

Perugia, Italy July 2-13, 2007



IAPSO

**INTERNATIONAL ASSOCIATION FOR THE PHYSICAL SCIENCES
OF THE OCEANS**

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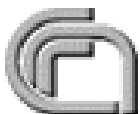
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Compiled by Lucio Ubertini, Piergiorgio Manciola, Stefano Casadei, Salvatore Grimaldi

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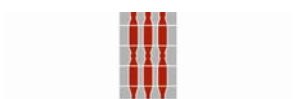
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Abbreviations

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

IRC	International Radiation Commission
PUB	Prediction in Ungauged Basins
SCAR	Scientific Committee on Antarctic 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, Scientific 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 codification referring to a specific Theme or Division.

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

Some examples:

US002

is a **Union Symposium**; **JGW001** is a **Joint IAG Workshop** with IAG as the Lead Association;

MS003

is an Association (IAMAS) **Symposium**. **AS III 020** is an Association (IAGA) **Symposium** sponsored by its **III** Division.

PS001**Symposium****(5770 - 5785)****Convener** : Dr. Maurizio Ribera D'Alcala'

Biogeochemical Budget and Cycles in the Mediterranean Sea

PS002**Symposium****(5786 - 5826)****Convener** : Dr. Andrea Bergamasco

Variability of the Antarctic Circulation and Water Masses and Their Sensitivity to Climate Change

PS003**Symposium****(5827 - 5840)****Convener** : Prof. Piero Lionello**Co-Convener** : Mr. Serge Planton

Mediterranean Circulation and Climate: Their Variability and Sensitivity to Future Emission Scenarios

PS004**Symposium****(5841 - 5895)****Convener** : Dr. Robin Muench

Ocean Mixing (co-sponsored by SCOR)

PS005**Symposium****(5896 - 5940)****Convener** : Dr. Eugene Morozov**Co-Convener** : Dr. Gregorio Parrilla

Flows and Waves in Straits

PS006**Symposium****(5941 - 5967)****Convener** : Dr. Jinping Zhao**Co-Convener** : Dr. Laodong Guo

Arctic Ocean Processes

PS007**Symposium****(5968 - 5988)****Convener** : Prof. John Simpson

Biogeochemical Fluxes Between the Shelf and Open Seas

PS008**Symposium****(5989 - 6023)****Convener** : Dr. Igor Belkin

Processes in Oceanic Fronts

PS009**Symposium****(6024 - 6036)****Convener** : Dr. Denise Smythe-WrightImpact of CO₂ Changes on Biogeochemical Processes and Ecosystem Functioning**PS010****Symposium****(6037 - 6097)****Convener** : Dr. W John Gould

New Insights into the Ocean and Its Circulation from Argo and GODAE

PS011**Symposium****(6098 - 6107)****Convener** : Dr. Trevor McDougall

Fundamental Physical and Chemical Principles Underpinning Ocean Science

PS012**Symposium****(6108 - 6109)****Co-Convener** :The Oceans - Their Past and Present; Considerations on their Future Behaviour
(invited abstracts only)

(P) - IAPSO - *International Association for the Physical Sciences of the Oceans*

PS001

5770 - 5785

Symposium

Biogeochemical Budget and Cycles in the Mediterranean Sea

Convener : Dr. Maurizio Ribera D'Alcala'

The Mediterranean is a unique ecosystem with unusual biogeochemical characteristics. It is ultra-oligotrophic with very low nutrient concentrations in most of the domain, anomalously high N:P ratios leading to P limitation, and evidence of temporal trends in nutrient pools. Paleo-records show large fluctuations in the trophic regime of the basin, probably due to drastic changes in water column dynamics and in nutrient fluxes from the boundaries. At present, there is widespread anthropogenic pressure which acts as an additional and changing forcing of this almost land-locked marginal sea. All of the above makes the basin both a fragile ecosystem under stress and a suitable natural laboratory to understand the role and controls on globally important biogeochemical processes such as nitrogen fixation, impact of atmospheric inputs (both natural and anthropogenically modified), nutrient co-limitation, etc. The symposium will particularly welcome contributions focused on: better constraining on fluxes from the boundaries of the basin and their time variability; assessment of nitrogen fixation at basin and regional scale; understanding the nature and importance of atmospheric inputs to the system; analytical studies connecting structure and functioning of the plankton food web to biogeochemical fluxes and anomalies; analysis of paleo-records, e.g., sapropels, to shed light on future trends in the Mediterranean trophic regimes; model simulations of biogeochemical processes either hindcasting observed processes or forecasting changes on the decadal-centennial time scale due to climate and/or anthropogenic changes; and/or multidisciplinary analyses connecting socio-cultural trends, past and future, of the Mediterranean region and their impact on basin dynamics.

XXIV 2007

PERUGIA

I T A L Y



(P) - IAPSO - *International Association for the Physical Sciences of the Oceans*

PS001

Oral Presentation

5770

The nutrient budget for the Eastern Mediterranean revisited; Implications for global controls on the Redfield ratio

Prof. Michael Krom

School of Earth and Environment University of Leeds IAPSO

Barak Herut

The constancy of the Redfield ratio (16:1) in most of the global ocean has been explained as a balance between N:P supply which is generally $\gg 16:1$, removal of nitrate by denitrification in organic rich sediment and water, and oceanic N fixation. Such N fixation is generally considered to be either P and/or Fe limited. The Eastern Mediterranean sea (EMS) is important in this regard because it is known to be P starved and Fe replete. It has a nitrate:phosphate ratio in the deep water of 28:1. If this high N:P ratio is due to high N fixation as has been suggested previously, this implies that N fixation is Fe and not P limited. As a result of our previous nutrient budget for the EMS (Krom et al., 2005), we suggested that the reason for this high N:P ratio in the basin and outflow from the EMS was in fact due to high N:P in the supply, together with low denitrification caused by the known ultra-oligotrophic conditions across most of the basin. This budget was in balance for N without any N fixation within the basin implying that N fixation could be P limited as has been shown recently for the tropical Atlantic. Here we revisit that calculation including recently published measurements for N fixation rates, as well as new estimates for the nutrient flux from other major sources to the basin including the river Nile. This new budget will show that while some measurements for N fixation are compatible with the previous calculated fluxes into the basin, other values produce values which greatly exceed all other known inputs. These results suggest that it is crucial to both carry out experiments to determine the rate and controls on N fixation in the basin and to develop a more sophisticated time dependant model for nutrient fluxes through the basin.

Keywords: nutrientbudget, easternmediterranean, nfixation



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PS001

Oral Presentation

5771

Contribution of nitrogen to the Mediterranean Sea by the endosymbiotic, nitrogen-fixing, cyanobacterium, *richelia intracellularis*

Mr. Edo Bar Zeev

Mina and Everard Faculty of Life Sciences Bar Ilan University

The Redfield ratio refers to the stoichiometric ratios of carbon: nitrogen: phosphorus which average, in the world oceans, 106:16:1 respectively. In the eastern Levantine basin of the Mediterranean Sea N: P is unusually high and may reach values up to 28:1. This creates an interesting paradox- an ultra-oligotrophic ocean with high N: P ratio. Geochemical and geophysical data indicate that these high N: P may occur due to a large influx of N via biological N₂ fixation. Recent studies indicate that N₂ fixation does occur, but no characterization or identification has been made of the organisms responsible for the phenomenon. The objectives of this study were to identify and characterize the spatial and temporal distribution of a possible contributor to biological N₂ fixation in the Levantine basin of the eastern Mediterranean the endosymbiotic cyanobacteria *Richelia intracellularis*. *R. intracellularis* is usually found as an endosymbiont within diatoms such as *Rhizosolenia* spp, *Hemiaulus* spp, or as an episymbiont attached to *Chaetoceros* spp. In addition to the conspicuous diazotroph *Trichodesmium* *R. intracellularis* is traditionally considered one of the most important diazotrophic plankton in marine tropical oceans and can fix N₂ at extremely high rates. In this study, two stations west of Israel were sampled monthly during 2005-2006. Additionally, more pelagic stations were sampled occasionally. *R. intracellularis* was identified by epifluorescent microscopy and molecular analyses (RT PCR of the *nifH* gene) which confirmed a ~98.8% homology with the *nifH* of known *R. intracellularis* sequences from around the world. Counts of surface *R. intracellularis* showed a range of densities between 10 200 cells L⁻¹ with the diazotroph found throughout the year. The corresponding measurements of N₂ fixation for these stations ranged between 0.4 - 3.05 nmol N L⁻¹d⁻¹ with integrated values ranging between 130-357 mol N m⁻² d⁻¹. These preliminary results suggest an important role for *Richelia* in supplying new N to the oligotrophic eastern Mediterranean and contributing towards the high N: P measured in these waters.

Keywords: nitrogen fixation, endosymbiotic



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PS001

Oral Presentation

5772

Effects of Saharan dust storms on the surface waters of the ultra-oligotrophic Eastern Mediterranean as determined by remote sensing and in-situ data.

Prof. Michael Krom

School of Earth and Environment University of Leeds IAPSO

Steve Groom, Barak Herut

It is known that the ultra-oligotrophic Eastern Mediterranean (EM) is underneath a major pathway of Saharan dust storms (SDS). A Nutrient budget of the EM has shown that atmospheric inputs including dust storms represent a significant source of externally supplied nutrients to the basin (~60%N and 30%P). They are considered particularly important during March-October when most of the SDS occur, the water column is seasonally stratified and vertical mixing is at a minimum. These storms also represent an important supply of inorganic particles, and, hence, iron and other trace metals to the microbial ecosystem. Remote sensing provides the opportunity to examine the magnitude of changes in chlorophyll and scattering particles in surface waters. In this study contemporary in situ and satellite data using data from the SeaWiFS, Aqua-MODIS and MMERIS satellites, have been used to elucidate the biological and potential optical effects; satellite data have been analysed before, during and after a number of other dust storm events recorded through in situ sampling. These data enable the dynamics of the biological effects to be quantified. Remote sensing data are calibrated against a major dust storm event (May 2001) which was sampled in situ. The dust pulse from that event was found to result in a short term increase in phosphate turnover rate and Prochlorococcus abundance but only a minute increase in chlorophyll-a abundance of ~5 ng l⁻¹. These results were consistent with results from the CYCLOPS P Lagrangian addition experiment and a more recent detailed study of the functioning of EMS microbial ecosystem which suggest that there is a very tight coupling between phytoplankton uptake of nutrients, biomass growth, and micrograzing in this ultra-oligotrophic system.

Keywords: dust, emediterranean, remotesensing



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PS001

Oral Presentation

5773

Nitrogen isotopic composition of wet and dry deposition over the Eastern Mediterranean Sea

Mrs. Paraskevi Mara
IAPSO

Kirstin Daehnke, Kay-Christian Emeis, Alexandra Gogou, Nikolaos Mihalopoulos

The oligotrophic character of the Mediterranean Sea and especially its eastern basin - one of the least productive oceans of the world on the basis of its low nutrient levels and low export productivity at the same time has anomalously high nitrogen to phosphorus ratio (N/P ratio ranging from 20-27, compared to Redfields ratio of 16), and curiously low nitrogen isotope ratios in dissolved inorganic nitrogen (DIN) (Bethoux & Copin-Montegut 1986, Gruber & Sarmiento 1997, Pantoja et al., 2002). Nutrient budgets, phytoplankton distributions and stable N isotope studies proposed that N₂ fixation could be the source of this excess and isotopically depleted reactive nitrogen to the Mediterranean Sea (Bethoux et al., 1986; Pantoja et al., 2002; dAlcala et al., 2003), although why that should be a significant process in a P-limited system is unclear. Pantoja et al. (2002), by measuring isotopic ratios of DIN in seawater, estimate that N₂ fixation accounts for 20 to 90% of the N supply to the western and eastern Mediterranean, respectively. On the other hand, recent work on atmospheric deposition measurements (Herut et al., 1999; Kouvarakis et al., 2002) and gross nutrient budgets (Krom et al., 2004) suggested that atmospheric deposition of reactive N is sufficient to account for anomalies in the N cycle in the E. Mediterranean. To quantify the role of atmospheric reactive N deposition in the nitrogen mass fluxes and isotope mixtures of the Mediterranean Sea, we collected dry deposition in bi-weekly and per-event wet-only precipitation since April 2006 on the island of Crete. Nitrogen isotopic ratio was analysed using the bacterial denitrifier method as described by Sigman et al. (2001). Both dry and wet deposition samples showed consistently negative $\delta^{15}\text{N}$ ratios (-1.7 to -5.1 for dry deposition, and -2.8 to -5.7 for wet deposition), implying a strongly depleted atmospheric source from Europe for reactive N. The implication of these results on biogeochemical N cycle in the area will be discussed.

Keywords: nitrogen, isotopes, deposition



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PS001

Oral Presentation

5774

Nitrogen fixation in the Eastern Mediterranean Sea.

Dr. Ilana Berman-Frank
Faculty of Life Sciences Bar Ilan University

Tali Yogev, Aharonovich Dikla, Oded Beja

Nutrient budgets and recent isotopic data suggest that nitrogen fixation may be an important process in the oligotrophic eastern Mediterranean supplying up to 90% of nitrogen into the eastern-basin. Yet, the organisms responsible for this contribution, and their respective nitrogen-fixation rates, have not been directly identified and characterized in this region. In this preliminary work, we began to identify and quantify the organisms responsible for nitrogen-fixation (diazotrophs) in the eastern Mediterranean . Free living and endosymbiotic cyanobacterial diazotrophs were identified by direct immunolocalization of nitrogenase antibodies on natural populations and by epifluorescent microscopy. We present data describing the molecular diversity of *nifH* genes from the eastern Mediterranean . Phylogenetic analyses of the *nifH* genes studied by RT-PCR showed differential patterns in the genetic potential for nitrogen-fixation (DNA) versus organisms that were actively expressing *nifH* genes (RNA). The high diversity of *nifH* genes found is extensive and includes members from three different *nifH* clusters (I, II and III). Initial rates of nitrogen fixation measured using acetylene reduction and ¹⁵N-uptake showed temporal and spatial variations in activity in stations east of Herzelia and Haifa .

Keywords: mediterranean sea, nitrogen fixation, *nif* genes

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PS001

Oral Presentation

5775

Do dust particles play an important role in driving biochemical processes in surface seawater of the eastern Mediterranean?

Prof. Barak Herut

Israel Oceanographic & Limnological Research Israel Oceanographic & Limnological Research

Tali Yogev, Ilana Berman-Frank, Michael Krom

Studies have shown that, in the long-term, dry atmospheric deposition is an important net supplier of N, P, Fe and other trace metals to the Low Nutrient Low Chlorophyll Eastern Mediterranean Sea (EMS). Significant quantities of exchangeable or leachable nutrients from dry atmospheric inputs become potentially bioavailable after deposition into EMS surface water. Recent nutrient budgets for the EMS suggest that a high percentage of these nutrients are exported by the anti-estuarine circulation through the Sicily straits while the rest are probably important drivers for the unusual high N:P ratios in the EMS deep water. While atmospheric input of dust following a Saharan dust storms does not produce a significant in-situ increase in chlorophyll, probably due to rapid grazing, on-board microcosm experiments yields essential information on the potential reactivity of dust with seawater, and hence its impact on EMS biogeochemical cycles. On-board microcosm experiments in which a gradient of fresh and pre-leached Saharan dust were interacted with EMS surface seawater (May), triggered a clear increase in P turnover time, bacterial production, phytopigments and primary production rates. Considering the relationships between experimental fresh dust concentrations and observed biological responses, it is very likely that because of rapid grazing reaction, moderate strength dust storms are mostly close to detection limit of stock measurements. Nitrogen fixation has been suggested as one of the potential processes generating the high N:P ratios in EMS deep water. Such N fixation is generally triggered in areas of relatively high Fe and/or P supply. Because both nutrients are supplied to the EMS via atmospheric deposition, preliminary on-board microcosm experiments (autumn and winter) were conducted to follow the impact of dust addition on nitrogen fixation rates. Preliminary results show low nitrogen fixation rates in both treatments of dust and N+P additions, perhaps reflecting seasonally low requirements for N-fixation when nutrient availability is enhanced via mixing.

Keywords: dust, nutrient, mediterranean



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PS001

Oral Presentation

5776

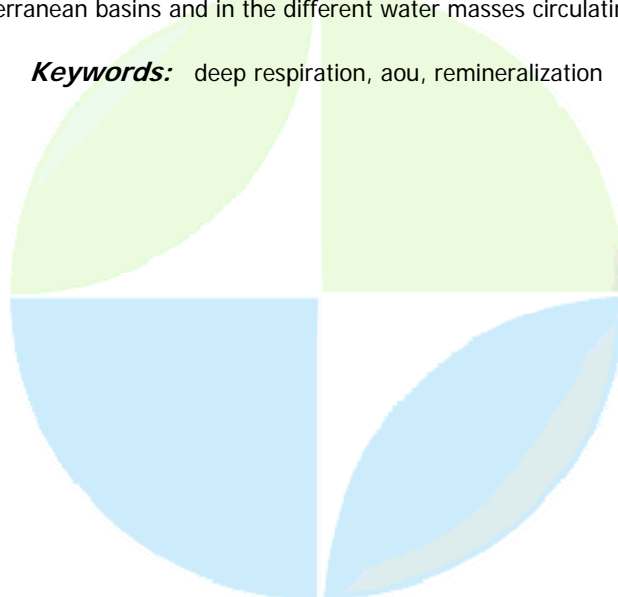
Relation between OUR and AOU in the dark pelagic waters of the Mediterranean Sea

Dr. Maurizio Azzaro
IAPSO

Rosabruna La Ferla

The Mediterranean Sea is considered to be one of the most oligotrophic regions in the world where only 2-3% of primary production is exported as sinking particles in the eastern basin and about 10% in the western basin. However, the export rates from the photic zone predicted by the sediment traps, proved to underestimate the total carbon flux because they did not take into account the more abundant dissolved organic carbon (DOC) present in the seawater. Recent investigations in the aphotic zone of the Mediterranean Sea showed that the instantaneous oxygen utilization was not due to the biological consumption of particulate organic carbon (POC), suggesting that the downward flux of DOC may play a major role in supporting respiration there. Moreover, although in the dark pelagic waters the measured respiration rates are one or two orders of magnitude lower than those measured in the corresponding surface waters, integrating the thickness of each water mass the remineralization in the deep layers appears far from negligible. This is particularly relevant especially in the frame of the present debate on the heterotrophy vs. autotrophy of present ocean. The contribution of all the different sources of organic carbon to deep biota-pelagic consumption can be determined from oxygen utilization rate (OUR). Such latter coupled with the apparent oxygen utilization (AOU) furnishes informations on evolutive patterns of organic carbon oxidation. In fact, these two measurements, OUR and AOU, are expression of instantaneous consumption of oxygen ($\mu\text{M O}_2 \text{ h}^{-1}$) and of the cumulative oxygen consumption ($\mu\text{M O}_2$) since the parcel water was last in contact with the atmosphere. Past studies on the Mediterranean Sea have been mostly focused on specific regions of the basin and an overall view of the functioning of the basin derived by a compilation of all data available has never been conducted. In this study we assembled a large data set of concurrent OUR (derived by ETS assay) and AOU observations collected in several cruises on different spatial and temporal scales in the Mediterranean basin with the aim of assessing: a) the consistency of the data set; b) the patterns emerging from the analysis; c) the contribution of the intermediate and deep layers of the Mediterranean to carbon recycling. A different scenario was detected in terms of organic carbon contribution to respiration, both in the two main Mediterranean basins and in the different water masses circulating there.

Keywords: deep respiration, aou, remineralization



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PS001

Oral Presentation

5777

Massive carbon burial in the Mediterranean Sea: are we still missing something?

Dr. Mario Sprovieri
IAMC CNR CNR IAPSO

Ribera Dalcala Maurizio

The Mediterranean sea has been the site for the last 10 My (106 years) at least of recurrent events of increased carbon burial which can be traced in the deep sea cores or in recently outcropped sedimentary succession. Those events are among the most regular processes occurring in the pelagic realm and share some similarity with black shales, which are among the most impressive events of carbon burial in the open oceans. While spectral traits of sapropel recurrence shows a clear correlation with orbital parameters and, therefore, with insolation regime, biogeochemical processes at the onset and during the sapropel deposition phase are still elusive. Indeed, higher carbon export as observed during sapropel events requires a concurrent nutrient input. Different mechanisms have been proposed but a quantitative assessment of the extent of the needed nutrient increase has been eluded so far. We made a quantitative analysis of needed or possible elemental fluxes during sapropel events and concluded that carbon burial during those events are hardly justified by the biogeochemical processes ruling the present biological pump. We argue that additional mechanisms of nutrient recycling has to be taken into account to account for massive carbon burial events in the Mediterranean Sea as well as in the open ocean.

Keywords: sapropels, carbon cycle, paleoclimate



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PS001

Oral Presentation

5778

Response of the Black Sea ecosystem to nutrient loads and climate changes

Dr. Joanna Staneva
ICBM University of Oldenburg IAPSO

This study describes the coupling between physical and biogeochemical models and provides an extensive analysis on the response of the ecosystem in the north-western Black Sea to nutrient loads and climate changes. We illustrate the basic physical and biological dynamics of upper ocean coupling three-dimensional physical and biogeochemical models. The physical model is based on the Princeton Ocean Model; additionally, a parameterisation of mixed layer is included. The biological model is based on the European Regional Sea Ecosystem Model (ERSEM) and consists of five modules: (1) primary producers, (2) microbial loop, (3) mesozooplankton, (4) benthic nutrients, and (5) benthic biology. The ecosystem in ERSEM is subdivided into three functional types, producers (phytoplankton), decomposers (pelagic and benthic bacteria) and consumers (zooplankton and zoobenthos). Model-data comparisons have been performed for both calibrating and verifying coupled model simulations. We address here the impact of nutrient discharge from the Danube River on the functioning of the biological system. The evolution of the mixed layer, as well as the response of the biological system to variability of the nutrient discharge from the Danube River are described in detail. Several scenarios have been developed to study the impact which nutrient reduction has on the coastal marine system. The model prediction indicate that the biological system is very sensitive to the changes in nutrient concentrations, as well as to their ratios

Keywords: ecosystem, blacksea, variability



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PS001

Oral Presentation

5779

The ultraviolet chromophoric dissolved absorbing compounds in the Central and Eastern Mediterranean basins

Dr. Luca Bracchini

Chemical and Biosystems science University of Siena

Rossana Del Vecchio, Arduino Massimo Dattilo, Franco Decembrini, Steven Arthur Loiselle, Chiara Santinelli, Claudio Rossi, Neil V. Blough

The study of the optical properties of chromophoric dissolved organic matter (CDOM) is one the most important theme in aquatic ecosystems. Nevertheless, the sources, sinks and nature of CDOM remain uncertain. Also, confusion is still present on the operative definition (and distinction) of humic substances (HA) and others chromophoric dissolved compounds. This distinction is also important in term of origin of CDOM (HA is terrestrial in origin) and its availability in the water column. In this work we adopted, as operative definition of HA, the presence of a clear exponential decrease of absorption in the visible (400-700 nm) portion of the spectra. Data were acquired at the end November at 11 stations in the Central Eastern Mediterranean Basin (from surface to near the bottom). Absorbance was measured against MilliQ water from 240 to 700 nm using a 10 cm quartz cell. To take account of existing literature, the absorption was modeled as an exponential decay and the spectral slope(s) was also calculated as a non linear fitting. Our results show no evidence of measurable absorption after 400 nm; no exponential decay between 300 and 700 nm; no exponential decay for absorption between 240-400 nm but a clear residual between theoretical exponential decay and absorption measured with depth; an exponential decay was instead found between 270-400 nm, with a higher spectral slope values at the surface and lower nearest the DCM; further, absorption measurements correlated with natural fluorescence of chlorophyll-a. Overall, in this region of the Mediterranean basin and during this cruise, the HA content is not measurable and thus the measured chromophoric dissolved compound is not of terrestrial origin. Results further support the idea that the chromophoric dissolved compounds observed in the UV region are of autochthonous origin.

Keywords: cdom



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PS001

Oral Presentation

5780

**A revaluation of Gibraltar dynamics in the elemental budgets of
Mediterranean Sea**

Dr. Gianmaria Sannino
ACSCIM-MOD ENEA

Vincenzo Artale, Adriana Carillo, Fabio Conversano, Maurizio Ribera Dalcal

The fluxes between Mediterranean Sea and the neighboring Atlantic Ocean, through the Strait of Gibraltar, have always been considered a key to better understand the functioning of the Mediterranean basin. Besides the heat and fresh water exchanges which certainly impact on the physical dynamics, nutrient and carbon fluxes affect both the region at the interface between the Mediterranean and the open ocean (e.g., Alboran Sea), and the internal basin. In the usual rendition the Strait of Gibraltar has been always described as a two layer system. In the present Mediterranean the buoyancy overall budget is negative and, therefore, Mediterranean water outflows denser in the subsurface layer while Atlantic water flows in the top layer. A realistic evaluation of the average transport of the two layers has been a controversial issue for a long time but, applying to it the assumed concentrations of the main elements reasonable budgets of the basin have been derived. A recent modeling study, based on a high resolution three-dimensional model of the Strait of Gibraltar, showed that a three layer system better represents the dynamics at the Strait. Using a three layer system to represent the exchange between Mediterranean and Atlantic ocean strongly impacts the fluxes because of the entrainment both in the entering and exiting waters. We are conducting an analysis of potential elemental fluxes in the three layer representation and comparing our result with the existing ones based on a two layer exchange. As the Atlantic Ocean is not the crucial supplier of nutrients to the basin, at least in terms of local concentration, it is the dynamics in the subsurface layers that convey the significant information. Our preliminary results show that the real dynamics at the straits exert indirect impact on the biogeochemistry of the basin.

Keywords: gibraltar, nutrient, carbon



(P) - IAPSO - *International Association for the Physical Sciences of the Oceans*

PS001

Oral Presentation

5781

Clues for the carbon cycle in Mediterranean Sea: patterns in dissolved organic carbon and dissolved oxygen distributions

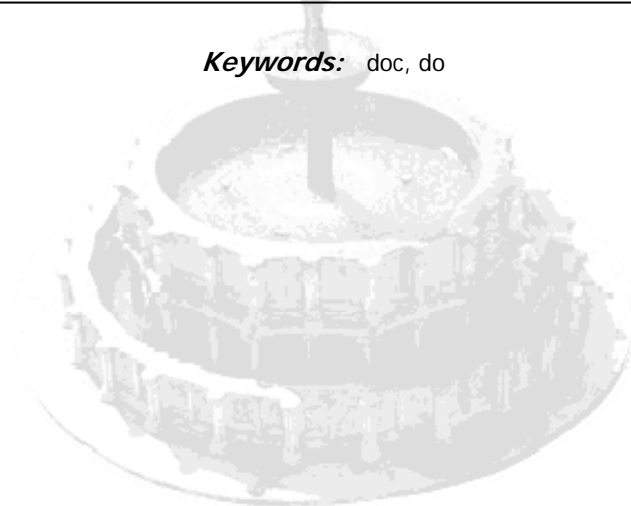
Dr. Chiara Santinelli

Biophysics Institute National Research Council (CNR) IAPSO

Luciano Nannicini, Alfredo Seritti

Marine Dissolved Organic Carbon (DOC) represents one of the major reservoirs of organic carbon on the Earth. While inorganic carbon (DIC) concentration in sea water depends on both biotic and abiotic processes, DOC concentration is strictly dependent on biotic activity in the ocean or on land. Because of the crucial role that ocean may play in the global carbon cycle, budgeting carbon in marine systems and analyzing the key nodes is crucial to constrain carbon dynamics in the global, as well in the regional marine systems. Christensen et al. (1989), analyzing ETS measurements, derived the first data on carbon oxidation in the Western Mediterranean deep waters. Their analysis showed that carbon oxidation is higher in the Western Mediterranean than in the Oceans and that carbon oxidation rates in the deep layers were much greater, than those expected from the sediment trap data. They hypothesized that DOC transport during deep water formation could overwhelm the flux sinking particulate in terms of available substrate for deep respiration. During several cruises in the Mediterranean Sea we collected data that strongly support their hypothesis. Our DOC and dissolved oxygen (DO) data derive from different regions of Mediterranean Sea (Ionian through Balearic Sea), starting in 1999. Many areas were investigated in different years and seasons, in order to analyze DOC and DO distribution as dependent on water mass characteristics and circulation. The Levantine Intermediate Water (LIW) forms in the Eastern Mediterranean and fills all the intermediate layer of the MED basin. Following the core of LIW, a gradual DOC and DO decrease with the distance from its source can be observed. DOC and DO concentrations are 545 M and 2005 M in the Ionian, 478 M and 1776 M in the Northern Tyrrhenian Sea, 481 M and 1771 M in the Sardinian Sea, 443 M and 1742 M in the Ligurian Sea, 486 M and 1807 M in the Algerian basin. The relationship between mean values of DOC and DO, calculated selecting only the samples collected in the LIW core in the different areas and periods, displays a significant linear relationship, with a slope of 0.36. This slope is about half of typical Redfield ratios (0.69). Deep waters in Mediterranean Sea exhibit DOC concentration (>80 M) higher than those reported for the Oceans (34-48 M), suggesting that in this basin the export of DOC to depth, during deep waters formation, can play a fundamental role for the deep waters ecosystem. The export of DOC to depth was studied in the Ionian and in Western Mediterranean. The different DOC values observed in deep waters may be explained by different DOC concentration at surface, during deep water formation, and by bacterial consumption. The ratio between DOC (M) and DO (M) was also investigated by using the mean values of DOC and DO in the core of each water mass. In general this ratio was of 0.30-0.33 in recently ventilated vein of WMDW, and it decreased to 0.21 in old vein of WMDW. In the LIW DOC:DO was almost constant (~0.28) in the Western Mediterranean independently from the period. In the Eastern Mediterranean DOC:DO was 0.26 in the LIW, 0.27 in Adriatic deep water (ADW) and 0.28 in Cretan deep water (CDW). The change of this ratio may be linked to the occurrence of DOC with different lability. Recently ventilated waters may contain a fraction of semi-labile DOC very reactive, its fast consumption determines a decrease in DOC concentration higher than in DO concentration. This is also confirmed by the almost constant values of DOC:DO in the LIW in Western Mediterranean, where the most labile fraction is presumably already consumed. As consequence higher respiration ratio may be expected in deep waters, where DOC could be more reactive than in the LIW.

Keywords: doc, do



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PS001

Oral Presentation

5782

**Nitrogen supply and dissolved organic nitrogen transfer in the
Mediterranean Basin: a box model assessment**

Mrs. Valeria Ibello

Ric G. Williams, Giuseppe Civitarese, Maurizio Ribera D'Alcal, George A. Wolff

Dissolved organic nitrogen (DON) and phosphorus (DOP) constitute the largest fraction of the nitrogen (N) and phosphorus (P) pools in many surface oligotrophic areas. In the Mediterranean Sea, DON and DOP are involved in several important processes: atmospheric and terrestrial inputs, subduction of Levantine Intermediate Water (LIW), lateral advection and, probably, nitrogen fixation (N₂ fixation). All over the basin, a high nitrate/phosphate ratio and DON/DOP ratio (>16) have been observed in deep layers (Ribera dAlcala et al. 2003, Moutin et Rainbault 2002). A careful analysis of processes supplying N and transferring it to the deeper layers needs to be developed in order to explain both the maintenance of nitrogen budget and the anomalies in the nutrient ratios. In order to understand the N supply and transfer mechanisms in the basin, we modelled the N pathways for the Mediterranean using a simple box model for salinity, nitrate, DON. Two hypotheses are tested by the model: (i) the impact of additional N supplied by N₂ fixation and (ii) the different cycling and transport of DON and DOP where the DOP is almost completely recycled in the surface layer and the subduction and eventual breakdown of DON leads to the increase of nitrate in deep layers. A nearly closed N and P budget can be obtained when the transport of DON and DOP from the Atlantic into the Mediterranean is included. Moutin, T., and Rainbault, P., 2002. Primary production, carbon export and nutrients availability in western and eastern Mediterranean Sea in early summer 1996 (MINOS cruise). *JMS*, 33 34, 273 288. Ribera dAlcala, M., Civitarese, G., Coversano, F., and Lavezza, R., 2003. Nutrient ratios fluxes hint at overlooked processes in the Mediterranean Sea., *JGR*, vol. 108, no c9, 1-16.

Keywords: boxmodel, don



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PS001

Oral Presentation

5783

Impact of atmospheric deposition of nitrogen and phosphorous on the ocean productivity in the Cretan Sea: A 1-D Modelling study

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The Mediterranean presents a strong west to east gradient in nutrient (like nitrogen and phosphorus) deficiency that result in a high oligotrophic eastern Mediterranean basin. These conditions can be affected by the atmospheric deposition of nutrients to the marine environment, process that is strongly affected by the humans. There are published studies that support the fact that the most limiting factor for primary production in the East Mediterranean sea is phosphorus. In the present study, atmospheric deposition measurements of nitrogen and phosphorus over Crete island in the East Mediterranean are coupled with the sea water observations of nutrient availability and chlorophyll in the Cretan sea by the mean of a 1-dimensional ocean biogeochemical model. The 1-dimensional ecosystem model taking into account the atmospheric inputs is firstly tuned to simulate the sea water observations at the Cretan sea. Then, the impact of the atmospheric inputs on the ocean productivity is evaluated by additional sensitivity simulations to these inputs. Further analysis of the underlying biogeochemical dynamics with emphasis on primary production is performed. The results are presented and thoroughly discussed.

Keywords: atmosphere, impact, ocean

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PS001

Poster presentation

5784

The Mediterranean Sea: a very high CO₂ and acidified environment.

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Catherine Goyet

The Mediterranean Sea ecosystems suffer from a very intense anthropogenic pressure that strongly affects most biogeochemical cycles. During the last century, the impact on the carbon cycle and especially on the carbonate system has been poorly understood given the scarce data available for total alkalinity (AT), total dissolved inorganic (CT), and/or pH. Since almost a decade however, several national and international programs were designed to increase the amount of high quality data in the region. Using this recent database we first describe the distributions for CT and AT for the whole Mediterranean Sea. The concentration of anthropogenic CO₂ (Cant) accumulated since the pre-industrial era and consequently the level of acidification are also estimated. It is shown that all waters (even the deepest ones in both the western and eastern basins) are contaminated by Cant. This trend is confirmed by the distribution of other anthropogenic tracers like CFCs and tritium. We show that the Cant averaged inventories in the Mediterranean Sea are approximately twice as those estimated in the North Atlantic Ocean, resulting in a much larger acidification of this semi-enclosed sea. Consequently, at depths, the Mediterranean Sea acts as a significant source of anthropogenic carbon for the Atlantic Ocean. The analysis of the temporal trends clearly reveals the impact of the EMT (Eastern Mediterranean Transient) which resulted in an intense sequestration of anthropogenic carbon into the deep waters of the eastern basin. The recent observation that Cant in the intermediate and deep waters of the DYFAMED site (western Mediterranean) is decreasing since the 1990s is also discussed in the light of the EMT event.

Keywords: carbon cycle, anthropogenic co₂, acidification

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Poster presentation

5785

Dissolved organic carbon and chromophoric dissolved organic matter in Western Mediterranean

Dr. Chiara Santinelli

Biophysics Institute National Research Council (CNR) IAPSO

Luca Bracchini, Rossana Del Vecchio, Luciano Nannicini, Arduino Massimo Dattilo, Antonio Tognazzi, Alfredo Seritti

Dissolved organic matter (DOM) represents the main reservoir of organic carbon in aquatic ecosystems as well as the source of food for heterotrophic bacteria. The fraction of DOM capable of absorbing light (i.e. the chromophoric dissolved organic matter, CDOM) plays a major role in determining the underwater light availability in aquatic systems. Following absorption of UV and visible light, CDOM undergoes photodegradation which in turn reduces its capability to further absorb light. Upon photobleaching CDOM is degraded into smaller compounds (with lower internal energy, different optical properties, lower molecular weight) that are overall more edible by bacteria. Despite the DOM and CDOM role in marine ecosystems and in global change, its role in affecting the spatial distribution and variability of carbon sources and sinks at global scale is far from being precisely quantified. The Mediterranean Sea represents a natural laboratory to study processes occurring in the ocean at large temporal and spatial scale; because deep waters within this basin are also rich in DOM, this sea represents an ideal environment to study CDOM properties and dynamics and to couple CDOM properties to marine carbon cycle. Samples for DOC and CDOM absorption measurements were collected in April/May 2005 and June/July 2006 in Western Mediterranean. In some key stations CDOM fluorescence properties were also investigated. In general DOC ranged from 32 M to 142 M in 2005 and from 30 M to 100 M in 2006 with a minimum in the core of Levantine intermediate waters and an increase in recently ventilated deep waters, in both periods. The spatial/temporal variation of carbon content, CDOM optical properties and DOC-to-CDOM dependence will be presented and put into context of marine carbon cycles and water masses dynamics.

Keywords: doc, cdom



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PS002

5786 - 5826

Symposium

Variability of the Antarctic Circulation and Water Masses and Their Sensitivity to Climate Change

Convener : Dr. Andrea Bergamasco

This symposium will address the Antarctic Circumpolar Current and its role in global scale thermohaline circulation, its variability and sensitivity to inter-ocean transport of heat and freshwater anomalies, and its impact on global climate. Presentations are invited on the following topics: (1) water transport processes of Antarctic intermediate water, subantarctic mode water, and deep and bottom water; (2) deep and bottom ventilation variability including shelf-slope dynamics, circumpolar deep water - shelf water interactions, and modified circumpolar deep water transformation processes; (3) Reconstruction of the circulation based on instrumental data, natural and documentary proxies, and model simulations focused on regional domains as well as the entire Southern Ocean. Particularly welcome are presentations analyzing the atmosphere-cryosphere-hydrosphere couple systems and the interactions between atmosphere and ocean variability, as well as Southern Ocean characteristic processes including sea ice, polynyas area and glacial shelf ice interactions. Also welcome are presentations on variability, trends, and Antarctic-ENSO teleconnection at decadal scale related with the Southern Annular Mode.

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Oral Presentation

5786

Circulation at the Southwest Indian Ridge in a high-resolution global ocean model

Mr. Jonathan Durgadoo

Oceanography Department University of Cape Town IAPSO

Ansorge I.J., De Cuevas B.A., Lutjeharms J.R.E., Coward A.C.

The Southwest Indian Ridge (SWIR) region of the Southern Ocean is an area where disturbances in the mean flow have been acknowledged to be dominant and crucial in sustaining the marine ecosystem of the Prince Edward Islands. Eddies shed at the ridge travel in a north-eastern direction pass the islands. These eddies have been extensively studied over the last decade with hydrographic, satellite, drifter and float data. To date, however, only two simple model experiments have been undertaken in the vicinity of the SWIR. This study explores the use of the 1/4o and 1/12o Ocean Circulation and Climate Advance Modelling (OCCAM) model outputs. The models representation of the dynamic nature of this region is assessed. Preliminary results show at this stage that on average 2-3 intense eddies are generated in the model per year; having longevity of 149-69 days with average speed of 5.39-1.58 km day⁻¹. The model generates more cold-core eddies than expected. Furthermore, latest results have revealed evidence that the SWIR region could play an important role in meridional heat flux south of Africa. A preliminary study of the cross Antarctic Polar Front heat flux in the model was undertaken.

Keywords: south west indian ridge, occam, eddies

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Oral Presentation

5787

The role of ocean circulation in the southern hemisphere ocean temperature and salinity biases in HadCM3 and HadGEM1

Dr. Zhaomin Wang

Physical Science Division British Antarctic Survey IAPSO

John Turner, Mike P. Meredith, William M. Connolley

We use the most comprehensive available ocean velocity data to validate the ocean currents and assess the role of ocean circulation in determining the structure and magnitudes of ocean temperature and salinity biases in the coupled climate model HadCM3 and its successor, HadGEM1. It is found that the simulated Antarctic Circumpolar Current in both models is significantly slowed in the near-surface layer, and faster at 900 m. Both models overestimate the near-surface westward equatorial current. The poleward meridional currents on both sides of the equator are significantly overestimated in HadGEM1. All the overturning cells in the southern hemisphere are more vigorous in HadGEM1 than in HadCM3. The weak high latitude overturning and the more realistic tropical upwelling cannot counterbalance the excessively large atmospheric freshwater input into the southern high latitudes and the tropical regions, which consequently leads to large surface fresh biases in HadCM3. The surface salinity simulation is improved in HadGEM1 because the high latitude overturning and the tropical upwelling are strong. However, the overly strong tropical upwelling in HadGEM1 causes large surface cold biases.

Keywords: validation, southern ocean, models

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Oral Presentation

5788

The role of convective and turbulent mixing on the formation of Southeast Pacific Antarctic Intermediate Water.

Dr. Bernadette Sloyan

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Lynne Talley, Teresa Chereskin, James Holte

The Southern Oceans Antarctic Intermediate Water is a globally significant upper ocean water mass that circulates in all the southern hemisphere subtropical gyres, and is a key component of the interbasin circulation associated with the Indonesian Throughflow, and northward flow of upper ocean water in the Atlantic that balances the southward North Atlantic Deep Water transport. Antarctic Intermediate Water is formed near the Subantarctic Front predominantly in the Pacific sector of the Southern Ocean. While air-sea fluxes, Ekman transport and cross-frontal mixing are suggested to set the characteristic properties of Antarctic Intermediate Water, the relative importance of any one process on the formation of the water mass is still poorly understood. During austral spring (2005) and summer (2006) hydrographic surveys in the southeast Pacific observed the formation of Antarctic Intermediate Water and subsequent restratification of the water column, respectively. We examine the vertical and spatial distribution of turbulent eddy diffusivity, estimated from density inversions in the CTD and XCTD profiles, to investigate the importance of mixing on the formation of Antarctic Intermediate Water and compare this formation process with convection driven by air-sea fluxes.

Keywords: watermasses, formation, mixing

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Oral Presentation

5789

Preliminary Analysis of a Southern Ocean State Estimate

Mr. Matthew Mazloff

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Patrick Heimbach, Carl Wunsch

A state-of-the-art general circulation model of the Southern Ocean with one-sixth of a degree resolution has been optimized to observations in a weighted least squares sense for the years 2005 and 2006. A cost function is used to compare the model to in situ observations (ARGO float profiles, CTD synoptic sections, SEaOS profiles taken via seal mounted instruments, and XBTs), altimetric observations (ENVISAT, GEOSAT, GRACE, Jason), and other data sets (e.g. NSIDC sea-ice concentration and sea surface temperature observations). Reduction of the model-observation misfit, the cost, is achieved by systematically adjusting the control variables (prescribed atmospheric state, initial conditions, and open northern boundary at 24.7 degrees south) using the adjoint method. Costs associated with control variable perturbations ensure a physically realistic solution. The years 2005 and 2006 mark the period when the Southern Ocean was most thoroughly observed, and the model state is now largely consistent with this wealth of data. There are, however, still regions where the misfit is unacceptable. A significant result is that the adjoint method is shown to work at eddy-permitting resolution in the highly energetic Southern Ocean. The mean transport of the Ross Gyre is 22 Sv. The Weddell gyre has a double cell structure with a mean transport of about 36 Sv common to both cells; an extra 5 Sv recirculates in the eastern cell and 10 Sv in the western cell. The mean Antarctic Circumpolar Current transport through Drake passage is 148 Sv, and exhibits no significant trend. This work is a contribution of the ECCO (Estimating the Circulation and Climate of the Ocean) consortium.

Keywords: state estimate, acc, transport

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Oral Presentation

5790

Defining Steady and Time-dependent Streamlines using Satellite Altimetry and Direct Velocity Observations of the Antarctic Circumpolar Current in Drake Passage

Dr. Yueng-Djern Lenn

Physical Oceanography Research Division Scripps Institution of Oceanography, UC San Diego

Teresa K. Chereskin

The definition of a well-resolved mean Antarctic Circumpolar Current (ACC) has been limited by the paucity of Southern Ocean observations. We present an estimate of the mean surface-layer ACC in Drake Passage that combines sea-surface height anomalies measured by satellite altimetry with a new data set of repeat high-resolution acoustic Doppler current profiler observations. A streamfunction (surface height field) is objectively mapped from the mean currents and compared to several recent climatologies. The comparison with the dynamic topography of Maximenko and Niiler [2005] is best, although the new streamfunction has better mesoscale resolution, resulting in narrower and stronger ACC fronts separated by quiescent zones of much weaker flow. Finally we evaluate the usefulness of tracking ACC streamlines in time-dependent maps of dynamic height and examine the meandering of the three ACC fronts in Drake Passage.

Keywords: antarctic circumpolar current, mean currents, dynamic height



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Oral Presentation

5791

Southern Ocean subsurface water mass structure and variability inferred from satellite altimetry

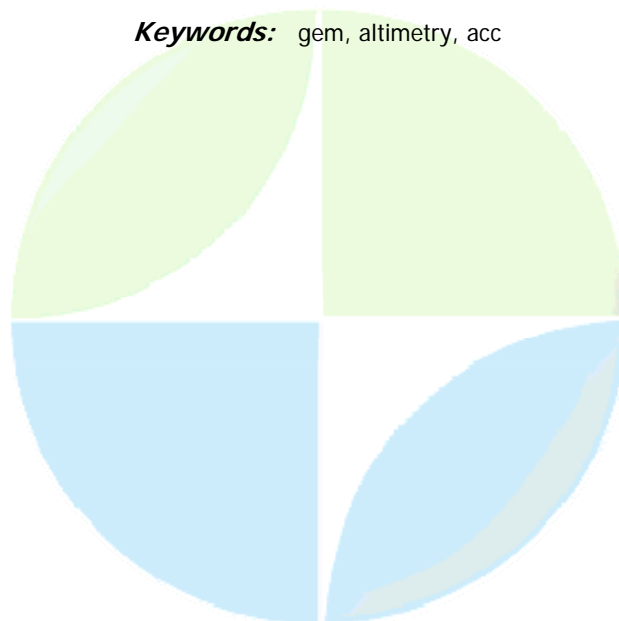
Mr. Andrew Meijers

*Mathematics and Physics, University of Tasmania ACE-CRC, CSIRO, University of Tasmania
IAPSO*

Nathaniel L. Bindoff, Stephen R. Rintoul

Utilising historical hydrographic data we construct a strong Gravest Empirical Mode (GEM) relationship over the whole Southern Ocean south of the Subtropical Front. This method uses objectively mapped sea surface dynamic height and longitude as spatially continuous proxies for full depth subsurface temperature and salinity profiles. Over much of the Southern Ocean this method captures 90-95% of the meridional temperature variance over all depths, with total surface RMS residuals (1.18 degrees) between the fitted GEM temperature field and observations, close to the a priori noise (0.78 degrees) in large areas of the domain. Below the seasonal thermocline this relationship becomes even stronger. The temperature and salinity fields created by the GEM accurately describe the mean circumpolar ACC frontal and water mass structure, while the dynamic height projection eliminates confounding effects from the highly variable frontal positions and eddies. ARGO profiling float data is used to independently evaluate the GEM fields and create a seasonal model of the upper 400m, significantly improving the GEM fit to hydrography and eliminating the summer bias in the field introduced by the historical data. ARGO also identifies regions where GEM errors are larger, notably south of western boundary currents, and during winter mixing. Elsewhere, the GEM fields accurately recreate ACC water masses along ARGO and ship tracks. The broad temporal range of the historical data used to create the GEM fields, and accuracy of its fit to much more recent ARGO data demonstrates the remarkable stability of the ACC frontal and water mass structure. TOPEX/Poseidon and Jason-1 SSH anomaly measurements can be used to create relatively high resolution (roughly 1/3 degree) ~10 day time varying T-S fields over the full depth range of the Southern Ocean from 1992 to present. The use of these fields to investigate the variability of circumpolar water mass volume and heat content over all depths on interseasonal and interannual timescales, and their correlation with wind stress and phenomena such as the SAM and ENSO will be discussed.

Keywords: gem, altimetry, acc



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Oral Presentation

5792

Constraints of PO₄* on the change in Antarctic Bottom Water production over the last 8 centuries.

Mrs. Hazel Grant

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A. C. Naveira Garabato, K. J. Heywood, D. P. Stevens

The processes of Antarctic Bottom Water (AABW) formation are not well understood and estimates of its production rate vary widely between 2 and 15 Sverdrups (Sv), depending on the method of estimation. Estimates using the quasi-conservative chemical tracer PO₄* have given a figure of 15 Sv (Broecker et al., Science, 1999) whereas decreased estimates are given using physical tracers such as potential temperature and salinity. To take account of these differences, Broecker et al. have suggested that the AABW production rate may have been decreasing over the last 800 years. An inverse box model of the Weddell Sea, using both physical and chemical quantities including PO₄*, has been developed. This method determines whether a consistent production rate can be achieved using both types of constraints. The box is bounded by the hydrographic transects of the ALBATROSS, WOCE A23 and SR4 cruises and the coast of Antarctica. Lowered Acoustic Doppler Current Profiler and mooring measurements are used to create initial reference velocities for geostrophic shear. The initial state gives estimates for the total transport of 21 Sv and 47 Sv by the Weddell Gyre. A variety of constraints such as volume conservation are applied to reconcile these two figures. From this model transport of AABW is diagnosed at around 5 Sv. The transports of PO₄* in this circulation will be discussed.

Keywords: weddell sea, aabw, po4star

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Oral Presentation

5793

A synoptic view of the Subantarctic Front in the southeast Pacific

Dr. Teresa Chereskin

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The velocity jets associated with the multiple fronts of the Antarctic Circumpolar Current (ACC) have most frequently been described from hydrographic observations, which resolve only the normal component of flow at the resolution of the station spacing. Direct velocity observations from surveys using acoustic Doppler current profilers (ADCPs) provide vector observations at high spatial resolution, although the measurement of total current includes ageostrophic currents that can mask the geostrophic signal. Using shipboard and lowered ADCP observations made during a 2005 austral spring survey in the southeast Pacific, the full-depth velocity structure of the Subantarctic Front of the ACC is mapped and the depth-dependent vorticity balance is examined. Objective mapping of the ADCP observations to a streamfunction enforces the geostrophic continuity constraint. The mapping employs a priori estimates of the mean at 2 depth levels: a surface dynamic topography derived from drifters and altimetry observations and an intermediate-depth pressure field derived from float observations. The Subantarctic Front is characterized by meanders of wavelength ~300 km over the relatively smooth topography upstream of Drake Passage. The barotropic or depth-averaged vorticity exhibits a balance between advection of planetary vorticity and relative vorticity. The depth-dependent vorticity balance implies a surface divergence which is balanced at depth by a divergence of the opposite sign.

Keywords: subantarctic front, antarctic circumpolar current, vorticity balance

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Oral Presentation

5794

Decadal changes in Ross Sea waters

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The characteristic properties of near surface Ross Sea waters are undergoing long-term changes (Jacobs, 2002). Inspection of historical profile data interpolated to selected depth levels and isopycnal surfaces indicates regions with the largest decadal variability in potential temperature and salinity. The inflow of Antarctic Surface Water to the eastern Ross Sea has become considerably fresher ($\Delta S = 0.2$ to 0.3) over the last 40 years. During the same time, Antarctic Surface Water near Ross Island has also freshened ($\Delta S = 0.05$) and cooled ($\Delta T = 1.0\text{C}$). Opposite to this during the same time frame, Circumpolar Deep Water inflows from the southern limbs of the Ross and Balleny gyres have become relatively warmer ($\Delta T = 0.3\text{C}$ to 0.4C) and saltier ($\Delta S = 0.03$ to 0.04). These two observations indicate that a more stable pycnocline has developed throughout the Ross Sea in recent years.

Keywords: ross, waters, decadal variability

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Oral Presentation

5795

Multiple jets of the Antarctic Circumpolar Current

Dr. Stephen Rintoul
Antarctic CRC CSIRO IAPSO

Maps of the gradient of sea surface height (SSH) and sea surface temperature (SST) reveal the Antarctic Circumpolar Current (ACC) consists of multiple jets or frontal filaments. The braided and patchy nature of the gradient fields is reminiscent of simulations of geostrophic turbulence on a beta-plane, but seems at odds with the traditional view, derived from hydrographic sections, that the ACC is made up of three continuous circumpolar fronts. By applying a nonlinear fitting procedure to 638 weekly maps of SSH gradient ($\text{grad}(\text{SSH})$), we show that the distribution of maxima in $\text{grad}(\text{SSH})$ (ie fronts) is strongly peaked at particular values of absolute SSH (ie streamlines). The association between the jets and particular streamlines persists despite strong topographic and eddy-mean flow interactions, which cause the jets to merge, diverge and fluctuate in intensity along their path. The SSH values corresponding to each frontal branch are nearly constant along the circumpolar path of the ACC. The front positions inferred from SSH agree closely with positions inferred from hydrographic sections using traditional water mass criteria. The existence of multiple branches of the Southern Ocean fronts explains why previous studies have sometimes disagreed on the location of the fronts. The path, width and intensity of the frontal branches are influenced strongly by the bathymetry. The meander envelopes of the fronts are narrow on the northern slope of topographic ridges, where the sloping topography reinforces the beta-effect, and broader over abyssal plains. The robust association between frontal filaments and particular streamlines, together with the invariance of water properties along streamlines, helps to reconcile the disparate views of the ACC derived from high resolution numerical simulations and from hydrographic sections.

Keywords: fronts, antarctic circumpolar current, jets

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Oral Presentation

5796

The Dynamics of the Antarctic Slope Front

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The Antarctic Slope Front is an oceanic front that appears to be a semi-permanent feature situated above or near long sections of the shelf break of the Antarctic continental shelf. These sections include the shelf break of the Ross and Weddell Seas. It is distinguished by a unique V-shaped structure, in which isopycnals slope downward from near the surface on both the shallow (continental shelf) and deep (continental slope) sides, towards the bottom near the upper part of the slope. In the regions where it is observed, the overflow of dense water from the shelf down the slope is observed or presumed to occur. Such overflows entrain fluid from the overlying stratified environment into the downflow, and this entrainment acts as a distributed sink of the overlying fluid. Here the response of this rotating stratified environment to such a spatial distribution of sinks is analysed with a semi-geostrophic frontal model. The result is a realistic depiction of the V-shaped structure, both on the shelf and over the slope, which is not dependent on the strength of the sinks provided that they are approximately steady and decreases with depth. The alongslope currents follow from geostrophy.

Keywords: antarctic, slope, front

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Oral Presentation

5797

Dynamics of the wind-driven sea level variation around Antarctica

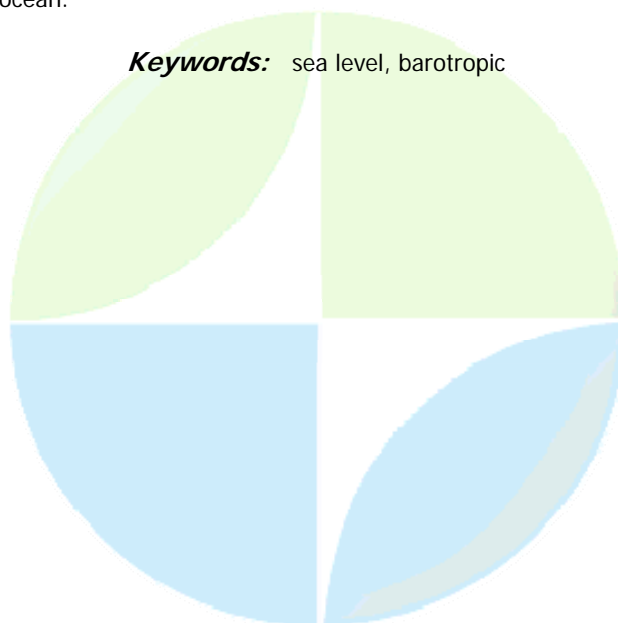
Dr. Kazuya Kusahara

Institute of Low Temperature Science Hokkaido University

Kay I. Ohshima

Coastal sea level variation around Antarctica is characterized by a circumpolar coherent fluctuation, correlated with the Antarctic Oscillation (AAO). This study addresses the dynamics of the wind-driven sea level variation around Antarctica. A barotropic numerical model incorporating the realistic wind stress and bottom topography well reproduced the observed sea level around Antarctica. The dominant circumpolar coherent signal and westward propagating signals are identified in the model. From spectral analysis of modeled coastal sea level in wavenumber-frequency domain, the amplitude of wavenumber-zero sea level, which is corresponding to the coherent variation, is the far largest component at periods longer than 10 days. At lower frequencies (0.005 cpd - 0.1 cpd), the spectral slope of the wavenumber-zero sea level can not be explained only by that of the wavenumber-zero forcing, corresponding to the AAO variation. This fact suggests that some dynamical effect amplify the coherent sea level variation around Antarctica at the lower frequencies. This dominant coherent sea level variation is trapped over the shelf and slope around Antarctica. As a mechanism of the trapped signal, we propose an analytical solution of oceanic response to alongshore wind stress over the shelf and slope in the circumpolar domain. In this solution, besides the shelf wave mode, the cyclic boundary condition yields a coherent mode, which characterizes the coastal dynamics around Antarctica. At periods from 10 to 200 days, the coherent sea level can be explained quantitatively by the solution of this coherent mode with a 5-10 day damping timescale. The coherent mode can respond to the wavenumber-zero forcing at any frequency and the degree of response increases with decreasing frequency. In addition, the wind stress of the wavenumber zero, corresponding to the AAO variation, is a dominant forcing. Therefore, the coherent sea level variation around Antarctica is generated preferably and resultingly becomes a dominant feature, particularly at lower frequencies. In the numerical model, the spectral peaks of the westward propagating signals, which can be explained by the resonance of the shelf wave mode are also found. The phase relation of observed sea level at periods from 13 to 16 days suggests that this westward propagating shelf wave mode at wavenumber one occurs in the real ocean.

Keywords: sea level, barotropic



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Oral Presentation

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Observed subsurface signature of Southern Ocean sea level rise

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LEGOS Physicien Adjoint IAPSO

Guillaume Valladeau

Satellite altimetry data show a strong increase in sea level in various parts of the Southern Ocean over the 1990s. We examine the causes of the observed sea level rise in the region south of Australia, using 13 years of repeat hydrographic data from the WOCE-SR3 sections, and the SURVOSTRAL XBT and surface salinity data. The hydrographic data show a poleward shift in the position of the Subtropical and the Subantarctic Fronts over the period. In the Antarctic Zone, the Antarctic Surface Water has become warmer and fresher, and the Winter Water tongue has become warmer, fresher, thinner and shallower. Increased freshening south of the Polar Front is linked to increased precipitation over the 1990s. Temperature changes over the upper 500 m account for only part of the altimetric sea level rise. The CTD sections show that the deeper layers are also warmer and slightly saltier and the observed sea level can be explained by steric expansion over the upper 2000 m. ENSO variability impacts on the northern part of the section, and a simple Sverdrup transport model shows how large-scale changes in the wind-forcing, related to the Southern Annular Mode, may contribute to the deeper warming to the south.

Keywords: hydrography, sea level, climate modes

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Oral Presentation

5799

A Stream function Diagnosis of the Antarctic Circumpolar Current Based on ARGO Profiles

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In the past few years more than 40,000 ARGO profiles have been collected in the Southern Ocean. The dataset proffers a new perspective to the region as compared with conventional hydrographic casts. In this study we apply a stream function projection method developed in Sun & Watts (2001) to diagnose the ARGO data. By comparing the results with previous hydrographic analyses, we are able to examine the long-term variability of water masses and heat flux in the Antarctic Circumpolar Current.

Keywords: acc, argo



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PS002

Oral Presentation

5800

Northern Hemisphere Influence on Transport of ACC

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We shall show that the surface boundary conditions on buoyancy in the Northern Hemisphere strongly influence the transport and stratification of the Antarctic Circumpolar Current (ACC). To demonstrate this, we use an ocean general circulation model in an idealized single-basin configuration with a high latitude circumpolar channel. A decrease of the northern hemisphere SST meridional gradient reduces production of deep water in the Northern Hemisphere, affecting the Meridional Overturning Circulation (MOC) and deepening the thermocline in both hemispheres. The induced change of stratification in the Southern Hemisphere circumpolar region increases the zonal volume transport of circumpolar current because of an increase in the local meridional density gradient and associated thermal wind shear --- the dominant baroclinic part of the total volume transport. The effects are strong and robust to changes in parameters and subgrid parameterization schemes (e.g., parameterization of mesoscale eddies, and of diapycnal diffusivity). For example, a 4 C increase in SST in the high latitudes of the Northern Hemisphere can lead to a change in the ACC transport of approximately 40 Sv. We will also discuss the implications of this result for the response of the ACC to climate change, which is predicted to be amplified in high latitudes in the Northern Hemisphere.

Keywords: acc, transport, interhemispheric

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5801

Response of the Antarctic Circumpolar Current to atmospheric variability

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Historical hydrographic profiles, combined with recent ARGO profiles, are used to obtain an estimate of the mean geostrophic circulation in the Southern Ocean. Thirteen years of altimetric sea level anomaly data are then added to reconstruct the time variable sea-level, and this new dataset is analyzed to monitor the position of the two main fronts of the ACC during the period 1993-2005. We relate their movements to the two main atmospheric climate modes of the Southern Hemisphere, the Southern Annular Mode (SAM) and the El-Nino Southern Oscillation (ENSO). We find that although the fronts are steered by the bathymetry, which sets their mean pathway at first order, in flat bottom areas the fronts are subject to large meandering due to mesoscale activity and atmospheric forcing. While the dominant mode of atmospheric variability in the Southern Hemisphere (SAM) is relatively symmetric, the oceanic response of the fronts shows substantial regional differences. Around the circumpolar belt the fronts vary in latitude, exposing them to different Ekman transport anomalies induced by atmospheric forcing. Three typical scenarios occur in response to atmospheric forcing : poleward movement of the ACC structure in the Indian basin during positive SAM event, a northward movement in the Central Pacific, and an intensification without substantial meridional movement in the Indo-Pacific basin. The study also shows the geographical regions which are dominated by a SAM or ENSO response.

Keywords: acc front, sam, variability

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5802

Variability and Adjustment in the Transport of the Antarctic Circumpolar Current

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David Marshall, Helen Johnson

Variability in the transport of the Antarctic Circumpolar Current (ACC) has a large influence on the rest of the world ocean and on climate. Here we investigate the hypothesis that interannual variability in the strength of the ACC is linked to tropical forcing, and aim to improve understanding of the physical processes controlling the variability of the ACC transport on a range of timescales. Two approaches to this are taken. Firstly, by considering the thermal wind balance across the Drake Passage, the ACC transport is broken down into components which depend on the stratification to the north and south. The stratification to the north of the Drake Passage may be closely tied to processes acting in the tropical Pacific through the propagation of coastally trapped Kelvin waves. The contributions from each of the transport components are diagnosed and analysed in a control integration of a coupled atmosphere-ocean general circulation model. We also consider the spin-up and adjustment of the ACC in a simple reduced-gravity model. This method allows us to identify the basic processes which control the adjustment of the ACC, and the mechanisms by which the changes are communicated from and to the rest of the global ocean.

Keywords: acc, variability



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5803

Winter observations of Antarctic Intermediate Water and Subantarctic Mode Water formation in the southeast Pacific

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Teresa Chereskin, Bernadette Sloyan, James Holte

Subantarctic Mode Water and Antarctic Intermediate Water are major global water masses, responsible for much of the anthropogenic carbon inventory and freshwater transport of the southern hemisphere. The formation of Subantarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW) was observed in late austral winter 2005, in the southeast Pacific west of Drake Passage. The new water masses formed as thick mixed layers (300 to 500 meters thick) in a 500 km band north of the Subantarctic Front. New SAMW and AAIW were clearly distinguished from each other. SAMW was formed in a meridional band characterized by relatively high surface salinity, apparently preconditioning the mixed layers to be the deepest in the region. The low potential vorticity SAMW layer spreading northward from the formation region was centered at potential density 27.02 kg/m³. In contrast, AAIW was formed in deep mixed layers exactly adjacent to the Subantarctic Front (SAF), with the potential density of the AAIW salinity minimum core, 27.05 kg/m³, set by the isopycnal that outcropped at the SAF. The SAF is a relatively strong barrier to isopycnal spreading of properties from south of the front to north of the front. However, some cross-frontal mixing is indicated by somewhat reduced salinity north of the front compared with the high salinity SAMW band. Mixing is likely to occur through cross-frontal intrusions with vertical scales of 50 to 100 m, evident at the base of the winter mixed layer and throughout the surface layer in the subsequent austral summer 2006 survey.

Keywords: watermass, mixed layer, antarctic intermediate water



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5804

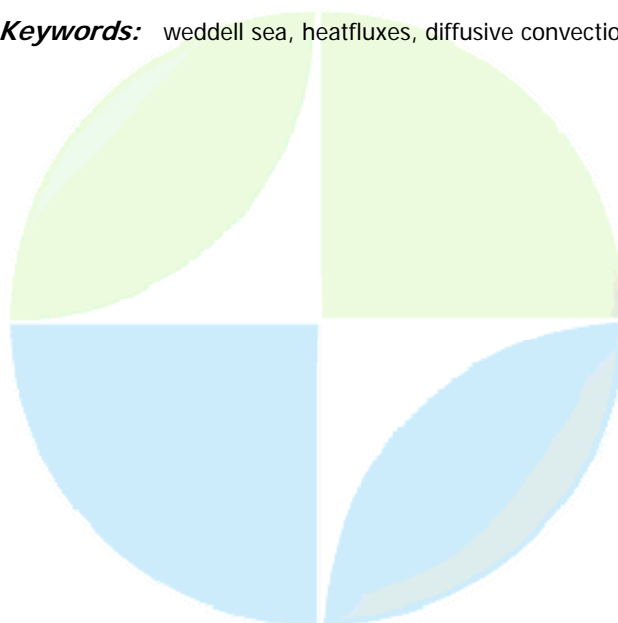
CANOPO Project: Vertical profiles of temperature in the Weddell Sea

Dr. Volfango Rupolo
ACSCIM-MOD ENEA

Artale Vincenzo, Balestrini Carlos, Bianchi Alejandro, Budillon Giorgio, Busdraghi Fabiano, Charo Marcela, De Alteris Arturo, Iudicone Daniele, Ochoa Hector, Ruiz Pino Diana, Schloss Irene, Ullrich Alejandro

In the frame of the joint Italian-Argentine CANOPO (PNRA) research project, 323 XBT temperature profiles (up to 700 -1000 m depths) were collected during four summer cruises from 2004 to 2007 in the Weddell Sea . The data were obtained in two repeated legs: from the tip of the Antarctic Peninsula to Orcadas Islands and from these islands to the Argentine Station Belgrano II (77 52 S 34 52 W). In the Weddell Sea relatively salty-warm Circumpolar Deep Water enters from its eastern part and cyclonically flows at intermediate depth in the Weddell Gyre where it is subjected to a progressive freshening and cooling due to the mixing processes with local waters. This process leads to the formation of Warm Deep Water (WDW), the major source of the Deep and Bottom waters of the Weddell Sea . Previous studies have shown a warming trend of the WDW from the 70's to 2000, both in the eastern (inflow region) and north western part (outflow region). Both legs mentioned above allow the monitoring of the core and upper layer of the Weddell WDW. The WDW westward southern branch was intercepted, depending on the ice condition, approximately from 74 S 25 W to 71 S 15 W, off both Brunt-Riiser and Larsen ice shelves. From 2004 to 2007 this WDW branch has not experienced any significant temperature trend, the WDW core is at approximately 300 m depth and it is characterized by a temperature maximum (Tmax) of 0.80-0.85C. In the North Western Weddell Sea, the WDW core is intercepted both south and west of the Orcadas Islands .In this area preliminary analysis on the collected data show a higher variability. The WDW core follows bathimetric isolines and its temperature ranges from 0.6 to 0.7C. Finally, many vertical profiles (about 20 %) show 'staircase' thermal structures (up to 80 m long), typical of diffusive convection between the salty and warm WDW water and the shallower fresher and colder water above it. A census of such structures in the central Weddell Sea will be presented in order to assess the importance of double diffusive phenomena in the vertical fluxes of heat.

Keywords: weddell sea, heatfluxes, diffusive convection



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5805

The Agulhas Current System in a global high-resolution OGCM simulation

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Mikiko Ikeda, Hiroyasu Hasumi

The Agulhas Current and its eddy activities were simulated in a high-resolution global ocean general circulation model (OGCM). The OGCM is newly developed one and numerically efficient because it is based on a cubic grid, a quasi-homogeneous grid on the sphere. The resolution of the global model is about 15 km, which is high enough to capture the small but important phenomena in and around the Agulhas Current System. Indeed the model reproduces characteristic eddy activities in this region as follows. In the model, the Agulhas rings are shed realistically and then deformed, merged with the eddy in the Cape Basin and sometimes reconnect with the Agulhas Retroflexion. Many rings and eddies exist at the same time in the Cape basin, where vigorous stirring and mixing occur. The model also shows a train of eddies in the Mozambique Channel, one of the upstream regions of the Agulhas Current. Natal pulse, solitary meander observed intermittently in the Agulhas Current, is also reproduced consistently with the observation; the meander of Natal Pulse is spawned at the Natal Bight triggered by the eddies from the Mozambique Channel and then grows as it flows downstream. Since those eddy activities are important in the interbasin exchange between the Indian Ocean and the Atlantic Ocean, the model would be applied to the study of the role of the Agulhas Current system in the global thermohaline circulation. Especially, this model could be able to evaluate in detail the relative contribution of the cold and warm water route in the return pass of the North Atlantic Deep Water (NADW).

Keywords: agulhas current, ocean model

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5806

Antarctic Coastal Polynya Response to Climate Change

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Antarctic coastal polynyas are regions of large sea ice production that produce dense shelf waters capable of driving Antarctic Bottom Water formation. We investigate the sensitivity of the Mertz Glacier Polynya to perturbations of air temperature, windstress, and precipitation associated with projected future climate change. Our Mertz Polynya Model simulations for 1996-1999 span a transitional period: a 1996-1997 strong polynya state is characterised by high sea ice growth and export, surface heat flux, shelf water density, and dense water export rate; in the 1998-1999 weak polynya state all these quantities are greatly reduced. The 1990's interannual variability in air temperature and precipitation is of similar magnitude to the IPCC assessment projected future changes for the Southern Ocean. We model the polynya with perturbed climate change forcing and find that the system shows a reduction in shelf water export in both the strong/weak modes. Overall, the dense water export is reduced by 40% for a 2 C surface warming, and by 33% for a 20 cm/a precipitation increase. In the weak polynya state that is more likely in future climate, shelf water export is reduced by 81% for the warming and by 65% for the freshening. The response to a 20% increase (decrease) in windstress is approximately equal in magnitude to a 2 C atmospheric cooling (warming). The reduction in dense shelf water export implies a weakening of the Antarctic Bottom Water formation that feeds the lower limb of the global meridional overturning circulation.

Keywords: polynyas, climate, model



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Eddy fluxes in the circulation of Antarctic Intermediate Water and implications for climate models

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Antarctic Intermediate Water (AAIW) is believed to play a key role in the oceanic uptake of anthropogenic carbon dioxide. The capability to adequately model the formation and circulation of AAIW is relevant for climate models with an ocean carbon cycle. The ventilation of AAIW in a global ocean model is greatly affected by the horizontal resolution of the model, particularly in the Atlantic sector. Three versions of OCCAM (run by colleagues at the National Oceanography Centre, Southampton) give significantly different values for the meridional volume transport of AAIW across 30° South in the Atlantic. For the period 1988-2002, the 1/12 degree (eddy-resolving) model exports an average of 5.4 ± 1.0 Sv of AAIW north of that latitude, more than double the volume transport obtained in the lower 1/4 degree (eddy-permitting) resolution (2.4 ± 0.9 Sv), while the lowest resolution (1 degree) gives an intermediate value of 3.5 ± 0.6 Sv. This difference in transport of the water mass is reflected in the changes of AAIW properties. At 1/12 degree resolution, the model maintains the initial climatology of the AAIW core, while at the lower resolutions increases of 0.2 in salinity and 1 degree C in potential temperature are observed. These results indicate that the representation of eddy fluxes achieved in the high resolution model is necessary for a realistic picture of the meridional circulation of AAIW. We discuss the implications for climate models that attempt to include the ocean carbon cycle but are at present limited to a low resolution of ocean circulation.

Keywords: aaiw, global ocean model, eddy flux



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Modes of Interannual to Multi-Century Water-Mass Variability in the Southern Ocean

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Detection of long-term climate change requires knowledge of natural variability in the ocean-atmosphere system. In the Southern Hemisphere, climate variability is evident on time-scales of days to centuries, yet we know relatively little about how this forces interior ocean fluctuations, nor how these fluctuations feedback to the atmosphere. In this paper we will examine the magnitude and mechanisms of Southern Ocean water-mass variability in models and (where available) observations. It turns out substantial heat content anomalies can be generated via natural oscillations in winds, sea-ice and air-sea exchanges. The Southern Annular Mode projects onto sea surface temperature in a coordinated annular manner - with a conspiring of dynamic and thermodynamic processes yielding a strong SST signal. We find that Subantarctic Mode Water (SAMW) variability reflects fluctuations in the equatorward Ekman transport of cool, low salinity water across the subantarctic front. In contrast, anomalies in air-sea heat fluxes and ice meltwater rates drive variability in Antarctic Surface Water, which gets subducted along Antarctic Intermediate Water (AAIW) density layers. SAMW variations also spike T-S variability in AAIW, particularly in the southeast Pacific and southeast Indian Oceans. Finally, we find that substantial water-mass change can result from a gradual latitudinal shift in the zonal wind-stress maximum associated with the subpolar westerlies. The implications of these findings for climate change/variability are discussed.

Keywords: water masses, southernocean, southernannularmode



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5809

The Global Ocean Conveyor Belt, the Southern Hemisphere Supergyre and their variations with time

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IAPSO

Bruno Blanke, Olivier Marti, Wenju Cai

The oceans role in climate manifests itself through its high heat capacity, its own rich internal dynamics and its capability to transport heat and fresh-water within the global ocean thermohaline circulation (THC). Because of the lack of observations, descriptions of the detailed circulation pathways have been difficult, and have been provided in terms of conceptual schemes. We have established the first quantitative, global three-dimensional picture of the THC using a Lagrangian reconstruction, which integrates hundreds of thousands of water parcel trajectories in a global ocean general circulation model. The resulting pattern enlightens the crucial role of the wind action in structuring the return flow to the North Atlantic. In particular, it reveals a strong link with the three subtropical gyres of the Southern Hemisphere (SH), which merge into a large three-ocean wide cell, referred to as the SH supergyre. Because the THC pathways connect different regions of air-sea interaction, variations in their structure may influence the water masses they convey, and their associated heat and fresh-water transport. This may induce large differences in the climate impact of the global ocean circulation. Therefore, the evidence that the supergyre plays a significant part in the THC has important implications for the understanding of the oceans role in the Earth climate and its changes. We show how the SH wind could have induced a different THC during the Last Glacial Maximum compared to the present climate could impact actual modifications of the supergyre and thus of the THC. We will also show how the supergyre and the water masses advected finally in the South Atlantic are affected by eastern boundary dynamics and nonlinear ocean dynamics

Keywords: climate, physical oceanography, ocean atmosphere dynamics



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Can surface buoyancy loss prevent deep upwelling in the Southern Ocean?

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The strength of the Antarctic Circumpolar Current and its associated meridional overturning circulation are tightly coupled to the windstress field over the Southern Ocean as well as to the surface buoyancy forcing. While it is arguably easier to constraint the surface buoyancy forcing than the winds in alternative climate states, most of the past research effort has been focussed on studying the role of the winds. Here we test the hypothesis that negligible buoyancy input to the Southern Ocean during glacial periods prevented the deep upwelling of dense water to the surface in spite of prevailing winds. We present results from an Ocean General Circulation Model study in which the surface buoyancy forcing over the Southern Ocean was systematically reduced to zero and discuss the implication of the results for glacial-interglacial carbon cycle dynamics.

Keywords: southern ocean upwelling, glacial intergalacial, carbon cycle

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Oral Presentation

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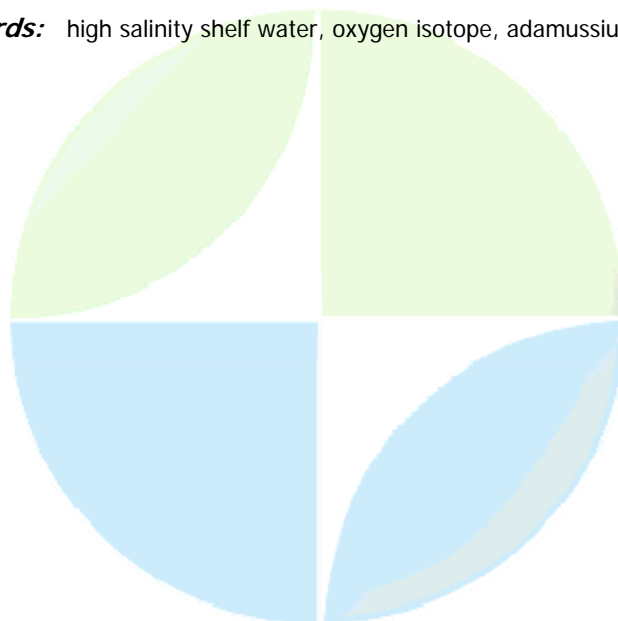
High Salinity Shelf Water Variability and its oxygen isotopic signature

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ISMAR CNR IAPSO

Stefano Aliani, Mariachiara Chiantore, Olaf Heilmayer

In the Pacific sector, High Salinity Shelf Water (HSSW) is a key constituent of the Antarctic Bottom Water (AABW) that plays an important role in ventilating the global deep ocean. HSSW is formed by brine release during sea ice formation when katabatic wind produces important polynya phenomena mainly in southern Victoria Land near Terra Nova Bay (TNB). The water masses characteristics become geochemical signals that can be coded once incorporated by benthic organisms. Isotopic and elemental chemistry of carbonate, whether formed as the shell of an organisms or through abiotic chemical reactions, captures a record of the temperature and chemistry of fluid from which it was formed, as such, carbonate chemistry serves as an important proxy. In near shore waters of the Ross Sea, one of the most conspicuous carbonate building organisms is the endemic scallop *Adamussium colbecki* (Smith, 1902, Chiantore et al., 2001). Stable isotope profiles of shell carbonate (for review see Richardson, 2001) have recently been applied to identify its annual growth pattern, as well as for other Antarctic invertebrates (e.g. Marshall et al., 1996; Brey and Mackensen, 1997). Stable oxygen ratios ($\delta^{18}O$) are inversely related to temperature (Epstein et al., 1953) hence lower $\delta^{18}O$ characterises shell parts deposited during spring/summer, whereas higher values correspond to parts formed during autumn/winter. TNB where *Adamussium* are present in large number is characterized to be a source of HSSW, dense enough to flow northward and trigger downslope processes to the abyssal depths. Moreover, it ventilates also the Ross cavity contributing to the ISW formation. These are super-cold waters, characterized by a temperature below the surface freezing point, originating below the RIS. The interaction leading to the melting and freezing in different areas produce plumes that outflow in particular positions along the RIS edge. This process can trigger important exchanges between the open ocean, interacting with the atmosphere, and the ocean cavity, which can have a longer memory of the past conditions. This study is based on data coming from current meter mooring in TNB area compared with stable isotope analysis of *Adamussium colbecki* samples collected during 2000 in the same area. A first step in coupling physical instrumental data and marine biological proxy signal will be shown.

