6th International Workshop on Modeling the Ocean

IWMO 2014

Agenda and Abstracts

June 23-27, 2014

Halifax, Nova Scotia

www.dal.ca/iwmo2014

MEOPAR

Lloyd's Register Foundation

DALHOUSIE UNIVERSITY
Inspiring Minds

IWMO

The Earth system is interconnected on a broad range of temporal and spatial scales. The International Workshop on Modeling the Ocean (IWMO) provides an excellent opportunity for international scientists to exchange their knowledge and experience in various research fields including coastal, regional and basin-scale studies, as well as interdisciplinary topics. This year's workshop focuses on many important aspects of ocean and coupled atmosphere-wave-sea ice and current-sediment modelling. The IWMO, which held its first workshop in 2009, evolved from the POM users group meetings which began in 1996. The workshop encourages participation from senior researchers and young scientists (graduate students and post-doctoral fellows) and hosts competition for the Outstanding Young Scientist Awards (OYSA).

Sponsors

MEOPAR

The Marine Environmental Observation Prediction and Response Network (MEOPAR) is a team of outstanding Canadian scientists who are working to reduce Canada's vulnerability and exposure to marine hazards and decrease response time when marine emergencies occur. Presently, almost 60 MEOPAR researchers from 12 universities and 4 federal government departments are collaborating on 7 research projects. The network, which was established in 2012, is funded by the Government of Canada's Network of Centres of Excellence Program, and is hosted at Dalhousie University.

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Dalhousie University

Dalhousie University, founded in 1818, is one of Canada's oldest universities and has an enrolment of more than 18,200 students from around the world. As Atlantic Canada's leading research university, Dalhousie attracts over $140 million in research grants and awards each year. Oceans are an area of special emphasis with more than 100 faculty involved in research ranging from oceanography and marine biology to law and engineering.

Contents

Social Events

1. **Monday, June 23 - Ice Breaker**
   15:00 - 17:00 Marion McCain Arts and Social Sciences Building, Lobby

2. **Tuesday, June 24 - Reception**
   19:00 - 21:00 China Town Restaurant

3. **Thursday, June 26 - Banquet**
   18:00 - 21:00 University Club

4. **Friday, June 27 - Peggy's Cove**
   Time TBA, Trip to Peggy's Cove (optional, $30 CAD/person). See website for updated information.

Keynote Speakers

George L. Mellor, Princeton University, USA
Richard Greatbatch, GEOMAR, Germany

International Science Committee

Chairman: Lie-Yauw Oey, National Central University, Taiwan
Local Host: Jinyu Sheng, Dalhousie University, Canada
Jarle Berntsen, University of Bergen, Norway
Bo Qiu, University of Hawaii, USA
Huijie Xue, University of Maine, USA
Vasiliy Vlasenko, University of Plymouth, UK
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Jinyu Sheng, Dalhousie University, Canada
Xiao Hua Wang, UNSW Canberra, Australia
Richard Greatbatch, GEOMAR, Germany
Jianping Gan, Hong Kong University of Science and Technology, China
Tal Ezer, Old Dominion University, USA

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Youyu Lu, Ocean and Ecosystem Sciences Division, Bedford Institute of Oceanography, Canada
Huijie Xue, School of Marine Sciences, University of Maine, United States
Kevin Lamb, Department of Applied Mathematics, University of Waterloo, Canada
Neil Gall, MEOPAR, Dalhousie University, Canada
Fred Woslyng, Department of Oceanography, Dalhousie University, Canada

Organizer

Dalhousie University

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The Marine Environmental Observation Prediction and Response Network (MEOPAR);
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Program Book
Design: Wei Chen
Editor: Fred Woslyng

Agenda

Monday, June 23, 2014

14:00-17:00 ***Registration (Marion McCain Arts and Social Sciences Building, Lobby)***

15:00-17:00 Poster Session and Icebreaker

(Marion McCain Arts and Social Sciences Building, Lobby)

1. Julio Salcedo-Castro, **Ricardo de Camargo** and Eduardo Marone, Combining numerical modeling and reanalysis data to study the air-sea interaction in the Southeastern Pacific: Application to the study of ocean swells off Chile
2. **Ricardo de Camargo**, Bruno Baize, Fabricio V. Branco, Ilana E.K.Wainer and Joseph Harari, Building a detailed dataset for extreme marine events in the western South Atlantic
3. **Christopher Chambers**, Gary Brassington, Ian Simmonds and Kevin Walsh, Precipitation changes due to the Introduction of eddy-resolving sea surface temperatures into simulations of East Coast Lows
4. **Katja Fennel,** F. Aikman, R. Hetland, D. Justic, D. S. Ko, A. Laurent, J. Lehrter, M. Murrell, L. Wang, J. Xu, L. Yu and W. Zhang, Inter-comparison of hypoxia models for the Northern Gulf of Mexico
5. **Mingxian Guo**, Peng Xiu, Shiyu Li, Huijie Xue, Fei Chai and Jiatang Hu, Biological effect of meso-scale eddies on the phytoplankton blooms in the vicinity of Luzon Strait
6. **Ke Huang**, Huijie Xue, Fei Chai and Sergio Derada, Comparison of couple-BOP numerical ocean modeling with observational data: physical results
7. **Arnaud Laurent,** Katja Fennel, Robin Wilson, John Lehrter and Richard Devereux, Parameterization of biogeochemical sediment-water fluxes using in-situ measurements and a steady-state diagenetic model
8. **Eric C. J. Oliver,** Simon Wotherspoon and Neil Holbrook, Estimating extremes from ocean and climate models: A Bayesian hierarchical model approach
9. **Benjamin Storer** and Francis Poulin, A semi-beta-plane model for shallow water
10. **Yujuan Sun** and Will Perrie, Simulation of the wave effects on ocean responses to Hurricane Juan (2003)
11. **Fumin Xu** and Will Perrie, Shallow water dissipation processes for wind waves off the Mackenzie Delta
12. **Feng Zhou**, Huijie Xue, Daji Huang, Peng Xiu, Fei Chai, Xiaobo Ni and Jiliang Xuan, A coupled physical-biological model of the East China Sea
13. **Shouxian Zhu**, Jinyu Sheng, Xiaomei Ji, The research on the separated character of long-term water and salinity transport in Zhujiang Estuary
14. **Vivien P. Chua** and Ming Xu, Impacts of sea-level rise on estuarine circulation: An idealized estuary model and San Francisco Bay

Tuesday, June 24, 2014

07:30-08:30 *Registration (Marion McCain Arts and Social Sciences Building, Lobby)*
08:30-09:00 *Opening remarks (Chris Moore, Dean of the Faculty of Science, Dalhousie University)*

09:00-09:30 Keynote Lecture: George Mellor, A Combined Derivation of the Integral and Differential, Coupled Wave-Current Equations.

09:30-09:50 *Coffee Break*

Session 1: Waves, Currents, and Their Interactions in Coastal and Shelf Seas
Chair: Xiao Hua Wang

09:50-10:10 **Will Perrie**, Bash Toulany and Don Resio, An optimized two-scale approximation for wave-wave interactions in operational wave forecast models

10:10-10:30 **Xin Liu** and Jun Wei, Forced ocean responses of the Kuroshio to typhoon Megi **(OYSA)**

10:30-10:50 **Fumin Xu** and Will Perrie, High precision simulation of hurricane generated waves in coastal shallow water

10:50-11:10 **Guoqiang Liu** and William Perrie, Wave effects on the surface currents: simulations with an updated fully coupled wave-current model

11:10-11:30 Dehai Song and **Xiao Hua Wang**, The effect of wave-current interaction on suspended sediment transport in the deepwater navigation channel, Yangtze River Estuary, China in the dry season 2009

11:30-11:50 **Lanli Guo** and Jinyu Sheng, Simulation of ocean waves over the North Atlantic Ocean using WAVEWATCH III with Climate Forecast System Reanalysis

11:50-12:10 **Fabricio Branco**, Ricardo de Camargo, Ilana Wainer, Bruno Biazeto and Enzo Todesco, Examining global wave climate for different representations of present and future conditions **(OYSA)**

12:10-13:30 *Lunch (Howe Hall, dining hall, first floor)*

Session 2: Circulation and Dynamics in Coastal Waters and Shelf Seas (part 1)
Chair: Jinyu Sheng

13:30-13:50 **Li Zhai**, Youyu Lu, Simon Higginson, Fraser Davidson, Fred Dupont, Francois Roy, Jerome Chanut and Greg Smith, High-resolution modelling of flow and meso-scale eddy variability around the Grand Banks of Newfoundland

13:50-14:10 **Jorge Urrego-Blanco** and Jinyu Sheng, Study of sea ice dynamics in the Gulf of St. Lawrence using a nested-grid ocean-ice model **(OYSA)**

14:10-14:30 **Yuehua Lin**, David B. Fissel, Ryan Clouston, Edward Ross and Alex Slonimer, A numerical study of the circulation in Chatham Sound, BC, Canada

14:30-14:50 **Li-Feng Lu** and Keiko Takahashi, Sea water temperature in Tokyo Bay under the influence of river discharges

14:50-15:10 **Fanghua Xu**, Dong-Ping Wang and Leo Oey, Modeling flocculation processes of fine-grained particles in a macrotidal estuary

15:10-15:30 *Coffee Break*

"OYSA**"** means the presenter of this talk is a candidate for the Outstanding Young Scientist Award.

Tuesday, June 24, 2014 (Continued)

Session 3: Circulation and Dynamics in Coastal Waters and Shelf Seas (part 2)
Chair: Jarle Bernsten

15:30-15:50 **Kyoko Ohashi** and Jinyu Sheng, Using numerical particle-tracking to study the movement of marine animals

15:50-16:10 Ming Xu, Guangliang Liu and **Vivien P. Chua**, Numerical modelling of circulation and exchange through Singapore Straits

16:10-16:30 **Catherine Brennan**, Laura Bianucci and Katja Fennel, Sensitivity of northwestern North Atlantic shelf circulation to surface and boundary forcing: A regional model assessment

16:30-16:50 **Siva Prasad** and Igor Zakharov, The implementation of sea ice model on a high resolution regional scale **(OYSA)**

16:50-17:10 **Shiliang Shan**, Jinyu Sheng and Blair J.W. Greenan, Modelling study of circulation and particle movement in a submarine canyon: Sable Gully **(OYSA)**

17:15-18:30 *Poster Session (continued)*

19:00-21:00 *Reception (China Town Restaurant)*

Wednesday, June 25, 2014

Session 4: Multi-Scale Ocean & Atmospheric Processes (part 1)
Chair: Leo Oey

08:30-08:50 **Yu-Lin Eda Chang**, Yasumasa Miyazawa and Xinyu Guo, The effects of STCC eddies on Kuroshio

08:50-09:10 **Yujuan Sun**, Jiayi Pan and Will Perrie, Simulation Study of Upper Ocean Responses to Typhoon Cimaron in the South China Sea **(OYSA)**

09:10-09:30 **Jingru Sun**, Fanghua Xu and Yanluan Lin, Influence of the ocean on typhoon Nuri (2008) simulation to various microphysical schemes **(OYSA)**

09:30-09:50 **Jianping Gan** and Zhiqiang Liu, Upwelling and potential vorticity dynamics around a coastal promontory

09:50-10:10 **Leo Oey**, M.-C. Chang, S.-M. Huang, Y.-L. Chang, M.-A. Lee and Y.-C. Lin, Far-reaching impact of a coastal front on the East Asian winter monsoon wind

10:10-10:30 ***Coffee Break***

Session 5: Multi-Scale Ocean & Atmospheric Processes (part 2)
Chair: Youyu Lu

10:30-10:50 **Sergey M. Varlamov**, Yasumasa Miyazawa, Yosuke Yamashiki and Toshiaki Sasaki, Impact of river discharges on circulation and material transport in Japanese coastal waters simulated by JCOPE ocean model

10:50-11:10 **Toru Miyama**, Yasumasa Miyazawa and Humio Mitsudera, Short-term fluctuations south of Japan and their relationship with the Kuroshio path: 40- to 80-day fluctuations

11:10-11:30 **Hao Wei**, Youyu Lu, Jiaxing Li and Xiaofan Luo, Inter-annual variations of water temperature and circulation in the East China Sea

11:30-12:00 Keynote Lecture: Richard Greatbatch, Deep Jets in the Equatorial Atlantic

12:00-13:30 ***Lunch (Howe Hall, dining hall, first floor)***

Session 6: Multi-Scale Ocean & Atmospheric Processes (part 3)
Chairs: Jianping Gan & Leo Oey

13:30-13:50 **Jia Wang** and Xuezhi Bai**,** Modeling seasonal and interannual variability of general circulation and thermal structure in the Great Lakes with FVCOM

13:50-14:10 **Dabin Liu**, Liqun Tang, Chonghao Wang and Chuansheng Guo Numerical Study of Influence from Changes in Circulation and Sediment Transport Associated with Human Activities to the Ecological Environment in Tieshan Bay

14:10-14:30 **Haibo Hu** and William Perrie, Influences of Indian Ocean interannual variability on different stages of El Niño: A FOAM Model Approach **(OYSA)**

14:30-14:50 **Youyu Lu,** Ji Lei, Simon Higginson, Frederic Dupont, Fraser Davidson and Gregory C. Smith, High-resolution modelling of inter-annual variations of circulation and freshwater pathway in the Arctic Ocean

Wednesday, June 25, 2014 (Continued)

14:50-15:10 **Gary B. Brassington**, Sampling the stochastic forecast errors using a multicycle ocean prediction system

15:10-15:30 *Coffee Break*

Session 7: Climate Dynamics and Modeling
Chair: Tal Ezer

15:30-15:50 **Tal Ezer**, The challenge of predicting uneven sea level rise and flooding risks associated with climatic changes in ocean dynamics

15:50-16:10 **Zhenxia Long** and William Perrie, Scenario changes of Atlantic water in the Arctic Ocean

16:10-16:30 **Xiaomei Ji** and Jinyu Sheng, The influence of coastline changes on tidal circulation in the abandoned Yellow River Mouth and adjacent coastal waters

16:30-16:50 **Zhigang Xu**, The All-Source Green's Function and Its Application to Storm Surge Modelling

16:50-17:10 **Eric C. J. Oliver**, Simon Wotherspoon, Matthew Chamberlain and Neil Holbrook, Projected change in Tasman Sea marine climate, extremes, and circulation through the 21st century

17:15-18:30 ***Poster Session (continued)***

Thursday, June 26, 2014

Session 8: Modeling and Prediction of Extreme Marine Events
Chair: Yasumasa Miyazawa

08:30-08:50 **Gary B Brassington**, The rapidly developing field of operational oceanography and its application to safety of life and infrastructure

08:50-09:10 **Xiangbo Feng** and M. N. Tsimplis, Change of wave and sea level extremes at marginal seas

09:10-09:30 **Ricardo de Camargo**, Alberto Francisco Mavume and Adilson Wagner Gandu, Numerical modeling of storm surges in the coast of Mozambique

09:30-09:50 **Yasumasa Miyazawa**, Nobuyoshi Yamashita, Sachi Taniyasu, Eriko Yamazaki, Xinyu Guo, Sergey M. Varlamov and Toru Miyama, Oceanic dispersion of anomalous perfluoroalkyl substances in the Western North Pacific associated with the great earthquake 0311 in Japan

09:50-10:10 **Heng Zhang** and Jinyu Sheng, Mapping present day extreme sea levels over coastal waters of northwestern Pacific

10:10-10:30 *Coffee Break*

Session 9: Coupled Bio-physical Ocean Models
Chairs: Katja Fennel & Danling Tang

10:30-10:50 **DanLing Tang**, H. J. Ye, Y. Sui and Y. D. Afanasyev, Surface and subsurface phytoplankton blooms induced by typhoon in the South China Sea

