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2001 Terrain-Following Ocean Models Workshop

Program and Abstracts

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Edited by H. Arango and T. Ezer

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PROGRAM

Monday, August 20 - 0830-1220
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0900 - *Representing Vertical Mixing in Ocean Models: An Overview.* William G. Large, National Center for Atmospheric Research, USA. Invited Lecture

0940 - *Waves, Boundary Layers and Turbulence.* George L. Mellor, Princeton University, USA. Invited Lecture

1020 - C*omparison of Vertical Mixing Parameterizations for the Wind-driven Coastal Ocean.* Scott Durski, College of Oceanic and Atmospheric Sciences, Oregon State University, USA.

1040 - Break

1100 - *Numerical Modeling of Nearshore Circulation Using a Primitive Equation Model.* Priscilla Newberger and John Allen, College of Oceanic and Atmospheric Sciences, Oregon State University, USA.

1120 - *Modeling Frontal Subduction with ROMS.* Bjørn Ådlandsvik and W. Paul Budgell, Institute of Marine Research, Bergen, Norway.

1140 - D*ownslope Mixing and the Use of Sigma Ocean Models for Climate Studies.* Tal Ezer, Princeton University, USA.

1200 - *Implementation of MPDATA and Isoneutral Diffusion in Sigma-Coordinate Ocean Models.* Jens Debernard, Norwegian Meteorological Institute, Oslo, Norway.

1220 - Lunch

Monday, August 20 - 1330-1730
Numerics and Models
Co-Chairmen: Dale B. Haidvogel and John L. Wilkin

1330 - *Advanced Numerical Techniques*. Alexander. Shchepetkin, Institute of Geophysics and Planetary Physics, University of California at Los Angeles, USA. Invited Lecture.

1410 - *Comparisons of Numerical Aspects in POM and ROMS.* Tal Ezer, Princeton University, USA.

1430 - A *Comparison of POM and ROMS for Modeling Internal Tides in Weak Stratification.* Robin Robertson and Aike Beckmann, Alfred Wegener Institut für Polar- und Meeresforschung, Bremerhaven, Germany.

1450 - *The Application of POM to the Cavity Beneath the Amery Ice Shelf.* John Hunter, Antarctic Cooperative Research Centre, University of Tasmania, Australia.

1510 - *On Internal Pressure Errors in Sigma-Coordinate Ocean Models.* Jarle Berntsen, Department of Mathematics, University of Bergen, Norway.

1530 - Break

1550 - A *Description of the NCOM Model*. Paul Martin and Alan Wallcraft, Naval Research Laboratory Stennis Space Center, MS, USA.

1610 - *The Development of a New Ocean Circulation Model in the Sigma Coordinate System: Numerical Basin Tests and Application to the Western North Atlantic Ocean.* Gary A. Zarillo and Sang Sup Yuk, Florida Institute of Technology, Melbourne, FL, USA.

1630 - R*OMS Embedded Gridding, Test and Application for the Simulation of the Central Upwelling of the Pacific Coast of the United States.* Pierrick Penven, Institute of Geophysics and Planetary Physics, UCLA, Laurent Debreu, Institut d'Informatique et Mathematiques Appliquees de Grenoble, France, Patrick Marchesiello, Institute of Geophysics and Planetary Physics, UCLA, USA.

1650 - *Nesting Ocean Model for Parallel Vector Processors.* Yasumasa Miyazawa, Institute for Global Change Research/ FRSGC, Japan Akihiro Musa, NEC Corporation, Inc., Japan, Koji Ogochi, Information Technologies of Japan, Inc., Japan.

1710 - E*ddy-Resolving Simulations of the Asian Marginal Seas and Kuroshio Using ROMS*. Y. Tony Song, Jet Propulsion Laboratory, Pasadena, CA, Tao Tang, Hong Kong Baptist University, Kowloon Tong, Hong Kong.

1800 - Group photograph and Dinner reception for registrants, NCAR's Mesa Lab.

Tuesday, August 21 - 0830-1230
Regional and Coastal Applications
Co-Chairmen: John S. Allen and Tal Ezer

0830 - *Equilibrium Structure and Dynamics of the California Current System* J. McWilliams, P. Marchesiello, and A. Shchepetkin, Institute of Geophysics and Planetary Physics, UCLA, USA. Invited Lecture

0910 - *Modeling the California Current System Mesoscale Observations: Eddy Dynamics and Limits in Predictability.*
Di Lorenzo E., Miller A.J., Nielson D.J., Cornuelle B., Scripps Institute of Oceanography, USA, Moisan J.R., NASA/GSFC Wallops Flight Facility, USA.

0930 - *Coupled Global and Regional Circulation Models for the Coastal Gulf of Alaska.* Albert. J. Hermann, University of Washington, Seattle, Dale. B. Haidvogel, Rutgers University, New Brunswick, E. L. Dobbins and P. J. Stabeno, PMEL/NOAA, Seattle.

0950 - *A Modeling Study on the Transport Reversal at Taiwan Strait* D.S. Ko, R.H. Preller, G.A. Jacobs, Naval Research Laboratory, T.Y. Tang, S.F. Lin, National Taiwan University

1010 - *Modeling Low-Latititude Western Boundary Currents and the Indonesian Throughflow using POM*. B. Bang, T. Jensen, T. Miyama, H. Mitsudera and T. Qu, International Pacific Research Center, University of Hawaii, USA, and Frontier Research System for Global ChangeTokyo, Japan.

1030 - Break

1050 - *Idealized River Plume Simulations.* Robert Hetland, Department of Oceanography Texas A&M University, College Station, TX, USA.

1110 - *Modeling Flow Over Steep Topography with Strong Stratification: The Circulation around Astoria Canyon.* Michael Dinniman and John Klinck, Center for Coastal Physical Oceanography, Old Dominion University, USA.

1130 - *Using ROMS Lagrangian-Float Simulations to Estimate Exchange Rates Between Spatial Compartments in a Tidal Estuary.* Mark Hadfield, National Institute for Water and Atmospheric Research, New Zealand.

1150 - *How Topographic Smoothing Contributes to Differences Between the Eddy Flows Simulated by Sigma- and Z-level Models.* Thierry Penduff, Bernard Barnier, Marie-Aurelie Kerbiriou, and Jacques Verron.

1210 - *Comparison of a Z-level GPOM and the POM for the Arctic-North Atlantic Oceans.* Sirpa Hakkinen and Jelena Marshak, NASA Goddard Space Flight Center, Greenbelt, MD, USA.

