar radiation and is likely sensitive to warming. The thinning of polythermal glaciers may result in a switch to cold thermal structure under appropriate conditions. The small size of Ariebreen makes it an ideal candidate to undergo such change. In order to determine the ice thickness and internal structure of Ariebreen, and to estimate its present ice volume, we conducted in summer 2006 a radio-echo sounding survey using a 200 MHz radar. Additional profiles are planned for spring 2007. The present ice thickness map, combined with the present upper surface topography and that for 2004, 1990 and 1936 (the two latter ones determined from aerial photographs), will allow us to estimate the ice volume changes during the period from 1936 to present. The analysis of the radar profiles shows an internal structure almost absent of endoglacial diffractions, typical of cold glaciers. This is consistent with the results from geochemical analysis. Two observations support this. First, the low conductivity of water flowing out of the snout (6.5 S, August 2006), similar to the conductivity of fresh snow on the glacier (ca. 10° S) and much lower than the conductivity of water in Arielva, downstream from the glacier (ca. 50° to 70° S). Second, there is a very low concentration of radon in the outlet stream (September 2006). This suggests hardly any contact of the glacial water with the bedrock and therefore low subglacial drainage. The radar profiling did not reveal a firn layer, which is consistent with the absence of snow at the end of 2006 melting season.

***Keywords:*** radio echo sounding, volume change

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**HW1011** **Oral Presentation** **4862**

# Analytical companions of bed-to-surface transfer characteristics of various approximations to the Stokes equation used in glaciology

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***Carlos Martin, Melanie Raymond***

In glaciology various approximations to the Stokes equations are used. These include among others the shallow ice approximation (SIA), the shallow shelf approximation including basal friction (SSAf), and the incomplete second order approximation (ISO). Quantifying the differences betweenthese approximation is a non-trivial task. Here we present a comparison of these approximations based on perturbation approach. The relationship between bed and surface is determined analytically for each of these approximations for Newtonian medium. The resulting transfer functions are compared to the correct transfer functions obtained usingthe full Stoke system. We find that SSAf and ISO greatly overestimates the bed-to-surface transfer at short wavelength, while the same transferis underestimated by SIA. If fact, at short wavelengths, the transfer prediced by SSAf and BPA is unphysical. This has some important implications for surface-to-bed inversion which we explore using Bayesian inversion approach to estimate the sensitivity of bedrock retrieval to the true system state.

***Keywords:*** cryosphere, glaciers

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**HW1011** **Oral Presentation** **4863**

# Surface mass balance and area change of the northern Prince of Wales Ice-field, Ellesmere Island, Nunavut, Canada

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***David Burgess, Martin Sharp, Shawn Marshall, Fiona Cawkwell***

In April-May 2001, nine shallow boreholes were drilled across the accumulation area of the northern half of the Prince of Wales Ice-field, Ellesmere Island , ranging in elevation from 930 m to 1720 m above sea level. 137Cs g-activity profiles of each borehole showed a peak count rate at depth that is associated with fall-out from atmospheric thermonuclear weapons testing in 1963. Measurements of snow, firn and ice densities enabled the determination of average surface mass balance (SMB) at these sites over the period 1963-2001. In addition annual SMB was measured over the year 2002-2003 at thirteen sites across a northern transect of the ice-field ranging in elevation from 130 m to 2010 m above sea level. Together these data were combined to reconstruct an elevation v. SMB relationship that was used in conjunction with DEMs to extrapolate the spatial pattern of SMB across the major glacial catchments of the northern part of the ice-field. Estimates of the mean SMB for individual catchments reveal positive and negative values that are consistent with observations of changing glacier marginal positions over approximately the last four decades, based on a comparison of aerial photography from 1959 with satellite imagery from 2000. As a whole, this northern part of the ice-field has had a clearly positive surface mass balance over the last four decades. The sensitivity of these glaciers to climate change is investigated. It is concluded that a moderately warmer climate, with an ELA raised by 200m, would be required for this region to change to an overall negative surface mass balance.

***Keywords:*** glacier, mass balance, cryosphere

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**HW1011** **Oral Presentation** **4864**

# Estimating basal properties of Rutford ice stream from surface measurement: a non-linear Bayesian inversion approach

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We introduce a non-linear Bayesian inversion approach to estimate the basal properties along a flowline of Rutford ice stream, i.e bedrock topography and basal slipperiness from observations of surface topography and surfacevelocities. In Bayesian inference, the uncertainties in the data are quantified as a probability distribution and combined using Bayes theorem with a priori information about the basal properties to yield a posterior probability distribution for the model parameters, i.e the basal properties.In this work, the forward function describing the relationship between the basal properties and the observations is solved numerically with a plane-flowfinite-element model. As there exist no explicit solution for the inversion ofthis non-linear forward function, the solution of the inverse problem must be sought numerically and iteratively. Hence, the a posteriori probability distribution for the model parameters is optimized via a nonlinear Gauss-Newton procedure. The first order forward model derivatives needed for inversion are approximated by analytical linear transfer functions. This approximation is attractive as it greatly enhances the numerical efficiency of the method by sparing the time-consuming evaluation of the numerical derivatives. Inversions performed with synthetic data showed that the inversion procedure behaves correctly and converges to the correct solution. The basal properties we compute for Rutford ice stream are consistent both with the surface observations and the radar measurements of bedrock topography.

***Keywords:*** inversion, cryosphere, icestreams

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**HW1011** **Oral Presentation** **4865**

# Arctic Sea Ice Variability Revised

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At projected rates of greenhouse gas loading, the Arctic may become seasonally ice free before the end of this century. Since observations show the sea ice is quickly shrinking as the Arctic continues to warm, the transition to a seasonally free Arctic Ocean is well underway. Linkages between variability in sea ice variations and atmospheric circulation have been shown in several studies. However, these studies did not include the last several years in which the sea ice significantly retreated in summer and winter. The goal of this study is to revisit previous investigations using the most up-to-date satellite observations of Arctic sea ice (through winter 2007) and to help answer the question of how much of the current variability in Arctic ice cover can be explained by a general warming signal in the Arctic versus changes in atmospheric circulation variability, such as that represented by the NAO/AO. Our analyses focus on the months of climatological minimum (September) and maximum (March) Arctic ice cover and employ multivariate statistical techniques to identify signals that explain most of the observed variance in Arctic sea ice, as well is signals that explain the joint variance between sea ice and other relevant atmospheric fields (e.g. surface air temperatures). Results from this analysis reveal that the current shift in recent years towards widespread ice losses throughout most of the Arctic (i.e. including both the eastern and western Arctic) in summer is a result of a generalized warming signal that is now dominating over circulation. However, despite recent winters of anomalously low sea ice which are unrelated to AO variations, the magnitude and duration of winter sea ice changes have not yet been sufficient to emerge in the multivariate space/time analysis, and the AO signal continues to dominate. Nevertheless, recent winter sea ice declines appear to be driven by a generalized Arctic warming, and if the trend continues as predicted from climate model simulations, we expect this signal to emerge in the multivariate analysis in the future.

***Keywords:*** seaice, climatechange

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**HW1011** **Oral Presentation** **4866**

# Increased dynamic thinning due to the enhanced basal flow induced by surface meltwater in the Greenland ice sheet

***Dr. Wang Weili***
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***Jun Li, Jay Zwally***

The satellite altimetry measurements during the time periods of ERS (1992 -2002) and ICESat (since 2003) have shown that the ice surface averaged thinning-rate at Swiss Camp Site, near the equilibrium line in the coastal region of West Greenland, increases from 0.14 m yr-1 to 0.68 m yr-1. Recent flowline modeling study indicates that the thinning during ICESat period is due to ~35% ice dynamic response to the increased seasonal basal sliding induced by surface meltwater and this dynamic thinning-rate increases about an order of magnitude from ERS period to ICESat period. A 3-dimensional ice flow model is developed with incorporation of the seasonal basal sliding induced by the penetration of surface meltwater through ice-sheet moulins and crevasses. The surface meltwater is determined based on the satellite observed surface temperature during the time period of 1982 -2006. The model is applied to the Greenland ice sheet to estimate the dynamic thinning caused by surface meltwater enhancing basal sliding, which provides a mechanism for rapid dynamic response of the ice sheet to climate change.