10:50-11:10 **Arnaud Laurent** and Katja Fennel, Phosphorus limitation reduces hypoxia in the northern Gulf of Mexico: results from a physical-biogeochemical model

11:10-11:30 **Laura Bianucci**, Katja Fennel and J. Paul Mattern, Evidence for temporal evolution in biological parameters in a 3D regional model

11:30-11:50 **Ango Hsu**, Huijie Xue and Fei Chai, Effects of NEC transport and bifurcation latitude on Japanese eel larval migration **(OYSA)**

11:50-12:10 **Liuqian Yu**, Katja Fennel and Arnaud Laurent, A modelling study of the physical controls on hypoxia on the Louisiana Shelf **(OYSA)**

12:10-13:30 *Lunch (Howe Hall, dining hall, first floor)*

Session 10: Simulation of Internal Waves
Chair: Kevin Lamb

13:30-13:50 **Kevin G. Lamb** and Alex Warn-Varnas, Shoaling internal solitary waves in the South China Sea

13:50-14:10 **Tsubasa Kodaira**, Takuji Waseda and Yasumasa Miyazawa, Numerical analysis of oceanic internal solitary wave generation around an island in stratified shear flow **(OYSA)**

14:10-14:30 **Robert Irwin** and Francis Poulin, Geophysical instabilities in a 2-layer rotating shallow water model **(OYSA)**

Thursday, June 26, 2014 (Continued)

14:30-14:50 **Francis Poulin**, Using the rotating shallow water model to study the stability of ocean currents

14:50-15:10 **Jun Zhao** and Y. R. Rao, Application of a numerical model for circulation and tracer distribution in Western Lake Ontario

15:10-15:30 *Coffee Break*

Session 11: Numerical Techniques and Approaches in Ocean Modeling
Chair: Richard Greatbatch

15:30-15:50 **Jarle Berntsen**, Johannes Dugstad and Helge Avlesen, Assessment of tidal current energy in the Lofoten area, Norway

15:50-16:10 **Bert Viikmäe**, Tarmo Soomere and Tomas Torsvik, Optimising fairways in the Gulf of Finland using patterns of surface currents **(OYSA)**

16:10-16:30 **Eric Bembenek**, Francis Poulin and Michael Waite, Realizing surface driven ocean flows in the primitive equations **(OYSA)**

16:30-16:50 **Fatemeh Chegini** and Masoud Montazeri Namin, An efficient algorithm for solving pressure Poisson system in non-hydrostatic free surface flow models **(OYSA)**

16:50-17:10 **John Yawney**, Francis Poulin and Paul Ullrich, A new high-order finite-volume ocean model to study ocean processes **(OYSA)**

18:00-21:00 *Banquet (University Club)*

Friday, June 27, 2014

Session 12: Numerical Techniques and Approaches in Ocean Modeling (Part 2)
Chair: Huijie Xue

08:30-08:50 **Michael Dunphy** and Kevin G. Lamb, Focusing and vertical mode scattering of the first mode internal tide by mesoscale eddy interaction **(OYSA)**

08:50-09:10 **Shivanesh Rao**, Huijie Xue and Min Bao, Modeling power potential for tidal turbine farms in the Western Passage **(OYSA)**

09:10-09:30 **Jean-Pierre Auclair**, Hal Ritchie and Jean-François Lemieux, Improving the numerics of sea ice models using the Exact Newton's Method **(OYSA)**

09:30-09:50 **Mingke Guo**, Peng Zhao, Juan Huang and Wensheng Jiang, A new method to evaluate the risk of storm surge induced by cold-air outbreak in the Bohai Sea

09:50-10:10 **Yign Noh**, Hyejin Ok and Eunjeong Lee, Parameterization of the effect of Langmuir Circulation in the ocean mixed layer model using LES and its application to the OGCM

10:10-10:30 ***Coffee Break***

Session 13: Numerical Techniques and Approaches in Ocean Modeling (Part 3)
Chair: Jia Wang

10:30-10:50 **Jinyu Sheng** and Xiaomei Ji, Circulation and variability in the Pearl River Estuary and associated coastal waters

10:50-11:50 ***Discussion – IWMO 2015***

11:50 ***Lunch (Howe Hall, dining hall, first floor)***

Abstracts

Keynote Lectures

A Combined Derivation of the Integral and Differential, Coupled Wave-Current Equations
(09:00 - 09:30, Tuesday, June 24, 2014)

George Mellor
Program in Atmospheric and Oceanic Sciences, Sayre Hall, Princeton University, Princeton, New Jersey, USA

In the literature there exist different theories for the representation of the effect of surface gravity waves on oceanic flow fields. In the past, the author has expressed his opinion that the theory, based on the vertically integrated, two-dimensional fluid equations of motion put forward by Longuet-Higgins and Stewart is correct and that theories deviating from their theory cannot be entirely correct. Further, the author has proposed vertically dependent, three-dimensional equations which have required correction but which when vertically integrated, agreed with the earlier, two-dimensional equations. In this paper, we derive both sets of equations from the same base and, importantly, using the same expression for pressure in the belief that the paper will contribute to the understanding and clarification of this seemingly difficult topic in ocean dynamics.

Deep Jets in the Equatorial Atlantic
(11:30 - 12:00, Wednesday, June 25, 2014)

Richard Greatbatch*, Martin Claus and Peter Brandt
GEOMAR, Kiel, Germany

Equatorial deep jets (EDJ) are a ubiquitous feature of the zonal flow along the equator in all three ocean basins. The jets appear as vertically alternating bands of eastward and westward flow with a vertical scale measured in hundreds of meters and velocities typically near 0.1 m/s. In the Atlantic, the EDJ are observed down to 3000m depth, exhibit quite regular behaviour associated with downward phase propagation (implying, according to linear theory, upward energy propagation) and a time scale of roughly 4.5 years. The 4.5 year signal can be seen in sea surface temperature (SST) as well as atmospheric data (e.g. surface wind and rainfall) indicating the significance of the deep jets for climate. The jets also play a role in ventilating the equatorial region and help explain the oxygen maximum along the equator that has been known since the German Meteor cruises of the 1920's. It has been found that the meridional width of the EDJ is roughly 1.5 times larger than expected based on their vertical scale. Here we exploit an old idea of Yamagata and Philander to argue that mixing of momentum along isopycnals can explain the enhanced width. A lateral eddy viscosity of around 300 $m^2 s^{-1}$ is found to be sufficient to account for the width implied by observations. The impact of the equatorial flanking jets is also discussed. These jets shield the equatorial band from the influence of extratropical Rossby waves and also contribute to enhance the width of the jets. Finally, it is noted that even modern high resolution ocean models have problems simulating the deep jets. Possible reasons for this are briefly discussed.

Session 1: Waves, Currents, and Their Interactions in Coastal and Shelf Seas

Chair: Xiao Hua Wang

An Optimized Two-Scale Approximation for Wave-Wave Interactions in Operational Wave Forecast Models

Will Perrie*, Bash Toulany and Don Resio
Bedford Institute of Oceanography, Dartmouth, NS, Canada

The two-scale approximation (hereafter, TSA) to the full Boltzmann integral representation of quadruple wave-wave interactions has been presented as a new method to estimate nonlinear transfer rates in wind waves, and implemented in the latest version (4.10) of a modern operational wave forecast model, WAVEWATCH III (WW3). Here, we present an optimized version of TSA, selectively excluding sets of interacting wave-numbers, obtaining a resulting code that remains relatively accurate compared to the full Boltzmann integral, although only about twenty times slower than DIA – the standard Discrete Interaction Approximation, which is used in most implementations of WW3. Tests include idealized spectral data, observed field measurements, including cases with directional energy shearing, fetch-limited wave growth, sheared spectra, and waves generated by selected extra-tropical hurricanes and nor'easter storms. Simple source terms, specifically WAMcycle 3 physics, denoted 'ST1', are used, as well as more modern 'ST4' physics, by Ardhuin et al. (2010, JPO). We show that the revised TSA is able to work well for the tests considered. We also present results for generalizations of the method (e.g. double, or multiple TSAs) as applied for complex multi-peaked spectra.

Forced Ocean Responses of the Kuroshio to Typhoon Megi

Xin Liu* and Jun Wei
Laboratory for Climate and Ocean-Atmosphere Studies, Department of Atmospheric and Oceanic Sciences, Peking University, Beijing, China

Relatively weak SST cooling (< 1ºC) induced by hurricanes was often observed in the Loop Current which was attributed to its strong advection, while remarkable SST cooling occurred in the Kuroshio as shown here in observations and modeling of the Kuroshio during the passage of Megi, a category-1 typhoon. The ocean model adopted in this study was the Regional Oceanic Modeling System (ROMS). Temperature and kinetic energy budget analysis indicated that the dynamic response of the Kuroshio depends mostly on its baroclinicity rather than typhoon strength. Different from the open ocean where ocean gains kinetic energy from wind stress work, the Kuroshio can obtain greater kinetic energy from its baroclinic pressure work and therefore produce stronger SST cooling even under weak winds. On the other hand, different from the Loop Current, advection effects are overall insignificant in influencing the temperature and dynamic changes of the Kuroshio during typhoon's passage. Such oceanic responses in the Kuroshio imply that typhoon-induced Kuroshio variability is more vigorous than expected because of its strong baroclinicity and relatively weak advection.

High Precision Simulation of Hurricane Generated Waves in Coastal Shallow Water

Fumin Xu* and Will Perrie
Key Laboratory of Coastal Disaster and Defence, Ministry of Education, College of Harbour, Coastal and Offshore Engineering, Hohai University, China

Hurricane Juan was one of the most devastating storms in the modern history of Nova Scotia, Canada. It generated huge and complex waves in Northwest Atlantic and coastal waters in Nova Scotia in late Sept 2003. A discussion of Hurricane Juan's development is introduced, observed winds and waves within Juan's wind range in deep open ocean and coastal area are presented and analysed. This study focuses on the high precision simulation of Hurricane Juan generated waves in coastal shallow water. Non-stationary computation of hurricane generated waves in coastal shallow water is more complex, compared with that in offshore and open ocean. (1) One of the elements influencing the accurate simulation of hurricane generated waves in coastal shallow areas is the wave model's numerical sensitivity to hurricane wind variations. In this study, numerical experiments are carried out by using different time steps and different iteration numbers during SWAN non-stationary computation in Lunenburg Bay domain, to check the numerical sensitivity in simulating Juan generated waves in coastal shallow water. (2) The wave spectral shape influence on the simulation precision is also evaluated, by using the observed two-dimensional wave spectra and JONSWAP shape two-dimensional wave spectra along the open boundaries in Lunenburg Bay domain. To construct reasonable open boundary wave conditions in Lunenburg bay domain based on the observed two-dimensional wave spectra at DWR (located on the open boundary), WAVEWATCH III model (WW3) and SWAN model are applied, and a five-layer wave model nesting (WW3-WW3-SWAN-SWAN-SWAN) simulation is applied to simulate Juan generated waves in northwest Atlantic and coastal shallow areas in Lunenburg Bay, therefore spectral wave relationships between open boundary points of Lunenburg Bay domain and DWR are obtained. With the reasonable-setting iteration number and time step, and well-constructed two-dimensional spectral waves along open boundaries, Juan generated waves in Lunenburg Bay domain are simulated and validated with observations. Finally, we give summaries and analysis.

Wave Effects on Surface Currents: Simulations with an Updated Fully Coupled Wave-Current Model

Guoqiang Liu* and William Perrie
Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, NS, Canada

Interaction between oceanic waves and current represents one of the primary driving forces in the coastal and offshore areas. In this study, the fully coupled wave-current (SWAN-ROMS) model system (COAWST), implementing the depth-dependent Radiation Stress formulation (RS) and the Vortex Force formulation (VF), is updated for two essential components. Firstly, the Stokes drift, which plays a significant role in wave-current interaction, is updated by using a formulation that incorporates the frequency-directional ocean wave spectrum instead of the old method based simply on bulk wave parameters. Second, a new version of the SWAN model, consisting of the newly developed wind-input and wind-breaking dissipation terms, (motivated by Ardhuin et al., 2010, JPO, and implementations in WAVEWATCH III) is coupled to ROMS. Thus, a series of simulations are conducted and validated by using observational wave parameters and drifter trajectories from field experiments in the Gulf of Saint Lawrence and on the Grand Banks of Newfoundland. We show that the resulting updated model system has improved the model performance, compared to the old COAWST system, and that the model results also compare well with the field measurements.

The Effect of Wave-Current Interaction on Suspended Sediment Transport in the Deepwater Navigation Channel, Yangtze River Estuary, China in the Dry Season 2009

Dehai Song and Xiao Hua Wang*
The Sino-Australian Research Centre for Coastal Management, University of New South Welsh, Australia

A three-dimensional wave-current-sediment coupled numerical model with wetting and drying processes is developed to understand hydrodynamics and sediment transport dynamics in the Deepwater Navigation Channel (DNC), the North Passage of the Yangtze River Estuary (YRE), China. The model reproduces the spring-neap variation between a well-mixed estuary and a highly-stratified estuary. Model results indicate that the estuarine gravitational circulation plays the most important role in the estuarine turbidity maximum (ETM) formation in the DNC. The upstream non-local sediment intrusion through the spill-over-mechanism is a major source of sediment trapping in the North Passage after the morphological changes. Numerical studies are conducted to show scenarios in the YRE under the effects of different forcings (river-discharges, waves, and winds). Between these study cases, surface-wave-breaking relieves the sediment trapping and bottom-wave-current-interaction aggravates the bed erosion and elevates the SSC in the ETM; the former and the latter has the least and largest influence on the suspended sediment transport in the DNC.

Simulation of Ocean Waves Over the North Atlantic Ocean Using WAVEWATCH III with Climate Forecast System Reanalysis

Lanli Guo* and Jinyu Sheng
Department of Oceanography, Dalhousie University, Halifax, NS, Canada

The ocean wave model known as WAVEWATCH III (hereafter WW3) is used to reconstruct the wave climate over the northwest Atlantic Ocean. The model domain covers the region between 20°N–65°N, 90°W –20°W. The wave model is forced by the six-hourly 10 m wind and ice fields (~33 km) extracted from the Climate Forecast System Reanalysis (CFSR) produced by the National Centers for Environmental Prediction (NCEP). A parameterized vortex is inserted into the CFSR wind field to improve the wind forcing associated with a tropical storm or hurricane. The wave model results are compared with the buoy observations and altimeter records. A comparison between the simulated significant wave heights and NDBC buoy data indicates that the accuracy of the wave simulation is improved by using the blended wind field in general. In some strong storm cases, like Hurricane Juan, the simulated significant wave heights using the blended wind forcing have noticeable overestimation over the extra tropical areas. Attempts are made to use better wind forcing to drive the ocean wave model.

Examining Global Wave Climate for Different Representations of Present and Future Conditions

Fabricio Branco*, Ricardo de Camargo, Ilana Wainer, Bruno Biazeto and Enzo Todesco
Department of Physical Oceanography, Institute of Oceanography, University of Sao Paulo, Sao Paulo, Brazil

During the last two decades, several researchers have been trying to understand the impact of global climate change in its various aspects: air, soil, water, oceans, health, economy, human occupation, risk areas, etc. Even after much effort, the level of knowledge is still incomplete, especially relative to wave climate impacts due to increased concentration of greenhouse gases and its relation to all other physical mechanisms in the oceans. Within this context, the contribution of this work is to present a comparison between different global wave climate statistics obtained with WAVEWATCH III for the 20th century (forced with NCEP-Reanalysis and CFSR), as well as for some of the 21st century projected scenarios (CMIP3: CCMS3.0, RESA2/RESB1; CMIP5: GFDL-ESM2M, RCP4.5/8.5). The statistical analyses are focused on both mean and extreme properties of the wave climate for some selected locations around the world. The choice of these locations was based on regions of interest of ongoing projects, and also to cover strategic offshore areas. Interesting results of tendencies were obtained when monthly averages are considered. Other relevant aspects emerge from the evaluation of changes in the occurrence of extreme events for these locations.