Keywords: high salinity shelf water, oxygen isotope, *adamussium colbecki*



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On the role of the Southern Ocean in the global ocean circulation

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The Southern Ocean has recently gained interest for its important role in the global thermohaline circulation. Recent studies propose that it is also the main player in the redistribution of tracers at global scale. A summary of the results from a quantitative analysis of the thermohaline circulation of the Southern Ocean of a steady state simulation of a coupled ice-ocean model is thus presented. The main aim of the study was to clarify the roles of surface fluxes and internal mixing, with focus on the mechanisms of the deep water upwelling. During the study a new approach for the evaluation of water-masses transformations in the ocean has been developed. The resulting analysis of the thermodynamic processes associated to the thermohaline circulation showed that Southern Ocean surface fluxes produce almost 40 Sv of Subantarctic Mode Water while brine rejection forms 5 Sv on the shelves of Antarctica and in the Weddell Sea. Mixing is found to compensate most of the surface transformations. A complementary Lagrangian analysis allowed to identify the main pathways associated to the thermohaline circulation in the Southern Ocean of the ice-ocean coupled model. The model Southern Ocean is characterized by a shallow overturning transforming 20 Sv of thermocline waters into mode waters and a deep overturning related to the formation of Antarctic Bottom Water. The consumption of North Atlantic Deep Water in the Southern Ocean was also characterized using both Eulerian and Lagrangian approaches. Most of the model North Atlantic Deep Water is found to be transformed into sub-surface and bottom waters. Its upwelling into sub-surface waters is due to internal process, mainly vertical propagation of the surface freshwater excess via vertical mixing at the base of the mixed layer. Finally, the Lagrangian analysis was used to address how the Southern Ocean redistribute freshwater in the oceans. As a main result the Antarctic Intermediate Water is found not to be the main freshwater export. The role of the Southern Ocean thermohaline circulation on the redistribution of natural CO₂(DIC) and nutrients at global scale will also be discussed.

Keywords: southern ocean, thermohaline circulation, biogeochemical tracers



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Carbon dioxide and respiration coupling across ACC (from NZ to Antarctica)

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Giorgio Budillon, Serena Fonda Umani, Andrea Bergamasco

Carbon dioxide and respiration coupling across ACCManno C. The dominant physical control on biogeochemical distribution in the Southern Ocean is the banded structure of the Antarctic Circumpolar Current (ACC) that extends unbroken around Antarctica. During the XXI Italian Antarctic expedition (CLIMA IV project, Climatic Long- term interactions for the Mass Balance in Antarctica), surface seawater samples were collected from underway continuous pump at every longitudinal degree (from 48 to 71) along the New Zealand Antarctica transect. Surface (underway continuous sensor) and subsurface (XTD probes) temperature data were used to localized the position of the main fronts which separate different water masses and dynamical regimes of the ACC. The 2600 km long transect was occupied in about 4 days at the beginning of January 2006 providing a quasi synoptic picture of the upper ocean thermal structure. Here we discuss the role of the main ACC fronts south of New Zealand in regulating CO₂ concentration emphasizing the contribution of planktonic respiration. First results show an anomalous warming of the surface layers extending south of the northern branch of the Sub Antarctic Front, as well as a southward shift of both the southern branch of the SubAntarctic Front and the Polar Front . In this area planktonic respiration was very high suggesting a fast shift from an atmospheric-ocean CO₂ sink to an oceanic CO₂ source.

Keywords: co₂, respiration, acc



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Interannual variability of the heat fluxes in the Ross and Weddell Seas

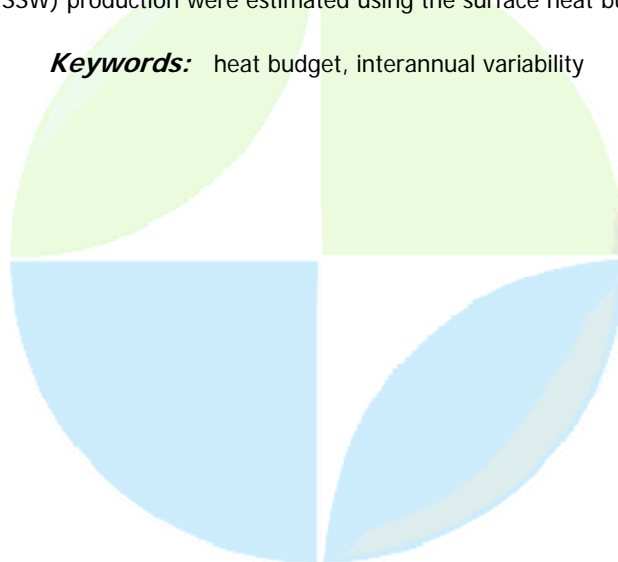
Dr. Giannetta Fusco

Dipartimento di Scienze per l'Ambiente Universit degli Studi di Napoli 'Parthenope' IAPSO

Tiziana Peluso, Giorgio Budillon, Giancarlo Spezie

In the polar regions, waters coming from the Antarctic Circumpolar Current are transformed into Antarctic bottom, deep, shelf and surface waters through complex processes of interaction with the atmosphere and with the glacial and sea ice. The intensity of the inflow and the outflow and the rate of the water mass conversions are clearly related to the seasonal and interannual fluctuations in surface wind stress and heat flux. In the Ross and Weddell Seas, dynamical and thermodynamical interactions between atmosphere and ocean are strongly influenced by the presence or absence of the ice cover, which forms an insulating layer over the ocean, hindering sensible heat fluxes and forming an effective barrier to evaporation and thus preventing latent heat loss. In this work we analyze the interactions between atmosphere and ocean focusing our attention on the heat budget in the Ross and Weddell Seas. Wherever the ice cover is absent all year round, such as in leads or polynyas, the air-sea fluxes can be very large, especially in winter when the air-sea temperature differences are strong. Heat exchanges between sea and atmosphere, whether ice cover was present or not, were calculated using ERA-40 re-analysis data provided by the ECMWF for the whole period available (September 1957 August 2002). In order to evaluate the role of the atmospheric forcing in the last years (2002-2006, for which ERA-40 re-analysis are not available), the ECMWF operational analysis were also used. Sea ice data were collected from the U.S. National Ice Center and National Climatic Data Center. Surface heat budget was estimated at each grid point (0.5 in both latitude and longitude) every six hours obtaining monthly and yearly averages. By integrating the surface heat fluxes over the studied areas we obtained the yearly mean heat budget. During the available period, in the Ross Sea, the heat loss reaches its maximum in 1989 (-130 Wm⁻²) and its minimum (-86 Wm⁻²) in 1980. A mean value for the entire period is -103 Wm⁻² with a standard deviation of about 9 Wm⁻². In the Weddell Sea the heat loss reaches its maximum in 1979 (-122 Wm⁻²) and its minimum (-91 Wm⁻²) in 1989 with a mean value for the entire period of -109 Wm⁻² and a standard deviation of about 8 Wm⁻². For both areas the CDW provides the major source of heat (and salt) compensating the yearly mean heat loss, from the sea to the atmosphere. Assuming a constant temperature of the incoming CDW we estimated the amount of water needed to preserve the annual surface heat budget for both Seas. Moreover, in the main polynya areas, the sea-ice and High Salinity Shelf Water (HSSW) production were estimated using the surface heat budget.

Keywords: heat budget, interannual variability



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Oral Presentation

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Variability and transport of the Antarctic circumpolar Current South of Africa

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Isabelle Ansorge, Sabrina Speich

Data from 21 hydrographic sections south of Africa, are used to estimate the transport of the ACC between Africa and Antarctica. Surface dynamic height (referenced to 2500 m) is derived from XBT data, by establishing an empirical relationship between vertically-integrated temperature and surface dynamic height calculated from CTD data. This temperature-derived dynamic height data compares closely (average RMS difference is 0.05 dyn m) with dynamic heights calculated from CTD data. A second empirical relationship between surface dynamic height and cumulative transport has been defined allowing us to monitor a more extensive time series of transport, derived from all available upper ocean temperature sections. Over a period of 16 years, XBT data taken from 18 hydrographic transects of the ACC, in the region of the study, produce an average baroclinic transport estimated at 87.5 3.97 Sv relative to 2500 m. This estimate is analogous with geostrophic transport values calculated from CTD data. Weekly maps of mean dynamic topography (MDT) collate closely with the CTD dynamic heights. The MDT dataset is used to deduce ACC transport estimates by exploiting the relation between dynamic height and cumulative transport. The estimated mean transport of the ACC, obtained here, is 110 18 Sv. These transports agree well with simultaneous in-situ estimates (RMS difference in net transport is 5.2 Sv). This suggests that sea level anomalies largely reflect transport changes above 2500 m. Dynamic heights derived using the methodology presented here will improve our ability to compare satellite sea surface height measurements with in-situ data, in a data sparse region. Additionally, improved measurements of transport, using high density XBT sections, allow us to monitor the variability of the ACC's flow on improved spatial scales while altimeter derived transports greatly advance the temporal resolution, than could not be undertaken using CTD sections or current meter arrays alone.

Keywords: transport, altimetry, acc



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Oral Presentation

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Submarine geomorphology and bottom current signature on antarctic sediment: examples from the George Vth continental shelf and slope (East Antarctica) George Vth, Holocene, Geomorphology

Dr. Laura De Santis

Geophysics of the Lithosphere Istituto Nazionale di Oceanografia e di Geofisica IAPSO

Andrea Caburlotto, Massimo Presti, Daniela Accettella, Andrea Cova

The production of deep water from the George Vth shelf (East Antarctica) has a key role in the formation of AntArctic Bottom Water, one of the water masses that regulate the global thermohaline circulation. Nowadays, the shelf depression between 142 and 150 E, is a main site of production on the shelf of dense and saline water mass. For this reason, sediment transport and deposition processes on the shelf, slope and rise of the area are being investigated by several projects (PNRA/WEGA 2000, NSF/CHAOS 2001, Images-MD130-CADO 2003, PNRA/MOGAM 2006) and further oceanographic cruises are planned in 2007 and 2008 (joint Australian-French IPY-CAML project, Australian IPY-CASO project, Italian IPY SASSI-SON proposal). Swath bathymetric, sub-bottom acoustic survey and sediment cores from the continental shelf, slope and upper rise of the George Vth Land documents bottom current activity since the Last Glacial Maximum and during past cycles. Detailed geology and geophysical study in the Mertz-Ninnis Trough have revealed clear signature of present bottom current activity and significant changes in the bottom current production throughout the Holocene warmest time interval (3000-5000 years). Signals of bottom current downslope flow and of its variations in past glacial and interglacial cycles, have been also detected in slope sediments, back to Isotopic stage S116. New multibeam survey shows that the continental slope and rise seaward of the Mertz-Ninnis Glacial valley sill is actually incised by a complex network of converging submarine canyons (the Jussieu Canyon system), some of which directly connected to the shelf depression. This sea bed character differ from that observed in other Antarctic margins (e.g. the Antarctic Peninsula) that generally show gullies across the shelf edge, smooth slope morphology and channel systems incising the upper rise. The peculiar morphology of the George Vth margin sea floor likely reflects the intense dynamics of dense water spilling off the shelf and flowing down the continental slope, probably channelled within the canyons. The strata truncation along the flanks of the canyons, the exhumation of buried, relict features along the present slope and thick turbiditic deposit (up to 1 m) recovered from the Jussieu Canyon levees in the rise would suggest that erosive processes still strongly affect the George V Land margin. In analogy with other areas of dense water production, we believe that shelf water cascading currents driven by salinity contrast and also entraining fine organic and terrigenous particles, might have the capacity for reshaping submarine canyon floors and carrying sediment to the deep sea environment. Further investigation of this margin in the frame of coordinated multidisciplinary International Polar year initiatives will collect the needed oceanographic observations to provide regional models of modern ocean-climate process.

Keywords: george vth, holocene, geomorphology

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Poster presentation

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ENSO and the west Antarctic Peninsula

Mrs. Margaret Wallace

Physical Sciences Division British Antarctic Survey Open University IAPSO

Mark Brandon, Mike Meredith, Andrew Clarke

The west Antarctic Peninsula (WAP) has experienced marked climatic warming over the past ~50 years. Atmospheric and cryospheric changes have impacted on the ocean, with profound implications for marine life, both on the biologically-rich WAP and potentially at localities downstream in the Antarctic Circumpolar Current (ACC). It is therefore vital that we understand the regions changing climate, and its associated oceanographic effects. Climatic reanalyses and global sea surface temperature products are used to address this, and show that the ocean here is coupled to the El Nio-Southern Oscillation (ENSO) phenomenon, although the mechanisms connecting the WAP to the equatorial (ENSO source) regions differ between the shelf and open-ocean domains. Nine years of oceanographic data from the Rothera Time Series (RaTS) of CTD casts from northern Marguerite Bay reveal the short-term sensitivity of the region to the ENSO cycle and provide information on the response of the subsurface ocean to this climatic forcing. Remote forcing from ENSO is joined by local forcing from variability in the flow of the sub-surface Circumpolar Deep Water (CDW). The combination of climatic and in situ oceanographic data provides insight into the forcing and response of one of the most rapidly changing regions in the world.

Keywords: enso, antarctica, upper ocean

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Poster presentation

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Ten years of currentmeters measurements in Terra Nova Bay (Ross SEA, Antarctica): data set presentation

Dr. Paola Picco

X

Andrea Cappelletti, Paola Esposito, Daniela Martucci, Giannetta Fusco, Roberto Meloni

Since 1994, in the framework of the activities of the Italian National Programme of Antarctic Research (PNRA), an oceanographic mooring is operating in Terra Nova Bay. It is located in the middle of the bay, at 7455.11' S; 16420.04' E at a sea depth of about 1100 m, an area characterised by the presence of a persistent, latent heat polynya. It is equipped with eulerian currentmeters and temperature and conductivity sensors. Mooring composition slightly changed from year to year, but measurements at three different levels: undersurface (100 m -140 m), intermediate (400 m -500 m) and deep (700 m - 1000 m) were always ensured. Thanks to the huge efforts to maintain this mooring, an impressive long time series of currents, temperature and salinity data in a crucial area of Antarctica is now available. A description of the data with some statistical information is presented. This allows to approach the study of the seasonal and interannual variability, thus contributing to a better understanding of the dynamics of the area. On the average, currents analysis reveal a strong barotropic northeastern flow with a limited interannual variability. The kinetic energy time serie presents a characteristic seasonal trend: currents at the intermediate and deep layers have the minimum energy during the summer period (November-February), then strongly increase reaching the maximum late August. Currents in the undersurface layer display a more pronounced interannual variability even an absolute maximum generally occurs between December and February. The seasonal cycle of melting and dense water formation is able to influence the salinity also at high depths: time series at 100 m-140 m evidence minima around 34.65 from April to June and maxima up to 34.85 from September to November, while salinity variations at greater depths, due to the different amount and characteristics of High Salinity Shelf Water produced each year, cannot be resolved.

Keywords: terra nova bay ross sea, currents, temporal variability



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Poster presentation

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SOPHOCLES -Southern ocean physical oceanography and cryospheric linkages.

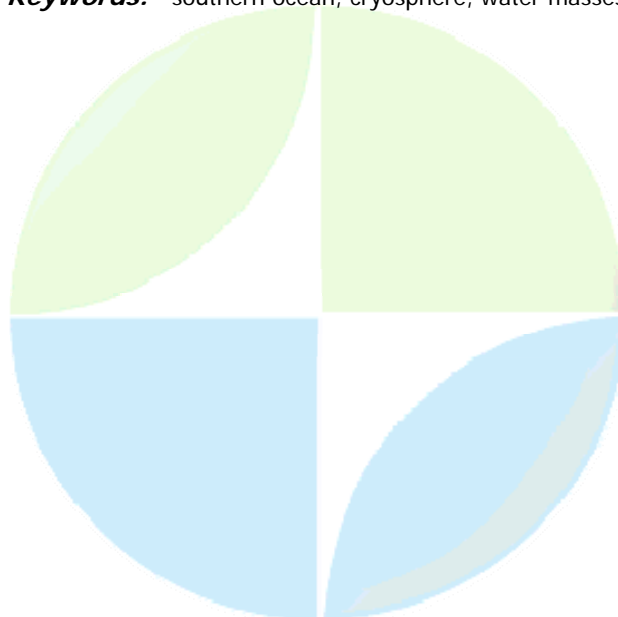
Dr. Siobhan Ofarrell

Marine and Atmospheric Research CSIRO IAPSO

Dr Victoria Lytle, Dr Anthony Worby, Dr Todd Arbetter

During the last 6-9 months there have been discussions underway as to how well models used in both regional and global modelling programmes for issues from sea ice forecasting through to climate change represent the processes that govern the interaction between the ocean and the marine cryosphere. In the Arctic, there is a European programme (DAMOCLES) that considers the physical range of process that governs the interaction of the cryosphere with the atmosphere and ocean. It also covers ecosystem and social issues. SOPHOCLES will be a much smaller programme focussed on the Antarctic region which will fill gaps in existing programmes. The timing of the programme has been driven by an increase in the quantity and quality of observational data that will be obtained through field programmes within IPY. There has also been an increase in the availability of ice thickness data from the Antarctic that can be used to verify the models, alongside the longer time series of ice concentration data. This improvement in ice thickness data is set to continue with more intense field programmes during IPY and data acquired from airborne and satellite sensors. Cryospheric processes to be focussed on include ice formation in coastal polynyas, snow and snow-ice formation and the flux of ice shelf water into the Southern ocean, and the interaction with the glacial ice both in the ice-shelf cavities and with direct melting of glacial ice and icebergs. It is intended that the region of interest will be broader than the sea ice zone and will include processes across the Southern Ocean since many ice-ocean process affect the dense water masses. As well as a focus on Southern ocean water masses, there will be a focus on the dynamics of the main ocean currents, their interaction with topography, and the representation of sub-grid scale processes such as down slope flows, eddy mixing and ocean convection. The ice and ocean model communities have close synergies; poor performance in one model component usually affects the performance of the other component. The aim is to include regional, circumpolar, and global ice-ocean models in different configurations.

Keywords: southern ocean, cryosphere, water masses



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Poster presentation

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The chemical signature of water masses mixing off Victoria Land, Ross Sea, Antarctica.

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Serena Massolo, Maria Luisa Abelmoschi, Andrea Bergamasco, Giorgio Budillon

The Ross Sea is one of the major contributors to the Antarctic Bottom Water (AABW), which plays an important role in ventilating the deep ocean. High Salinity Shelf Water (HSSW) is an important constituent of AABW. HSSW is formed by brine release during sea ice formation in Terra Nova Bay polynya and it contains relatively high concentrations of dissolved oxygen. One branch flows southward and it takes part in the production of Deep Ice Shelf Water (DISW), flowing underneath the Ross Ice Shelf. The other branch moves northward to the shelf break, where it sinks and mixes with Circumpolar Deep Water (CDW). CDW is a relatively warm, oxygen-low and nutrient-rich water mass, transported onto the shelf in an episodic but persisting way at specific locations along the continental shelf break. The CDW intrusions affect both thermohaline and chemical properties of the subpycnocline shelf waters. The area near the continental margin off of Victoria Land is considered to be one of the sources of the Antarctic Bottom Water originated during cascading down slope phenomena where HSSW dense waters mixes with CDW. The recently observed freshening of HSSW modify the thermohaline and chemical properties and the volume of locally produced bottom waters and, as a consequence, affect the ventilation processes of the deep layers. The chemical tracers NO, PO and PO₄^{*}, obtained by a combination of dissolved oxygen and nutrients concentration, can be used to estimate the relative contributions of shelf water to the deep layers, as they are quasi-conservative. Recently ventilated dense water spilling off the continental margin have the highest content of these tracers, as a direct reflection of the contribution from high-oxygen surface waters. This study is based on dissolved oxygen and nutrient data collected off Victoria Land (Ross Sea) during the austral summer 2005-2006 within the XXI Antarctic Expedition of the Italian National Program of Research in Antarctica (PNRA). Mesoscale experiments, focused on the interaction between overflowing HSSW and entraining CDW near the Antarctic slope, were carried out within the framework of Climatic Long Term Interaction for the Mass-balance in Antarctica (CLIMA) and Polar Deep Ocean VENTilation (PolarDOVE) projects. In this context, our primary aim was to trace by employing NO, PO and PO₄^{*} the recently ventilated water overflowing at the shelf break and its mixing with CDW. The results show that shelf water chemical signature at the shelf break is weak and it becomes comparable to the CDW signal on the slope. Therefore, it seems that in 2006 the active down slope phenomena were of low entity. An estimate of the production rate of the overflowing water, considering also volume and velocities of the involved water masses was done to confirm this finding. Finally, we evaluate the inter annual variability of HSSW fraction which can contribute to the overflow events, by comparing the 2005-2006 data set with data collected in previous surveys (2001-2005) of CLIMA and AnSlope projects.

Keywords: rosssea, ventilation, tracer

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Sulphur oxidised compounds stratigraphies from Talos Dome, D66, Law Dome Ice Core as proxy of climatic variability in the Southern Ocean

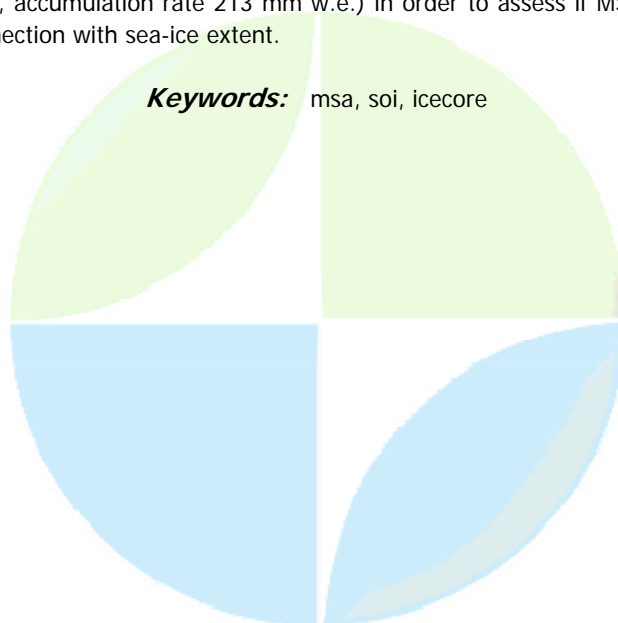
Dr. Silvia Becagli

Chemistry University of Florence

Emiliano Castellano, Andrea Morganti, Mirko Severi, Rita Traversi, Marco Proposito, Massimo Frezzotti, Mark Curran, Roberto Udisti

On interannual to decadal time scales tropospheric Antarctic circulation is dominated by three forces: SOI (Southern Oscillation index), AAO (Antarctic Oscillation or Southern Annular Mode) and ACW (Antarctic Circumpolar Wave), but their relative importance in affecting climate in Antarctica is still controversial also for recent time. Furthermore, the reconstruction of these meteo-climatic variability for the past represents a key issue in order to understand the processes correlated to global climatic change. The effect of climate change in the Southern Ocean is likely to be the major perturbation of the environment, which will lead to biogeochemical and ecological change. Several study hypothesize a correlation between SOI positive values (La Nina events) and sea ice extent in the Ross sea sector in turn related to biogenic activity. Ice algae in the sea ice zone contain large amount of organic sulphur species, such as dimethylsulphopropionate (DMSP), DMS precursor. Seasonal melting of sea-ice can release DMSP with consequent sea-to-air flux and subsequent formation of MSA and non-sea-salt SO₄²⁻ (nssSO₄) in the atmosphere. Methanesulphonic acid (MSA) measured along ice cores was largely used as a marker of past marine biogenic activity but MSA record from ice cores drilled in central Antarctic sites exhibits several interpretation problems due to the low accumulation rate (loss of seasonal signal and/or post-depositional movement in the ice or re-emission into the atmosphere). On the contrary, coastal sites ice cores are more suitable in reconstructing past oceanic productivity changes by MSA stratigraphies thanks to their conservative character and because they generally fix MSA in the snow (thanks to the higher accumulation rate) and are less affected by arrival of MSA from lower latitudes by long range transport. In this work, we discuss about the link between SOI and ACW and MSA stratigraphies obtained from three ice cores drilled in East Antarctica sites: Talos Dome (Northern Victoria Land, 7248S; 15906E, 2316 m a.s.l. accumulation rate 80.5mm w.eq), Law Dome (Dome Summit South, 6647S, 11249E, 1370 m a.s.l., accumulation rate 644 mm w.eq) and D66 (6856S, 13656E, 2333 m a.s.l., accumulation rate 213 mm w.e.) in order to assess if MSA could be a proxy for SOI and ACW via connection with sea-ice extent.

Keywords: msa, soi, icecore



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Poster presentation

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Spatial and temporal variability of the Southern Boundary of the Antarctic Circumpolar Current based on hydrographic data and satellite altimetry

Dr. Takashi Yabuki

Department of Geophysics Graduate School of Science, Tohoku University IAPSO

Toshio Suga, Kimio Hanawa, Koji Matsuoka, Hiroshi Kiwada, Tomowo Watanabe

The Spatial variability of Southern Boundary (SB) of the Antarctic Circumpolar Current and its temporal variability are investigated. The SB is the front corresponding to the southern limit of Upper Circumpolar Deep Water and has a direct relation to its upwelling. Spatial distribution of SB is estimated from sea surface height (SSH), which is calculated as sum of satellite measured sea level anomaly and climatological dynamic height. Compared with widely distributed hydrographic data provided by Japanese Whale Research Program in the Antarctic (JARPA), it is confirmed that the SB position determined by SSH is fairly precise with the error of 1.0 or less degrees in latitude. The map of SB during whole available period demonstrates that the location of SB is temporally stable near the Pacific Antarctic Ridge and unstable around the Kerguelen Plateau. Temporal variability has an annual component and an interannual component. The annual component is characterized by a different peak season depending on longitude. The interannual component also depends on the longitude, which appears partly related to the Southern Annular Mode.

Keywords: southern boundary, upper circumpolar deep water, satellite altimetry

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Poster presentation

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Antarctic Sea Ice, Large Scale Wind Patterns, and Climate Change

Dr. Simon Marsland

Climate Variability and Change Program ACE CRC

P.A. Reid

Sea level pressure analyses show a circumpolar wavenumber three pattern of standing low pressure systems over the seasonal sea ice zone of the Southern Ocean: a Weddell Sea cell; a Bellingshausen-Ross Sea cell, and an East Antarctic cell. On the western (eastern) limb of each low there is a tendency for northward (southward) wind driven sea ice transport. Regions of northward transport are loosely associated with the occurrence of coastal polynya systems, and perhaps coincidentally with the locality of the major Antarctic Ice Shelves. We examine the response of sea ice to windstress over the satellite era using an ensemble of NCEP-NCAR reanalysis daily forced simulations of the Max Planck Institute Ocean Model. While recent studies fail to find a significant sea ice response to climate change in the Southern Ocean over the satellite observed era, this study shows that regional responses can be interpreted with respect to changes in the Southern Ocean low pressure systems. The response is masked by seasonal and monthly differences in the observed changes of the wind regime.

Keywords: sea ice, antarctica, climate change

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Poster presentation

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Decadal Temperature Changes Across the ACC

Mrs. Astrid Dispert

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Claus W. Bning, Steve Rintoul, Martin Visbeck

Temperatures recorded between 700m and 1100m by ALACE floats in the 1990s have signalled a warming by 0.17 since 1950-1980, concentrated in the Antarctic Circumpolar Current (ACC). The mid-depth warming pattern could be a consequence of an increased surface heat flux into the ocean, however, could also be associated with a dynamic response of the ACC to changes in the Southern Annular Mode (SAM). In this study we utilize the rapidly expanding data base provided by ARGO floats, to address the question of the nature of the mid-depth Southern Ocean warming. Initial analysis has focused on several subdomains of the ACC. The zonally- averaged temperature changes between ARGO and historical profiles reveal two distinct anomaly patterns in both subdomains: a deep-reaching warming signal at the southern flank of the ACC, and a warming/cooling (decadal variability?) pattern apparently associated with the SAM. In the discussion we delineate the thermodynamic and dynamic contributions to these signals, by assessing the patterns and rates of temperature changes on isopycnal and isobaric surfaces.

Keywords: acc, temperature, sam



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Poster presentation

5825

Southern Ocean water mass formation in a finite-element coupled sea ice-ocean model

Dr. Ralph Timmermann

Carmen Bning, Qiang Wang, Jens Schrter, Sergey Danilov

A finite-element coupled sea ice-ocean model (FESOM) has been developed at the Alfred Wegener Institute for Polar and Marine Research. The sea-ice component is a dynamic-thermodynamic model with an elastic-viscous-plastic rheology. The ocean component is the hydrostatic, primitive-equation Finite Element Ocean Model (FEOM). An eight-compartment model of the marine ecosystem, featuring nitrate and silicate cycles and considering possible iron limitation, has been implemented. The coupled model has been configured in a circumpolar domain covering the Southern Ocean between the coast of Antarctica and 48S, and on a global grid with 1.5 mean resolution. Multi-decadal simulations have been performed in both configurations with a surface forcing derived from atmospheric reanalysis datasets. The model features a realistic representation of sea-ice coverage and large-scale ocean circulation. Results from a wide range of sensitivity studies confirm the crucial importance of a carefully chosen adaptive mixing scheme to parameterize vertical and horizontal mixing. Artificial passive tracers are used to identify water mass formation pathways. With the right choice of parameters and parameterizations, the model is able to reproduce observed water mass properties and formation processes realistically. We also discuss the representation of topography-guided currents and of circumpolar (coastal) waves in this z-coordinate model.

Keywords: fesom, southernocean, finite element model



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Poster presentation

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A comparison of the Mar Madel at 10-Km and 2-Km horizontal resolution

Dr. Giulia Clai
ENEA ENEA

Pellegrini Andrea

The aim of this study was to apply and evaluate the regional model MAR (Modle Atmosphrique Rgional) at high horizontal resolutions. The chosen resolutions were 10 and 2 km. The highest resolution (2 km) is supposed to highlight and amplify the model behavior and to underline the systematic error dependency. This application shows good qualitative agreement of the MAR model in the fine simulation along the eastern Ross Sea coast of dynamics processes like katabatic flows, mesocyclon generation, ground level temperature. The simulated results have been compared with temperature, pressure and wind speed recorded by some AWS's (Automatic Weather Stations). The comparison confirms the MARs qualitative satisfactory capabilities in modeling dynamical processes in Antarctic environment. In spite of this, systematical biases, especially referred to the 2 km resolution, which is at the limit of the orographical information, have been pointed out.

Keywords: antarctic atmospheric simulat, katabatic fields, high horizontal resolutions

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PS003

5827 - 5840

Symposium

Mediterranean Circulation and Climate: Their Variability and Sensitivity to Future Emission Scenarios

Convener : Prof. Piero Lionello

Co-Convener : Mr. Serge Planton

This symposium concerns the Mediterranean climate, focusing on the ocean circulation component, its variability, trends, and sensitivity to future emission scenarios. Particularly welcome are presentations analyzing the coupled atmosphere-ocean system and the interactions between atmosphere and oceanic variability. Themes included in this symposium are: the reconstruction of the past Mediterranean circulation based on instrumental data, natural and documentary proxies; model simulations focused on the Mediterranean region; connections between the variability of the Mediterranean Sea circulation and both the Tropics (ENSO, Monsoons, etc.) and the Mid-Latitudes (NAO, East Atlantic Pattern); variability and trends of temperature, salinity, and sea level at regional scales; the role of air-sea interaction at regional scale and the structure and relative intensity of the circulation cells of the Mediterranean Sea. It will be important to compare present trends and the results of future climate simulations.



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PS003

Oral Presentation

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Hydrographic Variations in the deep and shallow areas of the Egyptian Mediterranean Coast

Prof. Said Sharaf El Din

Oceanography Department, Faculty of Science Alexandria University IAPSO

Fahmy Mohamed Eid, Omneya Mahmoud Ibrahim, Kareem Mahmoud Tonbol

Water temperature, salinity and conductivity profiles were obtained at each location during the mobilization, service visits and final recovery from February, 1999 to January, 2000. A Seabird 19 CTD recorder was used to obtain data at regular intervals throughout the water column from 1m below the surface to the seabed. The instrument was set up to take readings at a rate of 2 samples every second. CTD data were recorded on both the downward and the upward casts. At locations C02, C05, C06, C07, C06, C09 and C12: CTD profiles at these shallow water locations showed the water column to be well mixed, with temperature, salinity and density being constant throughout depth. The calculated salinity at each of the service visits fluctuated around 39 with a slight increase in salinity in the months of October 1999 through to December 1999. Only at C7, the shallowest measurement location (7m), was a lower salinity value of 37.5 recorded. At locations C01, C03, C04, C10, C11, M01 and H01: CTD profiles taken at the deeper water moorings indicate a seasonal variation to the water column structure. During the months of February to April 1999, the temperature, salinity and density were fairly uniform throughout the water column, although an increase in density and a decrease in temperature were observed at most of the deeper water locations. During the June 1999 service visit, a variation in temperature and salinity at a depth of approximately 30 m was apparent for most of the locations. By August 1999, a strong thermocline at most of the above locations had started to appear in the profiles at a depth of approximately 30 m, with a variation in temperature of 10 °C above and below the thermocline.

Keywords: egyptiancoast, hydrography, ctd



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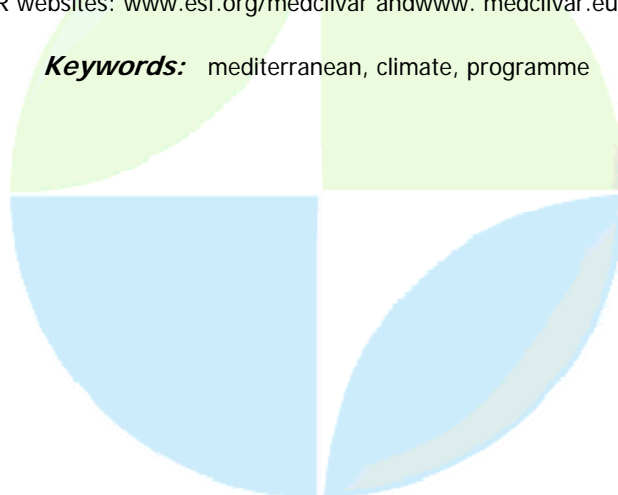
Mediterranean Climate Variability and Predictability (MedCLIVAR): an ESF Networking Programme

Dr. Roberta Boscolo
Oceanography IIM-CSIC IAPSO

Piero Lionello, Members Of The Scientific Committee,

The Mediterranean climate is characterized by the Mediterranean Sea, which represents a relatively large mass of water, and its peculiar geographical location: at mid latitude, on the west side of a large continental area, surrounded by three continents with high mountains ridges, and with a restricted exchange with the Atlantic ocean. In general the climate exhibits hot and dry summers, and mild and rainy winter seasons. However, within such a small spatial scale there are large climate contrasts as the area includes Alpin regions in the north, with permanent glaciers and relatively high precipitation rates, and subtropical semiarid regions in the south where the extended Atlas mountains ridge also play a major role. Moreover the Mediterranean is a transition zone between midlatitude climate regimes, located at the border of the midlatitude storm track, and the tropical climate, located under the descending branch of the Hadley cell. These characteristics make the Mediterranean region potentially very sensitive to climate change. Indeed, simulations of future climate scenarios tend to agree that higher emission level could produce a temperature increase larger than the global average value, further reduce summer precipitations and increase the interannual variability of both temperature and precipitation. Progress in the understanding of the Mediterranean climate has important environmental, societal and economical implications. The Mediterranean region is characterized by large cultural, economical, political, demographic gradients in a situation already under environmental stress (heat waves, highly variable precipitation, limited water resources, drought, floods), where lack of readiness and adequate adaptation strategies could result in critical situations, in particular in connection with the occurrence of extremes and inadequate evaluation of climate change impacts. The ESF MedCLIVAR Programme aims to assist scientists in developing coordinated research projects; favour the exchange of information and expertise; establish a network of European, Middle-East and North African institutes and scientists actively involved in regional climate studies; provide a source of information to assist governments and local authorities in decision-making; provide material and documentation to the public to inform them on climate issues. The ESF MedCLIVAR will pursue these goals through: - Annual workshops - Summer schools - Exchange Grants, to offer MedCLIVAR scientists the opportunity to spend up to 5 months in a host institution to exchange information, share data and develop common work on the Mediterranean climate. For the latest information on this Research Networking Programme, consult the MedCLIVAR websites: www.esf.org/medclivar and www.medclivar.eu

Keywords: mediterranean, climate, programme



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Oral Presentation

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**Temperature, salinity and associated sea level changes in the
Mediterranean Sea under global warming scenarios**

Dr. Marta Marcos

National Oceanography Centre, Southampton NERC IAPSO

Michael N. Tsimplis

Global sea level rise estimates during the 21st century range between 9 and 54 cm according to the 4th Assessment Report of the Intergovernmental Panel of Climate Change (IPCC), released in 2007. In this framework, atmosphere-ocean global coupled models (AOGCM) simulate the thermal expansion of the oceans under different emission scenarios, which describe different demographic and socio-economic conditions and future greenhouse and sulphur emissions. We have used the potential temperatures (θ) and salinities (S) coming out from the models and we have extracted the region of the Mediterranean Sea and the adjacent Atlantic area (longitude -15W to 36E, latitude 30N to 47 N). Changes in θ and S profiles are investigated at particular points in the Eastern and Western basins of the Mediterranean Sea with the aim of inferring the possible warming and salinification of intermediate and deep waters. The Mediterranean Sea is particularly interesting due to its locally forced thermohaline circulation independent of the Atlantic Ocean. We have also computed the regional sea level for the different climate scenarios defined by the IPCC using the available numerical AOGCMs.

Keywords: sea level, climate change

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Oral Presentation

5830

Influence on Mediterranean Sea deep water formation of air-sea exchanges at small spatial scales

Dr. Simon Josey

OOC National Oceanography Centre, Southampton, UK IAPSO

Simn Ruiz, Mikis N. Tsimplis, Marta Marcos, Damia Gomis

Variability in the air-sea forcing of the Mediterranean Sea over the period 1960-present will be investigated using the NCEP/NCAR reanalysis and the REMO high resolution atmospheric hindcast which has been produced by dynamical downscaling of the reanalysis fields (Sotillo et al., 2005). Particular attention will be paid to variations in the heat and freshwater fluxes at the main sites of deep water formation : the Adriatic Sea, Aegean Sea and Gulf of Lions. New results on the pattern of heat loss associated with the Eastern Mediterranean Transient will be presented based on an analysis of the high resolution fields. These results indicate that the well- established extreme heat loss during the severe winters of 1991-92 and 1992-93 was concentrated in a jet situated over the eastern side of the Aegean Sea. The accuracy of the high resolution model results will be evaluated using regridded observation based fields produced at the National Oceanography Centre, Southampton. Variations in the heat budget of the entire Mediterranean Sea basin, together with various sub-basins, will also be considered in the context of observed temperature and sea level variations over the past 40 years.

Keywords: mediterranean, air seaflux, deepwaterformation

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Oral Presentation

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A Regional System for climate change assessment in the Mediterranean region: preliminary results.

Dr. Vincenzo Artale
Environmental ENEA IAPSO

The Protheus Group (1Artale V., 2X. Bi, 1S. Calmanti, 1A. Carillo, 1A. Dellaquila, 2F. Giorgi, 2J. Pal, 1G. Pisacane, 2S. Rauscher, 1P.M. Ruti, 1G. Sannino, 1M.V. Struglia) 1ENEA, CR Casaccia, Rome (Italy) 2ICTP, Trieste (Italy) Climate change assessment and impact studies demand realistic prediction of atmospheric fields, which can be either derived from global-scale simulations through down-scaling procedures, or obtained by running regional climate models which use global-scale fields as boundary conditions. In particular nested limited-area atmospheric models have proven their ability to resolve small features that are missed by large-scale simulations. At present fully coupled regional climate models are being developed, so that the interactions among the distinct components of the climate system (i.e. ocean, atmosphere, biosphere and sea-ice) are explicitly simulated. Such models are expected to improve our skill in predicting reliable scenarios in complex regions such as the Mediterranean area, which is subject both to the influence of global scale dynamics (e.g. disturbances in the mid-latitudes, strength and meridional extension of the Hadley circulation), and to the effects of local physical processes. We present a new regional system consisting of the RegCM (atmospheric model), the MITgcm (ocean model) and BATS (Biosphere-Atmosphere Transfer Scheme), coupled via OASIS3. Preliminary simulations of the coupled system over the Mediterranean area will be discussed.

Keywords: modelling, mediterranean, climate

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Oral Presentation

5832

Variability in the Mediterranean Sea as the result of combined causes.

Dr. Vincenzo Artale
Environmental ENEA IAPSO

Adriana Carillo, Giovanna Pisacane, Gianmaria Sannino, Bruno Manca, Simona Masina

Experimental data spanning several decades show that the circulation of the Mediterranean Sea and the processes of water mass formation that it hosts are subject to pronounced variability. The Eastern Mediterranean Transient (EMT) which was detected in the 90s constitutes a direct observational evidence of such variability. With regard to the EMT, numerical models have proved to be a valuable instrument to assess the distinct, though concurrent, roles of external forcing (i.e. atmospheric temperature and wind stress anomalies) and basin internal variability. On the other hand, the changes in the salinity field in response to changes in the wind-driven circulation have been quantified in different regions of the Mediterranean Sea using data from several hydrographic surveys and the ECMWF wind field reanalyses. In particular, significant changes in sub-basin scale thermohaline circulation have been observed to affect the salinity distribution in the upper layer of the Eastern Mediterranean, thus establishing one of the prerequisites for dense water formation. In this work, we aim to investigate the feedback processes between the external forcing and the basin internal variability, together with the impact of a realistic representation of how the Gibraltar Strait regulates the fresh water supply from the Atlantic Ocean. To this purpose, an eddy permitting OGCM that reaches a (1/24) resolution over the Gibraltar Strait region is used. Such a resolution is achieved by means of a two-way nesting procedure. Results are then compared to the in-situ data provided by the MEDAR/MEDATLAS data-base. As a future follow-up of this work the role of the Mediterranean Sea on nearby and remote regions will be investigated in the context of present and future climate.

Keywords: mediterranean, variability, water masses



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PS003

Oral Presentation

5833

Simulation of tides and surges in the Adriatic Sea and the Lagoon of Venice through a coupled oceanic/atmospheric model

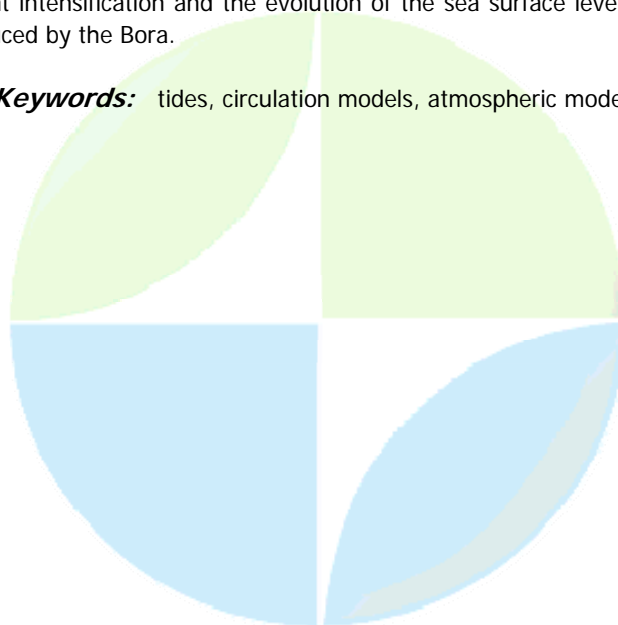
Mr. Tomas Lovato

Dept. of Environmental Sciences PhD Student

Alexei Androssov, Giovanni Ficca, Roberto Pastres, Angelo Rubino

A high resolution atmospheric model was used to force an oceanic model in order to simulate tidal and surge phenomena occurring in the Adriatic Sea and the Venice lagoon during intense winter events. The atmospheric model (BOLAM) is a hydrostatic regional model based on the primitive equations which are solved on a regular horizontal grid with two different discretizations, namely 20 km and 5 km grid step. In particular, the simulations carried out with the higher resolution permit an accurate description of topographically generated wind intensifications, including Bora wind events, which are known to exert a noticeable influence on the dynamics of the northern Adriatic basin. The oceanic model is based on curvilinear, boundary fitted coordinates and, due to a technique for the treatment of numerical movable boundaries, it allows for an accurate simulation of coastal flooding and dry up. In particular, its focus, located in the northern area of the Adriatic sea, allows for a joint simulation of the north Adriatic sub-basin and of the lagoon of Venice, because small scale circulation features induced by varying bathymetry in the lagoon are satisfactorily resolved (the maximum grid resolution is 60m). Firstly, the hydrodynamical model has been optimized for the prediction of the astronomical tides in a homogeneously spaced set of gauges. The used observational dataset is composed of the available in situ measurement of the Italian APAT network complemented with data found in the literature. The obtained results are in excellent agreement with the data of a validation set, the error in prediction being of the same order of state of the art models for the area. Different test experiments have been carried out varying the horizontal resolution of the meteorological model as well as the frequency at which the meteorological forcing is updated in the oceanic model. On this basis, several episodes of storm surges observed during the late autumn 2005 in the Lagoon of Venice have been simulated. This period was characterized by the almost daily occurrence of surges with maximum elevations higher than 80 cm, which is considered the alert threshold for acqua alta. Observed phenomena induced by Bora winds inside the lagoon and in the outer coastal area were captured. Moreover, the model correctly reproduced the current intensification and the evolution of the sea surface level along the coast of the north Adriatic sea induced by the Bora.

Keywords: tides, circulation models, atmospheric models



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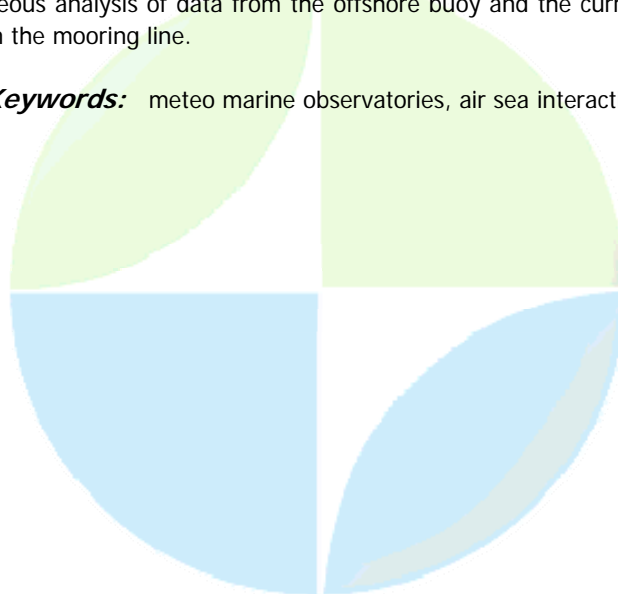
The Ligurian Sea Observing System: a laboratory for climatic and air-sea interaction studies in the northwestern Mediterranean

Dr. Stefania Sparnocchia

Sara Pensieri, Roberto Bozzano, Paola Picco, Maria Elisabetta Schiano

Given its role in the climate and circulation of the Mediterranean region, the Ligurian-Provencal basin has been the object of intense scientific investigation since the sixties. During winter, dense water formation takes place in the area and intense air-sea interaction greatly affects both the atmospheric and the marine circulation, determining a strong variability in the upper ocean thermocline. Biological productivity is very high and the ecosystem is very rich and complex. All these aspects make this area an interesting research site for oceanographers, physicists, and biologists. Studying such a complex zone, and particularly the intense air-sea interaction occurring there, requires dedicated observing systems as well as the development of specific parameterizations for the processes involved. Here, we present our observing system in the Ligurian Sea, an important instrument to obtain a complete picture of the many phenomena related to both marine circulation and climate evolution there. The system actually consists of two meteo-oceanographic buoys, one coastal and the other offshore. Since the offshore buoy is instrumented to monitor the surface layer up to a depth of 40 m, a submarine mooring line completes the system, giving information on the ocean interior. The need for this type of observing system is evidenced by the important results that will be presented here. Meteorological measurements from the offshore buoy have been used for validating ECMWF calculations by comparing them against the model reanalysis data. The results of the comparison show that the modelled daily and seasonal values are not suitable for the Ligurian basin. Specifically, the model is subject to an underestimation of high winds and an overestimation of light winds. The long and continuous time series of data from the offshore buoy also sustain the use of the surface water vapour as a climate indicator. Furthermore, the contemporaneous data from both the coastal and the offshore buoys were fundamental in studying the anomalous warming of the Ligurian Sea caused by the heat wave of summer 2003. The data, in fact, show that the event was confined to within a few meters below the surface as a consequence of prolonged periods of calm or light winds that summer. Finally, we will present the results of an ongoing study on the variability of the upper layer currents and its relationship with the atmospheric forcing, involving the simultaneous analysis of data from the offshore buoy and the current data obtained from the instrumentation on the mooring line.

Keywords: meteo marine observatories, air sea interaction



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Oral Presentation

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Climate change scenario for the Mediterranean Sea using an

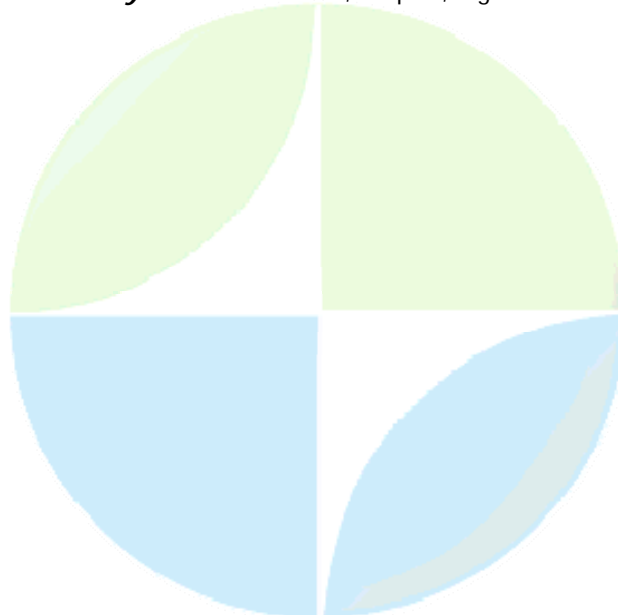
Mr. Serge Planton

Centre National de Recherches Meteorologiques Meteo-France IAPSO

Samuel Somot, Florence Sevault, Michel Deque, Marc Lucas

In order to study the evolution of the Mediterranean Sea for the 21st Century, we have developed a high resolution Atmosphere-Ocean Regional Coupled Model (AORCM). This model named SAMM (Sea-Atmosphere Mediterranean Model) results from a coupling between a global spectral AGCM (ARPEGE-Climate), whose variable resolution is maximum in the Mediterranean region and a Mediterranean sea limited area OGCM (OPA-MED8). The horizontal resolution of the AORCM is about 50 km for the atmosphere allowing us to represent the major atmospheric characteristics driven by the orography of the Mediterranean basin and 10 km for the Mediterranean Sea. A 140-year numerical experiment (1960-2100) was run with the AORCM. Up to year 2000, forcing was prescribed from observed values: SST at the global ocean surface (outside the Mediterranean sea), river runoff fluxes, Atlantic box hydrology, greenhouse gas and aerosol concentrations. A simple monthly heat flux correction on air sea exchanges was applied to ensure the model realism. Then, beyond 2000, an IPCC-A2 scenario was prescribed for the greenhouse gas and aerosol concentrations. An anomaly approach was used to represent the evolution of the other forcings that was provided from a global low-resolution coupled climate scenario run previously. A twin experiment (or control simulation with the same correction) was also run over the same period for checking the model stability under present climate conditions. The comparison of the transient simulations gives the impact of the climate change on the Mediterranean Sea circulation. The regional impact of the climate change on the Mediterranean SST has been assessed as well as the changes in the Mediterranean ThermoHaline Circulation (MTHC) and in the water mass characteristics. Comparisons between this regional coupled simulations and a previous scenario run with a forced Mediterranean model (Somot et al. 2006, Clim. Dyn.) have been analysed. Indeed, with a coupled ocean model as used in this study, the feedback of regional scale SST changes on the atmosphere is taken into account. This adds a new degree of freedom in the AORCM simulation with respect to the forced ocean approach.

Keywords: scenario, coupled, regional



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Dynamical downscaling of the Simple Ocean Data Assimilation (SODA) for the Mediterranean sea with a regional ocean model

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Physics Associated Professor

Eliseo Garcia Garcia, Jose Antonio De Frutos

Global coupled climate models, like those used in the IPCC reports, are too coarse to study the impact of climate change on regional scales. However, they can be used to provide boundary conditions and atmospheric forcing to regional climate studies with higher resolution. Regional ocean models can be the appropriated tool to study regional impacts of Climate Change in the ocean. The Regional Ocean Model System (ROMS) is a general circulation model widely used for regional and coastal studies. In this work, we downscale the Simple Ocean Data Analysis (SODA), in order to explore the ability of ROMS for regionalization studies of climate change. ROMS is forced with boundary conditions from SODA and forced with atmospheric fields from the NCEP reanalysis covering the period 1958-2001. The model domain covers part of the Atlantic basin and the Mediterranean. Its resolution is 1/6 degree and includes the entire Iberian Peninsula. The model results are compared both against observations and the SODA analysis.

Keywords: regional modeling, mediterranean, dynamical downscaling

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Oral Presentation

5837

Mediterranean wave climate in scenario simulations

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Maria Barbara Galati, Stefano Cogo

This study is based on 30-year long simulations of the wind-wave field in the Mediterranean Sea carried out with the WAM model for the A2, B2 emission scenarios and a control CTR simulation based on the 1960-1990 emission level. The wave model is forced by the wind field computed by a regional climate model simulation with a 50km resolution. The monthly mean SWH (Significant Wave Height) field of the A2 scenario is lower over large fraction of the Mediterranean sea in winter, spring and Autumn. In summer the SWH is reduced in the central part of the basin and increased in the eastern and western parts. All these changes are smaller or less significant in the B2 scenario, but in winter when average SWH is higher in the B2 scenario and in the western basin. The SWH reduction is valid also for extreme values and is larger for the A2 than for the B2 scenario. The only exception is a significant increase of the SWH extremes in the central Mediterranean during summer. In general results shows a milder wave climate in future scenarios than in the present climate, with changes that are consistent with those of the atmospheric circulation and cyclone activity.

Keywords: mediterranean, wave, climate

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Future storm surge climate in the Northern Adriatic Sea

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De Zolt Simona, Elvini Elena

This study describes the change of storm surge regimes inferred from regional for the low northern coast of the Adriatic Sea which is a densely populated region extremely vulnerable to sea level rise and to a change of intensity of the storm surge events. The storm surge simulations are carried out with a barotropic model (called Hypseam) using the sea level pressure and surface wind fields computed by the RegCM model at ICTP in Trieste for the A2, B2 and present climate (CTR). Results suggest a lower frequency of surge events in the future climate scenarios, but higher extreme values, showing a possible change in the frequency distribution of surge levels produced by the changes of the cyclone activity responsible for the storm surge generation.

Keywords: scenarios, storm surge, extremes

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5839

An evaluation of energy and mass balance for the Mediterranean Sea in future scenarios

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Letizia Congedi, Giulia Vicentini

This study represents an evaluation of the mass and thermal balance at the surface of the Mediterranean Sea in future climate scenarios on the basis of the simulations carried out with the RegCM model at ICTP. Three 30-year regional climate simulations, one for present day conditions (1961-1990) (CTR experiment) and two for future conditions (2071-2100) under the A2 and B2 IPCC emission scenarios are analyzed. The model grid spacing is 50 km and the model domain covers the European region and adjacent oceans. The RegCM model is driven at the lateral boundaries by meteorological fields from the Hadley Centre global atmospheric model HadAM3H. Sea surface temperatures (SSTs) are from corresponding simulations with the Hadley Centre global coupled model HadCM3. In the scenario simulations a 20% increase of the magnitude of the negative mass balance of the Mediterranean Sea is observed. Changes of heat flux would favor a decrease of the intensity of the formation of Levantine intermediate water and of the North Adriatic deep water.

Keywords: mass balance, heat flux, scenarios

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Oral Presentation

5840

Climatic variability of the subsurface sea temperatures in the Aegean-Black Sea system and relation to meteorologic forcing (preliminary results)

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Institute of Oceanography Hellenic Center for Marine Research IAPSO

Elina Tragou, Vassilios Zervakis, Dimitrios Georgopoulos, Alexander Theocharis

The MEDAR/MEDATLAS(2002) hydrographic database is utilized to construct climatic subsurface temperature time-series of the period 1950-2000 in two areas of the Aegean Sea, one in the southwest and another in the north-central, and one area in the southwest of the Black Sea. In order to minimize the effects of seasonal and higher-frequency variability in the climatic time-series and take advantage of the dense hydrographic data in the upper ~200 m for both Seas, winter and summer temperature averages have separately been considered for all years in each area for the sub-thermocline layer between ~80-120 m. In order to further minimize the bias in the temperature averages due to meandering of the existing circulation features, the corresponding temperature time-series were also constructed for appropriate isopycnal layers, which improved the quality of the climatic signal in temperature particularly in the Black Sea. All temperature time series are characterized by inter-annual oscillations with time-scales of 4-to-6 years and longer periods (...~1950-to-1967, ~1967-to-1993, ~1993-to-2000...) during which they exhibit different trends. In both Seas for winter and summer there is one distinct temperature-decreasing trend (~0.06 oC/year) during ~1967-1993 followed by an increasing trend (~0.10-0.15 oC/year for the Black Sea; ~0.15-0.20 oC/year for the Aegean) during ~1993-2000. A differentiation exists in the trend behavior between the different time series in the period ~1950-1967. Time series characterized by lower temperatures ('cold' time series), i.e., Black Sea in winter and summer (mean temperature ~7.5 oC) and north-central Aegean in winter (mean temperature ~14.5 oC), show in increasing trend (~0.06-0.07 oC/year) during ~1950-1967. Time series characterized by higher temperatures ('warm' time series), i.e., both Aegean areas in summer and southwest Aegean in winter (mean temperature > 15.0 oC), show no trend during ~1950-1967. The same turning points (~1965-1967 and ~1992-1993) with respect to trend behavior exist in the meteorologic time series of the N.A.O (North Atlantic Oscillation) and E.A.W.R. (East Atlantic West Russia) indexes. The trend changes prior to and after the turning points correlate between the NAO index and our 'warm' time series and between the EAWR index and our 'cold' time series. The turning points (~1965-1967 and ~1992-1993) seem to be associated with extreme weather and/or oceanic events, known to have occurred at least locally, such as the severe snowfall of winter 1967 in and the very cold winter of 1992 with massive formation of CDW (Cretan Dense Water). Investigation is under way to construct salinity time series and correlate all of them with atmospheric heat and salinity fluxes from COADS and ICOADS data.

Keywords: aegean sea black sea, ts climatic changes, atmospheric driving

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PS004

5841 - 5895

Symposium
Ocean Mixing (co-sponsored by SCOR)

Convener : Dr. Robin Muench

Themes covered by this symposium include: (1) abyssal mixing and potential sources for mixing adequate to resupply the abyssal ocean with potential energy that is lost to the meridional overturning circulation and to eddy formation processes; (2) issues related to parameterization of mixing in numerical models and, in particular, to inclusion of physics that will enable the model codes to include the effects of processes down to the smallest scales; and (3) new technologies and the means to collect information on ocean mixing over a far broader geographical area than has been possible to date. Results related to these themes and obtained using theoretical, model-derived and field methods are appropriate. Reports on work involving collaboration among modelers and mixing process specialists are especially welcome.

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Oral Presentation

5841

Wind Drag on Waves

Prof. Walter Munk
IAPSO

Spaceborne observations of ocean glint reflectance (Breon and Henroit 2006) have confirmed the linear dependence of the mean-square slope on windspeed (Cox and Munk 1955) and provided some new information on skewness and peakedness. An extension of the Stokes-Rayleigh formulation of finite (but small) amplitude surface waves to allow for up/downwind asymmetry suggests a central role of skewness in the momentum transfer across the air-sea boundary. We now depend on satellite measurements of the scattering cross-section of cm radar waves as a proxy for the momentum transfer. Remote sensing of wave skewness may provide a more direct measure of wind stress and mixing than the scattering cross-section of radar waves.

Keywords: wind mixing, wind stress, surface roughness



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PS004

Oral Presentation

5842

Laboratory observations of increased plume entrainment in the presence of submarine canyons and ridges

Dr. Anna Wahlin

Department of Earth Sciences Göteborg University IAPSO

E. Darelius, C. Cenedese, G. Lane-Serff

The continental slopes in the ocean are often intersected by small-scale topographic features such as submarine canyons and/or ridges. Cold, dense ocean currents that move geostrophically along the slope may encounter such features and portions or all of the dense water can then be steered by the topography down towards the deep sea. When the water is redirected in this manner it follows a shorter path to the deep sea, and it seems plausible that less total mixing will take place in the plume since the distance over which it entrains water can be much shorter. In order to investigate this question, a laboratory experiment has been conducted at the Coriolis rotating platform. A dense source was placed on top of a slope, and experiments were repeated with a straight slope, with a ridge, and with a canyon. The time development of the stratification in the receiving basin was monitored, and from this the total plume mixing could be calculated. Contrary to what was expected, the presence of a submarine canyon as well as a ridge increased the total mixing that took place in the plume. The product water that ended up in the laboratory basin was less dense when a canyon or a ridge was placed on the slope, compared to when they were removed. The reason for this extra mixing appears to be that the plume speeds up when it is steered by the topography, a phenomenon that has also been observed in the dense plume that moves along the Weddell Sea continental slope.

Keywords: entrainment, topography, canyons



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Oral Presentation

5843

Dissipation mechanism in the internal wave field in a deep ocean

Dr. Ranis Ibragimov

Mathematics McMaster University IAPSO

If sources of internal waves cannot be well quantified, the situation is even worse with their sinks. The dissipation mechanism for internal waves is poorly known and quantified. Little is known about the rate at which wave breaking extracts energy from the spectrum. Here I am going to present one possible approach on how to model the dissipation mechanism using recently developed numerical model for studying energy exchange between internal waves due to solely resonant interactions. The resonant internal wave simulator I am going to present does the following: It generates an arbitrarily large number of resonant triads of internal waves in wavenumber-frequency space with frequencies spanning the range of possible frequencies. Secondly, the model generates the evolution equations for the amplitudes for each resonant wave obtained in the first step. Next, the wave amplitudes are initialized based on a choice of the initial energy spectrum. Finally, the temporal evolution of the energy distribution among the various possible wave numbers and frequencies is computed. The approach is based on finding the correct approximation rate at which energy is dissipated from the initially flat spectrum and comparison the result with the Garrett-Munk (GM) spectrum which represents the stable state of the energy spectrum. The idea is the following: if the GM model represents the stable state of the energy spectrum then what happens if we start our model with an energy spectrum far from the GM? Will it go to the GM or will it go to some other state? The simulations I am going to present yield quantitative predictions of the time evolution of the GM spectrum and the flat spectrum without dissipation. Little change in the GM spectrum occurs (suggesting that the GM spectrum is an equilibrium state). We shall see from the results that the flat spectrum does not go to the GM spectrum. Instead, it approaches another equilibrium state about which it then oscillates. If the dissipation will be added correctly to the model, then the equilibrium state in the form of the GM spectrum must be achieved.

Keywords: dissipation, energy spectrum, resonant interactions



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Oral Presentation

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Mesoscale Eddy - Internal Wave Coupling and Closure of the Thermocline Circulation

Mr. Kurt Polzin

Physical Oceanography Woods Hole Oceanographic Institution IAPSO

Brian Arbic, Rob Scott

The standard paradigm for oceanic dynamics is to consider the stratified interior as an ideal fluid and place all dissipative processes in either the bottom boundary layer or associate them with eddy/mixed layer interactions. On the other hand, background potential vorticity gradients are clearly documented in hydrographic data, e.g. Robbins et al. (J. Phys. Oceanogr., 2000), and current meter data (Brown et al., J. Phys. Oceanogr., 1986) also document the presence of downgradient eddy fluxes of potential vorticity. Thus we arrive at an essential conundrum: what is the frictional or diabatic process that permits the material modification of potential vorticity within the stratified oceanic interior associated with the downgradient fluxes? It is clear that diabatic processes are far too weak. A case will be made here that a coupling between mesoscale eddies and the internal wavefield acts as a frictional process. The case to be presented will focus on the interpretation of observations. These include current meter array data obtained as part of the POLYMODE Local Dynamics Experiment (LDE). Brown and Owens (J. Phys. Oceanogr., 1981) found correlations between internal wave momentum fluxes (stresses) and eddy rate of strain estimates that they interpreted in terms of a horizontal viscosity of 200-400 m^2/s . A revised estimate of this horizontal viscosity (50 m^2/s) and a vertical viscosity (0.003 m^2/s) estimate will be presented. Viscosity coefficients of this magnitude indicate that transfers of energy, momentum and potential vorticity between internal waves and mesoscale eddies are a significant part of the eddy energy (Bryden, J. Mar. Res., 1982) and eddy enstrophy (potential vorticity squared) budgets. Spectral fluxes computed from altimetry data (Scott and Wang, J. Phys. Oceanogr., 2005) reveal that at horizontal scales greater than the Rossby radius of deformation an inverse cascade of kinetic energy towards larger horizontal scales takes place, while at horizontal scales less than the deformation radius, a forward cascade towards smaller scales takes place. Numerical simulations using an idealized 2-layer quasigeostrophic model indicate the pattern and magnitude of energy cascades in the satellite altimetry data are replicated with a horizontal viscosity of $O(50 m^2/s)$, but not if a horizontal viscosity of $O(5 m^2/s)$ is used. Significantly larger values of horizontal viscosity, of $O(500 m^2/s)$, result in a model eddy field that is less energetic, too baroclinic and has larger length scales relative to midlatitude observations. Somewhat surprisingly, dissipation associated with a horizontal viscosity operator of $O(50 m^2/s)$ plays a dominant role in the model energy budget at horizontal length scales one to two times larger than the deformation radius. We interpret the forward cascade as a result of mesoscale eddy - internal wave coupling. Our results have implications for eddy dynamics, the ocean energy budget, for the strength of the meridional overturning circulation, which is sensitive to the spatial distribution of dissipation, and for ocean general circulation models, which often use closures guided by numerical, rather than physical, considerations.

Keywords: mesoscale eddies, internal waves, mixing

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Internal Waves Across the Pacific

Dr. Jennifer MacKinnon

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Matthew Alford, Robert Pinkel, Zhongxiang Zhao, Jody Klymak

As part of the Internal Waves Across the Pacific experiment, we conducted intensive shipboard and moored observations spanning 25-37 N (1400 km) along an internal tide beam emanating from the Hawaiian Ridge. Our goal was to understand the processes affecting the long-range propagation of the oceans internal tides, and in particular their susceptibility to parametric subharmonic instability (PSI) at the "critical latitude of 28.8 N. At the critical latitude, velocity and shear were observed to occur in intense vertically-standing, inertially-rotating bands of several hundred meters vertical wavelength, consistent with generation through PSI. These occurred in bursts following spring tide, and contrasted sharply with the downward-propagating, wind-generated features seen at other latitudes. Details of the observed waves will be shown and implications for turbulent mixing in the global ocean discussed.

Keywords: internal waves, mixing

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5846

Tidal Beams and Mixing near Monterey Bay

Dr. Shaun Johnston

Scripps Institution of Oceanography University of California San Diego IAPSO

Dan Rudnick, Robert Todd, Sylvia Cole

As part of the Assessing the Effectiveness of Submesoscale Ocean Parameterizations project in the Monterey Bay area in August 2006, we conducted a repeated, broad spatial survey of internal tides and mixing. Hydrography, microstructure, and currents were obtained using the SeaSoar, a rapidly sampling conductivity microstructure instrument mounted underneath the SeaSoar, and shipboard ADCP. Data are binned at a horizontal resolution of 3 km and a vertical resolution of 8 m over a depth range from 0-400 m. By averaging over tidal phase, tidal beams were found in both velocity variance and Cox number. Existing mixing parameterizations based on shear and stratification for open-ocean and shelf environments are compared to mixing from microconductivity measurements.

Keywords: internal tides, mixing, aesop

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Oral Presentation

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Wave-Turbulent Mixing for Upper Ocean Multifractal Thermal Structure

Prof. Peter Chu

Oceanography Naval Postgraduate School IAPSO

Chung-Ping Hsieh

Upper layer (above 140 m depth) temperature in the western Philippine Sea near Taiwan was sampled using a coastal monitoring buoy (CMB) with attached 15 thermistors during July 28 August 7, 2005. The data were collected every 10 minutes at 1, 3, 5, 10, 15, and 20 m using the CMB sensors, and every 15 seconds at 15 different depths between 25 m and 140 m in order to observe turbulent thermal structure. Internal waves and solitons were also identified using the empirical orthogonal function analysis. Without the internal waves and solitons, the power spectra, structure functions, and singular measures (representing the intermittency) of temperature field satisfy the power law with multi-scale characteristics at all depths. Without the internal waves and solitons (turbulence-dominated type), the temperature fluctuation has maximum values at the surface, decreases with depth to mid-depths (60-65 m deep), and then increases with depth to 140 m deep. Such depth dependent (decreasing then increasing) pattern preserves during the internal wave propagation during 1000-1500 GMT July 29, 2005. However, this was altered during the internal soliton propagation to a pattern that increases with depth from the surface to 60 m deep, decreases with depth from 60 m deep to 100 m deep, and increases again with depth from 100 m to 140 m deep. The temperature fluctuation enhances with the internal wave and soliton propagation. Between the two, the internal solitons bring larger fluctuations. The observed temperature profile does not oscillate if there is no internal wave and soliton propagation. It oscillates evidently in the upper layer above 50 m with the internal wave propagation and above 80 m with the internal soliton propagation. The amplitude of the oscillation is much larger during the internal soliton propagation (maximum amplitude around 4°C) than the internal wave propagation (maximum amplitude around 2°C). The EOF analysis on the isopycnal displacement shows that the first baroclinic mode dominates the variability for internal waves (86.0% of variance) and internal solitons (74.4% of variance). The maximum variability is located at different depths with 30 m for the internal waves and 60 m for the Internal solitons. The amplitude of this mode fluctuates on two time scales with 4 CPH as a high frequency and around cycle per 5 hr as a low frequency for the internal waves, and on one time scale with frequency around 4 CPH for the internal solitons. The maximum amplitude is more than three times larger in the internal solitons than in the internal waves. Three types of thermal variability are identified: IW-turbulence, IS-turbulence, and turbulence-dominated. The power spectra of temperature at all the depths have multi-scale characteristics. For the IW-turbulence type and turbulence-dominated type, the spectral exponent is in the range of (1, 2) and thus the temperature field is nonstationary with stationary increments. For the IS-turbulence type, the spectrum is quite different and the spectral exponent is less than 1 for the low wavenumber domain. The structure function satisfies the power law with multifractal characteristics (Chu, 2004) for the IW-turbulence type and turbulence-dominated type, but not for the IS-turbulence type. The internal waves increase the power of the structure function especially for high moments. The internal solitons destroy the multifractal characteristics of the structure function. The power law is broken approximately at the lag of 8 min, which is nearly half period of the IS (with frequency of 4 CPH). The internal waves do not change the basic characteristics of the multifractal structure. However, the internal solitons change the power exponent of the power spectra drastically especially in the low wave number domain; break down the power law of the structure function; and increase the intermittency parameter. The physical mechanisms causing these different effects are also presented. REFERENCES Chu, P.C., 2004: Multifractal thermal characteristics of the southwestern GIN Sea upper layer, the journal "Chaos, Solitons and Fractals", 19 (2), 275-284.

Keywords: multifractal thermal structure, internal solitons, turbulence



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Oral Presentation

5848

The role of mesoscale eddies in the maintenance of deep stratification and the meridional overturning circulation.

Dr. Christopher Wolfe

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Paola Cessi

One of the most persistent mysteries in oceanography is that of the "missing mixing:" the measured open-ocean diffusivity appears to be much smaller than that required to close the abyssal circulation in the classical advective-diffusive theories of the thermocline. A popular solution to the disparity between the observed and required diffusivity is to posit the existence of mixing "hotspots" where the local mixing rates are vastly greater than the global average. While there is little doubt that such hotspots exist, it is not yet clear that they provide sufficient extra mixing to raise the global average to its required level. An alternative solution is to consider the effect of mesoscale eddies on the circulation which is primarily felt through an "eddy induced velocity" whose diapycnal component largely cancels the diapycnal component of the large scale mean flow. If the residual diapycnal velocity (the sum of mean and eddy induced velocities) is used instead of the mean velocity in the diffusive-advective scaling of the thermocline, the "extra" mixing required by the theory may be reduced or eliminated. This paper presents the results of a high-resolution, eddy-resolving ocean model posed in a idealized domain representing the Atlantic Ocean. Particular emphasis is placed on the role of mesoscale eddies in maintaining deep stratification and the meridional overturning circulation (MOC). The effects of varying surface buoyancy forcing and background diffusivity is systematically examined to determine scaling laws for the large-scale stratification and the MOC.

Keywords: mesoscale, abyssal stratification, overturning circulation



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Oral Presentation

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Variability of Turbulent Mixing Parameters off the Egyptian Mediterranean Coast

Prof. Said Sharaf El Din

Oceanography Department, Faculty of Science Alexandria University IAPSO

Fahmy Mohamed Eid, Nabil Saad, Khaled Alam El Din, Mohamed Elsharkawy

The analysis of the turbulent mixing structure is accomplished by the dynamical computations of the mixing parameters: buoyancy Frequency (N), viscous dissipation (ϵ), turbulent kinetic energy (E), Richardson Number (Ri), Reynolds Stress, diffusive salt flux (DSF), diffusive heat flux (DHF). The computations show that generally, the water column becomes more stable and less stratified at deep layers. Also, the dynamical process of vertical turbulent mixing are stronger in the surface layers.

Keywords: turbulence, surfacewaters, models

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Oral Presentation

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Modeling mesoscales in the mixed layer

Dr. Vittorio Canuto
unknown unknown IAPSO

M.S. Dubovikov, C.A. Clayson, M. Luneva

Thus far the physics of the oceans ML (Mixed Layer) has been based on 1d vertical mixing models. Such models have the tendency to lead to strong mixing leaving behind a largely unstratified layer whose depth may be sizably deeper than what is observed. Recent numerical simulations (Oschlies, 2002) have shown that mixing by mesoscales may be critically important. In fact, when a resolution of 1/90 that catches mesoscales was used, a robust re-stratification took place that brought the calculated ML depths into agreement with the data. The goal of this work is to formulate a model for mesoscales in the ML that can be used in coarse resolution OGCMs. The critical variable is the mesoscale vertical buoyancy flux must have a negative second z-derivative to produce re-stratification. The mesoscale model we have employed is the dynamical model used to construct a mesoscale representation in the adiabatic regime. The result is a function that contains two terms, one linear and one quadratic in z. Before using such a model in a coarse resolution OGCM, we have carried out several tests using an eddy resolving code that computes directly the vertical mesoscale flux and thus tests the validity of the model. Several tests of the new model will be presented. Ref. V.M. Canuto, M.S. Dubovikov, C.A. Clayson and M. Luneva. Modeling mesoscales in the oceans mixed layer, Ocean Modelling, 2007, submitted

Keywords: mesoscale, mixed layer, restratification

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Oral Presentation

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Modeling oceanic non-local mixing

Dr. Vittorio Canuto
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Y. Cheng, A.M. Howard

In stably stratified regimes, which are the more common in the ocean, eddies are in general smaller than in the unstable regimes and can therefore be justifiably treated with local mixing models. In unstably stratified regimes, exemplified by Deep Convective regimes, a local model is no longer justified. Thus far, non-locality has been treated with highly empirical models that are based on dimensional analysis considerations. Turbulence models are now sufficiently sophisticated to allow a reliable modeling of the non-local terms as assessments against LES data have shown. They have however never been employed in ocean codes because they are perceived as too complicated. Plume Models have been used for they are relatively simple and embody the main features of up and down drafts. Regrettably, the only model available, the Morton-Taylor-Turner (1956) model is quite limited in its validity since it assumes very skinny plumes and thus fails to account for the full entrainment process which make plumes fat to the point of becoming indistinguishable with the environment. It is therefore limited to the description of eddies in the early stages of development. Given this situation, we have constructed a model for non-local mixing which combines both turbulence and plumes: the model is based on turbulence modeling but plumenize the higher order moments equations so as to considerably simplify them. The new model can describe plumes at any stage of their development. Ref: V.M. Canuto, Y. Cheng and A.M. Howard Non-local ocean mixing model and a new plume model for deep convection, *Ocean Modelling*, 16, 28-46, 2007

Keywords: mixing, nonlocality, plume model



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Vertical mixing model with tides. a new BBL

Dr. Vittorio Canuto
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A.M. Howard, C.J. Muller, S.R. Jayne

TOPEX/POSEIDON data show that approximately 3.5 TW of tidal energy is dissipated in the ocean and that 30% of it is dissipated at the oceans bottom. This tidal dissipation influences the ocean dynamics by enhancing bottom drag and providing an additional source of deep mixing. OGCMs have recently begun incorporating spatially variable mixing due to the part of the tidal energy that is converted into internal tides. We have extended the GISS turbulence vertical mixing model to include both the dissipation into internal tides and the dissipation due to tidally-induced bottom drag which becomes particularly relevant in shallow seas. In order to do so, we have worked out a new Bottom Boundary Layer model for use in coarse resolution OGCMs. It includes the new effects of subgridscale tidal velocities in increasing the bottom drag on the mean velocity resolved by the OGCM, making the drag coefficient CD a function of the tidal dissipation instead of a constant, and generating additional bottom mixing due to subgridscale shears. We use an off-line model to calculate the tidal velocity field. We implement the new GISS mixing model with new BBL in a stand-alone OGCM and compare results with observations and with previous OGCMs incorporating the internal tide dissipation only. We also perform a sensitivity study, varying the fraction q of internal tidal energy that is released locally from the 0.3 value used by previous authors down to 0 and up 1. We find that including tidal effects improves model performance over the ocean as a whole, with the largest improvements occurring in the Arctic Sea. We found that improvements increased with increasing q , but leveled off somewhat after $q=0.3$. Our best model result was obtained at $q=0.7$. Ref. V.M. Canuto A.M.Howard, C.J.Muller and S.R.Jayne. GISS Mixing model with tides. Enhanced bottom mixing and a new bottom boundary layer. Ocean Modelling, 2006, submitted

Keywords: mixing, tides, bottom drag



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Oral Presentation

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Direct breaking of the internal tide over Kaena Ridge, Hawaii

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Two distinct ocean mixing mechanisms are at work in the waters above the Kaena Ridge, a site of strong barotropic to baroclinic tidal conversion on the Hawaiian Ridge. In the waters 800 m above the ridge crest, mixing events resemble their open ocean counterparts. There is no apparent modulation of mixing rates with the fortnightly cycle and they are well-modeled by standard open-ocean parameterizations. Nearer to the topography, there is quasi-deterministic breaking associated with each baroclinic crest passage. Large amplitude internal waves appear to be triggered by the baroclinic tide, consistent with lee wave formation at the ridge-break. These waves are high-mode with vertical wavelengths on the order of 200-m. During spring tides the waves are highly non-linear and exhibit convective instabilities on their leading edge. Dissipation rates exceed those predicted by the open-ocean parameterizations by up to a factor of 100, with the disparity increasing as the seafloor is approached. These observations are based on a set of repeated CTD and micro-conductivity profiles obtained from the R/P FLIP. FLIP was tri-moored over the southern edge of the ridge crest. Ocean velocity and shear was resolved to 4-m vertical scale by a suspended Doppler sonar. Dissipation was estimated both by measuring overturn displacements and from microconductivity wavenumber spectra. The methods agreed at depths below 200 m, where sensor resolution limitations do not limit the turbulence estimates. Clearly, at intense mixing sites new phenomena await discovery and existing parameterizations cannot be expected to work.