1230 - Lunch

Tuesday, August 21 - 1330-1730
Data Assimilation
Co-Chairmen: Hernan G. Arango and Pierre F. Lermusiaux

1330 - T*he All-Purpose Adjoint Model.* Andrew Moore, University of Colorado, Boulder, USA. Invited Lecture

1410 - *Advanced Data Assimilation Schemes: Physical and Interdisciplinary Research*. Pierre F. Lermusiaux, Harvard University, Cambridge, USA. Invited Lecture

1450 - *Subsurface Analysis of Mesoscale Variability Inferred from Altimetry: Assimilation into ROMS by Intermittent Optimal Interpolation* John L. Wilkin, Institute of Marine and Coastal Sciences, Rutgers University, USA.

1510 - *Combining the Inverse Calculation with the Princeton Ocean Model: An Application in the Gulf of Mexico.* Ruoying He and Robert Weisberg, College of Marine Science, University of South Florida, USA.

1530 - *Data Assimilation Efforts for Oregon Shelf Flows*. Alexander L. Kurapov, Peter R. Oke, Lana Erofeeva, J. S. Allen, Gary D. Egbert, Robert N. Miller, College of Oceanic and Atmospheric Sciences, Oregon State University, USA.

1550 - Break

Tuesday, August 21 - 1550-1730
Poster Session

1530 - *A Code for Assimilation of Sea Surface Data into POM.*
Alexey Yaremchuk, Institute for Global Change Research, FRSGC, Japan

1530 - *Use of Coupled Circulation/Biogeochemical Models to Assess Potential Coastal Carbon Flux Study Field Programs.* John R. Moisan, Laboratory for Hydrospheric Processes, NASA/GSFC Wallops Flight Facility, Wallops Island, VA, USA.

1530 - C*oupling a Bottom Boundary Layer in the Generalized Terrain-Following.* Y. Tony Song and Yi Chao, Jet Propulsion Laboratory, Pasadena, CA, USA.

1530 - *A Rapidly Relocatable Version of POM.* Germana Peggion, University of Southern Mississippi, USA, Daniel N. Fox, Naval Research Lab, Stennis Space Center, MS, USA.

1530 - *Long Term Simulation of Transport Using Spatially and Temporally Aggregated Models.* Brian Williams, University of Newcastle, Australia.

1530 - *A Coastal Circulation Now/Forecast System for Texas-Louisiana Continental Shelf.* K.-J. Joseph Yip, Matthew K. Howard and Robert O. Reid, Department of Oceanography Texas A&M University, College Station, TX, USA.

1530 - *A Prototype Nowcast/Forecast System for Prince William Sound, Alaska.* Inkweon Bang and Christopher, N.K. Mooers, Ocean Prediction Experimental Laboratory, Rosenstiel School of Marine and Atmospheric Science, University of Miami.

1530 - *Running POM on a Beowulf Cluster.* Stephen Cousins and Huijie Xue, School of Marine Sciences, University of Maine.

Wednesday, August 22 - 0830-1230
Model testing, tools and evaluation
Co-Chairmen: George L. Mellor and Robert Hetland

0830 - *Ocean Modeling Test Cases*. Dale B. Haidvogel, Institute of Marine and Coastal Sciences, Rutgers University, USA. Invited Lecture

0910 - *A Community Terrain-Following Ocean Modeling System* Hernan G. Arango, Institute of Marine and Coastal Sciences, Rutgers University, USA.

0940 - *Parallelizing ROMS for Distributed Memory Machines using SMS*. Daniel Schaffer, NOAA/ERL/Forecast Systems Lab, Boulder, USA.

1010 - Break

1030 - *Matlab Tools: SeaGrid and SeaSlice Tutorials.* Kate Hedström, Arctic Region Supercomputer Center, University of Alaska, Fairbanks, USA,Charles R. Denham, U.S. Geological Survey, Woods Hole, MA, USA,

1110 - Discussions

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ABSTRACTS

Modeling Frontal Subduction with ROMS

Bjørn Ådlandsvik and W. Paul Budgell
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Frontal subduction of Arctic Water has been observed in the Polar Front separating Atlantic and Arctic Water in the Nordic Seas. This process is recreated in an idealized setup with the ROMS model. The experiment is done in a rather deep periodic channel with an along-channel ridge.
Sensitivity studies are performed to examine the performance of the model and the robustness of the process with different resolutions and parameterizations. Emphasis is put on the dependence on the various vertical mixing schemes provided in ROMS.

A Community Terrain-Following Ocean Modeling System (TOMS)

Hernan G. Arango
Institute of Marine and Coastal Sciences, Rutgers University

Tal Ezer
Princeton University

Alexander F. Shchepetkin
Institute of Geophysics and Planetary Physics, UCLA

An Overview of an ongoing effort to develop a new generation Terrain-following Ocean Modeling System (TOMS) for scientific and operational applications over a wide range of scales from Global to sub-mesoscale will be presented. The current work is part of an expanding collaborative effort involving several groups around the US including theoreticians, developers, testers, and users.

TOMS will include state of-the-art numerical algorithms and sub grid-scale parameterizations, nesting options, advanced data assimilation schemes, an interface for coupling with atmospheric forecasting models, extensive web-based documentation and users-support software for model set-up, analysis and diagnostics. The system is intended for massive parallel shared- and distributed-memory architectures.

Modeling Low-Latititude Western Boundary Currents and the Indonesian Throughflow using POM

B. Bang, T. Jensen, T. Miyama, H. Mitsudera and T. Qu
International Pacific Research Center
University of Hawaii

Frontier Research System for Global Change
Tokyo, Japan

POM has been set up and applied for a study of oceanic processes associated with low-latitude western boundary currents (LLWBC) in the Pacific Ocean and in the Indonesian Throughflow (ITF) region. The model uses a telescoping variable grid. The highest resolution is 1/3 deg in a subdomain covering the ITF region and decreases gradually to 1.2 deg over 20 deg wide transition zones. The model domain is the Pacific and Indian Ocean north of 60S. Details of the model configuration will be discussed. Using monthly Hellerman- Rosenstein wind stress, reduced in magnitude to 70%, and a monthly NCEP re-analysis climatology of heat flux and net precipitation, a 30 year simulation was done. The model results show most of the observed flows, including the northward shift of the NEC bifurcation latitude with depth, a preferred transport of surface water through the Lombok Strait, with an annual cycle in phase with the observations. The annual mean ITF transport in the model is 17 Sv.

On Internal Pressure Errors in Sigma-Coordinate Ocean Models

Jarle Berntsen
Department of Mathematics, University of Bergen, Norway

Sigma coordinate ocean models, or models based on more generalized topography following coordinate systems, are presently widely used in oceanographic studies. The controversy over internal pressure errors in sigma coordinate ocean models is, however, still worrying to at least some of the users. In the present study experiments with the seamount case using both constant and large horizontal viscosities and a Smagorinsky type viscosity are performed. For the constant viscosity (2000 m^2s^{-1}) case the errors do not grow prognostically. For the more realistic case with Smagorinsky viscosity and a value of the viscosity parameter in the range usually recommended, 0.2, the errors grow very strongly prognostically. Large vertical transports associated with the eight cyclones and anticyclones around the seamount create strong and real internal pressures that add on to the initial erroneous internal pressure. The growth may be balanced by multiplying the viscosity parameter by approximately a factor 100.

