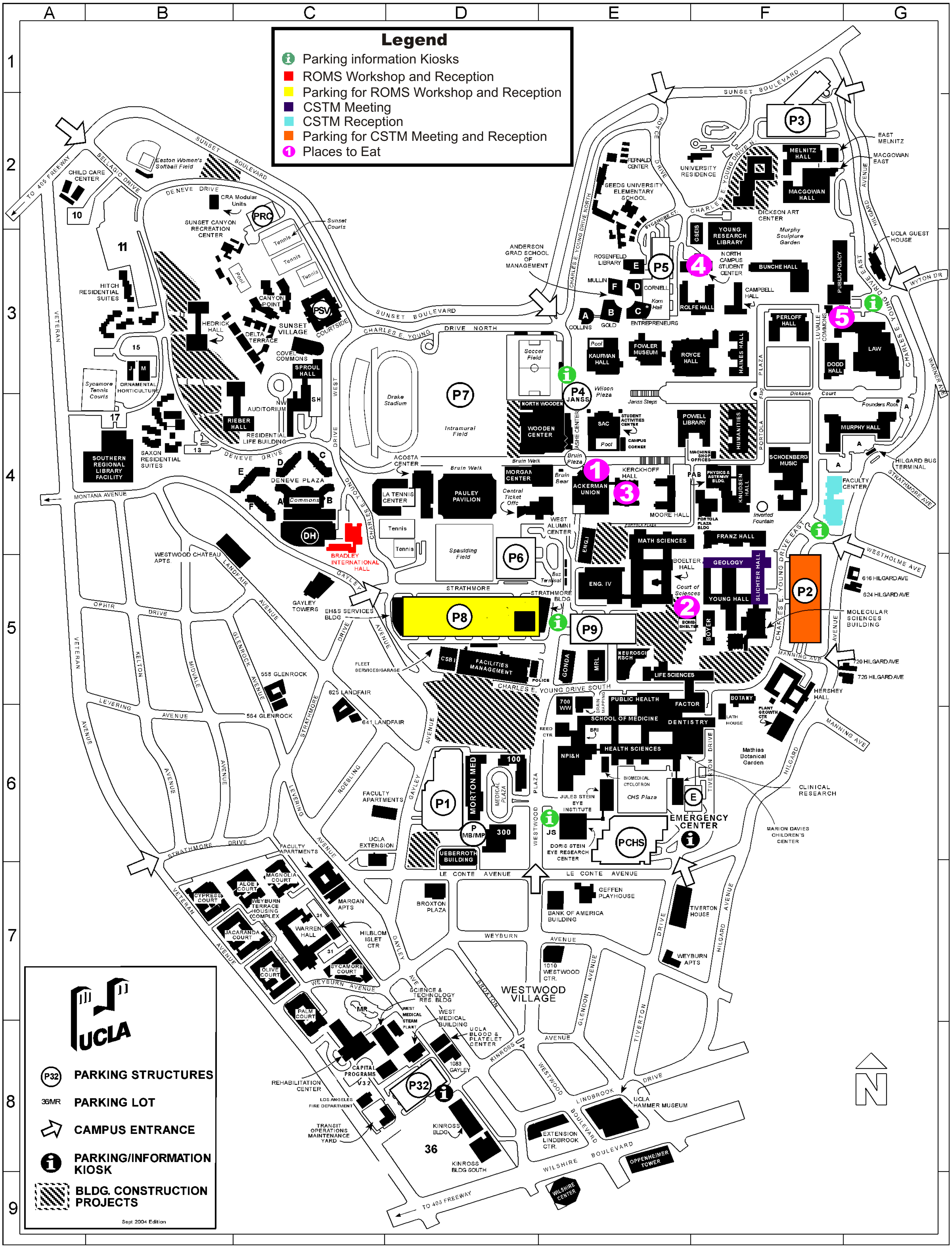
2007 ROMS/TOMS User Workshop

University of California, Los Angeles
Tom Bradley International Hall, Los Angeles, CA
October 1-3, 2007