***Keywords:*** dynamic thinning, greenland ice sheet, basal sliding

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**HW1011** **Oral Presentation** **4867**

# Simulating the evolution of the ice surface depression formed during the subglacial GJLP eruption, Iceland, 1996, using full stokes ice models

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***Magnus T. Gundmundsson***

The Gjlp eruption within Vatnajkull in 1996 provided a rare opportunity to study the response of a glacier to sudden changes in basal melting, including how it has adjusted its surface geometry in the period after the eruption. Basal melting during and following the eruption lead to the formation of a large depression above the subglacial eruption site. Meltwater drained continuously away from the eruption site into the Grmsvtn subglacial lake, and subsequently to the southern edge of the glacier. After the end of the 13 days long eruption, the surface depression had a volume of 1.6 km3, increasing to 2.3 km3 in June 1997 as more heat was released from the volcano. The evolution of the surface depression has been monitored by measuring surface elevation annually. These data have been used to produce topographic maps. Surface velocities of the ice around the eruption site and surface mass balance values have also been monitored. This extensive data set in combination with the existing bedrock topography was used to simulate the closing of the surface depression with time. Full Stokes, 2D ice models are used to simulate two main cross sections through the eruption site, a west-east running profile across the center of the edifice, and a profile along the main inflow area from the north. The possibility of modeling the northern part of the eruption site with a radial, 2D geometry is also investigated. The surface velocity data is used to constrain values for A, the rate factor in Glen's flow law. The main result of this study is that ice deformation and no heat flux at the base of the glacier would close the surface depression much faster than observed over the 10 years study period. Thus heat from the volcano is needed to explain the observed surface depression evolution. Heat flux values based on the numerical models will be presented.

***Keywords:*** full stokes, numerical ice models, ice volcano interaction

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**HW1011** **Oral Presentation** **4868**

# On the influence of topographic and geometric changes on modelled glacier mass balance

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Long-term records of direct glacier mass balance measurements are well established indicators of climate change, as changes in glacier geometry (advance/retreat) should result in a zero mass balance after a glacier specific response time. Continuously or increasingly non-zero mass balances indicate a constant or accelerated climatic forcing. As most mass balance measurements have been initiated for hydrological purposes, the measured values refer to the actual glacier size but ongoing geometry changes reduce the strength of the climate signal, as the same climate leads to a different mass balance for a changed geometry. The influence of topographic change on the mass balance should be considered when climate change is calculated from glacier mass balance records or vice versa.A promising tool to investigate the effects of topographic and geometric changes on mass balance are distributed mass balance models in combination with reconstructed DEMs of the former glacier surface. In order to calculate a maximum effect of the topographic and geometric change, we compare modelled mass balances for several glaciers in the Aletsch and Bernina region for a 1850 and 1985 glacier topography (both are close to steady-states). The model is based on the calculation of the energy balance at the glacier surface to fully account for topographic effects (e.g. shading) and utilizes high-resolution gridded data sets of climatic precipitation to account for its high spatial variability in the Alps. In our analysis we compare mean mass balances from four model runs: (a) todays climate with the 1850 and (b) 1985 topography as well as the climate from around 1850 with (c) the 1850 and (d) the 1985 topography.First results indicate that the observed mass balance changes are difficult to generalize. The temperature sensitivity does not change much under a changed topography (about -0.5 to -0.7 m w.e. for a 1 C increase). For an unchanged temperature all glaciers get more positive balances (+0.2 to +1.5 m w.e.) due to the geometric change from 1850 to 1985, in particular glacier parts that are now separated from a larger main glacier. For some glaciers the 1985 geometry was in balance with the 1850 temperature. Since that time temperature has increased by 1 C again and the current glacier geometries are thus out of balance. In consequence, most glaciers will continue to retreat in the future, even if temperature does not continue to rise. Mass balance reconstructions back in time will get too positive values if topographic changes are not considered, while those that include topography will get more negative mass balances for the same climate forcing.

***Keywords:*** mass balance, topography, alpine glaciers

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**HW1011** **Oral Presentation** **4869**

# Mass changes derived from satellite altimetry and firn-compaction modeling over the accumulation zone of Greenland ice sheet

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Ice sheet surface elevation changes (dH/dt) derived from satellite altimetry contain information of both short and long-term changes of the mass balance in terms of ice thickness change. Short-term elevation changes are caused by seasonal to decadal variations of surface temperature and accumulation, both of which affect the rate of firn densification. Long-term changes usually have ice dynamic causes, with the time scale typically of the order > 102-103 a, but long-term changes may be masked by the short-term changes. Estimation of mass changes from dH/dt measurements requires estimation of the dH/dt caused by variations in accumulation rate and the dH/dt from long-term dynamic changes and their associated ice densities. In this study we use satellite altimetry derived dH/dt data from ERS (1992-2002) and ICESat (2003-2006) combined with our densification model to derive the mass changes for the two periods. For two periods of 5 to 10 years length, the long-term dynamic changes should be the same. The model is driven by two decades surface air temperature (1982-2006) from AVHRR and an accumulation rate that varies according to the temperature. Using the model-produced density that is associated with increased accumulation rate, we calculated the mass change for each period. The results show that during the second period, the ice sheet received more mass in the accumulation region due to an increased accumulation rate, in addition to a long-term mass increase. These increases only partially offset the increased loss of ice from the ablation zone.

***Keywords:*** mass change, altimetry, firn compaction model

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**HW1011** **Oral Presentation** **4870**

# New aerogeophysical survey targets boundary conditions for the stability of the East Antarctic ice sheet during warm palaeoclimates

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As we enter the IPY the boundary conditions for much of the East Antarctic Ice Sheet (EAIS) still remain largely unknown. This is due to the lack of extensive geophysical exploration, in particular when compared to the more extensively surveyed West Antarctic Ice Sheet. Boundary conditions such as subglacial topography, subglacial hydrology, the distribution of subglacial sediments, heat flux, lithosphere rigidity, and tectonic features are important for ice sheet modelling, addressing the EAISs role in the global climate system and for sea-level change. This lack of information in key regions of the EAIS is a consequence of its remoteness and inaccessibility. One of these key regions is the Wilkes Subglacial Basin (WSB), in the hinterland of the partially glaciated Transantarctic Mountains. Dynamists for the EAIS have suggested that significant deglaciation of East Antarctica may have occurred during warm periods in the geological past (perhaps as late as the Pliocene), allowing for major marine incursion into the WSB region. Stabilists have argued based upon observations in the Dry Valleys block of the TAM that since ca 14 Ma there has been a relatively stable ice sheet with a polar desert climate since that time. This debate is significant since predictions for global warming suggest that the palaeoclimate conditions during these warm periods may potentially be akin to those predicted for the future. Hence determining how the EAIS reacted to past global warming is of crucial importance. Aiming at providing new boundary conditions to input into coupled-ice sheetpaleoclimate models a major aerogeophysical survey was flown over the WSB during the 2005/06 field season. This was part of a collaborative effort between the British Antarctic Survey and the Italian Antarctic Programme. Over 60,000 line km of new data were collected, including airborne radar, aeromagnetic and airborne gravity data. In this presentation we focus mainly on the airborne radar dataset. The airborne radar data provides ice thickness, bedrock configurations, ice layers and images subglacial lakes. We show for example how the new-sub-ice topography map significantly changes our initial view of the region. Deep subglacial trenches flanked by mountain blocks and plateau-like features are now revealed in the WSB region. Some of these features are similar to the sub-ice topography revealed by airborne radar data over dynamic and potentially unstable parts of the West Antarctic Ice Sheet.

***Keywords:*** antarctica, cryosphere, palaeoclimate

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**HW1011** **Oral Presentation** **4871**

# Glacier retreat on Nuussuaq Peninsula and Disko Island, West Greenland

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Mountain glaciers and local ice caps are believed to be the largest contributors of water to the current global sea level rise. Yet the knowledge of glacier retreat is very unevenly distributed. Greenland is estimated to be home to more than 20,000 glaciers outside the main ice sheet of which roughly 5,000 have previously been inventoried. However, there has been no systematic mapping of the retreat of these ice masses until now. Here we present the first step towards a new comprehensive inventory and change detection of the local glaciers and icecaps in Greenland , carried out as a part of the Global Land Ice Measurements from Space (GLIMS) project. Three concurrent Landsat 7 ETM+ scenes from August 2001, covering the Nuussuaq peninsula and most of Disko island in West Greenland , have been used to derive actual glacier extent by means of automated and well established multispectral classification (thresholded ratio images) as well as the position of Little Ice Age (LIA) moraines by manual digitizing. A considerable challenge was present due to difficulties in the discrimination between rock glaciers, push moraines and ordinary trimlines. Furthermore, the extent of the same glaciers in 1985 has been derived from aerial orthophotography, yielding more recent glacier change over the 16-year period 1985-2001. The result is a geographically comprehensive map, showing strong retreat of most glaciers since the LIA (partly exceeding 8 km) as well as a few glaciers with little change that could have surged in the past. The comparison between 1985 and 2000 displays somewhat more scattered glacier changes that could be partly due to misinterpretation of snow fields in the 1985 inventory. Standard methods have been utilized to calculate topographic glacier parameters by DEM fusion and to assess the changes in glacier length and volume, providing an estimate of their contribution to global sea level rise.