A more realistic experiment for the North Sea and the Skagerrak is also performed and model results and observations are compared. It is shown that conclusions from idealized experiments may not be valid in more realistic cases. For instance the best algorithm for the seamount case produced artificial vertical excursions in the Skagerrak.

The main conclusion is that the internal pressure errors may still be very significant in areas where we have a combination of stratification and varying topography. When applying Smagorinsky type viscosity, these errors may grow prognostically unless much larger values of the viscosity parameter than usually recommended are applied.

A new filtering technique that may reduce the pressure errors significantly will be presented.

Running POM on a Beowulf Cluster

Stephen Cousins and Huijie Xue
School of Marine Sciences
University of Maine

Linux based Beowulf clusters provide a relatively inexpensive way to achieve high-performance computing for scientific modeling. Funded by a grant from the Maine Science and Technology Foundation (MSTF), a joint project between the Computer Science department and the School of Marine Sciences at the University of Maine has been in progress since January of 2000. The goal of this project is to create a parallel version of the Princeton Ocean Model (POM), to run on a Beowulf cluster built by the Computer Science department. Specifically, the model is of Penobscot Bay on the coast of Maine.

Using the MP-POM code generated by the TOPAZ project at the University of Minnesota as a starting point, the code was changed to work with our Penobscot Bay model on the Beowulf cluster. An overview of the project and the project status will be presented.

Implementation of MPDATA and Isoneutral Diffusion in Sigma-Coordinate Ocean Models

Jens Debernard
Norwegian Meteorological Insitute, Oslo, Norway

Considered is the implementation of the positive definite advection scheme MPDATA and a rotated isoneutral diffusion tensor into DNMIs version of the POM model. The work is motivated by the fact that when constructing ocean models for use in climate change simulations the conservation of heat and salt becomes of paramount importance. The commonly employed leapfrog scheme for advection is severely dispersive and can produce artificial water masses when used in coarse resolution simulations. With the non-oscillatory MPDATA algorithm, the situation is greatly improved.

To further refine the water mass conservation a rotated isoneutral diffusion tensor is implemented to favorable mixing along density surfaces and to reduce dianeutral mixing.

The influence of these new implementations on the general model behavior will be illustrated.

Modeling Flow Over Steep Topography with Strong Stratification: The Circulation around Astoria Canyon

Michael Dinniman and John Klinck
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Submarine canyons along continental shelf edges are important topographical features that can have large impacts on coastal processes. The combination of steep topography and strong stratification that can be found makes this a challenging test case for terrain-following circulation models. The Regional Ocean Modeling System (ROMS) was used in a 83km x 100km domain off the U.S. West Coast, centered on Astoria and Willapa Canyons, in order to compare model results to an extensive velocity and temperature data set in Astoria that was obtained at small enough spatial and temporal scales to resolve the time-dependent circulation over and in the canyon. The model horizontal resolution (~ 300m x 420m) was fine enough to resolve the narrow (7km) Astoria Canyon and minimal bathymetric smoothing was used.

The mean horizontal flow, as measured by comparisons of flow vectors and relative vorticity, reproduced the observations moderately well. However, the model upwelling did not match the observed upwelling, as estimated by cross-sections and time histories of temperature and vertical velocity, and showed the model to be vertically "stiff" in the canyon. Sensitivity studies show the effect of different pressure gradient and tracer advection schemes that have recently been implemented in ROMS. Some possible causes of the differences between the observations and the model that are being investigated include vertical advection errors, wind forcing details and initial and offshore density structure.

Comparison of Vertical Mixing Parameterizations for the Wind-driven Coastal Ocean.

Scott Durski
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The Mellor-Yamada level 2.5 closure scheme is compared to an enhanced version the K-profile parameterization developed by Large, McWilliams and Doney for application to wind-driven coastal ocean circulation. Two features of the coastal ocean are examined in particular. 1) The level of stratification in the coastal ocean can range from well mixed to many times higher than that typically observed in the open ocean. The performance of the two schemes (forced by a surface stress) over this range of stratifications is compared and significant qualitative differences between formulations are noted. 2) The shallowness of the water column in the coastal ocean presents the potential for surface-bottom boundary layer interaction. Within ROMS, the Large et al. parameterization is appended to include a representation of a neutral bottom boundary layer, modeled after their surface boundary layer formulation. The two parameterizations are then compared over a range of statification in one-dimensional and two-dimensional experiments in which surface and bottom boundary stresses promote vertical mixing. Again qualitative differences arise which can be explained by how the two schemes represent mixing.

Downslope Mixing and the Use of Sigma Ocean Models for Climate Studies

Tal Ezer
Princeton University

The difficulties of representing overflow processes and deep water formation in course resolution z-level models point to some advantages of using terrain-following ocean models for long-term, large-scale climate problems, were traditionally other types of models have been used in the past. Experiments with an idealized generalized sigma coordinate ocean model demonstrate the sensitivity of deep water formation to the model grid. More realistic simulations of the North Atlantic Ocean and its adjustment to global climate change demonstrate the important role of overflows and bottom boundary layer dynamics. Sensitivity experiments explore how the parameterization of horizontal diffusion in POM affects long-term climate simulations.

Comparisons of Numerical Aspects in POM and ROMS

Tal Ezer
Princeton University

Different numerical aspects have been evaluated through a comparison between the Princeton Ocean Model (POM) and the Regional Ocean Modeling System (ROMS). While both models aim at modeling coastal to basin-scale problems with similar horizontal and vertical grids and similar subgrid-scale parameterizations, their numerical algorithms, model configuration and code size are very different. Sensitivity studies with an idealized channel flow and a steep seamount configuration demonstrate how different time stepping algorithms, different advection schemes and different pressure gradient schemes may affect the solution and the cpu requirement. The computational efficiency and numerical stability of the two models were compared and quantified for a range of different time step choices. It is shown for example, that while the simpler Leap-Frog time stepping in POM is more stable for small time steps, the more sophisticated Predictor-Corrector time stepping in ROMS becomes more stable for large time steps.

Using ROMS Lagrangian-Float Simulations to Estimate Exchange Rates Between Spatial Compartments in a Tidal Estuary

Mark Hadfield
National Institute for Water and Atmospheric Research
New Zealand

My colleagues and I are attempting to build a spatially aggregated ecosystem model to estimate aquaculture sustainability in Beatrix Bay, which is a branch of Pelorus Sound, New Zealand. Pelorus Sound is a drowned river valley system subject to tidal forcing and occasional large freshwater inputs. The water is normally stratified and the tidal flow along the contorted main channel generates internal tides and seiches.