Organized by: H. G. Arango, J. C. McWilliams and C. R. Sherwood



Legend
Parking information Kiosks
ROMS Workshop and Reception
Parking for ROMS Workshop and Reception
CSTM Meeting
CSTM Reception
Parking for CSTM Meeting and Reception
Places to Eat
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Easton Women's Softball Field
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CRA Modular Units
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SUNSET CANYON RECREATION CENTER
Sunset Courts
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HITCH RESIDENTIAL SUITES
HEDRICK HALL
CANYON POINT
PSV
SUNSET VILLAGE
DELTA TERRACE
COVEL COMMONS
SPROUL HALL
RIEBER HALL
RESIDENTIAL LIFE BUILDING
NW AUDITORIUM
Sycamore Tennis Courts
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Bruin Plaza
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KERCKHOFF HALL
MOORE HALL
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Court of Sciences
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SLICHTER HALL
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GONDA
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FACTOR
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DENTISTRY
HEALTH SCIENCES
NPI&H
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Mathias Botanical Garden
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UCLA EXTENSION
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BROXTON PLAZA
GEFFEN PLAYHOUSE
BANK OF AMERICA BUILDING
TIVERTON HOUSE
WEYBURN APTS
WESTWOOD VILLAGE
1010 WESTWOOD CTR.
HILBLOM ISLET CTR
WARREN HALL
MARGAN APTS
CYPRESS COURT
ALOE COURT
MAGNOLIA COURT
WEYBURN TERRACE HOUSING COMPLEX
JACARANDA COURT
OLIVE COURT
SYCAMORE COURT
PALM COURT
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1083 GAYLEY
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MACGOWAN HALL
DICKSON ART CENTER
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FERNALD CENTER
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YOUNG RESEARCH LIBRARY
Murphy Sculpture Garden
UCLA GUEST HOUSE
ANDERSON GRAD SCHOOL OF MANAGEMENT
ROSENFELD LIBRARY
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BUNCHE HALL
CAMPBELL HALL
ROLFE HALL
PUBLIC POLICY
WYTON DR
CORNELL
Korn Hall
ENTREPRENEURS
COLLINS
GOLD
MULLIN
KAUFMAN HALL
FOWLER MUSEUM
ROYCE HALL
HAINES HALL
PERLOFF HALL
LAW
DODD HALL
Founders Rock
POWELL LIBRARY
HUMANITIES
MURPHY HALL
SCHOENBERG MUSIC
HILGARD BUS TERMINAL
FACULTY CENTER
KNUDSEN HALL
PHYSICS & ASTRONOMY BLDG
PORTOLA PLAZA BLDG
Inverted Fountain
WESTHOLME AVE
STRATHMORE AVE
UCLA
PARKING STRUCTURES
PARKING LOT
CAMPUS ENTRANCE
PARKING/INFORMATION KIOSK
BLDG. CONSTRUCTION PROJECTS
Sept 2004 Edition

Parking Information:

The map above shows the parking and information booths in green. The booths are staffed by parking assistants who can help with directions and parking-related services. Parking for the ROMS workshop will be in lot 8, located at Stratmore Ave. and Westwood Ave. three blocks from Bradley International Hall, seen in red. There are 30 spaces reserved. Attendees should drive to the parking/information kiosk located on Westwood Ave. just in front of parking lot 8, seen in yellow. Give the parking attendant the confirmation number 208233 (the Regional Oceanic Modeling Workshop) to receive a parking gate access card and a parking sticker (good only for one day). You will need to go through this procedure all three days. If the 30 spaces have gone to other workshop attendees, you can purchase parking from the attendant for $8. The Workshop is in the Bradley International Hall.

Lunch Options:

Places to eat lunch are marked with numbered Magenta Circles. They are:

1. **Ackermand Student Union:** Full food court including some chain resturants like Taco Bell and Sbarro as well as some local resturants.

2. **Bombshelter:** Outside tables and food selections including health food, deli sandwiches and sushi.

3. **Kerckhoff Coffeehouse:** Probably the best coffee on campus with take-out snadwiches and other items.

4. **North Campus Student Center:** Small food court featuring sandwhiches, burgers, Mexican, Pizza, and organic foods.

5. **Lu Valle Commons:** Small food court featuring Asian, burgers, sub-style sandwiches and salads.