***Keywords:*** glaciers, greenland, glims

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**HW1011** **Poster presentation** **4872**

# Dynamics and mass budget of Amundsenisen, Svalbard: interpretation of surface elevation and radar data

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Amundsenisen is the large ice plateau, 80 km2 in area, located in Southern Spitsbergen. Glaciological studies at Amundsenisen were started in 1980 when the Russian and Polish scientists drilled a borehole in central part of the plateau to the depth of 583 m. In 1984 in this area the ground-based radio-echo sounding measurements were performed using a monopulse radar MPI-8 with central frequencies of 1 and 8 MHz and analog recording system. Radar studies were continued at Amundsenisen in April 2004 and April 2006 using a monopulse radar VIRL-6 with a central frequency of 20 MHz and RAMAC system with central frequency of 200 MHz. DGPS measurements were performed in 1991, 2001 and 2006. Also the following surface elevation data are available: 1990 topographic map and DEM by Kolondra and others based on aerial photographs; 1996, 2002 airborne laser altimetry ATM3 data; 2005 DGPS data along with laser altimetry tracks. The main task of these studies was to collect data on ice thickness, glacier surface elevation, bedrock topography and internal structure and bottom conditions at the ice plateau and in the upper parts of its main outlet glaciers. Data of ground-based radio-echo sounding show that Amundsenisen occupies a large depression between surrounding mountain ridges and strongly controlled by geological structure. Its ice volume is c. 27.1 km3 and the maximum measured thickness is 631 m. Mass balance of the Amundsenisen area has been measured by different methods. Stratigraphic studies at one site show that in 1989-1997 winter accumulation was in average 1.41 m w.e. a-1 and the net balance was c. 0.5 m w.e. a-1. Winter accumulation measured by high-frequency GPR in spring 2006 seems to be considerable higher than the average (bw2006 ~ 2.2 m w.e.). Nevertheless elevation data series show that during the last 16 years the majority of the Amundsenisen area was lowered due to ice discharge exceeding firn accumulation. The most pronounced decrease in thickness has been noted over Hgstebreen along the deepest subglacial valley. Surface flow velocity measured at upper reaches of Hgstebreen, Bygisen and Paierlbreen outlet glaciers which drain Amundsenisen are 7.22, 10.65 and 9.30 cm d-1 respectively (20 April-17 May, 2006). The surge of the Nornebreen-Paierlbreen system in the 1990s does not affect the Amundsenisen plateau surface so much. Possibly a threshold underneath the outlet prevented the drainage of a larger volume of ice. The ice plateau consists mainly of temperate ice, which at some places, mainly near nunataks and in the upper part of its outlet glaciers, is covered by a cold ice layer up to 250 m thick, i.e. shows polythermal structure. Internal reflecting layers at depths down to 80 m and deeper are detected at many radar profiles. They can be related to discontinuities or water-impermeable horizons in the snow-firn sequence. Reflections from flat bedrock are recorded at depths more than 500 m at four places in the central part of the plateau and in the upper part of outlet Hgstebreen. The largest flat bedrock section is 450 m long. These reflections are similar to radar reflections from subice lakes detected at many places of the Antarctic ice sheet. Judging by reflecting properties (character of fluctuation and power of reflected signals) and estimations of the hydraulic potential field, the sections of flat bed might be interpreted as reflections from near-bottom water bodies. While outlet glaciers undergo surges one can suggest that ice in the deepest part of Amundsenisen valley could be not affected by dynamic processes.

***Keywords:*** glaciology, arctic, svalbard

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**HW1011** **Poster presentation** **4873**

# New Stable Isotope Studies of Key Sections of Perennially Frozen Rocks in the Lower Reaches of the Kolyma River

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***Mauro Brilli, Paola Iacumin, Dmitry Mikhalev, Fedor Romanenko, Enricomaria Selmo***

Field studies of the Duvanny Yar section were performed in August 2004. The studied sequence is exposed in a scarp about 10 km long and up to 65 m altitude on the right side of the Kolyma River where it cuts through a surface about 70 to 100 m high heavily reworked by thermokarst. This sections are unique in Russian Arctic regions in that it has been studied by several generations of scientists and accessible for half a century. The exposure is continuously renewed due to lateral erosion of the rivers. In such a way, the third spatial component is added, while the data obtained at different years pertain to different part of the exposure. For the Duvanny Yar section the results of oxygen isotope studies performed by the authors in 1981 – 1986 have been reanalyzed and compared with newly obtained data on contents of heavy oxygen isotope (18O) and deuterium (D) in structure-forming ice and ice wedge polygons sampled and analyzed in 2004. The performed isotopic studies of perennially frozen sediments enabled climate-stratigraphic subdivision of the exposed sequence. According to our data, the basal part of the sequence was formed at pre-Kazantsevo time (MIS 6 stage?). Evidence of warm climate during one of the phases of the Karginsky (Molotkovsky, MIS 3) epoch has been obtained for the first time. Complex analysis of oxygen and hydrogen isotopes in the ice sampled in the section provided evidence of the ice wedges being formed of atmospheric water. Structure-forming ice showing massive cryostructure seems to be a product of frost desiccation of the ground during winter (isotope fractionation in a closed system). There existed an isotope exchange between the ice enclosed in organic-rich sediments and some products of the organic matter destruction; the exchange gained in intensity during warm epochs. Sections exposing perennially frozen rocks were studied also in the lower reaches of the Maly Anyui River (right tributary of the Kolyma R.) in August 2005. The so called Anyui Plain (northeastern part of the Kolyma Lowland) is composed of frozen sediments exposed in a number of sections, such as Molotkovsky Kamen', Krasivoye, Stanchikovsky Yar. Two principal geomorphic complexes are distinguished within the plain limits. Floodplains of the Kolyma and Maly Anyui are mostly not more than 6 – 12 m above the channels, with numerous "yedomas" towering over them. The latter are remnants of older surfaces 50 to 60 m above sea level composed of the Late Pleistocene "loess-ice" complex; they resulted from fluvial erosion and thermokarst. The sections have been studied for 30 – 50 years already. Noticeable changes, however, took place in permafrost and facies structure of the sections since the sections were first described. Some specialists believe this to be related to rapid thawing of the sediments and retreat of the exposure face. That being so, a third component should be taken into account – parts of the series studied in different years belonged probably to various lateral facies. Our field studies and climate-stratigraphic subdivision of the sequence based on oxygen isotope analysis of the sampled ground ices confirmed the Karginsky age (MIS 3) of the basal layers exposed in the Krasivoye and Molotkovsky Kamen' sections. Some pre-Karginsky (Zyryan, MIS 4?) sediments are found in the Stanchikovsky Yar section. The oxygen isotope data on ice wedges suggest January temperature range from -32 -34C to -45 -48C in the studied region during the Late Pleistocene – Holocene (the modern January temperature is -35C). Paleotemperatures calculated from data on texture-forming ice show a much greater range of January temperature fluctuations in the Late Pleistocene – Holocene – more than 20C. Investigations were supported by Agreement CNR – RAS and RFBR (grants 04-05-65314 & 07-05-00027).