Keywords: ocean mixing, internal tide, convective instability



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Oral Presentation

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Theoretical results on abyssally trapped near-inertial waves

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It is common in studies on geophysical fluid dynamics to neglect the components of the Coriolis force that are proportional to the cosine of latitude -- the so-called 'Traditional Approximation' (TA). Here it is shown that abandoning the TA gives rise a class of sub-inertial internal waves that have two remarkable properties: 1) they are short, and 2) they are trapped in the weakly stratified abyssal ocean; this suggests that they may provide an efficient pathway to abyssal mixing. Theoretical estimates show that 10-20% of the poleward propagating near-inertial wave energy may thus get trapped in the abyss. Another consequence of abandoning the TA is that it modifies the conversion rate in internal-tide generation, and hence the energy available for mixing.

Keywords: internal waves, mixing



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Oral Presentation

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Laboratory modeling of excitation of internal waves by turbulent buoyant plumes discharged from a submerged wastewater outfall

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Daniil Sergeev, Ekaterina Ezhova

Disposal of wastewaters of coastal cities to the ocean is a usual world practice. A typical outfall construction consists of a submarine pipeline with a diffuser section at the far offshore end a manifold with many small holes [Koh, Brooks, 1975]. Fresh water is discharged to ambient salty ocean water at rates 1-5 m/s to form buoyant plumes producing sensible stress on coastal water areas including effects on hydrodynamics of coastal zone and coastal ecosystems. Modern methods of investigation of the outfall area include modeling [Koh, Brooks, 1975, Bondur et al, 2006], contact field measurements [Bondur et al, 2004] and remote sensing by airborne and spaceborne instruments [Bondur et al, 2005]. The latter method is based on surface manifestation of the submerged outfalls hypothetically due to effect of internal waves generated by buoyant plums [Bondur et al, 2005]. The main aim of the present work is investigation of possibility of internal wave excitation by buoyant turbulent plumes and estimate of efficiency of such mechanism basing on laboratory scale modeling. The experiments were carried out in the large thermostated tank (overall sizes 20m²4m²2m) with artificial thermocline-like temperature stratification. The alcohol solution with density 0.93 g/cm³ was discharged at the rates $U_0 = 0.3 \text{ - } 1.9$ m/s from $b_0=0.3$ cm holes forming turbulent plumes trapped by the tank thermocline. These parameters provided scale modeling of Sand Island Honolulu wastewater outfall in Mamala bay (Hawaii) with the geometrical scale 1/27. $U_0=1$ m/s provide similarity in dimensionless parameters of the problem: the Richardson number and the dimensionless parameter of the ambient stratification (here Dr_0 is the initial difference between the plum and ambient densities, N is the maximum buoyancy frequency, g is the gravity acceleration). Excitation of intensive temperature oscillations was observed at significant distance (1.3-4 m) from the diffuser. For the discharge rates 95-105 m/s, corresponding to the scale-modeling conditions the amplitude of the isotherm oscillations was 3-5cm, which gives to 0.8-1.3 m for the field conditions according to the scale coefficient 1/27. The measured dependency of the amplitudes of oscillations on the control parameter of the problem Ri was typical for the presence of the Hopf bifurcation to the self-sustained oscillations of the buoyant plume [Huerre, Monkewitz, 1990]. The observed internal waves were interpreted as a result of impact of the oscillations on the thermocline.

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Keywords: buoyant plums, submerged wastewater outfall, turbulence

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Oral Presentation

5856

An energy-constrained parametrization of eddy tracer flux

Prof. Paola Cessi

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A parametrization for eddy tracer fluxes for use in coarse-grid models is developed and tested against eddy-resolving simulations. The development is based on the assumption that the eddies are adiabatic (except near the surface) and the observation that the flux of buoyancy is effected by barotropic, depth-independent eddies. Like the previous parametrizations of Gent and McWilliams (GM) and Visbeck et al. (VMHS), the horizontal flux of tracer is proportional to the local large-scale horizontal gradient of tracer, through a transfer coefficient assumed to be given by the product of a typical eddy velocity scale and a typical mixing length. The proposed differs from GM and VMHS in the selection of the eddy-velocity scale, which is based on the kinetic energy balance of baroclinic eddies. The three parametrizations are compared to eddy-resolving computations in a variety of forcing configurations and for several sets of parameters. The VMHS and the energy-balance (EB) parametrizations perform best in the tests considered here.

Keywords: eddy mixing, parametrization

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Oral Presentation

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Near-Inertial Parametric Subharmonic Instability

Prof. William Young

Scripps Institution of Oceanography University of California San Diego

Yue-Kin Tsang

I'll present a unified framework for understanding the role of parametric subharmonic instability (PSI) in energizing the near-inertial peak of the oceanic internal wave field. This theory, illustrated and validated with numerical simulations, provides analytic estimates of the rate at which energy is transferred from the coherent wave trains generated by tides to near-inertial oscillations. The resulting near-inertial waves have small vertical scale and large vertical shear so that the stage is set for mixing. The transfer of energy to small vertical scales is much faster than suggested by earlier estimates based on the random phase approximation. These results support the hypothesis that PSI is a rapid and robust mechanism for the transfer of energy from $2 f_0$ to the neighborhood of f_0 . Because of their spatial and temporal coherence, geostrophic eddies create strong spatial inhomogeneities in the oceanic environment through which internal gravity waves propagate. Thus as further validation of the hypothesis above, the role of geostrophic eddies in catalyzing PSI and in spatially organizing near-inertial waves is assessed.

Keywords: psi, near inertial, tides

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Propagation of Antarctic Bottom water through the Vema and Romanche fracture zones and mixing

Dr. Eugene Morozov

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In November 2005 and November 2006, Russian R/V "Akademik Ioffe" occupied hydrographic sections across the deep passages for Antarctic Bottom water (AABW): Romanche Fracture zone at the equator, and Vema Fracture Zone at 11 N in the Atlantic Ocean. The transports of AABW measured using the lowered acoustic Doppler profiler did not exceed 0.5 Sv in both channels, which is smaller than the previous estimates. Deep basins in the northeastern part of the Atlantic Ocean are filled with transformed AABW that passes through the Vema Fracture Zone but not through the Romanche FZ. The cause that AABW, which passes through the Romanche Fracture Zone, does not propagate to the north through the Kane Gap is explained on the basis of the results published by E.G. Morozov in 1995 in Deep-Sea Research. The amplitudes of internal tidal waves at the slope of Mid-Atlantic Ridge near the Romanche FZ (50 m) are much greater than those near the Vema FZ (20 m). Hence, AABW is mixed stronger at the Romanche Fracture Zone.

Keywords: vema, romanche, aabwmixing



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Oral Presentation

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Internal wave propagation and mixing in marginally stratified waters: the Mediterranean laboratory

Dr. Hans van Haren

physical oceanography Royal NIOZ IAPSO

The western Mediterranean Sea can be considered a laboratory for deep-ocean physical oceanographic process studies. Except for tides, which are generally very weak, many of the major processes can be studied : deep water formation, inertial motions and internal waves, double diffusive mixing, mesoscale eddies. The attractiveness of the western Mediterranean Sea for studying these processes is the relatively easy recognition of the different signals in observations. This is because of each of these processes occurs in localized areas and/or well-defined periods of time whilst regularly showing large amplitudes. Deep-water formation occurs in winter when favourable mountain winds blow, mainly in the region between Gulf of Lions and Ligurian Sea. The newly formed water spreads towards the south in the deep later, thereby creating thick (100-800 m) layers of homogeneous waters. Mesoscale eddies are formed along the Algerian coast and propagate northwards whilst reaching all the way to the bottom (~3000 m). The vertical density stratification in the layers between the homogeneous layers has a nearly fixed value of relatively weak, but non-zero stratification (buoyancy frequency several times the inertial frequency). This creates an environment for non-traditional internal wave propagation, in which the horizontal component of the Coriolis force is important and in which inertial waves play a dominant role. Here we are concerned with internal wave motions and associated instabilities across the interfaces between stratified and homogeneous waters. Such study is of eminent importance for deep-ocean mixing, where such layering does occur, albeit in a much more variable, and thus blurred form. Using moored ADCP, current meter and temperature sensor information, together with limited CTD data, we discuss : 1. inertial internal wave motions in truly homogeneous layers, 2. internal wave propagation across the interface between stratified and homogeneous waters, 3. the relationship between inertial shear and stratification leading to a marginally stable Richardson number, 4. the possible effect of inertial and buoyancy frequency motions on deep-ocean mixing.

Keywords: inertial motions, stratified and homogeneous, destabilization



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Overflows on the Mid-Atlantic Ridge

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Louis St. Laurent, Gilles Reverdin, Pascale Bouruet-Aubertot, Valerie Ballu

In order to close the global overturning circulation, buoyancy lost from the ocean to the atmosphere at high latitudes must be gained elsewhere along the path of the flow. In case of the deep and bottomwaters this buoyancy gain is primarily accomplished by mechanical mixing with overlying water. While previous observational programs have clearly illustrated the connection between rough topography and mixing, their spatial and temporal resolutions have not been sufficiently fine to investigate the processes giving rise to the mixing in detail. During a recent expedition to the crest of the Mid-Atlantic Ridge near 37N, a high-resolution CTD/LADCP survey was carried out to investigate flow dynamics in a region of rough topography consisting of two minor basins connected by several narrow passages. The survey revealed no less than three separate overflows, all of which are most likely hydraulically controlled. In order to separate temporal from spatial variability one of the overflows was sampled repeatedly at high spatial resolution (~2km station distance), and the flow at the sill was monitored using a submersible-deployed bottom-mounted ADCP. The data indicate strong mixing near the sill with extensive shear layers with Ri

Keywords: mixing, overflow, hydraulics

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Energetics of M2 barotropic to baroclinic tidal conversion at the Hawaiian Islands

Dr. Glenn Carter

Department of Oceanography University of Hawaii

Mark Merrfield, Katsuro Katsumata, Janet Becker, Yvonne Firing, Michael Gregg

Internal tides provide approximately half the energy required to maintain the global ocean stratification. Satellite observations show that 0.7 - 1.0 TW of energy is removed from the barotropic (surface) tide through conversion to internal tides at topographic features in the deep ocean. This energy then cascades via internal waves, to be available for mixing. The Hawaiian ridge is globally the largest convertor of surface to internal tides per unit area, and was the subject of an recent intensive research effort. We present a high-resolution primitive equation model simulation of the principal semidiurnal tide (M2) over a region of the Hawaiian Ridge from Niihau to Maui. This region includes one of the three main internal tide generation sites along the Hawaiian Ridge. The focus of this work was to examine the energy transfer from the barotropic to baroclinic tide. Barotropic and baroclinic energy equations were derived from the model equations. In terms of both barotropic and baroclinic energy components, the balance is primarily between flux divergence and conversion of energy from barotropic to baroclinic. Overall approximately 80% of the baroclinic energy radiates more than 120 km from the 3000 m isobath. However, almost all the baroclinic energy from a generation site at the eastern end of Oahu was lost locally. Over a section of the ridge crest northwest of Oahu (Kaena Ridge), 313 microstructure profiles were taken. The baroclinic dissipation estimated by the model is in agreement with these microstructure data.

Keywords: internal tide, hawaiian ridge, dissipation



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Overflow Turbulence on the Mid-Atlantic Ridge

Prof. Louis St. Laurent

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Andreas M. Thurnherr, Gilles Reverdin, Pascale Bouruet-Aubertot, Valerie Ballu

The densest waters of the ocean are formed by convection in several high-latitude seas. These waters circulate at depth below the oceanic thermocline, and communicate the thermodynamic conditions of the polar atmosphere with the entire global ocean. The buoyancy exchange between this water mass and the upper ocean occurs through turbulent mixing, though the turbulence levels throughout the ocean interior vary widely. New observations from the crest of the MAR in the subtropical North Atlantic suggest that passages (sills and narrows) connecting innumerable small sub-basins in rift valleys and ridge-flank canyons may provide the most energetic sites for turbulent mixing associated with rough topography. In previous studies, these sites have largely been overlooked as significant regions for the conversion of deep water. Direct measurements of flow and turbulence levels in a deep passage connecting minor sub-basins of the Mid-Atlantic Ridge show mixing levels typical of the ocean's most energetic hydraulically controlled overflows (e.g. in the Romanche Fracture Zone). Depth-averaged kinetic energy dissipation rates as large as $1e-6$ W/kg characterize the flow 100-200 m above the seabed downstream of the sill. Additional strong mixing was observed up to 500 m above the sill depth, where a strong shear layer separated the substantial flow sustained in the passage from the weaker circulation above. Unlike some previous observational studies of abyssal mixing, our study site is relatively shallow at 2000-m depth, and thus provides a direct mechanism for buoyancy exchange between deep water and the base of the thermocline.

Keywords: mixing, overflow, hydraulics



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Oral Presentation

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Southern Ocean Diapycnal Mixing in a Coupled General Circulation Model

Mr. Tim Graham

School of Mathematics PhD Student

David P Stevens, Adrian J Matthews

Recent studies have revealed high rates of diapycnal mixing in the Southern Ocean. A modelling study has been carried out in a coarse resolution coupled general circulation model (FORTE). In a series of model runs the diapycnal diffusivity is increased in the Southern Ocean. This presentation will consider the impact of this increase on the coupled climate system. Higher values of Southern Ocean diffusivity result in an increase of Southern Hemisphere sea surface temperature, a reduction and northward shift of the Southern Hemisphere westerly winds, and an increase in the strength of the Southern Ocean meridional overturning circulation. The remote response includes a reduction in Atlantic meridional overturning and modified heat fluxes in the North Atlantic.

Keywords: diapycnal, southern ocean

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Oral Presentation

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Impact of channel geometry and rotation on the trapping of internal tides

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Leo Maas

The generation and propagation of internal tides has been studied with an isopycnic 3D ocean model. We consider the response of a uniformly stratified sea in a channel which is forced by a barotropic tide on its open boundary. The tide progresses into the channel and forces internal tides over a continental slope at the other end. In a series of four experiments we show how the cross-channel geometry affects the propagation and trapping of internal tides and we discuss the penetration scale of wave energy, away from the continental slope. In particular it is found that a cross-channel bottom slope constrains the penetration of the internal tidal energy. Most internal waves refract towards a cross-channel plane where they are trapped. The exception is formed by edge waves that carry part of the energy away from the continental slope. In case of rotation, near the continental slope the Poincaré waves that arise in the absence of a cross-channel slope no longer bear the characteristics of the wave attractor predicted by 2D-theory, but are almost completely arrested, while the rightbound Kelvin wave preserves the 2D-attractor in the cross-channel plane, which is present in the nonrotating case. The reflected, barotropic rightbound Kelvin wave acts as a secondary internal wave generator along the cross-channel slope.

Keywords: internal waves, geometrical trapping, mixing hotspots

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Oral Presentation

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Internal Hydraulic Jumps and Overturning generated by tidal flow over a tall steep ridge

Dr. Sonya Legg

Atmosphere and Ocean Sciences Program Princeton University IAPSO

Jody Klymak

The interaction between tidal currents and oceanic topography is known to provide a mechanism for transferring tidal energy into baroclinic motion. This mechanism is hypothesized to provide a significant fraction of the energy needed for deep mixing in the ocean. A subject of ongoing investigation is the partitioning of that baroclinic energy into motions likely to lead to mixing local to the topography and radiating internal waves which ultimately cause mixing elsewhere. Here we examine one process which may lead to local mixing, namely the generation of transient internal hydraulic jumps. These tidally-driven jumps are predicted to occur when the vertical tidal excursion is large, which is shown to imply steep topographic slopes. The vertical length-scale of the jumps is predicted to depend on the flow speed such that the jump Froude number is of order unity. A series of numerical simulations explores the parameter space of topographic slope, barotropic velocity, stratification and forcing frequency. Results agree with the theoretical predictions, with finite amplitude internal hydraulic jumps and overturning forming during strong offslope tidal flow over steep slopes.

Keywords: tidal mixing

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Oral Presentation

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On bottom drag, horizontal eddy viscosity, and energy dissipation in models and observations of oceanic mesoscale eddies

Dr. Brian Arbic

Institute for Geophysics The University of Texas at Austin IAPSO

Kurt L Polzin, Robert B Scott

We utilize numerical simulations of forced-dissipated two-layer geostrophic turbulence, in-situ observations, and satellite observations, to study the energy dissipation of oceanic mesoscale eddies. We argue that both bottom drag and horizontal eddy viscosity are required to yield model eddies to compare well with observations. Moderately strong large-scale friction acting in the bottom layer only is required to yield realistically surface intensified eddy kinetic energy in the model. This is true whether the bottom drag is linear (1) or quadratic (2) in the flow. When the turbulence model is run at high resolution and only a spectral filter is used for small-scale dissipation, very little energy dissipation takes place in the upper layer, and the forward cascades at small horizontal scales are much smaller than those seen (3) in satellite altimetry data. Inclusion of a horizontal eddy viscosity of order $50 \text{ m}^2 \text{ s}^{-1}$ in the model generates the forward cascades at small scales, as seen in satellite observations, and energy dissipation in the upper layer, consistent with in-situ microstructure observations. Eddy viscosities of this order are in agreement with values inferred from in-situ current meter data at the POLYMODE Local Dynamics Experiment (see Polzin et al., this session), and from a nearly global analysis of altimetric data. The viscosities may represent interactions between mesoscale eddies and internal waves. We argue that the nondimensional eddy viscosity increases with increasing latitude, and that this may explain differences in the spectral kinetic energy fluxes that arise with changing latitude in the satellite observations. (1) Arbic, B.K., and Flierl, G.R., *Journal of Physical Oceanography*, volume 34, 2257-2273, 2004. (2) Arbic, B.K., and Scott, R.B., paper under review. (3) Scott, R.B., and Wang, *Journal of Physical Oceanography*, volume 35, 1650-1666, 2005.

Keywords: mixing, viscosity, eddies



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Near-resonant internal wave triads

Dr. Kevin Lamb

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Youna Hu

A resonant-triad is a set of three weakly-nonlinearly interacting waves whose wave vectors and frequencies sum to zero. They occur in many physical systems and have played an important role in our understanding of the nonlinear evolution of the internal wave field in the deep ocean. Near-resonant triads are sets of three waves which are detuned: the sum of the wave vectors and/or wave frequencies is no longer exactly zero. In this talk I will discuss numerical simulations of tidally generated internal waves in a linearly stratified fluid for which near-resonant interactions are the dominant form of weakly-nonlinear interactions in the internal wave field.

Keywords: internal waves, near resonance, tide topography interaction



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A Lagrangian based approach for determining trajectories taxonomy and turbulence regimes

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ACSCIM-MOD ENEA

In this work we propose the use of the ratio between the acceleration and velocity timescales $y=Ta/Tv$ to separate Lagrangian trajectories in homogeneous classes. In fact, analyzing subsurface floats data in the Atlantic and surface drifters data in the world's ocean basins, we observe that trajectories having different values of y are characterized by different shapes, correlation and dispersal properties. In particular, trajectories having similar values of the acceleration and velocity timescales clearly show the influence of eddies and are characterized by an oscillating velocity correlation function. We show that this trajectories 'screening' is a useful procedure to rationalize the analysis of real Lagrangian trajectories and to avoid a mixture of different regimes, when averaging quantities. The mean statistical quantities computed averaging on quasi homogeneous data sets put in evidence the role of the coherent structures in the dispersion properties, both in time and in the main oceanic current systems. These results are discussed in the context of the parameterization of eddy diffusivity in general circulation models

Keywords: lagrangian trajectories, eddy diffusivity, mesoscale



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Oral Presentation

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Mixing in the equatorial thermocline

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Mixing has a significant impact on the dynamics and thermodynamics of the ocean in many regions. The equatorial region is no exception. Modeling studies have demonstrated the great sensitivity of the state of the equatorial ocean to the level and form of imposed mixing and yet the processes by which the mixing is achieved are in general poorly understood. The focus here is on processes that form small vertical scale structures in the equatorial thermocline that can lead to both lateral and vertical mixing of momentum, potential vorticity and tracers. A manifestation of such small vertical scale features is the presence of the interleaving of water masses that are observed to have a vertical scale of $O(20\text{m})$, a meridional scale $O(200\text{m})$, and which can stretch more than 1000km in the zonal direction. Such features can have a significant impact on the basin scale dynamics. We report on studies looking at the stability of time-varying, sheared, equatorial flows and the subsequent evolution of the system. In geophysically relevant parameter regimes we find inertial instability, parametric subharmonic instability, and a mixed instability can play a role. Both the stability and equilibration are dependent on the form of the shear and the strength of meridional motions associated with the time-varying flow, which in turn affects the level of vertical and lateral mixing. The inference is that scale interactions may link mixing in the equatorial thermocline to variations of the larger scale flow on intraseasonal to interannual timescales.

Keywords: mixing, equatorial, interleaving



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Oral Presentation

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Study of the meridional overturning structure of the Antarctic Circumpolar Current using an eddy resolving ocean model

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Frontier Research Center for Global Change JAMSTEC

Hiroyasu Hasumi

The meridional overturning structure of the Antarctic Circumpolar Current (ACC) is studied by using an eddy resolving ocean model and sensitivity of the overturning structure to horizontal resolution is investigated using two different resolutions of $1/4 \times 1/6$ and $1/8 \times 1/12$ (longitude x latitude). The temporal-residual-mean framework is employed to evaluate time-mean subduction of a water mass, into which both the Eulerian-mean and mesoscale eddy contributions are incorporated. The model results show that the vertical transport of water mass in the ACC is very inhomogeneous in space. For the higher resolution case, the downward transport in the Malvinas-Brazil Current Confluence is strongest and the vertical component of the residual-mean velocity exceeds 10-5 m/s. The zonal averaged transport along isopycnal shows that water mass is transported upward in the poleward flank of the ACC and downward in the equatorward flank for both resolution cases. The strength of downwelling mass transport is more sensitive to the horizontal resolution than the upwelling.

Keywords: eddy resolving, temporal residual mean, antarctic circumpolar current

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Oral Presentation

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LES of Langmuir Circulations in unstratified and stratified upper oceans

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The influence of surface waves and applied wind stress are studied in an ensemble of large eddy simulations to investigate the nature of deeply penetrating jets into an unstratified or stratified upper ocean. The influence of a steady monochromatic wave is parameterised using the wave filtered Craik-Leibovich equations. The wave is set to propagate parallel to the wind direction. Turbulent kinetic energy (tke) budgets reveals how Langmuir turbulence is distinguished from classic shear turbulence. In the former tke production by Stokes shear dominates tke production by mean shear and a vertical flux term transports the tke to a depth where it is dissipated. In the latter tke production by mean shear is locally balanced by dissipation. At the base of the mixed layer internal waves propagate energy and momentum into the interior. Results are presented to show the interaction between Langmuir circulations and the internal waves field.

Keywords: langmuir, les, internal waves

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Oral Presentation

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Energetics of wind-induced turbulent mixing in the ocean

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Toshiyuki Hibiya

The pattern and magnitude of the global ocean overturning circulation is believed to be strongly controlled by the distribution of diapycnal diffusivity below 1000 m depth. Although wind stress fluctuation is a candidate for major energy sources of diapycnal mixing processes, the global distribution of wind-induced diapycnal diffusivity is still uncertain. It has been believed that internal waves generated by wind stress fluctuations at middle and high latitudes propagate equatorward until their frequency is twice the local inertial frequency and break down via parametric subharmonic instabilities causing diapycnal mixing. In order to check the proposed scenario, using a vertically two-dimensional primitive equation model, we examine the spatial distribution of "mixing hotspots caused by wind stress fluctuations. It is shown that most of the wind-induced energy fed into the ocean interior is dissipated within the top 1000 m depth in the wind-forced area and the energy dissipation rate at low latitudes is very small. Consequently, the energy supplied to diapycnal mixing processes below 1000 m depth falls short of the value required to sustain the global ocean overturning circulation.

Keywords: wind stress fluctuations, mixing hotspots, near inertial waves



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Mapping of Mixing Hotspots in the World Deep Oceans

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The global mapping of diapycnal mixing rates in the ocean interior is indispensable to improve the accuracy of meridional overturning circulation models and hence their ability in predicting future climate changes. For this purpose, we first estimate diapycnal mixing rates over a wide area in the interior of the North Pacific by applying the parameterization of Gregg [1989] to the fine-scale vertical shear of horizontal velocity measured by expendable current profilers. We then relate these estimates to the numerically predicted, available energy density of the semidiurnal internal tide (major energy source for diapycnal mixing) at each location and find an empirical formula to clarify the global distribution of diapycnal mixing rates in the ocean interior. Incorporating the numerically predicted energy density of the semidiurnal internal tide at each longitude and latitude in the world's oceans into the resulting empirical formula, we find that strong diapycnal mixing (mixing hotspot) is limited to the prominent topographic features at latitudes between 20 and 30. A possible explanation for this result is that the available semidiurnal internal tide energy can be efficiently transferred to dissipation scales by parametric subharmonic instability in this latitudinal band [Hibiya et al., 1996, 1998, 2002; Furuichi et al., 2005]. The validity of the obtained global map of mixing hotspots is confirmed by microstructure measurements at 28 key locations in the interior of the North Pacific including near the Aleutian Ridge, the Hawaiian Ridge, and the Izu-Ogasawara Ridge.

Keywords: diapycnal mixing rates, thermohaline circulation, semidiurnal internal tide



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Estimates of tidal energy dissipation and diapycnal diffusivity in the Kuril Straits using TOPEX/Poseidon altimeter data

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The Kuril Straits separating the Okhotsk Sea from the North Pacific Ocean are representative regions of strong tidal mixing in the world's oceans. In the present study, we first carry out numerical simulation of the barotropic tidal elevation field in the Okhotsk Sea using a horizontally two-dimensional primitive equation model. It is found that, to reproduce realistic tidal elevations in the Okhotsk Sea, the energy lost by the incoming barotropic tides to internal waves within the Kuril Straits should be taken into account. The numerical experiments show that the model predicted tidal elevations in the Okhotsk Sea best fit the TOPEX/Poseidon altimeter data when we take into account the baroclinic energy conversion in the Kuril Straits ~ 16 GW for the K1 tidal constituent and ~ 37 GW for the major four tidal constituents (K1, O1, M2, S2). For this baroclinic energy conversion, diapycnal diffusivity averaged over the whole area of the Kuril Straits is estimated to be ~ 8 cm²s⁻¹. This value is about one order of magnitude less than assumed for the Kuril Straits in previous ocean general circulation models. We offer this study as a warning against using diapycnal diffusivity just as a tuning parameter to reproduce large scale phenomena.

Keywords: strong tidal mixing, flow through straits, tide sill interactions



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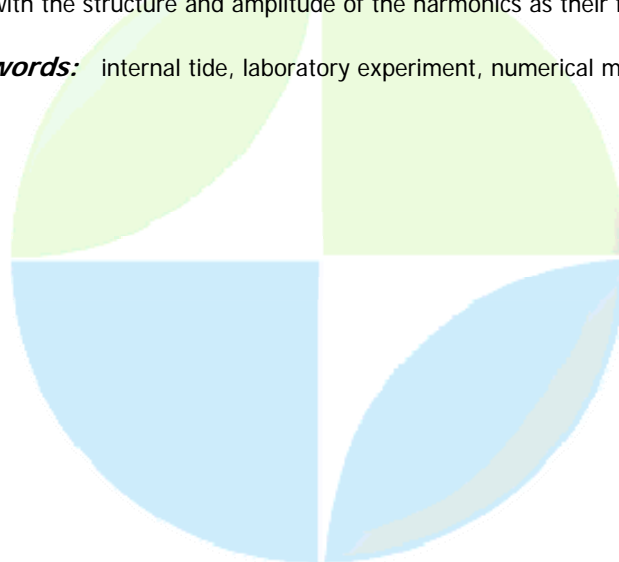
**Internal tide generation and propagation near a continental shelf:
experimental and numerical modeling approaches**

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LEGI CNRS-UJF-INP

Chantal Staquet, Joel Sommeria, Mehdi Mehdizadeh

Internal gravity waves in the deep ocean have been given much importance for ten years, since Munk & Wunsch (1998) proposed that the raising of the cold abyssal water masses is sustained by the energy sources that feed the mixing processes in the abysses. Mixing in the deep ocean is mostly due to breaking gravity waves, which are created by the wind and by the interaction of the tide with the bathymetry. The energetic content of both energy sources may be roughly estimated at global scale and are likely to be comparable, of the order of 1 TW. The thermal equilibrium of the deep ocean thus depends upon local, strongly intermittent processes which occur on small temporal scales (of the order of the hour and even less) and small spatial scales (of the order of ten meters). This gigantic difference in spatial and temporal scales requires the parameterization of the mixing processes in large scale circulation models, and even in regional models. This obvious requirement is still an open problem as it relies upon a direct study of the mixing processes. In this study, we address the nonlinear dynamics of the internal wave field generated by interaction of a barotropic tide with a continental slope. This is done with a joint approach combining experiments and numerical modeling. The experiments were made at the Coriolis platform in Grenoble and the finite-volume, non-hydrostatic and implicit free-surface numerical code developed at MIT has been used to mimic the experimental set-up. Two academic configurations are considered, a uniformly stratified fluid and a fluid with a thermocline close to its surface. In this talk, the focus is on the former case, in a two-dimensional geometry in which along-slope variations are neglected. In this simplified situation, the internal wave field organizes itself as a rectilinear wave beam at the tidal forcing frequency. The energy of the so-called internal tide propagates along beams tangent to the topography and reflecting at the bottom and at the surface of the ocean. The angle of the beams with the horizontal is predicted by the linear theory. Interest is given in particular to the generation mechanism of the beam and to the structure of the beam, relying on theoretical modeling of internal wave emission by an oscillating cylinder. The nonlinear dynamics of the internal wave field, resulting for example from wave-wave interactions, is also discussed. The conditions for the generation of waves at higher frequencies or harmonics due to nonlinear effects will be considered, together with the structure and amplitude of the harmonics as their frequency increases.

Keywords: internal tide, laboratory experiment, numerical modeling



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Intermittent mixing in equatorial deep jets as a consequence of inertial instability

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The closure of the mass budget in the global ocean circulation is a fundamental and still open problem in ocean science. In particular, the dynamics of the resupply to the abyssal oceans with potential energy lost through polar deep water formation is poorly understood. Equatorial deep zonal jets are a significant reservoir of kinetic energy, and their transport reaches about 2/3 of the thermohaline circulation. For these reasons, the equatorial regions are thought to be preferential places for abyssal mixing. Observations in the equatorial Atlantic show two distinct vertical scales. On the deep jets, of scale 500-800m, is superimposed a smaller scale signal of thin layers (50-100m) of well-mixed tracer fields [O₂, salinity, spice]. The thin layers coincide spatially with regions of zero or anomalous potential vorticity in the deep jets and, as such, are interpreted as due to inertial instability mixing. In recently performed very high resolution numerical simulations, equatorial deep jets of 500-800m vertical scale are successfully produced by a time-oscillating forcing in the western boundary of an ocean-scale basin. In such a flow, the time-evolution of a passive tracer field shows a characteristic depth of mixing of about 40m, and potential vorticity is latitudinally homogenized over approximately the same depth. In agreement with the observations, the two distinct vertical scales are reproduced in the simulations. Estimates of vertical diffusion in the numerical simulation yields values of 10-4m²/s.

Keywords: equator, mixing, inertial instability



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Inertial convective subrange in the bottom boundary layer of Rockall Channel

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Hans Van Haren

Deep-ocean high resolution moored temperature data were analyzed with a focus on super-buoyant frequencies. The existence of a buoyancy subrange (BSR) in between the inertia-gravity wave (IGW) frequency range and the inertial convective subrange was addressed. Potential energy spectra gave evidence of a direct transition from the IGW range to an inertial convective subrange (ICS) characterized by a $-5/3$ slope regardless the energy level in the IGW band. A fit for these potential energy spectra at super-buoyant frequencies, higher than twice the buoyancy frequency, is proposed that depends on the potential energy within the IGW band, PE_{IGW} , and the buoyancy frequency, N . The scaling for kinetic energy dissipation is $e \sim 0.3 PE_{IGW} N$ assuming a mixing efficiency of 0.2. This result is in contrast with classical fine-scale parameterization in which $e \sim PE_{IGW}^2$ valid for situations close to the Garrett and Munk spectral model. The presence of strongly stratified sheets that are well-known in the BSR are evidenced in the ICS in the present dataset and the spatial distribution of these structures is found to be set by the Ozmidov scale.

Keywords: turbulence, inertia gravitywaves, bottomboundarylayer

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Phytoplankton in a turmoil

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Floating and sinking are essential functions in the life cycle of phytoplankton, which cope with, or manage, them to match their basic biological needs, i.e., capture of light and nutrients, mitigation of mortality rate and, in some cases, mating. The results obtained in laboratory experimental set-ups have shown evident capabilities of buoyancy control up to positive values in calm water and, recently, accelerated sinking velocities as compared to calm water, in turbulent flow field. On the other hand the numerous numerical studies performed on particles moving in a turbulent flow field have either analyzed large particles or particles whose density was significantly different from the density of the fluid. This allowed neglecting some terms which appear in the complete form of the equation of motion for a particle in a fluid as established by the classical studies of Basset, Lamb, Maxey etc.. To investigate whether those terms, namely the added mass and the Basset history term, are significant when considering a phytoplankton particle embedded in turbulent sea-water, we conducted a study where the flow field was prescribed using 2D kinematic simulations, DNS and LES solutions and the size and density of the particles is varied within the ranges typical for phytoplankton cells. The differences in net vertical velocity and distribution patterns with and without the inclusion of all the terms of the above mentioned equation, will be presented and discussed in an ecophysiological perspective.

Keywords: turbulence, plankton, settling rate

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Diagnosing thickness diffusivities in eddy-resolving models

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Output from two eddy-resolving models of the North Atlantic and the Southern Ocean is used to estimate the thickness diffusivity (K) appropriate to the Gent and McWilliams (GM) parameterization, which accounts for the advective effect of meso-scale eddy mixing in the ocean. The effect of different choices for rotational eddy thickness fluxes on the estimated K is discussed and are found to be large. Reasonable results in terms of K are obtained using choices for rotational fluxes based on the suggestion of Marshall and Shutts (1981) and Medvedev and Greatbatch (2004). In the subtropical gyre of the North Atlantic, K shows large variations and ranges between 500 to 2000 m^2/s in the upper thermocline. Zonally averaged near surface values of K in the Southern Ocean remain smaller than 200 m^2/s polewards of the polar front, increases between 60-45°S to about 600 m^2/s and peak between 45-35°S at almost 3000 m^2/s . In both the North Atlantic and the Southern Ocean K stays high in the upper thermocline but is rapidly decreasing to zero below the thermocline. A previously neglected component of the (GM-) bolus velocity is also discussed which is interpreted as eddy-induced advection, rather than diffusion, of mean isopycnal layer thickness, showing up when the lateral eddy fluxes cannot be described by isotropic diffusion only. Strong anisotropic lateral mixing has been diagnosed from the models: In the North Atlantic we found westward eddy-induced advection of isopycnal thickness over much of the subtropical gyre and eastward (westward) advection at the poleward (equatorward) flank of the ACC.

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Dynamics of water exchange in deep ocean basins

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Carina P. Erlandsson

We have studied how the residence time T_e of the basin water depends on (i) the spectral distribution of the temporal density variability of potential new deepwater, (ii) the rate of diapycnal mixing of the basin water, and (iii) the time T_{fill} it takes to fill the basin with new deepwater. We identified two different classes of systems. Mixing systems have short T_{fill} and T_e depends on the rate of diapycnal mixing in the basin water and on the spectral distribution of the density variability of potential new deepwater. Long-period variations in the latter may to a large extent influence T_e if the mixing is weak. Transport systems, have long T_{fill} and T_e is determined by the baroclinic transport capacity of the mouth. Such systems are over mixed, which means that increasing the energy supply to vertical mixing of the basin water will have no effect on T_e . The model is applied to some coastal systems and to the vertical (thermohaline) circulation of the world oceans. It is found that the latter is a mixing system why the rate of vertical circulation is determined by the power supply to mixing processes in the deepwater and modified by the density difference between the surface layer and the deepwater. Our findings may help to explain differences between basins regarding, for instance, biological populations depending on oxygen conditions.

Keywords: residence time, vertical mixing, over mixing

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Towards a turbulence model for mesoscale eddies

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Possibilities for a turbulence closure for the effects of mesoscale eddies in non-eddy-resolving ocean models are explored. A pragmatic viewpoint is taken and the closure is constructed using elements of simple models of boundary layer turbulence. An eddy kinetic energy (EKE) budget, which can be prognostically integrated in a numerical ocean model, is combined with a diagnostic relation for an eddy length scale, which is given by the minimum between Rossby radius and Rhines scale. Combining EKE and the length scale in a standard mixing length assumption gives the thickness diffusivity according to the Gent and McWilliams parameterisation. Using the same diffusivity, down-gradient diffusion of potential vorticity can also be implemented allowing for the possibility of up-gradient momentum fluxes. The proposed closure is evaluated using synthetic data of two different eddy-resolving models covering the North Atlantic Ocean and the Southern Ocean, respectively. The diagnosis shows that the mixing length assumption together with the definition of eddy length scales and energy dissipation appears to be valid for the thickness diffusivity. The evaluation also shows consistently in all cases that a simplified local closure yields reasonable results with respect to the thickness diffusivity.

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Oral Presentation

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Some riddles about turbulent diapycnal mixing in the oceans

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The concept of "mixing efficiency" is at the core of the current view advocating the critical importance of turbulent diapycnal mixing as possibly being the main driver of the Atlantic meridional overturning circulation and oceanic heat transport. It is usually defined as the rate of increase in gravitational potential energy (GPE) over the dissipation rate of kinetic energy. The terminology of "mixing efficiency" strongly suggests that the GPE increases directly as a result of the turbulent kinetic energy (TKE) transfer, an interpretation often encountered in the literature. Equally plausible, however, is that the GPE increases at the expenses of internal energy, as would occur with molecular diffusion, with the turbulent flow simply acting as accelerating the process. The first riddle is whether the second hypothesis is actually of importance in the oceans. The second riddle, which is related to the issue of estimating the thermodynamic efficiency of the oceans, is whether the turbulence powered by winds and tides increase or decrease the rate of entropy production associated with irreversible mixing. Simple ideas will be presented that provide insights into these two crucial issues.

Keywords: mixing efficiency, thermodynamic efficiency, entropy production



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Oral Presentation

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Does double-diffusion matter anymore?

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Robin D Muench

Double-diffusion was discovered in the 1960s and was followed by rapid development of basic theories, visually compelling laboratory experiments, and oceanic profiler observations of layering structures that suggested double-diffusive origins. Turner's "4/3 law" showed how fluxes could be estimated from CTD observations of layer properties. Oceanographers expected observational evidence of double-diffusion's quantitative importance to follow within a decade, but this was not to be. The question we now assess is why not? Is double-diffusion merely a historical footnote, or does it matter? We will discuss double-diffusion in terms of diapycnal mixing and in terms of thermohaline intrusions. First, we review the role of double-diffusion in diapycnal mixing. Turner's "4/3 law" and Kelley's "G-curve" gave hope that effective bulk diapycnal diffusivities could be compiled and would be confirmed using microstructure observations. We attempt to reconcile those predictions with findings using microstructure, from tracer experiments, and with re-interpretations of inversions from the C-SALT experiment. The discovery by Stern that double-diffusive diapycnal fluxes could cause thermohaline intrusions to grow and extend across fronts led oceanographers to expect that double-diffusive intrusions could cause important lateral fluxes, or at least to have significance in terms of thermal and haline dissipation. Several observational discoveries are reviewed that qualitatively suggest this to be true. We summarize the quantitative findings from these discoveries, and argue that double-diffusion does indeed have a role.

Keywords: double diffusion, mixing, intrusions

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Stirring and mixing in the Nordic overflow plumes

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The dense Nordic overflows across the Greenland-Scotland Ridge contribute about one third or $6 \cdot 10^6$ m³/s to the volume transport of the deep limb of the Atlantic Meridional Overturning Circulation. Most of this water passes the deep gaps in the ridge, Denmark Strait and the Faroe Bank Channel. On their way to the deep basins of the North Atlantic the dense plumes entrain ambient water and thereby approximately double their associated transports. Repeated hydrographic and current observations from ship surveys and moored instrumentation made during the past 10 years are used to quantify this entrainment and the change of water mass characteristics in the plumes along their path of spreading. Mixing in the channels takes place by bottom and interface friction and through the development of a cross-circulation perpendicular to the mean flow path. Entrainment is largest within a few hundred kilometres of the sills and reduces substantially further downstream. There horizontal stirring by mesoscale eddies can explain most of the heat and salt fluxes into the plumes and their downstream development and consequently small scale vertical mixing appears to be of minor importance. In the Denmark Strait plume this may be due to capping of the near bottom flow by a low salinity lid, maintaining a strong pycnocline.

Keywords: overflows mixing

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Comparative quantification of physically and numerically induced mixing in a coastal model application

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Hannes Rennau

Mixing induced by the discretisation of advective terms in ocean models may have considerable impact on the simulated dynamics, specifically if moving fronts and overflows are simulated. In recent years, great progress has been made in the parameterisation of small-scale mixing in ocean models, but the question arises, whether the model performance fully profits from this gain, or whether much of the improvements are blurred by high background values of numerically induced mixing. It is thus useful to compare the physically with the numerically induced mixing. However, although for simple cases with equidistant grid spacing and constant advection velocity some analytical estimates of numerical diffusivity are available, for real applications the numerically induced diffusive fluxes are not easy to quantify. In the approach presented here, physically induced mixing of a certain tracer is quantified by the vertically integrated decay rate of the tracer concentration squared. The numerical mixing is quantified by the difference between the square of the tracer after the advection step and the square of the same tracer advected with the same advection scheme. The soundness of this approach is motivated by consideration of simple linear advection schemes. The performance of this method is demonstrated with the example of saline inflow events from the North Sea into the Western Baltic Sea, simulated with the General Estuarine Transport Model (GETM, see www.getm.eu), a coastal and shelf sea model with state-of-the-art turbulence closure models from GOTM, bottom-following coordinates and high-resolution TVD advection schemes.

Keywords: mixing, advection, parameterization



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Poster presentation

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The analysis of distributions of some turbulence characteristics in the Indonesian Seas based on results of simulations with a regional model

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The distribution of characteristics of turbulence such as energy and master scale along with vertical and horizontal mixing coefficients is analyzed by using results of simulations of the Indonesian Seas circulation with a developed regional model. The model, based on the Princeton Ocean Model (POM), has 250 x 250 grid cells in the horizontal with grid spacing of ~10 km and 29 σ -levels in the vertical. The turbulence parameterization scheme incorporated in the POM is a simplified version of the Mellor-Yamada 2 model. The Indonesian Throughflow is supplied by two primary sources: North Pacific Water (NPW) and South Pacific Water (SPW). These water masses have their own outstanding temperature and salinity characteristics, including, for example, a strong salinity maximum between ~100-200 m (SPW is saltier). However, the main characteristics of NPW and SPW are completely destroyed in the course of crossing the Indonesian Seas. The main reasons for this transformation include the highly complicated topography and the effect of the monsoonal wind system. The topography is such that adjacent basins are separated by sills and straits, resulting in deep overflows in the downstream direction, i.e. towards the Indian Ocean, with associated flushing, upwelling and strong mixing in the vicinity of the sill. The strong seasonal monsoonal winds result in relatively deep mixed layers at the surface and increased intensity of upwellings and/or downwellings.

Keywords: indonesian, turbulence, model



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Poster presentation

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Research of tide-current-induced mixing and its influence on seawater temperature vertical structure in the Yellow Sea

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The Yellow Sea is one part of the East China Sea, which is a sea of shallow water and have complicated dynamical and thermodynamical response, so research of Yellow sea is important to physical oceanography. Using the tide current data and CTD data obtained in the north of the Yellow Sea, tide-current-induced mixing in this sea area is analyzed systematically and its influence on seawater temperature vertical structure is discussed. By research it is pointed out that shearing stress in the vertical direction induced by the tide current in the north of the Yellow Sea is strong and shearing stress near sea bottom is stronger. The turbulence mixing induced by tide current is very important for the formation of seawater temperature vertical structure , and that on the middle and bottom layers is relevant more tightly to the tide current. Complicated temperature vertical structures, such as positive thermocline, negative thermocline, warm middle layer or cold middle layer will be generated by the tide-current-induced mixing.

Keywords: tide current induced mixing, seawater temperature, the yellow sea

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Poster presentation

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Bottom mixed layer in the northern East China Sea

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Shipboard ADCP, CTD and MSP (microstructure profiler) observations were made in the continental shelf in the East China Sea in August 2005 and August 2006. The data sets reveal variable bottom mixed layer heights with 5 ~ 15 m. Near the bottom, the turbulent kinetic energy dissipation rates are high that are typically $O(10^{-7} \text{ Wkg}^{-1})$ but occasionally close to 10^{-6} Wkg^{-1} and corresponding vertical eddy diffusivities reach to $10^{-2} \text{ m}^2\text{s}^{-1}$. High values of dissipation rate and vertical diffusivity are consistent with high turbidity especially in the shallow region. The data from repeated MSP castings and vessel mounted ADCP observations for 5 hours in 2005 and 25 hours in 2006 show that episodic intrusions of enhanced near-bottom turbulence into the upper layers of water column. Good correlation between the height of bottom mixed layer and the phase of tidal current indicates that near-bottom mixing in the region occurs mainly due to the tidal stirring.

Keywords: bottom boundary layer, mixing, dissipation rate



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Poster presentation

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Thermohaline interleaving over the Laptev Sea continental slope

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The double-diffusion (DD) and sequent interleaving in the Intermediate layer can be considered as one of the most efficient sources for the mixing in the low energy Arctic region. Interleaving structures are widely observed as alternating warm, salty and relatively cold, fresh layers, with vertical scale up to 100 m near the frontal zones of the Arctic Basin. These spatially coherent structures transport heat and salt hundred of kilometers toward the shelf and the inner basin, away from the Atlantic Water (AW) core. Number of CTD profiles and the long-term mooring records of temperature, salinity and current velocities obtained in 2002, 2003 and 2004 are analyzed to quantitatively estimate the vertical and horizontal fluxes throughout the thermohaline intrusions in the eastern part of the Nansen and Amundsen Basins of the Arctic Ocean. Different parameterizations of DD fluxes were used to estimate background diffusivities due to processes other than double diffusive mixing. It is found that these diffusivities are in the range from molecular exchange rates and up to 10^{-5} m²/s. By assuming rather diapycnal than isopycnal dynamics of the intrusions it results in 26% of less intensive vertical heat and salt fluxes through intrusive layers. The estimations of turbulent kinetic energy dissipation rates demonstrate that the continental slope area is three times more active then the central part of Nansen and Amundsen Basin. The estimated current velocities for intrusions vary but have an order of 3-5 mm/s in a good agreement with the real current records. It is also concluded that lateral mixing is most likely to account for AW core temperature decrease along its path eastward from the Fram Strait. The lateral heat loses was estimated to be 15-20 times larger than the heat loses at the upper boundary of AW layer.

Keywords: thermohaline, interleaving, arctic



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PS004

Poster presentation

5890

Observations and a Model of the Energy Variability of Near-Inertial Motions

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Seasonal variability of near-inertial horizontal kinetic energy is examined using observations from a Moored Profiler mooring at 39 deg N, 69 deg W in the western North Atlantic Ocean and a one dimensional depth integrated kinetic energy model. Depth-dependent and depth-integrated near-inertial kinetic energy are calculated from available mooring data after filtering to isolate near-inertial-frequency motions. Observational results document a pronounced seasonal cycle featuring a wintertime maximum in the depth integrated near-inertial kinetic energy. Further analysis of the depth dependent near-inertial kinetic energy shows that the winter enhancement derives chiefly from variability in the upper 500 m of the water column. A simple depth-integrated near-inertial kinetic energy model consisting of a wind forcing term and a dissipation term is proposed. The wind energy input into inertial motions is estimated using wind stress calculated from NDBC buoy observations supplemented with NCEP/NCAR Reanalysis data, and inertial surface velocities calculated by running the PWP mixed layer model. The dissipation term in the kinetic energy model is parameterized as the product of a quadratic kinetic energy term and a dissipation coefficient which is a function of the buoyancy frequency. The kinetic energy model captures the overall order of magnitude of the observed near-inertial kinetic energy, as well as the winter enhancement, though agreement on the time scale of individual wind stress events is poor.

Keywords: near inertial, mixed layer, energy



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Poster presentation

5891

Parameterizations of sub-grid turbulent transport in an eddy-permitting Ocean Model

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Sub grid turbulent transport (SGT) that should be parameterized in eddy permitting (1/4 deg.; P-grid) models are explored, based on the results from an eddy resolving (1/12 deg.; R-grid) ocean general circulation model experiment. The velocities (u , v) and tracers T and S in R-grid model are decomposed into the spatial (P-grid) averages and the anomalies, and SGT: ($\langle Tu \rangle$, $\langle Tv \rangle$) are calculated, where $\langle \rangle$ means spatial (P-grid) average and $T = T - \langle T \rangle$. The dependency of SGT on the P-grid mean quantities are examined. The directions of SGT velocities: $(u_E, v_E) = (\langle Tu \rangle, \langle Tv \rangle) / \langle |T| \rangle$ are compared with the direction of mean flow etc. The diffusivity coefficients are estimated using SGT and P-grid mean tracer gradient and compared with P-grid mean strain rates etc. It is suggested that the parameterization implemented in a P-grid model should be anisotropic and the diffusivity coefficient should be a function of velocity gradients. Several directions of anisotropy and diffusivity functions are tested conducting idealized channel P-grid model experiments.

Keywords: eddy permitting, diffusivity, anisotropy

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Poster presentation

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Three-dimensional modeling of tidal circulation and mixing over the Java Sea

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A combination of a three-dimensional hydrodynamic model and in-situ measurements provides the structures of barotropic tides, tidal circulation and their relationship with turbulent mixing in the Java Sea, in order to understand the impact of the tides on material distribution. The model retains the high horizontal and vertical resolutions and is forced by the boundary conditions taken from a global model. The measurements are composed of the sea level at coastal stations and currents at moorings embedded in SEAWATCH buoys, in addition to hydrographic data. The simulated tidal elevations are in good agreement with the data for the K1 and M2 constituents. The features of the K1 and M2 tides also are quite similar to the previous reports. The modeled tidal current seems to be reasonable compared with the observation. Our model results could explain the reason for the K1 constituent dominating in the Java Sea, while the adjacent deep-oceans (the Pacific and Indian Oceans) are dominated by the semidiurnal component. The K1 tide clearly shows the lowest mode resonance in the Java Sea with intensification around the nodal point in the central region caused by co-oscillation tide. The M2 tide is secondary and propagates westward from the eastern open boundary, along with a counterclockwise amphidromic point in the western part. The K1 tide produces a major component of tidal energy, which flows westward and dissipates through the node region near the Karimata Strait. Meanwhile, the M2 tide dissipates in the whole Java Sea. However, the residual currents are mainly induced by the M2 tide and flowing westward to follow the M2 tidal wave propagation. The tidal mixing is mainly caused by K1 tide which has a high peak in the central region and is consistent with the vertically uniform temperature and salinity. The calculated tidal bottom boundary layer (Ekman layer thickness) induced by K1 tide significantly exceeds the water depth due to the strong tidal current, especially in the central part.

Keywords: barotropic tides, resonance, tidal mixing



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Poster presentation

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Breaking of inertia-gravity waves as inferred from direct numerical simulations

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In the ocean large-scale down to submesoscale variability is strongly influenced by rotation and stratification. Instead, at small scales the dynamics is isotropic and the inertial subrange of 3D turbulence is retrieved. In the frequency domain, rotation and stratification come into play at frequencies smaller than the buoyancy frequency. Within this frequency range for supra-inertial frequencies, inertia-gravity waves IGW are an important source of turbulence when they break. Previous work suggests that the transition from a wave regime to small-scale turbulence depends on the energy level of the wave field. For the equilibrium energy level, defined by the Garrett-Munk model, there is an intermediate spectral range, the so-called buoyancy subrange BSR, in between the IGW domain and that of small-scale turbulence. However, for high energy levels the question of the existence of the BSR is raised, because the transition scale between the BSR and the inertial subrange increases with the energy level. Our work focuses on this wave to turbulence transition using direct numerical simulations. We show how this transition depends on the dynamical regime at sub-buoyant frequencies. We show with the numerical simulations that the shape of energy spectra depends on breaking mechanisms such as convective or shear instabilities. A fine-scale parameterization for energy dissipation resulting from IGW breaking is inferred from these results. Another related question is to characterize the intermittency of this turbulence. Numerical simulations and observations gave evidence of strongly stratified sheets that form as a consequence of wavebreaking events. While these structures were observed in the BSR, we show that these sheets still exist in more turbulent regimes.

Keywords: buoyancy subrange, inertial range, intermittency



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Turbulent fluxes in oceanic gravity currents

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Turbulent fluxes in oceanic gravity currents on an inclined ocean floor on the f-plane are determined using a hierarchy of models. The gravity currents considered are periodic in the direction of flow. The results from simulations with a hydrostatic ocean model (OPA) are compared to the simulations with a one dimensional shallow water model in which friction, mixing and entrainment are parameterized. The values of parameters appearing in the parameterization are adjusted using data assimilation. The experiments are performed for a variety of initial conditions observed in existing oceanic gravity currents. The special emphasis is put on determine the impact of the oscillatory modes that occur at Froud number less than 1/2.

Keywords: mixing, gravity current, turbulence

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Lagrangian statistics in Langmuir turbulence

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It has been recently suggested that the influence of the Langmuir circulation on the mixing processes has been previously underestimated and that the Langmuir turbulence could dominate the mixing in the open Ocean Mixed Layer (Li et al., 2005). The major challenge in setting up a numerical simulation of ocean turbulence is the necessity of describing a very wide range of length scales. The potentiality of Large Eddy Simulation (LES), where only some of the scales of motions are resolved directly and the computational cost required is much smaller than the one required by a DNS, in simulating ocean turbulence is currently widely recognized. This study is focused on the analysis of the Lagrangian dispersion of fluid particles in fully developed Langmuir turbulence simulated through a LES. The methodology here used for the analysis of mixing and dispersion processes in this kind of turbulence cover the classical one-particle and two-particles statistics together with the Finite Size Lyapunov Exponent analysis. In addition non-local mixing processes have been highlighted through the application of the transilient turbulent theory. The analysis shows that the presence of coherent turbulent structures (3D eddies) increases the mixing efficiency with respect to a 1D stochastic model for vertical dispersion, generally used in dispersion studies. In addition, it is important to note that the relative dispersion in terms of the FSLE pointed out the presence of Langmuir cells of about 30 m of diameter which generated an isotropization of the dispersion for scales up to 30--40 m. It is worth to note, in addition, the detection through an application of the transilient turbulent theory of an asymmetrical nature of the mixing connected with the realistic nature of the Langmuir cells.

Keywords: langmuir circulation, large eddy simulation, non local mixing

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5896 - 5940

Symposium
Flows and Waves in Straits

Convener : Dr. Eugene Morozov

Co-Convener : Dr. Gregorio Parrilla

Straits and passages connecting different basins play an important role in controlling the circulation by means of mass transport exchanges. Quantifying the transport through the straits and its variability are important for the circulation in the basins connected by straits. Modeling the motion in the straits and various approximations of the flow as well as topographic and boundary effects in the flows through straits will be among the main issues of this symposium. Very often, strong internal waves are generated in the straits due to the interaction of tidal currents with bottom topography. This is a characteristic feature of the Strait of Gibraltar and many other straits. The density distribution in the deep ocean, overflows across deep sills in the straits, and strong internal waves may induce intense mixing in the straits. The study of flows and waves in straits is especially important in Europe since the continent is surrounded by many seas and islands with a large number of straits between them.



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Oral Presentation

5896

The Structure of the Persian Gulf Outflow

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M. Ezam

Oceanography data and a dynamic model are used to consider the structure of Persian Gulf outflow. This outflow influences the physical properties of Oman seawater and variability of the outflow structure reflects the changing ecosystem of the Persian Gulf water. Thickness of the outflow, which is, banked against the Oman coasts due to the earth rotation, is about 200 meters with tongues extending east and north, which may be due to the internal waves. A dynamic model of the outflow based on potential vorticity conservation is used to find the horizontal extension of the outflow from the coast. Typical mass flux from the outflow is about 0.4Sv, which is larger than those reported by others. Hence, any change of the outflow source, the Persian Gulf Water (PGW), say salinity increase due to excessive evaporation or desalination (ecosystem factors) of the PGW may change the outflow structure and the product waters in the Oman Sea. The results of the model show that these can increase the outflow width and mass flux substantially.

Keywords: outflow plumes, potential vorticity, persian gulf



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Oral Presentation

5897

The role of internal waves in the formation of layered structure in exchange flows between two basins (Middle and Southern basins of the Caspian Sea)

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A. Shekarbaghani

Layered structures in the oceans have always attracted the attention of oceanographers. The formation of these structures have be attributed to phenomena such as doublediffusive convection, internal waves, turbulent modulated mixing. Here by examining the vertical structures of temperature, salinity and density, of the middle parts of Caspian Sea we have revealed that such layered structure may be due to the normal modes of the internal waves. Contours of iso-quantities of these physical properties show the existence of regular structures, which indicate that internal waves, which are produced of exchange, flow between two basins; as a result of horizontal density gradients (usually from middle basin to southern basin) may generate these layers. The flow velocity associated with this gravity drive flow is about 0.1 m/s which gives Froude number of about one The wave length of these internal waves are found be about 100 km and the frequency of these waves are of order of inertial frequency. The normal modes of these waves have a near steady structure and can fold the inflow front from the Northern part of the Caspian Sea to the Southern deep basin. The thickness of formed layers is found be about 10-20 m. These are in agreement with the values predicted by the model of Wong et al. (2001). In these waters density ratio is often negative, thus doublediffusive convection does not often occur and hence is less likely to produce these layered structures.

Keywords: internal waves, doublediffusive convection, caspian sea



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Oral Presentation

5898

Eddy Formation off the Entrance to Juan de Fuca Strait

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Numerical simulations with the Regional Ocean Modeling System are used to study the generation of the cyclonic Juan de Fuca Eddy located off the entrance of Juan de Fuca Strait in summer. An initial simulation forced with average summer upwelling favourable winds, tides, and buoyancy boundary conditions that maintain an estuarine flow in Juan de Fuca Strait produces an eddy and currents that are in reasonable agreement with observations. Sensitivity studies are then carried out to explore the importance of these three forcing mechanisms. The relative proximity of dense water in the bottom estuarine flow entering the strait is shown to lead to enhanced upwelling off Cape Flattery, at the entrance of the strait, when either wind or tidal forcing is applied. The tidal upwelling arises both directly and indirectly: i) west of the cape, M2 vertical excursions of nearly 20 m at 50 m depth bring denser water toward the surface on the flood tide where it mixes with the estuarine outflow and is advected offshore; and ii) tidal rectification enhances the mean upward vertical velocity through the centrifugal upwelling mechanism proposed by Garrett and Loucks (1976). The cyclonic eddy is a consequence of geostrophic adjustment to the doming isopycnals that arise from the upwelling.

Keywords: eddy, estuary, tides

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Oral Presentation

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Variability of the Kuroshio in the East China Sea and its volume transport through the Tokara Strait during 2000

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Chenghao Yang

On the basis of hydrographic data obtained in 5 cruises of 2000 onboard the R/V Chofu Maru and the QuikSCAT wind data during 5 cruises of 2000, the current velocity and volume transport (VT) of the Kuroshio in the East China Sea (ECS) are computed by using the modified inverse method. Main results are as follows. 1. The Kuroshio at Section PN has two current cores in January-February, October and November, and only one current core in April and July, respectively. 2. The Kuroshio through the Tokara Strait (TKS) has multi-current cores during five cruises of 2000, and is characterized by the southern and northern cores. The main current core of Kuroshio occurs only at the southern core, whose water depth is greater than 1200 m, in November, and occurs at the northern cores, whose water depth is less than the 400 m levels, in January-February, April, July and October, respectively. 3. The net northeastward volume transport (VT) through Section PN is maximal, 28.110 $6m^3/s$, in November among 5 cruises of 2000, and is next in July, and is minimal, 24.610 $6m^3/s$, in October among 5 cruises of 2000. The annual average of its net northeastward VT is 26.410 $6m^3/s$ in 2000. 4. The net eastward VT through the Tokara Strait is maximal also in November among 5 cruises of 2000, and is next in July, and is minimal in October and January-February among 5 cruises of 2000. Its annual average net eastward VT through the Tokara Strait is 21.910 $6m^3/s$ during 2000. The VT of the Tsushima current through the Korea/Tsushima Strait is maximal in January-February and April, and is minimal in July among 5 cruises of 2000.

Keywords: kuroshio in east china sea; flow in tokara strait; modified inverse method



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Oral Presentation

5900

A Note on the Deep-Water Inflow to the Bothnian Sea

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The deepest connection between the Bothnian Sea and the Baltic Proper is the narrow Understen-Mrket trench with a threshold depth of around 90 m. The deep- water flow through this passage, which is of great importance for the hydrographic state of the entire Gulf of Bothnia, was surveyed by the R/V Aranda in October 2004. On the basis of these field results as well as climatological data, it has been concluded that the deep-water flow can be described using a hydraulic framework applied to a channel of parabolic cross- section. The Understen-Mrket trench is sufficiently narrow to, in principle, permit neglect of the Coriolis force. Since it may prove useful for other systems, the study, however, also includes the analysis and evaluation of a scheme to determine rotational first-order corrections to controlled transports predicted using standard non-rotating hydraulic theory.

Keywords: hydraulics, rotating fluids, deep currents

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Oral Presentation

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Generation of Nonlinear Internal Waves from Luzon Strait

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Luzon Strait is the generation region of fast propagation (about 2.9 m/s) and large amplitude (over 140 m) nonlinear internal waves (NLIW) in northern South China Sea. Barotropic tides propagate from North Pacific Ocean and generate internal tide after crossing Batan Islands to enter Luzon Strait. Being the largest internal tide in NW Pacific Ocean, it generates the largest deep ocean NLIW when exiting Luzon Strait. Satellite SAR and optical images show the leading fronts of NLIW. Training fronts have smaller amplitude and they are often invisible in satellite images. Moored T-chain and ADCP data show the evolution process of internal tide over the western ridge of Luzon Strait, transforming into NLIW fronts as it propagates westward into northern South China Sea. The number of NLIW fronts increases during the propagation, while the energy flux decreases and the distance between succeeding fronts increases.

Keywords: nonlinear internal wave, luzon strait, generation

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Oral Presentation

5902

The analysis of temperature, salinity and transport distributions in the Indonesian Seas based on results of simulations with a regional model.

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Vladimir M. Kamenkovich

The basic properties of a developed regional model of the circulation of the Indonesian Seas are outlined. The model, based on the Princeton Ocean Model, has 250 x 250 grid cells in the horizontal with grid spacing of ~10 km and 29 σ -levels in the vertical. It is well known that the complex topography of the region strongly influences temperature, salinity and current distributions there. One of the significant properties of this model is that all basic topographic features are properly resolved. The model has four open ports to simulate inflow of North Pacific Water from the Mindanao Current, inflow of South Pacific Water from the New Guinea Coastal Current, outflow to the Pacific Ocean due to the North Equatorial Counter Current, and to the Indian Ocean due to the Indonesian Throughflow. Total transports through the open ports and typical normal velocities at the ports are specified from observations. Four experiments are discussed: seasonally varying and annual mean port transports and normal velocities both with and without local winds. The dynamics controlling the redistribution of the Throughflow between the main passages and straits in the region is discussed. The portion of North Pacific Water entering the Indonesian Seas relative to that leaving through the North Equatorial Counter Current port is fairly constant throughout the year. Most of this water takes the western route through the Makassar Strait. The portion of South Pacific Water entering the Halmahera Sea compared to that exiting in the North Equatorial Counter Current varies considerably with the seasons. The role of South Pacific Water in shaping the temperature and salinity distributions is examined. Turning off the local winds does not substantially influence transport through the main passages in the model domain. Surface circulation patterns change substantially with the seasons. The comparison of the basic structure of the model surface circulation and total transport values through the main passages with observations appears satisfactory.

Keywords: indonesian, regional, model



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Oral Presentation

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The influence of ocean ridges on ocean circulation in the Mozambique Channel and South of Madagascar

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Oceanography student

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The bottom topography of the ocean has a significant influence on the oceanographic environment. They can act as blocking barriers or they can enhance the inter-basin linking of ocean properties. They also determine the nature of the deep flows and cause vertical mixing. Hydrographic and satellite measurements portray the Mozambique Channel and areas around southern Madagascar as areas of high mesoscale eddy activity. These eddies are also observed in altimetry observations and model outputs. In the Mozambique Channel these eddies are predominantly southward propagating anticyclones. South of Madagascar they often are cyclone-anticyclone dipolar pairs which propagate south-westward. These dipole pairs are generated where the East Madagascar Current separates from the continental shelf, at the southern tip of Madagascar. The nature of formation and the direction of propagation of eddies from both, Mozambique Channel and South of Madagascar suggest that they are influenced by features of the bottom topography. A project has now been started using a Regional Ocean Modeling System (ROMS) in 1/6x1/6 resolution, to model these features in a realistic way in order to understand their origin and the influence of the bottom topography on their behaviour.

Keywords: eddies, topography, barriers

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Oral Presentation

5904

The Stability of Deep Overflows

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The stability of a hydraulically-driven sill flow in a rotating channel with smoothly varying cross section is considered. The smooth topography forces the thickness of the moving layer to vanish at its two edges. The basic flow is assumed to have zero potential vorticity, as is the case in elementary models of the hydraulic behavior of deep ocean overflows. Such flows are found to nearly always satisfy Ripas necessary condition for instability. Direct calculation of the linear growth rates and numerical simulation of finite amplitude behavior suggests that the flow are, in fact, always unstable. The growth rates and nonlinear evolution depends largely on the dimensionless channel curvature $\kappa(y)=2a(y)g'/f^2$, where $2a$ is the dimensional curvature, g' is the reduced gravity, and f is the Coriolis parameter. Small (or negative) values of curvature correspond to dynamically wide channels and are associated with strong instability and the breakup of the basic flow into a train of eddies. Moderate or large values imply dynamically narrower channels and are associated with an increase in width of the flow but maintenance of a coherent stream. The instability results from a resonant interaction between two waves trapped on opposite edges of the stream. Interactions can occur between two Kelvin-like frontal waves, between two inertia-gravity waves, or between one wave of each type. The growing wave has zero energy and extracts zero energy from the mean. At the same time, there is an overall conversion of kinetic energy to potential energy for $\kappa>0$, with the reverse occurring for $\kappa<0$. Among other things, the instability tends to eliminate the bands of counterflow that are predicted by hydraulic theory and that confound the prediction of volume fluxes in the ocean. Small values of κ can also produce eddies in the region downstream of sill.

Keywords: hydraulics, instability, eddies



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Oral Presentation

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Property structure and variability of Indonesian Throughflow Water (ITW)

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The observational phase of INSTANT ended in December 2006: 3 year-long time series of currents, temperature and salinity have been collected across the main straits of the Indonesian Archipelago as well as repeated CTD profiles within the interior. Updated paths of the ITF and its hydrological characteristics is shown to be in agreement with the results of the ORCA model of LOCEAN. North Pacific waters at thermocline and intermediate levels mostly supply the ITF via western route, and south Pacific water join the ITF via eastern route in the Banda Sea. Because of different pathway from Makassar strait/Halmahera sea to Indian ocean and different residence time in the Indonesian Seas, each Outflow strait has distinct hydrological characteristics. In western Banda sea, part of the north Pacific water will outflow via Ombai strait following a shorter route while the rest will prolong its journey to eastern Banda sea. Through Lombok strait, the shortest route of ITF, the signature of north Pacific water is the strongest while the Timor Passage exhibits a nearly constant salinity profile down to 1500m above its 1880m sill. There, an intense in/outflow from Indian to Timor basin feeds the Timor trench with the colder and more saline Indian Deep Water with intraseasonal variability. The corresponding deep mass, heat and salt fluxes are estimated.

Keywords: instantprogram, indonesia throughflowwater, outflowstraits

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Oral Presentation

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The Mediterranean outflow in Espartel sill, westernmost section of the Strait of Gibraltar

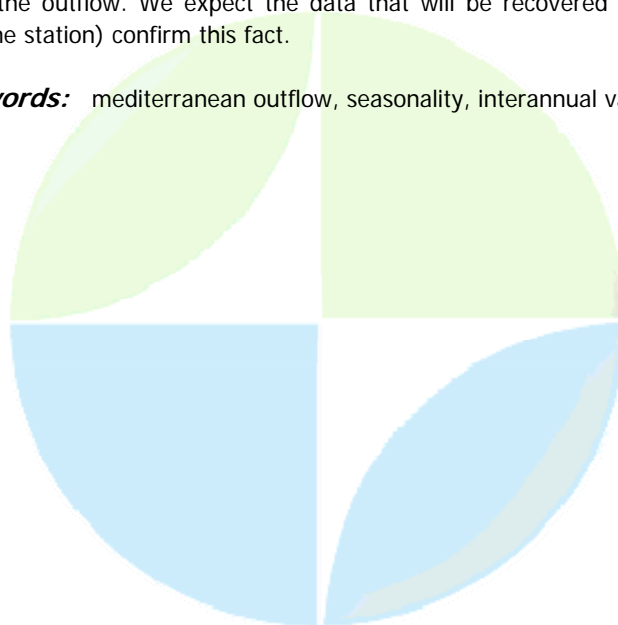
Dr. Jesus Garcia Lafuente

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Antonio Jesus Snchez Romn, Jos Carlos Snchez Garrido, Juan Miguel Vargas Domnguez, Francisco Criado Aldeanueva, Javier Delgado Cabello, Guillermo Daz Del Ro, Gianmaria Sannino

Since September 2004 and within the Spanish National-funded initiatives of Projects REN03-01608/MAR and CTM2006-02326/MAR (INGRES-1 and INGRES-2, respectively) a monitoring station, consisting of a near-bottom mounted, uplooking ADCP and an autonomous CTD moored at 10 m above the sea-floor, is collecting information at 35 52.0 ' N, 5 58.3 ' W off Cape Espartel, in the western side of the Strait of Gibraltar. In this location, the Mediterranean water flows through a relative narrow channel that gather advantageous conditions for monitoring the deep outflow, but not the Atlantic inflow. Dynamically, the section is also favourable because there is no important tidal rectification (strong positive correlation between tidal currents and tidally driven vertical oscillations of the interface that complicates so much the computation of the flow in the main sill of Camarinal), which implies that the subinertial flow can be easily computed by low-pass filtering the time series of ADCP horizontal velocity and the depth of null velocity. The 2.5-year long time series indicate noticeable mesoscale, meteorologically driven fluctuations that are more intense in winter (stormier weather), and also a seasonal signal that indicates more outflow in spring. This outflow is cooler and denser, suggesting that it follows the filling and emptying cycles of the Western Mediterranean Deep Water (WMDW) reservoir originated by the deep convection processes in the Gulf of Lyons by the end of winter. These processes exhibit important interannual variability, depending on the mildness of the winter, and therefore the Mediterranean outflow will echo this interannual signal. Strong support to this hypothesis is given by the clear cool signature of the outflow in spring of years 2005 and 2006 that followed the very severe winters of 2004-2005 and 2005-2006 when important volumes of dense WMDW where formed. On the contrary, winter 2006-2007 has been (and it continues to be) warmer and milder than average with the probable result of a very limited production of (not very dense) deep water, which in turn will remove the cool seasonal signal from the outflow. We expect the data that will be recovered in May 2007 (after the maintenance visit to the station) confirm this fact.

Keywords: mediterranean outflow, seasonality, interannual variability



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Adapting the Marginal Sea Boundary Condition (MSBC) to the Faroe Bank Channel Overflow

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Physical Oceanography Woods Hole Oceanographic Institution IAPSO

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Representing the global effect of deep ocean overflows and the resulting deep water formation in global coarse resolution climate models is still an ongoing challenge. A possible parameterization of overflows and exchange flows proposed by Price & Yang (1998) is the Marginal Sea Boundary Condition (MSBC). It is a simple formulation linking the watermass and flow properties in an upstream (or source) basin to the properties of the product watermasses which result from the exchange flow through a channel and the subsequent mixing of the dense overflow waters with ambient oceanic waters. Here the authors present an evaluation of the applicability of the MSBC to the Faroe Bank Channel Overflow (FBCO). The MSBC is tested against the results from a high resolution regional model of the FBCO using the MITgcm that has been shown to compare well to observations of the overflow. The dynamical characteristics and the tracer properties of the modeled overflow are compared to predictions from the MSBC. We focus on the short comings of the MSBC and the improvements necessary to better capture the true characteristics of the deep waters produced as a result of the overflow. In particular we are interested in improving the accuracy of the representation as the resolution of the model approaches that of typical climate models. Furthermore we investigate mechanisms that may lead to enhanced mixing but are not currently captured by the MSBC, including sudden widening of the overflow plume. The study presented here is aimed at helping the effective implementation of the MSBC into global climate models such as the Community Climate System Model, as part of the Climate Process Team on Gravity Current Entrainment.

Keywords: overflows, entrainment, faroebankchannel



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PS005

Oral Presentation

5908

Currents in the Bransfield Strait

Dr. Eugene Morozov

Internal waves Shirshov Institute of Oceanology IAPSO

In November 2005, Russian R/V "Akademik Ioffe" occupied a hydrographic section across the Bransfield Strait in the Atlantic sector of the Southern Ocean. The section crossed the Bransfield Current near the Greenwich Island. This coastal boundary current is an important element of circulation in this region. The hydrographic stations were made with an interval of 2 miles using the Sea-Bird 911 profile together with the lowered ADCP instrument. The core of the boundary current is located at a depth of 350- 400 m over the slope higher than the 750 m isobath. Maximal velocities measured by LADCP reach 47 cm/s, while the total transport is 0.8 Sv.

Keywords: bransfield, strait, antarctica

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Oral Presentation

5909

Absolute Geostrophic Currents in the Drake Passage

Dr. Roman Tarakanov

Sea Currents Laboratory IO RAS IAPSO

The Drake Passage is one of the most suitable regions for the research of the eastward Antarctic Circumpolar Current (ACC) because here it passes between two coasts. Two hydrographic sections were carried out across the Drake Passage onboard the Russian research vessels Akademik Sergey Vavilov and Akademik Ioffe during cruises in December 2003 and November 2005, respectively. Both sections were situated along the same track from Terra del Fuego to Elephant Island. Temperature, salinity and velocity profiles in the entire water column were measured by Sea-Bird 911 CTD profiler and LADCP (Lowered Acoustic Doppler Profiler) at each station. Satellite altimetry data (available at <http://www.jason.oceanobs.com>) were also used in the investigation. Absolute geostrophic currents across these sections were calculated by correcting the geostrophic calculations using altimetry data and LADCP measurements. The results revealed the advantage of altimetry corrections. The distributions of hydrographic properties over the sections show strong difference between synoptic situations in December 2003 and November 2005 resulting from ACC fronts splitting and subsequent eddy formation. In spite of foregoing distinction integrated flows across both sections were found very similar and approximately equal to 155 Sv eastward. Another important result of the investigation is revealing several western abyssal currents locked to deep passages in the Shackleton Ridge and southwestern slopes of the adjacent basins in addition to the well-known westerly currents in the South Shetland Trench, Antarctic and Terra del Fuego continental slopes.

Keywords: drake passage, geostrophic currents, altimetry



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Oral Presentation

5910

Water masses transformation in the Indonesian straits

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The Indonesian ThroughFlow (ITF) plays an important role in the global ocean circulation and regulation. In this passage incoming warm Pacific waters undergo strong transformations due to intense mixing. This mixing is mainly due to strong internal tides, which are trapped in the different semi-enclosed seas of the archipelago. Using tidal model results a parameterization of the associated 3d tidal mixing was developed. The resulting average vertical diffusivity is $1.5 \text{ cm}^2/\text{s}$, which independently agrees with the estimates inferred from observations, suggesting that the tide is a major phenomenon explaining the water masses transformation within the Indonesian archipelago. Introduced in a regional OGCM, the parameterization improves the water mass characteristics in the different Indonesian seas, suggesting that the horizontal and vertical distributions of the mixing are adequately prescribed. In particular, the salinity maximum of the inflow water is reduced along the main route, mainly in the Dewakang sill area. But also it is erased in the Halmahera and Seram seas, the entrance of the eastern route, so that salty water doesn't penetrate the Banda Sea. As a result the simulated Indonesian Throughflow Water are in good agreement with observations. Using this modeling results, we then try to quantify the water masses transformation. Lagrangian quantitative tool (Blanke et al. 1999, 2001) is used to describe the routes and the evolution of the water mass characteristics along them. The following issue for each water masses are raised : What are their route and associated resident time ? What the mass and salt transfer, and where are they occurring ? For each location of the transformation, is the mixing isopycnal or vertical ? Finally a diagnostic of water mass formation/transformation/consumption rates (Iudicone et al. 2006) is used to quantify the respective role of the forcing and each diffusion term in the water masses transformation. In particular, the quantification of the vertical mixing, the advection scheme, the shear and the forcing on diapycnal flux and on TS transformation are given.