More information can be found at: http://www.asucla.ucla.edu/restaurants/index.asp

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PROGRAM

---------- Monday AM, October 1, 2007 ----------

07:30-08:30 Registration

08:30-08:35 Welcome, logistics

Chairperson: Christopher R. Sherwood

08:35-09:05 (30 min) James C. McWilliams, IGPP, UCLA
Case Studies in Wave-Current Interaction

09:05-09:30 (25 min) Marcello G. Magaldi, RSMAS, U. of Miami
Capes and Form Drag: The Role of Stratification

09:30-09:55 (25 min) Richard P. Signell, USGS, WHOI
Modeling Sediment Dynamics of a Tidal Sand Bank

09:55-10:20 Break (25 min)

Chairperson: John C. Warner

10:20-10:45 (25 min) Yusuke Uchiyama, IGPP, UCLA
A High-Resolution Nested Simulation on Non-Cohesive Suspended Sediment Transport Around Palos Verdes, California

10:45-11:10 (25 min) Fengyan Shi, Center for Applied Coastal Res.
Modeling of an Erosional Hot Spot at Ocean Beach, California

11:10-11:35 (25 min) Xiaochun Wang, JPL, Pasadena, CA
Modeling Tides in the Alaska Coastal Oceans

11:35-12:00 (25 min) Mehmet Ilicak, RSMAS, U. of Miami
Performance of the Two-Equation Turbulence Models in the Red Sea

12:00-13:30 Lunch (90 min)

---------- Monday PM, October 1, 2007 ----------

Chairperson: Richard P. Signell

13:30-14:00 (30 min) Hernan G. Arango, IMCS, Rutgers U.
ROMS Framework and Algorithms

14:00-14:30 (30 min) John C. Warner, USGS, WHOI
Implementation of Grid Nesting: A First Look with Grid Mosaics

14:30-14:55 (25 min) Patrick Marchesiello, IRD, New Caledonia
Lateral Diffusion in Terrain-Following Coordinates: A Challenge

14:55-15:20 Break (25 min)

Chairperson: James C. McWilliams

15:20-15:45 (25 min) Xavier Capet, IO, U. of Sao Paulo, Brazil
Upwelling Systems at (Sub)Mesoscale Resolution

15:45-16:10 (25 min) Francois Colas, IGPP, UCLA
A Numerical Study of the 1997-98 El Niño off Peru

16:10-16:35 (25 min) Annalisa Bracco, Georgia Tech
Dynamics of Wind-Forced Coherent Vortices in the Open Ocean

16:35-17:00 (25 min) Changming Dong, IGPP, UCLA
PV Anomaly in Shallow-Water Island Wake

17:00-20:00 Reception

PROGRAM

---------- Tuesday AM, October 2, 2007----------

Chairperson: Hernan G. Arango

08:30-09:05 (20 min) (15 min)
Enrique Curchitser, IMCS, Rutgers U.
Kate Hedström, ARCS/University of Alaska
ROMS as a component of the Community Climate System Model (CCSM)

09:05-09:30 (25 min)
Brian Powell, U. of California, Santa Cruz
Data Assimilation in the IAS Using IS4DVAR in ROMS

09:30-09:55 (25 min)
Javier Zavala-Garay, IMCS, Rutgers U.
Towards an Operational Satellite-Based Analysis/Prediction System Using ROMS: An example for the East Australia Current

09:55-10:20 Break (25 min)

Chairperson: Bruce D. Cornuelle

10:20-10:45 (25 min)
Zhijin Li, JPL, Pasadena, CA
A ROMS Three-Dimensional Variational Data Assimilation System in Support of Coastal Ocean Observing Systems

10:45-11:10 (25 min)
Julia Levin, IMCS, Rutgers U.
Adjoint Sensitivity Studies in the Philippine Archipelago Region

11:10-11:35 (25 min)
Natalie Perlin, COAS, Oregon State University
Effects of Ocean-Atmosphere Coupling in a Modeling Study of Coastal Upwelling in the Area of Orographically-Intensified Flow

11:35-12:00 (25 min)
Maitane Olabarrieta, U. de Cantabria, Spain
Establishment of a Local Oceanography System: Application in the Cantabrian Coast

12:00-13:30 Lunch (90 min)

---------- Tuesday PM, October 2, 2007 ----------

Chairperson: Arthur J. Miller

13:30-14:00 (30 min)
Alexander F. Shchepetkin, IGPP, UCLA
10 Years of the ROMS Project: an Overview with Emphasis on what is Overlooked, Overdue, or Missing

14:00-14:25 (25 min)
Jeroen Molemaker, IGPP, UCLA
Toward a Dynamically Consistent Boundary Forcing

14:25-14:50 (25 min)
Y. Tony Song, JPL, Pasadena, CA.
The Non-Boussinesq ROMS and Its Applications

14:50-15:15 Break (25 min)

Chairperson: Alexander F. Shchepetkin

15:15-15:40 (25 min)
Jerome Fiechter, UC, Santa Cruz, CA
A Simple Model of Iron Limitation on Phytoplankton growth in the Gulf of Alaska