***Keywords:*** stable isotopes, permafrost, pleistocene

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**HW1011** **Poster presentation** **4874**

# Results of ASTER and LANDSAT imagery application to the glaciated regions of Russia in the frame of GLIMS project

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***Kotlyakov Vladimir, Nosenko Gennady***

GLIMS project (Global Land Ice Measurement from Space) aims to apply the space images for glacier monitoring for 6-year period of ASTER (scanning radiometer) operation installed on the Terra orbital platform. One of the Regional Center (RC16) of the GLIMS has been established in the Institute of Geography, Russian Academy of Sciences, Moscow, and it is responsible for the glaciated areas in Russian Arctic, the Urals, the Caucasus, Siberian mountains, Kamchatka, Altay (including Mongolian part), mountains in southern Kazakhstan. Wide variety of geographical environment and glacial types allows to assess the applicability of ASTER and Landsat data for different geographical settings and glaciological tasks. More than 3000 glacier outlines for Caucasus, Pamir and Tien-Shan have been derived from ASTER and Landsat imagery and provided in a standard form for ingest into the GLIMS database. The method of join statistical analysis of glacier data derived from ASTER and Landsat images and glacier data from WGI was worked out. The area for Caucasus 1163 glaciers was calculated for the middle (based on World Glacier Inventory) and for the beginning of XXI century (ASTER and Landsat). It was found out that the glacier area decreased on 15%. For Elbrus glaciers we received 7% of decreasing. The WGI data were also compared with the data of the first Caucasus Glacier Inventory (1911y). It was found that the total area for Caucasus glaciers decreased 33,4 % from the beginning to the middle of XX century. For Elbrus glaciers we received 10% of decreasing.

***Keywords:*** glaciers, space monitoring, decrease

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**HW1011** **Poster presentation** **4875**

# Seasonal mass balance of Alpine glaciers since 1865

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Temporal glacier variations are among the clearest natural indicators of ongoing climate change. Of several key parameters on glaciers, the mass balance most clearly reflects climatic variation. In order to diffentiating between the processes responsible for the changes observed and to interpret climatic signals mass balance in seasonal resolution is required. However, there is only a limited number of mass balance records available covering a relatively short time span and often having annual resolution only. We present a method for seasonal mass balance determination combining in-situ observations of snow accumulation and melt with results from ice volume change and measurements of the runoff. The temporal evolution and the spatial distribution of the mass balance is calculated using a teperature-index melt model with an accumulation scheme. The model is forced with air temperature and precipitation and is calibrated in multi-step procedure using decadal volume changes, in-situ observations and runoff measurements. This allows the determination not only of the net balance but also winter and summer balances. Special attention is given to the correct reproduction of the balance gradients. Our approach has been tested on the four Swiss glaciers Aletsch, Gries, Rhone and Silvretta poviding complete time-series since 1865. We present results of a sensitivity study. The influence of the different data sets will be discussed. In addition, first results reveal a considerable mass loss over the last 140 years in the Alpine region. We found a reduction between 32 and 96 m mean ice thickness four the glaciers analysed. Winter balances remain virtually unchanged since 1865, whereas summer balances display significant fluctuations. We identify two decades of mass gain and two periods with accelerated ice melt.

***Keywords:*** seasonal mass balance, in situ measurements, new approach

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**HW1011** **Poster presentation** **4876**

# Surface elevation change and velocities on the tongue of a high-altitude, debris-covered Tropical glacier: Chacra Glacier, Peru.

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***Samuel Clemmens***

Recent remote-sensing and ground-based research indicates continued, probably accelerating, thinning and retreat of tropical glaciers. One distinctive characteristic of many of these glaciers is the presence of a low-angled and heavily debris-covered terminal region, often extending from the base of an icefall to the glacier terminus. Because of the unstable nature and coarse scale of the surface debris in these areas accurate, high-resolution measurements of their geometric change are rare. In this study we use ground-based survey to measure two properties of the low-angled, debris-covered tongue of Chacra Glacier, Cordillera Blanca, Peru. First, we report the results of two reflectorless surveys of the surface elevation of three areas of the glacier tongue carried out in the dry seasons of 2004 and 2005. The resulting digital elevation models are then differenced and the resulting DEMs of difference are analysed and expressed in terms of surface change. Our data indicate a mean surface lowering of up to 1.5 m per year, while this average masked significant spatial variability - both at local and glacier scale. Second, we report the results of an optical survey of the velocities of 12 stakes measured over a period of 8 days during the dry season, 2005. Here, surface velocities were found to decrease quasi-exponentially away from the ice fall (where ice moved at several centimetres per day in a consistent down-valley direction) towards the glacier terminus (where velocity fell to less than a centimeter with a less consistent orientation).

***Keywords:*** glacier, mass balance, andes

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**HW1011** **Poster presentation** **4877**

# A distinctive snow algal community on a glacier in the Tienshan Mountains, China

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***Segawa Takahiro, Li Zhongqin***

Snow algae are cold-tolerant algae growing on snow and ice and have been reported on many glaciers in the world. Their community structure spatially varies on a glacier and also geographically varies among glaciers due to chemical and/or physical conditions of snow and ice. A snow algal community was investigated on the Urumqi No.1 Glacier in the Tienshan Mountains, China, where no report on snow algae has previously been available. In the ablation (ice surface) area of the glacier, filamentous cyanobacteria were dominant and no green alga was observed. Microscopy and DNA (16SrRNA) analysis revealed that the cyanobacteria consisted of mainly three species. Such community structure differs from those on Himalayan, Altaic, and Arctic glaciers, where green algae were dominant on the ablation surface. The dominance of cyanobacteria may be caused by the higher pH of glacial melt water due to a large deposition of desert dust on the glacial surface.

***Keywords:*** algae, glacier, tienshan

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**HW1011** **Poster presentation** **4878**

# Cryosphere-atmosphere interaction and implication for surface mass balance in East Antarctica

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***Urbini Stefano, Proposito Marco, Scarchilli Claudio, Gandolfi Stefano***

Predictions concerning the future contribution of Antarctica to sea level rise have been hampered by poor knowledge of temporal and spatial variability of surface mass balance. Snow accumulation is the most direct indicator of climate and has important implications regarding the palaeoclimatic record recovered from ice cores. Snow accumulation measurements (stake-farms, ice cores, snow radar) carried out along a transect of 500 km crossing Talos Dome (East Antarctica) have been used to understand the accumulation signal and the representativeness of ice core records. Snow accumulation results from precipitation in the form of snow, which is then modified by surface sublimation, erosion/deposition due to divergence/convergence of snowdrift transport and sublimation of drifting-snow particles (wind-driven sublimation). Sublimation (wind-driven and surface) removes mass from the surface, whereas erosion/deposition transports snow from one place to another. Spatial variations in accumulation are very well correlated with surface slope change along wind direction and could reach more than 200 kgm-2yr-1 within one kilometer. Wind-driven processes are very important and can sublimate and export huge quantities of snow into the atmosphere and then into the ocean. Wind-driven processes are not negligible in surface mass balance studies. Wind ablation driven by slope along the wind direction is very significant in terms of past and future surface mass balance evaluations. It must be taken into account in atmospheric models and when present surface mass balances are compared with precipitation from atmospheric models.

***Keywords:*** surface mass balance, temporal snow accumulation, east antarctica

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**HW1011** **Poster presentation** **4879**

# Percolation of surface melt at the equilibrium line of the Greenland Ice Sheet

***Dr. Ginny Catania***
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***Thomas Neumann***

Surface melting on the Greenland Ice Sheet is extending further inland with each new observation set. Water available on the surface of the ice sheet can either collect in lakes and streams and/or drain through the ice sheet. In the marginal areas, drainage is likely dominated by moulins that provide local water input to the subglacial water system. Upstream of moulin areas, percolation may also be important. We present evidence of percolation of water through nearly half the ice thickness at Swiss Camp, Greenland over a ten-day period during which a melt event occurred. The speed of percolation can only be explained by hydraulically connected fractures which can quickly transport water to the observed depths. Such fractures have been seen on other glaciers by (Fountain et al., 2005) who propose that they eventually evolve into the tubular conduit system that is characteristic of the englacial water system.