Sessions 2-3: Circulation and Dynamics in Coastal Waters and Shelf Seas

Chairs: Jinyu Sheng and Jarle Bernsten

High-Resolution Modelling of Flow and Meso-Scale Eddy Variability Around the Grand Banks of Newfoundland

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Spatial variability of mean flow and meso-scale eddy variability in the region around the Grand Banks of Newfoundland (GBN) are quantified by analyzing surface drifter observations, along-track satellite altimeter observations and the solutions of two-high resolution ocean models. The models are based on NEMO (the Nucleus European Modelling of the Ocean). The CREG12 model covers the Arctic and North Atlantic Oceans with a horizontal resolution of about 8 km in the study area. The GBN36 model covers the study area with a horizontal resolution of about 2.5 km, and takes lateral boundary forcing from CREG12. Both models are forced with the Canadian Meteorological Center's global reforecasts. Analyses are applied to model solutions during 2004-2006. Compared with estimates based on surface drifter observations, CREG12 overestimates the kinetic energy of the mean current (MKE) by 53%, whereas GBN36 obtains much closer agreement. GBN36 (CREG12) reproduces 70% (60%) of the eddy kinetic energy (EKE) observed from satellite altimetry. In terms of the spectra of sea surface height (SSH) anomalies, both GBN36 and CREG12 obtain a slope close to -5 on logarithmic spectral density scales at the high wave-number and frequency end.

Study of Sea Ice Dynamics in the Gulf of St. Lawrence Using a Nested-Grid Ocean-Ice Model

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A nested-grid ocean-ice model for the eastern Canadian shelf is used to study sea ice conditions in the Gulf of St. Lawrence (GSL). The model is based on the Nucleus for the European Modelling of the Ocean (NEMO) with OPA 9.0 as the ocean component and the 2-category dynamic-thermodynamic model LIM2 as the ice component. The model is forced by atmospheric reanalysis fields produced by Large and Yeager (2004). The model results are used to examine the effect of oceanic and atmospheric forcing on the sea ice formation in the GSL, with a special emphasis on (1) the role of thermodynamics and dynamics on the sea ice formation and (2) the sensitivity of sea ice formation to the net heat fluxes between the ocean-ice system and atmosphere in the GSL. The analysis of model results suggests that the presence of sea ice over most parts of the Gulf is more affected by thermodynamics than ice dynamics. In regions directly affected by the Gaspé current over the western GSL the ice dynamics is also important. A sensitivity study indicates that uncertainties in the estimation of sensible heat fluxes can lead to significant errors in the simulated sea ice coverage in the region.

A Numerical Study of the Circulation in Chatham Sound, BC, Canada

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Chatham Sound is a semi-enclosed inland sea located off Northern British Columbia, connected to the Pacific Ocean via the more exposed offshore areas of Dixon Entrance and Hecate Strait. Chatham Sound spans a total distance of approximately 70 km from south to north and has a width of 15-25 km, but water depths generally are less than 200 m. The ocean currents are highly variable due to a combination of wind, tides and large freshwater discharges from the Skeena River in the south. Larger wind speeds occur in fall and winter, of up to 35 m/s in central Chatham Sound. Tidal heights are also large with maximum tidal range for Prince Rupert reaching a value of 7.7 m and an average tidal range of 4.9 m. A better understanding for the circulation and hydrodynamics in Chatham Sound is required, not only because of its distinctive oceanic regime, but also the design criteria and environmental review supporting the recent growth liquefied natural gas (LNG) export marine terminals in this area. High resolution 3D finite-difference numerical modeling was conducted to investigate the tidal and wind driven currents in Chatham Sound. The model domain covers Chatham Sound and Brown Passage. The model was verified using historical ocean current data collected by the Institute of Ocean Sciences(IOS) and Canadian Hydrographic Service (CHS), DFO, at different locations, depths, and seasons. It is seen that the model simulated water levels and near surface/bottom currents are in good agreement with observations. Southern Chatham Sound was found to be dominated by tidal currents, while the surface wind plays an important role on the circulation variability in the Northern Chatham Sound. The 3D circulation model is used to drive a sediment model applied to determining the fate and transport of sediment released from marine terminal construction and dredge disposal at sea. The circulation model also sheds light on the development of the unstructured-grid, Finite-Volume Coastal Ocean Model (FVCOM) for Chatham Sound.

Sea Water Temperature in Tokyo Bay under the Influence of River Discharges

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Long term observation of sea water temperature in Tokyo Bay shows that the SST over the whole bay has a decreasing trend in summer and an increasing trend in winter, which may not only affect the environmental system but also the nearby urban climate. Considering the SST variation is affected by air temperature, prevailing wind, as well as the fresh water discharge from the land, a model incorporating four major river discharges has been established to study the variability in circulation and temperature in Tokyo Bay introduced by the fresh water input from the land. Results show that the fresh river water is transported toward the bay mouth along the west coast under the Coriolis force and strengthens the anti-clockwise circulation. At the same time, the heat transport from the open ocean is increased at the subsurface layer.

Modeling Flocculation Processes of Fine-Grained Particles in a Macrotidal Estuary

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Flocculation processes (fine-grain particle aggregation and breakup) have a significant impact on particle transport and fate in estuaries. The size of suspended particles varies with time, and can be orders of magnitude larger than those of primary particles. As a consequence, the particle settling velocity varies with time dramatically. In this study, a size-resolved flocculation model is implemented into the Princeton Ocean Model (POM) to simulate the fine-grained particle transport and fate in a macrotidal estuary in the Southeast of China. An observation study in the estuary (Wang et al. 2013) has shown that in-situ particle size changes dynamically during tidal cycles implying the dominant effects of flocculation. The numerical simulations compare well with the published observations in terms of the particle size variations. The fate of the suspended particles is predicted in the model.

Using Numerical Particle-Tracking to Study the Movement of Marine Animals

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We present two examples of the use of a numerical particle-tracking scheme, in combination with time-varying, three-dimensional fields of numerically simulated hydrography and circulation, in the study of marine animals. The hydrography and circulation are simulated using a coastal modelling system based on the Princeton Ocean Model. In both examples, information from tags that had been attached to marine animals, collected by our collaborators in a project known as the Ocean Tracking Network, provide benchmark values and guidance in setting experiment parameters. In the first example, the aim is to understand the effects of various observed and hypothesized behaviours in the American eel during a portion of its spawning migration, through the St. Lawrence Estuary and the Gulf of St. Lawrence. These behaviours include selective tidal stream transport, diel vertical migration, and a preference for higher salinity. The behaviours are prescribed to the particles in the numerical particle-tracking scheme, and the effects of each behaviour on the particles' spatial distribution and transit times are discussed. In the second example, the aim is to search overwintering sites of the Atlantic sturgeon in the Bay of Fundy. Passive particles are numerically tracked backwards in time to simulate the movement of tags between the time they reach the surface (after becoming detached from sturgeon in the subsurface) and the time of their first satellite detection. We also discuss features of the hydrography that may be guiding the Atlantic sturgeon in their annual migration into the Bay of Fundy, which is undertaken predominantly by those from the nearby Saint John River but is known to include some from as far away as Hudson River in New York.

Numerical Modelling of Circulation and Exchange Through Singapore Straits

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The circulation in the Singapore coastal region is complicated and influenced by the combination of tidal forcing of the surrounding seas, complex bathymetry, irregular coastlines, and seasonal monsoon and local winds. An unstructured-grid SUNTANS (Stanford Unstructured Nonhydrostatic Terrain-following Adaptive Navier-Stokes Simulator) model is employed to perform three-dimensional simulations of flow in Singapore coastal waters. The unstructured-grid has an average resolution of 50 – 100 m around Singapore and in areas close to the shoreline, while a coarse grid resolution is employed in the open waters. The model is tidally forced at the three open boundaries, located to the west, south and east of Singapore, using the 8 main tidal constituents as derived from the OSU Tidal Prediction Software (OTPS). A detailed calibration is performed, and the model-predicted water levels and currents compare well with observed data throughout the model domain. We examine the individual and combined effects of tidal and wind forcing by performing simulations with (1) tides only, (2) winds only and (3) both tides and wind. The exchange through Singapore Strait is investigated by computing volume fluxes and transport pathways at four transects, namely the Malacca Strait, Java Sea, South China Sea and Singapore transects. The transport pathways are computed by releasing particles on each side of the transects, and identifying the spatial distribution of the particles over one tidal cycle. Our results show that tidal forcing is predominant in Singapore Strait, and wind forcing is an important mechanism during the monsoon season. The residual effects that exist throughout the year are attributed to nonlinear interactions between tidal and wind forcing.

Sensitivity of Northwestern North Atlantic Shelf Circulation to Surface and Boundary Forcing: A Regional Model Assessment

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The northwestern North Atlantic shelf circulation, influenced by both North Atlantic subpolar and subtropical gyres, is one of the hydrographically most variable regions in the North Atlantic Ocean and hosts biologically rich and productive fishing grounds. With the goal of simulating conditions in this productive and complex region, we implemented a nested regional ocean model for the northwest North Atlantic shelves including the Gulf of Maine, the Scotian Shelf, the Gulf of St. Lawrence, the Grand Banks, and the adjacent deep ocean. Configuring such a model requires choosing external data to supply surface forcing and initial and boundary conditions, as well as the consideration of nesting options. Although these selections can greatly affect model performance and results, often they are not systematically investigated. Here we assessed the sensitivity of our regional model to a suite of atmospheric forcing datasets, to sets of initial and boundary conditions constructed from multiple global ocean models and a larger scale regional ocean model, and to two variants of the model grid – one extending further off-shelf and resolving Flemish Cap topography. We conducted model simulations for a 6-year period (1999-2004) and assessed model performance relative to a regional climatological dataset of temperature and salinity, observations collected from multiple monitoring stations and cruise transect lines, satellite sea surface temperature (SST) data, and descriptions of regional currents from literature. Based on this model assessment, we determined the model configuration that best reproduces observations. We find that while all surface forcing datasets are capable of producing model SST close to observed, the different datasets result in significant differences in model sea surface salinity (SSS). We find that initial and boundary conditions based on global ocean models do not necessary produce realistic circulation, and climatological initial and boundary conditions can improve model performance over those from global ocean models. Beyond optimizing model performance, we gained mechanistic understanding of model responses to variable nesting, surface forcing and domain choices.

The Implementation of Sea Ice Model on a High Resolution Regional Scale

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The Los Alamos sea ice model (CICE) was implemented on a high resolution (4 km x 3 km) regional scale to estimate ice parameters. The implementation of model equations to determine the dynamic and thermodynamic behaviour of sea ice included an algorithm of input data discretization and a solution of open boundary condition. The model has been validated using NCEP/NCAR (National Centre for Atmospheric Research) Reanalysis-2 data from 2010 and 2011. The sea ice simulation was performed over Baffin Bay and the Labrador Sea to retrieve important parameters such as ice concentration, thickness, ridging and drift. In addition, ice concentration estimated from the simulation demonstrated a good agreement with concentration derived from remote sensing measurements acquired by the Advanced Microwave Scanning Radiometer (AMSR). Besides high resolution, the advantage of the model is the possibility of including oceanographic parameters (e.g. currents) to provide accurate results.

Modelling Study of Circulation and Particle Movement in a Submarine Canyon: Sable Gully

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The Sable Gully is a broad submarine canyon located to the east of Sable Island on the edge of the Scotian Shelf. Being the home of many marine species including the endangered Northern Bottlenose Whale, the Gully was designated as a marine protected area (MPA) in 2004. Better understanding of physical environmental conditions over this MPA is needed for sustainable ecosystem management. In this study, a multi-nested ocean circulation model and a particle tracking model are used to examine the three-dimensional (3D) circulation and movement of particles carried passively by the flow over the Sable Gully. The 3D circulation model is driven by tides, wind, and surface heat/freshwater fluxes. The model performance is assessed by comparing the results with the previous numerical tidal results and current meter observations made in the Gully. The simulated tidal circulation over the Gully and adjacent waters is relatively strong on shallow banks and relatively weak on the continental slope. Below the depth of the Gully rim (~200 m), the tidal currents are constrained by the thalweg of the Gully and amplified toward the Gully head. The simulated sub-tidal circulation in the Gully has a complex spatial structure and significant seasonal variability. The simulated time-dependent 3D flow fields are then used in a particle tracking model to study the particle movements forward and backward in time, downstream and upstream areas, and residence time of the Gully. Based on the movements of particles released at the depth of the Gully rim and tracked forward in time, the e-folding residence time is estimated to be about 7 and 13 days in February and August 2006, respectively. The Gully flanks are identified as high retention areas with the typical residence time of 10 and 20 days in February and August 2006, respectively. Tracking particles with and without tides reveals that tidal circulation reduces the value of residence time in the Gully, particularly along the Gully flanks.

Sessions 4-6: Multi-Scale Ocean & Atmospheric Processes

Chairs: Leo Oey, Youyu Lu, Jianping Gan

The Effects of STCC Eddies on Kuroshio

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Kuroshio, the western boundary current in the North Pacific Ocean is presumed to obey the classical Sverdrup dynamics. The upstream Kuroshio (17~27N) is frequently impinged by the Subtropical Counter Current (STCC) eddies. This study examines the effect of STCC eddies on the Kuroshio and Luzon Strait intrusion in the inter-annual time scale by analyzing the numerical simulation from Japan Coastal Ocean Predictability Experiment 2.

Simulation Study of Upper Ocean Responses to Typhoon Cimaron in the South China Sea

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The mixed layer deepening induced by typhoon Cimaron is derived based on satellite observed sea surface temperature (SST) and climatological temperature profiles in the South China Sea (SCS). Corresponding to the SST drop of 4.4 °C on November 3, 2006, the mixed-layer deepened by 104.5 m relative to an undisturbed depth of 43.2 m, which is consistent with simulation results from the one-dimensional mixed-layer model (GOTM). Furthermore, baroclinic geostrophic velocity and vorticity are calculated from the surface temperature gradient caused by the typhoon. The negative vorticity, associated with the typhoon cooling, indicate an anti-cyclonic baroclinic circulation which is strongest at the base of the mixed-layer, and at the depth of 50 m, the geostrophic speed reached as high as 0.2 m s-1. Typhoon Cimaron proceeded slowly (1.7 m s-1) as it turned southwestward on November 3, 2006, resulting in a subcritical condition, with a Froude number (the ratio of typhoon translation speed to first baroclinic mode speed) of 0.6 around the maximum SST drop location. Thus, this situation facilitated a large amount of SST cooling and mixed-layer deepening due to absence of inertial-gravity waves in the wake of the typhoon. Comparisons of model simulations with Argo buoy data with the climatological temperature field suggest that the average uncertainty in the mixed-layer deepening estimation caused by the difference between Argo and climatological temperature profiles is less than 10 m.