Keywords: indonesianthroughflowwater, internal tides, oceangeneralcirculationmodel



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Oral Presentation

5911

Non-traditional effects of wave-flow-topography interaction in straits

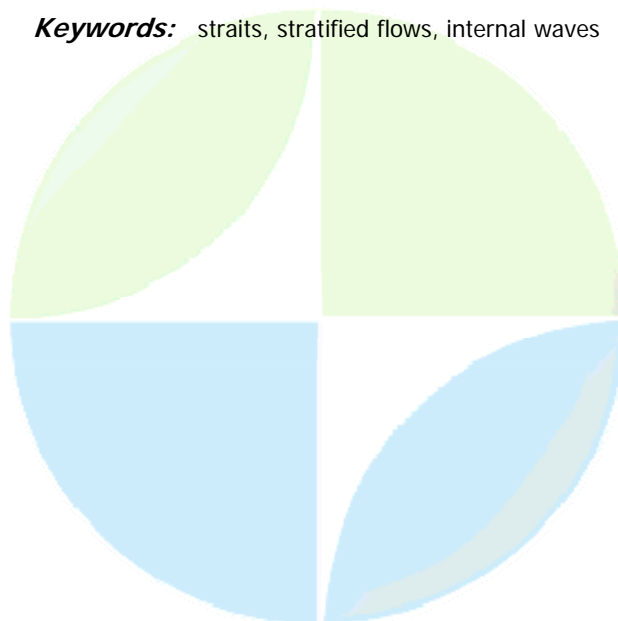
Dr. Vasyl Vlasenko

School of Earth, Ocean and Environmental Sciences Plymouth University

Nataliya Stashchuk

Channels and straits are common places for observation of large-amplitude oceanic internal waves. According to the well-studied mechanism of flow-topography interaction, these waves are normally generated by interaction of stratified currents with irregular bottom topography (sills or banks). The present study addresses the two aspects of this mechanism which normally remain beyond the traditional consideration. The first one concerns the multimodal structure of the baroclinic tides frequently produced by strong supercritical tidal flow. The Strait of Gibraltar is used as a case study to demonstrate this effect. The existence of higher baroclinic modes in tidal signal in this strait was identified in measurements performed in the area of Camarinal Sill (CS). Observational data and model results obtained with the use of fine-resolution fully-nonlinear nonhydrostatic numerical model revealed the presence of two types of tidal internal waves generated over CS. One propagates toward the Mediterranean and disintegrates into series of nonlinear short internal waves with amplitudes of 50 m and more. The second type, behind the first, propagates slower and has a longer wavelength. The vertical structure with both upward and downward displacements of isopycnals can be identified as a manifestation of higher baroclinic modes. The second important effect which usually is not taken into account, relates to the nonlinear mechanism of energy exchange between the generated internal waves and the background flow over inclined bottom topography. The energy balance equation derived for a continuously stratified fluid predicts that energy can either be transferred towards or away from the internal wave depending on the direction of propagation of both the wave and current. Four scenarios of wave-flow interaction over the inclined bottom were identified. Internal wave extracts energy from the background tidal flow during its propagation upslope-upstream or downslope-downstream and its amplitude grows. The wave loses energy propagating downslope-upstream or upslope-downstream and reduces in amplitude. This mechanism of suppression or amplification of internal waves by a current over an inclined bottom is verified numerically for the area of the Knight Inlet sill. This work was supported by NERC grant NE/D007968/1.

Keywords: straits, stratified flows, internal waves



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Oral Presentation

5912

Study of the supercritical stratified tidal flow in a strait

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SEOES University of Plymouth

Vasiliy Vlasenko

The baroclinic tidal regime in a strait separating the inner and the outer parts of the Loch Etive (Scotland) is studied on the basis of both in situ data and numerical simulations. Laterally integrated fully-nonlinear non-hydrostatic numerical model was used for this purpose. It was found that due to the presence of the sill in the strait, the sills area is subjected to a supercritical regime with maximum Froude numbers in excess of 5. Strong supercritical conditions lead to the formation of flow separation just above the sill's crest. As it is inherent to jet-type fjordic systems, this, in turn, should leads to a weak non-linear baroclinic wave response. On the other hand, observations and numerical results also revealed, however, the presence of propagating internal tidal waves with amplitudes up to 10 m several kilometres from the strait. It is shown that these baroclinic tidal waves are excited during the ebb phase over the inner flank of the sill, at a depth below 30 m, where the local Froude number is substantially less than unity. Thus the flow in fjord simultaneously exhibits both weak non-linear responses due to strong supercritical conditions with flow separation over the sill and a significant linear baroclinic tidal response generated the deeper flank of the sill. In this respect, Loch Etive may be referred to a new category - the 'hybrid-type' fjordic system. We suggest that many jet-type fjords with constrictions and sills will also generate a significant baroclinic response and should correctly fit into this new category. This work was supported by NERC grant NE/C50747X/1.

Keywords: straits, jet type fjord, internal waves



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Oral Presentation

5913

Modelling of internal wave generation in the area of a stratified plume

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SEOES University of Plymouth

Vasiliy Vlasenko

The present study is devoted to the investigation of internal wave generation occurring at the intrusion of river/strait waters into the sea. A series of satellite images taken recently in the areas of river/strait plumes revealed an evidence of generation of internal waves by the head of a surface gravity current during its transition from a subcritical regime when internal waves are arrested by strong discharge, to a subcritical one when they are released. In-situ measurements have shown that this mechanism of internal wave generation is quite effective at producing internal waves with amplitudes comparable with the total water depth. The physical processes controlling the internal wave generation at the frontal side of propagating plume are investigated through the application of an advanced numerical nonhydrostatic model. The conditions controlling formation of large-amplitude internal waves at the frontal side of the plume were identified and clarified in terms of various input parameters such as model geometry, river/strait discharge, bottom topography and sea water stratification. This work was supported by NERC grant NE/E01030X/1.

Keywords: straits estuaries, plumes, internal waves

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Oral Presentation

5914

A Modeling Study on Flows in the Strait of Hormuz

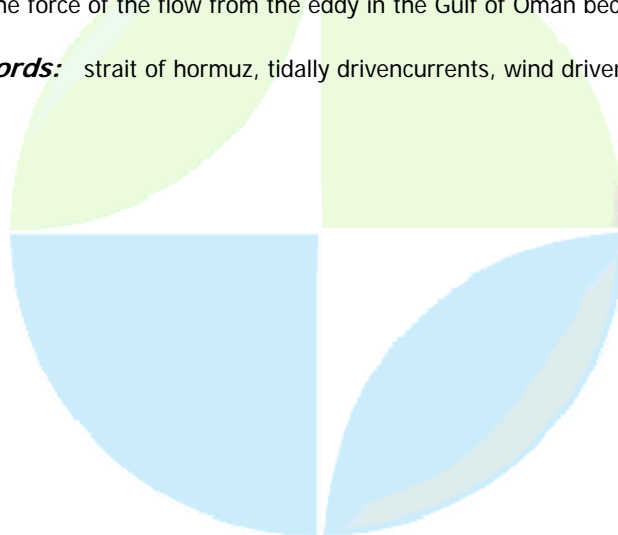
Prof. Peter Chu

Oceanography Naval Postgraduate School IAPSO

Travis Clem

The Strait of Hormuz (SOH), separating the Persian Gulf from the Gulf of Oman with a narrow channel of water that is 40 to an excess of 200 meters in depth, is bordered by the Iranian province of Hormozgar to the north and the Omani exclave on the Musandam Peninsula to the south. The strait is approximately 280 km long and about 50 km wide at its narrowest point. The SOH is influenced by the extra-tropical and Indian monsoon wind regimes. The extra-tropical wind regime occupies west of SOH. The mountains from Iran and Iraq act to channel winds to the southeast. The extra-tropical winds are predominantly northwesterly in the northern portion of the gulf, becoming more westerly further south and become southwesterly on the western portion of the SOH. Iran's Zagros Mountains restrict the strongest of the southerly winds to the southeastern Gulf (therefore, the western portion of the SOH). The Indian monsoon wind regime occupies east of SOH with northwesterly winds in winter and southwesterly winds in summer. The flow pattern and transition in SOH are investigated using the nowcast data of winds and currents (1 March to 31 July 2006) from a one-way coupled atmosphere-ocean model. The ocean component is the U.S. Navys Shallow Water Analysis and Forecast System (SWAFS), which has been developed on the base of the Princeton Ocean Model (POM) with data assimilation capability. The atmospheric component is the U.S. Navys Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). The surface winds, air temperature, and mixing ratio calculated from COAMPS are used as input to SWAFS. During the coupled model is running in the operational mode with assimilating satellite and in-situ observed data. Three main flow regimes are identified: (1) outflow regime with the surface current flowing out of the Persian Gulf and into the Gulf of Oman, (2) inflow regime with surface current flowing westward into the Persian Gulf, and (3) convergent regime. Smaller eddies formed in the eastern bend of the strait especially during the transition periods from inflow to outflow and from outflow to inflow. This is also the time period where the convergent flow regime is observed. A particular feature was an eddy that formed at the tip of the peninsula and rotated in a cyclonic fashion. This peninsular eddy was a near constant feature that disappeared during periods of heavy currents and was often displaced to the north towards Bandar Abbas, Iran as well as to the west towards the island of Queshm. However, eddies forming in the eastern leg of the strait rotated in an anticyclonic direction and were a transient feature that grew in frequency and population towards the early summer as the force of the flow from the eddy in the Gulf of Oman became more evident.

Keywords: strait of hormuz, tidally drivencurrents, wind drivencurrents



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Oral Presentation

5915

Do internal wave breathers exist in the ocean?

Prof. Tatiana Talipova

Hydrodynamics and nonlinear Acoustics Institute of Applied Physics RAS IAPSO

Kevin G. Lamb

The existence of internal solitary waves in the world oceans is well. Asymptotic weakly nonlinear theory of long internal waves based on the Gardner equation (extended Korteweg - de Vries equation) predicts the existence of stable oscillatory packets of nonlinear internal waves called breathers in zones with stratifications for which the cubic nonlinear coefficient is positive. The geographical distribution of such zones with positive cubic nonlinear term where the breathers can potentially exist is discussed. One zone is Luzon Straight where internal waves of amplitude of 140 m are observed. In spite of the large depth in the area (2000-2500 m) due to huge amplitudes the nonlinearity of the internal waves is strong. Solitons and N-pulses are very often visible on the wave records. In our opinion the observed N-shape waves are internal breathers. Numerical simulations of internal breather propagation in the frames of weakly and full nonlinear hydrodynamic models are performed. Possible methods of breather detection in wave records are discussed.

Keywords: internal waves, breathers, modeling



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Oral Presentation

5916

Timor Indonesian Throughflow as Measured by INSTANT

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CNRS LOCEAN IAPSO

Susan Wijffels, Janet Sprintall, Agus Atmadipoera, Indra Jaya

A 3-year time series of flow through the Timor Passage is described based on direct moored measurements as part of the INSTANT program. Four current meter moorings were anchored in the Passage, 100km wide with a sill 1880m deep. The mean flow represents more than half of the total throughflow towards the Indian Ocean except and a weak nearbottom inflow into the deep Timor Trench. The outflow is at maximum near the surface and at around 1300m. The flow above 500m is strongly sheared and most of the transport occurs above 300m. The shallow outflow displays little seasonality, while strongly vertically phase-shifted semi-annual variability is evident below 200m. Deep flow across the sill shows striking intraseasonal variability with oscillations of the transport below 1200m of +/- 3Sv. Flow, temperatures and salinities are correlated at the Timor Sill and suggest that Kelvin type waves remotely excited in the Tropical Indian Ocean or along the Java/Sumatra coast may modify the lateral density gradient across the sill and drive flows across it. Record averaged transports will be compared with those based on long term XBT data and previous mooring and pressure gauge work in the Passage.

Keywords: indonesia throughflow, strait, transport

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Oral Presentation

5917

Numerical modeling of tidal baroclinic exchange in the Strait of Gibraltar

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Departamento de Analisis Matemtico Universidad de Mlaga IAPSO

Manuel J. Castro, Carlos Pars, Jos M. Gonzlez-Vida

Understanding in depth the dynamics of the Strait of Gibraltar is a complex and fascinating problem that has attracted the attention of many researchers since long time. Numerical simulation of such complicated flows is of mayor interest and numerical efficient tools can greatly help to this understanding. The confinement of the flow by a strait can give rise to profound dynamic consequences including choking or hydraulic control, a process similar to that by which a dam regulates the flow from a reservoir. The funnelling geometry can lead to enhanced tidal modulation and increased velocities, giving rise to local instabilities, mixing, internal bores, jumps and other striking hydraulic and fine-scale phenomena. In short, sea straits represent choke points which are observationally and dynamically strategic and which contain a range of interesting processes. The Strait of Gibraltar is the more classical and, probably, the more fascinating of our straits. The flow configuration in the Strait of Gibraltar is characterized by two counter-currents: at the surface the less saline water of the Atlantic flows eastward, spreading into the Mediterranean and, at depth, the waters of the Mediterranean flow westward toward the Atlantic Ocean. This situation means that it is possible and useful to use two-layer models to represent the regions dynamics and to better understand the key processes involved. As result of the DAMFLOW project (www.damflow.com), a set of finite-volume two-layer shallow water models have been developed, comprehensively tested, and used to numerically simulate the dynamics of the Strait of Gibraltar. One-dimensional tidal modelling of the Strait ([1]) revealed a complicated pattern of time-dependent hydraulic fluctuations involving changing interfacial levels, moving control points and reversal of the layer flows at different stages of the tide, in good agreement with observations. Two-dimensional modelling ([2]) produces a more complex picture of tidal dynamics for the interpretation of which several numerical and graphical tools have also been developed. In our presentation we will aim to present a comprehensive overview of the 1d and 2d numerical modeling developed by our group, focussing on the modeling, numerical results and validation performed for the Strait of Gibraltar. The models developed present several distinctive features. A suitable treatment of wet-dry fronts ([3]) allows the models to deal with complex bottom topographies, representing up-wellings, nicely simulate "lock-exchange" problems and being very robust. The numerical techniques used permit the models to run in "frictionless-mode" with no friction or dissipation terms to stabilize computations. This allows to study the effect of friction and dissipation, and to compare numerical solutions against Armi-Farmer analytical frictionless approximations. Models can deal with channels with extremely irregular geometries, as is the case of the Strait of Gibraltar. For the 1d model channel cross-sections are supposed to be symmetric but, unlike other one-dimensional models, they are determined by a polygonal curve constructed as to preserve successive local wetted areas. Finally, the finite volume techniques used allow to efficiently represent very sharp interface profiles (non-regular solutions) as hydraulic jumps or bores, without significant damping or numerical dissipation. The main semidiurnal (M2 and S2) and diurnal (O1 and K1) tidal waves in the Strait of Gibraltar have been simulated by means of both the 1d and 2d models. First a steady state solution is obtained from "lock-exchange" initial conditions. This solution is then used as initial condition to simulate the main semidiurnal and diurnal tidal waves and mean integrated in depth velocities and flows in each layer. The boundary conditions imposed are obtained from observed tidal data. The numerical results are compared against observations being the models able to reproduce the observed features and their time-space structure. [1] Castro, M.J., J.A. Garca-Rodrquez, J.M. Gonzlez-Vida, J. Macas and C. Pars (2004).

Numerical simulation of two-layer shallow-water flows through channels with irregular geometry. J. Comp. Physics., 195, 202-235.[2] Castro, M. J., J. A. Garca-Rodrguez, J. M. Gonzalez-Vida and C. Pars (2006). "A parallel 2d finite volume scheme for solving systems of balance laws with nonconservative products: Application to shallow flows". Comp. Meth. Appl. Mech. Eng., 196, 2788-2815.[3] Castro, M.J., A.M. Ferreiro, J.A. Garca, J.M. Gonzalez, J. Macas, C. Pars and M.E. Vzquez (2005). The numerical treatment of wet/dry fronts in shallow flows: Applications to one-layer and two-layer systems. Math. Comp. Model., 42 (3-4), 419-439.

Keywords: straitofgibraltar, simulation, shallow water



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Oral Presentation

5918

**Ombai and Lombok Strait Indonesian Throughflow as measured by
INSTANT**

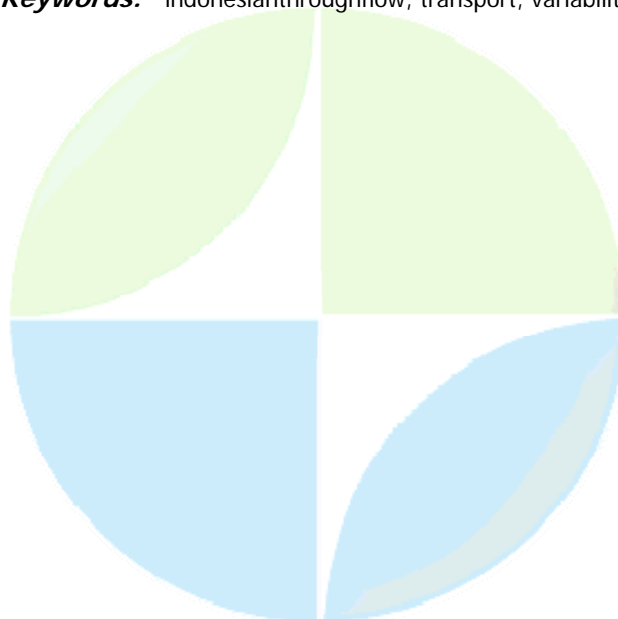
Dr. Janet Sprintall

Physical Oceanography Research Division Scripps Institution of Oceanography IAPSO

Susan Wijffels, Robert Molcard

The thousands of islands and numerous passages that connect a series of large, deep basins within the Indonesian seas provide a circuitous route for the Indonesian Throughflow (ITF) that is the interocean exchange of tropical waters from the Pacific to the Indian Ocean. The International Nusantara Stratification and Transport (INSTANT) program consisted of a three-year deployment (2003-2006) of an array of moorings in the major inflow and outflow passages of the ITF. Here we compare and contrast the flow and properties measured by the INSTANT moorings in the export passages of Ombai Strait (sill depth ~3250 m) and Lombok Strait (sill depth ~300 m). In Lombok Strait, the main southward flow of the ITF is subsurface (~50 m depth), with strongest flow occurring during the Southeast monsoon. On intraseasonal time scales flow reversals occur, primarily during the northwest monsoon from December to March, with higher surface speeds than the subsurface ITF that are evenly distributed across Lombok Strait. This strong northward surface flow results in northward transports through Lombok Strait of 2-3 Sv into the internal Indonesian seas. In Ombai Strait, the westward ITF is strongly confined to the southern side of the passage, and has strong shear. The upper component of the flow in Ombai South follows the seasonal cycle as in Lombok (southeast monsoon maximum), while the deeper component has opposite seasonal phasing with a strong westward flow (i.e. the ITF) occurring at ~200 m depth during the northwest monsoon. At Ombai North the flow is weaker and the subsurface flow is predominantly eastward and hence opposing the direction of the main ITF in this strait. Preliminary estimates of the mean transport through Ombai Strait are 4-5 Sv toward the Indian Ocean, although reversals of ~4 Sv are evident especially during the passage of Kelvin waves during the May monsoon transition. The total ITF transports and flows from the 3-year INSTANT measurements in all the outflow passages (Lombok, Ombai and Timor) will be discussed, and compared with earlier separate year-long deployments in each individual passage.

Keywords: indonesianthroughflow, transport, variability



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Oral Presentation

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Downslope windstorms and morning glories: analogues from the coastal ocean

Prof. Richard Peltier
Physics University of Toronto IAMAS

Marek M. Stastna

Internal waves are implicated in a wide variety of atmospheric phenomena including the downslope windstorms often observed in the lee of high topography, events that involve wave breaking and intense wave, mean-flow interaction. Equally notable in the atmosphere are the morning glory solitary wave related structures that are observed to form and propagate on low level atmospheric inversions in a wide variety of geographical locations, although they have been most famously described in the atmosphere above the Gulf of Carpentaria in . Although much more difficult to observe, identical internal wave related processes occur in the stably stratified coastal ocean environment. These analogies are especially interesting as a means of better understanding the forcing responsible for the excitation of the controlling wave mechanical processes. In this paper we will explore these oceanographic analogues through the application of both theoretical and direct numerical simulation techniques and compare the results to acoustic Doppler derived observations from the Knight Inlet of coastal British Columbia, . The mechanism responsible for solitary wave excitation in this environment appears to involve a resonance mechanism that may be in common with the atmospheric phenomenon. Insofar as the downslope windstorm analogy is concerned, this process appears to be connected to the same deep resonant excitation mechanism originally suggested to underlie the atmospheric phenomenon. In this case it is the breaking of upward propagating internal waves above their topographic source that leads to the establishment of a resonant cavity within which the internal wave field is subsequently amplified.

Keywords: internal waves, solitary waves, resonance



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Oral Presentation

5920

**A Twenty Year Average of the Regional Currents and Interbasin Exchange
in the Indonesian Region**

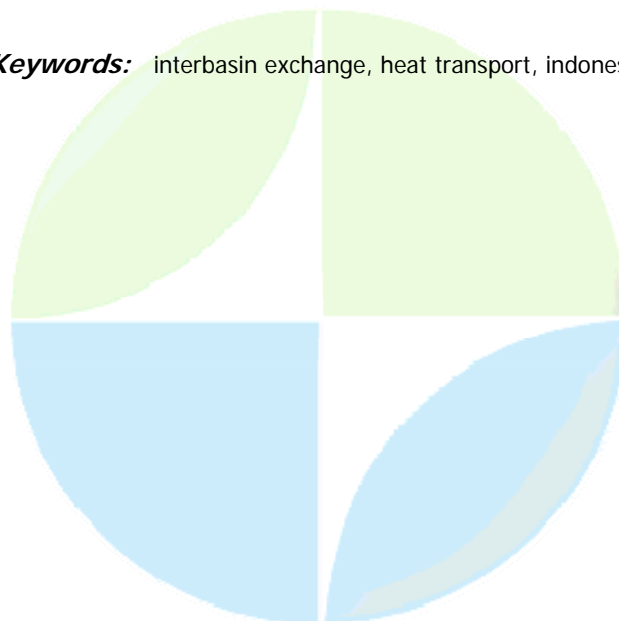
Dr. Susan E Wijffels

*CSIRO Marine and Atmospheric Research Commonwealth Scientific & Industrial Research
Org. IAPSO*

Gary Meyers, J. Stuart Godfrey

Twenty years of monthly or better repeat expendable Bathy Thermograph data are used to estimate the mean geostrophic velocity and transport relative to 750m of the Indonesian Throughflow (ITF) and its partitioning through the major outflow straits into the Indian Ocean. Ekman transports are estimated from satellite and atmospheric reanalysis wind climatologies. A subsurface maximum near 100m characterizes the geostrophic ITF, but Ekman flows drive a warm near surface component as well. A subsurface intensified fresh Makassar Jet feeds the Lombok Strait Throughflow (~2Sv) and an eastward flow along the Nusa Tenggara island chain the Nusa Tenggara Current (6Sv). This flow feeds a relatively cold 3.0 Sv flow through the Ombai Strait and Savu Sea. About 4-5Sv passes through Timor Passage, fed by both the Nusa Tenggara Current and likely warmer and saltier flow from the eastern Banda Sea. The Ombai and Timor Throughflow feature distinctly different shear profiles Ombai has deep reaching shear with a subsurface velocity maximum near 150m and so is cold (~15.5-17.1C), while Timor Passage has a surface intensified flow and is warm (~21.6-23C). At the western end of Timor Passage the nascent South Equatorial Current is augmented by recirculation from a strong eastward shallow flow south of the Passage. South of the western tip of Java, we find two mean eastward flows- the very shallow, warm and fresh South Java Current and a cold salty South Java Undercurrent. These, along with the inflow of the Eastern Gyral Current, recirculate to augment the South Equatorial Current, and greatly increase its salinity compared to that at the outflow passages. The best estimate of the twenty year average geostrophic plus Ekman transport is 8.9 1.7 Sv with a transport-weighted temperature of 21.2C and transport-weighted salinity of 34.73 near 110E. The warm temperatures of the flow can be reconciled with the much cooler estimates based on mooring data in Makassar Strait by accounting for local surface heat fluxes which warm the ITF by 2-4C during its passage through the region. We will also compare our results with mean transport estimates based on the mooring data from the INSTANT program.

Keywords: interbasin exchange, heat transport, indonesia



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Oral Presentation

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Observations of turbulent interfacial mixing in the Saint John River estuary, New Brunswick Canada

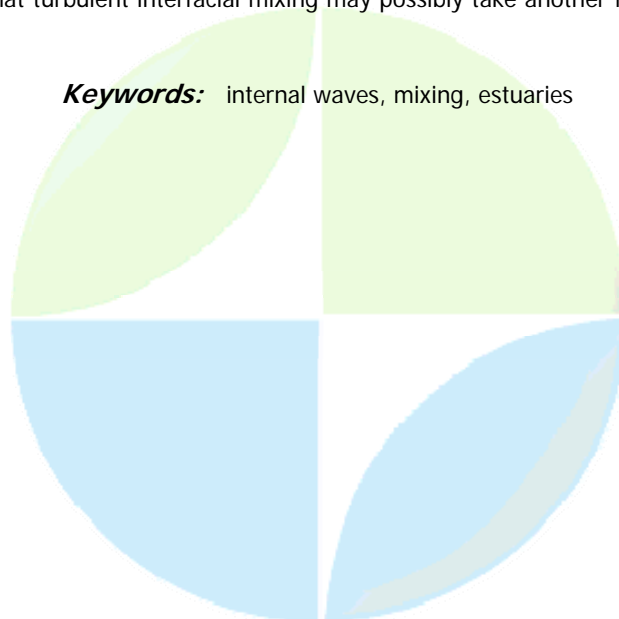
Mrs. Nicole Delpeche

Geodesy and Geomatics Engineering University of New Brunswick, Canada

John Hughes Clarke, Susan Haigh

Under highly stratified conditions a series of oceanographic surveys were performed in Long Reach (part of the Saint John River Estuary, New Brunswick) to map the main oceanographic processes occurring. The Saint John River empties into the Bay of Fundy, which is known to have a tidal range as great as 16metres. When river discharge is low in the river, salt water from the Bay of Fundy percolates up the river creating estuarine conditions from the mouth to approximately 60kilometres upstream. Long Reach is located in the upper section of the estuary. This study concentrated on a section in Long Reach where the bathymetry and geometry is irregular for several headlands, shoals, and deep hole areas exist. For the duration of a tidal cycle survey transects were performed along the study area to capture the main processes occurring during stratified conditions. Survey sensors such as a towed Acoustic Doppler Current Profiler, Conductivity Temperature Depth sensor and an echosounder were all implemented. Observations from all the sensors showed that turbulent interfacial mixing was the most dominant process taking place. Theoretical studies, laboratory experiments, numerical simulations and field studies suggest that turbulent interfacial mixing in stratified environments initially takes the form of internal waves. Calculations of the gradient Richardson number indicate that turbulent interfacial mixing occur in Long Reach at a period of maximum velocity shear within the vicinity of the headlands and shoals. The echosounder images showed different types of internal waves before, during and after the interfacial mixing process. Small amplitude periodic waves were observed at the interface throughout the survey area. A linear stability analysis was performed and identified these waves as non symmetric Holmboe waves. At late falling tide soliton wave packets appear within the vicinity of the shoals and in most instances they appear to be stationary. At approximately 2 hours after low tide the soliton wave packets disappear and a downward dip of the pycnocline occurs within the vicinity at the areas where the bathymetry shoals and then deepens. It is at the exact moment of the downward dip of the pycnocline that interfacial mixing was calculated to occur. This latter observation of the dipping of the pycnocline suggests that turbulent interfacial mixing may possibly take another form other than internal waves.

Keywords: internal waves, mixing, estuaries



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Estuarine versus transient flow regimes in Juan de Fuca strait

Dr. Richard Thomson

Department of Fisheries and Oceans Institute of Ocean Sciences

Steven F. Mihly, Evgueni A. Kulikov

Residual currents in Juan de Fuca Strait on the west coast of North America are observed to switch between two fundamental states: estuarine and transient. The estuarine regime which prevails 90% of the time in summer and 55% of the time in winter has a fortnightly-modulated, three-layer structure characterized by strong (~50 cms-1) outflow above 6015 m depth, moderate (25 cms-1) core-like inflow between 60-125 m depth, and weak (10 cms-1) inflow below 12510 m depth. Rotational effects increase the upper layer depth by 40 m on the British Columbia (Canadian) side of the channel and upwelling-favourable coastal winds augment inflow in the bottom layer by as much as 5 cms-1. Fortnightly modulation of the estuarine flow by tidal mixing in the eastern strait leads to cross-channel wandering of the residual current such that surface outflow leads intermediate inflow by 180 at the fortnightly period. Transient flows which occur 10% of the time in summer and 45% of the time in winter are rapidly evolving, horizontally and vertically sheared reversals in the estuarine circulation forced by poleward (downwelling favorable) wind events along the outer Pacific coast. Major events can persist for several weeks, lead to current reversals of 25 to 50 cms-1, and generate a net volume flux into the strait. A striking feature of major events is the formation of an ~10 km wide, surface-intensified, ~100 cms-1 inflow current along the Washington (USA) side of the strait. This Olympic Peninsula Countercurrent is accompanied by an abrupt decrease in salinity indicating that it is a buoyancy-driven flow originating on the outer Washington shelf.

Keywords: estuarine reversals, transients

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Oral Presentation

5923

The critical role of straits jamming in abrupt climate change

Dr. Doron Nof

Oceanography Florida State University

Catherine Sandal

The temporary paleo-jamming of the Bering Strait (BS) due to large icebergs is examined in the laboratory. Based on scour marks and ice rafted debris found on the Northwind Ridge and Chukchi Shelf, Cap and Borderland, it is hypothesized that icebergs created a temporary dam at the mouth of the BS. At the beginning of the Holocene, approximately 10,000 years before present, the BS opened once more for through flow of water due to rising sea levels. Both analytical and numerical indicate that, with an open BS and no convection in the North Atlantic, water would flow from the Arctic to the Pacific (contrary to modern day configuration). In addition, oceanic and atmospheric paleo-temperatures from the GISP II ice core record on Greenland indicates an abrupt increase in both in-situ and mean temperatures at the beginning of the Holocene. We propose that these are correlated to the breaking of a temporary iceberg dam at the mouth of the BS, allowing the removal of freshwater anomalies from the convection region in the North Atlantic through the Arctic and BS. Using a simple laboratory box model, the temporary damming and release of icebergs is recreated. It shows a similar abruptness to that seen in the GISP II ice core record. We find that the stability of the dam depends on the rate of sea level rise, which at 1 cm yr⁻¹ should be sufficiently slow to allow a temporary dam to exist for several thousand years. Sea ice probably fused icebergs together, and through ridging could have created a 30-40 m ice wall. On breaking (of the ice wall), approximately 2.5 Sv of water would have flushed into the North Pacific at a speed of 3 m s⁻¹ implying a flood lasting for approximately 28 days.

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Keywords: straits, jamming, climate



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Oral Presentation

5924

Five years of Florida Current Structure and Transport

Prof. Lisa Beal

Rosenstiel School of Marine and Atmospheric Scienc Research Assistant Professor IAPSO

Jules Hummon, Elizabeth Williams

Using ship-of-opportunity platform "Explorer of the Seas", five years of full-depth, direct velocity data have been collected across the Florida Straits at 26 N. Between May 2001 and May 2006 the mean transport of the Florida Current was 31.3 Sv with a standard deviation of 3.8 Sv. This compares to a mean transport of 32.4 Sv (standard deviation 3.2 Sv) inferred from cable voltages at 27 N over the same period. Thus, the inferred transport into the Straits through the Northwest Providence Channel is 1.1 Sv. The climatological core of the Florida Current at 26 N is 170 cm/s and sits at 280.2 E, 10 km east of the shelf break. The largest variance in velocity occurs directly over the shelf break, probably as a result of meandering related to continental shelf waves. A secondary variance maximum is present over the top 100 m of the water column all across the Straits and could be due to local wind events. The annual cycle of Florida Current transports has a range of 3.5 Sv, with a maximum in May-June-July and a minimum in January. The difference in velocity structure from summer to winter is surface intensified and centred at 280.3 E, with a maximum difference of 25 cm/s. On interannual to decadal timescales, low-pass filtered "Explorer" and cable transports correlate strongly ($r=0.83$), showing similar downward trends over the last five years, with transports reducing by 2 or 3 Sv. However, more than twenty years of cable data indicate there is no observable long-term trend in Florida Current transport.

Keywords: florida straits, western boundary current, interannual

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Oral Presentation

5925

The energetics of internal solitary waves in the ocean

Dr. Kevin Lamb

Applied Mathematics University of Waterloo IAPSO

Large amplitude solitary-like waves are common features in the World's oceans where they are predominantly generated by tidal flow over topographic features. They often contain a large fraction of the energy in the internal wave field making it important to understand the generation, evolution and dissipation of these waves. In this talk I will discuss the energetics of these large waves using the concept of pseudo-energy (sum of kinetic and available potential energy). Energetics in several numerical simulations will be used as examples, including waves generated by tidal flow over Georges Bank and in Luzon Strait, and in the breaking of shoaling waves.

Keywords: internal solitary waves, energetics

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Oral Presentation

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A soliton wave packet that travels in the opposite direction to the flow in the Saint John River Estuary, New Brunswick Canada

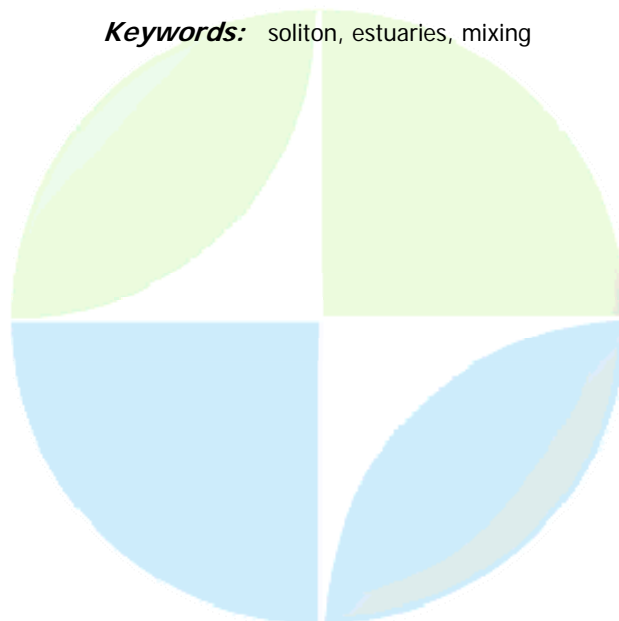
Mrs. Nicole Delpeche

Geodesy and Geomatics Engineering University of New Brunswick, Canada

John Hughes Clarke, Susan Haigh

The interaction of stratification, tides, irregular bathymetry and velocity shear are known to generate internal waves. In the summer of 2004 oceanographic surveys were performed along a section of Long Reach (part of the Saint John River estuary, New Brunswick) to determine the main processes that occur in an area where stratification, tides and an almost constant bathymetry exist. These surveys were performed to coincide with both neap and spring tides. The bathymetry of the study area is almost regular with a constant depth of ~23m the exception being at the centre of the study area where a 15m shoal exists. To the north and south of the shoal a 30m channel scour exists. These two channels scours converge upstream the shoal. The width of the study area was also constant with a breadth of 700m. Shipboard acoustic Doppler Current Profilers, Conductivity Temperature Depth sensor and an echosounder were used to map the processes occurring. Highly stratified conditions were observed for both neap and spring tides. At neap falling tides within the vicinity of the shoal the echosounder images showed the generation of a soliton wave packet. At this time the flow was moving predominantly downstream, however the soliton wave packet was observed to travel upstream. As the soliton wave packet traveled upstream it entered the area where two channel scours converge, by this time and at this location an increase in flow velocity was taking place. When this occurred, the soliton wave packet eventually dissipated. A decrease in density was observed to occur in the bottom layer when the soliton dissipated. Calculations of the gradient Richardson number did predict mixing to be occurring within the vicinity of the soliton wave packet and where the decrease in density was observed. At spring tides the soliton wave packet was not observed to occur and the decrease in density was also not present. These observations suggests possibly that: (1) mixing is occurring upstream and advected to the region or (2) within the vicinity of the shoal and channel scours mixing is occurring, but due to the restriction that all observations were made along the channel, the observations were not able to verify any secondary circulation mixing that may have taken place.

Keywords: soliton, estuaries, mixing



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Oral Presentation

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Interactions between the Kuroshio Main Stream and the Eddies East of Luzon Strait

Prof. Kentang Le

physical oceanography Institute of oceanology, CAS IAPSO

Zhao Wei

The in situ CTD data observed in Oct.,2005 and the corresponding altimeter data displayed that the Kuroshio main stream path was affected by its surrounding eddies in the region of the beginning Kuroshio. This paper describes the interaction processes between the Kuroshio main stream and the eddies east of Luzon Strait. It is found that if there existed a cyclonic (cold) eddy to the east of the Kuroshio, its main stream and the eddy will attract each other. Sometimes the eddy can get into the main stream before decayed. If there existed an anticyclonic eddy to the east of the Kuroshio, its main stream is tending to move westward. If the above two kinds of eddies exist in the same time, then the path of the main stream looks ,finally, like a mirror symmetry of S ,as a result of their interactions. Furthermore ,a numerical model are developed to simulate the above interactions ,which displays the similar interaction processes shown by the altimeter data.

Keywords: kuroshio, eddies east of luzon strait, interactions



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Oral Presentation

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The flow connection the South Pacific and Indian Ocean gyres south of Australia

Mr. Ken Ridgway

Marine & Atmospheric Research CSIRO Marine & Atmospheric Research IAPSO

Jeff Dunn

In situ observations are used to show that the largescale circulation systems in the South Pacific and Indian Ocean basins are connected by a narrow flow around southern. A high-resolution hydrographic atlas resolves the narrow boundary flow of the western Pacific gyre and its pathway around Tasmania, southern and into the Indian Ocean basin. This confirms the existence of the Southern Hemisphere supergyre, a nested system of subtropical gyres, present in recent ocean models. The observations show that the gyre flow is squeezed into a narrow band between Tasmania and the Antarctic Circumpolar Current (ACC). The residue of mean East Australian Current (EAC) transport turns westward around Tasmania and penetrates into the Indian Ocean (Tasman Leakage). The nature of the Tasman connection is examined for the influence of topography, its behaviour at different depths, and over timescales from seasonal to decadal. Further evidence for the interconnected gyres is presented from drifter compilations, while global ocean models demonstrate varying degrees of gyre connection. The Tasman Outflow is contrasted with the gyre relationship between the Indian and Atlantic systems south of Africa. While an outflow of Agulhas Current water into the Atlantic basin certainly exists, the gyre circulations appear to remain discrete. The life histories of parcels of Sub Antarctic Mode water (SAMW) and Antarctic Intermediate water (AAIW) are shown following a trajectory around the combined gyre.

Keywords: ocean gyre, connection, tasman outflow



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Oral Presentation

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What we can learnt from a 1d two-layer shallow-water model of the Strait of Gibraltar?

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Dpto de Matematica Aplicada Universidad de Mlaga IAPSO

Jorge Macas Schez, Manuel Jess Castro Daz, Carlos Pars Madroal

Two layer flows are interesting from a theoretical and practical point of view and so are models that can accurately represent such flows. As an example of a two layer flow, or to be more precise, a flow that can be idealized as such, we found the baroclinic tidal exchange through the Strait of Gibraltar, where the colder and less saline Atlantic water flowing at surface penetrates into the Mediterranean, and the deeper, denser Mediterranean water flows into the Atlantic. Understanding in depth the dynamics of the Strait of Gibraltar is a complex and fascinating problem and numerical simulation of such a complicated flow is of mayor scientific, social and economical interest. Under these circumstances numerical efficient tools can greatly help to improve this understanding. In the present study we want to point out what a highly robust and versatile 1d numerical model can provide us in order to better understand the key processes involved and to achieve a deeper comprehension of the complex dynamics taking place in this natural narrows. Many numerical tests and experiments can be performed by means of such a simple - conceptually speaking- model: the influence in the exchanged flow of the cross-sections considered (rectangular, triangular, trapezoidal or a polygonal preserving local wetted sections, for example), determining the magnitude of the maximal exchange for each of these configurations or how variations in Mediterranean waters density can affect the exchange. Although the time constant associated with changing properties of the outflowing Mediterranean water is many years, seasonal fluctuations undoubtedly occurs in the inflowing Atlantic surface waters. The resulting change in relative density difference will result in a seasonal fluctuation in the exchange rate. This is something that can be investigated with simple 1d numerical models. How the flux ratio, related to the evaporation-precipitation balance, can affect the flows exchanged. Sensibility to friction or dissipation and how these parameters can affect the amplitudes of monthly and fortnightly signals appearing in model variable time series when tidal simulations are performed also seem to be of interest. The role of mixing or the nonlinear interaction of simple tidal waves on the appearance of these signals, the influence of atmospheric forcing, etc. In this particular aspect concerning tidal simulations, one-dimensional tidal experiments of the Strait of Gibraltar ([1], [2]) have revealed a complicated pattern of time-dependent hydraulic fluctuations involving changing interfacial levels, moving control points and reversal of the layer flows at different stages of the tide, in good agreement with the analysis of observed data performed by Armi and Farmer in [3]. Therefore, these results and the validations performed seem to confirm that this approach is well suited for oceanographical purposes and, in particular, to understand some of the mechanisms that drive the exchange flows through natural channels as the Strait of Gibraltar. Visualizations of some model simulations can be found in the web site www.damflow.org. In our presentation we will try to show the potential of a 1d extremely robust finite volume two -layer shallow-water model. This model has been severely tested and validated (laboratory experiments, Armi-Farmer approximate analytical solutions,...) and presents several distinctive and novel features. First of all, a real geometry of the Strait of Gibraltar can be considered. This is a key point as former models (for example [4], [5], [6], [7]) have used simplified geometries, such as rectangular, triangular or trapezoidal approximations of the real channel geometry. The numerical techniques used permit the model a suitable treatment of Kelvin-Helmholtz instabilities and being stable in the limiting cases of stability for two-layered immiscible models. The model can be used in inviscid frictionless mode as it is not necessary -although is obviously possible- to mandatorily have to include dissipation or friction

terms in order to achieve stability, as is common practice in finite difference and finite element models. This represents an interesting property useful for better understanding model behavior and analyzing model sensibility to these parametrizations (dissipation and friction terms) or to compare numerical solutions against Armi-Farmer analytical frictionless approximate solutions. Finally, the finite volume techniques used allow to efficiently represent very sharp interface profiles (non-regular solutions) as hydraulic jumps or bores, without significant damping or numerical dissipation, which allows, together with an adequate treatment of wet/dry transitions [8], a suitable representation of the internal hydraulic jump taking place to the west of Camarinal Sill. [1] Castro, M.J., J.A. Garca-Rodríguez, J.M. González-Vida, J. Macas, and C. Pars (2004). Numerical simulation of two-layer shallow-water flows through channels with irregular geometry. *J. Comp. Physics.*, 195, 202-235. [2] Macas, J., J.M. González-Vida, Castro, M.J., and C. Pars (2007). "Simulation of tidally-induced currents in the Strait of Gibraltar with a 1D Finite Volume model". Preprint. [3] Armi, L. and D. Farmer / Farmer, D. and L. Armi (1988). "The flow of the Mediterranean water through the Strait of Gibraltar". *Prog. Oceanogr.*, 21, 1-105. [4] Bormans, M. and C. Garret (1989). "The effects of nonrectangular cross section, friction and barotropic fluctuations on the exchange through the Strait of Gibraltar". *J. Phys. Oceanogr.*, 19, 1543-1557. [5] Helfrich, K.R. (1995). "Time-dependent two-layer hydraulic exchange flows". *J. Phys. Oceanogr.*, 25(3), 359-373. [6] Brandt, P., W. Alpers, and J.O. Backhaus (1996). "Study of the generation and propagation of internal waves in the Strait of Gibraltar using numerical model and synthetic aperture radar images of the European ERS 1 satellite". *J. Geophys. Res.*, 101(C6), 14237-14252. [7] Brandt, P., A. Rubino, W. Alpers, and J.O. Backhaus (2005). "Internal waves in the Strait of Messina studied by a numerical model and synthetic aperture radar images from ERS 1/2 satellites". *J. Phys. Oceanogr.*, 27, 648-663. [8] Castro, M.J., A.M. Ferreiro, J.A. Garca, J.M. González, J. Macas, C. Pars, and M.E. Vázquez (2005). "The numerical treatment of wet/dry fronts in shallow flows: Application to one-layer and two-layer systems". *Math. Comp. Model.*, 42 (3-4), 419-439.

Keywords: straitofgibraltar, numerical, modeling

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Oral Presentation

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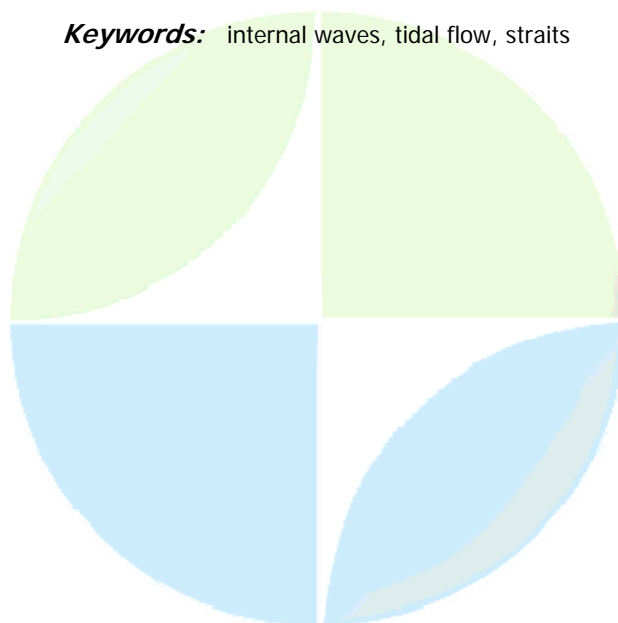
The effect of meteorologically forced subinertial flows on internal waves generation in the Strait of Gibraltar

Dr. Miguel Mejias

Agueda Vzquez Lpez-Escobar, Alfredo Izquierdo Gonzlez

Flow variability through the Strait of Gibraltar may be primarily categorised into three distinct types: long-term, subinertial and tidal. The long-term flow exhibits an seasonal and interannual variability and relates to the two-layer baroclinic exchange while, subinertial flows, with periods ranging from days to a few months, are mostly barotropic and have been found to be principally forced by the atmospheric pressure fluctuations over the Mediterranean Sea. Tidal flows, are also for the most part barotropic, at least in the vicinity of the main sill (Camarinal Sill) of the Strait. On the other hand, it is known that the interaction of this barotropic tidal flow with the sill bottom topography and the stratified water column generate internal tides which evolve, due to non-linear dynamics, into high amplitude (more than 100 m) internal waves that exhibit much shorter oscillation period than those related to the basic tidal variability. These internal waves have been found to be the major contributor to the interfacial mixing between the Atlantic and Mediterranean waters within the Strait. High amplitude internal waves, are formed during outflow phase (toward the Atlantic) of the barotropic tidal current. Generally, the greater is the flow velocity the more energetic is the internal wave process. Once they are generated, internal waves stand arrested by the flow around the sill, during some hours, until the flow is weakening enough to let their releasing toward the Mediterranean. Recent internal wave observations have shown that in many occasions, high amplitude internal waves generation around the main sill is dependent on the state of the subinertial flows, which which are basically driven by the atmospheric pressure fluctuations over the Mediterranean. In this way, depending on the meteorological situation over the Mediterranean, an expected internal wave event may be inhibited when subinertial flows are directed toward the Mediterranean. Also, the contrary situation, the generation of an internal wave event when it is not expected, may be activated when meteorologically forced subinertial flow are directed toward the Atlantic. The proposed mechanism to explain this relationship is based on the modification of the hydraulic conditions that subinertial flow provokes, mainly upstream of the sill.

Keywords: internal waves, tidal flow, straits



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Seasonal and tidal transports through the Strait of Gibraltar simulated by a 3D numerical model

Dr. Gianmaria Sannino
ACSCIM-MOD ENEA

Vincenzo Artale, Adriana Carillo, Jesus Garcia Lafuente, Antonio Sanchez Roman

Seasonal and tidal volume transport variability through the strait of Gibraltar has been evaluated by mean of a high resolution numerical model. The model uses a coastal-following curvilinear orthogonal grid, that includes the Gulf of Cadiz and the Alboran Sea, with very high resolution in the Strait (less than 500 m). It is forced by imposing the six major semidiurnal and diurnal tidal constituents (M2, S2, N2, O1, K1, P1) along the Atlantic and the Mediterranean open boundaries. The experiment covers two entire semidiurnal tidal cycle (29.58 days). Model results, in terms of cotidal elevation maps and major and minor axis of the current tidal ellipses were compared with all historical and most recent observed data. Transports have been estimated using different classical approaches. An alternative method, based on the particle tracking simulation, has been also applied to model results to evaluate, in a more objective way, the volume transport through the strait. Hydraulics and mixing within the strait have been also investigated.

Keywords: gibraltar, exchange, model



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Oral Presentation

5932

Recent changes in the inlets of the Venetian lagoon

Prof. Isaac Mancero-Mosquera

Coastal Oceanography Ist. Naz. di Oceanografia e di Geofisica Applicata

Miro Gacic, Andrea Mazzoldi

The Venetian lagoon is linked to the Adriatic Sea via three inlets, namely, Lido, Malamocco and Chioggia. Monitoring of currents velocities in the inlets is been carrying out since June 2001 (Lido, Malamocco) and February 2002 (Chioggia) using Acoustic Doppler Current Profilers, ADCP. This allows us to obtain detailed statistics about water exchange rates between the lagoon and the open sea, and the response to natural phenomena like storm surges, seiches, etc. Since the Italian Government approved the development of major works, in order to defend the city against flood events locally known as Acqua Alta, the interest in the possible impact in the environment has expanded. Currents velocities and water flow in the inlets has been studied and a comparison has been done between situations of before and after. The main construction works include external breakwaters, wharfs, refuge havens and navigation locks. They have had a significant impact in the Chioggia inlet only, where cross-sectional area is decreased by 18%. Long-term current velocity remain steady but an increasing trend in the variability is detected at the end of 2004. A significant change in the linear relationship between mean velocity, V [m/s], and water flow, Q_t [m³/s], followed, the new equation is $Q_t = 4023.5V18.1$. While the previous one was $Q_t = 4969.2V159.61$. Regarding tidal constituents, K1, M2 and S2 show increasing trends in their amplitudes since 2004. Additional studies are going on.

Keywords: current velocity, water flow, channel

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Oral Presentation

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Numerical study of internal tide transformation and dissipation

Dr. Yannis Cuypers

Espace Environnement Ecologie LOCEAN Laboratory IAPSO

Pascale Bouruet Aubertot

Internal wave shoaling is the main source of turbulent mixing in the ocean and is therefore believed to play a crucial role in oceanic circulation [Munk and Wunsch, 1998]. Recent estimations show that internal tide which is generated by the interaction of barotropic tide with topography represents almost half of the total internal wave energy. Several mechanisms that depend on latitude and stratification such as parametric subharmonic instability and solibore generation can initiate internal tide breaking. We aim to get further insight into internal tide shoaling mechanisms using direct numerical simulations. We focus on the processes leading to solibore generation as a result of the interaction of the internal tide energy beam and the pycnocline. Recently it was shown that a simple scaling law for kinetic energy dissipation in the form $\epsilon \propto EN$, could be efficiently adopted in the the pycnocline to represent internal tide induced mixing in the Indonesian throughflow [Koch Larrouy et al, 2006]. Such a scaling law was found above the Wave-Turbulence transition, in a domain where energy transfer is controlled by instabilities and turbulence by DAsaro and Lien, 2000. We will try to characterize under which conditions (stratification, latitude, energy) such a scaling law can be adopted to model internal tide breaking, we will notably try to determine whether such a law is well suited to represent solibore dissipation mechanisms. DAsaro, E.A., Lien, R.C. (2000). The wave-turbulence transition for stratified flows, *J. Phys. Oceanogr.*, vol. 30, pp. 1669-1678. Koch Larrouy, A., Madec, G., Bouruet-Aubertot, P., Gerkema, T., Bessires, L., Molcard, R. 2006. On the transformation of Pacific Water into Indonesian ThroughFlow Water by internal tidal mixing. *Geophys. Res. Letter.* Munk, W., Wunsch, C. 1998. Abyssal recipes II : energetics of tidal and wind mixing. *Deep-Sea Research I*, 45, 1977-2010.

Keywords: internal tides, solitons, wave beaking



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Oral Presentation

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**Energetic Internal Oscillations in the Straits of Florida Preceding
Formation of Strong Hurricanes in the Tropical Atlantic Region**

Prof. Alexander Soloviev

Oceanographic Center Nova Southeastern University IAPSO

Alexander V. Soloviev, Richard E. Dodge, Tom Gustafson

In this paper we report some intriguing results of the analysis of a seven-year observational data set obtained by a coastal ocean observatory established in 1999 on the Dania Beach, Florida shelf. The energetic internal oscillations with 10 hr period previously reported at this location appear to precede the formation of strong hurricanes in the tropical Atlantic region (including the Caribbean Sea and the Gulf of Mexico) with lead time from one week to one month. This phenomenon is presumably related to the fact that flow dynamics in the Straits of Florida reflect the state of the whole North Atlantic subtropical gyre and contain useful information about the conditions favorable for the hurricane formation and intensification such as the presence of warm pools in the tropical Atlantic region. The overheating of the tropical ocean preceding the formation of intense hurricanes increases pressure gradients in the western boundary current system, and the Straits of Florida resonate at an internal seiching period. The cause of the energetic 10 hr internal oscillation in the Straits of Florida has been attributed to the baroclinic cross-stream seiching. A natural period of the baroclinic (internal) seiching developing between Florida and Bahamas is approximately 10 hrs at the Dania Beach, Florida latitude. The location of the coastal observatory in the vicinity of the Gulf Stream front ensures the best conditions for detecting cross-stream seiching due to significant cross-stream current velocity and temperature gradients. When combined with other observational tools, such observations may be able to improve midterm hurricane forecasting capabilities.

Keywords: straits, seiching, hurricanes



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Poster presentation

5935

**Long-term variation of the Volume Transports through the Korea Strait
and the Tsugaru Strait**

Mrs. Hanna Na

School of Earth and Environmental Sciences Seoul National University IAPSO

Kuh Kim

The Korea Strait is the only inlet and the Tsugaru Strait is the major outlet of the East/Japan Sea, which is connected to the East China Sea and the North Pacific through four straits. Although it has been known that the variation of the inflow transport is closely related to the current structure and hydrography in the Ulleung Basin, which is located south of the subpolar front in the East/Japan Sea, little is known on the long-term variation of the outflow transport through the Tsugaru Strait. So long-term time-series of the monthly volume transports (VT) through the Korea Strait and the Tsugaru Strait constructed by using sea level difference across the straits and direct current data are examined in detail. The correlation coefficient between VTs through these straits is 0.7 for a period of 15 years from 1990 to 2004. The mean ratio of the VT through the Tsugaru Strait to that through the Korea Strait is about 0.60 with the standard deviation of about 0.08. Physical interpretation for this relatively stable ratio is attempted in this paper.

Keywords: transport, koreastrait, tsugarustrait

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Poster presentation

5936

Some Estimates of the Baltic Deep-Water Transport through the Stolpe Trench

Prof. Karin Borens
Research SMHI IAPSO

R. Hietala, J. Laanearu, P. Lundberg

The sub-surface flow of high-saline water masses from the Bornholm Basin through the Stolpe Channel plays an important role of the renewal of the Baltic Central Basin deep waters. In order to determine whether rotating 1-layer hydraulic theory is an appropriate tool for describing this process, maximal-transport estimates based on climatological data from the Bornholm and Gdansk Basins have been established. These were found to deviate considerably from observational realities, and hence similar hydraulic considerations were also applied to more-or-less synoptic field data from a Finnish field campaign carried through in the mid-1980s. Also in this case significant differences were found between calculated transport capacity and observations. Since it furthermore was demonstrated that the characteristics of the observed cross-channel hydrographic structure could be explained using a frictional-balance model of the deep-water flow, it was concluded that a hydraulic framework, although providing an upper bound of the transport, is of limited use when dealing with the Stolpe-Channel overflow. Although it cannot be ruled out that the inflow is inviscid, but sub-maximal, it is more likely that the transport is governed by the combined effects of friction and wind forcing.

Keywords: hydraulics



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Poster presentation

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Direct measurement of Tsugaru Through Flow

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Joon-Yong Yang, Kuh Kim

Outflow of deep water through the Tsugaru Strait in the East/Japan Sea can be inferred from the fact that three individual profiling floats deployed in the central East/Japan Sea flowed out to the Northwest Pacific Ocean through the Strait in March 1998, February 2000, and March 2000, respectively. The surface drifts of each float has been estimated with accuracy of less than 10 minutes and less than 1.7 km by following Park et al. [2005]. The probability of drifts during each float ascends and descends has been examined based on the probability distribution of surface current velocity and Davis [1992] experiment. The careful investigation strongly suggests that the water below the depth of 150 meters flow out over the shallow sill.

Keywords: tsugaru, outflow, argo float

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Poster presentation

5938

**Diagnosis of inertia-gravity waves in an oceanic general circulation model :
an intercomparison between numerical simulations and in situ-
measurements from the Cirne experiment**

Mr. Xavier Le Vaillant
LOCEAN-IPSL UPMC IAPSO

Pascale Bouruet-Aubertot, Sbastien Masson, Gurvan Madec, Keiko Takahashi

Turbulent mixing in the ocean interior mostly results from the breaking of inertia-gravity waves. These waves are mainly generated at the upper and lower boundaries by barotropic tides and indirectly by the atmospheric forcing and then propagate into the ocean interior. Owing to their typical horizontal wavelengths lying within the submesoscale domain they can only be partly resolved by OGCM. We here focus on the generation of these waves by the atmospheric forcing in an OGCM as a preliminary step toward the development of a specific parameterization of wavebreaking. The area of interest is the Indian Ocean where the Cirne experiment took place in Winter 2007. The analysis of numerical outputs from an OGCM with a high resolution vertical grid, ORCA05-L300, gave evidence of significant energy radiation into the ocean interior. A detailed analysis of the most energetic events is conducted and compared with in situ measurements performed in the same area.

Keywords: ogcm, inertiagravitywaves, parameterization

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PS005

Poster presentation

5939

A study of internal wave cinematic in the strait of Gibraltar analyzing in situ data

Mr. Jose Carlos Snchez Garrido

Applied Physics II Grupo Oc. Fsica, Universidad de Mlaga (Spain)

During May 2003 two mooring lines installed near the coast of Tarifa and Gibraltar (35 57.58 N, 5 32.99 W and 36 3.35 N, 5 10.09 W) provided data velocity and temperature each two minutes at different depths. Moreover, echo-sounder profiles within a mesoscale grid in the western part of the Alboran Sea were recorded. Data analysis reveals the regular presence of energetic internal wave packets (IWPs), tidally generated at the mean Sill of the Strait of Gibraltar, Camarinal Sill. Arrival time of IWPs to the easternmost station shows a remarkable diurnal inequality, with maximum difference between arrival time of two consecutive IWPs of six hours. This inequality is produced by the importance of the diurnal tide in the Strait, a fact which demonstrates that advection influences the phase velocity. Linear theory has been used by means of the Taylor-Goldstein equation in order to obtain theoretical velocities of propagation. The results are in agreement with the values obtained between the two monitoring stations (around 1.6 m/s), and predict a maximum velocity nearby Tarifa (around 2.5 m/s). The period and amplitude of internal waves are variable within a wave train, normally changing from high periods and amplitudes at the head, to low values at the rear. Characteristic values are 10-30 min for periods, and 10-50 m for amplitudes. Those properties, together with the increase of oscillations in a wave packet, its spreading, and the recovery of isopycnals at the rear of the wave packet, have been well detected in the data and compared with a model based on an analytical solution of the Korteweg de-Vries equation (Apel 2003).

Keywords: waves, bathymetry, fluid



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PS005

Poster presentation

5940

Short-scale circulation patterns in the coastal margins of the Strait of Gibraltar

Dr. Miguel Mejias

Jamal Chioua, Jeanette Romero Czar, Alfredo Izquierdo Gonzalez, Julio Prez Reyes, Agueda Vzquez Lpez-Escobar, Rafael Maanes Salinas

The dynamics of the water circulation in the Strait of Gibraltar has been commonly assumed to be aligned with the longitudinal axis of the Strait. However, the two-dimensional circulation patterns induced over the continental shelves by changes in the bottom topography and coast line shape, may play an important role in determining the processes of transport and water masses exchanges within the strait. The present communication contribute to the analysis of these short-scale processes, using numerical simulations, field data and sea surface temperatures images from NOAA satellites. The results indicate that cyclonic an anti-cyclonic eddies which are periodically formed in the coastal margins in response to tidal forcing, may provide an efficient mechanism by which water masses over coastal margins increase their residence timewithin the Strait. On the other hand, mass divergence in the upper layer induced by tidal flows in the central zone of the strait is able to produce significant cross-strait water masses movements toward this zone, from the coastal borders during the outflow (toward the Atlantic) phase of the tidal current cycle.

Keywords: tidal flow, eddies, straits



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PS006

5941 - 5967

Symposium
Arctic Ocean Processes

Convener : Dr. Jinping Zhao

Co-Convener : Dr. Laodong Guo

Remarkable changes in the Arctic Ocean have happened in recent years including changes in sea ice extent and thickness; water mass characteristics; ocean circulation; biogeochemical cycling, and the Arctic ecosystem as a whole. However, the impact and consequences of global and amplified polar warming remain poorly understood. Some evidence shows that there are positive and negative feedbacks to the atmosphere from the Arctic Ocean. Many studies have been focused on the Arctic changes in order to find the correlations among different phenomena. By data analysis, theoretical studies, and numerical modeling, many linkages among marine processes in the Arctic Ocean have been revealed. In this symposium, physical and biogeochemical processes related to the Arctic changes will be reported, and their driving factors and dynamic mechanisms will be discussed. The 2007/2008 International Polar Year (IPY) will provide ample opportunities to obtain more data for a better understanding of the Arctic changes. Therefore, this symposium will be a good occasion for polar oceanographers.



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PS006

Oral Presentation

5941

Simulating ice-ocean downscaling characteristics in the Beaufort-Chukchi seas by an IARC Coupled Ice-Ocean Model (CIOM)

Prof. Jia Wang

International Arctic Research Center University of Alaska Fairbanks IAPSO

Haoguo Hu, Kohei Mizobata

An IARC regional CIOM (Coupled Ice-Ocean Model) based on POM was used to simulate the downscaling ice and ocean processes with a 3.4-km resolution. The Beaufort Sea CIOM was nested to the CCSR/NIES/FRCGC high-resolution (1/6 x 1/4 degrees) global coupled atmosphere-sea ice-ocean-land model. Atmospheric forcing data were derived from the NCEP reanalysis. Simulation of seasonal cycle was conducted. In the Chukchi Sea, the Bering inflow separates into three branches: the first main branch flows along the Alaskas coast that is the Alaska Coastal Water (ACW); the second branch flows northward and turns to the right, joining the ACW along the Beaufort coast; and the third branch flows toward the Northwind Ridge. The Beaufort Gyre is well reproduced, superimposed by numerous mesoscale eddies, with anticyclones outnumbering cyclones. Downscaling sea ice dynamics was investigated, such as sea ice ridging, rafting, leads and landfast ice, which are not resolved in the previous coarse resolution model. This approach combining the global model for the 20th century climate simulation with the regional downscaling/nesting simulation helps understanding of both large-scale sea ice variability and small-scale sea ice dynamics. Sea ice breaks up offshore piece by piece with landfast ice untouched along the Beaufort Sea coast. Sea ice cracks from pack ice with irregular shapes due to 1) complex ocean circulation, coastal current, and mesoscale eddies, 2) multi-category sea ice dynamics, and 3) complex and high-resolution geometry and topography. Sea ice ridging, rafting, and openings/leads can be well reproduced in sea ice thickness and concentration. Model validation using in situ observations, satellite measurements, and historical datasets was also conducted.

Keywords: coupled ice ocean model, beaufort sea landfast ice, sea ice dynamic



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PS006

Oral Presentation

5942

Interannual and decadal variability in the Arctic Ocean shown in geochemical and physical data responding to atmospheric variability

Mr. Hiroyasu Yamaguchi

Graduate School of Environmental Earth Science Hokkaido University IAPSO

Motoyoshi Ikeda, Takayoshi Ikeda

The recent distribution of Russian hydrochemical data collected from the Arctic Basin provides useful information on ocean interior variabilities. The vertical gradient of the silicate below 100 m provides information on the vertical motion of the upper boundary of the Atlantic Water at a decadal time scale (Ikeda et al. 2005). In this study, we analyzed ocean interior variability using physical and geochemical data responding to atmospheric variability, for example the Arctic Oscillation (AO) (Thompson and Wallace 1998), and verified the interannual and decadal variability in the Arctic Ocean.

Keywords: interannual variability, decadal variability, atlantic water



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PS006

Oral Presentation

5943

Ocean circulation and freshwater exchange between the Arctic and North Atlantic

Dr. Peili Wu

Hadley Centre Met Office IAPSO

Richard Wood

This paper is mainly concerned with the understanding and attribution of the recent observed freshening trend in the subpolar North Atlantic Ocean. From previous coupled model studies, it seems unlikely that this freshening trend is a direct consequence of anthropogenically forced climate change. It is shown in this paper that the sub-polar North Atlantic can be freshened to the observed degree without invoking substantial large-scale surface freshwater flux changes. The source of freshening can come from a freshwater redistribution within the Arctic/sub-polar North Atlantic. The redistribution is carried by a perturbed ocean circulation change in the sub-polar seas and triggered by deep convection in the Labrador Sea. The freshening can be widespread but mainly in the north and northwest of the subpolar North Atlantic. A sustained 30 to 40yr freshening trend can be easily identified in specific locations such as the Labrador Sea or in the basin wide integral of freshwater storage. At the peak, the sub-polar North Atlantic can hold around 10,000 km³ of extra freshwater.

Keywords: ocean circulation changes, freshwater transport, freshwater content

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Oral Presentation

5944

Interrelated Changes of Arctic Sea Ice and Surface Air Temperature during last 100 years

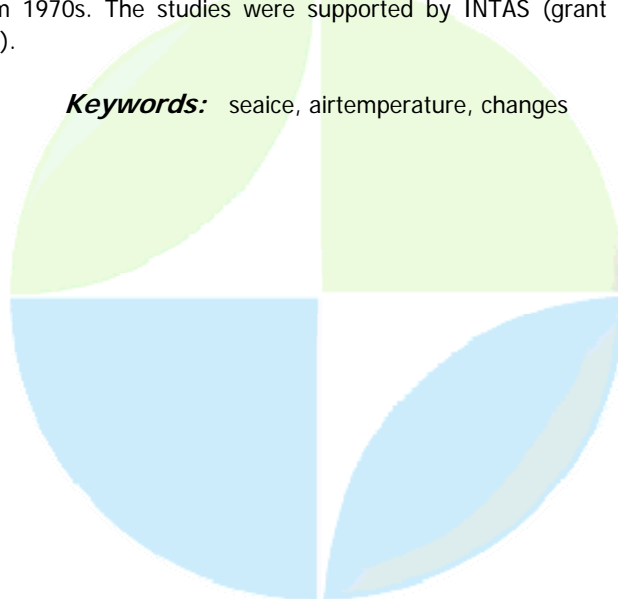
Prof. Genrikh Alekseev

Ocean and atmosphere interaction Arctic and Antarctic Research institute IAPSO

Ola Johannessen, Svetlana Kuzmina, Nikolai Ivanov

Sea ice cover in the Arctic is a clear indicator of the climate change and an important player for the interaction between the Arctic and the globe. Available estimations of the sea ice extent (SIE) in the Nordic Seas and adjacent regions in the Northern Hemisphere (NH) cover the period from XIX century. Since 1900 the ice information is available for the NH and since 1924 for the Siberian Arctic Seas and Barents Sea. Measurements of sea ice from the satellite started in 1973, regular monitoring are provided from 1978. The time series of SIE NH obtained from different data sets show significant disagreements for certain month. They, however, demonstrate a better agreement after the 1950s and especially since 1979 with onset of regular satellite observations. The amount of the data on sea ice thickness is much less. This data is primarily based on observations of ice draft from submarines using the upward-looking sonar after 1958. At Russian Arctic hydrometeorological stations land-fast ice thickness measurements have been carried out from 1930s up to now. Time series of monthly surface air temperature (SAT) at the Arctic stations cover periods from 1901 (7 series), 1936 (28) and 1951 (38) up to 2005. Based on all these data we analyze changes in the ice extent and thickness in the Arctic and its relations to SAT. Relations between SAT and SIE is explained by similarity of heat fluxes, which determine heat budget of near surface air layer and budget of surface sea ice. A good agreement between variations of the air temperature in the marine Arctic and SIE is found. Strong influence of summer SAT on the accelerated decrease of SIE in the Arctic is confirmed by high correlation (coefficient equal 0.85) between the sum of summer SATs in the marine Arctic and SIE in September. Acceleration of the September SIE decrease during last five years probably reflects the influence of positive feedbacks in joint evolution of SAT and SIE. The mutual influence of variations of winter air temperature and ice extent is weaker because winter ice extent anomalies depend not only on air temperature anomalies but also on the area occupied by freshened upper layer. Thickness of land-fast ice in the Siberian Arctic Seas shows the insignificant positive linear trend for 1934-2005 which agree with the SAT trend that points to absence of warming signal in both parameters. Such signal becomes apparent starting from 1970s. The studies were supported by INTAS (grant 03-51-4620) and RFBR (project 06-05-64054a).

Keywords: seaice, airtemperature, changes



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Oral Presentation

5945

Contribution of a pathway through the Arctic Ocean to the sea ice cover

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Graduate School of Environmental Science Hokkaido University IAPSO

Hiroyasu Yamaguchi, Akemi Yamada

As reported in recent articles, the sea ice cover in the Arctic Ocean has declined in the last 40 years and reaches the extreme condition, while its decadal variability has increased. The Polar Vortex has more significant decadal oscillations than the trend. The recently archived data extending from clouds, the atmospheric boundary layer to biogeochemical components in the Arctic Ocean have been analyzed for providing a close insight into Arctic environmental change, which may occur in response to global warming or as part of natural variability. An analysis has been extended to the sea level height in the Bering Sea vs. the Greenland Sea, and shows an increasing trend as a consequence of atmospheric circulation and contribution to inflow of the Pacific Water into the Arctic Basin. The timing of the Pacific Water inflow matches with the sea ice reduction in the Pacific sector and suggests a significant increase in heat flux. This component should be included in the model prediction for answering the question when the Arctic sea ice becomes a seasonal ice cover.

Keywords: sea level, sea ice, pacific water

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Oral Presentation

5946

Modeling transport, fate and lifetime of riverine dissolved organic carbon in the Arctic Ocean

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Earth, atmospheric and Planetary Sciences Massachusetts Institute of technology

Stephanie Dutkiewicz, Michael J. Follows, Chris N. Hill

The Arctic region is one of the most sensitive areas of the Earth to anthropogenic climate change. The ocean and the land biosphere of this region are both key players in the response to climatic perturbations via the carbon cycle (CC). We need to understand how these two function and how they are linked in the current Arctic CC before we can predict future responses to changes. In this study we focus on the CC of the Arctic Ocean and, here, present results of a study to further our understanding on the the riverine fluxes of dissolved organic carbon (DOC) that represents a key process linking the land and the ocean CC. We utilize the results of a global eddying version of the MIT General Circulation Model. The model is forced by interannually varying NCEP re-analyzed atmospheric products for the 1992-1002 period and uses a cube-sphere mesh that avoids mesh singularities in the Arctic. In the Arctic region resolution is approximately 18km laterally. The physical model solution we use has been generated as part of the ECCO2 ocean and sea-ice monitoring and measuring initiative. As described at <http://ecco2.org>, the physical model solution is adjusted toward satellite and in-situ observations for the simulated period. An explicit, seasonally varying, representation of river run-off into the Arctic basin provides a better representation of the salt-driven stratification and coastal ocean dynamics. We use the circulation fields from this global model simulation to transport idealized tracers, such as DOC, "offline" in an Arctic, basin scale study. We assess the role of both the basin-scale circulation and the remineralization in controlling the fate of DOC anomalies in the Arctic Ocean. Sensitivity experiments, and comparisons to observed DOC fields, are used to establish reasonable values for the time-scale of DOC remineralization and to investigate correlations between DOC and hydrographic properties.

Keywords: arcticoceancirculation, oceancarboncycle, biogeochemicaltraces



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PS006

Oral Presentation

5947

The Seasonal Cycle and Variability in Cloud Liquid Water Paths over the Sea-Ice-Free Arctic

Dr. Paquita Zuidema
RSMASMPO University of Miami IAMAS

Of the liquid and ice cloud phases, the liquid phase typically dominates the cloud optical depth and is most important to the surface radiation budget. The recent decline in sea ice and increase in surface temperatures foster expectations that cloud liquid water should be increasing in the Arctic. This justifies an examination of satellite microwave-derived liquid water paths (LWPs; SSMI and AMSR-E) and from the surface-based microwave radiometer dataset at Barrow, Alaska. While the satellite datasets are limited to sea-ice-free regions, they are a useful complement to cloud datasets based on visible and infrared sensors. The SSMI time series from 1987-2006, evaluated using two separate retrieval products, shows a wintertime LWP increase south of the Bering Strait and southwest of Greenland, an autumnal increase north of the Bering Strait, and decreases in other locations and seasons. The wintertime increase is also evident within the 2002-2006 record from the surface-based microwave radiometer at Barrow, Alaska. A wintertime rise in surface temperature could help explain the associated wintertime LWP increase. A strong seasonal cycle in cloud liquid water is well-resolved in the north Atlantic sector because large portions are ice-free year-round; lag/lead relationship with water vapor will be presented towards shedding light on the cloud formation mechanisms.

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Oral Presentation

5948

The long-term changes in the Siberian Arctic shelf waters during 20th century

Mr. Sergey Kirillov

Oceanology Arctic and Antarctic Research Institute IAPSO

Makhotin Mokhail, Dmitrenko Igor

Almost 30,000 oceanographic stations have been used to trace the long-term changes of sea water properties in the Siberian Arctic shelf waters since 1922. More than 10,000 of them include information on the hydrochemical properties of sea water. The time series of annual mean summer (August-September) and winter (March-May) temperature, salinity, nutrients and oxygen in the Kara, Laptev, East-Siberian and Chukchi seas have been reconstructed separately for surface and bottom layers. Combined with the estimated seasonal and coverage errors these series are analyzed to attribute their decadal oscillations to those in the large-scale atmospheric circulation pattern (through the Arctic Oscillation index), river discharges, the Atlantic Water heat and salt impact or the surface air temperature (SAT). We have revealed that river discharge does not affect significantly the long-term changes of any property of sea water. On the other hand high confident correlations between SAT and water properties in the surface layer are found. While SAT anomaly mostly governs the changes occurring in the surface layer, large-scale atmospheric circulation affects the changes in the bottom layer. It is evident that recent warmer climatic stage in the Arctic region results in less thickness of ice formed in winter period and more intensive ice melting in summer time. In turn it results in decreasing of surface layer salinities both in winter and summer periods. It is only in the Kara Sea where the surface salinities do not affirm the scheme suggested above. It seems to be greatly affected by exchange with the Barents Sea waters in the north-eastern and south-eastern parts of the Kara Sea. The high correlation of summer surface salinities and AO index implies that atmospheric circulation is a key process that regulates water exchange with adjacent regions here.

Keywords: long term, changes, shelves



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PS006

Oral Presentation

5949

Arctic oscillation controlled region and its spatiotemporal variation

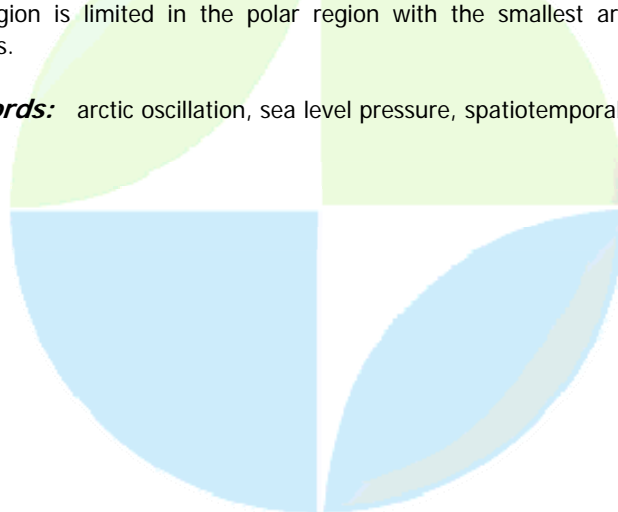
Dr. Jinping Zhao

College of Physical and Environmental Oceanography Ocean University of China IAPSO

Yong Cao, Shuiqing Wang

Arctic Oscillation (AO), a seesaw pattern of sea level pressure (SLP) fluctuates between positive and negative phases at the polar and middle latitudes, is defined by the first mode of Empirical Orthogonal Function (EOF) of the SLP north of 20N; and the time coefficient of EOF-1 is defined as the Arctic Oscillation Index (AOI) [Thompson and Wallace, 1998]. It has been used as a representative atmospheric circulation index to express climate change. The polarity of the AO is defined by the AOI, which exhibits high polarity or positive AOI in the early 1990s [Thompson et al., 2000], but switched to a near-neutral or negative phase in 1996-2004 [Overland and Wang, 2005]. The AO is expressed by a space-stationary and time-fluctuation structure [Ambaum et al., 2001]. However, AO pattern usually not fit the real variation. For example, AO pattern cannot explain the inconsistent variation of SLP in both Asia and North America. The SLP in fact is a spatiotemporal variation, and up to now, there is no more adequate method with exception of EOF. As an effort to exhibit the spatial behavior of SLP, Zhao et al. examined the correlation of SLP at all grids with AO index by calculating Running Correlation Coefficient (RCC) [Zhao et al., 2006]. With this method, the consistency of regional SLP with AO is clearly presented. A special region called Arctic Oscillation Core Region (AOCR) was found, which was never invaded by any non-AO event occurred outside this region. In AOCR, the SLP varies so consistently with AO index that the average SLP of AOCR is interchangeable with AOI. This result endows the AOI a clearly physical significance, i.e. AOI represents the average SLP of AOCR, which reveals the linkage of AOCR with the climate of Northern Hemisphere. In this paper, we use the AO index as a reference system to examine the consistency of grid SLP by using RCC method. If the RCC of SLP is closely correlated to AO index, the region is sorted out as AO-controlled region. Otherwise, it is the non-AO region. By this method, quite different patterns of AO-controlled region in different years are displayed and the inconsistency among different regions in North Hemisphere is clearly reflected. The following characteristics are displayed by the RCC figures. (1) The AO-related SLP controls different regions each year, which reveals why there is regional difference of SLP in North Hemisphere. (2) North Atlantic Oscillation (NAO) always exists in past 55 years, as there always is a region in which the SLP vary opposite to that of the AOCR, which is agreed to that the NAO paradigm may be more physically relevant and robust in NH than the AO paradigm [Ambaum et al., 2001]. (3) During the positive phase of AO, 1989-1995, the RCC figure show that AO-controlled region is limited in the polar region with the smallest area. This case is rarely occurred in other years.