***Keywords:*** greenland, ablation, ice

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**HW1011** **Poster presentation** **4880**

# Climate sensitivity of Gran Campo Nevado Ice Cap, Patagonia, and mass balance variations in past and future

***Mr. Marco Moeller***
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***Christoph Schneider***

A degree-day model (DDM) for surface mass balance (SMB) has been applied to derive the sensitivity of Gran Campo Nevado Ice Cap (GCN), southwest Patagonia (Chile), to climate change. AWS data of 6 continuous years (2000-2005) served as input for computing seasonal sensitivity matrices according to Oerlemans and Reichert (2000). This method highlights the impact of changes in temperature and precipitation regimes on surface mass balance in terms of monthly values. Results for the whole ice cap show an pronounced temperature sensitivity during the summer season with values up to 0.28 m w.e. K-1 and a balanced precipitation sensitivity of approximately +0.03 m w.e. K-1 in the course of the year. As surface mass balance sensitivity depends on meteorological variables, the variation of the sensitivity matrix was computed for different altitudes. Results indicate a general increase of temperature sensitivity during the summer season combined with an overall decrease with altitude. Outside the accumulation season this spatial and temporal pattern is superposed by an enhancement of the temperature sensitivity at the snow line. From spring on maximum values of temperature sensitivity show an increase in magnitude and a rise in altitude to about 0.5 m w.e. K-1 at around 600 m a.s.l. in late summer. Regarding precipitation sensitivity a similar pattern with distinctly reduced values was obtained. Within the course of the year maximum values of precipitation sensitivity occur in the uppermost parts of the ice cap throughout the year and in late summer at the snow line altitude. From early spring until late summer the local maximum moves upward from 400 to 700 m a.s.l. and increases to more than +0.06 m w.e. K-1 in late summer. The sensitivity matrix of GCN was used to reconstruct the surface mass balance according to Oerlemans (2001) based on monthly means of air temperature and precipitation derived from NCEP/NCAR reanalysis data. The correlation between the SMB derived with this method and the output of the DDM for the calibration time period (2000-2005) exceeds r = 0.9. Subsequently, a SMB time series starting in 1950 was reconstructed using this method. Following the different climate change scenarios presented by the IPCC Fourth Assessment Report, a second SMB time series until 2100 including lower und upper limits of probable future SMB variations was modelled according to data from several different GCM runs. To avoid increasing underestimation of SMB values in the future the ongoing retreat of the outlet glaciers of GCN due to climate forcing was taken into account for SMB time series modelling. A distinctly negative trend of SMB values reaching from over +1000 mm w.e. per year in the middle of the 20th century to between -1400 and -2100 mm w.e. at the end of the 21th century was obtained. References: Oerlemans, J., 2001: Glaciers and climate change. Balkema Publishers, Lisse, Tokyo. Oerlemans, J., Reichert, B.K., 2000: Relating glacier mass balance to meteorological data by using seasonal sensitivity characteristic. J. Glaciol. 46, 1-6.

***Keywords:*** patagonia, climate sensitivity, mass balance time series

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**HW1011** **Poster presentation** **4881**

# West Antarctic ice shelf sidewall attrition processes

***Mrs. Katherine Leonard***

***Stanley S. Jacobs***

Small-scale attrition of ice shelf fronts may constitute a significant component of the WAIS mass balance. Ablation of the subaerial portion of ice fronts, largely comprised of snow and firn, can occur by gravitational failure in response to unknown melt rates below the waterline. Recent observations of ice shelf and iceberg sidewall ablation in the SE Pacific sector, however, show that "avalanching" of large snow/firn slabs can also maintain the characteristic near-vertical ice fronts. Avalanching also appears to be correlated with wind direction, whereby increased snow loading of sidewall surface irregularities accompanies off-shelf aeolian snow transport. Conchoidal fracture surfaces are prevalent on ice fronts where avalanche-like processes were observed. Ice front orientation with respect to the local prevailing wind direction may influence morphology and ablation, with wind-parallel ice fronts showing less evidence of recent avalanche-like failure. Those ice fronts are frequently topped by well-developed cornices of snow overhanging the sidewall, inhibiting the snow-loading and subsequent avalanching of surface irregularities lower on the wall. Ice shelf surfaces that slope gradually toward the ice front, and the lack of wave-cut features at sea level, suggest an isostatic response to melting below the waterline. Curved and corniced ice shelves often display crevasses that will be a factor in episodic failure and calving events. This presentation will be illustrated by ice front photographs taken earlier this year in the Ross and Amundsen Seas.

***Keywords:*** iceshelves, antarctica, glaciology

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**HW1011** **Poster presentation** **4882**

# A volume inventory of austrian glaciers: test of methods

***Dr. Andrea Fischer***
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***Norbert Span, Michael Kuhn***

Ice volume data is essential for the interpretation of changes in volume and glacier area resulting from an adjustment to altered climatic conditions. Knowledge of glacier ice thickness allows the development of future scenarios of ice covered areas and runoff scenarios under different climatic conditions. Between 1995 and 2006, the ice thickness of 50 of 896 Austrian glaciers was measured with the Narod-GPR system operating at a centre frequency of 6.5 MHz. 97,3 km of the total Austrian glacier area of 470 km is included in this data set, among them 26 of the 31 largest glaciers. The sample consists of glaciers with areas between 17 and 0.4 km. The data base includes glaciers of all sizes, types and aspects and will be used for the compilation a volume inventory of all Austrian glaciers. For the development of a best method for the calculation of glacier volumes from ice thickness data, several case studies were carried out on Schaufelferner (Stubai Alps, ), where ice thickness was measured in a very dense grid. These case studies enable us to estimate the accuracy of glacier volumes derived from ice thickness measurements. The relation between measurement density and accuracy of calculated glacier volume was investigated. A series from ice thickness measurements during the year on the same location of Schaufelferner was carried out to investigate the effect of seasonal changes in surface properties on reliability of the ice thickness measurements. Along one profile in the ablation area of Schaufelferner, ice thickness data measured with the NAROD-Sensor at 6.5 MHz and a GSSI SIR 2000 System with 35 MHz are compared to investigate the effect of the wavelength used.

***Keywords:*** glacier, ice volume, gpr

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**HW1011** **Poster presentation** **4883**

# Ablation on the Taylor Glacier, Antarctica

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***Kurt Cuffey***

We present four years of ablation measurements from the Taylor Glacier, Antarctica. The Taylor Glacier is a polar glacier where sublimation is the dominant mass-loss process for most of the glacier. There is also some melt and runoff close to the terminus of the glacier, below our study area. Along with the ablation measurements, we present a model for ablation that uses weather station data as input. The weather station data comes from six weather stations that we set up on and near the glacier. The model calculates the latent heat flux which is then used to predict evaporation and sublimation of ice from the glacier. The model agrees with the measurements to within the measurement uncertainties. Implications of the modeling study for the past and future mass balance of the Taylor Glacier will also be discussed.

***Keywords:*** glacier, antarctica, ablation

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**HW1011** **Poster presentation** **4884**

# Estimating glacier changes in the Cordillera Blanca, Peruvian Andes at decadal scales using remote sensing, GIS methods and field-based measurements

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***Yves Arnaud, Mark W.Williams***

There is a paucity of field-based glacier measurements in the high Andes due to the difficulty of conducting field campaigns in rugged terrain and lack of logistical support. This limits our understanding of the temporal and spatial patterns of glacier dynamics and the sensitivity of glaciers to climate variability. Changes in glacial extent over time are often conducted by comparing historical aerial photography with recent remote sensing imagery. However, several problems are often encountered: old inventories from aerial photography often lack metadata and quality control; processing methods used to derive glacier outlines from satellite images are not standardized, leading to inconsistencies in the various datasets; previous glacier datasets are not in public domain. There is urgency in developing and testing new remote sensing tools to produce extensive, quality-controlled glacier datasets from this data-sparse region of the world.Here we investigate changes in glacier parameters (area, elevation and mass-balance)for Cordillera Blanca of Peru (830 S, 77W) and their connections with short-term climate variability. We used data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Systme Probatoire d'Observation de la Terre (SPOT) sensors, old inventories from 1962/1970 aerial photography, field mass balance measurements and meteorological observations. We produced a new set of glacier outlines from 2003 SPOT5 scenes and ingested it in the GLIMS Glacier Database at the National Snow and Ice Data Center (NSIDC), Boulder. Various remote sensing techniques were employed to derive changes in glacier parameters: 1) volumetric changes using DEMs on a pixel by pixel basis on a decadal time scale, 2) the AAR/ELA method to calculate yearly mass balances, and 3) glacier outline delineation, including mapping of debris-covered ice. At the basin scale, we compared glaciers from 2003 with the ones from 1962-1970 to derive detailed glacier statistics and changes in glacier area. We computed volumetric changes for selected glaciers by comparing elevations from an ASTERderived DEM and an older DEM constructed from topographic maps on a pixel-by-pixel basis. We obtained specific mass-balance estimates using the AAR/ELA method and we validated those using field-based measurements at selected sites. We linked these observed changes in glacier parameters with climate fluctuations at the mountain range scale by examining temperature and precipitation records.