Influence of the ocean on typhoon Nuri (2008) simulation to Various Microphysical Schemes

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The Weather Research and Forecasting Model (WRF) is applied to simulate typhoon Nuri passing through the Luzon Strait and the South China Sea in August 2008 with a grid spacing of 4 km. A series of numerical simulations were set up to explore the sensitivity of the typhoon simulation to various microphysical schemes, including WSM6, Purdue-Lin, FERR and SBU-YLIN. The simulated track, intensity and typhoon structure on various microphysical schemes are investigated. The model results indicate that the microphysical schemes significantly affect the intensity and inner-core structure of Nuri, but hardly influence the track of Nuri. The simulated minimum central pressure (Pmin) and maximum wind differ up to 20 hPa and 10 m/s, respectively. The maximum typhoon intensity was obtained using the SBU-YLIN scheme with the most concentrated diabetic heating. We found the interaction between the latent heating distribution and wind field evolution determines storm's intensity. Latent heating distribution, which is impacted significantly by microphysical schemes, also contributes to the size and kinematic structure of the storm.

Upwelling and Potential Vorticity Dynamics around a Coastal Promontory

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Amplifications of upslope cross-shelf transport and upwelling have been found in many coastal promontories around the world's ocean. The main underlying dynamics is linked to the locally intensified cross-shelf geostrophic transport induced by the along-shelf pressure gradient force (PGF). Motivated by the intensified upwelling observed in a coastal promontory in the East China Sea, we conducted dynamic analysis based on potential vorticity dynamics to provide a physical explanation for the origin of this unique phenomenon in the coastal ocean. It is found that a counter-current PGF is generated by negative bottom stress curl and strengthened by negative vorticity advection downstream of the promontory. The negative bottom stress curl arises from bottom shear vorticity of the coastal jet, and the source of negative advection downstream of the promontory is the negative shear vorticity on the seaside of the shoreward-bended jet around the promontory. Nevertheless, cyclonic curvature vorticity at the bottom and positive vorticity advection in the water column at the promontory weakens the negative PGF. Although nonlinear advection strengthens vorticity advection, it weakens bottom stress curl, and has little net effect on the counter-current PGF.

Far-Reaching Impact of a Coastal Front on the East Asian Winter Monsoon Wind

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In winter, a narrow streak of cold and less-saline coastal water is often observed from satellite imagery and in situ measurements along the eastern coast of China. The so called "China Coastal Current" flows southward from the Yellow and East China Seas, through the Taiwan Strait and, in some years of anomalously strong northeasterly monsoon, to as far south as the Hainan Island in the South China Sea. Seaward across the shelf, an oppositely-directed current carries warmer and more saline waters of mixed Kuroshio and South China Sea origin northward over the outer shelf of the East China Sea. The corresponding cross-shelf SST gradients have values comparable to those found in major ocean fronts, such as the Gulf Stream. Here we show using analytical and numerical models that the front causes an onshore veering of the low-level wind of the northeasterly winter monsoon, bringing moisture onto the East Asian continent, and accelerating the wind as a supercritical expansion fan onto the northern shelf of the South China Sea. Moreover, because in winter the cool surface of the northwestern Pacific is covered by a planetary boundary layer capped at the top by a temperature inversion where stratocumulus clouds tend to form, the onshore convergence extends far offshore ~1000 km. We use OLR (Outgoing Long-wave radiation) and precipitation data to assess the inter-annual and climate impacts of the process.

Impact of River Discharges on Circulation and Material Transport in Japanese Coastal Waters Simulated by JCOPE Ocean Model

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River discharges are important for formation of fresher coastal waters and details of coastal circulation around Japan. This impact is not local, and it supports the presence of lower salinity waters in many coastal areas along the Japanese coast. In an absence of rivers in the ocean model for appropriate reproducibility of ocean surface salinity it is often required to apply a salinity restoration approach. Additionally, rivers could bring to the oceans large amounts of suspended and dissolved substances, some of which are hazardous, like radioactive materials initially dropped on the ground following nuclear disasters like the Fukushima Dai-Ichi nuclear power plant accident. These could be washed to rivers by strong rainfalls. Method of counting inflow of fresh water from rivers as horizontal fluxes to the designated model cells is used. Demonstrated is the direct impact of rivers on formation of fresher waters along the coast of Japan and some cases of induced by discharges local ocean circulation patterns near the river mouth locations. Experiment where the model utilizes hourly information on the amount of river discharge demonstrates the importance of such approach for correct simulation of transport processes in extreme conditions like typhoon induced precipitation, that often takes place in Japan and East Asia. To achieve this capacity, we are looking for utilization of simple land waters hydrological models for main river basins that could transfer detailed meteorological precipitation forecast information in to the approximate forecasts of river discharges.

Short-Term Fluctuations South of Japan and their Relationship with the Kuroshio Path: 40- to 80-Day Fluctuations

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To detect short-term fluctuations south of Japan, we applied wavelet analysis to ocean-reanalysis data of the Japan Coastal Ocean Predictability Experiment 2 (JCOPE2) with a horizontal resolution of 1/36º. A type of fluctuation exists in a 40- to 80-day period band. The fluctuations are related to a temporal change of S-shaped meandering of the Kuroshio path. The 40- to 80-day fluctuations are especially active over the Izu Ridge, suggesting that topographic waves are dynamically important. The fluctuations of the 40- to 80-day period band are affected by a low-frequency shift of the Kuroshio paths. The fluctuations are stronger during the period of an offshore non-large-meander Kuroshio path than during a period of the nearshore non-large-meander Kuroshio path. This contrasts with another type of fluctuation in the 8- to 36-day band, which is more active during the period of the nearshore path (Miyama and Miyazawa, 2014). The lag correlation shows that this active period lags behind active periods of fluctuation in the upstream area of the Kuroshio in the east of Kyushu.

Inter-Annual Variations of Water Temperature and Circulation in the East China Sea

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Sea surface temperature (SST) in the East China Sea (ECS), based on in situ monitoring during 1960-2001 and satellite remote sensing during 1982-2011, are analyzed. The winter SST increased by 2.34°C in 52 years, with two winter cold-to-warm shifts occurring in 1977/1978 and in 1994/1995, respectively. The largest inter-annual SST variation exists in the inner shelf adjacent to the Changjiang estuary. The simulation results of a two-way nested global and Northwest Pacific model, during 1958-2007, are then analyzed. In winter, the model obtains similar spatial distribution of inter-annual variation of SST with observations; strong variability of bottom temperature is found along the 50 m isobath, to the east of the Changjiang estuary and over the outer shelf north of Taiwan. Strong winter temperature variation mainly occur in frontal areas whose locations vary due to the competition between coastal currents and the Taiwan Warm Current. Stronger winter monsoons drive more cold coastal water from the north and causes decrease in water temperature. In summer, inter-annual SST variation is less significant than that of the bottom temperature; and the strongest temperature variation occurs in the middle layer at sections south of 28°N associated with changes of the mixed layer depth. Temperature variation in this area is influenced by the intrusion of subsurface water of the Kuroshio onto the shelf near Taiwan. Further analysis links the intrusion variation to that of Kuroshio transport east of Taiwan, sea surface height, and the wind forced Rossby waves in the interior North Pacific.

Modeling Seasonal and Interannual Variability of General Circulation and Thermal Structure in the Great Lakes with FVCOM

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An unstructured Finite Volume Coastal Ocean Model was applied to all five Great Lakes simultaneously to simulate circulation and thermal structure from 1993 to 2008. Model results are compared to available observations of currents and temperature and previous modeling work. Maps of climatological circulation for all the five Great lakes were presented. Winter currents show a two-gyre type circulation in Lakes Ontario and Erie and one large-scale cyclonic circulation in Lakes Michigan, Huron, and Superior. During the summer, a cyclonic circulation remains in Lakes Superior; a primarily cyclonic circulation dominates the upper and central Lakes Huron; Lake Ontario turns to have a single cyclonic circulation, while circulation in the central basin of Lake Erie remains two-gyre type; Lake Michigan has a cyclonic gyre in the north and an anti-cyclonic one in the south. The temperature profile during the summer is well simulated when a surface wind-wave mixing scheme is included in the model. Main features of the seasonal evolution of water temperature, such as reverse stratification during the winter, the spring and autumn overturn, the thermal bar, and the stratification during summer are well reproduced. The lakes exhibit significant annual and inter-annual variations in current speed and temperature.

Numerical Study of Influence from Changes in Circulation and Sediment Transport Associated with Human Activities to the Ecological Environment in Tieshan Bay

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The study region to be reported is Tieshan Bay, which is located in the Beibu Gulf over the Northwestern South China Sea, and is about 40 km to the east of Beihai city, Guangxi Province. The Bay is an ecologically sensitive marine area with a natural preservation mudflat zone of mangrove forest and Dugong National Nature Reserve along the shore. Tieshan Bay is also located in the Beibu Gulf Economic Circle, with several large-scale harbours and docks projects in the Bay and significant aquaculture activities in the near-shore on its western side. As a drowned valley bay with small river runoff and a large tidal range, tidal forcing plays a dominant role in the Bay. A 2D tidal circulation and sediment numerical model was used to evaluate the potential impact of economic activities to the local ocean circulation and the sediment transport. The numerical model was first used to simulate the normal conditions of tidal sea levels, tidal currents, sediment movement, and the coastal evolution in the Bay. The model performance was assessed by comparing model results with the measured currents and sediment data. The model was then used to examine the impact on the flow structure, seabed erosion and deposition due to the change in the tidal and sediment conditions caused by recent human activities. It was found that the influence on the coastal circulation and sediment transport due to human activity is limited, and the influence to the environmentally sensitive area from the alteration in the flow and sediment condition in the Bay is also relatively small.

Influences of Indian Ocean Interannual Variability on Different Stages of El Niño: A FOAM Model Approach

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Both the tropical Indian and tropical Pacific Oceans are active atmosphere-ocean interactive regions with robust inter-annual variability, which also constitutes a linkage between the two basins in the mode of variability. Using a global atmosphere-ocean coupled model, we conducted two experiments (CTRL and PC) to explore the contributions of Indian Ocean inter-annual sea surface temperature (SST) modes to the occurrence of El Niño events. The results show that inter-annual variability of the SST in the Indian Ocean induces a rapid growth of El Niño events during the boreal autumn in an El Niño developing year. However, it weakens El Niño events or even promotes cold phase conversions in an El Niño decaying year. Therefore, the entire period of the El Niño is shortened by the inter-annual variations of the Indian Ocean SST. Specifically, during the El Niño developing years, the positive Indian Ocean Dipole (IOD) events force an anomalous Walker circulation, which then enhances the existing westerly wind anomalies over the west Pacific. This will cause a warmer El Niño event, with some modulations by ocean advection and oceanic Rossby and Kelvin waves. However, with the onset of the South Asian monsoon, the Indian Ocean Basin (IOB) warming SST anomalies excite low level easterly wind anomalies over the west tropical Pacific during the El Niño decaying years. As a result, the El Niño event is prompted to change from a warm phase to a cold phase. At the same time, an associated atmospheric anticyclone anomaly appears and leads to a decreasing precipitation anomaly over the northwest Pacific. In summary, with remote forcing in the atmospheric circulation, the IOD mode usually affects the El Niño during the developing years, whereas the IOB mode affects the El Niño during the decaying years.

High-Resolution Modelling of Inter-Annual Variations of Circulation and Freshwater Pathway in the Arctic Ocean

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In this study we analyze the hindcast simulation during 2003-2009 with a coupled ocean and sea-ice model covering the Arctic and North Atlantic Oceans. The model has a horizontal resolution of 3-8 km, and is forced with the atmospheric forcing obtained from a series of reforecasts from the Canadian Meteorological Centre's operational Global Deterministic Prediction System, at a horizontal resolution of 33 km. During the winters of 2004-2008, the modelled inter-annual changes of dynamic ocean topography (DOT) in the Canada and Eurasian Basins compare favourably with that obtained from remote sensing by the ICESat mission. Corresponding to changes in DOT, the model obtains changes in freshwater content, salinity, and circulation both at large-scale and near the coasts of Greenland. The relationship of these changes to atmospheric forcing is explored.

Sampling the Stochastic Forecast Errors Using a Multicycle Ocean Prediction System

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Forecast errors contain both systematic and stochastic components. A multicycle approach is introduced to efficiently sample the stochastic error. A simple average of a 4-cycle system filters a significant proportion of the stochastic errors such that they robustly improve all standard statistical metrics including skill score for all prognostic variables. A spectral analysis of the forecasts and 4-cycle ensemble average demonstrate the averaging has negligible impact on the low wave numbers but then transitions for a band of wave numbers to increased smoothing until the reduction in spectral power asymptotes. It is found that the cut-off wavenumbers closely approximate the scales resolved by the observing system relative to each variable. A multicycle (or M-cycle) ensemble is a time-lagged ensemble where the M cycles do not share any background information, thereby improving the independent sampling of stochastic errors. One of the M cycles is performed per forecast cycle and repeated every M forecast cycles. Each of the remaining M-1 cycles are performed on the remaining forecast cycles and each repeated every M forecast cycles. All of the M cycles have the same configuration in terms of model and data assimilation, observing system and atmospheric forcing. The source of small perturbations is obtained from the moving window of observations assimilated and the observation age error assigned to altimetry. Similar to a time-lagged ensemble it is computationally efficient. In addition, a small ensemble size (M=4) is found to significantly reduce stochastic error indicating the samples are approximately orthogonal. The results from the BLUElink Ocean Model, Analysis and Prediction System version 2 (OceanMAPSv2) an eddy-resolving ocean prediction system configured as a 4-cycle system and run operationally at the Australian Bureau of Meteorology will be presented.

Session 7: Climate Dynamics and Modeling

Chair: Tal Ezer

The Challenge of Predicting Uneven Sea Level Rise and Flooding Risks Associated with Climatic Changes in Ocean Dynamics

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Projections of global sea level rise (SLR) by semi-empirical methods or by global climate models may not be accurate enough on local and regional scales for making practical decisions on mitigations and adaptation for coasts and cities under threat (e.g., Norfolk, VA; Atkinson et al., 2013). In particular, land subsidence and climatic changes in ocean dynamics result in uneven SLR along the U.S. East Coast (Ezer, 2013). An Empirical Mode Decomposition/Hilbert-Huang transform (EMD/HHT), which separates seasonal, decadal and multidecadal variations from long-term trends, explains the striking latitudinal SLR pattern along the U.S. East Coast. Recent weakening of the Atlantic Meridional Overturning Circulation (AMOC) and slowdown in the Gulf Stream (Ezer et al., 2013) may explain why SLR is significantly accelerating only north of Cape Hatteras. A statistical approach based on bootstrap simulations (Ezer and Corlett, 2012) suggests that future SLR projections must consider climatic changes in ocean dynamics to account for uneven SLR patterns. Comparisons of our sea level projections with projections based on IPCC and National Research Council recommendations show the shortcomings of the projection methods currently being used.

Scenario Changes of Atlantic Water in the Arctic Ocean

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The present study explores how the water temperature associated with the Atlantic Water Layer (AWL) might be modified under warming-induced conditions due to climate change. We performed simulations from 1970 to 2099 with a coupled ice-ocean model (CIOM) implemented for the Arctic Ocean. The surface fields to drive CIOM were provided by the Canadian Regional Climate Model (CRCM), in turn driven by the third-generation Canadian global climate model (CGCM3) outputs following the A1B climate change scenario. Compared to PHC data, CIOM reproduces AWL at 200-900m. Both model simulation and PHC data show that the water temperature above 120m is near the freezing point in the central Arctic Ocean, while the water temperature below 900m is almost uniform with a magnitude about -1 to -0 ^{o}C. In terms of the possible future climate, the CIOM simulations show an increasing trend of water temperature averaged at 200-900m. Due to the surface warming in the Barents Sea, there is a significant decrease of sea ice in the northeastern Barents Sea, which increases the surface heat flux received by the Arctic Ocean. In addition, while there is no significant change in the Atlantic water inflow into the Arctic Ocean, the increased northward heat flux associated with increased water temperature plays an important role in the warming at 200-900m. Moreover, due to the increases in ice melting and Ekman transport, there is an increasing trend in sea surface height (SSH) and fresh water content in the Beaufort Sea.