Keywords: arctic oscillation, sea level pressure, spatiotemporal variation



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Oral Presentation

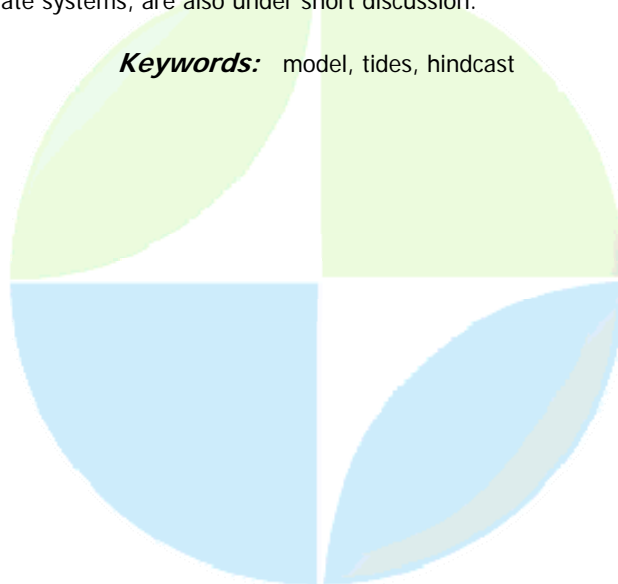
5950

The 1948-2002 ice-ocean monthly mean variability as derived by the Finite-Element Model of the Arctic Ocean (FEMAO): Towards the understanding of some physical processes in charge of the observed state of the Arctic Ocean formation.

Dr. Nikolay Yakovlev
IAPSO

The implementation of some programs of the Arctic Ocean modeling (e.g. AOMIP) reveals the striking differences in the model output for long-term simulations of the deep-water circulation. There are several problems concerning the role of tides, the physical mechanisms of narrow coastal jets generation, the role of small eddies in the transport of heat, salt and freshwater, and the ice-ocean dynamical coupling. To solve the problems, indicated above, the modified version of the coupled ice-ocean general circulation model is implemented. This model is based on the INM RAS finite-element model, intensively tested during the AOMIP (Arctic Ocean Model Intercomparison Project). The ocean model is free surface, z-coordinate one, with rotated spherical grid. Dynamical part of the ocean model involves parameterizations of the barotropic coastal jets (similar to the Neptune effect by Holloway, 1992, with approximations by Kazantsev, et. al., 1998 and Polyakov, 2001) and scalar eddy transport (by Gent and McWilliams, 1990, with the skew-flux formulation by Griffies). Ice model based on the Los Alamos Sea ice model physics of ridging and EVP rheology. Thermodynamics of multi-category ice and snow is similar to Sempter, 1976, although there are some improvements concerning physical parameterizations. The main peculiarity of the model is the method of numerical solution the Gelerkin (Finite Element) spatial approximation. Some general details of the model numerical implementation are presented. The set of sensitivity calculations is used to evaluate the role of various parameterizations of barotropic and baroclinic transports (by Holloway and by Gent and McWilliams respectively) and of ice-ocean dynamical coupling. The preliminary results of the numerical experiments with the explicit quantitative estimation of the role of tides in the formation of the climate system of the Arctic Ocean (water and sea ice) are also presented. The tidal forcing is specified as the incident M2 wave, similar to the approach by Kowalik and Proshutinsky, 1994. Some aspects of the model improvement during the EU-DAMOCLES (European contribution to the IPY 2007-2008) implementation period such as bottom topography approximation by analogue of partial cells and shaved cells, free-surface formulation in z and z* vertical coordinate systems, are also under short discussion.

Keywords: model, tides, hindcast



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Oral Presentation

5951

The critical role of the Bering Strait in climate change

Dr. Doron Nof

Oceanography Florida State University

Catherine Sandal

Understanding past abrupt climatic changes, such as the dramatic temperature increase in the beginning of the Holocene, is critical for the assessment of potentially critical future climate variations. Using laboratory and analytical models we propose that the above abrupt change was due to an abrupt opening of the Bering Strait (BS), which we suggest was initially jammed with icebergs. An open strait allows the global wind field to, (a) flush fresh water anomalies (which collapsed the meridional overturning cell during the Younger Dryas) out of the Atlantic, and (b) significantly enhance the convection in the Atlantic thus bringing more warm equatorial water to high latitudes. The associated increase in the northern hemisphere temperature (about 14C) is beyond the mean gradual increase typically associated with the termination of glaciation.

Keywords: bering strait

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Oral Presentation

5952

**Towards a warmer Arctic Ocean: Spreading of the early 21st century
Atlantic water warmer anomaly along the Eurasian Basin margins**

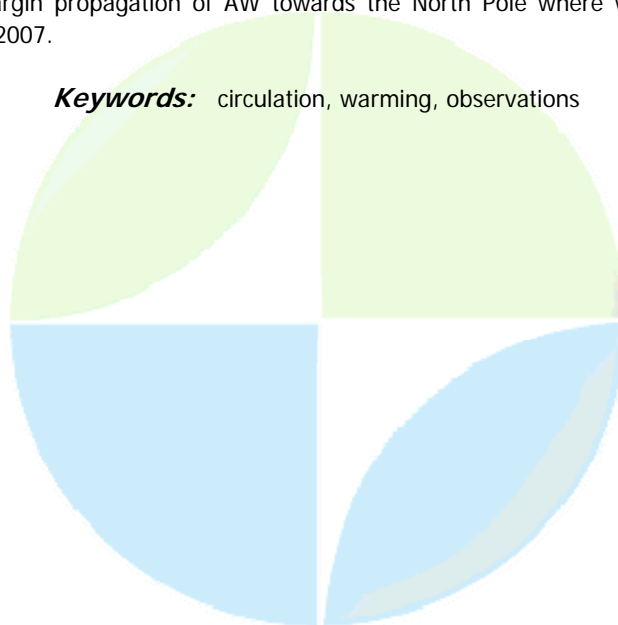
Dr. Igor Dmitrenko

International Arctic Research Center University of Alaska Fairbanks IAPSO

***Igor Polyakov, Sergey Kirillov, Leonid Timokhov, Ivan Frolov, Vladimir Sokolov,
Harper Simmons, Vladimir Ivanov, David Walsh***

Over the past several decades the Arctic Ocean demonstrates spectacular variability. Shifts in atmospheric circulation patterns have resulted in increased transport and temperature of warmer Atlantic water (AW) entering the Arctic. This study was motivated by recent reports that since the late 1990s, AW temperature has shown a new tendency to increase. Here we document through the analysis of 2002-2006 observational data the recent AW warming along the Eurasian Basin margins due to several AW warm impulses penetrated into the Arctic Ocean through the Fram Strate in 1999-2000. The temperature maximum of the AW layer is used as a tracer the AW circulation in the Eurasian Basin of the Arctic Ocean. The AW temperature record from our long-term monitoring site in the northern Laptev Sea shows several events of rapid AW temperature increase totaling 0.8C in February-August 2004. We hypothesize the along-margin spreading of this warmer anomaly has disrupted the downstream thermal equilibrium of late 1990s earlier 2000s. The anomaly mean velocity of 2.4-2.50.2 cm/s was obtained based on travel time required between the northern Laptev Sea and two anomaly fronts delineated over the Eurasian flank of the Lomonosov Ridge by comparison of 2005 snapshot along-margin data with AW climatology. The AW layer heat content on two cross-margin transects annually occupied in 2002-2006 across the Nansen Basin continental margin and separated along-margin by 385 km demonstrates coherent inter-annual variations. At 200 days of travel time estimated in 2003-2004, this distance corresponds to the propagation velocity of 2.2 cm/s. These estimations are independently confirmed by comparison of mooring-derived AW temperature time series of 2002-2005 with the downstream along-margin AW temperature distribution of 2005. Our mooring current-meter data also corroborate these estimations. Ongoing and future observations in this region will clarify our findings. They are also expected to capture continuous warming of the AW layer along the Eurasian Basin continental margins due to continuing influx of warmer AW through Fram Strait and the downstream along-margin propagation of AW towards the North Pole where we anticipate rapid AW warming will occur in 2007.

Keywords: circulation, warming, observations



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Oral Presentation

5953

Transformation of the Barents Sea inflow of the Atlantic water in the western Laptev Sea in 2005-2006: Impact of the upstream atmospheric circulation

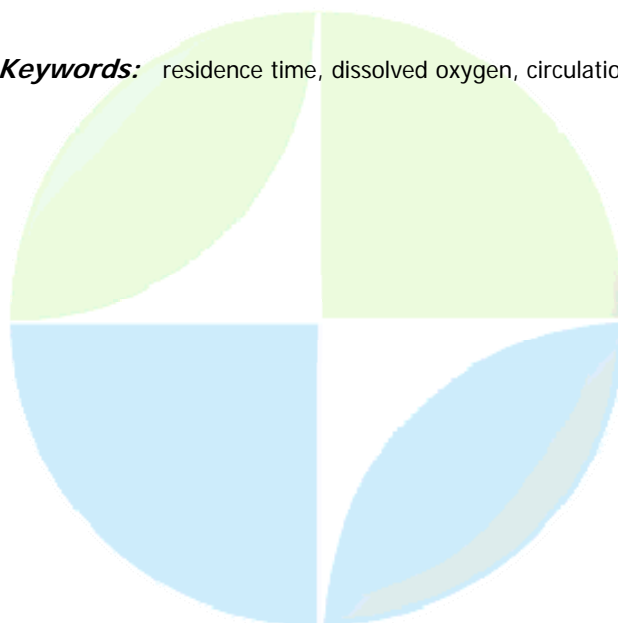
Mrs. Anna Rozhkova

Department of Ecology Russian State Hydrometeorological University IAPSO

Igor Dmitrenko, Dorothea Bauch, Jens Hlemann, Leonid Timokhov

The intermediate (100-1000 m) waters of the Arctic Ocean Eurasian margins are conditioned by the confluence of the warm and saline Atlantic water (AW) inflow through the Fram Strait, and relatively cold low saline AW inflow through the Barents Sea that enters the Arctic Ocean between Franz Josef Land and Severnaya Zenlya. Whilst over the Siberian margin the Fram Strait AW branch (FSWB) exhibits continuous dramatic warming beginning 2004, the tendency of the Barents Sea AW branch (BSWB) remains poorly known. Here we demonstrate through the analysis of 2005-2006 observational data the contrary tendency of the BSWB to cool. The data used in this study were collected from the icebreaker Kapitan Dranitsyn CTD survey over the continental slope of the Eurasian Basin for two consecutive years: 2005 and 2006. While in September 2006 the along-margin CTD/Water sampling transect has occupied the continental slope approximately following the depth of 1500 m between 31 and 142E, in September 2005 only the eastern portion between 97 and 142E has been sampled. Our data shows that in 2006 the BSWB core has been found saltier (0.16-0.35 psu), cooler (0.20-0.25 C), denser (0.02 kg/m³), deeper (150-200 m), and much better ventilated (7-8 $\mu\text{mol/kg}$ of dissolved oxygen, or 1.1-1.7% of saturation) comparing with 2005. We hypothesize the shift from the higher to lower intensity of the Icelandic low during the BSBW transit through the Barents and northern Kara Seas results in longer upstream residence time for the BSBW sampled in 2006 comparing that of 2005. We speculate the 2006 BSBW cooling and the higher concentration of the dissolved oxygen are attributed to the 2006 BSBW longer surface residence time. The BSBW core salinity inter-annual variability is within the range of the long-term mean inter-annual salinity variations through the Barents Sea opening. However, the higher silicate concentration of 2005 allows attributing the lower 2005 salinity to the more intensive interaction with fresher and silicate rich water of the coastal Norwegian current during the BSBW transit through the Barents Sea rather it is brine originated. The ongoing analysis of oxygen isotopes will help clarify our findings.

Keywords: residence time, dissolved oxygen, circulation



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Oral Presentation

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Organic carbon dynamics in the Western Arctic Ocean: Implications for shelf basin interactions

Dr. Laodong Guo

Marine Science University of Southern Mississippi IAPSO

Celine Gueguen, Tomoyuki Tanaka, Ming-Yi Sun

Water samples were collected from the western Arctic Ocean and characterized for dissolved (DOC) and particulate organic carbon (POC), colored-dissolved organic matter (CDOM), carbohydrate species, and isotopic composition to better understand organic carbon dynamics and its relation to shelf basin interactions in the Arctic. Distributions of DOC and CDOM show a strong influence of terrestrial organic matter with plumes defusing out from shelf to slope and to the basin, indicating that CDOM can be used as a potential tracer of water mixing and shelf-basin interactions. Radiocarbon composition of DOM samples shows a general decrease in $\Delta^{14}\text{C}$ value with increasing depth, with an overall younger ^{14}C age compared to that of the north Atlantic, indicating a greater influence of terrestrial DOM in the Arctic. Concentrations of dissolved carbohydrates, including MCHO and PCHO, varied from 4 to 18 M, comprising about 20% of the DOC. Both abundance and TCHO/DOC ratio first decreased from surface to the bottom of the halocline at ~200 m, but increased again from 200 m towards deep waters. High concentration of polysaccharides in deep waters likely resulted from low microbial activity and lateral transport processes. $\delta^{13}\text{C}$ values of POC ranged from 31 to 22‰, with higher values in the Chukchi Sea and lower values in the Mackenzie delta. However, the lowest $\delta^{13}\text{C}$ value was observed at the stations near the ice edge in the basin, showing a general decrease in lipid $-\delta^{13}\text{C}$ values with increasing lipid-C/TOC ratio. Significantly lower $\delta^{13}\text{C}$ -POC values compared to those of sediments suggest a preferential decomposition of organic components with lighter C isotope during their transport from upper water column to sediments.

Keywords: organic carbon, isotope, shelf basin



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PS006

Oral Presentation

5955

Arctic freshwater impacts on the intermediate water formation in the Labrador Sea

Dr. Hideaki Kitauchi

Frontier Research Center for Global Change JAMSTEC

Hiroyasu Hasumi

Arctic-origin, low-salinity water exported through the East Greenland Current (EGC) is considered to have a significant influence on the formation of intermediate water in the Labrador Sea (Labrador Sea Water, LSW), important for climate study. This freshwater transport stabilizes/destabilizes the near-surface density stratification in the Labrador Sea to prevent/enhance the open-ocean deep convection in wintertime. The present work focuses on the impact of the freshwater transport by the EGC on the LSW formation by the use of an eddy-resolving coupled sea ice-ocean circulation model (CCSR Ocean Component Model, COCO version 4, Hasumi, 2006). We performed two sensitivity numerical experiments: one with, the other without restoring of salinity and temperature near the surface layers of the model lateral boundaries, including the EGC entrance to the Labrador Sea, to mimic the strong and weak freshwater transport by the EGC, respectively. Our preliminary results with/without the restoring show the weakened/strengthened horizontal distribution and vertical depth of the wintertime deep convection as well as mixed layer depth over the Labrador Sea to decrease/increase the LSW formation.

Keywords: labrador sea, eddy resolving ocean model, east greenland current



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PS006

Oral Presentation

5956

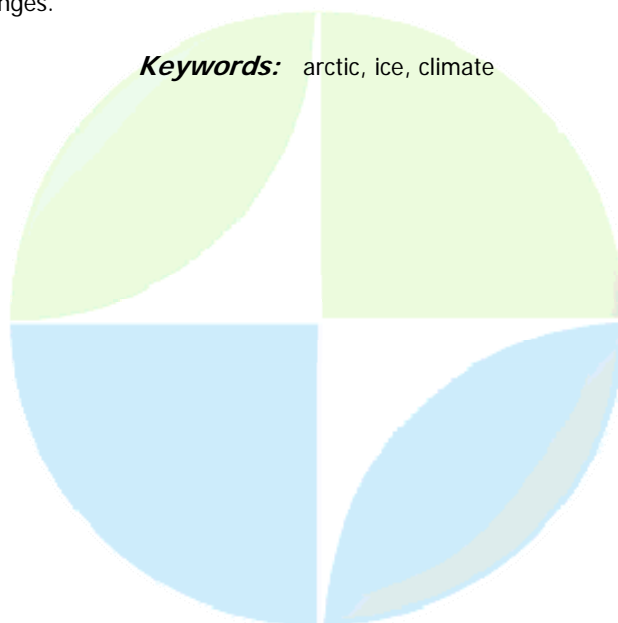
**Accelerated Multiyear Sea Ice Reduction: Present-day Manifestation,
Future Projection, and Underlying Physical Mechanisms**

Dr. Xiangdong Zhang

International Arctic Research Center University of Alaska Fairbanks IAMAS

Sea ice is an essential component of climate system and an outstanding indicator of global climate change. Recent dramatic shrinking of Arctic sea ice cover has drawn much attention scientifically and socially. Remarkable global warming has been manifested in the polar region, which may continue and be further amplified, leading to a rapid decrease of sea ice cover or an ice-free summer in the Arctic Ocean in future, as projected in global warming scenarios. The decreased sea ice would naturally result in significant climate consequences by changing energy budgets and hydrological cycle, for example, altering atmospheric circulation regimes and impacting the North Atlantic deep convections and Meridional Overturning Circulation. In this study, we analyzed changes of the Arctic sea ice cover, volume and transports based on the multiple model outputs for the IPCC AR4 (Intergovernmental Panel on Climate Change, the 4th Assessment Report). We focused on multiyear sea ice and first examined the sea ice simulations for the climate of 20th century (20c3m) and validated models performance against observations. Considering availability of accurate sea ice measurements by satellites, we selected a period of 1979-99 from ensemble means of each models simulations and compared model results with observational data. Then, we investigated changes of sea ice extend, area, volume and transports in the 20th century and in the 21st century under global warming scenarios (SRES A1b, SRES A2, and SRES B1). The results demonstrated various capabilities of the participating models in simulating sea ice climatology. A number of models relatively captured realistic sea ice climatology, while a few models noticeably overestimated or underestimated sea ice cover. Nevertheless, most models shows encouraging results in portraying sea ice decreasing changes during 1979-1999. In the global warming scenarios, all the models indicated a pronounced reduction of sea ice cover from 2000 to 2100 over the Arctic Ocean. Generally, the strongest sea ice decrease occurs in the SRES A1b scenario and the weakest one occurs in SRES B1. Close examination shows that a free-ice Arctic Ocean in summer can be expected in the later 21st century in a number of models. Using other modeling parameters in atmosphere and ocean, we explored dynamic and thermodynamic mechanisms controlling sea ice changes.

Keywords: arctic, ice, climate



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Oral Presentation

5957

Hindcast and Reanalysis of the Circulation in the Bering and

Dr. Gleb Panteleev

Oceanography International Arctic Research Center

Dmitri Nechaev, Vladimir Luchin, Phyllis Stabeno, Rebecca Woodgate, Ekaterina Panteleeva

We present results of a set of variational data assimilation experiments aimed at the reconstruction of quasi-stationary and time-varying circulations in the Chukchi and Bering Seas. Depending on the assimilated data, these experiments are focused on different regions and time periods. The model used for the reconstruction is designed specifically for efficient variational assimilation of long-term observations in ocean regions governed by flow through open boundaries and by atmospheric fluxes. The circulation in the Chukchi Sea is derived from various sources of observations including two months of velocity, temperature and salinity records from moorings and CTD observations in autumn 1990 (www.frontier.iarc.uaf.edu/~gleb). Assimilation of mooring velocities allows us to quantify volume, heat and salt transports in the Chukchi Sea. The reconstructed circulation pattern reveals periodical reverse of the East Siberian Current and flow through the Bering Strait, which are the important features of the Chukchi Sea circulation. The quasi-stationary circulation in the Bering Sea is recovered from drifter and mooring observations, climatological temperature and salinity data, and climatological surface fluxes of momentum, heat and fresh water. The estimates of volume transports through the Aleutian straits are presented. Several numerical examples show that the reconstructed climatological sea surface height distribution can be effectively used for operational hind-cast of the circulation in the Bering Sea. Experiments intended for evaluation of the Amukta Pass transports in January 2002 are conducted with assimilation of AVISO satellite altimetry anomalies and optimized climatological SSH. The obtained volume transports are compared with low-pass filtered transports through the Amukta Pass calculated from four moorings (Stabeno et al., 2005).

Keywords: 4dvar, assimilation, chukchisea



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PS006

Oral Presentation

5958

Interaction of high frequency hydrodynamic processes and brines evolution in the Storfjorden

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Espace Environnement Ecologie LOCEAN Laboratory IAPSO

Pascale Bouruet Aubertot, Frdric Vivier, Antonio Lourenco, Jean Claude Gascard

Dense water formation resulting from brine rejection while sea-ice formation is a process of fundamental importance in arctic regions that contributes to deep ocean ventilation and therefore to the global thermohaline circulation. We investigate the interactions between high frequency hydrodynamical processes and brine formation. Our study is based on in-situ measurements performed at the Storfjorden in the Savlabard archipelago, a place of intense brine formation. Fixed point measurements have been performed in winter 2006 at the limit of fast ice. These measurements gave evidence of the strong variability of the currents and stratification. To get further insights into these processes, the deployment of a mooring including an ADCP, a thermistor chain and conductivity sensors is scheduled between March and May 2007. This mooring will provide measurements over the whole water column with high temporal resolution (~30s). In addition the joint deployment of an autonomous prototype instrument called Ice-T (for Ice-Thickness), will achieve continuous measurements of ice thickness and thermal content. With the help of the data collected, we shall be able to characterize high frequency processes and eventually their interaction with brine evolution.

Keywords: brines, internal waves, mixing

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Poster presentation

5959

Interannual variability in the Arctic Ocean freshwater balance

Mrs. Alexandra Jahn

Department of Atmospheric and Oceanic Sciences McGill University IAPSO

Bruno Tremblay

The freshwater transport from the Arctic Ocean to the northern North Atlantic by sea ice and the surface ocean shows large interannual variability. As variations in the freshwater transported into the northern North Atlantic can have an impact of the strength of the meridional overturning circulation and cause Great Salinity Anomalies, a better understanding of the variability of these fluxes is necessary. We present a detailed characterization of the interannual variability of all terms of the Arctic Ocean freshwater balance (i.e., runoff, net precipitation, Bering Strait inflow, liquid freshwater export, and sea-ice export) over the period 1950-2005, as simulated by a high resolution version of the University of Victoria Earth System Climate model (UVic-ESCM). The UVic-ESCM consists of a 3-D global ocean circulation model, an elastic-viscous-plastic sea-ice model, a land surface and vegetation model, and an energy moisture balance model for the atmosphere. It is forced with daily NCEP reanalysis winds and global atmospheric CO₂ concentrations. The simulated interannual variability of sea-ice export through Fram Strait, as well as river runoff and Bering Strait flow are compared with available observations and other model results. We show the effect of atmospheric modes on different components of the freshwater balance in the Arctic Ocean, compare the magnitude of changes in the liquid and solid Arctic Ocean freshwater storage, and assess the effect of changes in freshwater storage in the Arctic Ocean on the simulated meridional overturning circulation.

Keywords: arctic, ocean, freshwater

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Poster presentation

5960

Internal waves under ice cover

Dr. Sergey Muzylev

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The influence of internal waves on the sea ice cover is a problem, which is practically important but poorly studied. It is a common assumption that the rigid lid approximation that filters out the surface mode and describes well the properties of internal waves should be valid also in the case, when the free surface is substituted by an ice cover. Since the vertical velocity at the surface is zero in the approximation, there should be no vertical displacements of the ice cover along the vertical. Thus internal waves can not be recorded on the basis of fluctuations of the sea ice cover. Such conclusion, however, contradicts the data of observations. We have developed theoretical model, which describes propagation of internal waves under ice cover. The sea water is considered inviscid, non-rotating, and incompressible, the BruntVisl frequency is supposed to be constant. The ice is considered of uniform thickness, with constant values of Youngs modulus, Poissons ratio, density and compressive stress in the ice. The boundary conditions are such that the normal velocity at the bottom is zero and at the undersurface of the ice the linearized kinematic and dynamic boundary conditions are satisfied. According to our results the deflections of the sea ice surface with the frequencies close but smaller than the BruntVisl frequency (i.e., with periods of tens minutes) can gain amplitudes sufficient for recording of internal waves. The model shows good agreement with observations in the Arctic Ocean. This study was supported by the Russian Foundation for Basic Research (project no. 06-05-65210).

Keywords: ice cover, internal waves

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Poster presentation

5961

The granular sea-ice model in spherical coordinates and its application to a global climate model

Prof. Lawrence Mysak

Dept. of Atmospheric and Oceanic Sciences McGill University IAPSO

Jan Sedlacek, Jean-Francois Lemieux, L. Bruno Tremblay, David M. Holland

The granular sea-ice model (GRAN) from Tremblay and Mysak (1997) is converted from cartesian to spherical coordinates. In this conversion, the "metric" terms in the divergence of the deviatoric stress and in the strain rate are included. As an application, the GRAN is coupled to the global Earth System Climate Model from the University of Victoria. The sea-ice model is validated against standard data sets. The sea-ice volume and area exported through Fram Strait agree well with values obtained from in-situ and satellite derived estimates. The sea-ice velocity in the interior Arctic agrees well with buoy drift data. However, the model tends to underestimate the thickness distribution. The thermodynamic behaviour of the sea-ice model over a seasonal cycle at one location in the Beaufort Sea is validated against the Surface Heat Budget of the Arctic Ocean (SHEBA) data sets. The thermodynamic growth rate in the model is almost twice as large as the observed growth rate, and the melt rate is 25% lower than observed. The larger growth rate is due to the thinner ice to begin with and the absence of internal heat storage in the ice layer in the model. The lower summer melt, on the other hand, is due to the smaller than observed net ocean heat flux.

Keywords: sea ice, modelling, thermodynamics dynamics

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Poster presentation

5962

Characteristics of heavy metals in Chukchi Sea sediments as compared to selected circum-arctic sea areas

Dr. Hao Ma

Engineering Physics Tsinghua University

Liqi Chen, Shi Zeng, Jianhua He, Xianzhang Zeng, Mingduan Yin, Wenyi Zeng

Surficial sediments from 11 stations in Chukchi Sea and 4 stations in Bering Sea were collected during summer on the First Chinese National Arctic Research and expedition from July to September 1999 and analysed by instrumental neutron activation analysis (INAA) for Al, Co, Cr, V, Zn, Fe and Mn. Multivariate analysis was applied to estimate sources of heavy metals on the basis of the INAA data. In comparison of the heavy metal concentrations in the Chukchi Sea with those of northeast of Chukchi Sea, the high Arctic shelves of Russia, East Greenland and the Beaufort Sea, there appear relatively lower levels of most metals in the Chukchi Sea. Presumably it was found in the Chukchi Sea sediment that the source of heavy metals in the sediment of the Chukchi Sea would be attributed to effects primarily from the natural geochemical process but from anthropogenic contribution. Therefore, it would be suggested that the concentrations of heavy metals reported here could be served as reliable baselines to monitor pollution for heavy metals in the western Arctic Ocean.

Keywords: heavy metals, sediment, chukchi sea

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Poster presentation

5963

Observations in the Arctic Ocean Do Not Confirm Weakening of Thermohaline Circulation in the North Atlantic

Prof. Genrikh Alekseev

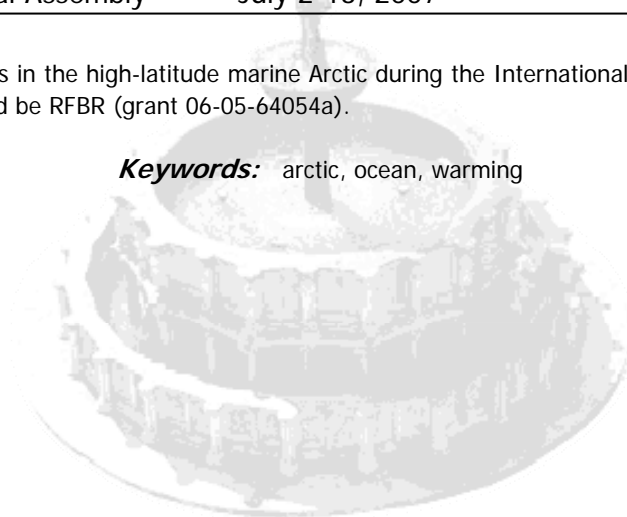
Ocean and atmosphere interaction Arctic and Antarctic Research institute IAPSO

Ivan Frolov, Vladimir Sokolov

Recently in the several publications have reported about weakening of thermohaline circulation and its meridional component (meridional overturning circulation) in the North Atlantic. However, the results of some other studies are contradictory to this conclusion. Under conditions of such uncertainty, monitoring of Atlantic water (AW) influx to the Arctic Basin holds special importance. This influx is the terminal segment of the North Atlantic part of the global oceanic conveyor belt. Here, the AW stream from Fram Strait to the Laptev Sea is concentrated in a narrow belt along the continental slope. Therefore, this stream can be monitored with icebreaker-type ships and a small number of long-term under the water or ice moorings. Atlantic water is an important heat source, as well as a salt source for the Arctic waters subjected to permanent freshening. Owing to a significant increase in the AW transport in the 1990s, the freshened layer become thinner in the AW spreading region and thicker in Beaufort Gyre, near the coast of Greenland, and in the Canadian Archipelago, which resulted in an increase in freshwater discharge from the Arctic Basin through the straits of the Canadian Archipelago. The field measurements performed in summer 2005 show that the extensive positive temperature anomaly of the Atlantic water is retained in the Arctic Basin. Moreover, a new thermal pulse in the AW flow through Fram Strait into the Arctic Basin was informed. The data about AW temperature obtained in 2005 in the Arctic Basin along the pathway of AW from Fram Strait to the east are compared with the data of many previous observations beginning from the 1920s. Six regions were chosen for comparison along the pathway of AW spreading, for which we could find the longest observation series within squares not exceeding 200 200 km in size (with a radius of 100 km for the North Pole region). The initial data were vertical profiles of water temperature measured within these squares in different years. The maximal temperature in the AW layer determined on each profile was plotted on the time variation graph for the given region. The longest time series from 1920 to 2005 was gathered in Fram Strait. These data demonstrate high AW temperatures in the 1930s and in the last two decade with the absolute maximum of 7.54 C in 2005. The modern AW warming can be traced in all regions chosen for this study, while warming of the 1930s can be seen up to 90 E. The temperature minimum of AW in the 1970s and beginning of the 1980s is seen clearly in all regions of the Arctic Basin. The time series make it possible to estimate approximately the time of spreading of temperature anomalies in the course of their propagation in the interior of the Arctic Basin. The time of the propagation of anomalies from Fram Strait would be equal to 3 - 4 yr up to the 80 N, 120 E region, 5 - 6 yr up to the 81 N, 150 E region, and no less than 4 yr up to the North Pole. In the North Pole area, a temperature increase was observed from 1990 to 2001, but the temperature decreased by 2005. According to the estimates of the temperature wave propagation presented above, a temperature increase is also expected here in 2006 - 2007. Thus, the results of the analysis of temperature variations in the AW layer in the Arctic Basin indicate the continuation of warming, which started in Fram Strait at the end of the 1980s and occupied almost the entire basin in the 1990s. After a slight decrease of AW temperature in Fram Strait in the 1990s, the temperature has been increasing again beginning from 1998. This increase is already appreciable over the AW pathway up to the Laptev Sea, and a further increase is expected. All this allows us to conclude that the Arctic part of the thermohaline conveyor belt has not been weakening, but rather, intensifying in the last 5--7 yr. Continuation of the AW monitoring is an important part of

studying the processes in the high-latitude marine Arctic during the International Polar Year 2007-2008. The study is supported by RFBR (grant 06-05-64054a).

Keywords: arctic, ocean, warming



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Poster presentation

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A column model for the Arctic Ocean ice cover

Prof. Karin Borens
Research SMHI IAPSO

Gran Bjrk

A coupled atmosphere-ice-ocean column model is used to calculate the Arctic ice cover and its sensitivity to changes in the forcing parameters. The model comprises formulations for ridging and ice export, two processes that are important for the ice thickness distribution. The study will focus on how the ice cover reacts to changes in the cloud distribution and to varying albedo. The effect of changes in the atmospheric heat flux will also be considered.

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PS006

Poster presentation

5965

The changes of temperature, salinity and hydrochemical characteristics over the Siberian Arctic shelves during the last century: data confidence and long-term trends

Mr. Mikhail Makhotin

Oceanology Arctic and Antarctic Research Institute IAPSO

Igor Dmitrenko

Well pronounced increase of the warming signal has been observed in the Arctic since the middle of 20th century and especially during the last decades. This warming is thought to cause concurrent changes in marine system. The main goal of our study is to examine the century-long behavior of the Kara, Laptev, East-Siberian and Chukchi sea waters. Based on historical hydrographic and hydrochemical observations obtained during both Russian and western polar expeditions since 1930 the long-term trends in sea water properties (i.e. temperature, salinity, oxygen, pH and nutrients) are analyzed. Ice cover and relatively remote position of considered regions to the sea transportation infrastructures makes these regions historically poor in data coverage both in space and time. That is why we have paid a special attention to estimation of the spatial and seasonal uncertainties to figure out the assumed trends more carefully. In particular the Monte-Carlo simulation has been conducted to obtain the errors due to insufficient data coverage. The seasonal errors have been estimated as the maximal differences between climatic means of any property averaged for every month. We divide the water column into the consecutive sub-layers 10-m thickness to compute the time series of seasonally averaged annual temperatures and salinities in each layer. These series have been further correlated to each other to bound the surface and bottom layers which demonstrate the same long-term changes during the last century. To reveal the role of large-scale atmospheric forcing during both cold and warm phases of Arctic climate we trace the linear trends separately for surface and bottom layers during 1930-1965 and 1965-2006 summer and winter periods.

Keywords: trends, siberia, shelf



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PS006

Poster presentation

5966

**Interannual variability of Pacific origin waters in the Canadian Basin
caused by large-scale atmospheric circulation over the Arctic**

Mr. Mikhail Makhotin

Oceanology Arctic and Antarctic Research Institute IAPSO

Roger Colony, Leonid A. Timokhov

Due to hydrostatic imbalance and atmospheric circulation, water from the North Pacific flows through the Bering Strait, enters the Canadian Basin from the Chukchi Sea via three main canyons (Herald, Central and Barrow), transits the upper levels of the Arctic Ocean, and finds its way to the North Atlantic. Our previous results reveal the significant interannual variability of Pacific origin waters (POW) circulation, which is influenced by the atmospheric processes associated with changes in atmospheric climate modes (i.e. the Arctic Oscillation (AO), sea level pressure difference and etc.), that allows us to use these atmospheric patterns for water mass circulations study in the Arctic Ocean. Using hydrographic and hydrochemical data (1950-1993), annual wintertime fields of thickness, volumes, heat content and position of POW boundaries are estimated for further correlation with different atmospheric patterns over the Arctic. Some recent data are also used to improve our results. We find that large-scale atmospheric processes strongly affect POW characteristics. Thus, the northern boundary of Pacific summer water shifts to the North in negative AO state and shifts to the South in positive AO state. Also we calculate geostrophic current velocities at winter and summer Pacific origin waters depths and show changes of currents velocities and directions in different atmospheric regimes.

Keywords: variability, Pacific, waters



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PS006

Poster presentation

5967

Radiation Climate of the Laptev and East-Siberian Seas Surface Layer in the Present and Past

Dr. Alexander Makshtas

Air-sea interaction Arctic and Antarctic Research Institute IAPSO

Roman Vlasenkov, Nina Belchiva, Alexander Charkin, Alexey Pavlov

The relations between turbidity, PAR, concentration of particulate material in sea water, and the depth of disk Seichi vanish, established with data of summer expeditions to the East-Siberian Sea in 2003 and 2004 are shown. Calculated with founded relations and all available historical data of Secchi disk observations in the Laptev and East-Siberian Sea the mean spatial distributions and temporal-spatial variability of turbidity and PAR during 1950s 2000s are demonstrated. The first data about relation between global and PAR radiation in dependence on turbidity, as well as spatial distribution of CDOM in the East-Siberian Sea, obtained with spectral measurements, executed during expeditions and laboratory spectral measurements of samples, collected in cruises, are presented. The influence of above mentioned characteristics on radiation and heat regime of sea surface layer in the study areas are estimated.

Keywords: radiation, turbidity, cdom



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PS007

5968 - 5988

Symposium

Biogeochemical Fluxes Between the Shelf and Open Seas

Convener : Prof. John Simpson

Shelf sea and oceanic regimes meet and must mutually adjust over the steep topography of the shelf edge. The processes involved in this adjustment control the exchange of water and many important properties between the continental shelf and the deep ocean. Topographic steering of the geostrophic flow along the slope tends to restrict this exchange but this constraint may be circumvented by a number of processes including cross slope transfer in the boundary layers and tidal motions. This symposium will focus on studies, both observational and modelling, of shelf edge transfer processes and the biogeochemical fluxes which they induce. We anticipate particular emphasis on (1) the fluxes of organic carbon to the deep ocean and (2) nutrient transfer from deep water into the shelf system, the understanding of which are critical in efforts to determine the role of shelf seas in relation to the global carbon budget and climate change.



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PS007

Oral Presentation

5968

Metal accumulation in the sediments of the exclusive economic zone (EEZ) of Bay of Bengal, India

Dr. Jayaraju Nadimikeri
GEOLOGY S.V. UNIVERSITY IAPSO

The EEZ of Bay of Bengal is subjected to different land based sources and marine activities. Twenty samples were collected from the EEZ and analyzed to determine the effects of increasing man made activities on the structure and chemical composition of seabed. Grain size analysis support the predominance of sand sized sediments with patches of sandy silt at the northeastern and southeastern areas. Coarse grained sand was characterized by elevated carbonate content reaching >90%. Off Vizag and opposite to industrial parks, the organic matter reached >6.4%. Cu (06.5-28.2 g/g), Pb (1.8-18.5 g/g), Co (1.9-8.7 g/g) and Mn (34.6-698 g/g) levels were high when compared to other Indian values. Stations were clustered on the basis of sediment texture rather than metal accumulation. The high organic content of northeastern sediments derived from plank tonic origin is coupled by low metals concentrations. Except for Cr, Cu, and Fe, the non-residual fraction of metals contributed between 52 and 86% of the total metals concentrations. Negligible or very low amount (< 5%) of the non-residue fraction of metals appeared in the exchangeable phase. Metals are mostly associated with the easily and non moderately reducible fraction (21% Fe, 14% Cr, 22% Co, 32% Mn, 13% Ni, and 16% Cu) due to strong scavenging capabilities of Fe-Mn oxides. Pb is partitioned equally among easily/moderately reducible and carbonate fractions, dominating in the latter. Co (36%) and Ni (32%) are mostly associated with organic matter /sulphide phase, while. The concentrations of bioavailable metal fractions (exchangeable and easily /moderately reducible) do not put at risk the economically important living resources.

Keywords: tracemetals, pollution, bayofbengal



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PS007

Oral Presentation

5969

**Impact of surface water circulation on the distributions of Cd and Ag in
Baha de Todos Santos, Mexico**

Dr. Silvio Marinone
Physical Oceanography CICESE

M. L. Lares, I. Rivera, A. Beck

Baha de Todos Santos is a small bay located in the northwest section of the Baja California peninsula in Mexico. Although, upwelling events occur all year long along the peninsula, these are more intense during Spring and Summer. In this study, we will report the impact of a summer upwelling event (August 2005) on the distributions of Cd and Ag within the bay. We choose Cd because the belief that this element is a good upwelling indicator (Bruland et al., 1978; de Baar et al., 1994). In contrast, Ag is considered a tracer of anthropogenic point-sources (sewage) (Saudo-Wilhelmy and Flegal, 1991). We hypothesize then that the different distributions and sources of these two trace metals could be used to trace water circulation patterns within the bay. Although actual current measurements are not available, we will present some preliminary circulation results obtained using a numerical model.

Keywords: cd, ag, circulation



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PS007

Oral Presentation

5970

Offshore transport of Trace elements in the Equatorial Undercurrent from Papua New Guinea

Prof. Chris Measures
Oceanography University of Hawaii

The trace element signal derived from continental weathering on land is normally removed close to its source by the enhanced productivity in coastal regions, thus limiting the transport of trace elements to the open ocean. This is particularly true for reactive trace elements such as Fe and Al. The Equatorial Undercurrent (EUC) however appears to have an extremely distinctive trace element signal in dissolved Al, and Fe which is associated with its high velocity core. It is speculated that this signal originates in the formation region of the EUC in the coastal region of Papua New Guinea (PNG). The source of the dissolved Al and Fe is believed to be from diagenetic processes that occur in the mud belts that are situated at the seaward end of these tropical rivers that drain the uplands of PNG. The transport of this shelf derived signal several thousand nautical miles across the equatorial ocean suggests a potentially greater role for shelves in promoting oceanic biogeochemical cycles than previously thought. The signal, which is easily visible at 140°W over 4,000 nautical miles from its presumed origin, can penetrate so far because it is associated with a sub-surface flow that is not impacted directly by biological processes. However the EUC shoals as it flows towards the East, and at ~ 140°W it begins to contribute biologically required Fe to the surface waters of the central and eastern Pacific. The gradual entrainment of the Fe into the upper waters and its scavenging in the sub surface waters by the particle rain that it helps to fuel in the overlying waters, results in the depletion of the dissolved Fe and the elimination of the signal by 110°W. The persistence of the dissolved Al signal to 110°W though indicates the relative scavenging rate of these two elements along this advective flow path and opens up the possibility that the EUC could be used to calibrate the relative scavenging rates of a variety of trace elements.

Keywords: trace elements, equatorial undercurrent, shelf transport



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Oral Presentation

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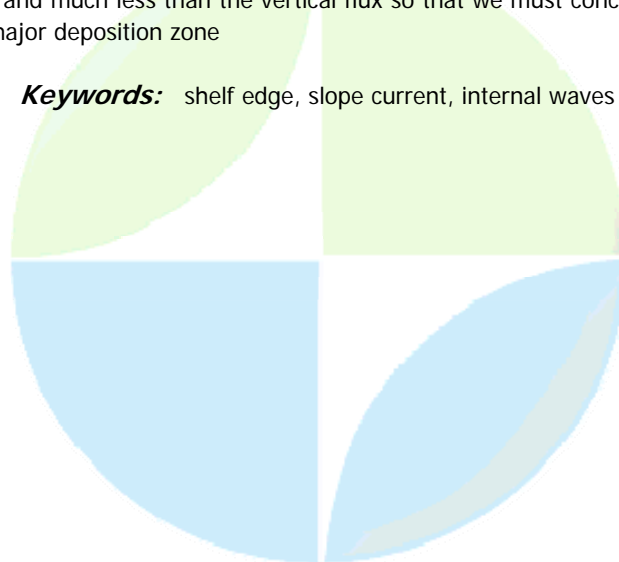
Dynamical Adjustment and Exchange at the Hebridean Shelf Edge

Prof. John Simpson

School of Ocean Sciences University of Wales, Bangor, IAPSO

At the lowest frequencies, the mutual adjustment of shelf and ocean is expressed as a persistent jet-like flow which occurs in a rather narrow region near the top of the continental slope. The LOIS SES observations have provided a very full picture of the structure and variability of the slope current. The flow is predominantly barotropic and is concentrated (width ~20km) over the upper part of the slope with a core speed of 20cms⁻¹ and a transport of order 1-2 sverdrups. The cross-slope dynamical balance is essentially geostrophic and the flow is closely parallel to the depth contours. This bathymetric control of the flow has been convincingly demonstrated by the trajectories of the SES drifters under both summer and winter conditions. The flow is persistent throughout the year, only rarely reversing in direction. There is a significant increase during the winter when the baroclinic component diminishes and the flow tends to broaden and intrude onto the shelf. At tidal frequencies, the mutual adjustment of shelf and deep ocean is expressed in the generation of the internal tide which involves large displacements of the isotherms over the slope (~30m in the SES area) and a baroclinic flow structure which is consistent with new models of the internal tide. The undulation of the pycnocline evolves into a series of propagating solitons which have been observed by measurements with thermistor chains and bottom mounted ADCPs which have allowed direct measurement of the relatively large (5cms⁻¹) vertical motions associated with the solitons. It is the mixing arising from dissipation in these internal motions which was hypothesised to be responsible for enhanced primary production at the shelf break. However inferences from the restricted variation in the seasonal cycle of stratification across the slope suggest only a limited enhancement of the vertical exchange occurring on the upper part of the Hebridean slope system. Biogenic material originating on the shelf or in surface production over the slope has been observed in deep water (1500m). Candidate mechanism for the rapid transport of this material into deep water are (i) down-slope boundary layer transport induced by the slope current or (ii) enhanced vertical settlement associated with aggregation ("marine snow"). Optical measurements in the boundary layer provided the first direct estimates of down-slope transport. Measurements of the oxygen consumption rates by the slope sediments indicate that remineralisation of organic carbon here is an order of magnitude greater than the vertical supply as measured by sediment traps which suggests a substantial horizontal advective supply. At the same time, burial rates of both organic and inorganic sediment components are small and much less than the vertical flux so that we must conclude that the Hebridean slope region is not a major deposition zone.

Keywords: shelf edge, slope current, internal waves



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Oral Presentation

5972

Vertical nitrate fluxes and primary productivity at the shelf edge driven by an internal tide.

Dr. Jonathan Sharples

Jacqueline F. Tweddle, J. A. Mattias Green, Matthew R. Palmer, Young-Nam Kim, Anna E. Hickman, Patrick M. Holligan, C. Mark Moore, Tom P. Rippeth, John H. Simpson, Vladimir Krivtsov

The edge of the continental shelf is often found to be a region of enhanced concentrations of phytoplankton. This is often thought to arise from locally-increased primary production in response to a supply of deep nitrate mixed upward by internal tides. Recent observations of vertical turbulent mixing and associated nitrate fluxes, along with estimates of primary production rates, at the shelf edge of the Celtic Sea quantify the response of the phytoplankton to the internal tidal mixing. In particular they indicate significant variability on the spring-neap tidal cycle, with spring tide nitrate fluxes up to 8 times greater than at neap tides. This spring tide nitrate flux appeared to be dominated by short mixing events driven by the passage of individual internal solitons. This has implications for how shelf edge processes are observed and for the capabilities demanded of numerical models of the coupled physics and biochemistry at the shelf edge. Combining the measurements of nitrate fluxes and primary production indicates a likely spring-neap pulsing of phytoplankton production in response to variability in the internal tide.

Keywords: shelf edge, internal tide, primary production



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Oral Presentation

5973

Dense Shelf Water Cascading in the Gulf of Lion and its implications

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CEFREM CNRS - University of Perpignan IAPSO

Canals M., Puig P., Heussner S., Palanques A., Calafat A., Estournel C.

Several recent experiments have highlighted the variability and the consequences of Dense Shelf Water Cascading (DSWC) in the Gulf of Lion (North-western Mediterranean). Winter and early spring DSWC may last for more than one month, during which large amounts of dense water are exported off the shelf. Submarine canyons, and specially the Cap the Creus Canyon, which cuts the south-western end of the Gulf of Lion margin, play a principal role in funnelling dense water downslope. DSWC shows a strong interannual variability, with three severe events occurring during the last decade. Severe DSWC events are able to carry very large quantities of dissolved and particulate matter to the deep basin. It thus appears as a significant natural carbon sequestration and deep ecosystem fuelling mechanism as, for instance, a total organic carbon transport of 0.6 Mtons was measured during the late winter-early spring event of 2005 only through the Cap de Creus Canyon. This represents a total organic carbon flux of 50 gC/m²/yr for the Gulf of Lion, which is larger than the average export due to open sea winter convection in the nearby Ligurian Sea. The particulate organic carbon flux is comparable to cascading-driven export in North Atlantic margins.

Keywords: cascading, mediterranean, canyon

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ITALY



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Oral Presentation

5974

Numerical study of the Tsushima Current branching and flow patterns over the shelf, slope, and deep sea off the Korea Strait in the Japan/East Sea

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The Japan/East Sea (JES) is a deep East Asia marginal sea connected to the East China and Yellow Seas, Northwest Pacific, and Okhotsk Sea by shallow straits. The Tsushima Current entering the southwestern JES from the Tsushima Strait bifurcates off the Strait, with branches flowing east and north over the slope. The former is referred to as the Offshore Branch (OB) and the latter is called the East Korea Warm Current (EKWC), the JES western boundary current eventually separating from the Korea coast further north, with the formation of an anticyclonic recirculation gyre (Uda, 1934; Kawabe, 1982; Yoon, 1982, 1991, 1999). Extremely high mesoscale variability of branching and flow patterns meridional shifts of bifurcation, strengthening/weakening/disappearance of either the OB or EKWC, formation of anticyclonic and cyclonic eddies over the slope and adjacent deep Ulleung Basin is documented from observational evidence (Kim and Legeckis, 1986; Katoh, 1994; Teague et al., 2004; Mitchell et al., 2005). Intensive mesoscale dynamics in the Ulleung Basin results in mixing of waters of different origin with different thermohaline and biochemical properties warm Kuroshio and Yellow Sea water with colder coastal and open sea water from the northwest JES. Physical mechanisms of this variability not linked to a seasonal cycle are poorly understood and are probably related to a variety of causes (Chang et al., 2004). The purpose of this study is to analyze an impact of wind stress curl on branching of the Tsushima Current off the Korea Strait and flow patterns in the Ulleung Basin on the base of numerical simulations with an oceanic model. The primitive equation quasi-isopycnic MHI model (Mikhaylova and Shapiro, 1992) forced by statistically obtained wind stress patterns (Trusenkova et al., 2007) is applied. Wintertime wind over the JES is characterized by prevailing cyclonic stress curl, while summertime patterns substantially differ by curl spatial distribution. The simulation results suggest that branching of the Tsushima Current is strongly influenced by large-scale and local wind stress curl. The large-scale cyclonic curl forces the intensified cyclonic gyre in the northern JES, southward shift of subarctic front and extension of subarctic water from the northwest JES towards the Ulleung Basin, thus preconditioning the EKWC weakening. The forcing by local cyclonic wind stress curl off the western Tsushima Strait results in transport redistribution in favor of the OB, weakening of the EKWC, and merging of the coastal and open sea water from the northwest JES. On the other hand, an anticyclonic wind stress curl results in the intensification of the EKWC, northward shift of bifurcation, and origination of the OB from the EKWC recirculation gyre. The branching patterns obtained in the simulations agree well with the Katohs (1994) patterns based on observational evidence.

Keywords: topographic control, mesoscale dynamics, wind stress curl

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Oral Presentation

5975

Ocean-shelf exchanges in the North-East Atlantic

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Shelf sectors from northern Spain to Norway are considered. This ocean margin has varied orientation and width, canyons, broken and fjordic coastlines. In a world-wide context, shelves here are relatively broad and riverine inputs of fresh water and sediments are relatively small. Lateral stirring and homogenization are weak, the LOICZ methodology is unreliable; emphasis is thrown on other ways of estimating ocean-shelf exchanges, especially on a process basis. Offshelf, broad oceanic flows in the top few hundred metres are generally southward from Biscay but poleward in Rockall Trough and further north. Mediterranean outflow water at 500-1500 m mixes as it progresses polewards against the continental slope, to Rockall Trough. There is a poleward current over most of the upper continental slope from Portugal to Norway. Beneath this slope current is a down-slope Ekman layer - a shelf-ocean exchange. Estimated shelf-ocean exchange from eddies is rather less, but important off Northern Scotland and Norway. A possible "overshoot" of the slope current at Goban Spur may give important exchange. Wind-forced exchange is important. Summer upwelling filaments off Iberia increase exchange, greatly exceeding the Ekman transport corresponding to the wind stress. Tidal currents cause very large transient exchange; locally, internal tides are also important. Off NW Spain, different approaches to estimating cross-slope exchange have given consistent results; these approaches include process-based estimates, supporting a modelling approach for estimates elsewhere. Exchange times are typically a few months, but just 2-3 weeks for the narrow South Biscay shelf and ~ one month off Northern Scotland. Exchange in the Irish Sea and Channel depends on through-flow and exchange times are typically a year. Elsewhere ocean-shelf exchange exceeds fluxes along the shelf. Some local budgets have been attempted. Salinity deficits relative to the open ocean are small (largest in the Norwegian Coastal Current, from the Baltic outflow, and in the Irish Sea). Fluxes of nutrients and carbon from rivers are generally small, relative to other fluxes in their shelf-wide budgets. However, nitrogen from rivers is significant in the Channel and Irish Sea. Rivers and atmospheric nitrogen inputs are broadly comparable with each other (Tables 3 and 6). However, their combination is generally less than denitrification and much less than the primary production requirement, even allowing for typical recycling factors (again, the Irish Sea and the Channel are exceptions). In most sectors, production is fuelled primarily by nutrients from the open ocean. Except off Norway, there is a ranking organic carbon flux to the sea bed <<<< dissolved carbon flows between sectors. Lack of sequestration in sediments implies a net export of organic carbon. For most sectors, however, a lack of available information highlights a need for more systematic measurement of constituents and the value of models for estimating budgets in complex domains.

Keywords: ne atlantic, exchange, processes



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Oral Presentation

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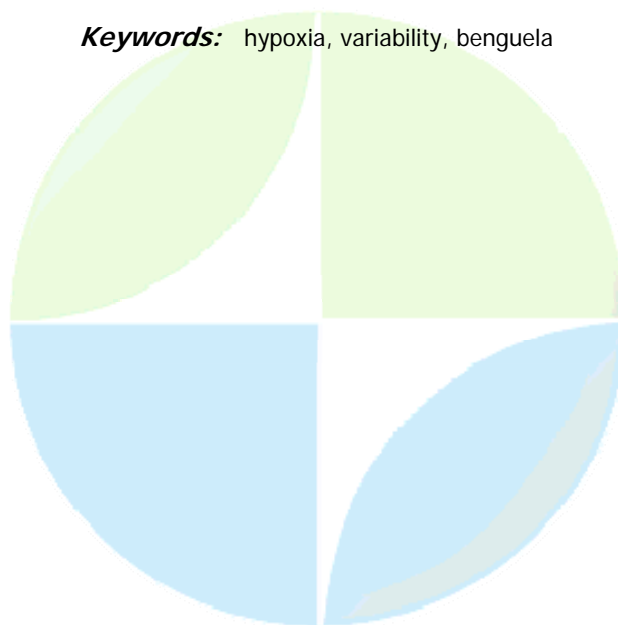
The link between the seasonal and interannual scales of hypoxia variability in the Benguela upwelling system and the dynamics of Ocean Shelf coupling

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Anja Karin Van Der Plas, Jean-Luc Melice, Pierre Florenchie

Emerging understanding of the variability of natural coastal hypoxia is divided between two main hypotheses: the biogeochemical oxygen demand linked to locally-driven organic matter decay or to supply of low oxygen waters by physical processes. The precise role of either trigger mechanism has remained elusive. In this study we examine the dynamical characteristics of coupled physical biogeochemical processes that modulate seasonal and interannual coastal hypoxia in the Benguela upwelling system in the south-east Atlantic. The results highlighted the role of advection to explain much of the seasonal interannual variability. These results challenge the predominantly biogeochemical basis, namely benthic pelagic coupling to understand the variability of hypoxia and its ecosystem implications. The results showed that the variability was insensitive to changes in the carbon export fluxes but strongly dependent on the advected oxygen fluxes. The dynamics of the interaction of equatorial and sub-tropical boundary conditions (ocean shelf exchange) and seasonally phased shelf advection were the key forcing functions that explained hypoxia variability in seasonal decadal time scales. A combined methane and oxygen high resolution year long hourly data time series in a coastal upwelling system suggests that these systems may be responding to a complex interaction between the two. The data show how anoxia is initially triggered by remote equatorial hypoxic waters after which it can be sustained by a local biogeochemical flux of exported production. Crucially, without a remote trigger the local forcing could not develop anoxic conditions because the physical flux of oxygen would be too high. The vulnerability of the system to climate change lies in the long term response of the equatorial system that governs seasonal and interannual warming at the Angola Benguela front as well as wind stress in the Luderitz southern boundary that governs ventilation. The proposed model was able to explain most of the decadal scale variability of two different ecosystem state indicators. The model predicts a long term decline of present ecosystem function with climate change.

Keywords: hypoxia, variability, benguela



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PS007

Oral Presentation

5977

Linkage of ground water fluxes to near-shore greening process and mudbank formation

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K.K. Balachandran, Thresiamma Joseph

The Arabian Sea coastal waters had sufficient hints of ground water seepages through narrow strips of submerged porous lime shell beds running almost parallel to the coastline. These ground water fluxes supply primary nutrients to the coastal waters and precondition it for rich primary production with the highest value of 14 mg/m³ for chlorophyll a, approximately 3 times greater than the peak values reported in these waters. A band of N/P > 15 funneling out from certain coastal regions indicated external source of nitrogenous compounds into the coastal waters. These sources of nutrients deserve identification as it was in regions far away from any river mouth. During the low tide, the polluted ground water near to the beach can be sucked through the porous lime beds into the surf zone and that creates a kind of hydrologic pump. The present investigation represented a period when the mud banks were not activated and the results showed fertilization of the coastal waters by injection of nutrients by hitherto unknown processes. The low saline ground water influx might be a triggering mechanism for mud bank formation in this coastal region. The differences in coastal land use had resulted in differences in the rate of nutrient loading to groundwater and hence to receiving coastal waters. The human population along the coastal belt with more than 70 % of households without proper sanitation facilities has resulted in concomitant increases in widespread use of septic tanks and nutrient inputs to coastal waters, particularly in regions occupying limestone beds. The ground water quality of the region had shown nitrate in sediment extract up to 12 µM, ammonia (in water) 8µM, urea (in water) 14 µM, urea (sediment extract) 15 µM. The necessary forcing for the ground water flow to overcome the frictional resistance of porous medium is gained when the fresh water level in wetlands (Cochin backwater) and the sea level difference had a critical value. Such conditions prevail during the peak southwest monsoon months due to heavy river discharges into the coastal wetlands. The possibility of heavy rains and flash floods linked with climate variability, such critical conditions can occur during other seasons and also at similar locations in the coastal region. The significance of this study is that subterranean flows could redefine the very concept of formation of mud banks, which is presently recognized only as an oceanographic process. Unlike the existing theories, it is argued that formation of mud banks is not entirely controlled by coastal oceanographic processes; instead a remote forcing from the land involving a subterranean flow through the submerged lime beds appears to be an initiative mechanism. The details of the exchange of coastal water and groundwater across the sediment-water interface and its role in mud bank formation deserve more attention and investigation

Keywords: mudbanks, coastal production bloom, groundwater fluxes

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Mesoscale eddies dominate ocean surface chlorophyll distribution in the Northern gulf of Alaska

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Peter J. Brickley, Andrew C. Thomas

Mesoscale eddies contain about 50% of the surface chlorophyll observed by satellite in deep-sea regions of the northern Gulf of Alaska, despite occupying only 10% of the surface area. We believe this enhancement of chlorophyll concentration is due to direct transport of chlorophyll by eddies from highly productive shelves to deep-sea waters, and also to higher nutrient (and iron) concentrations in mesoscale eddies. All significant eddies rotate anticyclonically. They form along the continental slope in winter or early spring and usually drift into deep-sea regions. Deep-sea surface waters of the Gulf of Alaska in late spring and summer are normally low in chlorophyll and relatively high in nitrate due to iron limitation. While near the continental margin, eddies entrain iron-rich and chlorophyll-rich coastal waters into their outer rings, sweeping these waters far offshore. When these anticyclonic eddies decay, their depressed isopycnals relax upward, injecting nutrients (including iron) up toward the surface layer. Eddies in the western sector of the gyre push coastal, iron-rich and chlorophyll-rich waters far offshore, allowing them to re-circulate around the gyre. Eddies decay slowly, providing a relatively steady upward supply of iron and nutrients. Therefore, we expect they behave as isolated oases of marine life in a lower productivity region.

Keywords: eddies, nutrients, chlorophyll



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Oral Presentation

5979

Shelf-Ocean Heat and Salt Exchange Caused by Cascading-Upwelling Circulation

Dr. Vladimir Ivanov
IAPSO

Dense water outflow from continental shelves (cascading) is one of the contributing processes of shelf-deep ocean exchange. As a means of cross-slope transport it is of topical interest to climate studies, nutrient and carbon fluxes. Dense water forms on shallow shelves by cooling, evaporation, freezing and salinization. After the dense water had accumulated on shelf it starts moving out of the production zone, cascading down-slope and turning to the right of the down-slope direction (in the Northern hemisphere) under the influence of Coriolis force. Numerical experiments, carried out on a primitive-equation regional model demonstrated that this along- and down-slope motion of dense water invokes an opposite-directed up-slope motion (upwelling) of lighter water from the deep. On the average, uplifted water moves above the near-bottom dense flow and eventually replenishes the upper layer in the production zone. Two oppositely-directed flows create a circulation loop with denser outflow near the bottom and lighter inflow near the surface. An example of this process was revealed in hydrographic observations in the northwestern Laptev Sea in the Arctic Ocean where traces of cascading were found in historical data. Development of dense water cascading from the Laptev Sea shelf in winter 1984-85 was simulated in numerical model. According to model results, the largest negative heat input associated with cascading-upwelling circulation at the Laptev Sea shelf and slope occurs in the intermediate Atlantic Water layer, while the largest salt input occurs in the overlying Cold Halocline layer. The magnitude of cross-slope heat and salt fluxes, associated with cascading-upwelling from the Laptev Sea shelf, is large enough to modify properties of intermediate waters in this part of the Arctic Ocean.

Keywords: cascading, upwelling, fluxes



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Oral Presentation

5980

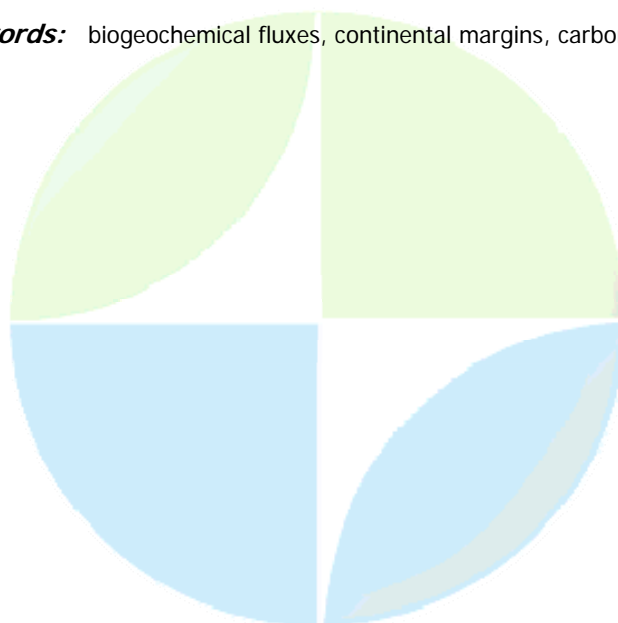
Biogeochemical exchanges between continental margins and the ocean interior

Prof. Kon-Kee Liu

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In the past decade, there has been a shift of the paradigm concerning the role of continental margins in the global carbon cycle. The conventional wisdom has it that continental margins are sources of CO₂ to the atmosphere due to the river loadings of carbon discharged to the coastal ocean or the upwelling of CO₂ laden subsurface water from offshore. However, observations in recent years suggest the contrary that continental margins are an important part of the CO₂ sequestration machinery in the ocean with an estimated strength of 0.1-1 Gt C/yr, representing 5-50% of the global ocean CO₂ uptake. It has been postulated that a combination of physical and biological pumps are responsible for the CO₂ uptake, but the details are still not thoroughly understood. This renders prediction of future changes difficult, if not impossible. Although the coastal ocean is more productive than the open ocean in general, it is not necessarily a more efficient biological pump. The carbon uptake either by biological fixation or by dissolution in seawater over the shelf may be released back to the atmosphere, when the organic matter gets mineralized or the shelf water warms up. These processes neutralize the continental shelf pump, unless there is a net transfer of carbon from the shelf to the ocean interior or the carbon gets buried in sediments. The high productivity in the coastal ocean is driven by the relatively rich nutrient supply, mainly from the ocean interior. It has been recently demonstrated and gradually appreciated that the coastal ocean is a more efficient processor for nutrient utilization and carbon transformation-transportation that enhance the net carbon uptake. Several important features of the coastal ocean contribute to the enhanced efficiency. These include intensified stratification due to warming and fresh water input in summer, rapid de-stratification and cooling in winter, repletion of trace metals for phytoplankton growth, benthic nutrient recycling and sediment-enhanced carbon transport and preservation. To understand the interplay between physical and the biogeochemical processes in continental margins, one must go beyond the 1-D approach often adopted in ocean biogeochemical studies. Although 2-D schematic diagrams are often used to depict coastal ocean processes, it would greatly accelerate the understanding if a fully 3-D approach can be adopted in these studies.

Keywords: biogeochemical fluxes, continental margins, carbon uptake



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Oral Presentation

5981

Transfer of material across the shelf edge of the northern Gulf of Mexico

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Eddies and winds in the northern Gulf of Mexico force the transfer of material both onto and off the continental shelf south of Louisiana and Mississippi. At the surface, offshore transport is enhanced by northerly and northwesterly winds associated with the passage of winter storms and in summer by westerly winds, both of which serve to reverse the westward longshore coastal current and initiate across-shelf and off-shelf flow. The Mississippi and Atchafalaya Rivers produce plumes of low salinity, highly turbid water that are easily driven by wind due to their buoyancy. The Mississippi River plume enters the Gulf in relatively deep water and thus is more prone to advection by slope eddies, both cyclonic and anticyclonic. Maximum seaward fluxes have been shown to occur in the interaction zone between these counter-rotating eddies. The presence of anticyclonic eddies, some of which separate from the Loop Current, cause a reversed offshore salinity gradient and enhanced nutrient and chlorophyll a concentrations at the shelf break east of the Mississippi delta. The increased chlorophyll concentrations have been detected in satellite imagery and at times have been tracked to the Florida Strait. Cyclonic shear-edge eddies and cyclones occur along the outer margin of the Loop Current, also as detached eddies along the shelf/slope edge. On the northern Gulf shelf east of the Mississippi delta the De Soto Canyon (near 29N, 87W) seems to be a focus for cyclonic circulation, which results in the uplift of nutrient-rich subsurface water to within a few meters of the surface. Hydrographic data suggest that much of the nutrient standing stock in the 15-60m depth range east of the delta results from upwelling events, particularly in summer. Despite the extent of the surface plumes, there is also a considerable transport of material off the shelf through bottom transport in mud plumes off both the Mississippi and Atchafalaya rivers. Transport in both directions across the shelf edge may be increased by either interaction between cyclonic and anticyclonic eddies or by hurricanes. Hurricane Ivan in summer 2004 intensified cyclonic circulation and provided a boost to upwelling in the De Soto Canyon region.

I T A L Y

Keywords: plumes, eddies, upwelling



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Oral Presentation

5982

Intrusion of the Kuroshio Intermediate Water onto the continental shelf of the East China Sea

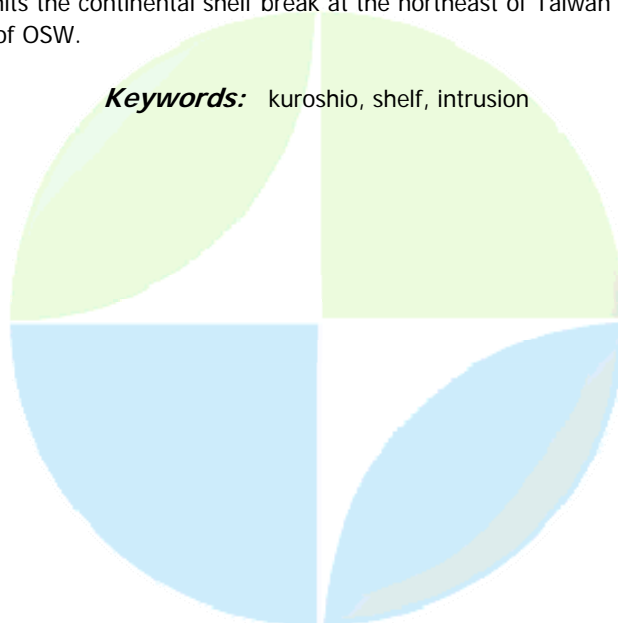
Prof. Takeshi Matsuno

Research Institute for Applied Mechanics Kyushu University IAPSO

Joon-Soo Lee, Shigefumi Yanao

The East China Sea is located in the western boundary of the North Pacific and has a wide continental shelf along with a trough surrounded by the shelf and Ryukyu Islands. A predominant western boundary current, the Kuroshio, flows along the continental slope. Interaction between the Kuroshio and the shelf water may control the biochemical environments of the shelf region. The continental shelf is well known as an area with high biological production resulting in abundant biological resources. It is considered that nutrients required for the primary production would come from rivers of the continent of . On the other hand, it is reported that input of nutrients from the open sea could be the same order as that from rivers. Since the estimation was made with a box model, it is not well known how the nutrients would be introduced into the shelf area from the open ocean. In this study we examine the behavior of the Kuroshio intermediate water(KIW) which could intrude into the continental shelf. When the Kuroshio flows into the East China Sea at east of Taiwan, a part of the volume transport intrudes into the continental shelf. While most of the intruded water would turn back to the Kuroshio and flow along the continental slope, a part of the water would be transported onto the continental shelf, particularly in summer. Numerical experiments suggest the seasonal variations in the intrusion of KIW. The KIW could be transported far onto the shelf area, while the surface water of the Kuroshio is blocked by Taiwan Warm Current intensified in summer. In winter, the Kuroshio water mostly flows along the continental slope without any intrusion caused by vertically well mixed structure in the shelf area. It is suggested that the bottom water with high salinity and high nutrients on the shelf could be supplied from KIW in summer. On the other hand, a detailed water mass analysis using historical data revealed that well characterized water mass is formed in the outer shelf region. The water mass, Outer Shelf Water(OSW), has values of salinity and dissolved oxygen slightly less than those of the pure Kuroshio water over a significant range of water temperature. The area covered with OSW is rather wide. It is an evidence for the contribution of KIW to form the bottom water of the shelf area. Diapycnal mixing processes when KIW hits the continental shelf break at the northeast of Taiwan could play an important role on the formation of OSW.

Keywords: kuroshio, shelf, intrusion



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PS007

Oral Presentation

5983

**Simulating the carbon cycle in a high latitude shelf sea (North Sea) -
evidence for decoupled carbon and nutrient cycles**

Mrs. Friederike Prowe

Department of Oceanography Dalhousie University

***Helmuth Thomas, Johannes Ptsch, Wilfried Khn, Yann Bozec, Laure-Sophie
Schiettecatte, Alberto V. Borges***

For the first time, the carbon budget of the North Sea, a Northwest European shelf sea, has been assessed using a three-dimensional coupled biogeochemical model resolving the carbon cycle. Simulations for the years 2001/2002 are thoroughly validated against high resolution field data sets from the same period. The results indicate that the North Sea acts as a significant sink for atmospheric CO₂. The uptake of CO₂ is balanced by an export of carbon into the deep waters of the North Atlantic, confirming observations suggesting the efficient removal of CO₂ from the atmosphere via the continental shelf pump mechanism. The simulated net community production (NCP) and net primary production (NPP) reveal the biological controls of this transport: despite the higher NPP in the southern North Sea, NCP, i.e. net carbon fixation, and the NCP/NPP ratio are small because of high remineralization of organic matter in the continuously mixed water column. In contrast, in the surface layers of the northern North Sea, NCP, net carbon fixation and the NCP/NPP ratio are high because of the high export of organic matter into the deeper layer of the seasonally stratified system, preventing organic matter remineralization in the surface layer. The implementation of overflow production releasing semi-labile dissolved organic carbon under nutrient limited conditions enables the model to reproduce the observed pCO₂ and DIC drawdown during summer. This decoupling of carbon fixation from the control of nutrient uptake via a fixed C/N ratio is essential for a realistic simulation of the magnitude of the air-sea flux of CO₂, and thus the carbon cycle of the North Sea.

Keywords: continental shelf pump, net community production, co₂



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Oral Presentation

5984

Nitrogen budget on the continental shelf off the west coast of Western Australia

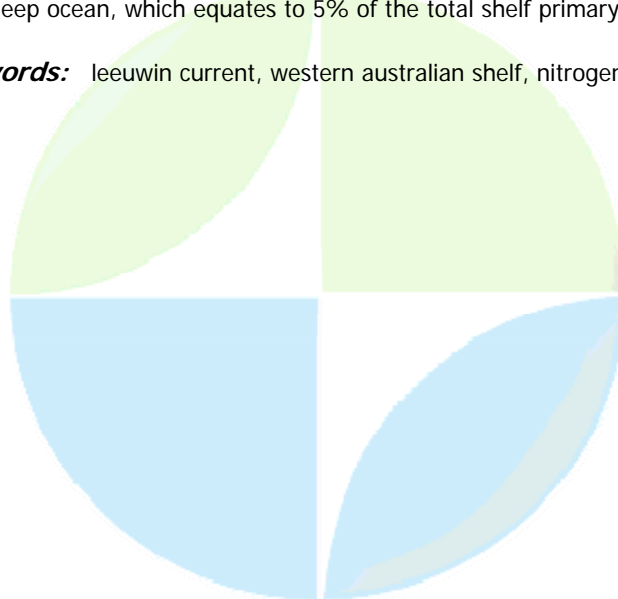
Dr. Ming Feng

CSIRO Marine & Atmospheric Research

Karen Wild-Allen

The continental shelf between North West Cape and Cape Leeuwin off the west coast of WA is on an average of 66 km wide at the 200 m isobath. Due to the influence of the poleward flowing LC, the shelf and offshore waters off the WA coast are oligotrophic in nature and the water column primary production is generally low. In the LC off the southwest WA coast, autumn-winter phytoplankton blooms are observed from satellite and in-situ measurements, likely due to nutrient injections by enhanced horizontal advection of the LC and vertical mixing, while enhanced summer production is observed off the North West Cape to Shark Bay due to upwelling favourable winds which episodically overcome the large-scale pressure gradient. The total nitrogen requirement for the primary production on the continental shelf off west coast of WA is estimated to be 14.8 gN m⁻²y⁻¹ in the water column and 2.0 gN m⁻²y⁻¹ in the benthic community, which equates to a total primary production of 111.3 gC m⁻²y⁻¹, or 1.1107 ton C y⁻¹. To support the annual production on the continental shelf off the west coast of WA, new nitrogen is derived from advection by the LC and its eddy field (8%), and seasonal upwelling (7%) from very preliminary estimations. Terrestrial and atmospheric contribution of nitrogen to the shelf accounts for less than 1% of the primary production. Although the direct offshore nutrient inputs may be small, they may still be important in driving the annual cycles in the marine ecosystem on the shelf. It is estimated that 84 % of the primary production is recycled on the shelf. Thus, even considering the uncertainties in the offshore input estimates, the continental shelf off the west coast of WA is primarily a recycling system, more typical of wider shelf regions. Improved quantification of benthic-pelagic coupling on the shelf will lead to a better understanding of the marine ecosystem. Of the total primary production, 7% is estimated to be exported offshore by the LC advection, Ekman transport, and eddy-driven offshore fluxes. This could be an underestimate. The upper limit of the offshore transport could be assumed to balance the onshore nitrogen fluxes (15% of the total production), which equates to a carbon flux of 17.2 gC m⁻²y⁻¹, or 1.7106 ton C y⁻¹ integrated over the whole shelf. Assuming an export flux of 30%, then 5.2 gC m⁻²y⁻¹, or 5.1105 ton C y⁻¹ integrated over the whole shelf, is transported from the shelf to the deep ocean, which equates to 5% of the total shelf primary production.

Keywords: leeuwin current, western australian shelf, nitrogen budget



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Oral Presentation

5985

Eddy-driven offshore transport of organic matter in the California current system

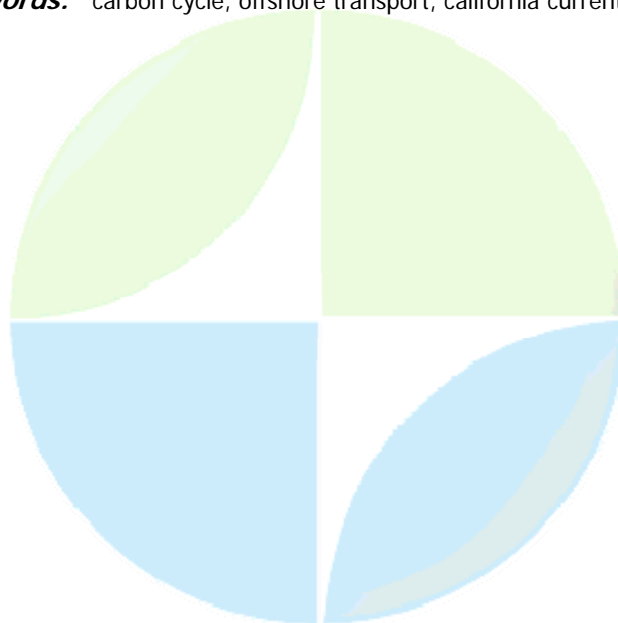
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Observations and recent high-resolution numerical studies of eastern boundary current systems have suggested that meso- and submeso-scale features, such as filaments, jets, and eddies are a primary determinant of biogeochemical balances. However, the role of these abundant features for the transport of biogeochemical properties from the productive nearshore environment typical of eastern boundary current systems into the relatively unproductive offshore regions has not been quantified well so far. In this study, we investigate the fluxes of carbon and associated nutrient elements in one of these eastern boundary current systems, i.e. the California Current System (CCS), using a high-resolution (5 km) coupled physical-biogeochemical numerical model with special emphasis on the quantification of the offshore transport and the mechanisms determining it. The model we employ is the Regional Ocean Modeling System (ROMS), which has been augmented with a Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) model and a full description of carbon biogeochemistry. A Reynolds decomposition analysis of the model simulated lateral fluxes over a 5-year period reveals that eddies and other mesoscale processes rather than Ekman-driven flow dominate the offshore transport of organic matter in the CCS. In the nearshore region (out to about 200 km), most of the transport occurs within narrow filaments that move recently upwelled waters, rich in both inorganic and organic constituents, past the shelf-break. Subduction of surface tracers is observed at the edge of these filaments, where strong confluent flows exist. The filaments of upwelled water, still relatively rich in nutrients and organic matter, are finally trapped into primarily cyclonic eddies, which then travel westward as Rossby waves, thus promoting continued offshore transport of organic matter up to about 800 km from the coast. Along their journey, further production of organic matter fueled by the trapped nutrients enhances the overall impact of these propagating eddies. We estimate that 60 to 70% of the total offshore transport of organic matter in the 200-800 km range is caused by these westward propagating eddies.

Keywords: carbon cycle, offshore transport, california current system



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PS007

Oral Presentation

5986

Shelf Seas - the link between land and ocean

Prof. Helmuth Thomas
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Biogeochemical cycles in shelf seas are influenced by pressures from land, the open ocean and the atmosphere. This mediator role will be discussed using examples from the North Sea, a NW European self sea, with particular consideration of carbon and nutrient fluxes.