***Keywords:*** andes, glaciers, remote sensing

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**HW1011** **Poster presentation** **4885**

# Algal biovolume in FIRN/ICE cores of the Chilean Lake District

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Firn/ice core analysis in temperate glaciers is complex due to meltwater percolation which results in strong mixing of chemical species and stable isotopes, effectively masking the seasonal/annual signals. Due to their larger size, microalgae are less affected by water percolation, as is shown by existing studies in glaciers of the Himalayas, North America and Patagonia. Microalgae growth occurs at the glacier surface during the melt season (spring-summer), when dissolved nutrients and light are maximum, and decay with the onset of autumn, when the glacier surface layer freezes and starts to be covered by a thick layer of several metres of seasonal snow, preventing microalgae growth. Microalgal biovolume is thus a potentially successful method for determining climate proxy records in temperate glaciers. Here we describe the first study to analyse algal biovolume in glaciers of the Chilean lake district (40-41S). Three firn/ice cores were collected: one at the summit of the glacier at Volcn Osorno (2652 m a.s.l.) and two at the glacier of Volcn Mocho-Choshuenco (one in the accumulation area at 2000 m a.s.l. and one at the summit at 2422 m a.s.l.). All cores were drilled during late spring, in November of 2005. The results show clear seasonal signals of algal biovolume and pollen abundance, allowing to estimate the annual mass balance. Protozoa (Tecameba Trinema spp.) were found in the cores as well, which enhances the seasonal interpretation obtained by means of microalgae and pollen. Results of chemical species are also presented, as well as basic physical parameters of firn density and concentration of ice lenses. This study confirms the potential of biological species as paleoindicators of environmental and climatic conditions.

***Keywords:*** microalgae, chilean lake district, firn ice cores

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**HW1011** **Poster presentation** **4886**

# Identification of culturable yeasts isolated from subglacial sediments, ice and melt waters of two italian alpine glaciers

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Viable yeasts were isolated from unfrozen subglacial sediments collected from two glaciers of the Italian Alps (Forni and Sforzellina - Ortles-Cevedale group). From 1.6 x 102 to 8.3 x 103 CFU/g of psychrophilic + psychrotolerant yeasts were counted. The number of filamentous fungi was similar (from 6.6 x 102 to 1.7 x 103 CFU/g), while that of bacteria culturable at 4C was somewhat higher (from 1.9 x 105 to 5.7 x 105 CFU/g). Significant variations in cell concentrations ($P < 0.01$) were observed among the different sampling sites. Ice and melt waters were also sampled. From 0.11 to 0.56 CFU/g and about 1 CFU/g of psychrophilic + psychrotolerant yeasts were counted in ice and melt waters, respectively. Isolated yeasts were identified by using MSP-PCR fingerprinting and 26S rDNA sequencing of the D1/D2 region. Strains were identified as belonging to the species Aureobasidium pullulans, Cryptococcus gilvescens, Cryptococcus saitoi, Cryptococcus terricolus, Leucosporidium antarcticum, Mrakia sp., Rhodotorula sp. Rhodotorula bacarum, and Rhodotorula laryngis. A significant part of isolated yeasts exhibited extracellular enzymatic activities (starch-degrading, lipase, esterase, protease, and pectinase activity). Previous investigations have demonstrated the presence of various bacterial populations in unfrozen subglacial sediments (heterotrophs, nitrate or sulphate reducers and methanogens) (Sharp et al., 1999; Skidmore et al., 2000; Foght et al., 2004). The results of this study suggest that the subglacial environment could harbour viable populations of yeasts which are predominantly aerobic. This seems to be consistent with a previous study (Skidmore et al., 2000) reporting that aerobic microbial growth can occur beneath glaciers. The heterotrophic metabolism of yeasts and their ability to degrade organic macromolecules could suggest their potential role in metabolising organic carbon and nitrogen. References Foght J, Aislabie J, Turner S, Brown CE, Ryburn J, Saul DJ, Lawson W. 2004. Culturable bacteria in subglacial sediments and ice from two southern hemisphere glaciers. Microbial Ecol, 47: 329-340. Sharp MJ, Parkes J, Cragg B, Fairchild IJ, Lamb H, Tranter M. 1999. Widespread bacterial populations at glacier beds and their relationships to rock weathering and carbon cycling. Geology 27: 107-110. Skidmore ML, Foght JM, Sharp MJ. 2000. Microbial life beneath a high arctic glacier. Appl Environm Microbiol, 66: 3214-3220.

***Keywords:*** yeasts, glaciers

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**HW1011** **Poster presentation** **4887**

# Near-surface density profiles in the firn of Hintereisferner 1964-2002

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From a data set of firn pits in the accumulation area of Hintereisferner in the years 1964 2002 the behavior of density and water equivalent was analyzed with a view to estimating the potential errors in the application of the geodetic method. Since annual specific balance ranged from 100 to 3300 mm w.e. the profiles were scaled to total depth. For the uppermost 10% of the annual deposit at a typical location the 1964-2002 mean density would be 350 kg/m-3 with a standard deviation of 110 kg/m-3; for the 10% layer at the base of the annual snowpack the respective figures are 510 +- 30 kg/m-3. The normalized long term means of an ensemble of 9 pits ranged from 310 to 380 kg/m-3 in the top layer and from 510 to 540 kg/m-3 in the bottom layer . When one outlier is removed the the range in the bottom layer reduces to 525 to 540 kg/m-3. This small local variance encourages the use of the geodetic method.

***Keywords:*** firndensity, densityprofiles, geodeticmethod

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**HW1011** **Poster presentation** **4888**

# Dangerous lakes in Kyrgyzstan - case study Petrov Lake (Tien-Shan)

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Global climate warming causes an intensive melting and retreat of glaciers in the majority of high mountains all over the world. This process is evident also in mountain regions of central Tien - Shan. Melting water of glaciers influences changes in hydrological regime of water streams and causes overfilling of high mountain lakes basins. Dams of many lakes are very unstable and they often burst open. To determine the degree of this risk, it is necessary to analyse the genesis of lakes, to characterize the morphology of lake basins and to know the particularities of their hydrological regime. In the mountain regions of there are now some 1500 lakes with an area of more than 0.01 km2. The dams of many lakes are extremely unstable and various natural processes cause their destruction. The lakes which pose the greatest threat in the area are under imminent risk of rupture and such event would have long reaching consequences for both population and property. According to our research, there are now in Kyrgyzstan 302 perilous lakes, out of which 15 are at risk of rupture. Petrov Lake is located in the foreground of the Petrov Glacier which is situated on the north-western slope of Ak-Sijrak massive in southern Tien-Shan. This hollow glacier is 69,8 km large and 23 km long and is the largest glacier in the whole River Naryn catchment. In front of the retreating glacier the process of lake broadening takes place. The lake takes concurrently share on the speeding up the process of the glacier thaw. In last 30 years the Petrov Lake enlarged in area by 1,5time while in recent years its area has been increasing by more than 6 ha per year! Enlarging of the lake size and volume together with weakening of moraine stability causes an extremely dangerous situation which could result in a large-scale natural catastrophe. In the case of the moraine rupture the storage facility of highly toxic waste on the territory of the gold mine Kumtor, which is operated by one canadian private company, could be washed out. In such case the toxic waste would contaminate a large area in the River Naryn catchment including two big dams and could get into the territory of adjacent Uzbekistan.

***Keywords:*** global climate warming, risk of rupture, petrov lake

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**HW1011** **Poster presentation** **4889**

# The evolution of Lys Glacier (Mount Rosa Group, Italy) over the past 30 years through indirect analysis and field measurements

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This contribution focuses on the recent (last 30 years) evolution of Lys Glacier (Mount Rosa group, Italy) derived from historical maps, remote sensing measurements and field investigations. Historical cartography (1975, 1991 and 1994 maps) was processed by GIS and DEMs were calculated; in addition 2003 aerial photographs were analysed to obtain an orthophoto and a DEM to be compared with the others from cartography. Furthermore a DGPS field campaign was performed in summer 2005 to collect data for calculating a DEM representative of the glacier tongue geometry. The whole glacier volume and area changes from 1975 up to 2003 were calculated (for the glacier tongue only the changes up to 2005 were evaluated) and their accuracy was evaluated as well. To investigate the glacier evolution, especially the recent behaviour of its tongue (it is being covered by debris), TIR information from remote sensed data were also analysed and the supraglacial temperature was evaluated. In addition during the summer seasons 2005 and 2006 field investigations were performed to measure surface debris temperature and buried and bare ice ablation rate. The field data integrated with the remote sensed ones permitted to develop an ablation model which was applied to reconstruct glacier mass balances over the past thirty years resulted in agreement with the volume changes obtained through indirect measurements.

