Calibration of the WaterGAP Global Hydrology Model WGHM with water storage variations from GRACE

A. Güntner[1], S. Werth[1], R. Schmidt[1], S. Petrovic[1], J. Stuck[1], L. Menzel[2], P. Döll[3]

(1) GeoForschungsZentrum Potsdam (GFZ), Germany, (2) Centre of Environmental Systems Research, University of Kassel, Germany, (4) Department of Physical Geography, University of Frankfurt a.M., Germany, (contact: guentner@gfz-potsdam.de)

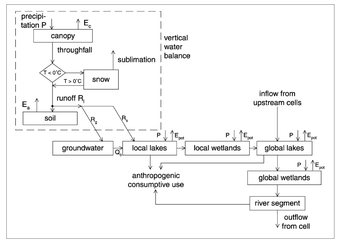
I Motivation

How can temporal water storage variations derived from GRACE time-variable gravity fields be used to improve a global hydrological model ?

II The model

WaterGAP Global Hydrology Model (Döll et al., 2003)

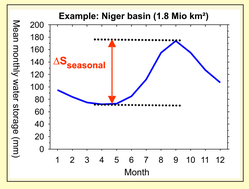
- conceptual global water balance model
- spatial resolution: 0.5 degree
- temporal resolution: 1day
- represents all important continental water storage compartments (snow, soil water, groundwater, surface water bodies)
- human water use is accounted for



III Against which observables to calibrate the model ?

The classical way to calibrate the WGHM model is to adjust a model parameter to adequately represent observed mean annual **discharge** (at 724 gauging stations worldwide), data by Global Runoff Data Center GRDC)

Average seasonal water **storage change** (summed over all storage compartments) is the most pronounced storage signal



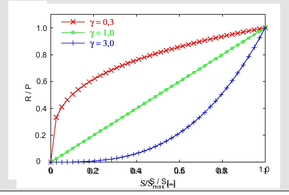
Multi-criterial model calibration

IV Which parameters to adjust ?

Basically, WGHM is calibrated against discharge with a parameter that governs the non-linear response of runoff as a function of the acutal soil moisture status (parameter gamma).

$$R_i = P_{\text{eff}} \cdot \left(\frac{S_s}{S_{s,\max}} \right)^{\gamma}$$

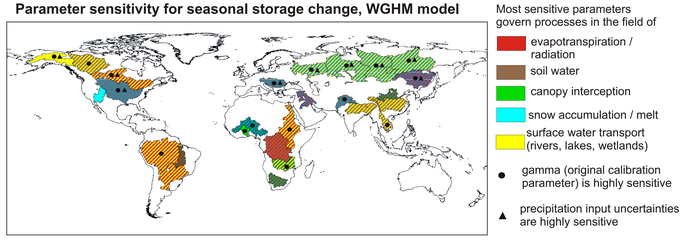
R_i: Runoff
S_s: Actual soil moisture status
$S_{s,max}$: Maximum possible soil moisture
P_{eff}: Effective rainfall
γ: Calibration parameter



Sensitivity analysis to identify parameters that are relevant for storage change

V Sensitivity analysis

For 40 model parameters, including the meteorological model input variables, uncertainty distributions were defined. Based on the Morris method, a ranking of parameter sensitivities was derived for the scale of the largest river basins worldwide.

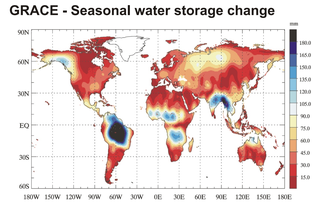


The subset of most sensitive parameters for seasonal storage change varies markedly between river basins. The geographical distribution of parameter sensitivity reflects the contribution of individual water storage compartments, that are affected by the respective parameters, to total seasonal storage change.

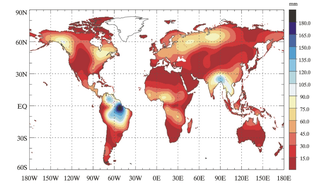
VI Water storage data

- 32 monthly gravity field solutions of GFZ Potsdam, reduced to hydrological mass changes for the period 01/2003 to 12/2005
- For the same time period, monthly water storage change was deduced from a WGHM model version that was calibrated to river dicharge only
- Analyses after conversion from spherical harmonics to spatial domain and Gaussian filtering (filter radius 500km)
- Seasonal storage change is defined by the amplitude of an annual sine function fitted to the monthly storage time series
- River basin values were derived by simple subsetting of the global fields for the basin area

GRACE - Seasonal water storage change



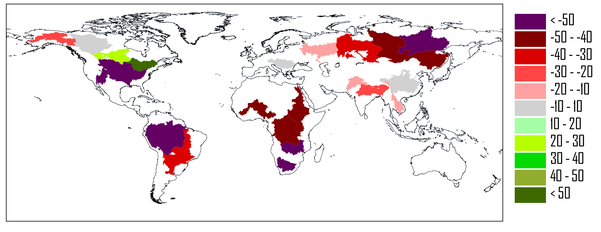
WGHM - Seasonal water storage change



VII Calibration

Basic calibration for river runoff only results in an underestimation of WGHM seasonal storage change for most river basins relative to GRACE.
Possible reasons for smaller seasonal storage change by WGHM than by GRACE:

Deviation of seasonal storage change simulated with WGHM relative to GRACE estimates (%)



- systematic model errors (e.g., overestimated evapotranspiration rates)
- biases in climate input (e.g., underestimated snow precipitation in high latitudes)
- errors in GRACE water storage estimates (e.g., aliasing errors)

VIII Conclusions

- The selection of calibration parameters for storage change should vary in space, depending on which water storage compartments dominate total storage change
- Current differences between WGHM and GRACE seasonal storage change are often too large to be removed by adjusting model parameters within their assumed uncertainty range

Reference: Döll, P., Kaspar, F., Lehner, B. (2003): A global hydrological model for deriving water availability indicators: model tuning and validation. J. Hydrol., 270, 105-134