Attempts have been made to estimate exchange rates between the spatial compartments in the ecosystem model using high-resolution hydrodynamic simulations with Eulerian tracers. At a given time each compartment is filled with a tracer, then the tracer field is examined one or two tidal cycles later to see how much of each tracer has escaped into the other boxes. From this information it is straightforward to estimate a matrix of exchange rates. This approach produces reasonable and self-consistent rates for horizontal exchange, provided the compartments are chosen appropriately. For vertical exchange the estimated rates are much too high. The main problem appears to be that undulations in the material surfaces due to internal waves are mis-interpreted as large vertical exchanges.

The ROMS model is being set up for the Pelorus Sound system in order to carry Lagrangian-float simulations of horizontal and vertical exchange. Given the extra information available from Lagrangian trajectories (relative to Eulerian concentration fields for the corresponding dispersion experiment) it should be possible to correct for some of the effects that generate excessively large vertical exchange.

Comparison of a Z-level GPOM and the POM for the Arctic-North Atlantic Oceans

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The GPOM model is applied in a z-level configuration for the Arctic - North Atlantic Basins as previously published for POM (Mauritzen and Hakkinen, 1997; Hakkinen, 1999, 2000). The model includes the same thermodynamic-dynamic ice model as embedded in the POM version. The parameterizations remain the same, except the horizontal viscosity had to be increased for the

GPOM to counteract the roughness of the step-wise topography. Overall, the differences between the model versions are not major. The most apparent differences are in the strength of the subpolar gyre, and the vertical overturning stream function. The GPOM has a Gulf Stream separation slightly north of Cape Hatteras which stabilizes after year 8 of the spin-up. The meridional heat transport at 25N is 1.2PW versus 1.4PW of the POM version.

Matlab Tools: SeaGrid Tutorial

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SeaGrid is a Matlab tool for generating curvilinear, orthogonal grids for ROMS and POM. It shares some distant ancestry with gridpak, but is interactive and bases its land mask on the coastline (usually more accurate than the bathymetry).

We will present some grid generation basics, followed by a demo of the SeaGrid package. The preparation of the coastline and bathymetry files for your region of interest will also be described. These files must be prepared before SeaGrid can be run in your domain of interest.

Combining the Inverse Calculation with the Princeton Ocean Model: An Application in the Gulf of Mexico

Ruoying He and Robert Weisberg
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University of South Florida

For a large-scale ocean circulation, assuming the system is geostrophic and non-dissipative, the conservation of mass and potential vorticity leads to the condition that the velocity is perpendicular to both density field and the potential vorticity gradients. Once the density and potential vorticity fields are known from the in-situ measurement or the climatological data, the absolute velocity field can be inferred by the so-called P-vector method. With the climatological T-S field, the monthly circulation fields in the Gulf of Mexico are calculated and found to be encouraging. With the fact that the regional domain coastal ocean model often suffers the problem of defining open boundary transports, the large scale "climatological" currents calculated from the inverse method may offer a solution to overcome the problem. An example of combining the inverse results with POM is presented and discussed.

Coupled Global and Regional Circulation Models for the Coastal Gulf of Alaska

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As part of the US GLOBEC NE Pacific program, we are simulating currents in the Coastal Gulf of Alaska (CGOA) to explore sources of interannual and interdecadal variability. To do so, we are developing coupled modeling systems composed of linked regional and global circulation models. Our initial regional model (SCRUM), configured with 13-22 km resolution in the CGOA, is forced at the surface by observed heat fluxes and wind stresses, at the continental boundaries by observed runoff, and at the open ocean boundaries by a combination of tracer climatologies and subtidal velocity and tidal elevation provided by a global finite element model (SEOM). A improved regional model (ROMS), with finer resolution (10 km) and expanded spatial coverage (from California to the Bering Sea), is now running on a massively parallel, distributed memory computing architecture. Here we describe the present and anticipated coupled systems, including the present method of inter-model coupling, describe a series of multi-year model hindcasts, compare hindcast results with Eulerian and Lagrangian field data obtained in the CGOA in fall 1996, and assess the impact of global information (barotropic subtidal velocities and tidal elevations) on the regional model under the present coupling strategy. We find that the regional model produces appropriate current systems (Alaskan Stream, Alaska Coastal Current) and scalar fields, but with mesoscale variability (of SSH and velocities) at somewhat reduced strength relative to data, and with temperature gradients somewhat larger than those observed. Barotropic subtidal information from the global model penetrates the regional model interior, supplying additional mesoscale variability, and modifying regional velocity and scalar fields in both shallow and deep areas. Tidal information exerts a significant influence on subtidal scalar and velocity structure only in specific shallow areas, where the tides (and tidal mixing) are strongest.

Idealized River Plume Simulations

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A series of numerical model runs is performed in an idealized domain to examine the formation of a river plume. Effects of estuary resolution are considered, as well as the effect of tides in the estuary. The along-channel length scale of the estuary can be shortened by increasing dissipation in the estuary, reducing the need to model the entire length of the estuary, while retaining identical exchange conditions. Tides may be included by modulating the riverine discharge in cases where tides on the shelf do not affect the plume. Using this method, tidal forcing along the open boundaries is unnecessary, avoiding complex and restrictive open boundary conditions as well as reflection of tides in the estuary. Resolution requirements of the estuary mouth an nearby coastal ocean are demonstrated using successively higher grid resolutions.

The Application of POM to the Cavity Beneath the Amery Ice Shelf

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The Princeton Ocean Model is presently being applied to the ocean cavity beneath the Amery Ice Shelf, Antarctica. The cavity covers an area of about 60000 square km, and has a volume of about 20000 cubic km; it therefore occupies about the same area as Bass Strait, Australia, but about five times the volume. The cavity is covered by an ice shelf of average thickness about 600 metres, which terminates at the ocean with a near-vertical ice cliff which stretches to about 200m below the sea surface. The circulation is characterized by buoyancy-driven currents (caused by melting and re-freezing at the base of the ice shelf) occupying a boundary layer which may be only tens of meters thick. Such a system can only be feasibly simulated using a model which involves either sigma- coordinates (or a variant of them) or isopycnic coordinates.

The presence of the ice cliff at the cavity entrance, and also the often steeply sloping ice/water interface and sea bed, presents a strong test of internal pressure errors and of the concept of hydrostatic consistency in sigma-coordinate models.

The process of adapting POM to include an ice shelf and appropriate ice/seawater thermodynamics will be described. Preliminary results for the Amery Ice Shelf will be presented.