15:40-16:05 (25 min)
Hartmut Frenzel, IGPP, UCLA
On the Role of Eddies for Coastal Productivity and Carbon Cycling

16:05-16:30 (25 min)
Xin Jin, IGPP, UCLA
Wind-SST Coupling in the Coastal Upwelling: An Empirical Numerical Simulation

PROGRAM

-------- Wednesday, AM, October 3, 2007 --------

08:30-09:00 (30 min)	David Robertson, IMCS, Rutgers U. **ROMS Web Site**
09:00-09:50 (50 min)	Richard P. Signell, USGS, WHOI **Tutorial 1: SVN and ROMS**
09:50-10:20	Break (30 min)
10:20-11:10 (50 min)	Kate Hedström, ARCS/University of Alaska **Tutorial 2: Setting up a Realistic ROMS Application**
11:10-12:00 (50 min)	Richard P. Signell, USGS, WHOI **Tutorial 3: Grid Generation with SeaGRID**
12:00-13:30	Lunch (90 min)

-------- Wednesday, PM, October 3, 2007 --------

13:30-14:20 (50 min)	John C. Warner, USGS, WHOI **Tutorial 4: ROMS Coupling**
14:20-15:10 (50 min)	Hernan G. Arango, IMCS, Rutgers U. **Tutorial 5: ROMS Code Overview, Parallelism, and Debugging**
9:50-10:20	Break (30 min)
15:40-16:30 (50 min)	To be determined **Tutorial 3: To be determined**

POSTERS

1. Chiggiato, Jacopo, CNR-ISMAR Venice, Italy
Implementing Posidonia Oceanica Effects in ROMS_SED

2. Chiggiato, Jacopo, CNR-ISMAR Venice, Italy
ROMS Operational in the Adriatic Sea: The AdriaROMS System

3. Colberg, Frank, Jet Propulsion Laboratory, USA
A High-Resolution Global Ocean Model of ROMS and its Application to GRACE

4. Cotrone, John, University of South Carolina
The Effects of Spatially Variable Wind Forcing on Freshwater Transport in a Buoyancy-Driven Coastal Current

5. Estrade, Philippe, U. of New South Wales, Australia
Using the GST Tools to Study Island Wake Sensitivity to Upstream Flow Perturbation

6. Harris, Courtney, Virginia Institute of Marine Science
Representation of Near-Bed Sediment Gravity Flows within the Regional Ocean Modeling System (ROMS)

7. Ide, Kayo, University of California, Los Angeles
Development of the Four-Dimensional Local Ensemble Transform Kalman Filter (4D-LETKF) for Coastal Oceans

8. Kim, Chang S., KORDI, South Korea
Variation of Residual Currents in Kyunggi Bay of Korea

9. Lachkar, Zouhair, Swiss Federal Institute of Technology Zurich, Switzerland
Ocean Carbon Cycling in Eastern Boundary Current Systems: The Canary Versus the California Current System

10. Masson, Diane, Institute of Ocean Sciences, Canada
ROMS implementation for the British Columbia coastal waters

11. Plattner, Gian-Kasper, Swiss Federal Institute of Technology Zurich, Switzerland
Ocean Carbon Cycling and CO2 Air-Sea Exchange Along the U.S. West Coast

12. Soosaar, Edith, Tallinn U. of Technology, Estonia
Numerical Modeling of Upwelling Filaments in the Gulf of Finland

13. Veneziani, Milena, University of California, Santa Cruz
Adjoint Sensitivities to Local and Remote Forcing in the Central California Region

14. Woo, Seung-Buhm, Dept. Ocean Science, Inha U., Korea
Wet/dry Model Application on Gyunggi-Bay Tidal Flat

15. Zhang, Bin, IMCS, Rutgers University, USA
The Infuence of Wind Stress and Topogrpahy on the ACC Frontal Locations in Drake Passage

Talk Abstracts

ROMS Framework and Algorithms

Hernan G. Arango
IMCS, Rutgers University, New Brunswick, NJ, USA

The typical annual overview of ROMS framework and algorithms will be presented. This year the emphasis will be on nesting, model coupling, and the recently released version 3.0. The structural F90 design of ROMS allows three types of nesting topologies: grid refinement, mosaic grids (contact through a boundary), and composed grids (superposition). Model coupling in ROMS is now possible with either the MCT or ESMF libraries. Tight coupling is very trivial with the MCT library but very difficult or impossible with the ESMF library. The pros and cons of ESMF coupling will be discussed.