Keywords: continental shelf pump, north sea, carbon and nutrient fluxes



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PS007

Poster presentation

5987

Frequency of the Kuroshio overflow on the continental shelf northeast of Taiwan as seen by along-track altimetry and HF radar data

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Daisuke Ambe, Ryoko Tokeshi

The strong western boundary current of the North Pacific, the Kuroshio, flows along the continental shelf edge in the East China Sea. Its meanders sometimes cause overflow on the continental shelf, possibly resulting in large inflow of nutrient-rich Kuroshio deep water onto the shelf. In this study, frequency of the Kuroshio overflow on the continental shelf is examined using along-track satellite altimetry data and long-range High Frequency (HF) ocean radar data northeast of . Cause of the Kuroshio variability there is also studied by use of wide data coverage of the altimetry data. Combining surface drifter data with along-track altimetry temporal anomaly data, the temporal mean geostrophic velocity component normal to the tracks is determined. The mean geostrophic velocity northeast of along a TOPEX/Poseidon and Jason-1 track clearly reveals existence of eastward Taiwan Warm Current and the eastward Kuroshio Branch Current (KBC) flowing on the shelf shallower than 200m. The KBC is found intensively vary with periods of a few months, accompanied by the Kuroshio axis movement to the south. The KBC tends to be strengthened when the Kuroshio moves southward to the north of Yonaguni Island to be away from the continental shelf. HF radars operating on Yonaguni and Ishigaki islands confirm the movement of the Kuroshio axis observed by the along-track altimetry data. The HF data and altimetry data suggest that the movement of the Kuroshio axis is induced by westward-propagating mesoscale eddies approaching to the Kuroshio east of Taiwan.

Keywords: kuroshio overflow, altimetry, hf radar



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PS007

Poster presentation

5988

Dissolved inorganic carbon dynamics in the Gulf of Biscay (June 2006)

Mrs. Kim Suykens

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Bruno Delille, V. Borges

The biogeochemical properties of an extensive bloom of the coccolithophore, *Emiliana huxleyi*, at the shelf break in the northern Gulf of Biscay was investigated in June 2006. Total Alkalinity (TA) values in the water column showed strong non-conservative behaviour indicative of the impact of calcification, with the highest TA anomalies (up to 26 $\mu\text{mol kg}^{-1}$) in the high reflectance coccolith patch. Partial pressure of CO_2 ($p\text{CO}_2$) values ranged from 250 to 338 μatm and the area was found to act as a sink for atmospheric CO_2 . Overall, $p\text{CO}_2@13^\circ\text{C}$ ($p\text{CO}_2$ normalized at a constant temperature of 13°C) in the water column was negatively related to TA anomalies in agreement with an overall production of CO_2 related to calcification. Hence, the calcifying phase of the *E.huxleyi* bloom decreased the sink of atmospheric $p\text{CO}_2$, but did not reverse the direction of the flux. Rates of pelagic respiration up to 5.5 $\text{mmol O}_2 \text{ m}^{-3} \text{ d}^{-1}$ suggested a close coupling between primary production and respiration and/or between organic carbon content and respiration. Benthic respiration rates were quite low and varied between 2 and 9 $\text{mmol O}_2 \text{ m}^{-3} \text{ d}^{-1}$, in agreement with the fact that the study area consists of sandy sediments with low organic matter content. Benthic respiration was well correlated to the chlorophyll a content of the top 1 cm of the sediment cores. Evidence was found for dissolution of CaCO_3 due to the acidification of superficial sediments in relation to the production of CO_2 and the oxidation of H_2S in the oxic layers.

Keywords: inorganic carbon, gulf biscay



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PS008

5989 - 6023

Symposium
Processes in Oceanic Fronts

Convener : Dr. Igor Belkin

Oceanic fronts are regions of enhanced dynamic physical and biological activity characterized by large exchange of momentum and water mass properties. They are areas of enhanced biological activity, forming distinct biogeographic provinces. Processes that control the dynamics of oceanic fronts range from the microscale (double-diffusion, density compensation, etc.) to global scales (air-sea interaction, climate zones, etc.). Oceanic fronts can be permanent or transient features exhibiting either a pronounced horizontal gradient extending to over 1000 m in depth or occurring seasonally. Fronts are further characterized as regions of high mesoscale variability. This symposium will cover all aspects of oceanic fronts, from fronts on the continental shelf to fronts of global dimensions. It will review the existing observation base and focus on processes of frontogenesis, frontal stability, and frontal decay. The role of fronts as water mass boundaries and their influence on marine life is expected to be an important aspect of the session. Presentations are sought on fronts in European seas, particularly tidal mixing fronts; salinity fronts of regions of freshwater influence (ROFI); fronts of the Mediterranean, Black, Baltic, North, Barents, and Nordic Seas; and on biological aspects of fronts including harmful algal blooms at fronts.

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PS008

Oral Presentation

5989

Evolution of solitary marginal disturbances in baroclinic frontal geostrophic currents with dissipation and time-varying background flow

Prof. Gordon Swaters

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The finite amplitude evolution of solitary disturbances in baroclinic frontal geostrophic dynamics in the presence of time-varying background flow and dissipation is shown to be governed by a 2-equation extension of the unstable nonlinear Schrodinger (UNS) equation with variable coefficients and forcing. The soliton solution of the unperturbed UNS equation corresponds to a saturated isolated coherent anomaly in the baroclinic instability of surface intensified oceanographic fronts and currents. The adiabatic evolution of the propagating soliton and the uniformly valid first-order perturbation fields are determined when both dissipation and time-variability are present. It is shown that the soliton amplitude parameter decays exponentially due to the presence of the dissipation but is unaffected by the time variability in the background flow. On the other hand, the soliton translation velocity is unaffected by the dissipation and evolves only in response to the time variability in the background flow.

Keywords: frontal geostrophic dynamics, dissipation, instability



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Oral Presentation

5990

ADCP Current data analysis in the Rio de La Plata salinity front: variability from tidal to synoptic time scales

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CIMACONICET-UBA Centro de Investigaciones del Mar y la Atmsfera IAPSO

Virna Loana Meccia, Walter Dragani, Raul Guerrero, Mario Nstor Nuez

The first ADCP current data collected at two locations of the Ro de la Plata salinity front during a period of around 6 month and salinity profiles gathered at and around those locations are used to study the vertical structure of currents response to wind variability in the tidal to synoptic time scales and its implications on stratification. Data shows that even though tides were though to dominate the system dynamics, they only account for 25% of the variance. Baroclinic currents provide the first evidence of the occurrence of internal waves, which can account for another 25% of the total variance. In the northernmost location, predominantly zonal oscillations with semidiurnal period, and oscillations with a dominant meridional component and diurnal period are found. Whereas the first ones can be related to the semidiurnal tide, the second ones seem to be atmospherically forced by the land/sea breeze. In the southernmost location, more rotational oscillations are observed, with periods around the inertial and diurnal ones. Inertial oscillations could result of wind relaxation, whereas diurnal oscillations also seem to be forced by breeze. Wave activity in the diurnal band was less frequent in the northernmost than in the southernmost location. This can be attributed to less frequent favorable stratification conditions in that area during the observed period. Wave activity in the southernmost location resulted weaker during the observed fall than during the summer. This could be a typical feature given that in autumn both, the number of storms destroying the thermohaline structure increases, and land/sea breeze is less frequent. This suggests a likely seasonal cycle in the diurnal wave activity in this area, given that those unfavorable conditions are even more marked during winter. In larger time scales, results indicate that the estuary rapidly responds to prevailing southwesterlies/northeasterlies with currents that decay towards the bottom with only little rotation in depth. For the less frequent southeasterlies/northwesterlies the estuary develops a strong vertical structure with a defined inversion in current direction between surface and bottom layers. These patterns derive from estuaries geometry and bathymetry. Results have important implications on the salinity vertical structure that are verified on the analyzed profiles. Firstly, the combination of the bathymetry and coastline with the prevailing wind variability is highly favorable to the maintenance of a salt wedge structure in this estuary. Secondly, weakening and eventually breakdown of stratification can only occur for intense and/or persistent southeasterly winds, which even can be very strong, are not frequent. This can explain why the Ro de la Plata displays the unusual feature of being an area of spawning and nursery for a number of coastal species that use the wedge as an essential element for their reproduction. Results show that stratification is highly affected by short term wind variability -which is its major characteristic in the area- changing the classical concept of summer-winter seasonality as the main feature of estuarine wind forced variability.

Keywords: riodelaplata, internalwaves, synopticvariability

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Oral Presentation

5991

Structural features of the mixing zone between river and sea waters near the Amur River mouth

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Physical Oceanography scientist IAPSO

Vyacheslav Dubina, Luiza Propp, Pavel Tishchenko

The Amur River is the world's eighth longest river with an average discharge of 9800 m³/s. The combined use of ocean color data, infrared images, synthetic aperture radar images and hydrographic (CTD)/ hydrochemical measurements permits observation of spatial structure of the Amur River discharge into the Okhotsk Sea. The structural changes were strongly pronounced between the northwestern and southeastern portions of the Amur River Estuary. A front divided the low salinity water related with Amur River discharge and the relative high salinity vertically mixed water of the southern part of the Amur River Estuary. The satellite images show that most of the water discharged by the Amur River flows to the north. During spring-summer flood the jet like outflow from the estuary to form anticyclonic circulation and associated frontal structure in the Sakhalin Bay of the Okhotsk Sea. The Amur River plume is located in the eastern part of the Sakhalin Bay. The freshening of the upper layer with thickness up to 20 m is detected. The plume is bounded on offshore side by a distinct plume front. Although nutrients concentrations are lower in the Amur River plume than in the surface water of the Okhotsk shelf due to the photosynthesis, the bottom nutrients under plume are greatest as a result of the mineralization. In the whole of Sakhalin Bay upper layer is oversaturated with respect to the dissolved oxygen and it is undersaturated with carbon dioxide owing to the photosynthesis.

Keywords: front, plume, amur



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Oral Presentation

5992

Evolution of air-sea interaction parameters during the temperature front passage: the measurements on an oceanographic platform

Mrs. Natalia Komarova

Earth Remote Sensing Space Research Institute

Goryachkin Yury N., Pospelov Michael N., Repina Irina A.

The results of the experiment CAPMOS05 performed on an offshore oceanographic platform in the Black Sea in June 2005 are presented. The experiment aimed on investigations of air-sea interaction by means of direct and remote measurements was carried out in framework of the INTAS project "Combined Active / Passive Microwave Measurements of Wind Waves for Global Ocean Salinity Monitoring (CAPMOS)". The project united experienced research teams from Russia, Ukraine and Italy. A specialized research platform managed by the Marine Hydrophysical Institute provided a unique opportunity of long-term measurements of sea and atmosphere parameters using remote and contact sensors. The following instrumentation was used: radio-interferometer for precise measurements of water surface; Ku-band scatterometer (polarizations VV, HH or cross); L-band radiometer; S-band radiometer (V-pol.); K-band radiometer (3 Stokes parameters); Ka-band radiometer (3 Stokes parameters); W-band radiometer (V- and H-pol.); IR-radiometer (8-12 mkm); optical digital camera; three 3-component sonic anemometers; air pressure and humidity sensors; three air temperature sensors; water vapor and carbon dioxide sensor; 6-strings wave gauge; two CTDs; five current meters; water turbulence sensor. The measurements on a platform were carried during June, 1-20 round a clock. A detailed study of upwelling on June 11-12 is presented. During this event water temperature dropped by 14 degrees, from 22 to 8 C, whereas the salinity increased by 1 psu. Maximal temperature decrease reached 2.5 degrees per hour. Direct measurements of a sensible heat flux across the air-sea interface demonstrated changing of the sea-atmosphere interaction regime in the course of upwelling development. CTD sections illustrated the evolution of upwelling and intensive mixing from surface to bottom. Spatial structure and temporal evolution of this phenomenon was also traced by the NOAA satellite. The study was supported by INTAS Grant 03-51-4789 and RFBR Grant 05-05-64451.

Keywords: air sea interaction, front



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Oral Presentation

5993

Restratification at ocean fronts

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The ocean surface mixed layer is regularly remixed by convective and wind events. Between these events, surface heating and dynamical processes that slump horizontal density gradients restratify the layer. Subsequent mixing events depend critically on the amount of restratification that has occurred. Processes such as deep convection, mode water formation, phytoplankton biology, and air-sea chemical and heat exchange are thus sensitive to the restratification. An important class of processes involved in dynamical restratification include submesoscale instabilities that develop along fronts formed by the mesoscale straining field. These frontal submesoscale instabilities develop along fronts on time scales of the order of a day and rapidly restratify the upper ocean by slumping fronts. Presently theories and models of the upper ocean ignore these instabilities. I will demonstrate the importance of submesoscale frontal instabilities in altering the ocean surface boundary layer properties, and in the surface boundary conditions for the whole ocean circulation. The restratification of the surface layer will be addressed in particular, and a parameterization of the effects of these eddies during restratification will be introduced. Numerical simulations resolving and parameterizing the restratification in prototypical ocean conditions will be contrasted. The climate sensitivity of these parameterizations in global ocean models will be discussed.

Keywords: restratification, mixed layer, front

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Oral Presentation

5994

The upwelling of downwelling currents

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Elbio D. Palma

The term downwelling currents refers to currents with a downslope mass flux in the bottom boundary layer. Examples are the Malvinas and Southland Currents in the southern hemisphere and the Oyashio in the northern hemisphere. Paradoxically many downwelling currents generate the same kind of highly productive ecosystems usually associated with upwelling regimes. These highly productive areas are caused by the upwelling of nutrient-rich waters, but the mechanism that may drive such upwelling are unclear. In this presentation we postulate that the interaction between a downwelling current and the continental slope generates shelfbreak upwelling. The proposed mechanism is relatively simple. As a downwelling current flows along the continental slope bottom friction and lateral diffusion spread it onto the neighboring shelf, thus generating alongshelf pressure gradients and a cross-shelf circulation pattern that leads to shelfbreak upwelling. To prove this hypothesis we present the results of a series of process-oriented numerical experiments using a 3-D primitive equation model.

Keywords: upwelling, shelfbreak fronts, models

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Oral Presentation

5995

On the significance of mid-latitude oceanic frontal zones in the mean state and dominant variability of the tropospheric circulation

Dr. Hisashi Nakamura

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Takeaki Sampe, Atsushi Goto, Daisuke Hotta, Wataru Ohfuchi, Shang-Ping Xie

Significance of mid-latitude oceanic frontal zones on the extra-tropical tropospheric circulation is discussed with particular emphasis on their close association with storm tracks and westerly polar-front jets. Along a near-surface baroclinic zone that tends to be anchored around a frontal zone, storm track activity is enhanced within a well-defined polar-front jet with modest core velocity. This eddy-driven jet exhibits a deep structure with the strong surface westerlies maintained mainly through poleward eddy heat fluxes. The westerly wind stress exerted along the frontal zone acts to maintain it by driving the oceanic current system, suggestive of a feedback loop via mid-latitude atmosphere-ocean interaction. In the storm track core over the South Indian Ocean, their association is so robust that it can be observed even in austral winter when a subtropical jet intensifies, and thus marked as the region of the maximum westerly momentum input into the ocean. Our "aqua-planet experiments" with an AGCM demonstrate the significance of a mid-latitude oceanic frontal zone in the tropospheric general circulation, via anchoring a storm track and the surface westerlies. Here, an important concept is what may be called "oceanic baroclinic adjustment". Although the large heat capacity of the ocean mixed layer acts to damp thermal fluctuations associated with individual cyclones and anticyclones, the presence of sharp cross-frontal SST gradient causes a sharp meridional contrast in heat release into the atmosphere, acting against the relaxing effect of eddy heat fluxes to maintain the near-surface atmospheric baroclinicity. In a sensitivity experiments where the frontal SST gradient in mid-latitudes is artificially eliminated, the storm-track activity weakens substantially and so does the westerly polar-front jet, resulting in the equatorward shift of the entire circulation system. Associated influence of the oceanic frontal zone on the annular variability is also discussed.

Keywords: storm track, polar front jet, baroclinicity



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PS008

Oral Presentation

5996

Mesoscale variability of the Adriatic Sea and its response to strong wind events

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Simulations of the Adriatic Sea using the DieCAST model applied on a 1.2-min grid (about 2-km resolution) are presented. The simulations resolve the mesoscale variability because the grid size falls below the first baroclinic deformation radius (about 5-10 km) and DieCAST has very low horizontal dissipation. The model is initialized with seasonally averaged temperature and salinity data and forced with climatological winds and surface buoyancy fluxes (both heat flux and evaporation minus precipitation). River discharges are varied daily according to a perpetual year for every river, and the open-boundary conditions at Otranto Strait are obtained by nesting in two larger-scale models. The present simulations demonstrate that the DieCAST model allows mesoscale instabilities to develop at length scales of 5-20 km and over time scales of a few days. The simulated variability exhibits pronounced similarities with the actual mesoscale variability, in terms of location, nature and temporal evolution of fronts and other mesoscale features. Meanders, swirls and eddies are noted along the relatively smooth Italian coast while offshore jets and filaments better describe the mesoscale activity along the more rugged coast of Croatia. The present simulations also show that the seasonal hydrography of the Adriatic Sea is intrinsically unstable to mesoscale perturbations, and that the mesoscale variability along the Italian coast is the result of baroclinic instability of the Western Adriatic Current. It is shown how the properties of this instability are related to the local bottom topography. The Adriatic Sea response to strong wind events was investigated for a summer event of bora (11-20 August 2001), when the water is stratified, and the other one chosen for winter (11-22 February 2003), when the water is vertically homogeneous. The summer of August 2001 event leads to the generation of a coastal current directed paradoxically to the left of the wind and identified with the summertime Istrian Coastal Counter current (ICCC). Analysis of the physics simulated by the model leads to the conclusion that this current is caused by baroclinic geostrophic adjustment of the Istrian coastal waters following a rapid but strong wind impulse. According to both satellite observations and model simulations, the current persists for more than a week after the bora event. The winter event of February 2003 generates a slightly less complicated situation because the shallow northern Adriatic is then vertically homogeneous, but in-situ observations at the time of this particular event permit a comparison of model results with observations and thus an evaluation of the model performance. In particular, the model simulates correctly a series of current, bifurcations and confluences of the wind-driven currents across the northern Adriatic basin.

Keywords: mesoscale structures, adriatic sea, numerical simulations

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Oral Presentation

5997

Coastal water dynamics in the eastern English channel and its impact on the transport and assemblages of the vertically migrating larvae

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Alexei Sentchev

Effects of tides, turbulence and freshwater buoyancy input on the marine organisms transport and assemblage in the eastern English Channel are studied. A 3-D circulation model coupled with a particle-tracking module is used to simulate the migration of fish eggs and larvae under realistic forcing conditions. Results of modeling are compared with observed concentrations of Flounder (*P. flesus*) larvae. Numerical experiments are performed with passive and active particles, representing sea-water organisms. Passive particles are neutrally buoyant whereas active particles are able to exercise light dependent and tidally cued vertical migrations equating to the swimming behavior of the larvae. The experiments reveal that the strongest accumulation of particles occurs along the French coast on the seaward margin of the Region of Freshwater Influence (ROFI). Tides and freshwater input induce net alongshore horizontal transport toward the North. Tidal currents modulate the magnitude of horizontal transport whereas the freshwater input controls more the location of accumulation zones. The experiments with active particles indicate that the vertical migration leads to a significant departure from the passive particle transport pattern. Differences lie in the shape of the particle transport pattern and the rate of the migration. The model predicts and explains larvae drift routes, zones of larvae accumulation, and demonstrates that throughout the entire particle-tracking period the horizontal structure of the particle distribution is consistent with the larvae concentrations observed during the field experiments.

Keywords: rofi, mesoscale fronts, larvae transport



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Oral Presentation

5998

Validation of a high-resolution ocean shelf model using automated front detection

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Jason Holt

Techniques have been developed for increasing the value of cloud-affected sequences of Advanced Very High Resolution Radiometer (AVHRR) sea-surface temperature data and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectroradiometer (MODIS) ocean colour data for visualising dynamic physical and biological oceanic processes such as fronts and eddies. The composite front map approach is to combine the location, strength and persistence of all fronts observed over several days into a single map, which allows intuitive interpretation of mesoscale structures (Miller, 2004, in press). This method achieves a synoptic view without blurring dynamic features, an inherent problem with conventional time-averaging compositing methods. This paper explores how composite front maps may be equally applied to surface maps simulated by a high-resolution (2 km) 3-D hydrodynamic model. Visual and quantitative comparison of frontal locations in EO and modelled data are presented for the North Sea. This enables validation and improvement of parameters of the ocean model in terms of physical structures, which would not be possible using standard pointwise comparison of model simulations against EO or in situ data. This method also enables mesoscale indices to be derived from model hindcasts in an analogous manner to EO data. A variety of quantitative validation methods are explored based on both (1) extraction and comparison of individual front contours, and (2) local regional comparison of frontal properties. Miller, P.I., Multispectral front maps for automatic detection of ocean colour features from SeaWiFS, *International Journal of Remote Sensing*, 25 (7-8), 1437-1442, 2004. Miller, P.I., Composite front maps for improved visibility of dynamic sea-surface features on cloudy SeaWiFS and AVHRR data, *Journal of Marine Systems*, in press.

Keywords: ocean fronts, front detection, model validation



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Oral Presentation

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Statistical Modelling of New Zealand's Southland Front From Space

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Mr Peter Challenor, Dr Andrew Shaw

The Southland Front is a localised section of the global southern Subtropical Front that runs along the southeast coast of South Island, New Zealand. It is the boundary between warmer subtropical water in the north and colder subantarctic water from the south. It is associated with strong physical and nutrient gradients which lead to enhanced biological productivity. In this paper we discuss a new method to determine the position and gradient (i.e. strength) of a thermal ocean front. A weighted local likelihood estimation technique in which estimates of frontal parameters (position and strength) are based upon weighted contributions from surrounding points is described. We use this new technique to study the characteristics of the Southland Front and the variation in its properties over the period 1985-2005 from AVHRR imagery. We find the mean path of the Southland Front to be bounded by the 500m isobath and observe a gradual increase in meandering intensity northwards along its path. Its mean width increases from 17 to 30 km and its thermal gradient decreases from 0.22 to 0.13 C/km as it flows northwards from Otago Peninsula towards the Chatham Rise. These trends are maintained throughout the seasons, with the exception of winter, where a constant width and gradient of 20 km and 0.17 C/km respectively are observed along the length of the front. Spectral analysis of the 21 year time series reveals evidence for possible links with the El Niño Southern Oscillation.

Keywords: front, modelling, variability

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Oral Presentation

6000

Inner Shelf Transient Downwelling Fronts: The Effect of Curved Coastline

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Rosario Sanay, George Voulgaris

A series of process-oriented numerical experiments (using ROMS) was conducted in order to delineate the role of curved coastline in the development of downwelling circulation. The model utilized an idealized domain with a concave-shaped bay bounded by capes; a topography which resembles typical conditions on parts of the South Atlantic Bight shelf (Carolinas coast). Both stationary and variable wind stress, as well as various bottom friction settings, were used. The results show that for all experiments the curved coastline leads to the generation of both a velocity and a pycnocline disturbance at the upstream cape, which propagates downstream. This transient disturbance is more pronounced under non-stationary forcing and is best developed after the wind stress peaks. The propagation path differs depending on the relative strength of inertia and bottom friction in the vicinity of the capes. When inertia dominates, the disturbance detaches from the cape and travels downstream along the isobaths. In this case, a strong countercurrent develops near the shore, while the downwelling front lies further offshore compared to a linear coastline and uniform shelf case. When friction is more important than inertia, the disturbance propagates at a lower speed and is located close to the shore (i.e., coastline-arrested disturbance). This results in a significant alongshore temperature gradient and the formation of an almost shore-perpendicular thermal front that moves with the disturbance. The numerical results qualitatively agree with SST satellite imagery and emphasize the role that coastline morphology can play in the formation of synopticscale shelf fronts.

Keywords: downwelling, inner shelf, transien front

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Oral Presentation

6001

Topographically-steered jets at the tip of the Antarctic Peninsula

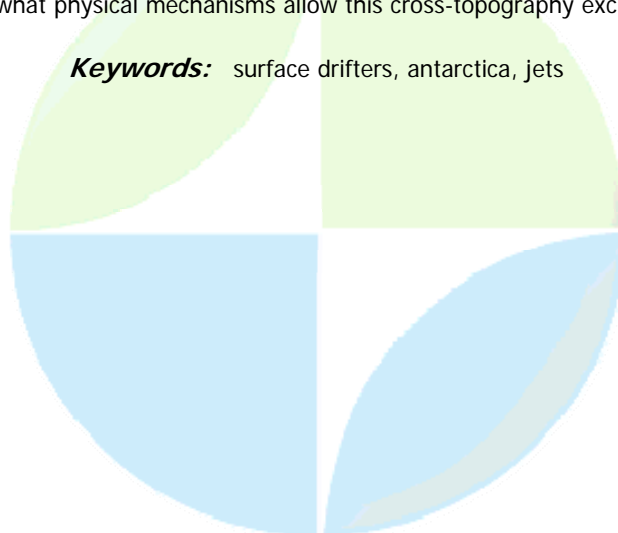
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Karen J. Heywood, Sally E. Thorpe, Angelika Renner, Armando Trasvina Castro

Two distinct features associated with westward flow, the Antarctic Slope Front and the Antarctic Coastal Current, dominate most of the margins of Antarctica. However, the behaviour of these flows near the tip of the Antarctic Peninsula is poorly documented due to their interaction with complicated topography and a scarcity of observational data. Fronts and jets in this region play a crucial role in the retention and/or dispersal of krill larvae spawned on the continental shelf and they may also provide an important link between current systems to the east and west of the Antarctic Peninsula. In February 2007, a transect was conducted across the continental shelf and slope at the tip of the Antarctic Peninsula into the deep Weddell Sea. Along this transect 40 surface drifters, drogued at 15 m depth, were deployed to study the role of topographical forcing on the splitting and steering of the frontal jets. The position of the fronts are initially identified using the hydrographic section data as well as both lowered and shipboard Acoustic Doppler Current Profiler measurements. The fine spacing of the drifters, less than 5 km within the Antarctic Slope Front and less than 10 km elsewhere, indicates that the region is characterised by a banded structure consisting of at least three strong northward currents with velocities exceeding 10 cm/s, separated by regions of weak or eddying flow. The distinction between regions of strong and weak flow is highlighted by dispersion statistics calculated from the drifter paths, as well as the deformation of three drifter triads deployed respectively on the continental shelf, shelf break and slope. Initial results show that the drifters have a remarkable tendency to follow complex topographical features, even where the water column depth is greater than 1000 m. Virtual drifter paths are generated from particle-tracking in the velocity fields of three eddy-resolving numerical ocean-ice models with various resolutions (OCCAM 1/12 degree, TPAC 1/8 degree and ORCA 1/4 degree). These models display a wide range of residence times (time required to reach South Georgia from the Antarctic Peninsula), from as short as five months in TPAC to as long as ten months in OCCAM. A comparison of these virtual paths is made with the historical drifter data, deployed to the north and west of the Antarctic Peninsula, and the new drifter data, south and east of the Peninsula. A comparison is also made between drifter tracks and geostrophic velocity fields derived from satellite altimetry. Together, these results not only provide insight into where krill and other passive tracers are likely to cross topographical features and thus escape into the strong currents of the Antarctic Circumpolar Current, but also into what physical mechanisms allow this cross-topography exchange.

Keywords: surface drifters, antarctica, jets



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PS008

Oral Presentation

6002

Subsurface counter current simulated by an asian Mediterranean Sea model

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Satoshi Nakada, Naoki Hirose, Jong Hwan Yoon

The structure of the counter current beneath the coastal Tsushima Warm Current (TWC) is investigated using an ocean general circulation model. The TWC flows into an Asian Mediterranean, the Japan Sea through the Tsushima Straits. Upper layer of the southern Japan Sea is filled with the warm water transported by the TWC, and the counter current is found in subsurface layer beneath the nearshore branch of the TWC flowing northeastward along the Japan Islands (e.g. Yoon, 1991; Hase et al., 1999). In our model, the counter current appears as nearshore parts of subsurface clockwise eddies from spring to early winter. The simulated speed of the counter currents are several centimeters per second while that of the nearshore branch in the surface layer is a few tens centimeters per second. The vertical structure of the counter current satisfies the thermal wind relationship. The permanent and seasonal pycnoclines form an opposite horizontal density gradient near the Japanese coast in summer. It is remarkable that the second baroclinic mode is dominant in the nearshore parts of the subsurface clockwise eddies in summer that are attributed to the nearshore density structure. A finer horizontal resolution nested model often shows the more energetic counter current than that in the original model. However, the average speed of the counter current in the finer resolution model is slower than that in the original model, while the average barotropic velocity is intensified in the finer resolution model. We considered that the finer resolution model generates stronger baroclinic instability and transfers the internal energy from the counter current to the barotropic velocity as explained by Hogan and Hurlburt (2000).

Keywords: subsurface counter current, tsuhima warm current, japan sea



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Oral Presentation

6003

A trans-Pacific hydrographic section traversing North Pacific Central Mode Water

Dr. Toshio Suga

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Hiroko Saito, Tomowo Watanabe, Masao Fukasawa

A quasi-zonal expendable conductivity-temperature-depth (XCTD) section traversing mid-latitude North Pacific in summer 2001 provides a synoptic picture of Central Mode Water (CMW). Remarkable subsurface pycnostad is captured; its local vertical core becomes lighter to the east from 26.6-26.7 sigma-theta near 40N and 154E to 26.0-26.1 sigma-theta near 35N and 164W, which is consistent with the climatological distribution of deep wintertime mixed layer. This pycnostad fills the gap between the lateral minimum of potential vorticity (Q) corresponding to CMW in the isopycnal climatology and the CMW formation area deduced from the mixed layer climatology, presenting evidence for the direct connection between these two and supporting the idea that they are disconnected by several hundreds kilometer due to over-smoothing. High mesoscale variability at 165E-170W along the section suggests that eddies carry denser CMW to the south, which plausibly explains the CMW spreading across the mean geostrophic streamlines into the inner side of the subtropical gyre. Less remarkable but substantial pycnostad is found east of 160W, which corresponds to the CMW carried by the southward/southeastward gyre flow. The pycnostad is systematically shifted to the east from the climatological isopycnal Q minimum, suggesting that the actual advection path of newest CMW is situated a couple of thousands kilometers to the east from the climatological low Q tongue. It is noted that the westernmost part of the prominent pycnostad at 154-167E is considerably heavier than the canonical CMW (26.0-26.5 sigma-theta), suggesting that the subtropical permanent pycnocline down to 26.6-26.7 sigma-theta is directly ventilated in the open North Pacific.

Keywords: transition zone, water mass formation, subduction



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PS008

Oral Presentation

6004

A new type of pycnostad in the western subtropical-subarctic transition region of the North Pacific: Transition Region Mode Water

Dr. Toshio Suga

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Hiroko Saito, Kimio Hanawa, Tomowo Watanabe

A new type of pycnostad is identified in the western subtropical-subarctic transition region of the North Pacific, based on the intensive hydrographic survey carried out in July, 2002. The potential density, temperature and salinity of the pycnostad were found to be 26.5-26.7 σ_θ , 5-7°C and 33.5-33.9 psu respectively. The pycnostad is denser, colder and fresher compared to those of the North Pacific Central Mode Water and are different from those of other known mode waters in the North Pacific. The thickness of the pycnostad is comparable to that of other mode waters, spreading over an area of at least 650 500 km around 43N and 160E in the western transition region. Hence, we refer to the pycnostad as Transition Region Mode Water (TRMW). Oxygen data, geostrophic current speed and climatology of mixed layer depth in the winter suggest that the TRMW is formed regularly in the deep winter mixed layer near the region where it was observed. Analysis of surface heat flux also supports the idea and suggests that there is significant interannual variability in the property of the TRMW. The TRMW is consistently distributed between the Subarctic Boundary and the Subarctic Front. It is also characterized by a wide T-S range with similar density, which is the characteristic of such a transition region between subtropical and subarctic water masses, which forms a density compensating temperature and salinity front. The frontal nature also tends to cause isopycnal intrusions within the pycnostad of the TRMW.

Keywords: subarctic boundary, subarctic front, water mass formation



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Oral Presentation

6005

Characteristics and variability of the summertime coastal front in the Taiwan Strait

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Using the sea surface temperature and salinity underway measurements and CTD data during several summer cruises in 2004-2006, associated with sea surface temperature and wind remote sensing data and numerical model results, characteristics and variability of summertime coastal front in the Taiwan Strait have been analyzed. It can be concluded that: (1) During the cruise in July-August 2004, the coastal upwelling front appears along the southwestern coast of Taiwan Strait with a small temperature and salinity gradient at the surface layer. Sectional CTD data indicate a low temperature and high salinity water climbing towards the coast. (2) During the cruise in July 2005, low temperature and high salinity water upwells towards surface layer along the southwestern coast of Taiwan Strait. As demonstrated by the temperature and salinity distributions, two low temperature and high salinity centers are located respectively in the east of Dongshan and nearshore of Nan-ao with the sea surface temperature less than 23 °C and sea surface salinity greater than 34.0. But two low temperature and high salinity centers merge into one that moves to the southwest of Nan-ao below 10m layer with the temperature less than 21 °C and salinity greater than 34.5. Therefore, obvious coastal upwelling fronts are observed along the coast. (3) During the cruises in June-July and August 2006, coastal upwelling mainly exists along the coast between Dongshan and Nan-ao. Temperature and salinity gradient thus appears nearby the coastal upwelling. In order to reveal the mechanism and variability of summertime coastal fronts, a three dimensional numerical model is established. Numerical results confirm the observed coastal fronts during the cruises and indicate that the coastal upwelling is induced by the southwesterly winds and the variability of coastal front is greatly related to the local wind conditions. Long time series of sea surface temperature remote sensing data further verify the variability of coastal fronts in the summer seasons of 2004-2006.

Keywords: coastal front, taiwan strait



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Oral Presentation

6006

**Propagation of Temperature-Salinity Anomalies along North Americas
Eastern Seaboard**

Dr. Igor Belkin

Graduate School of Oceanography University of Rhode Island IAPSO

John E. O'Reilly

Satellite and in situ data are used to study TS-anomalies and their propagation along North Americas eastern seaboard. The Shelf-Slope Front appears as a main conduit for these anomalies which originate in the Arctic and propagate southward along the shelf break. For the first time, these anomalies are traced as far south as Cape Hatteras. Decadal-scale cold, fresh anomalies commonly referred to as the Great Salinity Anomalies (GSA) are observed off the U.S. Northeast in 1987-1988, 1996-1997 and 2005. The intervening warm, salty anomalies are less noticeable, except for a distinct warm anomaly in 2000. Thus, the Arctic forcing appears as a dominant factor that causes decadal-scale regime shifts in the Northwest Atlantic Ocean.

Keywords: northwest atlantic, shelf slope front, decadal variability



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Oral Presentation

6007

Fronts in the World Oceans Large Marine Ecosystems

Dr. Igor Belkin

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Kenneth Sherman, Marie-Christine Aquarone

Oceanic fronts shape marine ecosystems; therefore front mapping and characterization is one of the most important applications of frontal oceanography. Here we describe the first effort to map and describe all major fronts in the World Oceans Large Marine Ecosystems (LMEs). Apart from a geographical review, these fronts are classified according to their origin and physical mechanisms that maintain them. This first-ever zero-order pattern of the LME fronts is based on a unique archive of frontal maps objectively derived with the Cayula-Cornillon algorithm from 12 years of daily Pathfinder satellite SST 9-km resolution data. In addition to delineating LMEs, these frontal maps serve as guidance in using hydrographic data to explore subsurface thermohaline fronts, whose surface thermal signatures have been mapped from space. In our presentation we will discuss numerous diverse links between fronts and oceanic ecosystems, particularly the enhanced bio-productivity at fronts and fronts importance as most prolific fisheries grounds.

Keywords: front, large marine ecosystems

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Oral Presentation

6008

**The eddy field of the Polar front in the southern Norwegian Sea from
SeaSoar-CTD and VM-ADCP observations**

Dr. Kjell Arild Orvik

Geophysical Institute University of Bergen IAPSO

Pierre Jaccard

Extensive studies have been carried out in the Iceland-Faroe Front (IFF) over the past decades. This study deals with the dynamics of the extension of the IFF; the Polar Front in the southern Norwegian Sea. The eastward flow of North Atlantic water associated with the IFF bifurcates north of the Faroe Islands where it partly continues into the Norwegian Sea as the western branch of the Norwegian Atlantic Current, and partly turns into the Faroe-Shetland Channel joining the major Atlantic flow toward the Arctic Ocean. This study is based on a series of quasi-synoptic Sea Soar-CTD and ADCP parallel transects across the Polar Front (20- 25 km apart) about 300 km downstream from the bifurcation zone into the Norwegian Sea during 4-11 July, 2002. From the observations, the flow field superimposed on the frontal jet shows a meandering and eddy structure, with cold-core cyclonic eddies and warm-core anti-cyclonic eddies. The most prominent features are the warm-core eddies on the cold side of the front, transporting warm water into the Norwegian Sea. Another striking feature is a nearly 100 km wide anti-cyclone with current speeds up to 100 cm/s in the bifurcation zone northeast of the Faroes. We investigate the meandering eddy field in light of topographic effects, eddy shedding and baroclinic instability.

Keywords: polar front, seasoar adcp, eddies



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Oral Presentation

6009

Modeling of Sharp Frontal Interfaces in the Near-Surface Layer of the Ocean

Prof. Alexander Soloviev

Oceanographic Center Nova Southeastern University IAPSO

Alexander Soloviev

High-resolution measurements in the near-surface layer of the ocean occasionally reveal sharp frontal interfaces. These cases are usually associated with re-stratification of the upper ocean mixed layer (e.g., due to the presence of a barrier layer). The sharp frontal interfaces are presumably related to the subduction process. Strong asymmetry of the horizontal structures associated with the appearance of the sharp frontal interfaces suggests that this is a non-linear process. The analytical solution of this non-linear problem in the framework of the hydrodynamics equations is not feasible. Numerical modeling is complicated by non-hydrostatic conditions in this hydrodynamic system. In this work, a Computational Fluid Dynamics (CFD) technique has been applied for modeling the interaction of sharp frontal interfaces with wind stress (the effect of Stommel's overturning gate). The results of the numeric experiments are discussed in the context of the field data obtained during TOGA COARE and GasEx experiments.

Keywords: fronts, subduction, modeling



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Oral Presentation

6010

Physical and biochemical aspects of the South Equatorial Current in the Indian Ocean

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National Oceanography Centre National Oceanography Centre IAPSO

K. Stansfield, D. Smythe-Wright, D. A. Smeed, A. J. Evans, S. G. Alderson

Results will be presented from a detailed hydrographic survey around the Mascarene Plateau in the Indian Ocean undertaken during June-July 2002. We examine how the westward-flowing South Equatorial Current (SEC), a major front in the Indian Ocean, crosses the Plateau, and how the structure of the flow determines the supply of nutrients to the surface waters. We find that the flow of the SEC across the Plateau is highly dependent on the complex structure of the Banks which make up the Plateau. Furthermore, the SEC forms a sharp boundary between subtropical water masses from further south which are low in nutrients, and waters from further north which are relatively nutrient rich. Overall, the SEC delivers relatively high levels of nutrients to the near-surface waters of the central and northern regions of the survey, as compared with the southern regions of the survey. This is partly due to uplifting of density surfaces through Ekman suction on the northern side of the SEC, and partly due to the higher levels of nutrients on those density surfaces on the northern side of the SEC. This appears to drive increased production of phytoplankton in these areas, which would in turn be expected to fuel increased abundances of zooplankton and higher levels of the food chain.

Keywords: front, water masses, nutrients

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Poster presentation

6011

Tidal mixing fronts in the Okhotsk Sea

Dr. Igor Zhabin

Physical Oceanography scientist IAPSO

Shallow sea tidal mixing fronts produced by tidal stirring. The regions of intensive tidal mixing belong to areas of high biological productivity. Many studies focus on shelf regions subjected to strong tides forcing (Georges Bank, Irish Sea) nevertheless only few work have focused on the Okhotsk Sea tidal mixing fronts. The Okhotsk Sea north/ north-western shelf is a area of strong tidal currents. These currents induce high levels of turbulent dissipation. The location and structure of the tidal mixing fronts, which separated stratified waters and vertically well-mixed waters on the Okhotsk Sea continental shelf during the ice-free period are investigated on the basis of satellite infrared images, historical bottle and CTD measurements. The tidal fronts are located near the Shelikhov Bay and around the Shantar Islands. The oceanographic conditions over the Kashevarova Bank, Iona Bank and around Saint Iona Island are also determined by tidal mixing. Tidal mixing fronts appear in June-July after ice melting when the thermocline is formed, and disappear in the fall when the stratification is destroyed.

Keywords: okhotsk, tidal, fronts

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Poster presentation

6012

Velocity and position variations of the Kuroshio axis south of Japan influenced by mesoscale eddies in the Kuroshio recirculation region

Dr. Hiroki Uehara

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Shoichi Kizu, Yasushi Yoshikawa, Kimio Hanawa

Kuroshio or its Extension is the front that separates the water masses in the recirculation area from the coastal waters south of Japan or from the water masses of the subpolar origin. It has been reported in the previous studies that these water masses are exchanged across the Kuroshio Front, in association with the variations of the Kuroshio path, and that the path changes are related with the variations of the Kuroshio velocity or volume transport. Recent studies that analyzed satellite altimetric height data pointed out that mesoscale eddies coalesce into or collide with the Kuroshio and affect its path variations. In this study, the velocity and temperature section data along the line between Tokyo and Ogasawara (Bonin) Island taken by the ADCP and XBT are analyzed in order to examine the effect of mesoscale eddies on the variations in the position and velocity of the Kuroshio axis (maximum velocity core of the Kuroshio). The ADCP/XBT data show that the Kuroshio small meanders are associated with the increase of its velocity. It is suggested from the satellite altimetric height data that these meanders are triggered by the mesoscale eddies propagating from the east, in particular, by the anticyclonic eddies that revolve clockwise south of Kuroshio with a period of several months.

Keywords: kuroshio, mesoscale eddies



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Poster presentation

6013

Observations of cross-shelf penetrating fronts off the southeast coast of China

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KLOCAWS Physical Oceanography IAPSO

Hui Zhou, Ruixiang Li, Hui Lei, Fan Wang, Dunxin Hu

Nearshore cross-shelf penetrating fronts refer to oceanic fronts of temperature, salinity, and any other oceanographic parameters that have direct and large penetration from their mean positions. The penetrating distance is usually on the order of or larger than 100 km. This kind of phenomenon is first observed off the coast of the South Atlantic Bight by Li et al. (2003). Similar fronts are also observed off the southeast coasts of China by Yuan et al. (2005). The subsurface structure and hydrography of such fronts have never been measured before. On October 16, 2006, a cross-shelf penetrating front off the Hangzhou Bay mouth is observed by the Ke Xue 3 ship of the Institute of Oceanology, Chinese Academy of Sciences. The hydrographic data show that the density structure of the penetrating front is determined primarily by a salinity front produced by offshore excursion of the nearshore fresh water. The subsurface temperature front in this area appears in its mean seasonal position and is offshore of the salinity front. Significant temperature inversion is observed associated with the penetration of the salinity fronts. The penetration represents significant cross-shelf exchange of mass and property, which is traditionally believed difficult to happen. Associated with the salinity fronts, high concentration anomalies of suspended sediment and chlorophyll are also observed to move in the offshore direction. The frequent appearance of such penetrating fronts in the coastal area and off the major river mouths suggests that its dynamics and variability are important to the oceanographic environment of the coastal oceans.

Keywords: cross shelf, penetrating, front



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Poster presentation

6014

Revisit of climatological view of North Pacific Intermediate Water

Dr. Taiyo Kobayashi
IORGC JAMSTEC IAPSO

This study reexamined climatological features of North Pacific Intermediate Water (NPIW) east of Japan defined as the salinity minimum with a composite dataset including numerous Argo data. In the region south of the Kuroshio Extension the salinity minimums with similar properties spread widely in almost all profiles. While in the Mixed Water Region their characteristics vary largely: Fairly less saline NPIW are found along the northern flank of the Kuroshio Extension and near the Oyashio Front. Clear structures of salinity minimum (NPIW) are rarely found in the Oyashio region except for the region southeast Hokkaido, which means that the northern boundary of NPIW corresponds to the Oyashio Front as is shown in the previous studies. NPIW east of Japan has a well-defined salinity-density relationship: NPIW with salinity less than 33.9 is distributed around $26.7 \sigma_\theta$, while saltier NPIW than 34.1 around $26.9 \sigma_\theta$ albeit only the saltier (and denser) salinity minimums in the Kuroshio region. A mode water in the intermediate depth of the Okhotsk Sea (Okhotsk Sea Mode Water, OSMW) has the properties much denser and saltier than the fresher part of NPIW east of Japan; thus it is hardly likelihood that OSMW is the single origin of NPIW there.

Keywords: npiw, mixed water region, okhotsk sea



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Poster presentation

6015

Field investigations of sea surface and atmospheric near-surface layer diurnal dynamics above a depth dumping

Dr. Victor Bakhanov

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Aleksei Ermoshkin, Vasilii Kazakov, Olga Kemarskaya, Vadim Lobanov, Irina Repina, Victor Titov, Emma Zuikova

The variability of the surface wave anomaly characteristics in a shelf area depending on time of day and hydrometeorological conditions was investigated in field experiments in June, - July 2006 in region of city Gelendzhik (Black sea). The experiments were carried out in the interests of development of a bottom topography remote (radar and optical) diagnostics. Experiment area are characterized by abrupt depths dumping (fall 50 - 1250 m), and irregularity of a bank vault (numerous canyons). Such bottom topography at the presence of alongshore current creates conditions appearance of hydrodynamic perturbations on a thermocline and corresponding anomalies on sea surface and in atmospheric surface layer characteristics. The measurements were carried out simultaneously from high coast by means X-band radar, worked in a circular scan mode and registered the radar panoramas of a marine surface, and from the research vessel "Aquanaut" (Institute of Oceanology RAS). The bottom configuration was registered by echo-sounder. The investigation of the hydrological characteristics of the water bulk was realized by combined SVP-CTD probe. It was shown, that the upper intermixed area grows as approaching shallow water. The surface wave characteristics in length range 4 mm - 5 m were measured by X and Ka Doppler radar, two-dimensional optical spectrum analyzer and linear array of CCD sensors. Air temperature, relative humidity, atmospheric pressure, wind velocity and direction were measured. The acoustic anemometer-thermometer for recording pulsations horizontal and vertical components of the wind and temperature in atmospheric surface layer was used. The measurements were accompanied by recording of marine surface characteristics in the given region from the satellite. It was explored, how the features of bottom topography cause variability of surface waves, the dependence of surface wave variation on their length and propagation direction. The change of location of surface wave intensification and weakening areas in a shelf region depending on time of day is detected on marine surface radar panoramas. Surface wave transformation, in turn, gives in variability of mesoscale component of meteorological fields in atmospheric near-surface layer [1, 2]. The streams of heat and impulse above surface wave were determined from direct measurements of temperature, horizontal and vertical wind velocities pulsations [3]. The intensification of an energy exchange and increase of atmospheric turbulence was observed in a front on the continental shelf. This work was supported by the grant RFBR 05-05-64942-a, and Research school program (NSH 6043.2006.2). References: 1. Bakhanov V.V., Repina I.A., Titov V.I., Zuikova E.M. Experimental field investigations of surface waves and atmospheric near-surface layer variability above features of bottom topography.

Keywords: wave, wind, shelf

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PS008

Poster presentation

6016

Structure of zones with high salinity gradient from the point of view of diurnal variations

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FEB RAS POI IAPSO

Horizontal structure of hydrological "river-sea" fronts and vertical structure of continent shelf water are considered by the example of the front in the Razdol'naya River estuary (Peter-the-Great Bay, Sea of Japan) and water off the i. Sakhalin (Sea of Okhotsk). Diurnal salinity distributions in sea part of estuary out of front zone are subordinated to the normal law and corresponding standard deviations s are minimal, as a rule. Within the front zone, exponential growth of s and increase of asymmetry of the minimal and maximal salinity values for day concerning average salinity take place. On the highest horizontal salinity gradients site, s values and the asymmetry reach a maximum and then decrease. In a river part of estuary, s values are minimal and diurnal salinity distributions are normal again. The similar regularities were observed in water off the i.Sakhalin. Standard deviations and asymmetry of the minimal and maximal salinity values for day at 40-130 m water depth below jump of density are minimal. Sharp growth of s and increase of the asymmetry in a layer of density jump, occur. At 5-10 m water depth, s values and the asymmetry reach a maximum and then decrease. The described phenomena peculiar to oceanic fronts, probably.

Keywords: horizontal, structure, front

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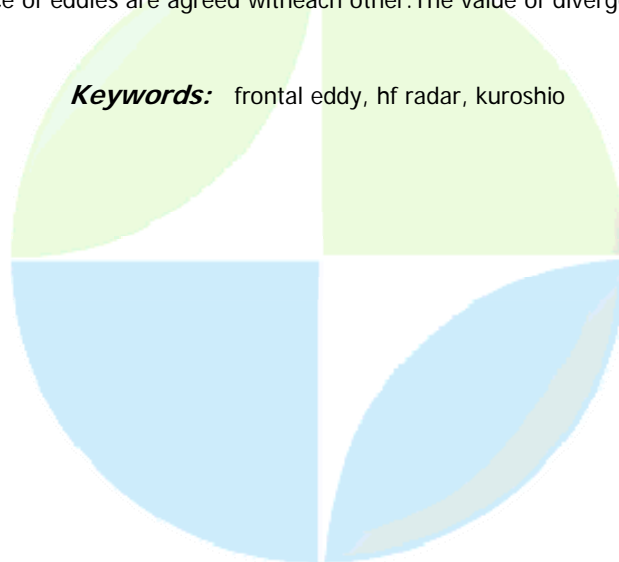
Observation of frontal eddies between the Kuroshio and coastal waters

Mr. Akitsugu Nadai

Applied Electromagnetic Research Center NICT IAPSO

These days, the HF ocean surface radar has been recognized as one of powerful instruments to measure ocean surface currents in wide area with high spatial and temporal resolution. The current measurement by HF ocean surface radar is based on the Bragg resonant backscattering due to ocean wave components, the wavenumber of that are parallel in direction and twice in magnitude of that of radar wave. The Bragg resonant backscattering produces two strong and sharp peaks, called first-order echoes, with Doppler shifts corresponding to the relative phase velocity of the wave components, on Doppler spectra of receiving signal. The difference between measured Doppler velocity from the theoretical phase velocity of ocean wave components agree the Bragg resonant condition becomes the radial component of ocean currents. The spectral shapes of first-order echoes change in time and position. Sometimes the spectral shapes of first-order echoes are extremely broadening and splitting in two around the area with large change of radial velocity due to current phenomena like eddies and velocity fronts. Nadai (2006) simulated the spatial distribution of radar cross-section and the spectral shape of first-order echoes taking the effect of wave-current interaction on spectral density of causal ocean waves into consideration, and revealed that the wave-current interaction made the spatial distribution of radar cross-section non-uniform and that this non-uniform spatial distribution of radar cross-section caused the broadening and splitting shape of first-order echoes and the measurement error of radial current velocity by HF ocean surface radar. Nadai (2006) also proposes the averaging of radial current velocities extracted from each first-order echo to reduce the measurement error of HF ocean surface radar. In the southern sea off Yakushima Isl. of Tokara Islands, many strong frontal eddies are observed in previous observation (e.g. Nadai et al., 1995). In the ocean area with frontal eddies, the spectral shape of first-order echoes become broadening and splitting. Because the strong eddies corresponds to large change of currents in small area, the radar cross-section in the area becomes non-uniform due to the results of wave-current interaction. Therefore, the measured current field by HF ocean surface radar system may include large error due to the non-uniformity of radar cross-section. In this study, the radial current velocity is extracted from the Doppler spectra of HF ocean surface radar using averaging method proposed by Nadai (2006). The structure of frontal eddies is analyzed more accurately than the previous studies. The eddies were accompanied with upwelling current field. The distribution of rotation and divergence of eddies are agreed with each other. The value of divergence is a half or weaker than that of rotation.

Keywords: frontal eddy, hf radar, kuroshio



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Okhotsk Sea surface thermal fronts evolution based on 1999-2006 NOAA satellites data

Mr. George Novinenko

Remote Sensing Dept. Sakhalin Research Inst. of Fisheries & Oceanology

Okhotsk Sea surface temperature (SST) fields, based on NOAA series satellites data were observed. 2x2 km resolution data from SakhNIROs SST database for period of 8 years since 1999 was involved in research. Cayula-Cornillon edge detection algorithm and gradient methods were applied for data. As result all well-known surface thermal fronts for explored period were distinguished. Frontal location extremes using the gradient varying alongside the normals of fronts were determined within the seasonal and year-to-year variability for half-month averaging.

Keywords: sst, evolution

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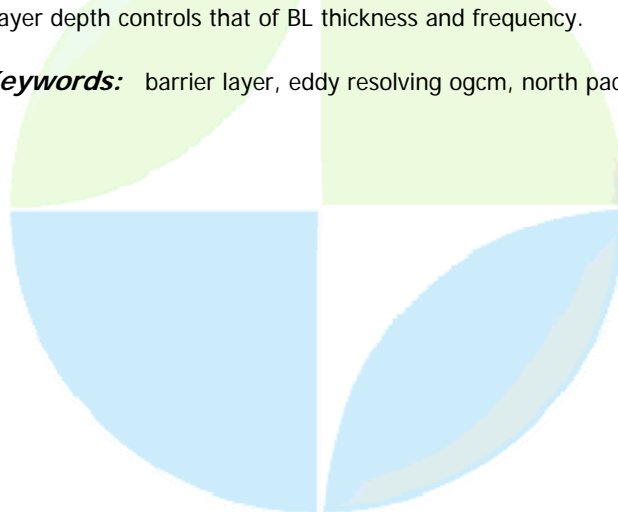
Formation mechanism of the barrier layer in the North Pacific subtropical gyre

Dr. Kanako Sato
IORGC JAMSTEC IAPSO

Toshio Suga, Kimio Hanawa, Hideharu Sasaki, Yoshikazu Sasai

The formation mechanism of the barrier layers (BLs) in the North Pacific subtropical gyre is investigated in detail by using the simulated data in OFES (OGCM for the Earth Simulator), which is an eddy-resolving OGCM forced by the monthly atmospheric data of the NCEP/NCAR reanalysis climatology. The OFES well reproduces the distribution of the BLs on a small scale of about 100km, the seasonal change of BL thickness and occurrence frequency in the North Pacific subtropical gyre observed by the Argo profiling floats. The local freshening due to precipitation is unlikely to be a main factor of the BL formation in winter and spring, because 70% of the grids with BLs have an excess evaporation. This result is consistent with the suggestion from the analysis of the Argo profiling float data. Since the sea surface height distribution indicated that the locations of BLs are related to that of eddies, we examined the formation of BLs around an anticyclonic eddy as a case study. A series of phenomena to form BLs are observed as follows. A filamentary structure of the low salinity at the sea surface evolves around the eddy. BL spreads underneath this low salinity water along this filament. The salinity difference between the low salinity water associated with this filament and surrounding water is quite large, causing a strong salinity front at the sea surface near BL. This filamentary structure has the vertical shear of the horizontal velocity so that the strong salinity fronts tilt. It appears that the low salinity water piles up on higher salinity water. As a result, the vertical stratification of salinity becomes strong, forming BLs. Therefore, the strong salinity front, which is essentially caused by enhancement of the background horizontal gradient of salinity due to the filamentary structure associated with the eddy, plays an important role on the BL formation. In the whole subtropical gyre of the North Pacific, the strong salinity fronts in the mixed layers such as that observed in the above case study are distributed where BLs are distributed. The salinity changes across these salinity fronts make greater contributions to density changes than the temperature changes across the same salinity fronts. Many BLs appear near the strong salinity fronts. Therefore, it is suggested that the formation mechanism described in the present case study mainly works. In addition, we try to identify the main factor which causes the seasonal change of the BL thickness and occurrence frequency; BLs are thicker and more frequently observed in winter and spring. The isothermal layer is deeper in winter and spring than the other seasons. We will argue that deep isothermal layer is a necessary condition for BLs to be formed and that the seasonal change of isothermal layer depth controls that of BL thickness and frequency.

Keywords: barrier layer, eddy resolving ogcm, north pacific



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PS008

Poster presentation

6020

Variations of sea surface thermal fronts in the China Seas based on an assembled front detecting method

Dr. Fan Wang

CAS Key Laboratory of Ocean Circulation and Waves Institute of Oceanology IAPSO

Chuanyu Liu

This work presents an assembled front detecting method including a set of objective algorithms for satellite remote sensing sea surface temperature (SST) data and discusses the variations of the surface thermal fronts in the China Seas. The assembled front detecting method is an incorporation of the gradient oriented front detection method and the entropic oriented front detection method with some modifications and improvements. The advantage of the assembled method to the previous methods is that it can detect both lengths and widths/intensities of fronts with different spatial scales from fine scale silks to large scale frontal sets. The method is used in the present study to detect and trace fronts in the China Seas from the monthly mean Advanced Very High Resolution Radiometer (AVHRR) SST data with a spatial resolution of 9.28 Km from January 1985 through December 2002. Several typical fronts are selected from 16 fronts detected and their patterns and evolutions are analyzed. Most of the fronts reveal similar seasonal signals although they might be induced and controlled by different oceanic and atmospheric processes. Compared to seasonal signals, the interannual variations of the fronts were pretty weak during the period of 1985-2002.

Keywords: front, detecting, sst



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PS008

Poster presentation

6021

Understanding the Subtropical Convergence in the South-West Indian Ocean

Dr. Isabelle Ansorge

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Johann Lutjeharms

The Subtropical Convergence forms the generic, equatorward border of the Southern Ocean. In the western part of the Indian sector it is one of the strongest fronts in the world ocean. In this region, the extension of the Agulhas Current, the Agulhas Return Current strengthens the horizontal gradients of this front considerably leading to the formation of intense mesoscale eddies. These heat anomalies have been shown to have a marked influence on the overlying atmosphere and on local biota. Recent investigations at the Subtropical Convergence, using both satellite remote sensing as well as modelling have demonstrated the climatological importance of primary production here. It has been shown that primary production at this front occurs as event-scale blooms and not as persistent enhancement as was suggested previously. We aim to present hydrographic and biological data collected during the April 2007 cruise to the Prince Edward Islands in order to better understand the nature of the Subtropical Convergence in the South-West Indian Ocean.

Keywords: subtropicalconvergence, fronts, eddies

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PS008

Poster presentation

6022

**Satellite Climatology of SST and Chlorophyll Fronts in the Northeast U.S.
Large Marine Ecosystem**

Dr. Igor Belkin

Graduate School of Oceanography University of Rhode Island IAPSO

John E. O'Reilly

Satellite data from several thermal and color sensors (AVHRR/NOAA, SeaWiFS and MODIS/Aqua) were processed with a newly developed algorithm to generate a climatology of SST and chlorophyll fronts in the Northeast U.S. Large Marine Ecosystem. Our approach is based on the Canny (1986) edge detection algorithm. The main novelty is a systematic use of shape-preserving, scale-sensitive median filtering applied selectively and iteratively until convergence, which is fast and guaranteed. When applied to chlorophyll data, our approach emphasizes spatial patterns peculiar to this field, namely chlorophyll enhancement associated with thermohaline fronts, and small- and meso-scale chlorophyll blooms. These patterns are modeled as ridges and peaks; they need to be preserved and treated differently from SST fronts modeled as steps or ramps. The resulting climatology of front statistics (frequency/persistence, magnitude, and direction) is based on 20 years of SST and 9 years of chlorophyll data. In our presentation we will describe the main spatial patterns and temporal features, relationships between SST and chlorophyll fronts, and long term trends of this climatology.

Keywords: front, sea surface temperature, chlorophyll

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PS008

Poster presentation

6023

Three types of South Pacific subtropical mode waters: Their relation to the large-scale circulation of the South Pacific subtropical gyre and their temporal variability.

Mr. Takamasa Tsubouchi

Geophysics The Oceanographic Society of Japan IAPSO

Toshio Suga, Kimio Hanawa

A detailed spatial distribution of South Pacific subtropical mode water (SPSTMW) and its temporal variation were investigated using the World Ocean Atlas (WOA) 2001 climatology and high resolution expendable bathythermograph (HRX) line data. In the WOA 2001 climatology, SPSTMW can be classified into western and eastern parts. Detailed examination of spatial distributions using HRX-PX06 line data revealed that the eastern part can be further divided into two types by the Tasman Front (TF) extension. Consequently, SPSTMW can be classified into three types, referred to in the present study as the West, North, and South types. The West type, situated in the recirculation region of the East Australia Current (EAC), has a core layer temperature (CLT) of about 19.1°C; the North type, in the region north of the TF extension, has a CLT of about 17.6°C; and the South type, in the region south of the TF extension, has a CLT of about 16.0°C. The long-term (>6 years) variations in the inventories of the three types were dissimilar to each other. The short-term (<6 years) and long-term variations in the mean CLT of the North and South types were greater than that of the West type. Winter cooling in the previous year may have influenced the short-term variation in the South-type CLT. Moreover, the strength of the EAC may have influenced long-term variation in the West-type inventory and thickness and that of the North-type thickness and CLT.

Keywords: subtropical mode water, south pacific ocean, tasman front



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PS009

6024 - 6036

Symposium

Impact of CO₂ Changes on Biogeochemical Processes and Ecosystem Functioning

Convener : Dr. Denise Smythe-Wright

This symposium will bring together a multidisciplinary approach to consider the impact of a high CO₂ world on the biological and biochemical processes within the ocean. There is now clear scientific consensus that the increasing atmospheric levels of CO₂, resulting mainly from human activities, are causing environmental change. While we understand the chemical processes involved when CO₂ from the atmosphere dissolves in seawater, we know little about the impact. A range of coupled climate models has been developed to investigate the response of the physical ocean-atmosphere system to increased greenhouse gases and aerosols. These simulations predict increases in ocean temperatures, more salty water in the subtropics and fresher water at high latitudes, increased oceanic stratification and a reduction in the mixed layer depth, and changes in cloud cover and sea ice. In turn, these changes are highly likely to cause significant alteration in nutrient and light availability and the length of the growing season and, taken together, will severely alter biological community structure. For example, warmer more oligotrophic conditions could result in increases in cyanobacteria, while increases in dust will induce more nitrogen-fixers. In addition, there is now increasing concern about ocean acidity. The surface ocean pH is already 0.1 unit lower than pre-industrial levels and, by the end of the century, it will become another 0.3 - 0.4 units lower under the IS92a "business as usual" scenario. Experimental evidence suggests that if trends in ocean acidity continue, key marine organisms such as corals and coccolithophores will have difficulty in maintaining their calcium carbonate skeletons. Contributions that address all the above issues are welcomed.

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Oral Presentation

6024

Natural hazards in the lake Kivu Basin, Western Rift Valley of Africa

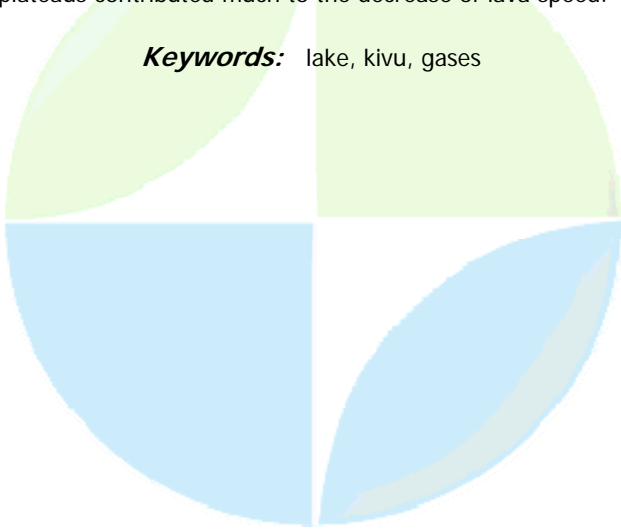
Mr. Wafula Mifundu Dieudonne

Department of Geophysics CRSN GOMA IAPSO

Augustin Menga Kwetuenda, Matthieu Mapendano Yalire

The lake Kivu with geographical coordinates 2 S an 29E is one of the four lakes ranged from north to south in the Western Rift Valley of the East African Rift Valley System. This lake with altitude (1462m) and maximum depth (485m) is the most highest in the Western Rift. The lake Kivu basin is among the most active region in this Rift. In its northern part is located the Virunga volcanic region with the very active volcanoes Nyiragongo and Nyamuragira. Similar to the other lakes in the East African Rift Valley, the lake Kivu is stratified with three layers: epilimnion (0 -50m), metalimnion (50 - 75m) and hypolimnion (75m -). The metalimnion is composed of mineral salts, however the hypolimnion is composed of gases such as carbon dioxide CO₂ (75%) methane CH₄ (15%) and 10% other gases. The quantity of CO₂, is estimated to 256 km³, CH₄ 54 km³ and the volume of the lake water is 560 km³ on a 2,055Km of surface. The two gases are intimately bound. The methane is produced by the bacterial reduction carbon dioxide (70%)and bacterial reduction of acetate (30%). The carbon dioxide is produced by methane oxidation, decomposition of magmatic carbonate, decomposition of organic material and also the atmosphere contribution. In the lake Kivu, the possibility of happening CO₂ gas explosion as in the lake Nyos in 1986 is very small at present, because the dissolved gases carbon dioxide and methane do not reach to the saturation points in the hypolimnion and the temperature profile from bottom to the depth of 60 m, the fall of temperature is comparatively rapid, and than it works to increase the solubility with decreasing depth. The most cataclysmal explosion might occur if very fast lava flow entered rapidly in the lake to break the metalimnion natural barrier. Other possibilities for the gases explosion should be the occurrence of volcanic eruption of Nyiragongo in the lake close to the shore line or that of a big earthquake in lake generating Tsunamis. The gases explosion should be a big catastrophe because of the location of cities of Goma (D.R.C.) and Gisenyi (Rwanda) in the northern end of the lake, Bukavu (D.R.C.) and Cyagungu (Rwanda) in the southern end, and several villages on its the margins. More than one million of people might be affected. The Nyiragongo eruption on January 17, 2002 did not break the natural barrier, probably because the speed of the lava flows and its temperature which decreased during the 5 km of route from the effusion fissures to the fall point in the lake. The lava crossing Goma city transported a lot of materials which decreased its speed and the temperature, so the impact with the lake water was not very strong. The location of Goma on a plateaus contributed much to the decrease of lava speed.

Keywords: lake, kivu, gases



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PS009

Oral Presentation

6025

Design and Field Testing of a Prototype Free Ocean CO₂ Enrichment (FOCE) System for Assessment of Impacts of Ocean Acidification

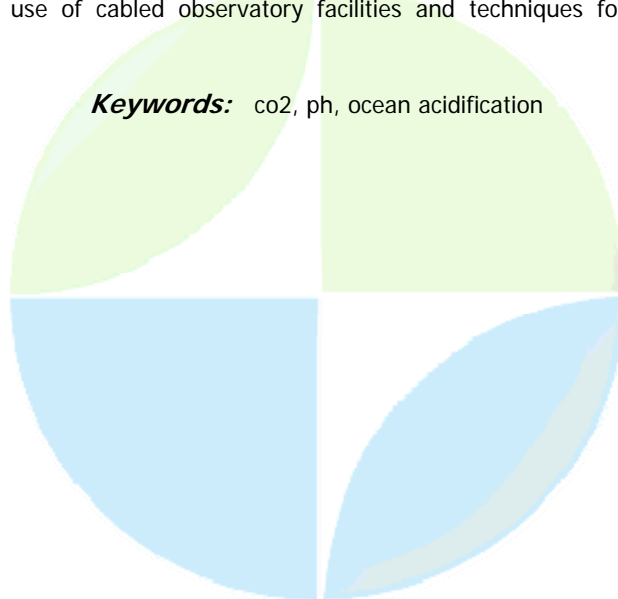
Mr. William Kirkwood

Research and Development Monterey Bay Aquarium Research Institute IAPSO

Edward T. Peltzer, Rachel M. Dunk, Peter M. Walz, Peter G. Brewer

The well documented change in ocean pH due to fossil fuel CO₂ invasion will apply stresses on marine organisms that have not been seen on Earth in millions of years. The effects of elevated atmospheric CO₂ levels on land plants have been investigated by a series of Free Air CO₂ Enrichment (FACE) experiments carried out world-wide. Are such experiments possible for the oceans? The impacts of elevated CO₂ levels on marine phytoplankton may be studied with short-term controlled closed mesocosm experiments, but benthic communities, coral reefs etc will require a different approach. Here we report on early pilot studies on the design and field testing of a FOCE system. The prototype design is a circular frame of 2m diameter, with emitters on the periphery. It tests the ability to control and maintain elevated CO₂/lower pH levels within a fixed but freely exchanging volume of sea water with velocity fluctuations from tidal forcing. The requirements include piped transfer of CO₂ rich sea water to the observing point, metering of the working fluid to produce local sea water of the desired delta-CO₂, a delay line with appropriate time for the reaction kinetics to occur and pH equilibrium to be established, and calibrated pH and velocity sensors for feedback and control. Field test results of the prototype on the ocean floor demonstrated the capability of the system to maintain closed loop control of pH in real time using acid addition for convenience. A fundamental limit is imposed by the time to reach pH equilibrium for mixing background and CO₂ enriched sea water. This may be greatly reduced by larger scale emitter tubes where the pumping rate is adjusted to match the local velocity so that almost all of the sea water within the control volume has had an equilibration time equal to about 3 e-folding times for the hydration reaction before introduction. In separate experiments we have developed systems for controlled enrichment of local sea water with CO₂ to produce a potent working fluid. Discussion and analysis includes control algorithm development, systems in-situ results, corrective actions, control algorithm modifications adapting to modified chemical kinetics, and upgrades in materials and components to address physical forcing and long-term stability. The prototype has established the viability of the FOCE technical concept to an extent that we are strongly pursuing further development and investigating the use of cabled observatory facilities and techniques for providing power and control.

Keywords: co₂, ph, ocean acidification



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Oral Presentation

6026

**Real-Time Measurements of Ocean pH and Sensor Calibration at Depth
from a Remotely Operated Vehicle**

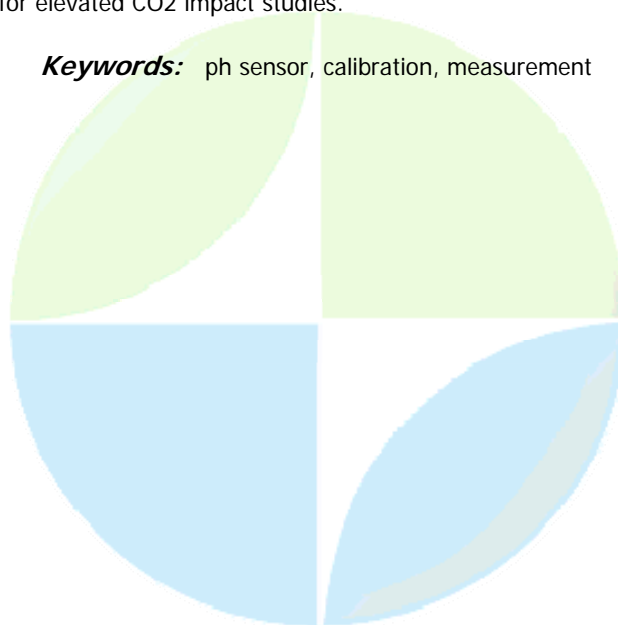
Dr. Edward Peltzer

Research and Development Monterey Bay Aquarium Research Institute

Peter G. Brewer, Rachel M. Dunk, William J. Kirkwood, Peter M. Walz

We have built the essential technology and expertise for conducting a series of small-scale in situ controlled ocean pH and CO₂ enrichment experiments for biogeochemical impact studies, using ROVs to carry down, deploy, and manipulate the experimental systems. Essential for this is the ability to accurately measure ocean CO₂ system properties at depth. The seawater alkalinity field below about 400 m is well constrained by ocean observations and has been mapped with considerable precision and accuracy, thus by adding in situ pH measurements the CO₂ system is in principle well defined. In order to make these measurements, we need an accurate and precise pH sensor that is both rugged, stable over the long-term, and calibratable at depth. We have built a PC based interface that allows us to use a SeaBird (model SBE 18) pH sensor with both MBARI ROVs that allows for real-time data display in the ROV control room. While there are some operational difficulties when these sensors are used in a profiling mode due to a pressure and temperature related hysteresis traceable to effects on the liquid junction of the reference electrode, these difficulties can be overcome with the implementation of the appropriate procedures. Once at depth the electrodes typically quickly stabilize, and in the thermally stable and electrically quiet deep ocean remarkably low noise levels (± 0.0006) and minimal drift ($< 0.0016/\text{hr}$) are observed. We have extended our ability to calibrate the system at depth by taking down several large volume flexible containers of sea water adjusted to different pH values, and calibrated on the ship by standard buffer techniques. We have developed flow cell procedures whereby the experimental system can be flushed with standards, and any offsets or drift recorded and corrected. We present the results of these in situ calibration efforts and give specific examples of how a pH system calibrated at depth can be used to measure in situ the kinetics of the CO₂ hydration reaction, provide a precise monitor of CO₂ enrichment of seawater as an experimental fluid, and even perform an in situ alkalinity titration. By minimizing cell dimensions and flushing times, and establishing the needed frequency of calibration, it appears to be possible to consider long-term deployments of well-constrained experimental systems for elevated CO₂ impact studies.

Keywords: ph sensor, calibration, measurement



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PS009

Oral Presentation

6027

Investigating the effects of changing CO₂ concentration on a natural marine plankton community using a chemostat system

Mrs. Judith Piontek
IAPSO

Nicole Hndel, Mirko Lunau, Anja Engel

Rising CO₂ concentration in the atmosphere leads to significant changes in seawater chemistry and potentially influences biological processes in the upper ocean. Recent studies demonstrated the sensitivity of marine phytoplankton, such as coccolithophores, to changes in seawater pCO₂. However, little is known about the potential influence of climate change on microbial activities and degradation processes. In order to come to a mechanistic understanding of CO₂ effects on marine biogeochemical cycling, the influence of pCO₂ on biological processes related to autotrophic production needs to be known as well as the co-response of the heterotrophic community. We investigated the combined effect of pCO₂ and nutrient supply on organic matter production and degradation during a phytoplankton bloom in the Atlantic Ocean (Gulf of Biscay). Prescribed CO₂ concentrations were achieved in chemostat incubators by aeration with CO₂ ranging from low (180 ppm) and present-day (370 ppm) to high pCO₂ (1400 ppm). Here, we present first results on the production and composition of dissolved and particulate organic matter and bacterial dynamics. Our findings indicate strong effects of variations in pCO₂ on production as well as on degradation processes. We discuss potential implications for the future marine carbon cycle.

Keywords: ocean acidification, carbon cycle, phytoplankton

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Oral Presentation

6028

Relation between pteropod shells dissolution above the chemical lysocline and TCO₂ concentration in the water column (Ross Sea, Antarctica)

Dr. Clara Manno

DISAM (Dipartimento Scienze Ambientali) Universit Parthenope

Silvai Sandrini, Laura Tositti, Alessandra Accornero

The observation of badly preserved shells of the pteropod *Limacina helicina* in deep (880 m) sediment traps moored in the polynya of Terra Nova Bay (Ross Sea, Antarctica) was the first inspiration that led us to investigate the chemical and physical processes affecting the aragonitic shells of these organisms upon their death. For this purpose we determined the chemical saturation state of CaCO₃ in sea water from Total Dissolved Inorganic Carbon (TCO₂) and Total Alkalinity (TA) data. The results showed that the saturation level for aragonite was located at about 1000 m depth, hence below the trap level. Anyway a few lines of evidence concur to suggest aragonite dissolution above the chemical lysocline in the investigated area: (i) fluxes of *Limacina helicina* shells near the bottom were very low, despite the large abundance of these pteropod in the upper 200 m of the water column, (ii) the shells collected near the bottom showed a state of advanced chemical degradation, in contrast to the shells collected by the shallow trap, which appeared intact and well preserved and (iii) carbonate fluxes observed in the bottom trap corresponded to only 1% of fluxes measured in the shallow one. The presence in this study area of HSSW (High Salinity Shelf Water) seems to be the main factor inducing the degradation of the shells. This aspect suggests an underestimation of the CaCO₃ budget in the deepest waters especially when the pteropods represent the dominant contributors as well as an important implications for the mechanisms influencing the Ross Sea inorganic carbon cycle since partial dissolution of the shells in the water column act as a potential sink for atmospheric CO₂.

Keywords: pteropod, tco₂, antarctica



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Oral Presentation

6029

Ocean Ecosystems in a Warmer World

Dr. Francisco Chavez
Ocean Sciences Member

This presentation debates the response of ocean ecosystems in a warmer world. We analyze the recent and paleoclimatic evidence for how ocean ecosystems have behaved under warmer conditions. We look at natural variability and the spatial distribution of effects. From recent data it is clear that there are strong differences between northern and southern hemispheres and also between ocean basins. Surprises emerge from paleoclimatic records.

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Oral Presentation

6030

Modelling the effect of increasing PCO₂ on pelagic aragonite production

Mrs. Reidun Gangsto

University of Bern Climate and Environmental Physics

Marion Gehlen, Laurent Bopp, Birgit Schneider, Fortunat Joos, Olivier Aumont

Increasing ocean uptake of anthropogenic CO₂ leads to a decrease in carbonate ion concentrations and a consequent shoaling of the aragonite saturation horizon. Model studies predict that the surface waters in the Southern Ocean may be undersaturated with respect to aragonite already by the end of this century. This may be especially threatening for aragonite producing pteropods as they may have difficulties with maintaining their shells in undersaturated waters. Changes in pteropod abundance could in turn influence the entire food chain up through higher trophic levels. The fore seen impacts of acidification on aragonite production, as well as its contribution to short term CO₂ neutralization, calls for an inclusion of aragonite in biogeochemical models. Furthermore, as aragonite is likely to constitute a large part of the shallow depth CaCO₃ dissolution suggested by researchers, implementing aragonite may yield a better model description of the carbonate budget. In this work we used the biogeochemical-ecosystem model PISCES coupled to the OPA/ORCA2 global-scale ocean general circulation model. In its standard version, the PISCES model distinguishes two phytoplankton and two zooplankton size classes. We have implemented aragonite as a new tracer in the model. The production of aragonite by pteropods is described by the distribution of their size class (mesozooplankton) as a function of saturation state. The climatological calcite and aragonite production, dissolution and sinking fluxes are consistent with existing literature estimates. Including aragonite production and dissolution in addition to calcite improves the modelled CaCO₃ budget compared to results obtained with a calcite-only model. The model predicts a total dissolution flux above 2000 m in line with independant estimates. The PISCES model was next forced with atmospheric pCO₂ increasing from the pre-industrial level of 286 ppm to 4 times this value. The effect on CaCO₃ production and dissolution, and the consequent changes in ocean uptake of atmospheric CO₂, will be presented.