A Prototype Nowcast/Forecast System for Prince William Sound, Alaska

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A Nowcast/Forecast system is under development for the Prince William Sound (PWS), Alaska and a prototype has been operational for almost one year. Near-realtime wind observed by NDBC (National Data Buoy Center) buoy 46060 in the central PWS, monthly surface heat flux from COADS (Comprehensive Ocean and Atmosphere Data Set), monthly freshwater flux derived from a hydrological model (Simmons 1996), and the monthly volume transport at the open boundary are driving forces of the ocean model which is based on POM. Tide is also included at the open boundary for eight constituents, which were interpolated from Dr. Foreman's (Institute of Ocean Sciences, Canada) 2-D tide model. Three-day run, one day for nowcast and two days for forecast, is performed everyday and the results are posted at the web. Results are compared with near-realtime observational data at Valdez for sea level and at NDBC buoy 46060 for surface water temperature.

A model validation study was performed for 1996 when observational data were relatively abundant. Comparison with observational data reveals strength and weakness of the model. Of the weaknesses, bottom-trapped current flowing northward from the Hinchinbrook Entrance (HE, major inflow port) and shallow heat penetration need to be more scrutinized. Also a study with expanded model domain provides an insight into the factors controlling the flow fields at HE and the Montague Strait (major outflow port of the Nowcast/Forecast model domain).

Simmons, H.L., 1996. Estimation of freshwater runoff into Prince William Sound using a digital elevation model. M.S. Thesis, University of Alaska, Fairbanks, Alaska.

A Modeling Study on the Transport Reversal at Taiwan Strait

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The transport at Taiwan Strait is in general positive from South China Sea to East China Sea even during the winter when the northern monsoon prevails. During October and November, 1999 currents at the Taiwan Strait were measured with bottom mounted ADCP at four locations. The measurements show strong transport reversals at bi-weekly periods.

Based on the analysis of the nowcast fields from NPACNFS (North Pacific Ocean Nowcast/Forecast System which is based on POM) and the wind stress we found that the observed strong periodic transport reversals during October and November, 1999 might be induced by a combination of local wind and the coastal trapped wave generated by the wintertime wind bursts at Yellow Sea. The coastally trapped waves were further enhanced by the alongshore wind propagating at about the same speed as waves at East China Sea.

Applying a hydrodynamic version of POM and based on the analytic solutions, the individual effect of local wind and the remotely forced coastal trapped wave on the transport reversals were identified.

Data Assimilation Efforts for Oregon Shelf Flows

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Our objective is to build a coastal data assimilation (DA) system to constrain circulation models with observations such as HF radar surface currents, moored ADCP currents, and ship-borne data collected in Oregon coastal waters. Two main components of the system are a POM-based DA model of wind-driven circulation and a spectral in time tidal DA model, that also uses sigma-coordinates. In the wind driven circulation DA model, surface HF radar currents for the summer of 1998 were assimilated using an optimal interpolation (OI) sequential algorithm. A time-distributed averaging procedure was incorporated in an OI DA scheme to overcome problems of data compatibility and initialization. The baroclinic tidal model is based on the linearized primitive equations. HF radar surface currents harmonicly analyzed in short time windows were assimilated into this model using a variational generalized inverse method and an efficient representer algorithm. Validation of the DA results against independent ADCP measurements suggests that surface current measurements contain valuable information about subsurface flows, both subinertial and superinertial. Connections between the two components of the DA are being established. Theoretical analysis indicates that the spectral model, applied at subinertial frequencies, can be used to build a forecast error covariance for the time-dependent wind circulation DA model. The tidal model may be used to detide ship-borne observations before they are assimilated in a wind-forced circulation model. The latter, in turn, can supply the tidal model with time-variable hydrographic fields and subinertial currents that are believed to cause internal tide.

Representing Vertical Mixing in Ocean Models: An Overview

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In Ocean General Circulation Models (OGCMs) boundary layer turbulence, at scales of tenths to hundreds of meters, is subgridscale and must be parameterized. The known and potentially important features of any such parameterization are presented. These range from the semi-empirical similarity theory of Monin-Obukhov, to the results from recent Large Eddy Simulations (LES) of oceanic regimes. Some common representations of ocean mixing are examined in the context of these turbulent features. Of particular interest are the validation of these mixing parameterizations, especially the criteria and framework used to judge performance.

Advanced Data Assimilation Schemes: Physical and Interdisciplinary Research

Pierre F. Lermusiaux
Harvard University

Data assimilation is a modern methodology combining natural data and dynamical models. All dynamical models are to some extent approximate, and all data sets are finite and to some extent limited by error bounds. The purpose of data assimilation is to provide estimates of nature which are better estimates than can be obtained by using only observations or a dynamical model. Most assimilation schemes are rooted in control theory, estimation theory and inverse techniques. State variables, parameters and their respective uncertainties can be estimated, processes inferred, dynamical hypothesis tested, necessary data identified, and fundamental models developed. However, the complexity and scope of advanced studies require substantial computational resources and adequate data sets, and will likely continue to necessitate new developments.

The presentation overviews, compares and illustrates different schemes and their applications to physical and interdisciplinary research. Research issues are discussed and some future challenges identified. A scheme for efficient data assimilation with nonlinear models, error subspace statistical estimation (ESSE), is overviewed. ESSE is based on evolving an error subspace, of variable size, that spans and tracks the scales and processes where dominant errors occur. The methodology and its results are discussed and evaluated for several physical, acoustical and biological applications of scientific and operational relevance.

Modeling the California Current System mesoscale observations: eddy dynamics and limits in predictability

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Moisan J.R.
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Hydrographic and ADCP surveys of temperature, salinity and velocity from CalCOFI surveys, altimetric measurements of sea level and drifter observations of temperature and velocity during the 1997-98 El Nino are now being fit using a Green's function technique (strong constraints) with an eddy-resolving ocean model (ROMS) of the Southern California Bight (SCB) region to obtain dynamically consistent estimates of eddy variability and to asses what physics sets the spatial/time scale of predictability in the coastal ocean. Skill evaluations are quantified by the model-data mismatch (rms error) during the fitting interval and after the forecasting of independent data.

A Description of the NCOM Model

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NCOM is a three-dimensional, free surface, baroclinic ocean model that was developed for coupling with the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS). NCOM is based on the primitive equations and the hydrostatic, Boussinesq, and incompressible approximations. The model uses an Arakawa C grid and second-order, centered, spacial finite differences, but has options to use some higher-order differences including 3rd-order upwind advection. The temporal differencing is leapfrog with an Asselin filter to supress timesplitting. The propagation of surface waves and vertical mixing are treated implicitly. A choice of the Mellor-Yamada Level 2 or Level 2.5 turbulence models is provided for the parameterization of vertical mixing.