Dynamics of Wind-Forced Coherent Vortices in the Open Ocean

Inga Koszalka and **Antonello Provenzale**
ISAC-CNR, Torino, Italy

Annalisa Bracco
Georgia Institute of Techonology, USA

The dynamics and transport properties of wind forced anticyclones are investigated in an idealized model domain representative of open ocean conditions. It is shown that: (1) the horizontal circulation is in many aspects similar to that of vortex-dominated quasigeostrophic turbulence (3) locally the circulation is strongly ageostrophic, and (4) vertical motions associated with eddies might reach values and level of spatial complexity akin to those reported for oceanic fronts. Indeed, we can reach values of 100 m/day, and displays a fine 3D spatial structure linked to the presence of coherent vortices and filaments and to their interactions with the Ekman circulation. Within and around vortices and filaments upwelling and downwelling regions alternate and do not correlate with relative vorticity but result from the interplay of advection, stretching and instantaneous vorticity changes. The distributions of vertical velocity are strongly non-Gaussian and their tails account for the large vertical escursions of Lagrangian tracers.

In light of recent observations on the critical role played by mesoscale eddies by increasing nutrient supply, primary production, and efficiency of the biological pump, this work remarks on the complexity of submesoscale variability of wind-driven vortices, particularly in the vertical velocity field, which is linked to ageostrophic motion and cannot be captured by low resolution (or simple) models. Our results may help in understanding the extraordinarily intense and sustained plankton blooms observed in mode-water eddies near Bermuda and the submesoscale variability within (McGillicuddy et al., 2007).

Upwelling Systems at (Sub)Mesoscale Resolution

Xavier Capet
IO, Universidade of Sao Paulo, Brazil

James McWilliams
Institute of Geophysics and Planetary Physics, University of California, Los Angeles, USA

Fronts and eddies seen in satellite imagery attest to the turbulent behavior of upwelling systems and have received widespread attention because they exert a significant influence on the mean state of their respective systems. Sigma-coordinate regional models are a priori of well-suited tools to quantify this influence. However they pose a challenge in terms of diagnostics because horizontal and vertical tracer fluxes are difficult to disentangle from each other. In particular, it has proven difficult to estimate vertical buoyancy fluxes (wb, mean and eddy) and their divergence in configurations with realistic bathymetry. wb are key quantities because they provide insight into the origin of turbulent activity (they represent conversion term between potential and kinetic energy) and restratification processes (through their z-derivative).

In this talk we propose and evaluate a new method for accurately computing wb-type terms. Results are discussed in the context of the seasonal variability of the California Current System.

A Numerical Study of the 1997-98 El Niño off Peru

Francois Colas, **Xavier Capet**, **James C. McWilliams**, and **Alexander Shchepetkin**
Institute of Geophysics and Planetary Physics, University of California, Los Angeles, USA

A ROMS numerical simulation for the Peru-Chile System over most of the 1990s is analyzed, with a focus on the 1997-98 El Niño. Atmospheric and lateral oceanic forcings are realistic and contain a wide range of scales from days to interannual. The solution is validated against altimetric observations and the few in-situ observations available. Simple dynamical analyses are performed to explain the 1997-1998 evolution of the upwelling in the model. The intensity of the upwelling appears to be determined by an interplay between alongshore, poleward advection (related to coastal-trapped waves) and wind intensity, but also by the cross-shore geostrophic flow and distribution of the water masses on a scale of 1000 km or more (involving Rossby waves westward propagation and advection from equatorial currents). In particular, the delay of upwelling recovery until fall 1998 is partly due to the persistent advection of offshore stratified water toward the coast of Peru. Altimetry data suggest that these interpretations of the numerical solution also apply to the real ocean.

ROMS as a Component of the Community Climate System Model (CCSM)

Enrique Curchitser
IMCS, Rutgers University, New Brusnwick, NJ, USA

Kate Hedström
ARCS/University of Alaska, USA

William Large, **Donald Stark**, **Jon Wolfe**, and **Mariana Vertenstein**
National Center for Atmospheric Research, USA

The Community Climate System Model (CCSM) is the main community climate model in the US. The various components are either developed or maintained at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. The CCSM is one of the models that consistently participates in the work leading to the Intergovernmental Panel on Climate Change (IPCC) reports. It consists of a coupler and models for each of the atmosphere, ocean, ice, and land, all on global grids. One of the capabilities envisioned for the next generation of climate models is the ability to selectively increase resolution in target areas. This is desired both as a way of studying regional climates as well as a means of improving climate model biases. Examples in the ocean are upwelling regions, narrow straits, etc. As a consequence, efforts are underway to couple both ROMS and WRF into CCSM. In this presentation, we describe the ROMS coupling to CCSM and give a status report on this effort.