The Influence of Coastline Changes on Tidal Circulation in the Abandoned Yellow River Mouth and Adjacent Coastal Waters

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The abandoned Yellow River Mouth (AYRM) in Northern Jiangsu Province, China is a typical erodible silty and muddy coast which has been undergoing severe coastal erosion since 1855 when the Yellow River diverted directly into Bohai Sea. A coastal circulation model based on POM has been used to investigate the circulation and variability in the AYRM and adjacent coastal waters. The simulated flow pattern is dominated by a bi-directional current of low ellipticity in the northern part and the coastal waters, which gradually changes into a rotary current with increasing ellipticity toward the south and toward the open ocean. Using the same coastal circulation model, based on the restored coastline position and underwater topography of the Abandoned Yellow River Delta, the influence of coastline changes on tidal circulation has been studied. The results show that the coastline changes strongly affect the tidal amplitude, the tidal range, the positions of the amphidromic points and then the tidal circulation in the region.

The All-Source Green's Function and Its Application to Storm Surge Modelling

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This paper describes a new method of modelling storm surges with the All-Source Green's Function (ASGF). The method features super-fast modelling speed and data assimilation. The paper will show how an ASGF can be efficiently constructed from a numerical model and how it can be further developed into a liner regression model with the singular value decomposition (SVD). A Real case application of the method to model storm surges at points of interest in the Estuary and Gulf of St. Lawrence will be presented too.

Projected Change in Tasman Sea Marine Climate, Extremes, and Circulation through the 21st Century

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The surface waters of the western Tasman Sea are warming at almost four times the global average rate. Observational and modelling studies suggest that the increased sea surface temperature (SST) is largely due to a spin-up of the South Pacific Gyre (SPG) over recent decades. However, given the complex nature of the western boundary current in the South Pacific the consequences of the spin-up of the SPG in this region are not obvious. In particular, the enhancement of the EAC extension does not represent a simple change in the mean flow, but rather complex pulse and eddy changes, and is likely to affect higher order statistics such as the frequency of warming or cooling events. Extreme temperature events in particular can have catastrophic impacts on fragile coastal ecosystems. We investigate how the marine climate in the Tasman Sea is projected to change during the 21st century. Here, we discuss results from a high-resolution (~10 km) ocean circulation model, forced by output from a large-scale climate model simulation and validated against satellite remotely sensed SST and sea level, for the Tasman Sea region through the 2060s. We present the projected Tasman Sea marine climate in terms of changes in (i) the overall climate statistics (mean SST, SST variance, etc), (ii) occurrence of extreme SST events, and (iii) the mean circulation and eddy field. The results show that the mean SST is predicted to increase in a hotspot located in the Tasman Sea and the SST variance is also predicted to change, with a pattern distinct from that of the mean. The SST extremes in the Tasman Sea are predicted to change significantly due to a combined effect of the change in mean SST and the SST variance. The mean circulation and eddy kinetic energy in the Tasman Sea are predicted to change considerably by the 2060s. We interpret the projected changes in the mean circulation using changes in the wind field and link these changes to the overall spin-up of the SPG.

Session 8: Modeling and Prediction of Extreme Marine Events

Chair: Yasumasa Miyazawa

The Rapidly Developing Field of Operational Oceanography and Its Application to Safety of Life and Infrastructure

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The past two decades has seen a concerted international effort for the development and operational implementation of ocean forecast systems on a global and regional scale. This follows the many technological advances prior and during this time to routinely observe the ocean remotely through a constellation of satellites and *in situ* with an array of moorings, drifting buoys, expendable bathythermographs and autonomous profiling floats. Ocean forecasting systems are focused on the ocean's weather which shares many analogies to atmospheric weather but is comparatively finer in spatial scale O(100) km and longer in temporal scale of days to weeks. The anatomy of a forecast system involves the retrieval and processing of large volumes of observations, the merging of this information with highly resolved models of the ocean and the subsequent forward integration of these models forced by the surface exchange with an atmospheric model. These forecast systems produce a daily updated three-dimensional reconstruction of the ocean state and circulation together with a forecast for seven days or more. The information produced by these systems has a very broad range of applications including search and rescue operations, hazardous chemical response, ship routing, offshore operations, port management, coastal management, weather forecasting, naval defence and more. The statistical performance of these products has been continually improving over time as larger volumes and new types of observations are collected, quality of the observation increases, more optimal techniques and models are introduced leading to greater reliability and accuracy. Nonetheless, there are several challenges for operators in the use, interpretation and integration of these products as a part of their decision-making. The information collected by observations is never uniform in time or in space and there are practical challenges related to real-time communications. Practitioners need to determine the availability of observations in assessing every forecast. In addition, the ocean is a chaotic system which leads to some areas developing forecast errors more rapidly than others and that the locations and rates of forecast error growth will change with every forecast. In this case practitioners need to use additional information to assess the likelihood that the information might be less reliable by comparing different systems, using ensemble forecasts or other related techniques. Still further, within each application, practitioners have typically developed specific systems and practices for which the new information may be incompatible requiring further investment before consistent positive impacts can be achieved. At present there are four international centres producing global ocean forecasts and several other centres producing regional ocean forecasts. Harnessing this information for the full range of applications is an ongoing challenge but one that is critical to improving the safety of both life and infrastructure at sea. That is why Lloyd's Register Foundation (LRF) support for the LRF Global Network to Improve Prediction of Extreme Marine Events is so important and through it has enabled several advances toward addressing these challenges, enabled the sharing of this knowledge throughout the international community and importantly furthered the experience of promising young scientists in this field.

Change of Wave and Sea Level Extremes at Marginal Seas

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The relationship of significant wave height with maximum wave height over 1980-2009 in the Norwegian sea is established. The annual variability of wave height is found to correlate with NAO, and this relationship is dominated by the association of the NAO with more frequently encountered wave heights. Changes of wave height over the past 500 years and future 100 years is further explored based on the NAO index records. The area between Iceland and the British Isles is the region where the extreme waves are dominated by NAO. Sea level records from 1954 to 2012 at twenty tide gauges at and adjacent to the Chinese coasts are used to analyze extremes in sea level and in tidal residual. Significant increase in sea level extremes is primarily driven by changes in median sea level, but also linked with increases in tidal amplitudes at some stations. Tropical cyclones, median sea level and the 18.6-year nodal cycle are found to have different impact on annual variations of the extremes in different regions. The climate indices are attempted to link with sea level extremes. Global mean atmospheric temperature appears to be a good descriptor of the inter-annual variability of tidal residual extremes induced by tropical cyclones but the trend in global temperature is inconsistent with the lack of trend in the residuals.

Numerical Modeling of Storm Surges in the Coast of Mozambique

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The coast of Mozambique is particularly vulnerable and under severe risk of coastal floods due to storm surges. With a wide and shallow continental shelf, dominated by substantial astronomical tides, exceptionally high water levels can be produced by tropical and extratropical cyclone activity. Considering that: (i) the majority of coastal areas of Mozambique comprise low-lying and poorly protected land including important rivers (Zambezi, Limpopo and Pungoe); (ii) these coastal regions support a high concentration of people, important coastal resources and infrastructures, among other assets; and (iii) there is a lack of sea level data obtained by tide gauges in the area, this work presents a numerical modeling effort to evaluate the generation and the propagation of storm surges at the coast of Mozambique. These initiatives are being developed under a cooperative project between researches of both countries funded by Brazilian federal agency CAPES. Hindcast simulations of the period 1948-2010 were analyzed to evaluate the representativeness of modeled results for severe meteorological situations. The modeling approach consists of a large scale domain with 1 degree resolution that considered SODA2.2.4 monthly averages of TS climatology and high frequency NCEP/Reanalysis-I atmospheric forcing, superposed to tidal oscillations. These results were used to preliminary analyze the storm surge events in terms of seasonality and typical amplitudes, as well as to perform some validation with optional available observations. Afterwards, these results were used to supply initial and boundary conditions to a one-way nested grid for Mozambique Channel with 0.25 degree resolution. These nested simulations considered the period 1979-2010 with meteorological forcing specified through Climate Forecast System Reanalysis (CFSR). The comparison between both grids for the recent period shows the improvement of the modeled surges, which is related to the increased resolution as well as the detailed wind field.

Oceanic Dispersion of Anomalous Perfluoroalkyl Substances in the Western North Pacific Associated with the Great Earthquake 0311 in Japan

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The great earthquake of magnitude 9.0 on 11 March 2011 followed by TSUNAMI and fire in Japan has resulted in serious environmental problems in and around Japan. A huge amount of materials has been discharged into the ocean after the tremendous flood damage by the TSUNAMI. A research group of the National Institute of Advanced Industrial Science and Technology has sampled the perfluoroalkyl substances (PFAs), which are chemical materials included in the industrial products, in the Western North Pacific for the past few years. They found some evidence showing an abrupt increase of the PFAs concentration east of Japan in 2011. To confirm the anomalous input of two typical PFAs (PFOA and PFOS) from the Japanese coast into the ocean, we conducted a series of chemical tracer simulations using an eddy-resolving ocean reanalysis product, JCOPE2, by assuming the oceanic dispersion of the PFAs dissolved in sea water mainly driven by the ocean current. Comparison of the simulation results with the observation actually indicates a spike-like input of PFOA into the Western North Pacific after the earthquake; however, the simulations could not well explain the observed distribution of PFOS, suggesting some differences in the oceanic dispersion processes between PFOA and PFOS. The simulations suggest important roles of the Kuroshio Extension and mesoscale eddy processes in both the horizontal and vertical distribution of PFAs.

Mapping Present Day Extreme Sea Levels over the Coastal Waters of Northwestern Pacific

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Extreme sea levels with the 50-year return period over the coastal waters of northwestern Pacific (CWNP) associated with storm surges and tidal surface elevations are conducted by using a 2-D ocean circulation model driven by tidal forcing and atmospheric forcing. The atmospheric forcing is the combination of a parameterized vortex and large-scale Climate Forecast System Reanalysis (CFSR fields) at 6-hour intervals. The parameterized vortex is inserted into the CFSR fields to better resolve the atmospheric profiles associated with typhoons. The performances of the 2-D circulation model in simulating tidal and surge-induced sea levels are assessed by using observations over the CWNP. Results show that the 2-D circulation model can reasonably reproduce tides and storm surges over the CWNP. The simulated surge-induced sea levels are used to estimate the 50-year extreme sea levels associated with storm surges over the CWNP by using an extremal analysis technique. The regions experiencing significant impacts from the 50-year surge-induced sea levels are then mapped. The simulated surge-induced and tidal sea levels are used to estimate the 50-year extreme total sea levels using the Monte Carlo method. Results show that the highly risky regions to be threatened by the 50-year extreme total sea levels are similar to those of the 50-year extreme surge-induced sea levels, but with much higher extreme values.

Session 9: Coupled Bio-physical Ocean Models

Chairs: Katja Fennel and Danling Tang

Surface and Subsurface Phytoplankton Blooms Induced by Typhoon in the South China Sea

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Typhoons have an important impact on marine ecosystems. Previous studies show that typhoons often induce chlorophyll a (Chl-a) blooms in the surface waters. This paper shows that Chl-a blooms can occur not only on the surface but also just above the thermocline after the passage of a typhoon. We used satellite and cruise survey data to analyze physical and biological characteristics in the South China Sea after the passage of Typhoon Nuri in August 2008. This paper shows that a subsurface (20 to 100 m depth) Chl-a bloom (1.31 ± 0.47 mg m^{-3}) occurred and lasted for three weeks, stronger and longer than the surface Chl-a bloom (0.48 ± 0.23 mg m^{-3}). The maximum value of Chl-a of 2.10 mg m^{-3} was detected at 50 m depth. This value was approximately 4–5 times higher than the background value of 0.48 mg m^{-3} measured at non blooming areas at the same time and about 7.5 times higher than the mean Chl-a value of 0.28 ± 0.13 mg m^{-3} measured over a period of five years. The mixed layer depth and the thickness of the Chl-a bloom increased after the typhoon. Our analysis clearly shows that a subsurface upwelling caused by the passage of the typhoon transported nutrients to the euphotic zone and supported the Chl-a bloom. These observations provide some insight on the effect of typhoons on marine ecosystems, especially as related to the Integrated Primary Production.

Phosphorus Limitation Reduces Hypoxia in the Northern Gulf of Mexico: Results from a Physical-Biogeochemical Model

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In the northern Gulf of Mexico, excess dissolved inorganic nitrogen and phosphorus loads from the Mississippi-Atchafalaya River system promote high primary production and contribute to the seasonal development of hypoxic bottom waters on the Louisiana Shelf. While phytoplankton growth is considered to be typically nitrogen-limited in marine waters, phosphorus limitation has been observed in this region during peak river discharge in spring and early summer. Here we present a synthesis of recent investigations that quantitatively assessed, using a realistic physical-biogeochemical model, the effect of phosphorus limitation on primary production and hypoxia development in the Mississippi-Atchafalaya River plume. Our model simulations indicate that phosphorus limitation delays and displaces westward a portion of river-stimulated primary production and depositional fluxes, resulting in a redistribution of respiration processes toward the western Louisiana Shelf. Despite this redistribution, phosphorus limitation did not promote a westward expansion or relocation of hypoxia, as some had previously speculated. Rather, the onset of hypoxia was delayed and the size of the hypoxic zone reduced. In other words, P limitation diluted the effects of eutrophication on the Louisiana shelf. Simulations with altered nutrient river loads show that despite phosphorus limitation, the co-reduction of nitrogen and phosphorus remains the best strategy to reduce hypoxia. Yet, a 50% reduction in both nutrients was not sufficient to meet the Gulf Hypoxia action plan goal of a $5 \bullet 10^3 km^2$ hypoxic area in our model simulations. This result emphasizes the need for a drastic co-reduction of N and P loads from the Mississippi-Atchafalaya River system to significantly reduce hypoxia in this region.

Evidence for Temporal Evolution in Biological Parameters in a 3D Regional Model

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Marine ecosystems are complex and highly non-linear and the approaches to their modelling can vary from very simple to very complex. While simple models ignore the diversity in species composition by solely dividing plankton between autotrophs and herbivores, complex models have to deal with a large number of parameters, most of which are difficult to constrain from observations. This presentation highlights an optimization method that allows parameters to vary with time, allowing one to parameterize some of the real-ocean complexity in a relatively simple ecosystem model. The novel technique combines a statistical emulator and the chlorophyll evolution observed by satellite to estimate optimal values of a small number of model parameters. Here, using a high-resolution, 3-dimensional coupled physical-biological model of the northwest North Atlantic, we optimized the mortality rate of phytoplankton with the goal of assessing and understanding its temporal and spatial variability. We chose this parameter because the mortality of phytoplankton is one of the largest loss terms of photosynthetic biomass in the model, as well as one of the most poorly quantified processes and most oversimplified parameterizations (linear rate). A simulation with an optimized time-varying mortality rate performed better than a simulation with a constant, globally optimized parameter and a simulation with temperature-dependent phytoplankton mortality. The optimized time-varying mortality rate showed a clear seasonal cycle, which was significantly correlated with the depth of the mixed layer and with the abundance of small phytoplankton species (dinoflagellates, nanoplankton and picoplankton). Considering that phytoplankton mortality in our model configuration implicitly represents the grazing by microzooplankton, these results suggest that the time-varying mortality rate may implicitly represent the change in species composition through the year, from large plankton in spring to smaller cells in summer.