The horizontal grid is orthogonal curvilinear. The vertical grid uses sigma coordinates for the upper layers and z-level (constant depth) coordinates for the lower layers and the depth at which the model changes from sigma to z-level coordinates can be specified by the user. Hence, sigma coordinates can be used for just the surface layer, for several layers between the surface and a specified depth, or for all the layers.

An arbitrary number of levels of nesting is implemented by using dynamic memory allocation and by passing model variables through subroutine argument lists so that the same subroutines can calculate the different nested grids. Domain decomposition with MPI or SHMEM is used for running on distributed memory, multi-processor computers.

Equilibrium Structure and Dynamics of the California Current System

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We have examined the structure and dynamical mechanisms of regional and meso-scale physical variability in the Northeast Pacific Ocean using ROMS. It is configured in subtropical, west-coastal domains that span the California Current System (CCS), with meso-scale resolution that currently is as fine as 3.5 km. Its forcing is by the mean seasonal cycle for atmospheric fluxes at the surface and adaptive nudging to gyre-scale fields at the open-water boundaries. Its equilibrium solutions show realistic mean and seasonal states and meso-scale eddies, fronts, and filaments. We find that the amount of eddy kinetic energy produced in the model is comparable to drifter and altimeter estimations in solutions with sufficiently fine resolution, from which we conclude that the dominant mesoscale variability in the CCS is intrinsic rather than forced. The dominant eddy generation is by baroclinic instability of the upwelling, along-shore currents. There is progressive movement of eddy energy off-shore and downwards into the oceanic interior in an annually recurrent cycle. The associated eddy heat fluxes provide the principal balance against the near-shore cooling by mean Ekman-transport and upwelling. The currents are highly non-uniform along the coast, with capes and ridges having very important influences in both maintaining mean standing eddies and launching off-shore transient filaments and fronts.

Waves, Boundary Layers and Turbulence

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A turbulence closure model is applied to the case of an oscillating bottom boundary layer; model calculations compare favorably with data. Wave induced oscillations can be temporally resolved in a one-dimensional model but not in three-dimensional ocean models, and, indeed, statistical wave models, working in consort with ocean models, can only provide information on expected wave periods and amplitudes. Therefore, a way has been found to parameterize the effects of bottom oscillations and, at the same time, to determine wave dissipation due to the oscillations.

The experience gained in the above research is being extended to more general interactions of ocean circulation, waves and turbulence.

Nesting ocean model for parallel vector processors

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Akihiro Musa
NEC Corporation, Inc., Japan

Koji Ogochi
Information Technologies of Japan, Inc., Japan

We developed a nesting ocean model based on the Princeton Ocean Model for parallel vector processors to perform predictability experiments of the Kuroshio path variation south of Japan. The meso-scale eddy activities are indispensable factors for the Kuroshio path variation (Miyazawa et al, 2001). The horizontal/ vertical resolution significantly affects representation of meso-scale eddy activities. Moreover the coastal application of the model results needs the nesting method; embedding higher resolution model in the present version of the model. In order to satisfy the above demands, a one-way nesting ocean model in which two models on different nodes are connected by MPI is developed. The higher resolution model itself is parallelized on different processor nodes by MPI using the domain decomposition method for reasonable load distribution. The part assigned to each node is properly vectorized for effective computation on the architecture of vector-parallel processors.

Use of Coupled Circulation/Biogeochemical Models to Assess Potential Coastal Carbon Flux Study Field Programs

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A collaborative investigation is presently ongoing between researchers at NASA/GSFC, UCLA, Scripps and Rutgers University to develop a fully coupled circulation/biogeochemical model for both East and West Coasts of the U.S. One aspect of this study has been to develop a model that could resolve the observed coastal features that have been observed from the NASA SeaWiFS and NOAA AVHRR sensors. We have made comparisons of the model against these satellite data as well as against actual field data in order to provide validation of the model's ability. The results from the model have been used to investigate the potential errors associated with potential coastal carbon flux field programs or observations. There has been a considerable amount of effort in recent years to develop coastal observation programs. The presentation will outline the potential for using highly-resolved coastal models to investigate the cost benefits and effectiveness of a variety of scenarios for making field measurements of carbon flux along the coast.

The All-Purpose Adjoint Model

Andrew Moore
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In this talk I will discuss some of the many powerful applications of adjoint models to geophysical flows, and provide some examples. I will also discuss how adjoint models can derived from existing model codes.

Numerical Modeling of Nearshore Circulation Using a Primitive Equation Model

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As part of the NOPP funded project, Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean, we are adapting the Princeton Ocean Model (POM) for use in the nearshore region to describe the shortwave-averaged circulation. The POM is a fully three dimensional primitive equation ocean model which has been widely applied to coastal and large scale ocean modeling. Major issues in the nearshore region include the parameterization of the turbulent mixing under breaking waves including the determination of appropriate boundary conditions for the turbulent quantities, appropriate forms of the forcing by breaking waves for the depth dependent model and the addition of a sub-model for the enhancement of bottom stress in the presence of waves. We present the results of initial work in all these areas. Both Mellor-Yamada and k-epsilon turbulence closure models have been tested in a two dimensional context (variation with depth and across shore). Each closure model has been implemented with and without boundary conditions reflecting the increases in turbulence caused by breaking waves. An efficient bottom boundary layer sub-model parameterizing the influence of the waves on the bottom stress has also been embedded in POM. The circulation model is forced by gradients in radiation stresses from the incident breaking waves. The forcing functions are obtained either directly from measured wave data or from a wave transformation model initialized by offshore wave data. Additional effects of rollers are included in some of the formulations.

A Rapidly Relocatable Version of POM

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University of Southern Mississippi

Daniel N. Fox
Naval Research Lab

NRLPOM is a version of the Princeton Ocean Model (POM) that has been implemented at the Naval Research Laboratory (NRL) for nowcasting and short-term (2-day) forecasting in support of real-time naval applications. The model is rapidly relocatable from deep to shallow, from open sea to inlets.

NRLPOM principal attributes are a user-friendly interface, the inclusion of tidal flow, and the option for several initialization procedures (warm, cold, diagnostic and combination) and boundary conditions algorithms. The system also has the capability of 1-way coupling with other real-time operational models or 1-way nesting (NRLPOM to NRLPOM). The boundary condition algorithms and the coupling/nesting procedure are robust and allow more accurate solutions for the inner high-resolution coastal domains.

The system has been designed to provide good solutions everywhere, rather than the best solution for a given problem on a given geographical region. We will discuss the main issues connected with this approach and the skill and limits of the relocatable model, while presenting the results from real-time exercises.