PV Anomaly in Shallow-Water Island Wake

Changming Dong, **James McWilliams** and **Alexander Shchepetkin**
Institute of Geophysics and Planetary Physics, University of California, Los Angeles, USA

Leif Thomas
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It has been shown that the source of the vorticity in the deep-water island wake is primarily generated by the stress in the lateral boundary (Dong, et al, 2007). In the shallow-water island wake, the mechanism for vorticity generation differs from the deep-water wake significantly. The Regional Oceanic Model System (ROMS) is applied to the study. The PV budget is calculated to analyze the generation and evolution of the PV anomaly in the wake. During the study, a general PV budget package for the ROMS model product, which is extended from L.Thomas (2006), is developed, which will be shared with the ROMS community.

A Simple Model of Iron Limitation on Phytoplankton Growth in the Gulf of Alaska

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A simple NPZD lower trophic ecosystem model with explicit iron limitation on nutrient uptake is coupled to a three-dimensional coastal ocean circulation model to investigate the regional ecosystem dynamics of the northwestern coastal Gulf of Alaska (CGOA). Iron limitation is included in the NPZD model by adding governing equations for two micro-nutrient compartments: dissolved iron and phytoplankton-associated iron. The model thus involves separate budgets for nitrate (the limiting macro-nutrient in the standard NPZD model) and for iron, with iron limitation on nitrate uptake being imposed as a function of the phytoplankton realized Fe:C ratio. Simulated nitrate and chlorophyll concentrations exhibit striking similarities with available remotely-sensed and in situ observations. In addition to reproducing the seasonal variability in a "climatological" sense over a 10-year period, the model provides useful insight on the different modes of variability affecting the physical and biological variables as a function of cross-shelf position. Simulated SSH, nitrate concentrations, and chlorophyll concentrations typically exhibit a strong seasonal cycle on the inner- and mid-shelf, and become more significantly modulated by mesoscale events at the shelfbreak. Overall, the results suggest that a simple NPZD ecosystem model, which includes iron-limiting effects, may be used to investigate the processes that control biological variability on monthly, seasonal, and interannual timescales. The ability of the model to differentiate between light-, nitrate-, and iron-limited growth regimes is also a first step towards understanding the role of environmental gradients in defining the complex phytoplankton community structure in the CGOA.

On the Role of Eddies for Coastal Productivity and Carbon Cycling

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Nicolas Gruber, **Gian-Kasper Plattner** and **Zouhair Lachkar**
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The impact of meso- and submesoscale processes on ocean productivity and carbon cycling are not well understood. While eddies and other mesoscale variations have been shown to represent key processes enhancing nutrient supply and biological productivity in open ocean conditions, little is known for the coastal ocean. We will demonstrate the impact of mesoscale eddies on coastal ocean productivity and biogeochemistry using an eddy-resolving coupled physical-ecosystem-biogeochemical model of the California Current System. Our results suggest that in coastal upwelling systems mesoscale processes tend to reduce biological productivity and the downward export of carbon, opposite to the effect reported for open ocean waters. In contrast, their integrated impact on coastal air-sea fluxes of CO2 is relatively small. The reduction in biological productivity is caused by a lateral eddy-induced transport that brings warm, nutrient depleted waters toward the shore, thereby suppressing the effect of Ekman-transport induced upwelling. This mechanism could explain the substantially lower productivity of the California Current System in comparison to the Canary Current or Benguela Current upwelling systems, since the latter two have a substantially lower eddy activity, despite similar upwelling strengths. In the California Current System, strong lateral transport of organic carbon associated with persistent mesoscale circulation structures leads to substantial spatial decoupling of export from new production. Westward propagating eddies represent the main vehicle for transporting organic carbon from the nearshore region to the offshore, thereby enhancing heterotrophic consumption in the open ocean. In summary, meso- and submesoscale processes are of fundamental importance in shaping coastal biogeochemistry and carbon balances.