Effects of NEC Transport and Bifurcation Latitude on Japanese Eel Larval Migration

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Numerical Lagrangian experiments were conducted to study the effects of current strength and position on Japanese eel larval migration in the western North Pacific. Particles were released from the grid points that cover a Japanese eel spawning area and from different depths during the spawning seasons of 19 years (1991-2009), and the percentages of particles that reach the coastal areas of Taiwan and Japan were calculated at the end of one-year simulation. The percentages of particles that reach Japan are related to, but lower than, those that reach Taiwan, because Taiwan is on the migration route of Japanese eel larvae to Japan. More particles reach Taiwan when the transport of the North Equatorial Current (NEC) is stronger and when NEC bifurcates at more southern latitudes, because the particles are able to travel through NEC and to enter the Kuroshio more quickly. When the NEC transport is strong, high percentages of particles that reach Taiwan come from the northern part of the spawning area, while when the transport is weak, they come more evenly from the entire spawning area. Since the NEC transport and bifurcation latitude are controlled by wind forcing in the tropical western Pacific, which also regulates the El Niño Southern Oscillation (ENSO), the inter-annual and decadal variability of successful Japanese eel larval migration are thus related to the ENSO events and to the climate variability.

A Modelling Study of the Physical Controls on Hypoxia on the Louisiana Shelf

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The physical processes controlling the development of seasonal hypoxia (dissolved oxygen below 2 mg/l) on the Louisiana shelf (LA shelf) are examined using a three-dimensional circulation model with a relatively simple dissolved oxygen model. The model assumes that the net oxygen utilization rate by biological processes is constant in time and only varies with bathymetry, and hence isolates the role that physical forces have on regulating oxygen dynamics. Despite its simplicity, the model reasonably reproduces the observed variability of dissolved oxygen and hypoxic area on the LA shelf, highlighting the important role of physical controls on hypoxia. Model results demonstrate that both river discharge and wind forcing have strong effects on the distribution of plume water and stratification, and thereby on bottom dissolved oxygen concentration and hypoxia formation on the LA shelf. The seasonal cycle of hypoxia is relatively insensitive to the seasonal variability in river discharge, but the integrated hypoxic area over time is very sensitive to the overall magnitude of river discharge. Changes in wind speed have the greatest effects on the simulated seasonal cycle of hypoxia and hypoxic duration, while changes in wind direction strongly influence the geographic distribution of hypoxia.

Session 10: Simulation of Internal Waves

Chair: Kevin Lamb

Shoaling Internal Solitary Waves in the South China Sea

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The interaction of the barotropic tide with Luzon Strait topography generates westward propagating internal bores and solitary waves that can have amplitudes of O(200) m. These waves eventually shoal and dissipate on the western side of the South China Sea. Numerical simulations of the shoaling of internal solitary waves at the site of the Asian Seas International Acoustic Experiment have been undertaken to investigate the sensitivity of the shoaling to a variety of environmental factors including the bathymetry, stratification, effects of rotation and viscosity. Over the slope secondary solitary waves and mode-two wave packets are generated before viscous effects become important in shallow water on the shelf.

Numerical Analysis of Oceanic Internal Solitary Wave Generation Around an Island in Stratified Shear Flow

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Synthetic Aperture Radar (SAR) images with parabolic patterns around the Izu Islands were obtained. Almost all the images were taken in summer seasons when the Kuroshio approached the Islands and wind was gentle. The patterns in the SAR images were estimated to manifest nonlinear internal waves (NIWs) generated by a near critical stratified shear flow, the Kuroshio, and we conducted a non-hydrostatic numerical simulation to examine the generation. The initial and boundary conditions depended on the JCOPE2 but simplified by neglecting Coriolis force and applying steady boundary conditions. When the upstream flow is supercritical for mode 3 internal waves, mode 2 and 3 NIWs were excited and trapped as leading waves around the Miyake Island and the Mikura Island, respectively. Mode 1 internal waves were generated but not trapped because of the greater propagation speed. The surface convergence field shared the prominent features shown in the SAR images. Therefore, we suggest NIWs are generated around the Izu Islands by the Kuroshio and they are detected by SAR under certain atmospheric and oceanic conditions.

Geophysical Instabilities in a 2-Layer Rotating Shallow Water Model

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The stability characteristics of oceanic jets are investigated using a two-layer, Rotating Shallow Water model. We consider a Bickley jet in geostrophic balance for the horizontal velocity profile. This jet uses a piecewise vertical structure to idealize the vertical structure of physical oceanic jets. We use a linear stability analysis to compute dispersion relations and modal structures of three types of profiles: purely barotropic flow, purely baroclinic flow, and mixed barotropic-baroclinic flow. Even though these are idealized case studies, they are generic enough to give us insights into what can occur in the oceans. The linear stability analysis allows us to classify the unstable modes as barotropic or baroclinic, and also allows us to determine how their spatial structures depend on the governing nondimensional parameters. Subsequently, we study the nonlinear evolution to learn about the nonlinear equilibration process.

Using the Rotating Shallow Water Model to Study the Stability of Ocean Currents

Francis Poulin
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Oceanic currents are an essential part of ocean dynamics. Important examples are western boundary currents that exist in all of the ocean basins as a result of the wind-driven motions. The very energetic currents are important because of the fluid transport in the oceans but also because they are responsible for generating a substantial amount of vortical motion at both the mesoscale and the submesoscale. Idealized models of these jets can shed much insight into the time scales at which vortices form and their length scales. The particular theoretical model used to investigate these jets should be guided by the questions that are being asked. In this talk I will give an overview of recent studies that have used the Rotating Shallow Water (RSW) model to study the stability properties of ocean currents. This model has the advantage of considering both slow Rossby waves and fast gravity waves as well as their possible interactions. Also, the RSW model is relatively simple in that it neglects the complications that arise from continuous stratifications. I will give an overview of how the linear stability problem can be solved numerically very accurately using spectral collocation methods, which can predict the structure of the onset of the instability. Subsequently, we present rules from numerical simulations of the nonlinear dynamics that confirms that the exponential growth is well described by the linear theory but also gives us insight into how nonlinear equilibration occurs. Examples will include observations recently done in the coastal Bransfield current and a current in the Gulf of Oman and how they have been investigated using this methodology.

Application of a Numerical Model for Circulation and Tracer Distribution in Western Lake Ontario

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The three-dimensional hydrodynamic Estuary Lake Coastal Ocean Model (ELCOM) was used to study the water circulation and contaminant dispersion in Western Lake Ontario and Hamilton Harbour. To assess the model performance, we first simulate the circulation and temperature distribution of the lake in 2006 and compare the model results with the observations made in the lake during this period. The model showed considerable skill in reproducing the thermal structures and circulations. The simulated currents are used to examine the transport and dispersion of passive particles in Western Lake Ontario and Hamilton Harbour. Numerical results demonstrate that the movements of passive tracers are primarily controlled by the wind-driven currents.

Sessions 11-13: Numerical Techniques and Approaches in Ocean Modeling

Chairs: Richard Greatbatch, Huijie Xue and Jia Wang

Assessment of Tidal Current Energy in the Lofoten Area, Norway

Jarle Berntsen*, Johannes Dugstad and Helge Avlesen
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The throughflows in Lofoten, north Norway, may be used to produce tidal energy. The flow through Moskstraumen at the tip of Lofoten is especially energetic. The tidal flows through inlets into the fjords may also be used to produce electricity. Saltstraumen close to Bodø is for instance a famous tourist attraction due to the strong currents and whirlpools. To assess the potential for tidal energy production in the throughflows and inlets a high resolution depth averaged ocean model for the Lofoten area is implemented. Estimates of tidal energy potential for inlets and throughflows will be presented. Possible effects of turbine drag on the tidal amplitude will also be addressed.

Optimising Fairways in the Gulf of Finland Using Patterns of Surface Currents

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Several ways of detection of coherent and semi-persistent patterns in the surface layer of seas and oceans are used and the possibilities for their use for environmental management of potentially dangerous offshore activities explored. The study area is the Gulf of Finland in the Baltic Sea. The possibilities of using statistical analysis of Lagrangian trajectories of persistent parcels of pollution, passively advected by surface currents are addressed, in order to calculate the spatial distributions of probabilities and times for such parcels to reach the coastal area (to exert a coastal hit), and of the subsequent use of these distributions for environmental management of ship traffic and specification of environmentally optimized fairways. The analysis is mostly based on trajectories evaluated by the TRACMASS code from velocity fields calculated by the RCO circulation model for 1982–2001 with a horizontal resolution of 2 nautical miles and the OAAS model with 1 nautical mile resolution.

A method is developed for establishing the location of the equiprobability line, from where the probability of current-driven propagation of pollution to the opposite coasts is equal. Spatial distributions of probabilities and of the time it takes for a pollutant to reach the nearshore are calculated based on 10–20-day-long trajectories. The optimum fairways minimizing the probability and maximizing the time for coastal hits are mostly located to the north of the gulf axis. The typical root mean square deviation between the optimum fairways specified from different criteria is 6–16 km. The most frequently hit nearshore areas are short fragments between Hanko and Helsinki, the north-eastern coast of the gulf to the south of Vyborg and longer segments from Tallinn to Hiiumaa. A short section of the fairway to the south of Vyborg and a segment to the west of Tallinn are the most probable starting points of parcels. The inclusion of the artificial spreading of the modelled Lagrangian trajectories substantially changes the appearance of single trajectories and the spreading of initially closely located parcels but almost does not impact the pattern and frequency of hits to the nearshore. Finally, the sensitivity of the results to the spatial resolution of the model is analysed.

Realizing Surface Driven Ocean Flows in the Primitive Equations

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Buoyancy driven flows at the surface of the ocean are inherently different from their interior dynamics. One model that has recently become very popular in idealizing these surface flows with strong rotation is Surface Quasi-Geostrophy (SQG). Many of the numerical simulations of SQG have shown that vortices are frequently generated at very small scales, scales that are beyond the limits of SQG. In this talk we examine the dynamics of a rotating three-dimensional elliptic vortex in both the SQG model and the non-hydrostatic Boussinesq primitive equations. In the case of strong rotation (small Rossby number) we confirm the predictions from SQG. With weaker rotation (moderate Rossby number) we see the non-SQG effects that arise and find that the appropriate regime for SQG can be very limited. We conclude that some of the predictions that arise from the SQG model might not be very accurate in idealizing geophysical flows at the surface.

An Efficient Algorithm for Solving Pressure Poisson System in Non-Hydrostatic Free Surface Flow Models

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In recent years, the development of non-hydrostatic free surface flow models has been the topic of many research activities. However, the application of these models is limited due to their high computational cost. The non-hydrostatic pressure solution, in all non-hydrostatic numerical models, is the most computationally expensive part of the numerical scheme. In models that apply the projection method, this involves a time-consuming pressure Poisson equation (PPE) solution and that such an approach may be contemplated at all relies on highly efficient equation solving methods. In this paper, a new scheme is developed to efficiently solve the system of obtained PPE. A non-hydrostatic finite volume model is developed to simulate free surface flow in a two-dimensional vertical plane. The algorithm is based on a projection method including the solution of the pressure Poisson equation (PPE). The model is developed in a z-level grid in which the size of all the cells in the computational domain, excluding those of the top layer, is constant in time. To simulate the variable water surface, the heights of the top layer cells are variable and proportional to the local water elevation. Taking the layout of the grid system into consideration, a new method is proposed to solve the PPE derived in z-level grids. In this method, the system of pressure equations is divided into two subsystems, namely a sub-system for the upper layer cells and another for the remaining cells. The coefficient matrix of the former is variable with respect to time, whereas that of the latter remains constant. Therefore, the coefficient matrix of the latter subsystem can be inverted once and saved throughout the simulation. The application of this procedure reduces the computational cost compared with other PPE solvers if the ratio of the number of horizontal to vertical cells is less than seven. The model is applied to simulate a series of numerical tests including strong vertical accelerations and is verified against analytical and experimental results, demonstrating satisfactory performance.

A New High-Order Finite-Volume Ocean Model to Study Ocean Processes

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We have recently developed a new numerical model (Tempest) that is designed to investigate the three-dimensional dynamics of the mesoscale and submesoscale in idealized process studies. It uses a high-order finite volume method that accurately resolves the propagation of waves in comparison to low-order methods and is faster than most spectral based methods because of the smaller stencil. The model can evolve the fully nonlinear non-hydrostatic Boussinesq equations but also has an option to assume hydrostatic balance, which is faster and more appropriate for large-scale processes. In the horizontal it assumes a rectangular geometry but implements a terrain-following coordinate system that allows for the flow over two-dimensional topography. In this talk we will present the basics of the model but also show preliminary results of how we have used it to study the instability of a surface trapped front.

Focusing and Vertical Mode Scattering of the First Mode Internal Tide by Mesoscale Eddy Interaction

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Numerical experiments are performed using the MITgcm to investigate the interaction of a mode-one internal tide with barotropic and baroclinic mode-one mesoscale eddies. Results show that after a mode-one internal tide passes through a barotropic eddy, spatial hot and cold spots of energy flux are produced in beam-like patterns. The magnitude of the energy flux in the hot spots can exceed twice the incident flux while in the cold spots can reach nearly zero. Passing a mode-one internal tide through a mode-one baroclinic eddy results in the scattering of energy from the incident mode-one to modes two and higher. The higher mode waves are produced in beam-like patterns. For the parameter regime explored here, we find conversion efficiencies that reach 13% for eddies of diameter 120 km. The Rossby numbers for our experiments are order one, corresponding to energetic mesoscale eddies that are typically found in western boundary current extensions and in the southern ocean. These eddies have length scales comparable to those of low-mode internal tides, and we expect that interaction between the two will be easily formed in locations where these phenomena coexist.

Modeling Power Potential for Tidal Turbine Farms in the Western Passage

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Tidal power potential is determined across the Western Passage in the Passamaquoddy Bay using the Finite Volume Circulation Ocean Model (FVCOM). The tidal turbines are implemented in FVCOM using the disc actuator theory method to determine the power potential for different densities and arrangements of tidal turbines. Initial results suggest that for a single row of turbines, the optimal distribution is ~40 meters apart. At the most efficient setting for 10 turbines across the Western Passage, the power coefficient is 2 and the total available extractable power is ~280 MWh. Parallel distribution of turbines in an array diminishes the energy extraction for turbines in the shadow of other turbines, while staggered distribution in an array increases energy extraction, due to speed gains in the gaps between turbines.

Improving the Numerics of Sea Ice Models Using the Exact Newton's Method

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Accurate representation of small scale ice features such as openings in landfast ice and ice leads constitutes a challenge for current sea ice models. The strong velocity gradients present in high resolution simulations of the ice slow the convergence of numerical solvers. This results in increased computational time, often preventing models from reaching properly refined solutions. Errors in the sea ice velocity field impact both ice cover and thickness. These can in turn propagate and significantly affect weather forecasts by modifying the exchanges of energy and moisture between the ocean and the atmosphere. In order to address this issue, new numerical solvers are being considered for the sea ice momentum equation. The use of a Jacobian free version of Newton’s method has allowed models to solve the equation for a velocity field more rapidly, but it too suffers from issues at high resolutions. In this presentation, the addition of an analytically derived Jacobian to Newton’s method in a one-dimensional sea ice model will be described, along with preliminary results.