How Topographic Smoothing Contributes to Differences Between the Eddy Flows Simulated by Sigma- and Z-level Models

Thierry Penduff, Bernard Barnier,
Marie-Aurelie Kerbiriou, and Jacques Verron

The characteristics of the mesoscale turbulence simulated at a resolution of 1/3 deg by a sigma-coordinate model (SPEM) and a geopotential-coordinate model (OPA) of the South Atlantic differ significantly. These two types of models differ with respect to not only their numerical formulation, but also their topography (smoothed in SPEM, as in every sigma-coordinate application). In this paper, we examine how these topographic differences result in eddy flows which are different in the two models. When the topography of the Agulhas region is smoothed locally in OPA, as is done routinely in SPEM, the production mechanism of the Agulhas rings, their characteristics and their subsequent drift in the Subtropical Gyre, are found to converge toward those in SPEM.

Furthermore, the vertical distribution of eddy kinetic energy (EKE) everywhere in the basin interior becomes similar in SPEM and OPA and, according to some current meter data, seems to become more realistic when mesoscale topographic roughness is removed from the OPA bathymetry (as in SPEM). As expected from previous process studies,this treatment also makes the sensitivity of the Agulhas rings to the Walvis Ridge become similar in SPEM and OPA. These findings demonstrate that many properties of the eddies produced by sigma- and geopotential-coordinate models are, to a significant extent, due to the use of different topographies, and are not intrinsic to the use of different vertical coordinates. Other dynamical differences, such as the separation of western boundary currents from the shelf or the interaction of the flow with the Zapiola Ridge, are attributed to intrinsic differences between both models. This study shows that topographic smoothing, which is of major importance in defining sigma-coordinate model configurations, should also be considered seriously when defining z-level configurations.

ROMS Embedded Gridding, Test and Application for the Simulation of the Central Upwelling of the Pacific Coast of the United States

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What most clearly distinguishes near-shore and off-shore currents is their dominant spatial scale, O(1-10) km near-shore and O(100-1000) km off-shore. In practice, therefore, they are usually both measured and modeled with separate methods. In particular, it is infeasible for any regular computational grid to be large enough to simultaneously resolve well both types of currents. In order to obtain local solutions at high resolution while preserving the large-scale circulation at affordable computational cost, a nesting capability has been integrated into the Regional Ocean Modeling System. It takes advantage of the AGRIF (Adaptive Grid Refinement in Fortran) Fortran 90 package based on the use of pointers.

The nesting procedure has been applied to a domain that covers the central upwelling region of the United States West Coast, around Monterey Bay, embedded into a domain including the whole US Pacific Coast. Long term simulations (10 years) have been conducted to obtain yearly cyclic statistical equilibria. The final solution shows no discontinuities at the parent-child domain boundary and a valid representation of the upwelling structure, at a CPU cost only slightly greater than for the inner region alone. The solution is compared to a model of the whole US Pacific Coast at high resolution.

A Comparison of POM and ROMS for Modeling Internal Tides in Weak Stratification

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Internal tides were simulated using both ROMS and a modified version of POM for two different cases of stratification and topography and the results compared. The two cases include a two-dimensional cut over the continental slope in the Weddell Sea and a small three-dimensional region in the southern Weddell Sea. Identical input parameters and fields for the two models were used, as much as possible. Although both models showed reasonable agreement with existing observations, significant differences were seen in the results. First, the internal tides developed much faster with ROMS than with the modified version of POM, ~15 days as compared to ~40 days. The internal tidal fields were also quite different in the major axis of the tidal ellipses, and both the positive and negative rotary amplitudes. Potential causes, such as differences in lateral and vertical mixing, vertical coordinate stretching, etc., were investigated.

Parallelizing ROMS for Distributed Memory Machines using SMS

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The National Oceanographic and Atmospheric Administration Forecast Systems Laboratory (FSL) has developed a directive-based tool for parallelizing weather and ocean models. The user inserts directives in the form of comments into existing FORTRAN code. SMS translates the code and directives into a parallel version that runs efficiently on both distributed and shared memory machines.

Here we describe the SMS tool and show how it has been used to parallelize a Northeast Pacific scenario of the ROMS model. The parallel code is currently being run in production on FSL's cluster of Alpha workstations. Analysis of the parallel scalablity is given. Plans to handle distributed memory parallelization of a nested ROMS and a coupled COAMPS/ROMS model are discussed.

Coupling a Bottom Boundary Layer in the Generalized Terrain-Following Coordinate System

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A wave-enhanced Bottom Boundary Layer (BBL) scheme is incorporated into the generalized terrain-following coordinate system. The method is based on the combined techniques of the generalized vertical coordinate system Kasahara (1974), the general pressure gradient formulation of Song (1998), and the embedded BBL scheme of Song and Chao (2000). A suite of process-oriented test problems will be used to evaluate the accuracy and efficiency of the new scheme. A science application with the coupled eddy-sediment transport in a coastal ocean model will be presented. The objective of the study is to develop a general vertical coordinate capability with hybrid Z-, Isopycnal, and Sigma-coordinate features to better represent the subgridscale mixing and BBL processes. The developed techniques will be first applied to the ONR-initiated Expert Modeling System for future ocean nowcast/forecast applications.

The new computational kernel of ROMS

Alexander Shchepetkin
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This talk presents new class of elementary time stepping algorithms for the system which is the prototype of either shallow-water external mode, or three-dimensional coupled density-momentum internal mode equations. All known time-stepping algorithms for this system may be subdivided into two big groups: synchronous (where r.h.s. of both equations are computed at the same time, and then both variables are updated together) and forward-backward (step one equation, then the other immediately using the newest available information). It is shown that one can generalize forward-backward approach, which result in increased range of numerical stability without, if desired, sacrificing numerical accuracy.
Build around these new time-stepping algorithms is the updated kernel of ROMS - essentially a coupled split-explicit system, which uses optimized forward-backward predictor-corrector methods for both subsystems. Consideration will also be given to aspects of numerical stability of mode splitting exposing the link between splitting error in pressure gradient terms and model stability limits (cf., Higdon - de Szoeke, 1997; Hallberg, 1997) and a new definition of definition of barotropic mode suitable for sigma-coordinates is introduced.
Consideration of parallelization issues (including comparison of efficiency of shared-memory and MPI options coexisting in within the same source code) completes the discussion the the new engine.

Eddy-Resolving Simulations of the Asian Marginal Seas and Kuroshio Using ROMS

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Tao Tang
Hong Kong Baptist University, Kowloon Tong, Hong Kong

The western North Pacific region is characterized by complex geometry and consists of many peninsulas, islands, straits, and passages dividing into several marginal seas and coastal oceans. The Asian marginal seas, including the South and East China seas, Sea of Japan, and Philippine Sea, interacting with Kuroshio circulations and the Indonesian throughflow, is one of the most challenging problems in ocean modeling. Surrounded by the coastal waters, East Asia is one of the highly populated and industrialized regions in the world. As a consequence, high rates of anthropogenic emissions and discharged materials into coastal waters, spreading globally after passing through the marginal seas, have been observed in the region. Their effects on the marine environment locally and globally are rather less known.