***Keywords:*** alps, glacier shrinkage, debris covered glacier

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**HW1011** **Poster presentation** **4890**

# Analysis of micro-meteorological records (2001-2006) from Storbreen and Midtdalsbreen, two glaciers in southern Norway

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We compared two 5 year meteorological records obtained from automatic weather stations (AWS) located in the ablation zones of Storbreen (1580 m a.s.l.) and Midtdalsbreen (1450 m a.s.l.), two glaciers in southern Norway. Storbreen is located further inland and experiences a more continental climate than Midtdalsbreen. The meteorological data cover the period September 2001-September 2006 and have been recorded by two identical AWS operated by the IMAU, Utrecht University, the Netherlands. Measured variables are incoming and reflected solar radiation, incoming and outgoing longwave radiation, air temperature, relative humidity, air pressure, wind speed and wind direction. In addition, surface height change is monitored. Values are stored every 30 minutes, which enabled a detailed calculation of the surface energy balance. The most striking difference between the two locations is that wind speed is a factor 1.75 larger on Midtdalsbreen, which means that also the turbulent fluxes are larger. During the melt season, the average net longwave radiation is less negative on Storbreen, although the difference is small (5 Wm-2). Net shortwave radiation is 20% larger on Midtdalsbreen and mainly a reflection of larger incoming solar radiation. This could be a result of less frequent or less thick clouds. For both locations, approximately 60% of the surface energy flux is determined by net radiation, while turbulent fluxes account for the remaining 40%. The total surface energy flux during the melt season is a factor 1.5 larger for Midtdalsbreen. As winter snow depth at the two locations is comparable, the larger surface energy flux results in an earlier disappearance of the snow pack on Midtdalsbreen and more ice melt than on Storbreen.The warmest summers in the record are 2002 and 2006, resulting in maximum surface energy fluxes. The summer of 2004 has the lowest mean surface energy flux, which can be attributed to relatively low air temperatures and wind speeds.The interannual variability of the net mass balance at the AWS locations is found not to be solely determined by variations in the summer energy flux, but to be also dependent on the maximum winter snow depth.

***Keywords:*** glacier, micro meteorology, energy balance

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**HW1011** **Poster presentation** **4891**

# The glims glacier database: successes and challenges

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***Khalsa, S.J.S., Helm, Christopher, Armstrong, R.***

The Global Land Ice Measurement from Space (GLIMS) project is acooperative effort of over sixty institutions world-wide with the goalof inventorying and monitoring a majority of the world's estimated 160000 glaciers. Each GLIMS institution oversees the analysis of satelliteimagery for a particular region containing glacier ice. Data received bythe GLIMS team at the National Snow and Ice Data Center (NSIDC) inBoulder, Colorado are inserted into a geospatial database and madeavailable via a web site featuring an interactive map, text-basedinterface, and a Web-Mapping Service (WMS). The GLIMS Glacier Databasenow contains outlines of over 56 000 glaciers on all continents havingglacial ice except Africa.As submissions to the database from all over the world have increased,we find that we must accommodate a greater diversity in the characterand quality of the data submitted than originally anticipated. SinceGLIMS began as an ASTER Science Team project, we envisioned that imageryfrom ASTER would be the primary data source. The glacier outlines thatGLIMS is receiving come from many different institutions, produced usinga variety of tools and derived from a variety of sources. Satelliteimagery from SPOT and Landsat, in addition to ASTER, has been used.Also, we have accepted outlines based on maps, primarily derived fromaerial photography. These map-derived outlines provide a context forcurrent satellite-based assessments.Often submissions lack required metadata, or in some other way do not fullyconform to the GLIMS data transfer specification. The GLIMS projectcreated GLIMSView, a tool for generating digital outlines of glaciers fromimagery, to assist in this process. GLIMSView exports results of glacieranalysis into a format that is suitable for direct ingest into thedatabase.Other problems encountered include incorrect geolocation of thesubmitted data, which is sometimes subtle, sometimes gross. Another sourceof problems is different interpretations of what constitutes a glacier.Comparative image analysis experiments have revealed quantitativemeasurements of variability of analysis results. An illustrated manual andtutorial, produced by the GLIMS project, should help with these sorts ofproblems.Our presentation will provide an overview of the current glacier outlineinventory, and will then examine selected regions in some detail tohighlight issues of coverage, data quality, and the capacity to detecttemporal change. Glacier systems in Alaska, Chile, Scandinavia and theHimalaya are among those examined. Supplementary data such as elevationmodels and additional satellite imagery are used to perform theseassessments. While GLIMS has made substantial progress in building thisdatabase, much remains to be done. We will conclude by discussingquality-control measures we have put in place, as well as the tools andprocedures available for contributing to this project.

***Keywords:*** glims, glaciers, remote sensing

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**HW1011** **Poster presentation** **4892**

# GLIMS application: glacier hazards, evolution, and satellite monitoring

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***Roberto Furfaro***

Glaciers normally melt as part of their accumulation/flow/ablation cycle. Whether due to global warming or not, lakes are normal components of many glaciers. Lakes form in contact with glacier ice when meltwater drainage is impeded by the glacier itself or rock debris on/in the glacier (ice marginal, subglacial, and supraglacial lakes) or by moraines, landslides, bedrock basins, or other glaciers. If the glacier is well incised by crevasses and moulins and if surficial or ice-marginal basins do not exist, or if dams are penetrated by drainage conduits, then meltwater and rainwater runoff freely exits the glacier, and lakes do not form. Steep surface slopes and high dynamical activity of glaciers favor efficient drainage, whereas low valley gradients, ice stagnation, glacier tributary detachment, high erosion rates and abundant sediment supply (especially if containing both coarse and blocky and fine-grained components), and formation of high moraines can favor lake formation.Glacier lakes are among the most dynamically unstable type of lake on Earth. This is because the damming material is usually unconsolidated debris near angle of repose; or ice that can melt (and undergo runaway melting due to preferential absorption of sunlight and/or release of gravitational potential energy along meltable conduit walls); ice that can be lifted buoyantly; or ice that is in motion due to both ductile and brittle deformation. Transient increases in heating and/or water generation can exceed drainage capacity and cause lakes to overflow. Ice thinning, seismicity, geothermal or volcanic activity, moraine collapse, supraglacial landslides, unplugging of debris-clogged moulins or crevasses, or thermal incision of drainageways through glaciers or ice-cored moraines can initiate drainage. Multiple aggravating factors commonly are linked. Many lakes form and drain seasonally or episodically. Remote sensing monitoring can be used to track the areal extent of lakes; the height of dams; glacier activity (e.g., length changes, flow speed, surging, and crevasse formation) related to lake formation and drainage; glacier tributary detachments; the temperature of glacier and lake surfaces; surface coverage by dry or wet snow, glacier ice, debris, and water; the abundances of icebergs; lake turbidity; and the area of water in proglacial drainages. Remote sensing data can be assessed for outburst flood potential with the aid of empirical records of past glacier/lake behavior; satellite image classification (hard and soft classifications) of surface materials on glaciers; analytical sedimentological and hydrological models of ice flow, debris flows, water runoff, lakes, and water turbidity; climate records and models; and statistical or fuzzy-logic-based assessments of multiple datasets relating to aggravating factors. We will present a scheme for remote sensing assessment of the future formation, disappearance, or evolution of lakes; future development or disappearance of unstable ice masses; the probability of glacier lake outburst floods, debris flows, and ice avalanches; and glacier hazard monitoring. The historic record of glacier disasters and other dynamical events is a valuable guide, but the past is definitely not the key to the present and future, because the dynamical regimes of glaciers are changing. In some regions, such as Peru (the Andes), glacier hazards will progressively diminish in general, as glaciers waste and damming moraines either are breached (thus rendering them less effective for future breakouts) or prove their robustness. In other regions, such as the Chugach Range in Alaska and parts of the Himalaya, tributary detachment type lakes and supraglacial lakes will sequentially form, grow, and disappear, and with their evolution the hazards they present will also evolve. Changing glacier profiles will force shifts in dynamical instabilities, such as increases or decreases in the propensity of glaciers to surge. Debutressing of hanging glaciers caused by recession of valley glacier tongues, and destabilization of cirque glaciers by warming-induced bed thaw will cause hazards due to ice avalanches

and associated debris flows to increase in some areas, such as glaciated ranges in Alaska and the Himalaya and New Zealand, whereas in the Cascades and most of the Andes, this type of hazard will diminish over time as their glaciers disappear. Engineered mitigation schemes can reduce the dangers in some areas for some types of potential disasters, but will be ineffective against other types of hazards. Sensible development plans should take into account the changing nature of hazards in each region and on a glacier-by-glacier, village-by-village basis. Planning should consider the past record of potentially dangerous events, but should also consider the effects of similar past events on encroaching populations and infrastructure. Assessments of future hazards shoud consider not just the effects of monotonic climate change, but the roles of extreme weather events, decadal oscillations in regional climate, and decadal to millennial glacier dynamical instabilities of a nonclimatic nature. The surge/waste cycle and climate-related changes of it are of special concern for planning of major infrastructure, such as pipelines, since it may appear that a glacier is wasting monotonically, but in fact that may be part of a cycle to be followed by a rapid advance. This work is an applied research thrust for GLIMS (Global Land Ice Measurements from Space).