Performance of the Two-Equation Turbulence Models in the Red Sea

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Mixing between overflows and ambient water masses is a critical problem of deep-water mass formation in the downwelling branch of the meridional overturning circulation of the ocean. Modeling approaches that have been tested so far rely either on algebraic parameterizations in hydrostatic ocean circulation models, or on large eddy simulations that resolve most of the mixing using nonhydrostatic models.

In this study, we examine the performance of a set of turbulence closures in Regional Ocean Modeling System (ROMS), that have not been tested in comparison to observational data for overflows before. We employ k-ε , k-ω , KPP, and Mellor-Yamada turbulence closures with different stability functions. We also use a new k-ε turbulence model without any complex stability functions but only Richardson number dependent turbulent Prandtl number (Peters and Baumert 2007). To our knowledge, this is the first time that this new model adopted for a 3D ocean model.

The performance of different closure models are evaluated by conducting numerical simulations of the Red Sea overflow and comparing them to observations from the Red Sea Outflow Experiment (REDSOX). It is found that, most of the two-equation turbulence models capture the basic structure of the overflow, consisting of a well-mixed bottom layer (BL) and entraining interfacial layer (IL). KPP model leads to less mixing and thin IL, and on the contrary, Mellor Yamada leads to high mixing and BL signal becomes weak. The other models including the new k-ε give reasonable result in error analysis with respect to the REDSOX observations.

Wind-SST Coupling in the Coastal Upwelling: An Empirical Numerical Simulation

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Dudley B. Chelton
College of Oceanic and Atmospheric Sciences, and Cooperative Institute for Oceanographic Satellite Studies, Oregon State University, USA

Observations have shown that there is a relationship between the sea surface wind and underlying SST gradient, quantified by Chelton et al. (2001, 2007). In present study, the empirical wind-SST relationship is implemented into the Regional Oceanic Model System (ROMS) to couple the wind field and modeled SST. The empirical coupling scheme is applied to an idealized coastal upwelling problem to examine its evolutionary consequences. It is found the initially uniform wind field is adjusted to a cross-shore wind profile that is similar to realistic ones. The upwelling front and associated mesoscale eddies evolutions are significantly altered by the modified wind field. The physical processed involved in the coupling are discussed.

Adjoint Sensitivity Studies in the Philippine Archipelago Region

Julia Levin, **Hernan Arango**, **Enrique Curchitser** and **Bin Zhang**
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Philippine archipelago ROMS model has been set up to study meso- and submesoscale processes in an area with complex topography and bathymetry. Generation dynamics and predictability of meso- and submesoscale eddies near straits is driven both by local and remote forcing. To understand relative importance of these mechanisms, optimal perturbation and adjoints sensitivity studies have been performed.

Optimal perturbation analysis has been done to understand the limit of tangent linear approximation. Several different metrics have been defined in the adjoint sensitivity studies to quantify the influence of wind forcing, surface fresh water and heat fluxes, bathymetry and wave dynamics on the processes in the straits. Understanding these theoretical issues is important for planning observational strategies for data assimilation.

A ROMS Three-Dimensional Variational Data Assimilation System in Support of Coastal Ocean Observing Systems

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Jams C. McWilliams and **Kayo Ide**
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A three-dimensional variational data assimilation (3DVAR) system (ROMS3DVAR) has been developed for the Regional Ocean Modeling System (ROMS). This system provides a capability of predicting meso- to small-scale variations with temporal scales from hours to days in the coastal oceans. ROMS3DVAR utilizes several novel strategies. These strategies include the implementation of three-dimensional anisotropic and inhomogeneous error correlations, application of particular weak dynamic constraints, and implementation of efficient and reliable algorithms for minimizing the cost function. ROMS3DVAR has been implemented in a real-time

fashion in support of both the Southern and Central California Coastal Ocean Observing System (SCCOOS and CenCOOS). ROMS3DVAR assimilates a variety of observations, including satellite sea surface temperatures and sea surface heights, High Frequency (HF) radar velocities, ship reports and other available temperature and salinity profiles. The evaluation of data assimilation and prediction showed encouraging performance.

Capes and Form Drag: The Role of Stratification

Marcello G. Magaldi, **Tamay M. Özgökmen**, **Annalisa Griffa**, **Hartmut Peters**, and **Mohamed Iskandarani**
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Headlands and capes are important topographic features affecting the dynamics of the coastal circulation. Formation of eddies behind these features may have biological and ecological consequences, by trapping of pollutants as well as floating organisms and nutrients. From a more physical point of view, capes and headlands are associated with enhanced mixing, drag and dissipation. Phenomena like current separation, lee waves and generation of leeward eddies result in a drag force imparted on the larger scale flow.