Keywords: acidification, modelling, aragonite



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Oral Presentation

6031

Simulations of plankton functional types response to atmospheric CO₂ increase

Dr. Marcello Vichi
ANS CMCC-INGV

Pier Giuseppe Fogli, Lavinia Patara, Simona Masina, Elisa Manzini

The CMCC-INGV coupled climate model consisting of atmospheric, oceanic (with dynamic sea-ice) and marine biogeochemistry components have been used to investigate the response of the system to increasing levels of CO₂. The preliminary experiment was a simplified analysis of 1xCO₂ vs 2xCO₂ climate conditions with 100 years simulation times. The biogeochemistry model is PELAGOS, which is a global ocean implementation of the Biogeochemical Flux Model (BFM, <http://www.bo.ingv.it/bfm>). Global sea surface temperature raises of about 2 degrees C in 100 years of 2xCO₂, with a sudden drop in the southern hemisphere sea-ice volume. Major changes are observed in the North Atlantic and subarctic Pacific where the mixed layer depth decreases from 100 m to less than 40 m on average, with a consistent decrease in diatoms abundance and a shift towards pico- and nanophytoplankton. A comparison of annual mean distributions of plankton functional types (PFT) indicates a generalized decrease of diatoms abundance in the 2xCO₂ scenario, with localized increases in formerly ice-covered regions. The PFTs in subtropical gyres respond differently in the major oceans. Both nanophytoplankton and picophytoplankton increase in the subtropical Atlantic and northern Pacific, while the latter decrease significantly in the Indian Ocean and show an increment in the western Pacific. These preliminary results are generally consistent with stratified ocean conditions that favor the development of microbial food webs.

Keywords: earth system models, pft, climate change



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Oral Presentation

6032

The influence of increasing carbon dioxide concentrations on the release of halocarbon by phytoplankton

Dr. Denise Smythe-Wright

Ocean Biogeochemistry and Ecosystems National Oceanography Centre, Southampton IAPSO

Young – Nam Kim

It has been argued that since phytoplankton naturally take up carbon dioxide any increase in oceanic concentrations of this gas due to man's activity would lead to increased productivity. For the majority of phytoplankton studied to date, this does not seem to be the case and it has been concluded that doubling the present carbon dioxide concentration will only affect the rate of photosynthesis by 10%. An exception is *Emiliana huxleyi*, which has shown a greater rate of photosynthesis in response to elevated levels of carbon dioxide, suggesting a beneficial role for this organism. *Emiliana huxleyi*, together with many other phytoplankton are known to produce a wide range of halogenated trace gases as a result of their metabolic processes. These gases are important for stratospheric and tropospheric ozone depletion and iodinated species may also be important for the formation of cloud condensation nuclei. Whether trace gas production in the ocean will increase as a result of increased carbon dioxide concentrations is unclear. Not only is there a potential for increased productivity due to elevated dissolved carbon dioxide but also there is the possible impact of changing oceanic pH. We have made culture studies of trace gas release under the influence of different environmental conditions, including increased carbon dioxide levels, and will discuss the effects and implications for global change.

Keywords: carbon dioxide, halocarbon, phytoplankton

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PS009

Oral Presentation

6033

The role of Subantarctic Mode Water in global biological production

Prof. Jorge Sarmiento
Geosciences Princeton University IAPSO

J. Simeon, A. Gnanadesikan

Previous studies have shown that Subantarctic Mode Water is the primary pathway by which nutrients that are lost to the deep ocean by organic matter export are returned to the main thermocline. In this presentation we discuss model simulations of how the SAMW nutrients are fed from the main thermocline into the surface ocean, there to drive biological production; and how SAMW responds to global warming in the NOAA GFDL CM2.1 coupled climate model.

Keywords: samw, nutrients



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PS009

Poster presentation

6034

Interannual to interdecadal variations of primary production and air-sea CO₂ flux in the North Pacific using a 3-D NEMURO model

Mrs. Maki Aita

Frontier Research Center for Global Change JAMSTEC

Akio Ishida, Yasuhiro Yamanaka

Interannual to interdecadal scale oscillations in atmosphere-ocean systems affect the environment for marine ecosystems by altering nutrient supply across the thermocline and horizontal advection. We simulated changes in the lower trophic level ecosystems and air-sea flux of CO₂ caused by interdecadal climate variability, using data from 1948 to 2002 to drive an ecosystem model, NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography; developed by MODEL Task Team of PICES (North Pacific Marine Science Organization)) embedded into a global three-dimensional physical-biogeochemical coupled model, 3D-NEMURO. Comparing mean values before and after the 1976/77 climatic regime shift, primary production decreased in the Oyashio region, subtropical western and eastern Northern Pacific and the Bering Sea, but increased in the central North Pacific. This corresponds to the Pacific Decadal Oscillation (PDO) that indicates interdecadal climate variability in the subtropical and tropical Pacific. In the north central Pacific biomass correlates positively with PDO index, while that in the eastern and western north Pacific correlates negatively with PDO. We conducted simulations with two boundary conditions for atmospheric pCO₂: one using the historical increase in atmospheric pCO₂ from year 1837 to 2002 (historical run), another with a constant pre-anthropogenic concentration of 278 atm (control run). Anthropogenic carbon cycle in the model is computed as the difference between the historical and control runs. In the central North Pacific, the models interannual variability of air-sea CO₂ flux and primary production were positively correlated. That is, when primary production was greater, so was the oceanic uptake of CO₂. The anthropogenic air-sea CO₂ flux (excluding natural CO₂ flux) also correlated with primary production. We examine in detail the relative contributions of physical and biological control of oceanic CO₂ uptake.

Keywords: regime shift, co2 flux, nemuro



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PS009

Poster presentation

6035

Biogeochemistry of a late coccolithophorid bloom at the continental margin of the Bay of Biscay

Mr. Jerome Harlay

Oceanography Universite Libre de Bruxelles IAPSO

De Bodt Caroline, D'Hoop Quentin, Roevros Nathalie, Borges Alberto V., Delille Bruno, Suykens Kim, van Oostende Nicolas, Sabbe Koen, Piontek Judith, Hndel Nicole, Schmidt Sabine, Groom Steve, Engel Anja, Chou Lei

Recent findings have led to growing concern regarding the impact of ocean acidification on marine calcifiers, but little is known about their biogeochemistry in natural (field) conditions (a major but overlooked pre-requisite for realistic modelling of the future evolution of marine C cycling in a high CO₂ world). The changes that will undergo these species in the near future and the biological feedback to decreasing oceanic pH are still open to debate. Coccolithophores, among which *Emiliana huxleyi* (Ehux) is the most abundant and widespread species, are the dominant calcifying phytoplankton in the sub-polar and temperate zones of the world's oceans. Within the framework of the Climate and Atmosphere Belgian Federal Science Policy Office programme, the continental margin of the Northern Bay of Biscay (North Atlantic Ocean) was visited in June 2006 during a transdisciplinary investigation of a late-spring bloom dominated by Ehux. Remote sensing images, transmitted onboard on a daily basis, were of valuable significance to pinpoint the coccolithophorid bloom along the margin, and to sample stations with contrasted biogeochemical properties. We determined ¹⁴C-based primary production and calcification rates, as well as pelagic respiration rates (O₂ incubations). The magnitude of the biological and carbonate carbon fluxes will be synthesized and discussed in the light of biogeochemical parameters, such as Transparent Exopolymer Particles (TEP), chlorophyll-a, particulate carbon concentrations, particle dynamics and particulate organic carbon export (deduced from ²³⁴Th fluxes). Additional information on the bloom biogeochemistry will be presented (activity of dissolved esterase enzymes and bacterial community structure) to emphasize the importance of coccolithophorid blooms in the contemporary carbon cycle.

Keywords: coccolithophores, carbon, caco3



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PS009

Poster presentation

6036

Impact of CO₂ Changes on Biogeochemical Processes in the northern Bering and Chukchi Seas and its relationship to ecosystem structure

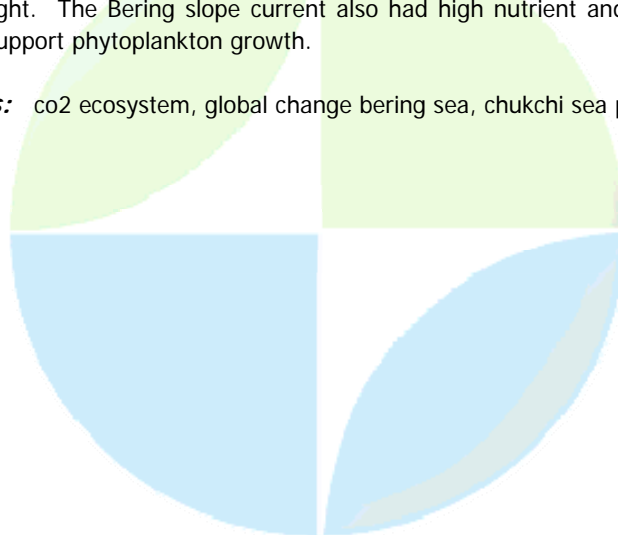
Dr. Liqi Chen

*Key Laboratory of Global Change and Marine-Atmosph State Oceanic Administration (SOA),
China*

Zhongyong Gao, Jianjun Wang

Because the Bering/Chukchi region is likely to be the site of net carbon sequestration, and because the region has experienced rapid change, it is important to improve our understanding of carbon cycling in this region. In the summers of 1999 and 2003, the 1st and 2nd Chinese National Arctic Research Expeditions measured the partial pressure of CO₂ in the air and surface waters (pCO₂) of the Bering Sea and the western Arctic Ocean. Distributions of pCO₂ in the Bering and Chukchi seas during July-Sept 1999 and 2003 displayed obvious geographic differences, with the lowest values being found in continental shelf waters, increased values over the Bering Sea shelf slope, and the highest values in the waters of the Bering Abyssal Plain(BAP) and the Canadian Basin. These differences arise from a combination of differing initial concentrations in the various source waters, biological uptake, and seasonal warming due to the Bering Strait throughflow being highly variable and reversible. Our data suggest that, during the time of our observations, the Chukchi Sea was a carbon dioxide sink. This uptake of carbon dioxide was the result of the availability of open water resulting from rapid sea ice melting, high primary production over the shelf and in marginal ice zones (MIZ), and transport of low pCO₂ waters from the Bering Sea. As a consequence of differences in inflow water masses, concentrations of pCO₂ fluctuated sharply over the Chukchi continental shelf, with relatively low concentrations occurring in the Anadyr waters that dominate the western portion of Bering Strait, and relatively high values in the waters of the Alaskan Coastal Current in the eastern portion of the strait. Due to the presence of blooms in August, pCO₂ in mid-August in the Bering Strait region (66-69°N) is, in general, much lower than at the end of July. In August, high concentrations of pCO₂ between 68.5-69°N along 169°W were associated with higher sea surface temperatures (SST) than in July, possibly as an influence of the Alaskan coastal current (ACC). In August in the MIZ, pCO₂ was observed to increase along with the temperature, indicating that SST plays an important role when the pack ice melts and recedes. CO₂ in surface waters of the Chukchi Sea was generally lower than 200 matm, and nutrients were almost depleted during summer. In contrast, nutrients in the Anadyr waters on the western side of Bering Strait remained high and were able to fuel phytoplankton growth so long as there was sufficient light. The Bering slope current also had high nutrient and low pCO₂ waters and thus the potential to support phytoplankton growth.

Keywords: co2 ecosystem, global change bering sea, chukchi sea ph chlorophyll



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PS010

6037 - 6097

Symposium

New Insights into the Ocean and Its Circulation from Argo and GODAE

Convener : Dr. W John Gould

The Global Ocean Data Assimilation Experiment (GODAE) has been a driving force in developments in ocean state estimation. The powerful combination of satellite altimetry with the rapidly increasing abundance of data from the Argo array of profiling floats has made possible a wide range of research and operational data assimilation efforts. This symposium provides a platform to explore the wide range of regional and global results and new data assimilation techniques that have been made possible by the link between Argo and GODAE.

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Oral Presentation

6037

Validation of Argo Salinity Data from the Indian Ocean

Dr. Pankajakshan Thadathil

Quality of Argo salinity data from the Indian Ocean are examined using different validation approaches. While collocated floats match-ups are used to find float-to-float consistency, ship board CTD profiles from a number of cruises are used for validating the Argo salinity and also to find the salinity drift in the floats CTD. Drift in the floats CTD is also examined using collocated match-ups between old-floats and floats deployed recently. While the validation for float-to-float match-ups are performed on theta (potential temperature) surfaces of 2 or 3o C, the float-to-shp board CTD validation uses CTD profiles greater than 1000 m. During three cruises specific CTD casts up to 2000 m were made in stations close to the floats. At collocated positions floats were found to be consistent enough to report the sality within 0.01 PSU, except in a few cases where the match-ups involves profiles soon after the deployment of the floats (initial profiles). The study also discusses salinity drift in the floats CTD.

Keywords: salinity, drift, argo

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Oral Presentation

6038

Estimation of sonic layer depth using remote sensing and argo observations

Mrs. Sarika Jain

Department of Space National Remote Sensing Agency

Sonic layer depth (SLD), an important parameter in underwater acoustics, is the near surface depth of first maxima of the sound speed in the ocean. The lack of direct observations of vertical profiles of velocimeters and/or temperature and salinity, from which sound speed/SLD can be calculated, hampers the investigation of SLD. Hence, it is of importance to see whether the SLD can be inferred from surface observations. An important alternative to direct observations would be the ability to estimate SLD from surface parameters easily available from satellites. In this study we demonstrated the estimation of SLD from surface meteorological observations using artificial neural network (ANN) approach. ANN model requires large dataset for training. While surface observations are already available from satellites for a long time, subsurface temperature and salinity profiles from which SLD is to be estimated is very much limited, particularly, over the data sparse Indian Ocean region. Recent deployment of Argo floats gave an opportunity for developing the ANN model. For this purpose, we used temperature and salinity profiles from Argo floats during 2002-2006 and the surface meteorological parameters from the collocated satellite observations. Surface parameters that controls SLD are wind speed (WS), sea surface temperature (SST), sea surface height anomaly (SSHA), net heat flux (NHF), and net radiation (NR). WS, SST and SSHA are used from remote sensing platforms whereas NHF and NR from other model outputs. Sound speed profiles are estimated using UNESCO algorithm from the temperature and salinity measurements from Argo floats from which SLD is estimated. The ANN model is developed considering SLD as the predictant and the surface observations as the predictors. Observations during 2002-2005 are used for developing the model and 2006 for prediction. SLD could be estimated with an RMS error of 15 m. This model is used to estimate SLD using surface meteorological observations. This study provided an opportunity to estimate SLD over larger spatial and better temporal scales using which seasonal and inter annual variations of SLD in north Indian Ocean could be studied.

Keywords: sonic layer depth, artificial neural network, remote sensing



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Oral Presentation

6039

Optimal spectral decomposition (OSD) for Argo Data Analysis

Prof. Peter Chu

Oceanography Naval Postgraduate School IAPSO

Charles Sun

A popular method to process ocean data is the optimum interpolation (OI). Using the OI method (Gandin 1965), the background field (or called first-guess field) and autocorrelation function (or decorrelation scale) should be given. For the velocity field, both background field and decorrelation scale are unknown. For the temperature or salinity field, the decorrelation scale is unknown. Usually, the decorrelation scale is user defined in the OI application. Therefore, the estimated fields are dependent on the decorrelation scale. Without knowing the background field and decorrelation scale, the optimal spectral decomposition (OSD) method can process sparse and noisy data (Chu et al., 2003 a, b). Any field (temperature, salinity, or velocity) can be decomposed into generalized Fourier series using the OSD method. The three dimensional field is then represented by linear combination of the products of basis functions (or called modes) and corresponding Fourier coefficients. If a rectangular closed ocean basin is considered, the basis functions are sinusoidal functions. If a realistic ocean basin is considered, the basis functions are the eigen-values of the three-dimensional Laplace operator () with real topography. After the decomposition, the three-dimensional field is represented by a set of Fourier coefficients. This method has three components: (1) determination of the basis functions, (2) optimal mode truncation, and (3) determination of the Fourier coefficients. Determination of basis functions is to solve the eigen-value problem. Chu et al. (2003a, b) also developed a theory to obtain the basis functions with open boundaries. The basis functions are only dependent on the geometry of the ocean basin, not dependent on the oceanic variables. This is to say, no matter which variable (temperature, salinity, or velocity) is concerned, the basis functions are the same, and can be pre-determined before the data analysis. For data without error, the more the modes, the more the accuracy of the processed field. For data with error, this rule of the thumb is no longer true. Inclusion of high-order modes leads to increasing error. The Vapnik variational principal (Vapnik, 1982) is used to determine the optimal mode truncation. After the mode truncation, optimal field estimation is to solve a set of a linear algebraic equation of the Fourier coefficients. This algebraic equation is usually ill-posed. The rotation method (Chu et al., 2004) is developed to change the matrix of the algebraic equation from ill-posed to well-posed such that a realistic set of the Fourier coefficients are obtained. The OSD method is a power tool to process temperature, salinity, and velocity data from the ARGO drifters. References Chu, P.C., L.M. Ivanov, T.M. Margolina, T.P. Korzhova, and O.V. Melnichenko, Analysis of sparse and noisy ocean current data using flow decomposition. Part 1. Theory. *Journal of Atmospheric and Oceanic Technology*, 20, 478 - 491, 2003a. Chu, P.C., L.M. Ivanov, T.M. Margolina, T.P. Korzhova, and O.V. Melnichenko, Analysis of sparse and noisy ocean current data using flow decomposition. Part 2: Application to Eulerian and Lagrangian data. *Journal of Atmospheric and Oceanic Technology*, 20, 492-512, 2003b. Chu, P.C., L.M. Ivanov, and T.M. Margolina, Rotation method for reconstructing process and fields from imperfect data. *International Journal of Bifurcation and Chaos*, 14 (8), 2991-2997, 2004. Chu, P.C., L.M. Ivanov, and O.M. Melnichenko, 2005a: Fall-winter current reversals on the Texas-Louisiana continental shelf. *Journal of Physical Oceanography*, 35, 902-910. Chu, P.C., L.M. Ivanov, and T.M. Margolina, 2005b: Seasonal variability of the Black Sea Chlorophyll-a concentration. *Journal of Marine Systems*, 56, 243-261.

Keywords: optimal spectral decomposition, argo floats, data analysis

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Oral Presentation

6040

Effect of Mesoscale Eddies on Subtropical Mode Water Variability from the KESS Profiling Float Measurements

Prof. Bo Qiu

Department of Oceanography University of Hawaii at Manoa IAPSO

Peter Hacker, Shuiming Chen

Forty-eight profiling floats have been deployed in the Kuroshio Extension (KE) region since May 2004 as part of the Kuroshio Extension System Study (KESS) project. By combining the float temperature--salinity measurements with satellite altimetry data, this study investigates the role played by mesoscale eddies in controlling the property changes in North Pacific Subtropical Mode Water (STMW). Following a 3-yr period of low eddy activity in 2002--04, the KE transitioned to a high eddy kinetic energy state in 2005. This transition is the result of delayed oceanic response to the 2002 shift in the basin-scale surface wind forcing in connection with the Pacific decadal oscillation. The high eddy kinetic energy state of the KE is characterized by successive shedding of strong cold-core rings into the recirculation gyre, resulting from the interaction of the KE jet with the Shatsky Rise or the pre-existing cutoff rings. By transporting northern-origin, high potential vorticity (PV) KE water into the recirculation gyre, the enhanced eddy activity affects STMW in two ways: first, it hinders the formation of deep winter mixed layer (hence the source for STMW) by modifying the upper ocean stratification and, secondly, it provides a direct high-PV source to mix with the surrounding low-PV STMW. The eddies's influence upon STMW is observed to be both significant in magnitude and efficient in time. Compared to 2004, the PV signal in the core of STMW was reduced by half in 2005 and this weakening of STMW's intensity occurred within a period of less than 7 months. This result supports our recent findings based on historical temperature data that the variability in STMW formation depends more sensitively on the dynamic state of the KE than on the overlying atmospheric conditions.

Keywords: mesoscale eddies, cross frontal exchange, pv preconditioning



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Oral Presentation

6041

Improving Indian Ocean SST simulation by assimilating Argo profiles

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Centre for Atmospheric and Oceanic Sciences Indian Institute of Science IAPSO

C. S. Aneesh

A large number high quality temperature and salinity profiles are available from the Argo floats in the Indian Ocean, particularly from the Arabian Sea. We have explored the possibility of using these profiles to improve the quality of sea surface temperature (SST) simulation by an Indian Ocean model based on the Regional Ocean Modeling System. The Indian Ocean model is forced by winds and fluxes from NCEP/NCAR reanalysis system. Numerical experiments have been carried out for the year 2004 with and without assimilation of Argo profiles into the model. Objectively analyzed Argo profiles are assimilated into the model using a simple suboptimal sequential assimilation procedure. In the absence of relaxation of model SST to observations, it was found that the simulated SST shows large differences with respect to TMI SST. These differences reduce considerable when Argo profiles are assimilated into the model. The root mean square (RMS) error of the model simulated SST grows significantly over time and this error remain nearly constant in the model run with data assimilation. The correlation between model SST and TMI SST also improves over the entire model domain as a result of Argo data assimilation. However, regions with higher data density show higher correlation than regions with lower data density.

Keywords: assimilation, indianocean, roms

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Oral Presentation

6042

Thermohaline properties of the southeastern Mediterranean Sea as measured by profiling floats between 2000 and 2006

Mr. Riccardo Barbanti

OCEANOGRAPHY Istituto Nazionale di Oceanografia e di Geofisica

Pierre-Marie Poulain, Isabelle Taupier-Letage

The temperature and salinity data collected by profiling floats in the southeastern Mediterranean Sea from 2000 to 2006 are used to study the spatial distribution and temporal evolution of the Mediterranean thermohaline properties and to compare them with climatological values and ancillary ship-based hydrographic measurements. Since 2000, 53 profiling floats equipped with CTD sensors were deployed in the southeastern Mediterranean to monitor its thermohaline structure for scientific and operational purposes. In particular, starting in mid-2004, float operations were coordinated at the international level in the framework of the EU-sponsored MFSTEP project and were integrated into the international Argo program. Both APEX and PROVOR battery-powered profiling floats equipped with Sea-Bird pumped CTD sensors were operated in the southeastern Mediterranean Sea. They were programmed to descend and drift at an intermediate parking depth (between 350 and 650 m), to descend further down to depths of 650 - 2000 m before ascending to the surface while measuring pressure, temperature and conductivity. Once at the surface, they transmitted the data via the Argos satellite system and repeated the above-described sampling cycle. The cycle length was 5 days for the majority of the floats and 10 days for some units. The float temperature and salinity (S) profile data were processed, quality-controlled and distributed by the CORIOLIS Operational Oceanography Data Centre at IFREMER in Brest, France. In this work, the potential temperature (θ) and S values measured by the floats are studied in the Ionian, Cretan and Levantine sub-basins. The deep waters near 2000 m are found to be slightly warmer and significantly saltier when compared with values of the MEDAR MEDATLAS II climatology. In the Ionian, θ and S at 2000 m are 13.50 C and 38.74, respectively. These values increase to 13.60C and 38.77 in the Cretan Passage and to 13.65C and 38.78 in the Levantine. In contrast, the MEDAR MEDATLAS II climatology indicates values near 13.40C and 38.68 in the Ionian, 13.50C and 38.75 in the Cretan Passage, 13.40C and 38.73 in the Levantine. In the depth range 300-400 m, in addition to the natural variability associated with sub-basin and mesoscale structures, all sub-basins of the southeastern Mediterranean Sea have θ values similar to the climatology but S appears larger than climatology by about 0.05, especially in the Ionian and Cretan Passage. Since the MEDAR MEDATLAS II climatology is essentially based on hydrographic observations collected in the 20th century, the above-mentioned variations are thought to be related to decadal, or possibly longer-term, variability of the whole Mediterranean Sea, including changes known as the Eastern Mediterranean Transient (ETM).

Keywords: profiling floats, temperature, salinity

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Oral Presentation

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Argo observes global variability in the oceans

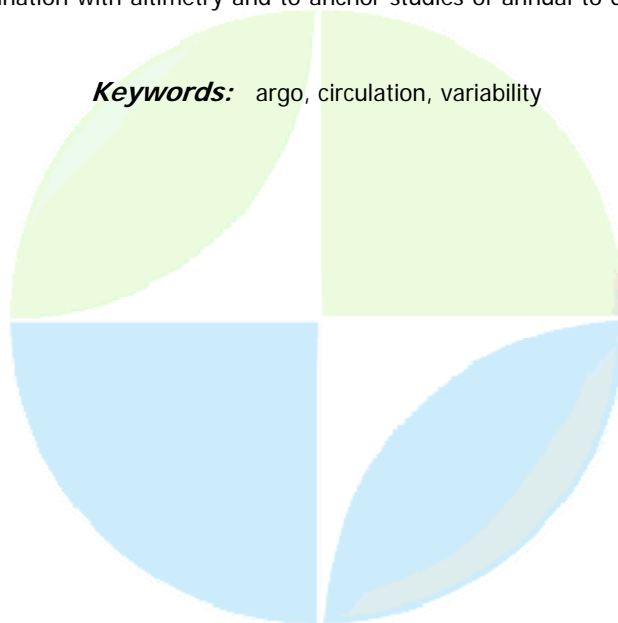
Prof. Dean Roemmich

Scripps Institution of Oceanography University of California San Diego IAPSO

John Gilson

There are now three years of continuous global coverage by the Argo profiling float array, providing an unprecedented ability to observe the upper 2000 m of the ocean. With three-year mean fields for temperature and salinity, we can begin to form a fixed-era climatology that eliminates many problems inherent to the mixed-era climatologies of the past. The multi-year mean will continue to improve with additional data, enabling estimates of temporal variability on a variety of time-scales: - An annual cycle is determined with good accuracy on large spatial-scales, averaged over the three-year period. For example, the annual cycle of globally-averaged steric height of the sea surface, having an April maximum of 4 mm, has an error of less than 1 mm, closing the oceans sea surface height budget together with altimetric height and satellite gravity measurements. Globally, the annual cycle of ocean heat content shows the dominance of the integrated Southern Hemisphere oceans due their larger area, in spite of greater magnitude of warming and cooling in the northern oceans. - Decadal variability is seen in combinations of Argo data with satellite altimetry and with WOCE and other historical datasets. The limitations of historical data in these comparisons greatly underline the need to sustain the Argo array for an extended period. The largest signal of the past decade in terms of zonally integrated heat content and steric sea surface height was a warming at 40 degrees S. Downward displacement of isopycnals and spin-up of subtropical gyre circulations occurred in all three oceans. The largest signal in terms of temperature and salinity change was a warming/salinity increase in the northern North Atlantic. The tropical oceans also warmed, especially the western Pacific and eastern Indian Ocean, due to opposing tradewind anomalies. While pre-Argo measurements of salinity and deep temperature levels are very sparse for global analysis, data from WOCE and Argo indicate that the wind-driven isopycnal displacements extend to at least 2000 m and that the freshening of intermediate waters seen in the WOCE era continues in Argo data. The Argo array now includes about 2800 active floats, and will provide more than 100,000 temperature/salinity profiles in 2007. Argo is observing the global oceans and is in many respects a subsurface analog to satellite altimetry. Argo provides a reference dataset for comparison and combination with altimetry and to anchor studies of annual to decadal variability in the oceans.

Keywords: argo, circulation, variability



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Oral Presentation

6044

Comparing the steric height in the Northern Atlantic with the satellite altimetry

Dr. Vladimir Ivchenko

climate system Alfred Wegener Institute for Polar and Marine Rese IAPSO

Sergey Danilov, Dmitry Sidorenko, Jens Schroeter, Manfred Wenzel, Dmitry Aleynik

Anomalies of dynamic height derived from an analysis of Argo profiling buoys data are analysed to assess the relative roles of contributions from temperature and salinity over the North Atlantic for the period of 1999-2004. They are compared with dynamic topography anomalies based on TOPEX/Poseidon and Jason altimetry. It is shown that the halosteric contribution to the anomalies of dynamic height is comparable in magnitude to the thermosteric one on the interannual scale. Taking salinity into account improves the agreement between zonally averaged trends in satellite dynamic topography and dynamic height. The correlation between the trend curves increases to 0.74 from 0.56 when only temperature variability is taken into account. The implication of this result is that the salinity contribution cannot be neglected in estimating the change of the ocean heat content through anomalies in the sea surface height derived from the satellite altimetry.

Keywords: steric, satellite, altimetry

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Oral Presentation

6045

Identification of a new subsurface water mass in the Tropical Pacific Ocean from ARGO data analysis

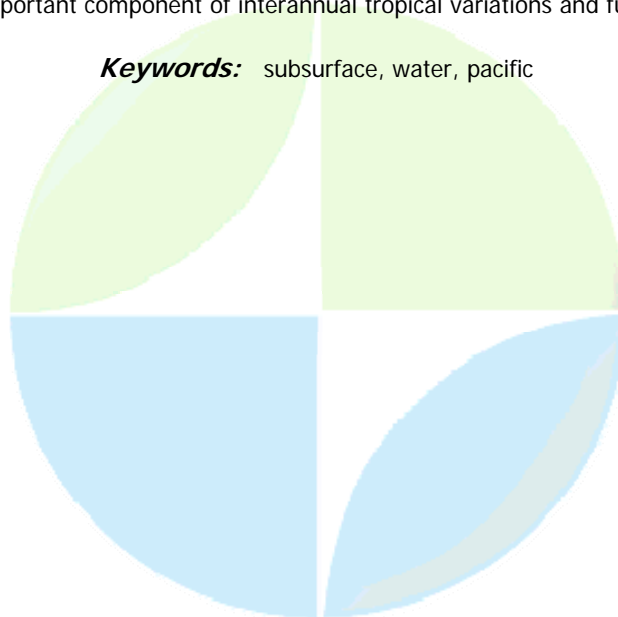
Dr. Fan Wang

CAS Key Laboratory of Ocean Circulation and Waves Institute of Oceanology IAPSO

Yanhui Zhang, Nan Zang, Dunxin Hu

The western tropical Pacific Ocean is known a crossroad of water masses at depth, among which the subsurface North Pacific Tropical Water (NPTW) and South Pacific Tropical Water (SPTW) are formed in the central Pacific where evaporation is larger than precipitation and featured as vertical salinity maximum. The NPTW was reported to enter the Celebes Sea via the Mindanao Current and then feed the Indian Ocean via the Indonesian Throughflow, or return to the Pacific, while the SPTW to enter the northern hemisphere via the NGCUC, its shallow part then turn to the east while the deep part spreading northward and feeding the Mindanao Undercurrent. Therefore, the subsurface water masses in the western tropical Pacific have strong tie with exchanges between gyres, hemispheres, and oceans. In this study, delayed mode Argo data gathered during 2002-2005 and CTD data in the WOD01 dataset were used to study the distributions of the subsurface water masses in the western tropical Pacific. To separate different subsurface water masses with similar salinity, the salinity extremes of each profile in the subsurface layer between $22.5 \sigma_{\theta}$ and $25.5 \sigma_{\theta}$ were used to trace the spreads of water masses with their salinity cores kept, instead of defining salinity values as boundaries between water masses. Besides of the NPTW and SPTW, a new subsurface water mass also featured as vertical salinity maximum was found between 5N and 10N and centered at $24.0 \sigma_{\theta}$, with salinity maximum (34.8 psu) lower than those of the NPTW (35.2 psu) and SPTW (35.6 psu) in the western pacific. The subsurface water seems to be formed in 140W - 110W , 15N - 25N where evaporation is larger than precipitation. It subducts and spreads southward carried by southeastern recirculation of subtropical gyre, and then joins tropical gyre recirculation as moving westward carried by the North Equatorial Current. Its remnant spreads westward as far as reaching the western boundary. The subsurface water called as the Pacific Tropical Water (PTW) in this study can be identified as a water mass different from the NPTW, because the former is obviously fresher than the latter, sourced from the area more southeastward and closer to ITCZ, and directly joins tropical gyre recirculation and shallow overturning. Therefore, the WPTW might be an important component of interannual tropical variations and further study is needed.

Keywords: subsurface, water, pacific



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PS010

Oral Presentation

6046

Indian Ocean - Monsoon coupled interactions and impending monsoonal droughts

Dr. Krishnan Raghavan

ArgoGODAE Symposium, Perugia, Italy - July 2007 The 24th Assembly of the IUGG, Perugia, July 2007 IAG

K. V. Ramesh, B. K. Samala

An investigation of the nature of ocean-atmosphere coupled interactions, on intra-seasonal time-scales in the tropical Indian Ocean region, is carried out by analyzing subsurface temperature measurements from Argo floats and XBT observations; ocean model simulations and satellite observations of surface winds and sea level anomalies for the period (2002-2005). It is seen that the intra-seasonal variations of the monsoonal winds produce significant changes in the thermocline depth leading to anomalous SST gradients in the equatorial region. In turn, the anomalous SST gradients are found to influence the intra-seasonal variability of surface winds and convective activity over the equatorial region and the Indian subcontinent. The results suggest that ocean-atmosphere coupled interactions on the intra-seasonal time-scale in the tropical Indian Ocean play a key role in forcing extended monsoon-breaks, thereby leading to occurrence of droughts over the subcontinent.

Keywords: monsoon, indian ocean, coupling

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Oral Presentation

6047

How well can ARGO measure heat storage and its variability in the North Atlantic Ocean ?

Dr. Neil Wells

United Kingdom National Oceanography Centre IAPSO

Rachel E Hadfield, Dr Simon Josey

Since 1999, Argo floats have collected almost 50,000 temperature profiles in the North Atlantic Ocean. The accuracy with which this dataset can be used to estimate the upper ocean temperature and heat storage in the North Atlantic has been investigated. A hydrographic section across 36N was used to assess uncertainty in the temperature field. The RMS difference in the Argo based temperature field relative to the section measurements is about 0.6 C. In comparison, the difference of the section with respect to the World Ocean Atlas (WOA) is 0.8 C. For the upper 100 m, the improvement with Argo is more dramatic, the RMS difference being 0.56 C, compared to 1.13 C with the WOA. The Ocean Circulation and Climate Advanced Model (OCCAM) was used to determine the Argo sampling error in mixed layer heat storage estimates. Using OCCAM subsampled to typical Argo sampling density, it is found that outside of the western boundary, the mixed layer monthly heat storage in the subtropical North Atlantic has a sampling error of 10-20 Wm⁻² when averaged over a 10x10 area. This error reduces to less than 10 Wm⁻² when seasonal heat storage is considered. Further results will be presented that demonstrate closure of the heat budget to within 10 Wm⁻² in the central and eastern subtropical ocean.

Keywords: heat storage, heat fluxes, variability

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Oral Presentation

6048

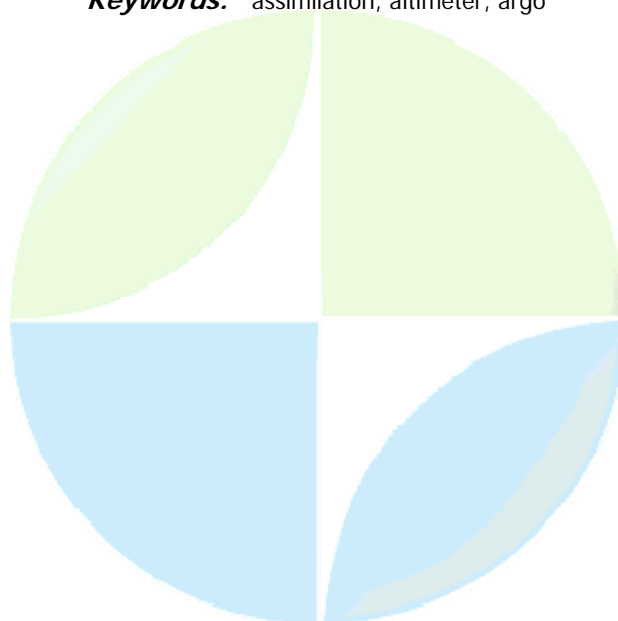
Assimilating altimeter sea surface height data into the FOAM operational ocean forecasting system

Dr. Matthew Martin
Ocean Forecasting Met Office

Adrian Hines

The Forecasting Ocean Assimilation Model (FOAM) system produces operational short-range forecasts of the deep ocean every day. It assimilates in situ and satellite sea surface temperature data, in situ temperature and salinity profile data (including Argo data), and along-track altimeter sea level anomaly (SLA) data into various resolution models, including a $1/9^\circ$ model of the North Atlantic. The method used to assimilate the SLA data is the Cooper and Haines (C-H) scheme. The idea behind this scheme is to displace vertically the model profiles of temperature and salinity so that the displacement of the top surface matches that of the data. The scheme preserves the model T-S relationship and hence cannot correct for errors or drifts in the T-S structure during the ocean analysis period. Altimetry does not give an absolute height displacement, but rather it provides the displacement relative to a 7 year annual mean (1992-8). The C-H scheme however requires an absolute sea-level. Thus a mean dynamic topography (MDT) is required from some other source. Using altimetry data can provide information on the ocean variability and on the seasonal cycle but not on the mean state. Corrections to the mean state can come through the use of the MDT. If this MDT is of high quality and is compatible with the model, these corrections can be advantageous, but conflicts between the model mean state and the MDT used can occur. The ocean model component of FOAM is currently being transitioned to use the NEMO modelling framework. As part of this work, various aspects of the altimeter data assimilation have been investigated. In particular, the question of whether to use the models MDT or an observed MDT has been addressed. Related to this is the extent to which the in situ profile data and SSH data are consistent, and the effect of the MDT on this consistency. The strategy for updating the model based on the analysis increments, including the spreading of the increments in time and the effect of geostrophic balancing increments, has been investigated. The results of these investigations will be presented, together with the validation of a hindcast using NEMO in which the altimeter data are assimilated.

Keywords: assimilation, altimeter, argo



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Oral Presentation

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The impact of assimilating Argo data into the UK Met Office FOAM system

Dr. David Acreman

Ocean Forecasting R&D UK Met Office

Matt Martin

The UK Met Office Forecast Ocean Assimilation Model (FOAM) produces real-time analyses and forecasts of the temperature, salinity and currents of the deep ocean up to five days ahead. Assimilating Argo profiles into the FOAM system has been shown to improve model temperature and salinity fields in 5 year long hindcast runs. The assimilation of Argo data not only improves the model temperature and salinity but also has an impact on derived fields such as mixed layer depth and sound speed profiles.

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Oral Presentation

6050

Oceanic response to the Madden-Julian Oscillation as observed by Argo

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Prof. Karen J. Heywood, Dr. Adrian J. Matthews

Argo floats offer an unprecedented opportunity to study subsurface variability on various timescales. The Madden-Julian Oscillation (MJO) is the dominant mode of intraseasonal variability in the tropical atmosphere, with a typical timescale of 30-90 days. Using the Argo data set, we show that changes in atmospheric forcing associated with the MJO, i.e. anomalies in surface wind stress, surface heat flux, and precipitation/evaporation, induce changes in the upper ocean structure. Although changes in sea surface temperature (SST) are well documented, this is the first time that a significant effect of the MJO has been documented at depth in the ocean, and in salinity as well as temperature. Temperature and salinity from Argo floats in the Indian and Western Pacific Oceans from 2003 to 2005 inclusive were mapped to a regular weekly-mean grid with one-degree horizontal and five-metre vertical resolution. Composites of SST anomalies during MJO events show the well-known pattern in which SST variability lags surface heat flux by a quarter of a cycle. This signal extends to 50 m. Below that, an MJO-related signal is seen to a depth of 1000 m in the equatorial Pacific that is out of phase with the surface signal, because the thermocline is raised and lowered by propagating waves in response to surface wind stress. Composites of salinity anomalies show complex patterns due to the existence of the surface fresh pool in the western Pacific and the subsurface salinity maximum in the central Pacific. Salinity anomalies at these interfaces vary out of phase of each other when the haloclines are raised or lowered in response to surface wind stress.

Keywords: madden julian oscillation, argo, salinity



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Oral Presentation

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Preliminary observed lateral West to East changes of dry season (2004 - 2006) ARGO derived SST and SSS in the Gulf of Guinea:

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Dry season in the Gulf of Guinea is usually between the months of October to March annually. Sea surface temperature and salinity measurements derived from Argo floats are assessed between longitudes 100W to 8.50E of latitudes 0.40N to 4.50N in the Gulf of Guinea. Lateral variations in sea surface temperature profiles were observed from west to east within the region. In the west (around 5.70W and 4.20N), sea surface temperatures averaged about 20.90C while sea surface salinity averaged 35.6‰. In the east (around 4.70E and 4.20N) sea surface temperatures averaged 28.40C while salinity averaged 32.3‰. Lateral primary thermocline changes were also observed along these two sectors in the Gulf of Guinea. The observed lateral dry season changes in the Argo derived sea surface temperature and salinity in the Gulf of Guinea could enhance knowledge of metocean dynamics and climate variability in the region. Lateral primary thermocline changes were also observed along these two sectors in the Gulf of Guinea. The observed lateral dry season changes in the Argo derived sea surface temperature and salinity in the Gulf of Guinea could enhance knowledge of metocean dynamics and climate variability in the region.

Keywords: gulf of guinea, seasurface temperature, salinity

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Oral Presentation

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**Analysis of the annual cycle of the oceanic heat budget of the mixed layer
in the Atlantic using different surface flux products**

Dr. Claudia Schmid

NOAAAOMLPHOD NOAAAOMLPHOD

Rick Lumpkin, Xiangdong Xia

A better understanding of the mixed layer heat budget in the tropical Atlantic is important for climate research and prediction. Of particular interest are regions where the heat balance is not dominated by the surface heat fluxes. Such regions include, for example, the equatorial cold tongue and the coastal upwelling regions off Africa. The approach is based on the analysis of a wide range of insitu and satellite observations covering the years 1992-2006. Hydrographic profiles are used to derive a time series of the monthly heat storage rate. The oceanic heat transports for 1998-2005 are derived from drifter observations in conjunction with geostrophic velocities from altimetric fields and Ekman currents from scatterometer winds. An annual climatology of the heat storage rate and the oceanic heat transport from this time series is compared with time series of the surface heat flux from different products (e.g. Da Silva, Southampton Oceanography Centre (SOC), ECMWF 15 and 40 year reanalysis (ERA15, ERA40), NCEP/NCAR reanalysis project). It is well known that these surface flux products have differences in the annual means, both regionally and globally. In some regions there are also differences in the characteristics of the variability. For example, in the tropical South Atlantic (10-3S, 15-0W, equatorial cold tongue), all the products are dominated by the annual cycle, but the months with the smallest/highest net surface flux are not always the same. The amplitude of the annual cycle varies quite a bit as well (100 W/m² to 150 W/m²). Most products indicate a net gain of heat that needs to be compensated by the oceanic transport and entrainment. For some surface flux products the heat budget can be closed very well throughout most of the year (Da Silva, SOC constrained, and NCEP reanalysis annual cycle from 1992-2006 data). In the upwelling region off Africa (30-10W, 3-15N) the heat storage rate is dominated by a semi-annual cycle. Most surface flux products also have a semi-annual cycle of similar amplitude, with a positive almost constant offset of 30-70 W/m² (Da Silva, SOC constrained and unconstrained, and NCEP reanalysis annual cycle from 1992-2006 data). Currently, the amount of oceanic observations does not allow a closure of the heat budget in this region.

Keywords: mixedlayer, heabudget, atlantic



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Oral Presentation

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Now Cast Global Current Fields: A Feasibility Study of Using Argo trajectory data to produce Monthly, 4-D, Ocean Current Maps

Dr. Fengying Ji

ArgoGODAE symposium Argo IAPSO

Lin Shaohua

First, an operational Argo trajectory data QC system is set up, which is used to check the Argo float clock drift and jump, and delete the abnormal location time and position data. Second, the global real time surface current and Argo float parking depth current are derived from Argo trajectory data based on Park (2006) method. Third, P-Vector method (Peter, 1992) is used to calculate the absolute velocity by Argo parking depth velocity and hydrographic data. Based on the foregoing work, the monthly, 4-D, Ocean Current Maps are produced.

Keywords: argotrajectory, oceancurrent



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Oral Presentation

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New perspective on Mode Water studies: Review

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Mode water studies are greatly progressing and seem to be now facing to new stage. Especially, accumulated Argo data bring new findings and insights in this research field. In this paper, I summarize the Mode Water studies done since the previous review (Hanawa and Talley, 2001) and will give some comments on future studies. (1) Finding of new Mode Waters: The North Pacific Central Mode Water (NPCMW) was divided into denser type and lighter type. Transition Region Mode Water (TRMW) was newly found in the North Pacific. The Indian Ocean Subtropical Mode Water (IOSTMW) was described. (2) Detailed description of property change of Mode Waters: Argo data with temporarily and spatially high resolution enabled us to describe the mixing nature of Mode Waters and surrounding waters. In general, Eastern Subtropical Mode Waters (ESTMW) quickly lose their properties due to the double diffusive convection in their lower portions. (3) Mode Waters and reemergence of wintertime SST anomaly: Co-located-type reemergence areas of wintertime SST anomalies were found to coincide with Mode Water formation regions. STMW in the North Pacific was found to have remote-type reemergence area too, since NPSTMW is formed in the strong current (Kuroshio Extension) region. (4) Formation mechanism and subduction process of Mode Waters: Numerical approaches were made to clarify the Mode Water formation and subduction processes. (5) Biogeochemical process related to Mode Waters: Chemical sensors measuring Chlorophyll-a and dissolved oxygen were installed on Argo floats and provided interesting biogeochemical process in Mode Waters.

Keywords: mode water, argo, reemergence



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Oral Presentation

6055

Spreading of the Antarctic Intermediate Water in the Atlantic derived from Argo and other observations

Dr. Claudia Schmid

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Silvia L. Garzoli, Elizabeth Forteza

The Antarctic Intermediate Water (AAIW) is part of the upper branch of the Meridional Overturning Circulation in the Atlantic Ocean. The general pathway to the north starts with the subtropical gyre in the South Atlantic. In the southern branch of the gyre water from Pacific origin subducts to form the fresher variety of this water mass. It also mixes with older AAIW that has recirculated around the subtropical gyre. In the eastern Atlantic (mainly in the Cape Basin) this blend of AAIW mixes with more salty AAIW from the Indian Ocean. In the northern branch of the subtropical gyre the AAIW reaches the western boundary near the Rio Grande Rise where it splits into northward and southward branch. The northward branch eventually crosses the equator, but it also feeds into the complex system of zonal currents of the tropical Atlantic. This pattern was derived from observations widely scattered in space and time. Now a more precise picture can be derived thanks to the much larger data density achieved largely with profiling floats. A combination of hydrographic, Lagrangian and quasi-Lagrangian data is used to increase the understanding of the spreading of the AAIW in the Atlantic Ocean. The hydrographic data are used to follow the salinity minimum and to study the change of the temperature-salinity relationship, especially in the regions where the different blends of AAIW mix. The quasi-Lagrangian and Lagrangian observations from profiling and other floats are used to derive the flow field and estimate transports.

Keywords: watermass, spreading, mixing



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Oral Presentation

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**The GODAE/Mercator-Ocean global ocean forecast and analysis system,
assimilating ARGO temperature and salinity profiles.**

Dr. Marie Drvillon

MERCATOR-OCEAN cerfacs IAPSO

***M. Benkiran, R. Bourdall-Badie, L. Crosnier, E. Dombrowsky,, Y. Drillet, E. Durand,
N. Ferry, G. Garric, S. Guinehut, E. Greiner,, O. Le Galloudec,, F. Hernandez,, J.-M.
Lellouche, L. Nouel,, L. Parent,, C.-E. Testut,, B. Tranchant, N. Verbrugge***

The Mercator-Ocean global ocean forecasting and analysis system was designed in the framework of the international GODAE program and the European MERSEA program for operational oceanography. The system comprises NEMO (Nucleus for European Models of the Ocean) which presently includes the latest version of the OPA ocean model, coupled to the thermodynamic-dynamic sea ice model LIM2 (Louvain sea Ice Model). The global configuration, developed jointly with the DRAKKAR project, has a horizontal resolution and 50 levels on the vertical, with a special focus on the first 300 m of the ocean. The assimilation component of the Mercator-Ocean system SAM2, is based on a reduced-order Kalman filter (the SEEK or Singular Extended Evolutive Kalman filter). The error statistics are represented in a sub-space spanned by a small number of dominant 3D error directions. The data assimilation system allows to constrain the model in a multivariate way with Sea Surface Temperatures (RTG-SST), together with all available satellite Sea Level Anomalies, and with in situ observations from the CORIOLIS database, including ARGO floats temperature and salinity measurements. The first ocean analyses performed with this new PSY3v2 system are compared with analyses from the previous PSY3V1 version of the system, which did not assimilate in situ measurements and SST data. Although some improvements of the system are due to the new model parameterisations and data assimilation technique, the results show the importance of constraining the system with in situ measurements from the ARGO program, which has a major impact on the quality of the real time estimations of the 3D ocean state.

Keywords: model, assimilation, operational



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Oral Presentation

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Reconstructing global ocean variability using a physically-based data assimilation method

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Keith Haines, Dan Lea, Ben Macdonald

Our focus is on improving the realism of ocean data assimilation schemes and using assimilation to investigate ocean climate signals. The main aim is to produce a high-resolution reconstruction of the global ocean over the last 50 years, assimilating temperature and salinity observations. The relative abundance of collocated temperature and salinity observations provided by Argo are used to develop an assimilation scheme whereby temperature and salinity profiles are assimilated on isotherms and isopycnals. This allows us to exploit the larger spatial and temporal decorrelations of these quantities, compared with assimilation on geopotential surfaces, allowing flow dependent assimilation and recovery of water mass information. Two configurations of the NEMO ice-ocean model will be employed in this study. A 1 degree resolution version with a tropical enhancement to 1/3 degree will be used mainly for testing and sensitivity studies, while the degree DRAKKAR version will be used to perform the high-resolution reanalysis. Results from a series of experiments over the Argo period, assimilating on depth, temperature and density surfaces will be presented. Preliminary results from a first 50 year reanalysis using this model-data synthesis method will also be shown.

Keywords: data assimilation, reanalysis, argo

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Utilizing ARGO data to improve short-term climate prediction

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In this study, the Argo observational data are assimilated into the Beijing Climate Center-Global Oceanic Data Assimilation System (BCC-GODAS). The results indicated that the application of Argo observational data in BCC-GODAS leads to notable improvement in assimilation results. Compared with observational data, the assimilated SST of BCC-GODAS can well describe the climatological states of SST. A global atmosphere-ocean coupled model is also used to perform contrast experiments in order to explore the improvement of the seasonal predictability for the boreal summer rainfall influenced by the oceanic assimilation system with or without Argo observational data. Firstly, the global oceanic data assimilation system is utilized to get oceanic assimilation data with or without Argo observational data. Then the global atmosphere-ocean coupled model is used to make hindcast experiments for the summer rainfall using the two sets of the assimilation data as initial oceanic conditions, respectively. The results indicate that when initial oceanic field with Argo observational data are used, the seasonal predictability of the summer rainfall, especially in China is raised a great deal. The distribution of summer rainfalls over China hincasted by the atmosphere-ocean coupled model with Argo data is more consistent with observations than that without Argo data. The area of positive correlation between hindcasts and observations becomes larger, and the hindcast skill for summer rainfall over China is improved significantly compared with the situation when no Argo data is used.

Keywords: argo, data assimilation, seasonal prediction



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Oral Presentation

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Sea surface salinity variation detected by the Argo float array in the World Ocean: Evidence of an enhanced hydrological cycle?

Dr. Shigeki Hosoda

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Toshio Suga, Nobuyuki Shikama, Keisuke Mizuno

Surface salinity distributions observed by the Argo floats were analyzed in the World Ocean. The salinity is important factor of seawater density such as temperature. Unlike temperature anomalies, salinity anomalies in the surface layer do not change directly precipitation and evaporation (E-P), which would restore salinity levels; therefore, signals of salinity variations tend to be conserved and survive in the ocean. Some studies have examined long-term or linear trends in salinity variation using limited historical salinity data for the middle and deep layers. However, few detailed investigations have examined the spatial and temporal variation in the surface salinity because of the lack of salinity data, although surface salt is the origin of middle and deep layer salinity. Recent ocean observations by the Argo float array have enabled documentation of changes in large-scale ocean variation. Therefore we used the Argo float data to show the distribution of surface salinity anomalies in the World Ocean and their relation to change of a global hydrological cycle. Based on annual mean salinity (WOA01), recent surface salinity is generally fresher (saltier) in the subpolar and tropical regions (subtropical region), while the salinity in the subpolar North Atlantic region is saltier. The spatial contrast of negative/positive salinity anomalies tends to clarify that of low/high annual mean salinity and also that of negative/positive annual mean E-P flux. Unfortunately, observations of basin-scale E-P flux distributions are difficult at the sea surface; therefore, surface salinity variation is an effective measure of detecting accumulated E-P flux anomalies. According to the simple calculation of the E-P flux anomalies, the global hydrological cycle is enhanced about 1 % in a few decades. Our results show that the hydrological cycles are enhanced in the global atmosphere-ocean system and that the global change may be associated with global warming.

Keywords: argo float, surface salinity, hydrological cycle



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Oral Presentation

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The seasonal cycle of salinity in the Indian Ocean from Argo and Hydrobase

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The rapidly expanding Argo dataset is providing incredible insight into the variability of ocean salinity. We have combined 8 years of Argo temperature and salinity profiles in the Indian Ocean with profiles from the Indian Ocean Hydrobase to estimate the seasonal cycle of salinity on potential temperature surfaces from 2000 m to the sea surface. Using robust linear regression, we have fitted a linear climate drift, and annual and semi-annual harmonics to the data. In this talk we describe the seasonal evolution of salinity throughout the Indian Ocean. We then focus on the southeast Indian Ocean, giving examples of strong seasonal variation and identifying their likely cause.

Keywords: salinity, indian, seasonal

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Oral Presentation

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Improving Ocean Climatological Fields using Argo and Altimetry

Mr. Ken Ridgway

Marine & Atmospheric Research CSIRO Marine & Atmospheric Research IAPSO

Jeff Dunn

The dramatic build-up of global Argo sampling provides for the first time the capability of producing accurate climatological fields for a common period of the modern era. Multiple temperature and salinity profiles are now available for previously unsampled remote ocean regions. However, shortcomings in the coverage remain. High variability western boundary current eddy fields, continental slope and shelf boundaries and topographic complex regions may all be below their optimal sampling requirements. We describe several simple methods to supplement and improve standard interpolation schemes and apply them to the available data within the southwest Pacific region. This region includes a major current system, the East Australian Current, complex topography, and large ENSO related interannual variability in the north. The first method simply uses satellite data (SST & SLA) to directly correct sampling errors in in situ derived mean surface height and temperature fields. The surface correction is projected through the water column (using an empirical model) to modify the mean subsurface temperature fields. The second approach uses mean fields from the historical archive (1900-1990) as a first-guess with adjustments from the recent data, following standard OI methods. Additional techniques are tested such as removing spatial and temporal clusters of data, applying anisotropic spatial scales, and an interannual correction based on the Southern Oscillation Index. The errors inherent in all these calculations are examined and the results compared with simply expanding the correlation length scale (increased smoothing) - how much realistic extra spatial structure may be extracted? The mean fields are compared with independent estimates on repeated XBT sections, a mooring array and full-depth CTD transects. The structure of the mean surface height shows significant change south of 30S and adjacent to the western boundary. This is associated with an adjustment of the EAC separation and poleward extension.

Keywords: ocean interpolation, southwest pacific, climatology



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Oral Presentation

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Dynamical ocean state estimation using recent Argo profiling data

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Toshiyuki Awaji, Nozomi Sugiura, Takahiro Toyoda, Yoshihisa Hiyoshi, Hiromichi Igarashi

The monitoring system using Argo floats is nearly completed, and nearly 3000 floats are providing high-quality temperature-salinity profiles from the sea surface to the depth of 2000m in the world's oceans. Within this background, our 4-dimensional variational (4D-VAR) data assimilation experiment has attempted to obtain an objective mapping of the oceanic state in the global ocean using all available observational data and particularly recent Argo profiling data (2000-2006). The 4D-VAR approach is an attractive prospect for modern oceanography because it provides the best possible time-trajectory fit to the observations and hence can create a dynamically self-consistent dataset offering greater information content on the oceanic state than can be derived from models or data alone. The obtained reanalysis field shows good consistency with previous knowledge of the ocean state and also its time-change. For example, density structures in the upper layer of the subarctic North Pacific, which are characterized by the maximum and minimum potential temperature in a vertical location, are successfully reproduced. The dynamical self-consistency of obtained reanalysis field enables us to clarify the water mass formation and movement processes, which should improve our understanding of the structure of the density field (or the current system) in the real ocean.

Keywords: data assimilation, argo, reanalysis



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Oral Presentation

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A global 4D-Var data assimilation experiment with a fully coupled GCM

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Toshiyuki Awaji, Shuhei Masuda, Takashi Mochizuki, Takahiro Toyoda, Toru Miyama, Hiromichi Igarashi, Yoichi Ishikawa

A four-dimensional variational (4D-Var) data assimilation system with a fully coupled global ocean-atmosphere-land surface model has been successfully developed with an aim to better define both mean structure and temporal evolution of coupled seasonal to interannual phenomena. Application to state estimation of global climate during the period from 1996 to 1998 shows, for example, that the structure in the tropical Pacific region becomes extremely realistic and hence the atmospheric condition associated with the 1997/98 El Nino event is better represented. An optimal synthesis of observational data and coupled model provides suitable oceanic initial conditions to the El Nino evolution together with the adjustment of coupling intensities regarding the air-sea exchange of fresh water, momentum, and heat. These data well reflect the realistic trend of seasonal to interannual variabilities, thereby enabling us to offer a 9 month-long lead predictability for the El Nino. These results suggest that our 4D-Var coupled data assimilation system has an ability to provide superior state representation and forecast potential than earlier assimilation methods.

Keywords: coupled model, 4d var, assimilation

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Interannual variabilities of eastern subtropical mode waters in the North and the South Pacific identified from reanalysis datasets obtained by 4DVAR data assimilation

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The interannual variabilities of the eastern subtropical mode waters (ESTMWs) in the North and the South Pacific Ocean are investigated using the ocean reanalysis dataset obtained by our 4-dimensional variational data assimilation experiment in 1990s. In the North Pacific, the fresh formation of the ESTMW shows a distinct interannual variability, which is explained by the interannual variability of 3 factors: 1) salinity convergence by Ekman flow in the preconditioning phase, summer and autumn, 2) solar insolation affected by stratocumulus amount in the preconditioning phase, and 3) wintertime surface cooling. This is consistent with the climatological formation mechanism by Toyoda et al. (2004). Further, we have examined the counterpart in the South Pacific whose formation mechanism is suggested to be similar in previous studies. In doing so, we focus on the relationship to the ENSO phenomena. These investigations may provide an appropriate benchmark in the data assimilation products for realistic reproduction of water masses formation and movement that closely relate to the mixed layer variability and subduction processes.

Keywords: 4dvar, mode waters, interannual variability



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Oral Presentation

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**Improved CGCM Simulations for Process Studies of the Indian Ocean
Climate and the Asian Summer Monsoon**

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***Nozomi Sugiura, Toshiyuki Awaji, Toru Miyama, Takahiro Toyoda, Shuhei Masuda,
Hiromichi Igarashi***

To enhance accurate estimates of seasonal to interannual (S-I) variations over the Asian monsoon region and the Indian ocean by a coupled general circulation model (CGCM), the oceanic initial conditions and the bulk adjustment factors that control latent heat, sensible heat and momentum fluxes are optimized using a 4-dimensional variational data assimilation method. This is the first challenge to apply an adjoint method to a fully CGCM toward a realistic modeling of S-I climate variations. Both the climatological seasonal cycle and the interannual variations during 1997-1998 are better defined by this optimization. The optimized bulk adjustment factors primarily reduce the model biases in climatological fields and amplify the sea surface temperature anomalies relating to the Indian Ocean Dipole Mode event. In addition, better initialized water-temperature anomalies that propagate as tropical oceanic waves work to improve the thermal conditions of the upper ocean throughout the assimilated periods.

Keywords: assimilation, cgcm, 4d var

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Oral Presentation

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Heat content variations of the Indian Ocean and its relation with air-sea parameters

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K.V Ramesh

The ocean-atmosphere interaction plays a vital role in determining the climate variability. Studies have shown that tropical Indian Ocean plays an important role in seasonal to interannual variations in the seasonal mean circulations in the Indian subcontinent. As Indian Ocean is unique in experiencing semi-annual winds, its not clear that how the warming/cooling is distributed on both seasonal and annual time scales and its association with the overlying atmosphere on different time-scales. To study the upper ocean heat content changes of the Indian Ocean and its variability at various time scales we have used observed temperature profiles from the years 2002-2005 from ARGO floats (<http://www.ifremer.fr/coriolis>) and combined with available XBT and CTD observations (<http://www.aoml.noaa.gov/phod/trinanes>) over the Indian Ocean (Lon 40-100 deg E and Lat 30S:27 deg n). These data have been girded on a 1deg X 1deg for the period 2002-2005. The main objective of this study is to understand the observed variability in the upper ocean heat content and its associated impacts on the air-sea interactions in the Indian Ocean for the period 2002-2005. Along with seasonal and annual heat content changes, We have also studied the relationship between the observed change in heat content and air-sea parameters like sea surface temperature, surface winds and sea surface height anomaly. For this purpose we have used data from multi sources viz. ocean observations, NCEP reanalysis products, TMI derived SST and Quikscat winds. On an annual time scale warming is noticed in the Arabian Sea and cooling in Bay of Bengal and equatorial Indian Ocean. Results show that air-sea interaction in the Indian Ocean influences the upper ocean heat content and their relations are region specific. In the Arabian Sea and Bay of Bengal heat content variability is directly correlated with surface winds, SST and SSHA while Eastern equatorial Indian Ocean is negatively correlated with these parameters.

Keywords: heatcontent, indianoceanargo, seasonalvariations



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Oral Presentation

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Impact of the Incremental Analysis Updates on a Real Time System of the North Atlantic Ocean

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CLS Mercator-ocean IAPSO

Eric Greiner And Charles-Emmanuel Testut

We propose a new ocean data assimilation algorithm based on the Reduced-Order Optimal Interpolation (ROOI) technique, which calculates corrections for model fields such as it remains consistent with a priori statistical and dynamical information. The algorithm uses 1-D vertical multivariate Empirical Orthogonal Functions (EOFs of temperature, salinity, horizontal baroclinic velocities profiles and the barotropic streamfunction) to unravel statistically-coherent information from the observation. We assimilated both temperature and salinity profiles, sea surface temperature and altimeter data. It is then applied to a 1/3 gridded model of North and Tropical Atlantic ocean between 20S and 70N. At last, we used PALM coupler which provides a general structure for modular implementation of a data assimilation system, and makes easier the changes in analysis algorithm. After a brief presentation of the set of starting values as input to the model, we present recent results obtained with the multivariate multi-data system. We also compare statistically 7-day and 14-day forecast of the multivariate system. On the real time mode, we confront these results with the ones previously obtained by using IAU (Incremental Analysis Updates) in the North Atlantic region from Mercator-ocean.

Keywords: data, assimilation, operational

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Oral Presentation

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Transition Region Mode Water of the North Pacific and its rapid modification

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Hiroko Saito, Kimio Hanawa, Nobuyuki Shikama

Formation region and spatial distribution of Transition Region Mode Water (TRMW), which is a new type of pycnostad in the subtropical-subarctic transition region in the North Pacific, and its rapid modification are investigated based on the analysis of Argo float data. The examination of the formation field of water masses around the transition region shows that TRMW is formed in the wide area from the western to the central transition region, separated from the formation region of the denser variety of CMW (D-CMW) to the south by the temperature and salinity (T-S) front. T-S properties of the TRMW are 4-9C and 33.3-34.0 psu, which are colder and fresher than those of the D-CMW, with the significant volume in the density range of 26.3-26.6 σ_θ . Thick TRMW is distributed widely in the transition region. However, the core properties of TRMW are found to gradually get saltier and warmer to the downstream along the density surface; the cold and fresh TRMW pycnostad is eventually modified to the warm and salty D-CMW pycnostad within a year. Quasi-Lagrange observations by isopycnal-following Argo floats reveal that the mechanism of the rapid modification is salt-fingering double-diffusive convection. The analysis of time depending synoptic field inside the ocean provided by Argo floats presents the evidence that the modification due to this mechanism takes place in a wide area over the western to central transition region. It is demonstrated based on the analysis of climatology that the strong salt fingering is caused inside TRMW by geostrophic current with vertical shear crossing the density-compensating T-S front, which brings warm and saline water with similar density to the upper part of TRMW and results in unstable stratification of salinity.

Keywords: isopycnal argo float, salt fingering, subduction



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Oral Presentation

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A system for monitoring of mesoscale structures in the Japan Sea based on ARGO, altimetry and SST data

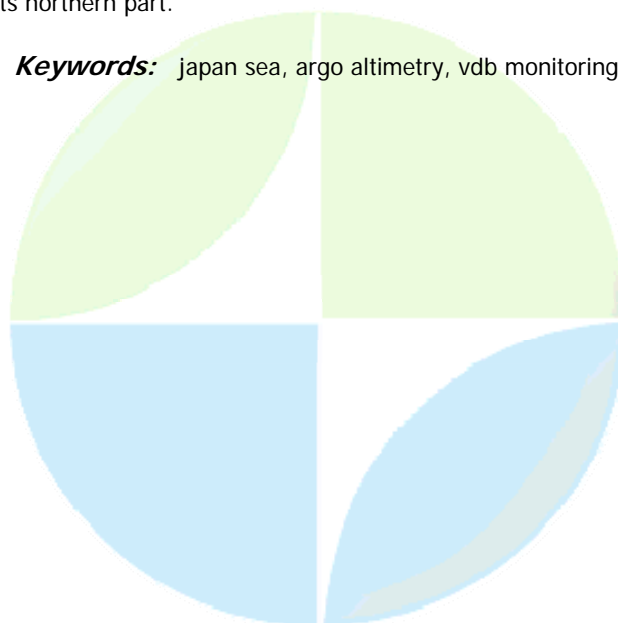
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V.I. Il'ichev Pacific Oceanological Institute senior research scientist IAPSO

Timofei A. Gulenko, Svetlana Yu. Ladychenko

Mesoscale water dynamics associated with meandering streams and eddies is an important component of circulation in the Japan Sea. The trajectory and CTD data obtained from ARGO profiling floats have been widely used now for study of inertial motions from global to regional scale including water dynamics of the Japan Sea. CTD profiles of ARGO merged with the CTD data from the ship-borne observation could give detailed information on the water mass structure from basin scale to mesoscale features. The examination of the float track provides useful information on deep currents. Much higher spatial and temporal resolution data may be obtained from satellite altimetry that provides a field of sea surface height (SSH) anomaly and satellite infrared images providing sea surface temperature (SST) pattern. Here we describe our monitoring/assimilation system based on Virtual Database (VDB) technology implemented through the World Wide Web network dedicated to study mesoscale structures in the Japan Sea. Our tool for assessing dynamic and water mass characteristics of mesoscale eddies is based on using merged dataset of ARGO and NEAR-GOOS insitu data with the along track data obtained from the Version 2 of the TOPEX/POSEIDON Sea Surface Height Anomaly (TPSSHA) the JASON-1 Sea Surface Height Anomaly (J1SSHA) dataset distributed by the Jet Propulsion Laboratory, Physical Oceanography Distributed Active Archive Center (JPL PO.DAAC), NOAA AVHRR infrared images data and New Generation SST (NGSST) daily data developed in Tohoku University by merging NOAA AVHRR infrared data, MODIS/Aqua and microwave AMSR-E/Aqua data. This provides sustained monitoring of the eddies and meanders which require detailed repeated surveys that are not feasible for major part of the world ocean. However for the area of the Japan Sea a current flow of hydrographic data available through Internet might be enough to resolve mesoscale structures and obtain in some cases detailed dynamic characteristics of eddies motion. Hence, in particular combination of available Argo floats, ship CTD, satellite altimetry and SST allows to improve investigation of mesoscale water structure in the Japan Sea and obtain kinematics, dynamics and water mass characteristics of even relatively weak anticyclonic eddies in its northern part.

Keywords: japan sea, argo altimetry, vdb monitoring



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Oral Presentation

6070

Estimate of Mediterranean Sea circulation by assimilation of in situ and satellite data

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CMCC

Nadia Pinardi, Claudia Fratianni, Vicente Fernandez, Marina Tonani

Starting from September 2004 eighteen ARGO floats were deployed in the Mediterranean as a part of the Mediterranean Forecasting System (MFS). Observations by these floats were assimilated using 1/16 degree horizontal resolution oceanographic model, together with other in situ and satellite observations in the Mediterranean, in order to produce daily oceanographic analyses. The assimilation of in situ and satellite data into the high resolution oceanographic model provides the estimates with a high spatial and temporal variability. Daily analyses give a possibility to detect at the same time the large scale variability and processes that govern the development of Mediterranean eddies. Here we present the major characteristics of the Mediterranean Sea circulation and variability estimated from MFS analyses.

Keywords: mediterranean, analyses



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Oral Presentation

6071

Comparing and combining Argo data with Altimeter data

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Anne-Lise Dhomps, Gilles Larnicol

Our ability in describing and understanding the ocean vertical structure strongly depends upon the availability of ocean observations. On the one hand, temperature (T) and salinity (S) profiles measurements from Argo profiling floats and other probes provide sparse in-situ data but with precise estimations of the ocean vertical structure every 10 days and for large part of the world ocean. On the other hand, satellite altimetry provides synoptic observations of sea level every 7 days and over the world ocean. Despite sea level being a surface signal, it reflects the state of the ocean at depths and makes satellite altimetry a powerful tool for studying global ocean dynamics and thermodynamics. The aim of the study is to analyze the differences and complementarities between altimeter and Argo profiling float T/S data at different time-scale from seasonal to interannual - and space-scale from basin-scale to global-scale. It is performed to analyze the physical content of altimeter measurements (e.g. barotropic/baroclinic signals), to better understand the vertical structure of the ocean and to detect systematic errors from one data type or the other. At seasonal and basin scales, the main application is to partition the ocean into barotropic and baroclinic modes needed for altimeter assimilation purposes and for altimeter/in-situ data combination. The sensitivity of the results on the latter application will be illustrated. At interannual and global scales, the main application is the study of global ocean sea level change and its thermosteric and steric parts. A careful estimation of sampling error from in-situ measurements is presented in terms of global trend and spatial tendency. The complementarities between thermosteric, steric (including salinity effects) and altimeter sea level are also studied in term of global trend and regional tendency for the last 14 years.

Keywords: barotropic baroclinic signals, global sea level change



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Oral Presentation

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Submerged trajectories and ocean velocity from Argo floats

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The majority of floats in Argo use the Argos data telemetry and positioning system. This provides position at a number of discrete times, typically once every few hours, while the float is on the surface broadcasting data. There are unknown displacements between arrival and departure from the sea surface and the first and last reported positions; also the reported positions are themselves subject to error. The simplest assumption is that the floats submerged displacement (and hence the ocean velocity at the floats drift depth) is the difference between the last reported position from one surface cycle and the first reported position from the next. Errors in the implied submerged displacements can be reduced if we are able to estimate the actual surface arrival and departure positions for each surface cycle. A variety of methods have been proposed for estimating surface arrival and departure positions, which involve fitting a trajectory while on the surface to the discrete time/position fixes, and extrapolating to the arrival and departure times. The present study involves two stages. First, published surface arrival and departure times have been checked for consistency, or estimated if the float does not report the information as part of its engineering data. Second, a number of different algorithms have been implemented and evaluated for the surface trajectory extrapolation. We present an analysis of errors in extrapolated positions, and an implementation that can be used to generate a single consistent submerged trajectory product for the global Argo fleet.

Keywords: argo, trajectories, currents



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Oral Presentation

6073

The regional Mercator-Ocean high resolution analysis and forecasting system : a benchmark for the future global high resolution forecasting system.

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MERCATOR-OCEAN CERFACS IAPSO

The Mercator Team

The international GODAE program offered a very favorable research and development context for operational oceanography. Mercator-Ocean, the French contribution to this program, is developing a series of ocean analysis-forecasting systems, increasing horizontal and vertical resolutions, improving models and assimilation schemes. In this contribution, we focus on the new regional high resolution system. The ocean model, called ATL12, is based on NEMO developed at LOCEAN (IPSL, Paris) and is designed to simulate the Atlantic and Mediterranean oceans between 20S and 80N with a 1/12 horizontal resolution and 50 levels on the vertical. This ocean model is coupled to the thermodynamic-sea ice model LIM2 (Louvain sea Ice Model). The last high resolution system used optimal interpolation to assimilate conjointly altimeter data, SST and in situ observations from the Coriolis database (temperature and salinity profiles, including ARGO data) in a fully multivariate way. The new system assimilates the same type of data, with a reduced order Kalman filter using 3D multivariate modal decomposition of the forecast error covariance. The use of 3D modal representation for the error statistics is intended to improve analyses in highly inhomogeneous and anisotropic regions of the ocean. After a brief presentation of this new high resolution forecasting system, we will present some validation results at all the circulation scales (from the large scale to meso-scale, and eventually sub meso-scale) modelled by the assimilative system when these scales are observed and acknowledged. Assessment and validation of this high resolution system is of crucial importance for the next global 1/12 high resolution system in the framework of MERSEA project.

Keywords: forecasting, assimilation, operational



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Oral Presentation

6074

The Global Ocean Data Assimilation Experiment (GODAE)

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Ifremer Ifremer IAPSO

The Global Ocean Data Assimilation Experiment (GODAE) has been running its main demonstration phase since 2004. Operational and research institutions from Europe, Australia, Japan and the United States are performing global ocean data assimilation and ocean forecast in order to provide regular and comprehensive depiction of ocean fields such as temperature, salinity and currents at high temporal and spatial resolution. Canada and China started more recently to develop a national contribution to GODAE. GODAE provides an integrated depiction of the ocean that combines remote sensing data, in-situ data and models through data assimilation. The way GODAE was developed as well as its main achievements and successes will be summarized. We will then review the use of Argo data by GODAE centers and the contribution of Argo to GODAE and its applications. Challenges and perspectives for the last phase of the experiment (2007-2008) will finally be highlighted.

Keywords: godae, argo, assimilation

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Oral Presentation

6075

Combining in situ and altimetry observations in a low resolution global ocean reanalysis

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Anthony Weaver, Marie-Helene Rio

Each week MERCATOR-OCEAN is delivering ocean predictions. Besides those operational activities, advanced assimilation techniques are also explored. The variational technique is applied to estimate the global low resolution ocean state in the context of reanalysis and ocean climate monitoring. Here we present a 1993-2001 reanalysis made with the ORCA 2 model (OPA, LODYC) and the OPAVAR assimilation code (A. Weaver, CERFACS) in its 3DVar version. In situ temperature and salinity observations are assimilated with along track Sea Level Anomalies. The problem of combining in situ and altimetry observations is address. Both data sets contain different information about the heat and salt content and this can lead to incoherencies due to misspecification of observation error, model error or to the choice of the Mean Dynamical Topography. We show the benefit of using a realistic MDT, as the one computed by Rio, compared to a model MDT. The ability of the assimilation to reproduce the observed variability in terms of heat content and sea level is demonstrated. The model acts as a spatial interpolator and gives us access to the entire water column properties, allowing us to get an estimation of the deeper changes in the heat content of the ocean and their spatial repartition. Contribution of the thermosteric, halosteric effects and mass fluxes to the sea level changes are also estimated. The remaining problem is the uncertainties of those estimations.

Keywords: assimilation, variational, reanalysis



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Oral Presentation

6076

Global Sea Surface Salinity and Temperature database from ARGO

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In the context of sea surface salinity remote sensing from space, the qualification and validation of the salinity products will require a global high quality sea surface temperature and salinity database. The ARGO project provides such an opportunity. A global surface database is assembled corresponding to observations made at the depth closest to the surface since 2001. To complement the ARGO real and delayed time qualification procedures, additional data checks are proposed and applied. Climatological mean and standard deviation are computed over 2 degrees by 2 degrees geographical boxes. The statistics are compared to World Ocean Atlas 2005 as well as satellite surface temperature products from the Advanced Microwave Scanning Radiometer (AMSR-E). A zonal-anomaly approach is proposed to analyze the combined surface temperature and salinity fields. Removal of an adequate temperature seasonal cycle proxy enables deriving more significant statistics for the parameter variability. The resulting surface temperature and salinity anomaly fields are shown to be highly correlated with well-known large scale dynamical structures of the ocean surface layer. On this basis, a classification method applied to these anomalies is developed to characterize dynamical regimes and the associated thermohaline variability. Further, a method is proposed to validate the future satellite salinity products.

Keywords: sea surface salinity, temperature database, argo

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Oral Presentation

6077

Quantitative and dynamical analysis of EDW formation using a model-data synthesis

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EAPS, MIT postoc associate IAPSO

John Marshall, Guillaume Maze

The formation of North Atlantic Eighteen Degree Water (EDW) is analyzed using observations and the MIT General Circulation Model (GCM). We focus on the past several years during which there was unprecedented data coverage due to the advent of ARGO and global microwave SST observations. Employing the ECCO adjoint modeling framework, the data are interpolated under the constraint of GCM dynamics leading to a quantitative and dynamical analysis of observed EDW signals. In the region in which EDW is formed, the constrained model solution is shown to faithfully represent the observed evolution of subsurface stratification and surface outcrops. Transformation rates are computed from estimated air-sea fluxes to place the model EDW volumetric census into perspective, and discuss the formation and mixing processes at work. The importance of the adjustments to the surface fluxes required to fit the model to the observations is investigated. Finally, an adjoint sensitivity analysis is presented to further assess the surface control of EDW formation.

Keywords: climode, argo, ecco

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Oral Presentation

6078

Development of a new ocean prediction system 'FRA-JCOPE' using hydrographical data monitored by Japanese fisheries research institutions

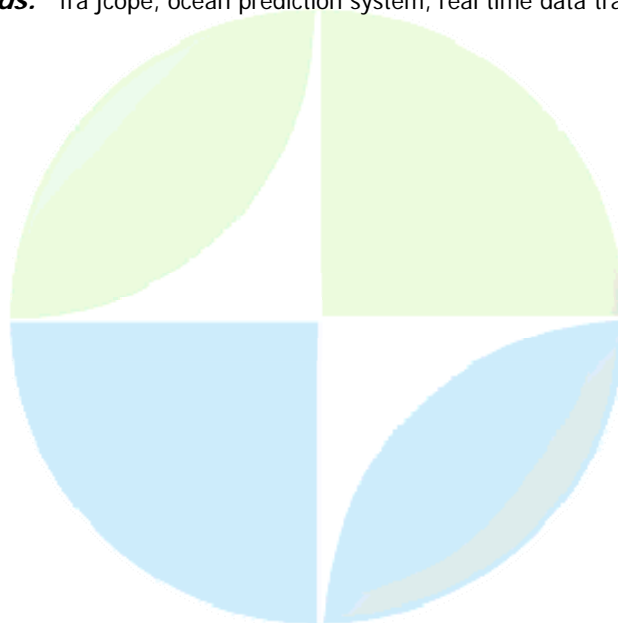
Dr. Kosei Komatsu

National Research Institute of Fisheries Science Fisheries Research Agency IAPSO

Takashi Setou, Yasumasa Miyazawa, Kazuyuki Uehara, Shin-Ichi Ito, Akira Kusaka, Shigeho Kakehi, Manabu Shimizu, Akira Okuno, Hiroshi Kuroda, Lee Jun-Su, Yugo Shimizu, Tomonori Azumaya, Hiroshi Yoshinari, Takahiko Kameda, Hideki Akiyama, Mitsuyuki Hirai

A new ocean prediction system, FRA-JCOPE, developed in the collaborative research between Fisheries Research Agency (FRA) and Japan Agency for Marine-Earth Science and Technology (JAMSTEC), has started operating this April. The system is based on the previous version of Japan Coastal Ocean Predictability Experiment (JCOPE) developed by JAMSTEC, which is composed of a POM based eddy-resolving OGCM and data assimilation method using satellite SSH/SST and in situ temperature/salinity profiles obtained by ARGO floats and ships. Japanese local fisheries research institutions (JFRI) conduct horizontally close-arranged observation, however most of their hydrographical data have not been reported in (quasi-) real-time via Global Telecommunications System (GTS) and therefore not been utilized in operational prediction systems including JCOPE. By developing and coupling a real-time data transfer and feedback system, FRA-JCOPE distributes the hydrographical data obtained monthly by JFRI via GTS and incorporates the data into a data-assimilation method composed of the sequential processes: gridding observational data with an optimal interpolation (OI), estimating T/S profiles with a multivariate OI (MOI), and noise elimination. After modification of the OI and MOI parameters correspondingly to incorporation of JFRI data, FRA-JCOPE increased reproducibility of distribution of mesoscale water masses off in the western North Pacific, caused by fluctuation of the Kuroshio and the Kuroshio Extension, variation of the Oyashio intrusion and formation of warm/cold eddies. The new system increased accuracy of the ocean forecast for fisheries off Japan and promoted ecosystem based managements of fisheries in combination with ecosystem models applied to each species of pelagic fishes.