In his study, an eddy-resolving free-surface primitive-equations model is established for the Asian Marginal seas and their adjacent waters. The model uses a nonlinear terrain-following coordinate system for a better representation of bottom topography and narrow passages. The model domain has a horizontal resolution of one sixth degree (about 18.5 km) extending from 100E to 155E and from 5S to 45N with topography from shallow 20 m to deep 5000 m. The model is initialized with the Levitus annual climatology data and forced by the monthly mean air-sea fluxes of momentum, heat, and freshwater derived from COADS. Based on state-of-the-art modeling techniques and observational data, we

investigate the exchanges of waters among the marginal seas and the effect of Kuroshio variations under monsoon wind forcing. High-resolution is identified as an important factor of representing the exchanges of waters through narrow straits and passages among the seas and their adjacent waters. Particular attention is given to determining open boundary conditions which are critical for the successful simulations.

Subsurface analysis of mesoscale variability inferred from altimetry: Assimilation into ROMS by intermittent optimal interpolation

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Altimeter sea surface height observations in the Leeuwin Current, Western Australia, and East Auckland Current, New Zealand, have been projected to subsurface temperature and salinity anomalies using statistical methods. These analyses were assimilated in ROMS using the intermittent optimal interpolation scheme of Dombrowsky and De Mey (JGR, 1992) to obtain hindcasts of mesoscale variability in these two boundary current regions. Qualitative features of variability, and quantitative estimates of hindcast skill, are presented.

Long Term Simulation of Transport Using Spatially and Temporally Aggregated Models

Brian Williams
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In order to test nutrient control strategies, simulations of algal blooms over planning periods of 20 years or more are desirable for the management of catchments surrounding significant bodies of water. With current computing technology, if transport and water quality processes are simulated simultaneously within POM at hydrodynamic grid-scales, this is a massive computational task.

For situations in which the transport processes are largely wind-driven, it may be possible to use a hydrodynamic model such as POM to determine the mass transport between moderate sized 'boxes' within the computational region under a set of wind regimes. The mass transport, in the form of a matrix for each wind condition, could then be used with a stand-alone water quality model, which selects appropriate transport matrices in the course of its simulation.

The major concern with this proposal is the extent of numerical diffusion, which will take place in the spatial integration process, and ultimately how this will affect prediction of algal blooms. The proposal in this project is to compare the results from a water quality model using the integrated transport process with a full resolution model, which is incorporated into POM at the scale of the hydrodynamic grid. This paper provides some preliminary results from an investigation of appropriate time steps for the wind transport matrices and some comparisons of short-term simulations of the transport model and the full resolution model.

A Code for Assimilation of Sea Surface Data into POM

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A tangent and its adjoint codes to POM are developed and used for implementation of a hybrid 4D-Var/SEEK incremental variational-smoothing assimilation scheme of sea surface height data into a barotropic sector of POM under the perfect-model/data hypothesis. Impacts of the model and control grid refinement and innovation vector error covariance matrix rank on the system conditioning and performance are addressed and an algorithm for numerical comparison of particular system realizations is presented.

A Coastal Circulation Now/Forecast System for Texas-Louisiana Continental Shelf

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An automatized continental shelf circulation forecast system (second generation) will be presented. This system has been providing predicted surface current on Texas-Louisiana continental shelf since May 1, 1999 for oil spill prevention project sponsored by Texas General Land Office (TGLO). The predicted surface currents is then transferred by Internet to TGLO for driving a dynamic trajectory model. There are 4 major components in this system: (1) forecast wind field retriving and preparation module, (2) shelf circulation model module, (3) simulation plotting module and (4) web display and file transfer module.

The wind field used in this system is a 3-hour interval ETA-22 forecast gridded wind from NCEP based on 00Z, 06Z, 12Z and 18Z model runs. A step-up temporal natural cubic spline interpolation is then implemented to obtain hourly gridded field primarily for the purpose of the model forecast simulations.

Early last year a modified version of Princeton Ocean Model (POM) to cover larger area which includes most of the Northern Gulf of Mexico (GOM) is implemented for a shelf circulation

model module changeover. POM simulations, at the meantime, have focused on the use of realistic wind forcing, mixing and diffusion parameters, high resolution bathymetry, and climatological temperature and salinity for model initializations. Parameter tuning is also performed to optimize the wind-driven circulation simulation over the shelf. A series of POM nowcast simulations holding temperature (T) and salinity (S) fixed throughout the model runs, using realistic wind fields as driving force, and without data assimilation was carried out. Comparisons of the results from April to December of 1999 to the observation from TABS current meters were carried out as well. The TABS moorings chosen for the comparison are mooring P, B, D, J and K. The wind-driven simulations show reasonable qualitative agreement between TABS measurement and modeled currents at locations D, J, and K in April-May period, and at P, B and J in June-July period. These show noticeably strong inertial motions throughout the experimental period likely produced by onset of frontal events during April and May, and by diurnal wind event during June and July. From the experiments conducted demonstrate the feasibility of using POM for prediction of the shelf circulation.

The Development of a New Ocean Circulation Model in the Sigma Coordinate System: Numerical Basin Tests and Application to the Western North Atlantic Ocean

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A primitive equation model in the s-coordinates system was formulated to remove the limitations of s-coordinate model calculations over steep bottom topography. The model primitive equations are solved numerically using finite difference methods. Several experiments in a numerical basin having steep seamount topography are conducted to examine the differences between a conventional s-coordinate model and the new model termed the Florida Tech Ocean Model (FOM). The new model is applied with full bottom topography to the limited regional area of the North Atlantic Ocean including the Florida Current, the Gulf Stream, and the Gulf Stream extension area.

Over steep bottom topography the FOM is found to be more numerically stable compared with conventional model formulations. During the model simulations prognostic variables such as temperature and velocity attained a quasi-steady state. In contrast, simulations with a conventional model formulation produced transient results and in some test cases, calculations over steep topography did not converge to numerical stability. These differences are attributed to the formulation of the governing equations rather than to numerical solution schemes.

The newly implemented model realistically simulates complicated ocean features in the limited regional area of the western North Atlantic Ocean. The major surface features such as the western boundary of the Florida Current and the Slope Water, the Gulf Stream, and the recirculatory current system are simulated without numerical instability over long-term integrations. The Deep Western Boundary Current (DWBC) along the continental rise is also simulated with little seasonal change. Predicted seasonal variability of surface temperature and volume transports of Gulf Stream System were comparable to published estimates based on observational data.