A New Method to Evaluate the Risk of Storm Surge Induced by Cold-Air Outbreak in the Bohai Sea

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Storm surge can be ranked as the most serious disaster among the marine disasters. Most of the serious disasters that occurred along the coastal zone are associated with storm surges induced by extreme weather systems. In China, almost all the coastal zones are susceptible to storm surges. In the coastal zone of the south-east part of China, storm surges are usually induced by typhoons or tropical cyclones that generate over the northwestern Pacific, but in the Bohai Sea, which is located in the high latitude and seldom affected by typhoons and tropical cyclones, storm surges caused by cold-air outbreaks in winter usually lead to a sustained significant sea level rising along the south-western coastal zone. By analyzing the characteristics of cold-air outbreaks, three typical characteristics are summarized to calculate the storm surge. After the sensitivity experiment with these characteristics, the cold-air outbreaks are divided into four categories according to the major track by which they attack China, and in each category there are one control scenario and four more extended scenarios. Therefore, the cold-air outbreaks over the Bohai Sea are described by these 20 scenarios. Base on these cold-air scenarios, storm surges induced by cold-air outbreaks in the Bohai Sea are modeled by FVCOM. It is found that the tops of the Bohai Bay and the Laizhou Bay are most seriously affected by the storm surges in the Bohai Sea. The characteristics of storm surges change with the tracks of cold-air outbreaks. The cold-air outbreaks from the NW and N track could place both the Bohai Bay and the Laizhou Bay at risk, the cold-air outbreaks from a NE track usually lead to significant water level rising to the top of Bohai Bay, but the ones from a W track can only affect the Laizhou Bay. After discussion of the water level rising induced by cold-air outbreaks, the risk of storm surge in Tanggu, Huanghua and Yangjiaogou is analyzed. As the areas of most concern, the risk of inundation in Tanggu and the Yellow River Delta is investigated respectively according to the strength of the cold-air outbreaks. In order to estimate the risk along the coast more reasonably, the time period that the water level exceeds a given threshold is involved. Based on the function considering the surge elevation, the probability of the storm surge scenarios and the time period mentioned above, the risk along the coast of the Bohai Sea is estimated, and the distribution of risk of storm surge along the Bohai Sea can be presented easily and clearly by this method.

Parameterization of the Effect of Langmuir Circulation in the Ocean Mixed Layer Model Using LES and Its Application to the OGCM

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Analysis of LES data reveals that Langmuir circulation (LC) induces a significant enhancement of the turbulent length scale and consequently of vertical mixing in the ocean mixed layer (OML), when stratification is weak and MLD is shallow (Noh et al. 2011). Based on the LES results, the OML model (Noh and Kim 1999, Noh et al. 2002) is modified to include the effects of LC, such as the enhancement of the length scale and the inclusion of the wave-force production of TKE. The prediction from the new OML model under the ideal conditions of surface wind stress and heat flux shows a good agreement with LES results, including the evolutions of temperature and dissipation rate. The new OML model is then embedded into the global ocean model MRI.COM with the global estimation of the Langmuir number. The OGCM results are found to improve the reproduction of the upper ocean structure significantly. The new OML model helps especially to produce sufficient mixing in the Southern Ocean during summer, while maintaining a realistic thermocline structure globally.

Circulation and Variability in the Pearl River Estuary and Associated Coastal Waters

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The Pearl River Estuary (PRE) is a bell-shaped semi-enclosed sea on the east coast of Guangdong Province of South China. The PRE connects the Pearl River with the South China Sea. The Pearl River is the largest river system in Southern China, with an annual mean discharge of ~$3.36\times10^{11}m^3$. The Pearl River Delta occupies the low-lying areas alongside the PRE with a population of ~50 million people and is one of the most densely populated areas in China. The economic developments over this region have frequently been under threat from natural hazards such as typhoons, storm surge and river floods. A coastal ocean circulation model is used to examine the dynamic interaction between the PRE and shelf waters immediately outside of the Estuary. The circulation model is the modified version of DalCoast-PRE, which consists of three sub-models based on the Princeton Ocean Model (POM). The outer sub-model (OM) has a coarse horizontal resolution (~7 km) for simulating the two-dimensional tidal and wind-driven circulation over the China Seas of the northwest Pacific Ocean. Nested inside the OM, an intermediate resolution (~3 km) middle sub-model (MM) is used to simulate the three-dimensional (3D) shelf circulation over the inner shelf of the northern South China Sea. Nested inside the MM, a fine-resolution (1.2 km) inner sub-model (IM) is used to simulate the 3D estuarine circulation over the PRE and adjacent coastal waters. A two-way nesting technique is used to exchange information between the middle and inner sub-models. In this presentation, preliminary model results will be presented and discussed.

Poster Session

Combining Numerical Modeling and Reanalysis Data to Study the Air-Sea Interaction in the Southeastern Pacific: Application to the Study of Ocean Swells off Chile

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A re-construction of surface circulation and waves climatology off Chile will be carried out by using National Centers for Environmental Prediction (NCEP) reanalysis data, Princeton Ocean Model (POM) and WAVEWATCH III (WW3). This type of study is relevant considering some indicatives of an increase of wave significant height and extreme waves for the next decades. Therefore, this hindcast and reconstruction of past sea level, surface circulation and waves is a first step aiming to develop a study to estimate the impact of climate change under different scenarios. Because of the scarcity of data about sea level, surface currents and waves off Chile, the modeling effort is an alternative way to study these phenomena. We expect to gain insight on air-sea interaction in the Pacific Ocean by analyzing separately the effect of tides, wind and atmospheric pressure on the ocean surface circulation and wave characteristics. Moreover, an improvement in the simulations will be expected by increasing the temporal and spatial resolution from regional to local scale.

Building a Detailed Dataset for Extreme Marine Events in the Western South Atlantic

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The occurrence of intense meteorological activity and its impacts in the Western South Atlantic are the main focus of this study. Within an R&D project funded by the Research Center of Brazil Oil Company (CENPES/PETROBRAS), an extensive numerical effort was carried out considering long integrations for atmospheric circulation with BRAMS, ocean circulation with POM and wind waves with WW3 for the period 1982-2010. The reference atmospheric fields came from NCEP-Reanalysis-I. The atmospheric downscaling with BRAMS has 30km of spatial resolution every 3 hours, yielding to a detailed dataset of surface winds and fluxes for the study area. Ocean circulation with POM has a resolution of 25km and considered tidal oscillations superposed to a weak nudging of temperature and salinity 3D fields from SODA2.2.4 dated monthly averages. Wind waves were solved locally by WW3 with 20km resolution forced with BRAMS winds, with spectral specification at the open boundaries given by a global domain of WW3 with 1 degree in lat/lon forced by NCEP-Reanalysis-I. Some specific cases of extreme events occurred in different seasons of the year were analyzed, as well as an evaluation of their variability during the modeled period. Extreme values analyses with their correspondent return periods were also obtained for winds, currents and waves.

Precipitation Changes Due to the Introduction of Eddy-Resolving Sea Surface Temperatures Into Simulations of East Coast Lows

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Weather Research and Forecast model (WRF) simulations are used to investigate how the distribution of precipitation is related to the distribution of sea surface temperatures (SST) during the life cycle of four east coast lows. Focus is placed on investigating changes caused by the introduction of complex eddy and filament structures present in the Bluelink reanalysis SST dataset. Past research on the effect of SST gradients on surface winds has shown that convergence occurs when air flows from a warm to a cold sea surface. In an unstable environment, such as that associated with a cold core upper-level low, this convergence may help to trigger thunderstorms and consequently affect precipitation. In the simulations enhancement/suppression of rainfall is found over and downwind of warmer/cooler SSTs. Warm eddies are at times associated with a pronounced enhancement of rainfall along their downwind flank where a strong SST gradient exists. These relationships are dependent on atmospheric conditions and the location of storm features like rain bands and fronts. Sensitivity to initialization time simulations are used to test the statistical robustness of these findings. Global Position and Tracking System (GPATS) lightning data are overlaid on maps of SST and sea level height anomalies to look for relationships between thunderstorms and upper ocean heat content. A complex picture emerges of a correspondence between the distribution of upper-ocean temperature gradients and that of lightning strikes. The WRF simulations are used to establish what atmospheric changes contribute to the observed distribution of thunderstorms and how these changes are related to the SST distribution.

Inter-Comparison of Hypoxia Models for the Northern Gulf of Mexico

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Observations of coastal hypoxia have increased dramatically over the past 50 years likely due to increased anthropogenic nutrient loading. The largest of these hypoxic zones in U.S. coastal waters (15,000 ± 5,000 km2) forms every summer over the continental shelf in the northern Gulf of Mexico due to nutrient and freshwater input from the Mississippi/Atchafalaya River System. The hypoxic zone varies inter-annually in terms of both extent and location due to variations in spring nutrient load, freshwater discharge, atmospheric forcing and circulation patterns. Several coupled circulation-hypoxia models are under development for this region in order to improve mechanistic understanding of the primary factors controlling hypoxia formation and to inform nutrient management decisions in the watershed. Here we report on an inter-comparison of hypoxia models for the northern Gulf of Mexico that is being undertaken within the NOAA-funded Coastal & Ocean Modeling Testbed project. The following four models are included: 1) an implementation of the Regional Ocean Modeling System (ROMS) coupled with its native hypoxia module, 2) an implementation of the Finite Volume Coastal Ocean model (FVCOM) coupled with the ROMS hypoxia module, 3) an implementation of FVCOM coupled to a modified version of the Water Analysis Simulation Program model, and 4) an implementation of the U.S. Navy's coastal ocean model coupled with the Gulf Ecosystem Model. The comparison will focus specifically on oxygen sources (determined by primary production, air-sea gas exchange and vertical stratification) and sinks (due to respiration in the water column and sediments) with the ultimate goal of improving model formulations, hindcasts, forecasts and mechanistic understanding.

Biological Effect of Meso-Scale Eddies on the Phytoplankton Blooms in the Vicinity of Luzon Strait

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The physical and biological evolution of mesocale eddies in the vicinity of Luzon Strait were investigated using the Regional Ocean Modeling System (ROMS) coupled with a Carbon, Silicate, and Nitrogen Ecosystem model (CoSiNe). Physical structure analysis showed that eddies formed in the northwest of Luzon Island shoaled the isotherms at the edge of the coastal upwelling area, and generated a sharp front in the northern periphery of the eddy as an interaction with the Kuroshio. These processes induced large vertical silicate-rich nutrient flux in the interior of the eddy. When the eddy departed from the upwelling area, the isopycnal keep the 'dorm' shape under the mixed layer. After it propagated northwestward, the fronts in the periphery decayed and the isopycnals became flat gradually. Corresponding to the physical processes, biomass of diatom increased and reached the peak during the formation of the eddy, then decreased when the eddy decayed. The biomass of large zooplankton showed change similar to the diatoms, but peaked after diatoms. When the growth of the diatom was depressed, the small phytoplankton started to grow. Potential vorticity analysis showed that water exchange only occurred around the periphery of the eddy when the eddy formed and propagated, and then water mass transported freely through the isopycnal layer during the decay period of the eddy, which indicated silicate-rich water mass in upwelling area were trapped and transported to the deep sea area, contributing to the phytoplankton blooms in the deep sea area.

Comparison of Couple-BOP Numerical Ocean Modeling with Observational Data: Physical Results

Ke Huang*, Huijie Xue, Fei Chai and Sergio Derada
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Temperature, salinity and sea level from a $1/12^o$ bio-optical-physical (BOP) numerical ocean model for the Indian Ocean (IO) are examined. This model is based on the Naval Coastal Ocean Model (NCOM) configured with 40 σ-z levels in the vertical. Atmospheric forcing is prescribed using the momentum and heat fluxes derived from NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA) dataset, and oceanic forcing is constructed from the operational $1/8^o$ Global NCOM physical fields, the World Ocean Atlas 2009 and Carbon Dioxide Information Analysis Center (CDIAC) biogeochemical fields. To determine the accuracy of the physical results, the authors present a series of comparisons at seasonal and inter-annual timescales, and examine the model simulated seasonal cycle, warm pool, the anomaly pattern, and the southwest IO Thermocline Ridge. Datasets used for comparison include NOAA extended reconstructed SST version 3 (ERSST.v3), TOGA and WOCE XBT lines, Japan Meteorological Agency historical ocean analysis (ISHII.v6.13) and AVISO altimeter sea level. The results of these comparisons are quite inspiring. The model captures the seasonal cycles of SST in all three considered regions, viz. the northern, equatorial and southern IO, although the magnitudes are weaker with average biases ~ 0.5 ^oC. The modeled thermal structure resembles the annual mean thermal structure derived from XBTs and the most significant error corresponds to the equatorial undercurrent at thermocline depths. The spatial structures of SSS and sea level are generally well simulated in the tropical. The differences of thermocline are largest in the eddy production regions of western boundary currents and near the southern open boundary. Wavelet and power spectrum analyses of the monthly SST time series show that there is significant energy at annual periods in ERSST. The spectra of the model results also reflect the annual band. Compared with the EOF modes of inter-annual ISHII temperature anomaly (TA), the surface layer in the model is categorized into the lower and upper layer groups. The lower layer, including 100 m and thermocline depth, successfully captures both of the first two modes of observations with nearly all characteristics of each mode. The upper layer, above the 50 m depth, can only capture part of the first two ISHII modes. The inter-annual variability of upper ocean (<100 m) heat content is also examined, which demonstrates that the model is able to simulate the HC in the first mode, but the model's third mode is similar to the second mode from the observations.

Parameterization of Biogeochemical Sediment-Water Fluxes Using In-Situ Measurements and a Steady-State Diagenetic Model

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Sediment biogeochemical processes are important drivers of water column biogeochemistry in coastal areas. For example, sediment oxygen consumption can be an important driver of bottom water oxygen depletion in hypoxic systems, and sediment-water nutrient fluxes support primary productivity in the overlying water column. Yet, biogeochemical sediment-water fluxes are often parameterized crudely and only poorly constrained in coupled physical-biogeochemical models. Here, we present a method for parameterizing biogeochemical sediment-water fluxes realistically and efficiently, using in-situ measurements and a steady state diagenetic model. We apply this method to the Louisiana Shelf where high primary production induced by excess nutrient loads from the Mississippi-Atchafalaya River system promotes the development of hypoxic bottom waters in summer. The implementation of the parameterizations in a coupled circulation-biogeochemical model of the northern Gulf of Mexico results in realistic sediment-water fluxes that enable a sediment-water column feedback at low bottom oxygen concentrations.

Estimating Extremes from Ocean and Climate Models: A Bayesian Hierarchical Model Approach

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Estimating oceanic and atmospheric extremes from ocean models is not trivial as these models often poorly represent extreme events. However, these models do tend to capture the central climate statistics (e.g., the mean temperature, variances, etc) well. We have developed a Bayesian hierarchical model (BHM) to improve the predictions of extremes from ocean and climate models. This was performed by first modeling the observed extremes using an extreme value distribution (EVD). Then, the parameters of the EVD were modeled functions of climate variables predicted by the ocean or atmosphere model over the same time period as the observations. By assuming stationarity of the model parameters, we have estimated extreme values for a projected future climate given the climate statistics for the projection time period (e.g., a climate model projection for the 21st century under a specified carbon emissions scenario). The model has been demonstrated for extreme sea surface temperatures (SSTs) in the Tasman Sea, off southeast Australia, using satellite-derived observations and downscaled global climate model output for the 1990s and the 2060s under an A1B emissions scenario. The extreme SSTs were modeled using the Gumbel distribution (the EVD) along with the climate statistics provided by the downscaled climate model output. Using this as a case study we will present a suite of statistics that can be used to summarize the probabilistic results of the BHM including posterior means, 95% confidence intervals, and probabilities of exceedance. We will also present a method for determining the statistical significance of the predicted changes in extreme value statistics. Finally, we will demonstrate the use of the BHM as a toy model for testing the response of extreme values to prescribed changes in climate.