***Keywords:*** glacier, hazard, glims

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**HW1011** **Poster presentation** **4893**

# Snow-Ice-Soil radiative transfer MODel (SISMOD) for optical simulation of complex snow/ice/soil mixtures of glaciers

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Mapping and monitoring glaciers and changes in their extent; in seasonal and long-term evolution of snowline and equilibrium line elevations; and in surface coverage by debris, coarse-grained ice, snow, and meltwater are key parts of an effective glacier monitoring program, such as GLIMS (Global Land Ice Measurements from Space). Satellite multispectral remote sensing is indispensable for effective glacier monitoring. Reflectance modeling provides a link between (1) spectral data collected in laboratory, (2) field spectroscopic measurements, (3) space-based multispectral imaging, and (4) interpretation of imagery in terms of glacier dynamics. For example models can be used to test the relationships between ice grain size and orientation and the spectral response of glaciers; the content of fine debris and bubbles in ice; the coverage by coarse debris and meltwater; and the linkages of these factors with glacier dynamics. We have developed a new radiative transfer tool called Snow-Ice-Soil radiative transfer MODel, or SISMOD, which has been conceived to simulate the transport of wavelength-dependent photons in glacier structures composed of pure or intimately intermixed combinations of snow, ice and soil/rock. The basic modeling approach relies on first principles (i.e. conservation of photons moving through a granular medium) to describe the basic physics behind the interaction between light and glaciers. SISMOD has been implemented by designing an algorithm capable of numerically solving the linearized Boltzmann equation using the Analytical Discrete Ordinate (ADO) method in combination with accelerating techniques for fast and accurate computation of the basic radiometric parameters used to characterize the glacier optical behavior. The modeler interfaces with SISMOD by directly specifying the basic glacier composition in terms of ice, snow and soil percentage as well as by directly defining the soil particle distribution, ice/snow grain size, shape and orientation and mixing mode. The latter allows the users to define the mixing between the various components. For example, for a single glacier simulation, SISMOD can compute the mixture reflectance assuming that the glacier is composed of patches of pure soil, ice and snow (percentage of covered area) or the model can assume intimate mixture across the observed area. SISMOD also can simulate multi-slab configurations of the basic components (e.g. thin ice or snow on top of rock), providing enough flexibility to simulate complex scenarios. The model is useful in investigating the effects of grain size, orientation and type on the Bidirectional Reflectance Factor (BRF) as a function of the incident and observed radiation. Finally, SISMOD can be the basis of a physical-based inversion algorithm capable of retrieving glacier structural and biochemical parameters using remote sensing observation. The SISMOD algorithm will be tested against radiative transfer benchmarks and simulations of glacier-like mixtures. Basic and more advanced simulations will be presented to show the potential of the methodology.

***Keywords:*** remote sensing, radiative transfer, ice snow soil mixtures

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**HW1011** **Poster presentation** **4894**

# Modelling historical and recent mass loss of a polythermal Arctic glacier (McCall Glacier, Alaska)

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Volume loss of valley glaciers is now considered to be a significant contribution to sea level rise. Understanding and identifying the processes involved in accelerated mass loss are necessary to determine their impact on the global system. Here we present results from a series of model experiments with a higher-order thermomechanically-coupled flowline model (Pattyn, 2002; Pattyn et al., 2005). Boundary conditions to the model are parameterisations of surface mass balance according to observations, geothermal heating, observed surface and 10m ice depth temperatures. The time-dependent experiments aim at simulating the glacier retreat from its LIA expansion to present according to different scenarios and model parameters. Model output was validated against measurements of ice velocity, ice surface elevation and terminus position at different stages. Results demonstrate that a key factor in determining the glacier retreat history is the importance of internal accumulation (>50%) in the total surface mass balance. The persistence of a basal temperate zone characteristic for this polythermal glacier depends largely on its contribution. Accelerated glacier retreat since the early nineties seems directly related to the increase in ELA and the sudden reduction inAAR due to the fact that the Lower Cirque previously an important accumulation area became part of the ablation zone.

***Keywords:*** glaciology, modelling, arctic

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**HW1011** **Poster presentation** **4895**

# DEgradation processes of glaciation in caves of Lake Baikal

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Lake Baikal is the pearl of Asia. 14 caves with snow and ice formations are situated here. Ice cave observations are carried out from 1976 to 2006. In the karstic cavities congelation, sublimation and deposited and metamorphosed ice is explored. From 1977 to 1997 the observations of dynamics of perennial ice were accomplished in cave Iya: in November 1977 the area of the aufeise-layer was 226 m2 with depth from 1.5 to 2.5-2.8 m; in July 1993 its size have decreased to 6.9 m2 with ice depth from 6 to 88 cm, in July 1996 to 1.5 m2 and maximum ice depth 7-8 cm. Complete melt of aufeise-layer was registered in July 1997. Observations of ice formations melting in both Baidinskaya and Mechta Caves were marked. During last ten years the average intensity of melting was reached 12 cm per year in Bolshaya Baidinskaya Cave, 1.7 cm per year in Malaya Baidinskaya Cave and 3.2 cm per year in Mechta Cave. A comparison of the dynamics of cave glaciation and trends of annual average temperatures by meteorological stations Irkutsk-observatory (1882-2005) and Uzur (1952-2005) allow to reveal the relation between the parameters considered.

***Keywords:*** degradation processes, cave ice, lake baikal

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**HW1011** **Poster presentation** **4896**

# Updated inventory and recent variations of glaciers at the Aconcagua basin, Central Chile

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***Andres Rivera, Cesar Acua, Gino Casassa, Jorge Carrasco, Francesca Pelliciotti***

The great majority of Chilean glaciers have been shrinking in recent decades, with a high variety of retreat rates ranging from a maximum of more than 900 m a-1 in Patagonia to only few meters per year at debris covered glaciers of central Chile. Although some anomalous responses have been observed on calving glaciers where factors other than climatic could be important, this overall negative trend seems to be related to the widespread temperature increase detected above 850 hPa. In the Andes of central Chile (30-35S), glaciers had been receding and negative mass balances have been measured in response to a rise in the 0C isotherm. Melting water is crucial for population and economic activities existing downstream this region, where glaciers contribute up to 70% of total river runoff during dry seasons, especially during drought years associated to the presence of La Nia events. Aconcagua river (33S) is one of the major glaciated basins in central Chile, with 10% of the total ice and snow surfaces in this region. The first glacier inventory was carried out in mid 1980s based upon traditional glacier mapping from 1:10,000 vertical aerial photographs, yielding a total ice surface of 151.25 km2 distributed between 267 glaciers. Very little is known about glacier variations in this region from that time, therefore this work aims to update the glacier inventory, analysing frontal, areal and elevation changes experienced in recent decades. High-resolution Landsat ETM+ and Aster imagery, as well as SRTM data, have been collected for accurate delineation of glacier basins and determining surface topographies. The recent images when compared to scenes acquired in previous decades allowed detection of glacier changes well above error signals. The total glacier surface in Aconcagua has resulted in 121 km2 for year 2004, representing an ice loss of 30% mainly explained by changes of larger glaciers such as Juncal Norte (3302S, 7006W, ~8 km2), nevertheless a remarkable reduction has been observed in number of ice bodies under 0.1 km2 which are 60% smaller than in mid 1970s. The observed glacier wastage will probably turn into a critical aspect for future water resources availability in central Chile.

***Keywords:*** central chile, glacier inventories, climate change

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