Keywords: fra jcope, ocean prediction system, real time data transfer syste



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Oral Presentation

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Combination of altimetry and ARGO data for estimating the 3D ocean velocity field

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The ARGO array has been deployed for almost seven years now, almost reaching its maximum number of 3000 floats. In addition to measuring the temperature and salinity profiles of the upper 2000 m of the ocean, it provides an invaluable estimate of the ocean velocity at the float parking depth. The objective of this study is to evaluate how this information can be combined to the temperature and salinity measurements and to altimetric data to reconstruct the 3D ocean velocity field. ARGO velocity data at 1000m from the YOMAHA database are used and a focus is done on the North Atlantic area. The sampling capability of the ARGO array is a crucial issue to assess before any use of the data for scientific applications. The first step is therefore to examine the optimal spatio-temporal resolution that can be achieved using the ARGO array for depth velocity mapping, as a trade-off between resolution and accuracy. This information is then entered (in term of spatial and temporal correlation length), together with an estimate of the ARGO velocity errors, as input to a multivariate objective analysis procedure, for optimal mapping of the dynamic topography and corresponding circulation at 1000 m. In order to validate the obtained 1000 m dynamic topography field, we compare it to independent estimates computed subtracting the ocean dynamic heights at 1000 m deduced from the ARGO T/S profiles from simultaneous altimetric ocean dynamic topography values. Once the velocity at the ARGO parking depth has been mapped, the 3D circulation of the ocean can be reconstructed using the 3D Temperature and Salinity products from the ARMOR system (in which altimetric data and in-situ T/S profiles are combined to reconstruct the 3D temperature and salinity fields, Larnicol et al, 2006) The 3D ocean velocity field is finally compared to outputs from the MERCATOR system.

Keywords: argo, velocity, altimetry



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Poster presentation

6080

Seasonal Variability of Barrier Layer in the Arabian Sea

Dr. Pankajakshan Thadathil

Seasonal variability of Barrier Layer Thickness (BLT) in the Arabian Sea is examined utilizing the most comprehensive data set. Nearly 7000 profiles of temperature and salinity from the recently deployed Argo floats in the Arabian Sea contribute towards the major data source for this study. During winter monsoon (November-February) thick BL (30-50m) occurs in the Eastern/South-Eastern Arabian Sea. During summer monsoon (June-September) thick BL (30-50 m) is confined to the central and southwestern Arabian Sea. While thick BL during summer monsoon season is caused by Ekman convergence, the distribution of low saline water by the West India Coastal Current (WICC) causes the formation of thick BL in the Eastern/South-Eastern Arabian Sea. The thick BL in the Eastern/South-Eastern Arabian Sea during winter monsoon is characterised by surface layer temperature inversion. Whereas, surface layer temperature inversion was not associated with the

Keywords: barrierlayer, arabiansea, freshwater

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Poster presentation

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A new climatology of the surface mixed layer in the North Pacific based on the ARGO observation

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A new climatology of the surface mixed layer in the North Pacific is constructed using the Argo observations obtained from 2000 through late 2006. The climatology consists of monthly mean, 2X2 average mixed layer depth (MLD) and physical parameters such as temperature, salinity and density of the layer based on the observations. Optimal methods for the Argo observation are selected and used to evaluate the mixed layer depth for each density profile. Physical properties are also evaluated from each profile and then are averaged to obtain the value in each grid. This climatology is one of the very first attempts to construct the climatology from the Argo observation and is believed to show much more realistic features of the ocean mixed layer than those of the previous studies because they suffered from sparsity of the observation in most of the ocean basin before the Argo Era. The MLD climatology shows that clear seasonal variations are found north of about 20N. Fairly deep mixed layer develops in the western part of the subtropical and subarctic gyres, up to 250m in late winter while less than 30m of MLD is found in summer. In the region south of 20N, seasonal cycle is less apparent. Maximum MLD appears in December to January in the 20N-30N belt, January to February in the region 30N-40N, 130E-140W, March to April in 40N-50N, 180-140W in the central subarctic region and February to March in 40N-50N 140W-120W. The maximum MLD appears one to two months earlier than the month of mixed layer density takes its maximum in the northwestern part of the basin, the region to the east of Japanese Islands. On the other hand, in the northeastern part of the basin around the Alaska Bay, the month of the maximum MLD corresponds that of the maximum density in the mixed layer but the accumulated cooling is maximum about one month prior to the time of the MLD maximum. These facts strongly suggest that the mixed layer processes in the seasonal cycle are far from one dimensional.

Keywords: surface mixed layer, argo data, north pacific



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Poster presentation

6082

**Circulation near Ulleung Basin in the East /Japan Sea as studied from
ARGO data**

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Shree Ram Prakya

The surface features in the East Sea are remarkably rich with boundary currents such as East Korea Warm Current (EKWC), North Korea Cold Current (NKCC) and Tsushima Warm Current (TWC), with the existence of the permanent subpolar front situated in the middle of the basin, around which numerous eddies are generated. Besides, meso-scale warm eddies are well recognizable in various locations such as Ulleung Basin in the East/Japan Sea. Satellite images of Sea Surface Temperature and Sea Surface Height show surface oceanic features such as meso-scale warm eddies, fronts. However, the vertical extent of these features can not be studied by using satellite images due to the known fact that the measurements made by a satellite sensor only represents oceanic surface. In situ observations are essential to study the vertical extent of these features. ARGOS global array of profiling floats will provide the in situ observations in time and space. The present study aims on investigating the formation of Ulleung Eddy, its horizontal and vertical extent using the autonomous profiling ARGO floats data. The Ulleung Eddy originates from the EKWC and forms from a southward flow that closes into anticyclonic circulation around Ulleung Island. This could penetrate up to deeper depths (approximately 700 m) from the surface. The interaction between warm and cold waters both in the horizontal and vertical yields a high variability of circulation in the Ulleung Basin .

Keywords: east sea, argo float, subsurface circulation



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Poster presentation

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Indian Ocean Subtropical Mode Water

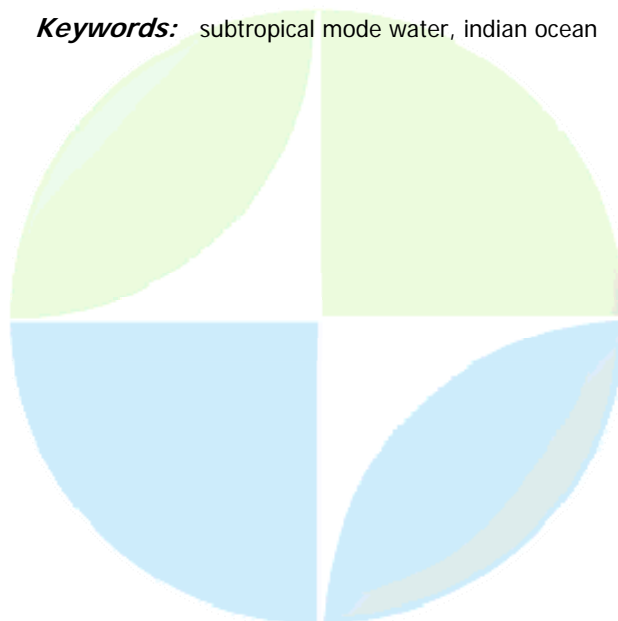
Mr. Takamasa Tsubouchi

Geophysics The Oceanographic Society of Japan IAPSO

Toshio Suga, Kimio Hanawa

It is generally recognized that subtropical mode water (STMW) is located in the western part of the subtropical gyre in each basin (Hanawa and Talley, 2000). However, spatial distribution of Indian Ocean STMW (IOSTMW) has not thoroughly been described yet and even its permanent existence is unclear. The western part of the Indian Ocean subtropical gyre has unique characteristics, such as overshooting and retroflexion of the western boundary current, Agulhas Current, before its separation from the coast and weak density (temperature) stratification at a depth of about 100 m to 800 m. In this study, we investigate spatial distribution and water characteristics of IOSTMW and answer the question whether IOSTMW exists as a permanent structure. Then, we suggest a simple criterion to detect IOSTMW based on temperature data. We will also discuss why there is no significant main thermocline in this area using Argo data. We used the HydroBase (Kobayashi and Suga, 2005) temperature and salinity data in the Southern Hemisphere summer. Through careful examination of vertical temperature gradient structure in this region, we confirmed the existence of a minimum layer of the vertical temperature gradient as a substantial water mass. This thermostat is located in the region of 30-50E and 33-38S with water characteristics of 16-17C, 35.3-35.5 psu and 25.8-26.2 $\sigma\theta$. As a result, we concluded that IOSTMW exists as a permanent structure in this region. The temperature of IOSTMW is lower by 1C than that recognized in the previous studies. It was also revealed that IOSTMW can not be detected as a minimum layer of vertical temperature gradient with any single criteria of vertical temperature gradient, because IOSTMW vertical temperature gradient changes zonally and the temperature stratification below IOSTMW is considerably weak. Though IOSTMW does not form the minimum layer of potential vorticity, IOSTMW forms a lateral minimum of potential vorticity on the 25.9-26.2 $\sigma\theta$ isopycnal surfaces. We suggest the criterion to detect IOSTMW as the temperature layer of 15.5-17.5C with thickness greater than 110 m. It will be shown that main thermocline is very weak possibly because IOSTMW above the main thermocline and Subantarctic Mode Water below that are mixed vertically due to salt fingering using Argo data.

Keywords: subtropical mode water, indian ocean



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Poster presentation

6084

The role of ARGO on the ECMWF operational ocean analysis system

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Seasonal Forecasting ECMWF

David Anderson, Arthur Vidard

The impact of ARGO on the new ECMWF ocean analysis system during the period 2001-2006 has been assessed by conducting a set of observing system experiments. The experiments evaluate the information content of ARGO temperature and salinity data, and its synergy with the altimeter data. The impact of ARGO is gauged in terms of its influence on the ocean state and its impact on skill of the seasonal forecasts.

Keywords: argo, ocean reanalysis, seasonal forecasts



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Poster presentation

6085

Negative bias of dissolved oxygen measurements by profiling floats

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IORGC JAMSTEC IAPSO

Toshio Suga, Nobuyuki Shikama

We report the performance of dissolved oxygen (DO) measurements by profiling floats deployed in the North Pacific by Japan Agency for Marine-Earth Science and Technology and Tohoku University. Compared with the shipboard bottle sampling observations at the deployments, the first DO profiles of floats show negative biases systematically: the biases on isothermal surfaces are about 0-10 $\mu\text{mol kg}^{-1}$ in the deep layer and then they increase in the upper layers. The maximum value of the biases exceeds 40 $\mu\text{mol kg}^{-1}$ in surface layer. These features are found in all floats and both Optode and SBE43. It is concluded that the negative biases of the sensors be greater than their nominal measurement errors even though a part of them must be caused by frontal variations. The larger biases are found in the layers with strong vertical gradient of DO, which suggests one of the major causes of these biases be slower response of DO sensor. These biases are comparable with estimated values of the annual DO consumption rates there, thus DO measurements by profiling floats with the current DO sensors should be used for water mass analysis with further consideration of absolute accuracy.

Keywords: oxygen measurement, profiling float, argo

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Poster presentation

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A method for predicting the average lifetime of modern APEX floats

Dr. Taiyo Kobayashi
IORGC JAMSTEC IAPSO

Brian A. King, Nobuyuki Shikama

To estimate the average lifetime of floats is very important for Argo, because the total cost of maintaining the monitoring network is largely dependent on float lifetime. An estimate can be made by examining past float survival. However, a degree of complication is introduced by floats still operating at sea and because of continuous improvements of float hardware. APEX floats are the most widely deployed in the world ocean. In this study we estimate the lifetime of the latest version APEX type floats: that is to say floats with all the mechanical and electronic hardware improvements. Our analysis and predictions are based only on floats fitted with alkaline batteries. Expected lifetime is estimated with a statistical method that correctly allows for floats still active, and floats that failed due to a known and corrected hardware fault that should not cause failure in latest version floats. As an example, we analyse the APEX fleets whose data are managed by JAMSTEC and the UK, because we have access to float databases in which the causes of failure have been carefully attributed to known hardware problems. The expected lifetime of the modern APEX, is 136 cycles from analysis of the JAMSTEC fleet (n= 425) and 119 cycles from analysis of the fleet (n= 178) (as of September 7, 2006). The difference arises from (i) some floats in the UK fleet that suffered from unexplained premature mid-life battery drain (later than 90 cycles), which reduces the average survival rate for that fleet, and (ii) the presence in the JAMSTEC fleet of about 70 floats in tropical regions that profiled to 1500-m rather than the maximum Argo depth of 2000-m. These floats increase the average survival rate of the JAMSTEC fleet.

Keywords: argo program, float lifetime, float hardware

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Poster presentation

6087

Developing ocean prediction system for the sea surface temperature around Korea

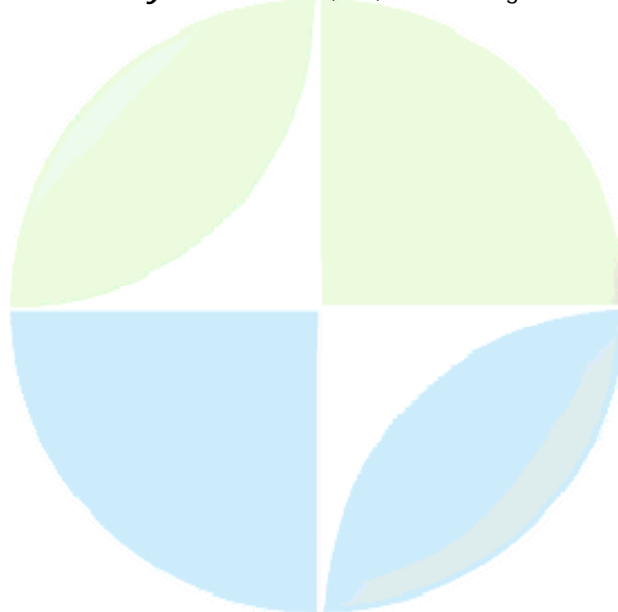
Prof. Yang-Ki Cho

Department of Oceanography Chonnam National University IAPSO

Yong-Hoon Youn, Byoung-Ju Choi, Sangil Kim, Young Ho Kim

To provide accurate prediction of sea surface temperature which is essential information for weather prediction, an ocean prediction system was developed for the northwest Pacific Ocean and its marginal seas using the Regional Ocean Modeling System (ROMS). The system also can be used to study the dynamic processes in the marginal seas and coastal ocean. Model domains were implemented from the regional scale to the coastal zones of interest. The regional model domain of 0.25o horizontal resolution and 20 vertical sigma levels included the East China Sea, the Yellow Sea, the Japan/East Sea and northwestern part of the Pacific Ocean. Discharges of Changjiang River and Huanghe River were included. Tidal forcing was applied along the open boundaries using eight major tidal components so as to examine the effect of tidal mixing on the sea surface temperature. Boundary conditions were obtained from a global ocean. For the Yellow Sea where plays crucial role in determining Korean weather, its model grid has a horizontal resolution of 10 km and its initial condition and boundary condition are obtained from the regional model. The coastal model with a nominal horizontal resolution of few hundred meters is nested for the study of local weather variation. The effect of the tidal and the wind mixings on the sea surface temperature was evaluated. Heat fluxes between the tidal flat and the sea water were quantitatively calculated to understand the effect of tidal flat in the coastal region. The Ensemble Kalman Filter is being implemented for the regional model. A regional atmospheric model will be developed and its product will be used for the ocean prediction system. The atmospheric model will be coupled to estimate the effect of the air-sea interaction, which leads to improve accuracy of the ocean prediction system and to understand the response of the ocean by the changes in atmospheric forcing, and vice versa. The predicted sea surface temperature by assimilating real time observed data from research vessels, satellites and ARGO floats in the northwest Pacific will be used for weather prediction.

Keywords: roms, sst, multineasting



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Poster presentation

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Topographic steering of mid-depth currents obtained from Argo float trajectories with and without correction of surface drift

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School of Earth and Environmental Sciences, Seoul National University IAPSO

Kuh Kim

We have investigated topographic steering of mid-depth currents which are estimated from Argo float trajectories in the East/Japan Sea (EJS, within the area of 128°E~141°E, 35°N~45°N) and in the North-Western Pacific (NWP, within the area of 142°E~180°E, 30°N~45°N). By removing full surface drifts from the float trajectories as Park et al. [2005] reported, we have obtained the distance vectors which a float drifts at the parking depth for 7 or 10 days. The average magnitudes of the vectors reach about 30 km in the EJS and about 65 km in the NWP (~ 4 cm/s @EJS and ~ 7 cm/s @NWP). Probability distribution of directional difference between the distance vectors and the isobaths underneath the floats suggest that the stronger currents (> 2 cm/s) with careful correction of surface drifts are likely to have the direction aligned with isobaths. It may result from the increase of signal to noise ratio, that is, the high reliability of strong mid-depth currents after the correction. Therefore, the results show that the correction of surface drift is necessary to secure more accurate mid-depth currents from Argo float trajectories. Additionally we have examined the basin-wide and seasonal differences of topographic steering characteristics in the EJS and NWP as carefully considering the measurement error and have discussed their possible factors to control the differences in this study.

Keywords: deepcurrent, topographic steering, argo trajectory

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Poster presentation

6089

Usage of Argo floats in the marginal sea and in the Antarctic Ocean

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Institute IAPSO*

Moon-Sik Suk

Korean contribution for the Argo and GODAE activities in the world oceans is described, especially about the Antarctic Circumpolar Currents (AACC) in the Drake Passage and also about the usefulness for the circulation in the marginal sea. KORDI (Korea Ocean Research & Development Institute) and KMA (Korea Meteorological Agency) have been joining the Argo program from 2001 and deployed a few tens of floats every year (180 in total up to 2006) in the East Sea, in the northwestern Pacific, and in the Antarctic Ocean. Not only temperature and salinity but also dissolved oxygen contents have been also measured in the East Sea since 2005, which is still in an experimental stage to monitor the circulation of the marginal sea with the dissolved oxygen sensor. Meso-scale eddy activities and the front are important in the East Sea of Korea and the orographic effect is critical in the variability of the flow path of the AACC across the Drake Passage. Both real-time and delayed-mode data are provided, which are planned to be assimilated primarily for forecasting the hydrography and fishing ground in the marginal sea.

Keywords: meso scale eddy, orographic effect, antarctic circumpolar current

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Poster presentation

6090

Structure and Modification of the South Pacific Eastern Subtropical Mode Water

Dr. Kanako Sato
IORGC JAMSTEC IAPSO

Toshio Suga

We examine the structure and modification of South Pacific Eastern Subtropical Mode Water (SPESTMW) by analyzing all available temperature/salinity profiles (15,528 profiles) obtained by Argo floats from July 2004 to June 2006. SPESTMW is located at 35-5S, 160-70W and characterized by temperature of 17-25C, salinity less than 34.5psu, potential density of 24.5-25.8kgm⁻³, and potential vorticity magnitude less than 2.5 10⁻¹⁰ m⁻¹s⁻¹. Examination of the vertical structure of SPESTMW in austral spring immediately after the formation period reveals that temperature and salinity in SPESTMW are uniformed vertically in its formation area, but that the vertical gradients of temperature and salinity in SPESTMW get larger and larger downstream from its formation area. The vertical changes in temperature and salinity tend to compensate for each other in terms of density changes so that associated increase in potential vorticity is moderate. Consequently, the low potential vorticity signature of SPESTMW spreads much wider than its signature as thermostad. As the seasons progress, the vertical gradients of temperature and salinity get larger even in the formation region. Therefore, SPESTMW is truly vertically uniform water, that is, thermostad, halostad and pycnostad simultaneously only in the formation region immediately after the formation period, while it is pycnostad but neither thermostad nor halostad. The density compensating temperature and salinity vertical gradients of SPESTMW result in the condition favorable for salt fingering and lead to rapid modification of its properties; temperature and salinity near the SPESTMW core and its lower part begin to decrease soon after its formation.

Keywords: mode water, salt fingering, seasonal change



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Poster presentation

6091

Vertical structure of various pycnostads in the North Pacific

Mr. Katsuya Toyama

Department of Geophysics Tohoku University

Toshio Suga

Vertical structure of pycnostads in the North Pacific is examined using the Argo data taken in 2005. Pycnostad is defined as a layer where the vertical change of density is very small with forming a local minimum of its vertical gradient. That is, pycnostad has low potential vorticity because of its vertical homogeneity of density. A good example of pycnostad is a mode water. In previous studies of mode waters, it was generally recognized that mode waters were pycnostads and, at the same time, thermostads (halostads). Some recent studies using dataset with high vertical resolution, however, suggest that some types of mode waters are pycnostads but not thermostads (halostads). The purpose of this study is to examine the vertical structures of pycnostads using the Argo data during 2005. Total number of profiles used in this study is 16,327. Vertical minimum of potential vorticity was detected from each profile. When the potential vorticity at the minimum was lower than a certain criterion and the thickness of the layer was larger than a criterion, we defined those minima as pycnostads. Vertical structures, geographical distribution and physical properties of detected pycnostads were examined with changing a criterion. Pycnostads corresponding to Subtropical Mode Water (STMW), Central Mode Water (CMW), Eastern Subtropical Mode Water (ESTMW), Transition Region Mode Water (TRMW), dichothermal water in the Bering Sea and some others were detected as pycnostads in the North Pacific. Pycnostads corresponding to the STMW were very homogeneous within the layer. On the other hand, vertical homogeneity of pycnostads corresponding to the CMW was lower than that of the STMW. Characteristics in vertical structures of some types of pycnostads, including mode waters, will be discussed.

Keywords: mode water, pycnostad, vertical structure



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Poster presentation

6092

The assessment of assimilated global ocean initial data on a CGCM

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Hye-In Jeong, Soo-Bong Lee, Yong-Hoon Youn

For the study the impact of ocean data assimilation on long-term weather forecast, assimilated ocean data were used as the initial condition of 15 years of seasonal hindcast experiment using a CGCM. The impact was studied by comparing the hindcasted CGCM results with and without initial conditions of the CGCM assimilated to the global ocean temperature and salinity observation from ARGO, TAO, and XBT. The CGCM, so called PNU/CME CGCM is consisted of CCM3 AGCM, MOM3 OGCM and a plastic viscous sea ice model and no flux adjustment is used in the experiment. In this study, the coupled model climatology is obtained from the hindcast experiments started at 4 different periods of a year (January, April, July, and October) from 1992 to 2005 for 12 months of lead time. The model anomaly is defined as the deviation from the coupled model climate obtained from each and every leads of 4 different hindcasts. According to the comparative CGCM hindcast experiment, the systematic errors of the ocean model such as cold bias in equatorial eastern pacific and warm bias in the Indian Ocean are alleviated due to the effect of data assimilation given as the initial conditions. It implies that three dimensional ocean temperature and salinity are simulated more realistically in the CGCM hindcast experiment which uses assimilated initial condition from global ocean observation. Furthermore, not only the CGCM performs well with the assimilated initial data but also the effect of data assimilation persists for a considerable integration time. Consequently, the role of data assimilation as an initial condition of CGCM is very important because it produces better hindcast/forecast for the CGCM by providing reasonable inertial memory to the CGCM. It is concluded that the impact of data assimilation as an initial condition of a CGCM is essential for the forecast of climate and long-term weather forecast.

Keywords: assimilation, prediction, cgcm



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Poster presentation

6093

Ocean data assimilation of profile data on density levels in FOAM

Dr. Daniel Lea

Environmental Systems Science Centre Reading University

Prof. Keith Haines

We modify the UK Met Office FOAM (NEMO) OI ocean data assimilation system to assimilate profile data (including Argo) on density levels. The model background field is converted to spiciness on a set of specified density levels and the depths of those density levels are calculated. The profile observations are also converted to spiciness and density level depth for the same set of specified density levels. We perform two analyses, first of spiciness on density levels with the data being spread over large spatial scales, and second of density level depth with smaller spatial scales. The order of the analyses is not important. The resulting increment fields are converted back to temperature and salinity on model z-levels. The results of this are compared to the standard FOAM assimilation on z-levels over a 1 year period assimilating the same observations. The advantage of spreading the information along density levels is illustrated by comparing the results to withheld data.

Keywords: isopycnal, assimilation

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Poster presentation

6094

Biogeochemical observation by an Argo float

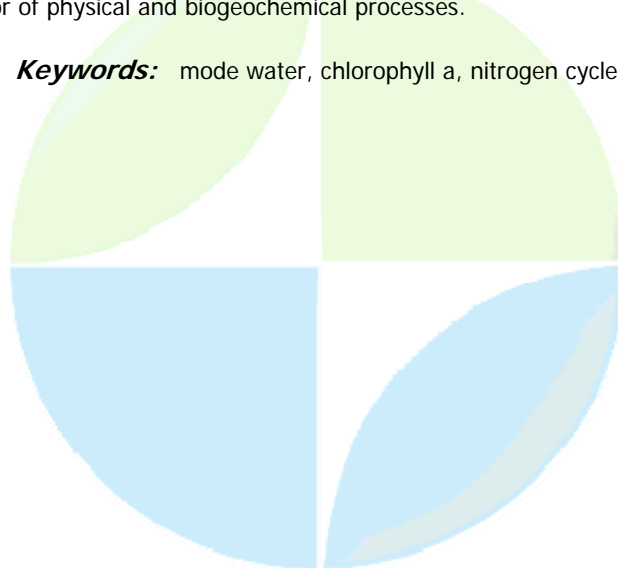
Dr. Chiho Sukigara

Department of Geophysics Tohoku University IAPSO

*Toshio Suga, Toshiro Saino, Katsuya Toyama, Daigo Yanagimoto, Kimio Hanawa,
Nobuyuki Shikama*

The global array of vertical temperature-salinity profiling floats (Argo floats) has been revealing water mass structures and physical processes in the ocean. In the North Pacific subtropical gyre, Argo floats observed the changes of water structure associated with formation and erosion processes of Subtropical Mode Water (STMW). Frequent time-series vertical profiles during warm period (April to August) showed continuous reduction of the layer thickness of STMW and weakening of the low potential vorticity feature near its upper boundary. On the other hand, the surface layer above STMW in warm period is known as low nutrients region because of utilization by phytoplankton. However, it is not clear what influence the upwelled water from STMW has on biological activities in the euphotic zone. In this study, we aim to observe and understand the relationship between dynamics of the STMW and biological activities using the time-series data set of the temperature-salinity vertical profiling float with a fluorometer (measuring chl.a concentration) and dissolved oxygen sensor from March to July 2006. From results of the temperature and salinity data, the STMW was formed in winter, subducted under the seasonal pycnocline in early spring and eroded from the top during warm period as already reported. The chl.a concentration in the euphotic zone (0-200m) peaked in March, decreased progressively until the end of May, and kept a constant value in June and July. The depth of chl.a maximum appeared mainly near the surface (>40m) in early spring, thereafter shifted to the subsurface layer (40-80m). Furthermore, the concentration of dissolved oxygen also peaked in subsurface layer at the same season. The existences of deep (subsurface) chl.a maximum (DCM) and seasonal dissolved oxygen maximum (SOM) show evidences of constant primary production by phytoplankton and predict continuous supply of nutrients from the deeper layer in summer. The turbulent diffusion from STMW in summer may supply 35 mgNm⁻²day⁻¹ of nitrate to the seasonal pycnocline layer in summer, the observed primary production where requires 90 mgNm⁻²day⁻¹ of nitrogen. STMW would play an important role in the ecosystem in the subtropical ocean as a major provider of nutrients in the euphotic zone above STMW. To clarify the mechanism of climate change, we need to comprehend the global material cycles which remain in a state of indeterminate. This experiment shows that Argo floats are quite useful as detector of physical and biogeochemical processes.

Keywords: mode water, chlorophyll a, nitrogen cycle



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Poster presentation

6095

Application of ensemble kalman filter to a regional ocean modeling system of the northwest Pacific Ocean

Prof. Yang-Ki Cho

Department of Oceanography Chonnam National University IAPSO

Byoung-Ju Choi, Sangil Kim, Young Ho Kim, Yong-Hoon Youn

The primary goal of the ocean prediction system is to provide accurate prediction of sea water temperature and currents which are valuable information for weather prediction, fisheries, ocean surface transportation and reduction of natural disaster. We have developed an ocean prediction system for the northwest Pacific Ocean and the marginal seas using the Regional Ocean Modeling System (ROMS). The regional model domain with 0.25o horizontal resolution and 20 vertical sigma levels include the East China Sea , the Yellow Sea , the East/Japan Sea and northwestern part of the Pacific Ocean . Discharges of Changjiang River and Huanghe River were included. Tidal forcing was applied along the open boundaries using eight major tidal components so as to examine the effect of tidal mixing on the sea surface temperature. Boundary conditions were obtained from a global ocean model (ECCO; Estimating the Circulation and Climate of the Ocean). The Ensemble Kalman Filter (EnKF) was implemented to the ocean prediction system. Filter performance was verified by twin experiments in our previous study. The technical approaches are based on the original algorithm of Evensen (1994) and the modified algorithm of Burgers et. al (1996). It is relatively easy to implement the algorithm for the EnKF to a sophisticated nonlinear model since the data assimilation algorithm is independent of the forecast model. In this study, sea surface temperature data observed by satellites in the Northwest Pacific are assimilated and the filters solutions are evaluated by comparing with the independently observed sea surface temperature and sea surface height. We will improve the filter performance by including sea surface height data from satellite altimeters and subsurface temperature data from ARGO floats.

Keywords: ensemblekalmanfilter, roms, northwestpacific



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6096

Oceanographic Conditions in the Eastern Tropical Pacific off Central America Revealed by Argo Data

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Laboratorio de Oceanografía y Manejo Costero Universidad Nacional IAPSO

Two features dominate the upper ocean in the Eastern Tropical Pacific (ETP), east of 120 W, between 0-15 N: the Costa Rica thermal dome (CRD), an upwelling centre located at the end of the equatorial current system, and seasonal (November - April) gap-winds blowing off Central America over the ETP where large, long lived anticyclonic eddies propagate to the west. The eddies driven at the Costa Rica Nicaragua border by the wind jet known as Papagayo propagate over the CRD. The CRD and the Central America gap winds constitute the main physical controls on primary productivity in the northern ETP. One of two Argo autonomous profilers deployed in December 2005 (at 10 N, 87 W) sampled the CRD over an annual cycle providing new insights into the oceanographic conditions of the system. Argo data and satellite derived information on sea surface temperature, sea surface height, wind stress and near-surface chlorophyll contents is used to describe the evolution of the CRD and Papagayo eddies. The seasonal cycle of the thermocline depth in the CRD is described using the depth of the 20 C isotherm obtained from Argo profiles. Wind driven variations in the thermocline depth are also analysed. Information on the sub thermocline circulation in the CRD area, a topic under debate, is obtained using Argo trajectories. Finally, displacements of Argo buoys at the surface reveal new details on the Costa Rica Coastal Current, sampled between October and December 2006, and the ageostrophic advection of water parcels under the Papagayo jet.

Keywords: costa rica dome, gap winds, eddies



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Poster presentation

6097

The circulation in the subtropical South Indian Ocean derived from Argo floats.

Mr. Klaus Getzlaff

National Oceanography Centre, Southampton NOC IAPSO

Brian King, Elaine Mcdonagh, Harry Bryden

This study investigates the circulation in the subtropical South Indian Ocean from 2002 to present. Datasets used to quantify interannual variability in the gyre strength include profiling float data from the global Argo array, the repeated hydrographic transect along 32S and satellite altimetric height. After a delayed mode quality control has been applied to the Argo dataset, an optimal interpolation scheme is used to map the float data onto the 2002 cruise track along 32S. The comparison between the Argo-based estimates relative to the hydrographic measurements taken in 2002 yield a root-mean-square difference in salinity of 0.06 PSU and in temperature of 0.8 degC. Towards the western boundary the errors are much larger, due to the sparse coverage of profiles and the large variability in this area. Relative geostrophic transports are computed with a zero-velocity surface (ZVS) at 1990 dbar. The time mean from the float data represents the structure of the subtropical gyre well and the estimated strength of the gyre is 53 Sv relative to and above 1990 dbar. The analysis of the annually sliced data suggests a stagnation of the decadal spin-up of the subtropical gyre in 2004. We have also computed a circulation scheme using reference velocities from the float's subsurface drift at 2000 dbar, and compared it with an inverse solution based on 2002 cruise data. Although there is a difference in the overall gyre strength in both calculations, the float solution reproduces mesoscale features revealed by the inverse solution, like the deep fronts in the Lower Deep Water in the Crozet Basin (60E) and the Perth Basin (104E).

Keywords: gyre circulation, indian ocean, southern hemisphere



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6098 - 6107

Symposium

Fundamental Physical and Chemical Principles Underpinning Ocean Science

Convener : Dr. Trevor McDougall

The oceans are a unique environment, as challenging as outer space. Within the oceans are a range of extremes - high pressure; complex chemistry; turbulent boundary layers; a crucial interface with the atmosphere for the transfer of gases, particulates, heat, and momentum. Our understanding of the oceans on a global scale and our ability to probe their interior depends on the details of a wide range of physical and chemical processes and phenomena that include - gas transfer; the equation of state; the physics of bubbles; turbulent mixing in the ocean interior and at its boundaries; the propagation of sound and ocean optics. This session will invite papers that describe our understanding of these physical and chemical processes, and the potential for their exploitation.

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Oral Presentation

6098

On acoustic volume backscattering by Antarctic Zooplankton at 38 and 150 KHz using ADCPS Echo Data.

Mrs. Michele Baques

Underwater Sound Division Naval Service of Research & Development IAPSO

Silvia Blanc

During the LMG06-01 cruise to the Antarctic Peninsula held on January 2006 with the L. M. Gould icebreaker, under the frame of the US National Science Foundation Antarctic Program, echo data were recorded with two vessel mounted Acoustic Doppler Current Profilers ADCP. In the role of local scientific at-sea observer, the first author had access to raw measurements for further analysis at her home institute. Along a track of approximately 900 km, in the Northwest - Southeast direction, across Drake Passage, simultaneous vertical ensonification of the water column was performed with a broad band ADCP operating at 38 kHz and a narrow band one at 150 kHz. The gathered data were used to compute absolute Acoustic Volume Backscattering Strength in dB, SV, for both frequencies. SV determined at 38 kHz lie within the interval -130 dB to -100 dB for depths ranging between 46 m and 406 m. At 150 kHz, the obtained SV values lie between - 90 dB and - 60 dB for the 22 m - 302 m depth-interval. No biological sampling took place during the track to enable robust conclusions on this coupled biological-physical process. However, an attempt to infer the composition and spatial/temporal distribution of the zooplankton (such as euphausiids, copepods, pteropods) producing the acoustic response is presented here, with the aim of interpreting experimental acoustic data. This analysis is based upon: a) an exhaustive bibliographic search of reported physical properties values of different zooplanktonic organisms, b) theoretical modelling of their corresponding backscattering cross-section following a slightly modified high-pass model due to Johnson^{1,2}, and c) the experimentally obtained Sv. 1 Johnson, R., J. Acoust. Soc. Am., 61, 375-377, (1977). 2 Blanc et al, Acoustics Letters, 23, 9, 175-182, (2000).

Keywords: sound backscattering, adcp, antarctic zooplankton



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Oral Presentation

6099

A New Look at the Conductivity Density Relationship for Seawater

Dr. Frank Millero

Division of Marine and Atmospheric Chemistry University of Miami IAPSO

The original measurements that were used to determine the equation of state of seawater used seawater of a known Chlorinity. The salinity of these samples were determined using the Kundsén relationship ($S = 1.80655 Cl$) that may not be valid at the present time. A number of measurements in the Atlantic, Indian, Pacific oceans and the Baltic Sea indicated that the calculated densities for deep waters were higher than calculated from the equation of state. This was attributed to the added salts to seawater due to the dissolution of $CaCO_3(s)$ and addition of CO_2 and nutrients from the mineralization of organic matter. In this paper, I will examine the comparison of the measured density of seawater with those calculated from the equation of state using conductivity derived salinities. New measurements of the density of seawater to 80°C as a function of salinity (5 to 60) will also be reported. This is part of a study to extend the equation of state of seawater over a wider range of temperature and salinity. The results will be useful in examining the use of ionic interaction models to estimate the density over a wide range of temperature and ionic strength and in the future to examine the PVT properties of hydrothermal waters.

Keywords: seawater, density, conductivity

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Oral Presentation

6100

Deep Ocean CO₂ Hydration Kinetics Fundamental Rate Measurements

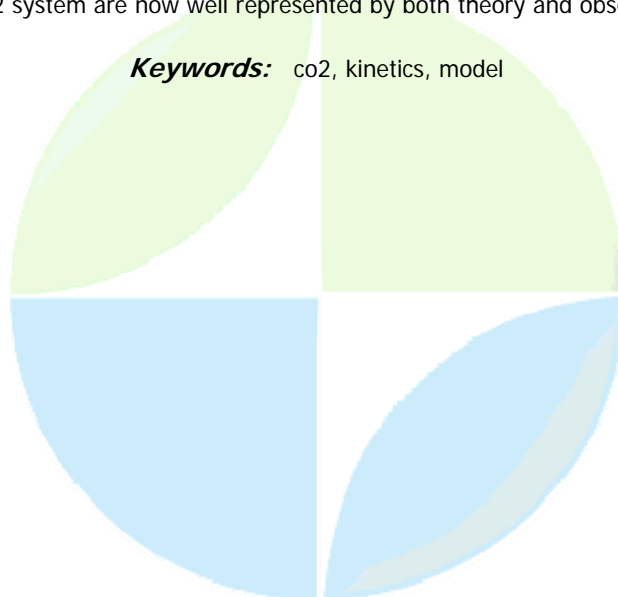
Dr. Edward Peltzer

Research and Development Monterey Bay Aquarium Research Institute

Peter G. Brewer, Rachel M. Dunk, William J. Kirkwood, Peter M. Walz

Measurement of the oceanic CO₂ system properties TCO₂ and alkalinity are now tied to fundamental standards and the benefit has been large. Global surveys have been carried out with a precision and accuracy unachievable earlier, and measurements between teams of different nations may be unambiguously tied together. As this field shifts from observation of the massive transfer of billions of tons of fossil fuel CO₂ to the ocean, to the execution of perturbation experiments to assess impacts, new knowledge of the rate at which perturbations of the sea water CO₂ system relax to equilibrium will be required for experimental design and control. We report on a series of such experiments. That CO₂ hydration kinetics are slow at typical oceanic temperatures and pressures is well known, but use of this information has rarely been required. This is now changing. In recent studies of CO₂ dissolution in seawater we have observed a significant under-estimation of total CO₂ concentrations when pH alone is used in close proximity to the CO₂ source because of this slow reaction. For similar reasons, we anticipate analogous errors when using pH electrodes to estimate total CO₂ concentrations in close proximity to sea-floor CO₂ vents. Recently, Zeebe and Wolf-Gladrow (2001), have compiled a comprehensive model of the kinetics of the CO₂ system reactions. We have experimentally verified this model in a novel series of ROV carried field experiments, and have added terms for the reactions at pressure. We have observed the effects of temperature (T=5-20C), pressure (P=0-1000 dbar), and size of perturbation ($\Delta\text{pH} = \text{pH}(\text{initial}) - \text{pH}(\text{final}) = 0.1-0.6$) on CO₂ hydration kinetics. A small volume (1ml) of dilute hydrochloric acid or CO₂ enriched seawater at equilibrium was injected into 500ml of local seawater contained in a continuously circulating reaction chamber. At the injection point the pH drops precipitously generating a small parcel of seawater where the bulk of the CO₂ is in the form of the dissolved gas molecule and undetectable by a pH sensor. This high CO₂ parcel is rapidly mixed (about 4 sec) within the experimental chamber. The CO₂ then slowly hydrates, generating hydrogen ions and lowering the pH. From the observed exponential drop in pH we are able to determine the reaction relaxation time, and compare this to models. The results show excellent agreement with the Zeebe and Wolf-Gladrow model, and thus the kinetics of reaction and the time to equilibrium of the perturbed oceanic CO₂ system are now well represented by both theory and observation.

Keywords: co₂, kinetics, model



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Oral Presentation

6101

Absolute Salinity versus Practical Salinity and other proposed revisions to Seawater Thermodynamics such as the equation of state

Dr. Trevor McDougall
IAPSO IAPSO IAPSO

The SCOR/IAPSO Working Group 127 on the Thermodynamics and Equation of State of Sea water is charged with defining the thermodynamic properties of seawater in terms of the modern ITS-90 temperature scale, and incorporating the refinements in our knowledge of the thermodynamic properties of seawater since its properties were last defined in 1980. This talk will summarise our progress to date, including the steps towards a proposed new definition of salinity which approximates the Absolute Salinity of seawater. In the future we plan to incorporate the spatial variations in dissolved material into this definition of Absolute Salinity. We are also making progress with defining a revised Gibbs function, along the lines of Rainer Feistels 2003 Gibbs function, from which associated quantities (for example density, specific heat capacity, enthalpy, entropy, chemical potential of sea salt, freezing temperature, latent heats of vaporization and of freezing) can be found.

Keywords: salinity, density, thermodynamics



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Oral Presentation

6102

Polarizations of the oceanic surface flow

Dr. Shane Elipot
PHOD NOAAOML

Sarah Gille, Rick Lumpkin

Recent developments in ocean observing systems have provided the oceanographic community with unprecedented datasets covering a wide range of spatial and temporal scales. New observations, such as the ones provided by the Global Drifter Program, allow us to characterize oceanic flow in a manner not previously possible. In drifter measurements of ocean surface flow, polarization is defined as the relative partition of kinetic energy between anticyclonic and cyclonic motions as a function of frequencies. Understanding the polarized nature of the surface flow is important, because it can be intrinsically linked to the coherent vortices that are ubiquitous in the world ocean, and that play a role at the ocean-atmosphere interface that is not yet fully understood. Zonally-averaged surface drifter observations from the Southern Ocean indicate that the geostrophic and ageostrophic components of oceanic surface currents may be polarized differently. The ageostrophic oceanic velocities are found to be purely anticyclonic, not only around the inertial frequency but also at subinertial frequencies. In contrast, the geostrophic component, as estimated from altimetry, can be of either polarization, depending on the frequency of the motions, but it is nevertheless predominantly cyclonic at sub-inertial frequencies, and this polarization is more pronounced towards lower latitudes. A hierarchy of Ekman models that predict an anticyclonic polarization at all frequencies qualitatively and quantitatively explain the polarization of the ageostrophic component of the drifter velocities. In contrast, the cyclonic polarization of the geostrophic component at sub-inertial frequencies is not clearly understood and may stem either from a hypothesized drifter bias in favour of sampling cyclones or alternatively from the predominance of cyclones in the ocean predicted by recently advanced geophysical fluid dynamic theory.

Keywords: velocity, polarization, drifter



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Oral Presentation

6103

Will slowing of the MOC warm or cool Europe?

Dr. Doron Nof

Oceanography Florida State University

We were motivated by Bryden et al. (2005) analysis which implies that the MOC has slowed down significantly (20%) during the past 50 years and that, as a result, Europe should have cooled during this period. Although the article has been subject to strong criticism, and, although there have been claims in various blogs (e.g., www.realclimate.com) that Bryden himself retracted at least some of his conclusions, his results are consistent with recent observations of an increased fresh water flux into the Atlantic. And yet, western Europe failed to cool during the past 50 years. To examine this issue, we considered a coupled analytical model where fundamental counter-intuitive heat-flux aspects are considered. Convection, heat exchange, fresh water fluxes and Ekman layers are all parts of the model dynamics. On the basis of that model, we suggest that, in contrast to what the global numerical climate models predict, a slow down of the MOC will cause Europe to warm, not cool. As in the numerical models, the analytically modeled slow-down is accompanied by a reduced heat flux to the atmosphere. However, this reduced amount of heat is applied to a significantly smaller amount of air. We show that the strong horizontal diffusion that is unavoidably employed by the numerical simulations camouflages the local warming by mixing the negative heat flux anomaly around making it appear as if there is a broad cooling.

Keywords: moc, europe



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Oral Presentation

6104

Thermodynamic efficiency of the oceans

Dr. Remi Tailleux

Walker Institute for Climate System Research University of Reading

Recent theoretical and experimental studies stemming from the work of Sandstrom seem to have definitively established that the oceans would have a very low thermodynamic efficiency if they were driven by buoyancy fluxes only (of the order of 7×10^{-7}). What matters, however, is to determine whether the thermodynamic efficiency of the oceans depends sensitively upon the presence of the mechanical forcing of the winds and tides, and whether the latter may significantly increase it. In this study, a rigorous definition for the thermodynamic efficiency of the oceans will be introduced. The main result is that the presence of the winds and tides modifies both the Carnot efficiency and the actual efficiency. Whether the actual efficiency is increased compared to the buoyancy-driven case depends on whether turbulent mixing increases or decreases the internal entropy production due to irreversible diffusive mixing. Some simple theoretical ideas are presented to shed light on these issues, and define a path for future research.

Keywords: mixing efficiency, thermodynamic efficiency, entropy production

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Oral Presentation

6105

Baroclinic instability over topography: Eddy formation near the West coast of Greenland

Dr. Annalisa Bracco

Earth and Atmospheric Sciences Georgia Institute of Technology

This work extends the work of Bracco and Pedlosky (2003) investigating eddy formation in the eastern Labrador Sea. A quasigeostrophic model consisting of a meridional, coastally-trapped current with three vertical layers is used to investigate the mechanism of formation of the eddies near the West coast of Greenland. The current configuration and topographic domain are chosen to match as closely as possible the observations of the boundary current and the varying topographic slope along the West Greenland coast. The role played by the bottom-intensified component of the boundary current on the formation and vertical structure of the Labrador Sea 'Irminger Rings' is explored. Results suggest that at the time of formation the eddies are characterized by a strong circulation at depth, allowing for the transport of near-bottom water from the Deep Western Boundary Current into the interior basin. Furthermore this work supports the idea that changes in the vertical current structure could be responsible for the observed variability in the number of the Irminger Rings that are formed and for their characteristics.



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Oral Presentation

6106

The Raman signal of water in seawater

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Department of Chemistry University of York

Peter G Brewer, Edward T Peltzer, Peter M Walz

Water is arguably the most important chemical compound on planet Earth as a result of its vital role in biology, ecology and geochemistry. Despite this, the simple H₂O molecule remains one of the most mysterious and least understood compounds. In particular, the structural form of liquid water within natural systems is of fundamental interest, and is yet to be fully elucidated. Here we report both laboratory and field results from a Raman investigation of the structure of liquid water within the temperature (T) and salinity (S) range expected for natural water bodies, with particular focus on the Raman signal of water in seawater. Our interest is two-fold. Firstly, MBARI has developed a Deep Ocean Raman In-Situ Spectrometer (DORISS). Raman spectroscopy is well suited to meet the challenges of in-situ ocean analysis and is equally applicable to the analysis of solids, liquids, gases and dissolved species. Furthermore, it is often lauded for its avoidance of interference by water due to water's weak Raman cross-section across much of the useful spectral range, and the relatively large frequency shift. Nevertheless, to enable identification and quantification of analytes at low concentrations it is advantageous to accurately subtract the water signal. This in turn requires the ability to accurately model the water signal under the varying experimental conditions. Secondly, the O-H stretching bands, which lie near the high-wavenumber extreme in Raman spectra (~2800-3800 Dcm⁻¹), are rich in information about the structure of water. Thus Raman spectroscopy also provides a means by which to interrogate the structure of liquid water in the oceans. We present results from a laboratory calibration of the DORISS instrument (T = 4-25C, S=0-40), and comparison to analysis of in-situ oceanic depth profiles (100-1000m, T=4-10C, S=33.5-35.5). Despite the small ranges in T and S examined, our results show clear identification of both the T and S dependent Raman isosbestic points for liquid water. These are most easily described by the two-state mixture model of Robinson and demonstrate that observable changes to the structure of liquid water occur with depth in the ocean. Combining numerical analysis of the water stretching region with an assessment of the relative intensity of the water stretching band and the sulphate (S-O) band allows non-contact determination of seawater T to better than 0.5C, and S to better than 1 on the millimetre spatial scale. Looking forward, a sea-going Raman spectrometer with enhanced precision could feasibly provide a multi-purpose analytical instrument, capable of monitoring water mass characteristics such as temperature and salinity in addition to analysis of other water column constituents. The use of a laser beam with a small focal point in combination with precise positioning would allow the ability to observe gradients on small spatial scales, e.g. to examine double diffusion processes under ice in real time

Keywords: water structure, raman spectroscopy

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PS011

Poster presentation

6107

Statistical characteristics of diurnal variation in hydrochemical parameters

Mrs. Olya Shevtsova
FEB RAS POI IAPSO

Standard deviations s and variation coefficients for salinity, major constituents, carbon dioxide system elements, suspended matter, dissolved oxygen, major nutrients and activity of hydrogen ions were estimated on experimental and printed scholarly data from time series stations at several points in a coastal zone and in an open ocean area. At Amur bay (Sea of Japan) with the average diurnal salinity in a range 22.633.0, all s values for the listed parameters are in an interval from $2.4E(-10)$ (hydrogen ions activity) up to 3400 mg/kg (salinity). They are connected with corresponding diurnal average values P linearly ($r=0.63$, a number of pair $k=264$). Values of P change from $4.7E(-9)$ (hydrogen ions activity) up to 33000 mg/kg. Parameters of printed scholarly data for some other points of ocean follow these regularities. Standard deviations for partial pressure of carbon dioxide are ranging from 14 to 210 ppm. The greatest variation coefficients are characteristic for phosphate (14-108%), silicate (13-56%), ammonia (31-81%), nitrate (35-103%) and nitrites (25-130%). There is a need to take that high changeability to evaluate correctly the variability at different time period, for example seasonal time, and to represent maps of spatial distribution of records. Parameters with greater diurnal average concentration are presenting the greater diurnal variability in each of 19 investigated points at surface, intermediate and near-bottom waters of Amur bay. The similar regularity was observed in the several observation points of open ocean area. Linear dependences $s=b+aP$ are established for the parameters in question at Amur bay. Also the rule that $a<0$ for salinity and dissolved oxygen, $a>0$ was systematized for other parameters. Formation of these dependences was connected with river influence and bottom sediments mainly. Similar interrelations are noted in several points of open ocean area.

Keywords: diurnal, variation, parameters



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6108 - 6109

Symposium

The Oceans - Their Past and Present; Considerations on their Future Behaviour (invited abstracts only)

Co-Convener :

This symposium will feature three distinguished invited speakers who will each present their perspectives on the ocean circulation and biogeochemical processes during different time slices of ocean history. In the past, the land-ocean basin configuration, the position of gateways between basins, the extent of the cryosphere and air-sea exchanges of carbon dioxide have played important roles in determining the nature of upwelling, ocean gyres and overturning circulations. In the future, it is anticipated that due to human activities, the large-scale ocean circulations will change, and this could impact on marine productivity. Thus it is natural to ask where the present ocean circulation patterns and biogeochemistry fit into the spectrum of past and possible future behaviour

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Oral Presentation

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Future changes in climate, ocean circulation, ecosystems and biogeochemical cycling simulated for a business-as-usual CO₂ emission scenario until year 4000 AD

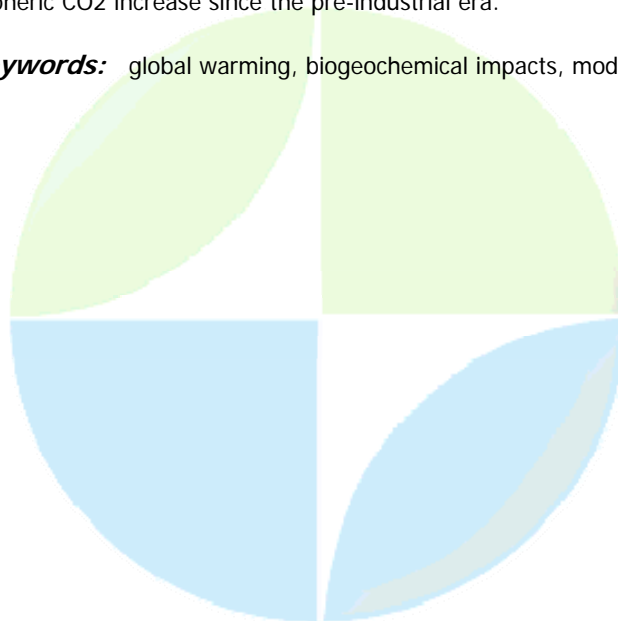
Dr. Andreas Schmittner

College of Oceanic and Atmospheric Sciences Oregon State University IAPSO

Andreas Oschlies, H. Damon Matthews, Eric D. Galbraith

The latest IPCC report presents the strongest and most compelling evidence for human influence on climate. Actions to reduce emissions of radiatively active gases such as CO₂ have not been successful yet and global emissions have been higher in recent years than ever before. Here we explore possible impacts of a scenario of business-as-usual CO₂ emissions until year 2100 (SRES A2) and a linear decrease to zero at year 2300 by means of numerical simulations. A model of intermediate complexity is used including a newly developed simple upper ocean plankton ecosystem component and a detailed component of ocean circulation and biogeochemical cycling. First the model is evaluated against a suite of observations from the past 150 years and found to be consistent with those data. In the scenario simulation atmospheric CO₂ increases to more than 2000 ppmv near year 2300 followed by a gradual decline to ~1700 ppmv at year 4000. Almost half (44%) of the additional CO₂ at year 4000 is due to positive carbon cycle climate feedbacks. Global surface air warms by ~10C, sea ice melts back to 10% of its current area and the circulation of the abyssal ocean collapses. Subsurface ocean warming leads to lower oxygen concentrations, a tripling in the volume of suboxic water and quadrupling of global water-column denitrification. We estimate a 22% (60 ppb) increase in atmospheric nitrous oxide concentrations owing to doubling of oceanic production of this greenhouse gas, leading to a weak positive feedback and contributing about 0.24C warming at year 4000. Global ocean primary production doubles until year 4000. Planktonic biomass increases at high latitudes and in the subtropics whereas it decreases at mid latitudes and in the tropics. In our model, which does not account for possible impacts of acidification on ocean biology, production of calcium carbonate doubles, further increasing atmospheric pCO₂. This represents a new positive feedback mechanism and leads to strengthening of the positive interaction between climate change and the carbon cycle on a multi-centennial to millennial time scale. Changes in ocean biology become important after year 2600 and at year 4000 they account for 22% of the atmospheric CO₂ increase since the pre-industrial era.

Keywords: global warming, biogeochemical impacts, modeling



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Oral Presentation

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**Nitrogen, Oxygen, Physics and Export Production in the late Quaternary
North Pacific: Links to CO₂, Climate and the Southern Ocean**

Dr. Tom Pedersen

School of Earth and Ocean Sciences University of Victoria, Victoria, BC, Canada

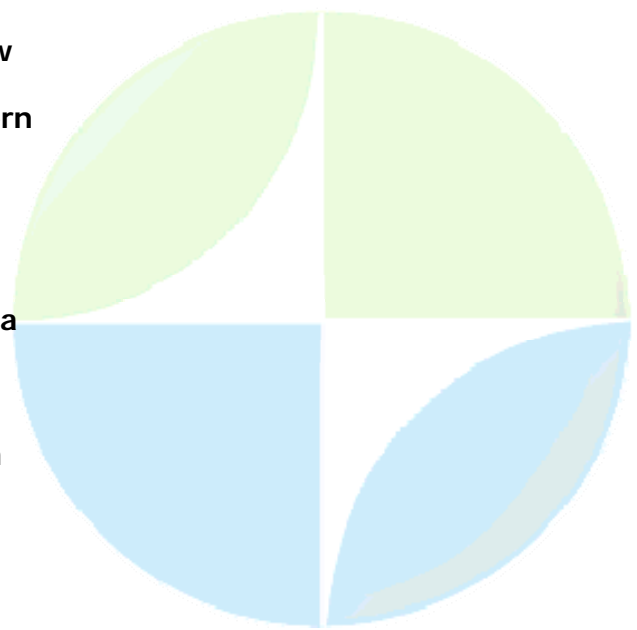
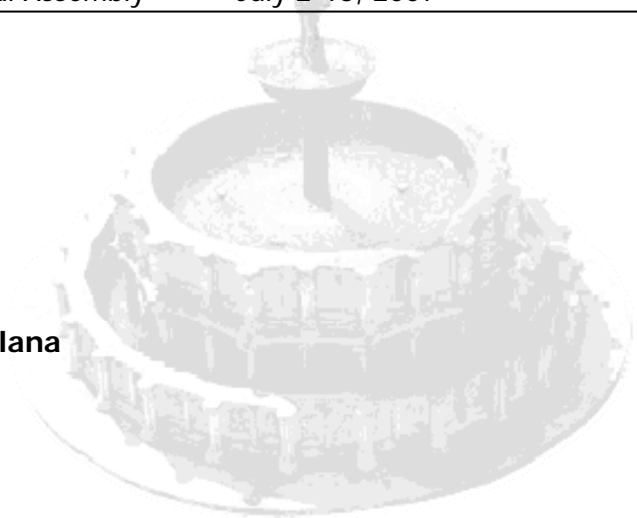
Alice Chang, Eric Galbraith, Ingrid Hendy, Sam Jaccard, Danny Sigman

The biogeochemistry of the Southern Ocean has received much attention over the last two decades as a possible modulator of atmospheric CO₂. But other areas of the ocean may also have played key roles. The consumption of nitrate in the oxygen-depleted intermediate waters of the northeastern Pacific, for example, constitutes the major sink for fixed nitrogen in the oceanic water column, rendering NO₃⁻ as a limiting nutrient. Changes in the areal scale of the northeastern Pacific oxygen minimum zone (OMZ) through time and/or the intensity of oxygen consumption within it should have an impact on aggregate export production globally in the sea, the biological pump, and the exchange of CO₂ between ocean and atmosphere. This supposition is supported by multi-proxy high-resolution analyses of a growing number of sediment cores that have been raised in recent years from the western margins of North and Central America and the Kamchatka and Japan margins. Moreover, new data from deep sites off Kamchatka and in the Gulf of Alaska show that the vast pool of deep waters in the North Pacific hosted large concentrations of CO₂ (and nutrients) during the Last Glacial Maximum. Multiproxy data reveal that during the glacial-interglacial transition, those waters were mixed vertically and rapidly, enhancing both the flux of CO₂ to the atmosphere, but also the flux of nutrients to the surface waters which in turn supported a compensating increase in primary and export production. Such phenomena did not occur in isolation from changes in the Southern Ocean. On the contrary, shifts in the modes of physical circulation, both in intermediate and deep waters that originated at high southern latitudes may well have driven the observed variations that are now being seen in the North Pacific, a conclusion that is supported by coupled paleo-modelling studies.

Keywords: paleoceanography, nitrogen cycle, carbon dioxide



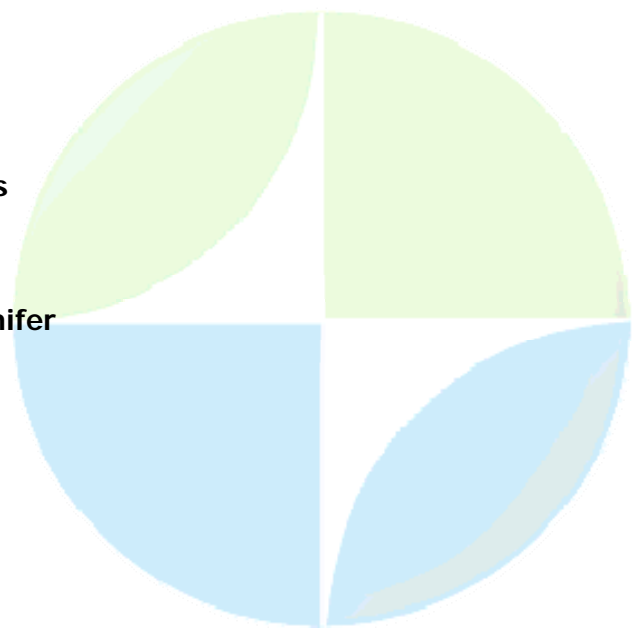
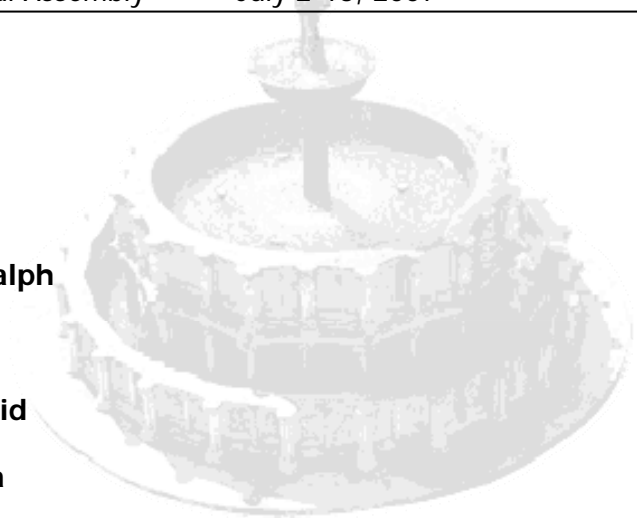
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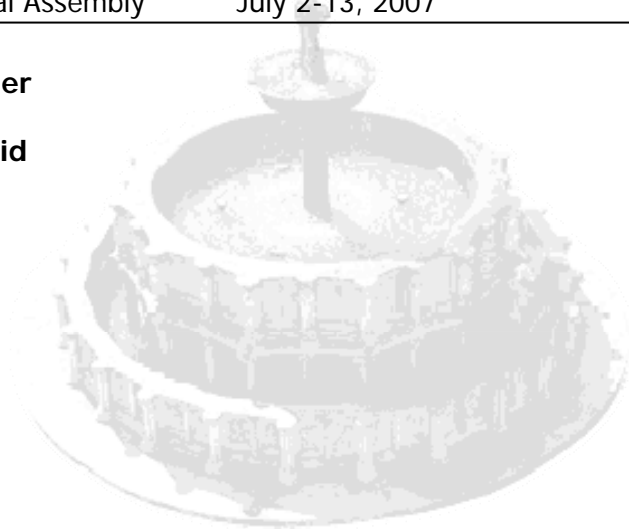
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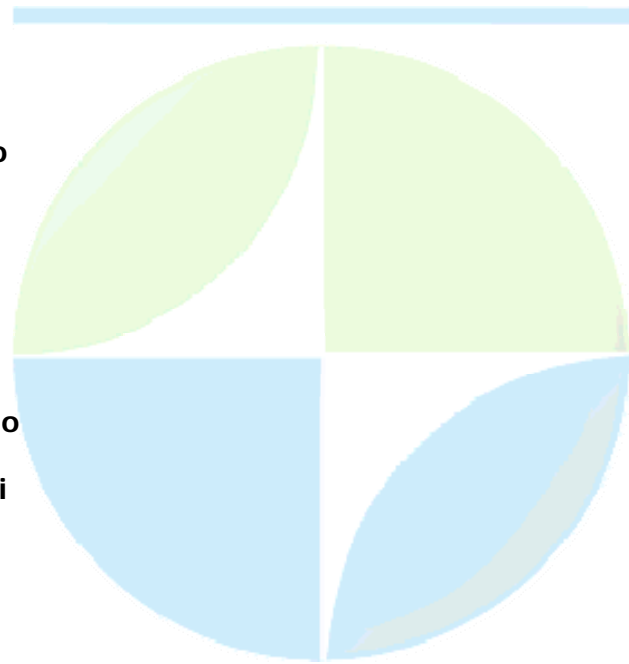
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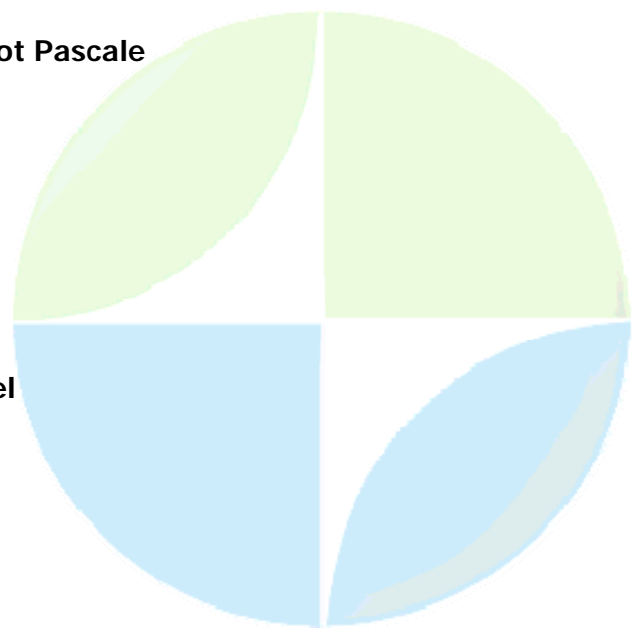
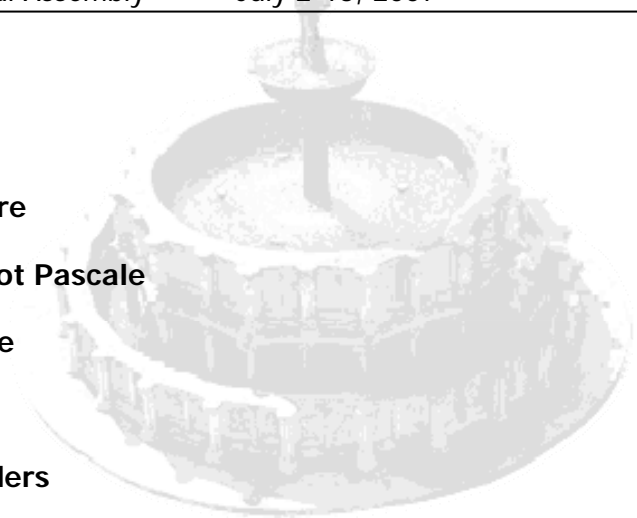
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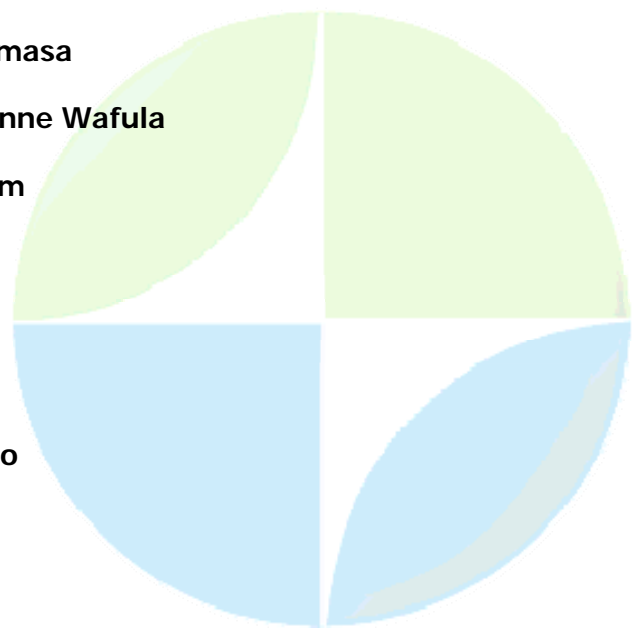
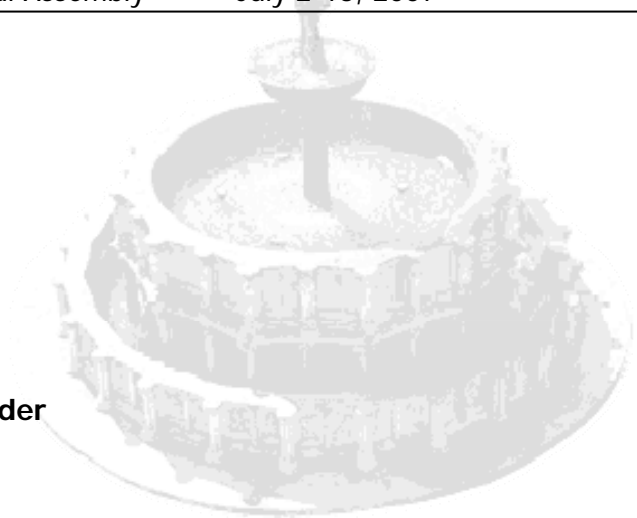
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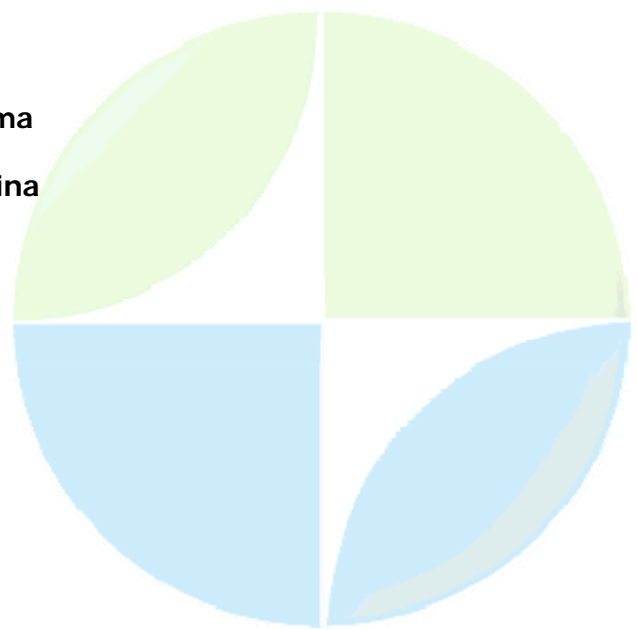
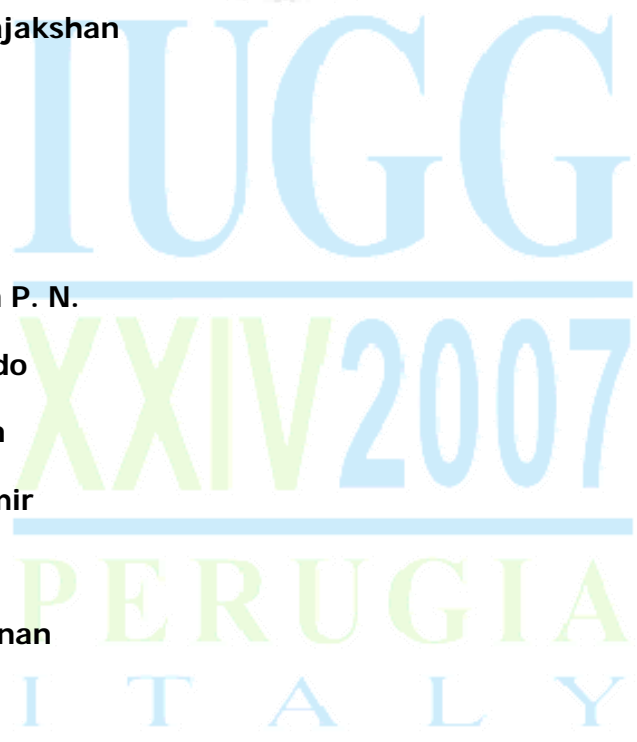
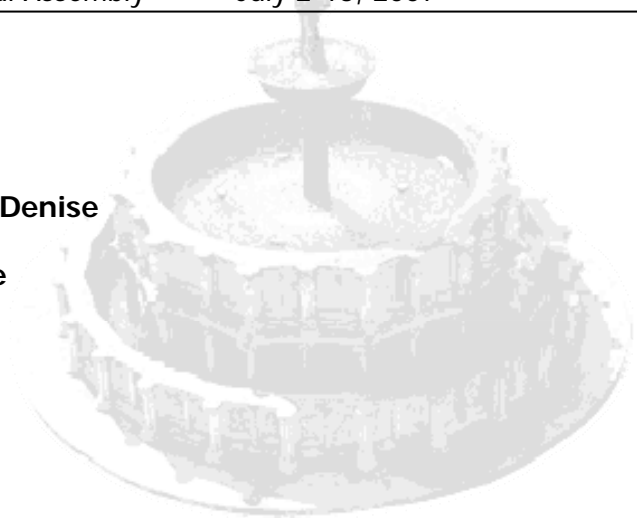
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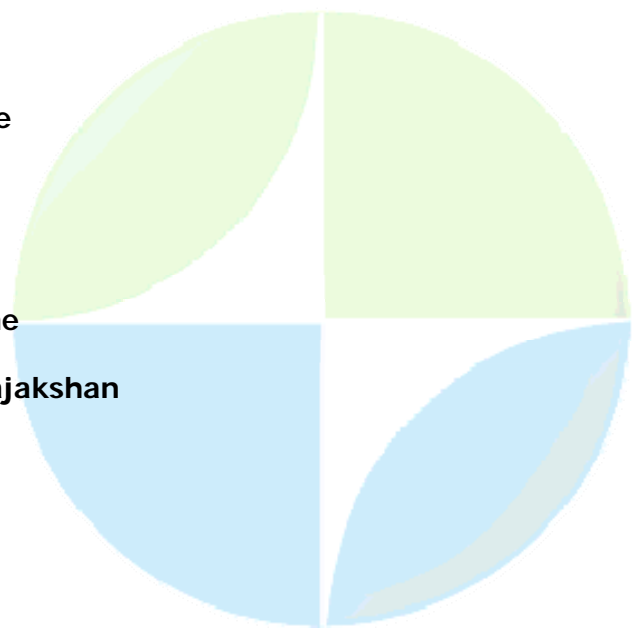
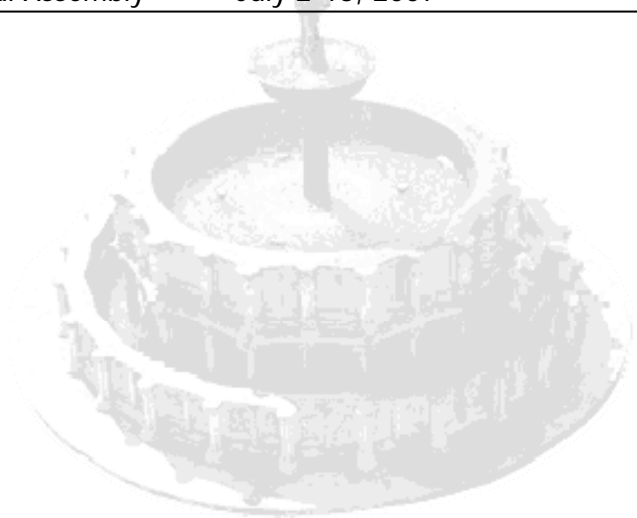
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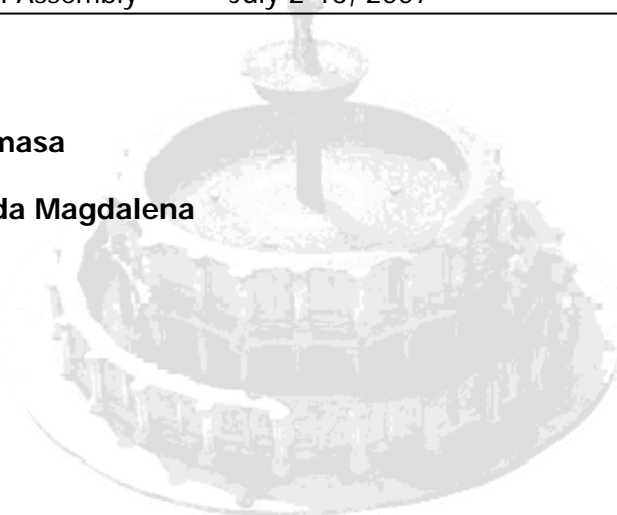
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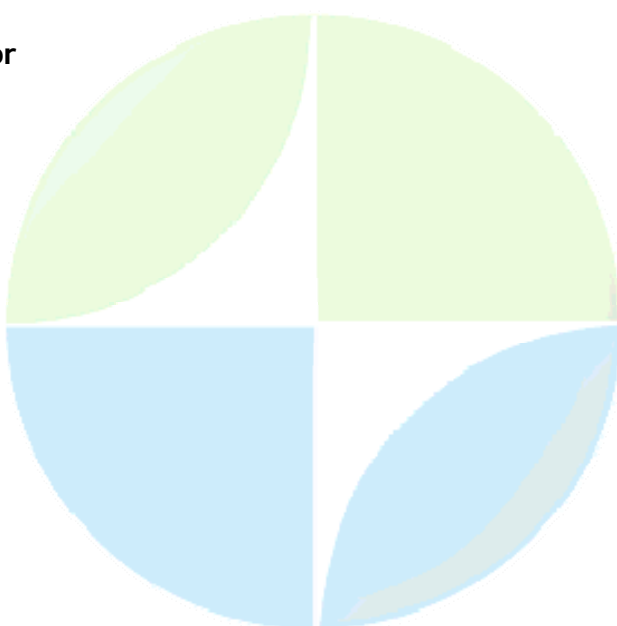


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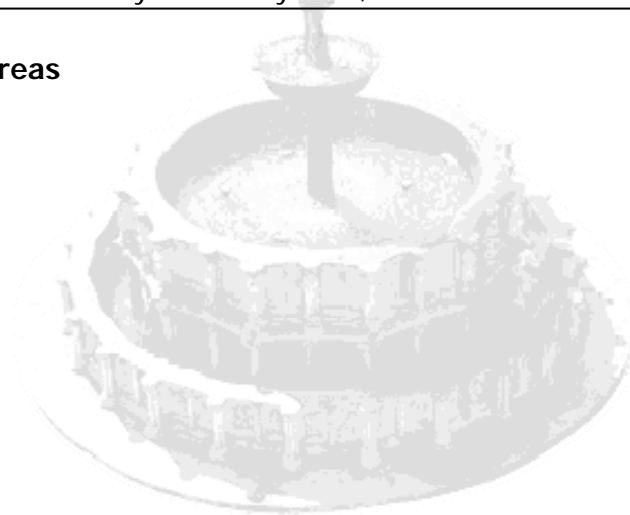


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