A Semi-Beta-Plane Model for Shallow Water

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In large-scale ocean processes, the small aspect ratio can be exploited to greatly simplify the full Boussinesq model by idealizing the stratification as being either constant or piecewise constant. Two popular models that are often used for studying these types of processes are quasigeostrophy (QG) and f-plane shallow water (fSW). QG enables the study of Rossby (planetary) waves, while fSW permits the study of gravity (i.e. Poincare and Kelvin) waves. Unfortunately, these models are disjoint: QG cannot express gravity waves and fSW cannot support Rossby waves. A beta-plane shallow water model has the advantage of allowing for both wave motions, but generally needs to be solved numerically. Instead, a semi-beta-plane model is introduced to unite QG and fSW: it is complex enough to contain both planetary and gravity waves, while still maintaining analytic solvability. The semi-beta model allows us to study relationships between planetary and gravity waves, such as the direction of meridional trapping and the dispersion relation. Analytic solutions are discussed for a zonal channel, while numerical solutions are presented for both rectangular and circular basins. These solutions can form the basis of modal decompositions into Rossby and gravity waves respectively, which we propose as a novel methodology for analyzing large-scale oceanic flows. The domain limitations of the semi-beta model are discussed.

Simulation of the Wave Effects on Ocean Responses to Hurricane Juan (2003)

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An unstructured grid implementation of FVCOM, the Finite-Volume Community Ocean Model, is used to investigate the ocean responses to Hurricane Juan, which occurred in late September 2003. A wave model named SWAVE is coupled with FVCOM. The simulations are conducted in both the coupled and uncoupled models. Comparisons of results of the simulations show the effect of wave-current interactions and the coupling on the wave propagation and the storm-induced surface currents during the hurricane propagation and development process. Simulation results also show that the wave-current interactions can affect the intensity of the cyclonic eddy, induced by the hurricane, and anti-cyclonic eddy, caused by the upwelling in and around the wake of the storm.

Shallow Water Dissipation Processes for Wind Waves off the Mackenzie Delta

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This study focuses on two physical processes for waves in shallow waters off the Mackenzie Delta: bottom friction and depth-induced breaking terms. We use field observations of winds and waves, the state-of-the-art Simulating Waves Nearshore (SWAN) model, and reanalysis wind and wave data. The two field observation periods are an August 2008 field experiment, during which in situ field data were collected, and an Arctic storm when data were recorded by buoy measurements from 4 to 6 August 1991. Wind and wave development processes are analyzed during these two periods with comparisons to observed winds and waves. Our analyses show that bottom friction is the main shallow water physical process during the August 2008 field experiment, whereas depth-induced breaking is the dominant shallow water physical process during the 4–6 August 1991 storm, in conjunction with the effects of bottom friction. The SWAN wave model is used to investigate the shallow water physical processes during these two observation periods. Simulation results indicate that the model can give reasonable results, with an appropriate Collins coefficient of 0.006 and a wave breaking parameter of 0.55 to represent bottom friction and depth-induced breaking physics, respectively.

A Coupled Physical-Biological Model of the East China Sea

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The onset and spreading of hypoxia off the Changjiang River estuary and the adjacent coast changes from year to year, and the mechanism is poorly known due to a variety of nutrient sources and complicated circulation systems. Regional Ocean Modeling Systems (ROMS) coupled with a 13-component biological module has been applied to the East China Sea in an attempt to reproduce the hypoxia in 2006 when it was most significant. The physical part of the model driven by climatological forcing is verified before realistic forcing is applied. The biological module is based on the Carbon, Silicate, Nitrogen Ecosystem Model (CoSiNE). Here we present some recent progress focusing on quantitative estimations of phytoplankton production in the potential hypoxic zone and contributions from different factors.

The Research on the Separated Character of Long-Term Water and Salinity Transport in Zhujiang Estuary

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*S*ubstance transport is the key problem of ocean environment and engineering studies. According to the traditional view, the residual current, such as Euler residual current (ERC) and Lagrange residual current (LRC), is used for describing the direction and speed of long-term water and substance transport. In the previous study, the viewpoint that the long-term water and substance transport may be separated was suggested, and 2D quantities for the separated character were given. In this paper, 3D quantities describing long-term water and substance transport of each vertical layer are defined, which include 3D long-term water transport velocity (LWTV), 3D long-term substance transport velocity (LSTV) and 3D tidal bumping substance transport velocity (TBSTV). The relations between 2D and 3D quantities are discussed. And the dynamical mechanism for the separation of long-term water and substance transport are given by Euler and Lagrange points. According to Euler tide-averaged point, the nonlinear of tidal current transporting the tidal oscillatory component of substance concentration induces the separation of long-term water and substance transport. According to Lagrange tide-averaged point, the substance concentration variation of the single fluid micelle in its Lagrange track may induce the separation of long-term water and substance transport, and the average of many fluid micelles may also do so. The physical quantities for the separated character of long-term water and substance are used for analyzing the simulated current and salinity results from POM in Zhujiang estuary. ERC, LRC, LWTV and LSTV are different from each other. In some parts of the estuary, the direction of LWTV is opposite to that of LSTV.

Impacts of Sea-Level Rise on Estuarine Circulation: An Idealized Estuary Model and San Francisco Bay

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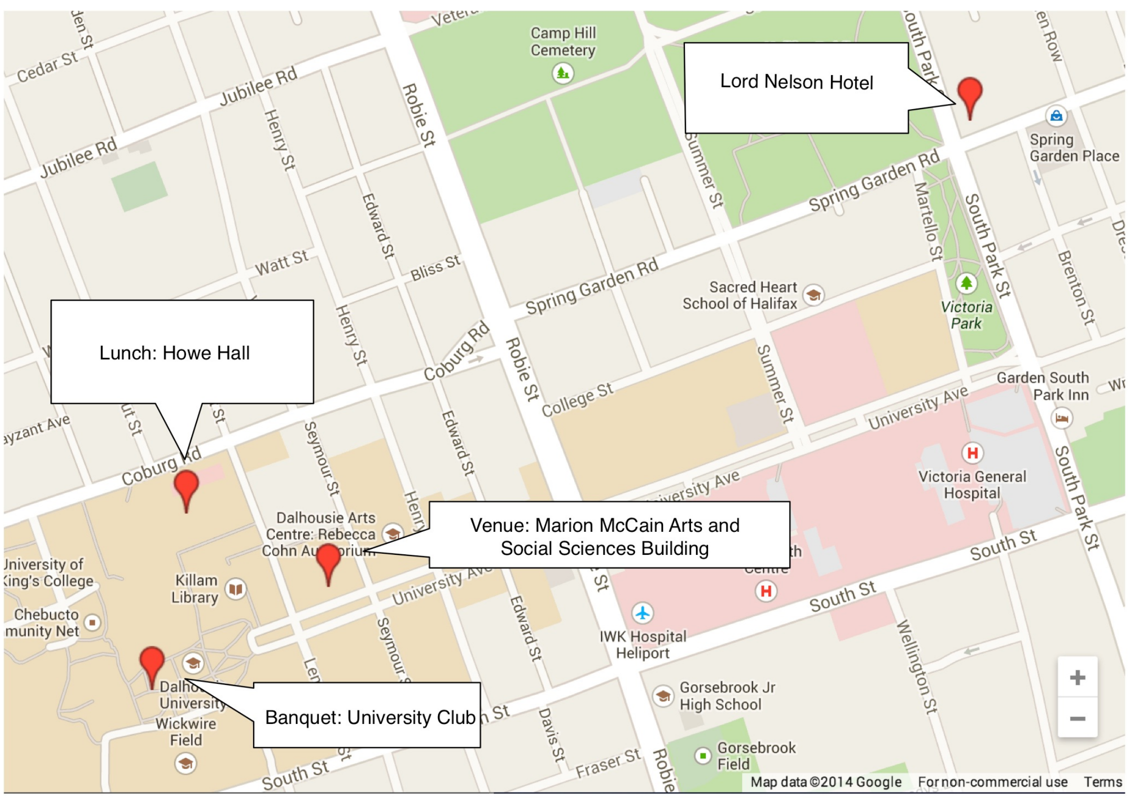
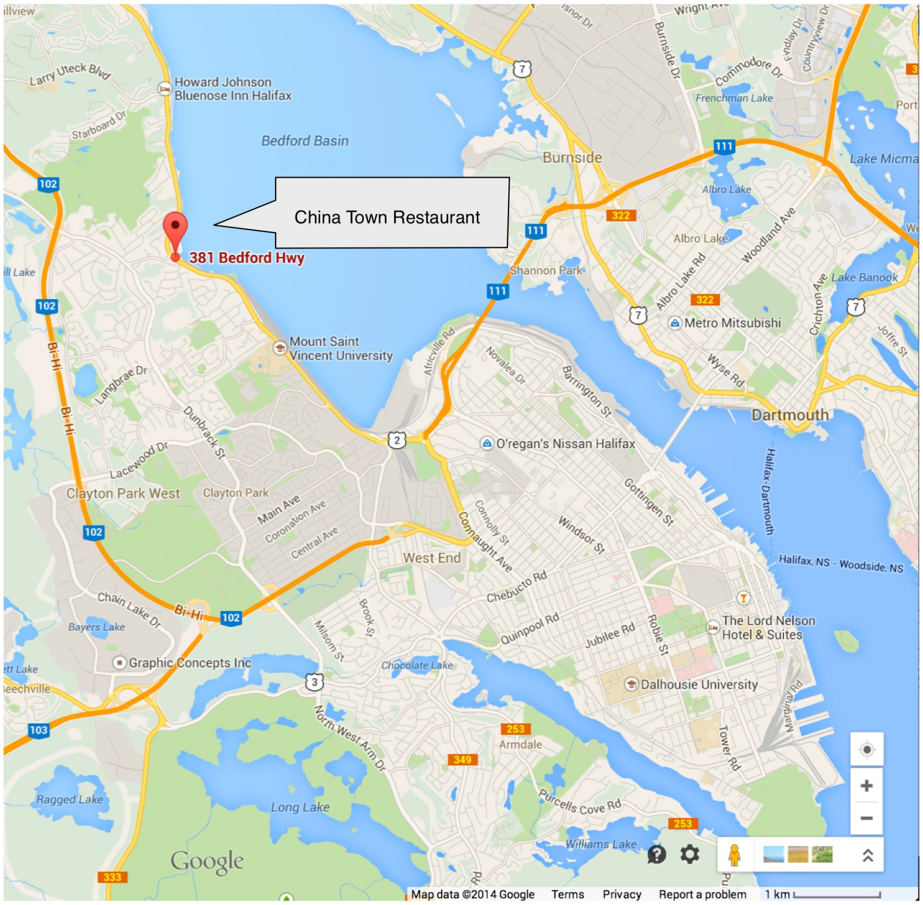
Estuaries lie at the interface of land and sea, and are particularly vulnerable to sea-level rise that might lead to intrusion of salt water further upstream and affect circulation patterns. Climate change is also likely to have a major impact on hydrological cycles and consequently lead to changes in freshwater inflows into estuaries. In this study, an idealized estuary model is employed to investigate the effects of sea-level rise and freshwater inflows on estuarine circulation. The simulations are performed with an idealized model to remove the influence of irregular coastlines, lateral variation in depth and presence of bathymetric features, so that the effects of sea-level rise on estuarine circulation are isolated. Increased inflows compress the salinity gradient, and lead to a stronger longitudinal salinity gradient $\partial s/\partial x$, which in turn drives a stronger gravitational circulation U_GC and higher longitudinal dispersion K. Rising sea levels result in a stronger longitudinal salinity gradient $\partial s/\partial x$ and reduces the vertical mixing, both of which lead to an increase in the strength of gravitational circulation U_GC and higher longitudinal dispersion K. A regression analysis is performed to determine the power-law dependence of intrusion length scale L on sea-level rise. Under low-flow conditions, the exponent is the largest, since sea-level rise has a greater effect on salinity intrusion due to weaker vertical stratification in the presence of low inflows. For high inflows, the exponent is reduced approximately by a factor of 2, owing to the suppression of mixing by stratification. Supporting climate change simulations from northern San Francisco Bay are presented. The intrusion length scale L is used as a substitute for regulating inflows to ensure that sufficient fresh water is available to flush the Bay. Following a set of standards explicitly stated in the 1994 Bay-Delta Accord, a series of simulations are performed and we find that with sea-level rise stronger inflows are required to maintain L at the proposed locations.

Author List

The list is in alphabetical order by author's last name

Travel Guidance




China Town Restaurant
381 Bedford Hwy
Bedford Basin
Howard Johnson
Bluenose Inn Halifax
Burnside
Mount Saint
Vincent University
Dartmouth
O'regan's Nissan Halifax
Clayton Park West
West End
Metro Mitsubishi
The Lord Nelson
Hotel & Suites
Dalhousie University
Graphic Concepts Inc
Long Lake
Armdale
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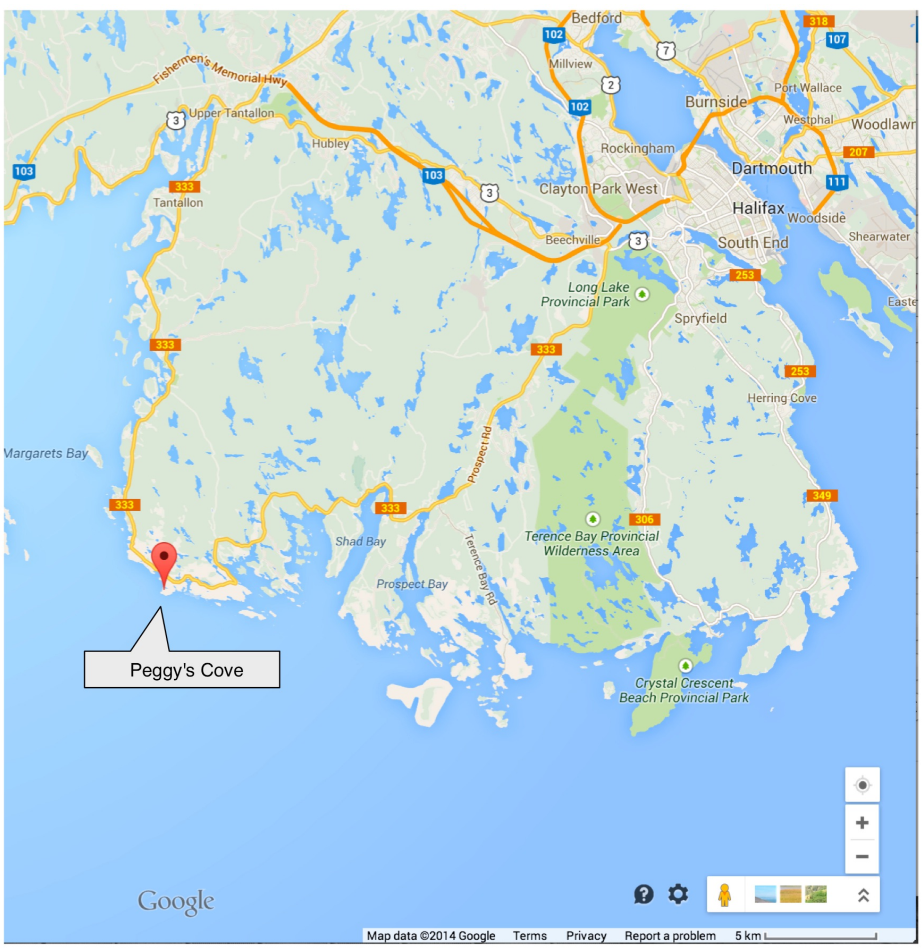
1 km


Peggy's Cove
Bedford
Burnside
Dartmouth
Halifax
Clayton Park West
Upper Tantallon
Tantallon
Hubley
Rockingham
Beechville
South End
Woodside
Long Lake
Provincial Park
Spryfield
Herring Cove
Shad Bay
Prospect Bay
Terence Bay Provincial
Wilderness Area
Crystal Crescent
Beach Provincial Park
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5 km