The effect of stratification on the generation of lee eddies and on the energy extracted from the larger scale flow can benefit from further investigation. Here we present a sensitivity study of the dynamics of a steady barotropic current impinging on an idealized headland. Numerical experiments are conducted using ROMS in a wide range of parameters, represented by the Burger number, Rossby number and the slope of the cape. We quantify the form drag exerted by the cape on the coastal current and mixing downstream. We find a clear relation between form drag and the Burger number.

Lateral Diffusion in Terrain-Following Coordinates: A Challenge

Patrick Marchesiello and **Xavier Couvelard**
IRD, Noumea center, New Caledonia

We have applied the nested version of ROMS (ROMS_AGRIF) to the southwest Pacific. The region has complex topographic features including numerous islands, ridges and trenches. These are generally meridionally orientated, i.e. accross the dominant zonal flow. A terrain-following coordinate model is therefore a proper tool to investigate the role of topography in shaping the South Equatorial Current and driving its multiple branches. However, we have found along the way that the model solution is very sensitive to the choice of lateral diffusion, provided either through diffusive advection terms or diffusion operators. We will argue that, after recent advances have been made in the pressure gradient computation, the problem of lateral diffusion in terrain-following coordinates might present a new challenge.

Case Studies in Wave-Current Interaction

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Surface gravity waves have significant dynamical influences on oceanic currents, especially in the upper ocean and near the coastline. Wave effects are being incorporated in circulation models, including ROMS, based on a multi-scale asymptotic theory that identifies the principal conservative effects --- vortex force, material transport, and Bernoulli-head pressure gradient --- and on parameterizations of non-conservative wave breaking. Several case studies will be discussed: (1) stably stratified, surface Ekman currents under high winds; (2) deep-water infragravity wave generation and global seismic hum; and (3) shear instability of wave-generated littoral currents.

Toward a Dynamically Consistent Boundary Forcing

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Evan Mason
Universidad de Las Palmas de Gran Canaria, Spain

The introduction of a new set of open boundary conditions in ROMS allows for a more accurate representation of flow dynamics near the boundaries of the domain. We will show several ways in which the dynamical consistency of the supplied boundary forcing can be improved within the context of off line, one way nested ROMS grids. It is shown that the improved dynamical consistency leads to a dramatical reduction of interior-boundary flow mismatches and accompanying boundary rim currents. Additionally, we'll show how the solution at the outermost ROMS grid can be successfully forced by using a combination of Word Ocean Atlas and absolute SSH data at the boundaries.

Establishment of a Local Oceanography System: Application in the Cantabrian Coast

Maitane Olabarrieta, **Sonia Castanedo**, **Raul Medina**, **Inigo J. Losada**, and **Angel David Gutierrez**
cean and Coastal Research Group, IH Cantabria, Universidad de Cantabria, Spain

As a consequence of the Prestige oil spill (November, 13th, 2002) the Spanish Ministry of Science funded the ESEOO (Establishment of an Operational Oceanography System in Spain) project. The work described in this paper is part of ESEOO´s 4.3 task, known as "Local scale circulation model". The main objective of this task is to develop and improve the tools required to predict currents and trajectories of pollutant in local areas, including harbours and estuaries. This paper focuses basically on the development of the algorithms and procedures required to perform the downscaling from regional to local models, and on the establishment of an operational system in the North coast of Spain and in the West Coast of the Cantabrian coast.

The developed downscaling process links the regional hydrodynamic model with the local model. The regional model used in ESEOO is the POLCOMS (Proudman Oceanographic Laboratory Coastal Ocean Modelling System) model (Holt and James, 2001) and it runs operationally in Puertos del Estado forecast system. The regional model has a spatial resolution of 0.05º and covers the whole Atlantic domain around Spain (ESEOAT grid).

The local hydrodynamic computations are carried out using the ROMS model (Shchepetkin and McWilliams, 2005). This model was modified by Peven et al. (2006) to take advantage of the AGRIF (Adaptative Grid Refinement in Fortran) package (Debreu and Vouland, 2003). In order to make a downscaling from the regional to the 300 m resolution local domain, a two step downscaling is performed. Taking as initial and boundary conditions those given by the ESEOAT model, an intermediate resolution model is also run to provide the required boundary conditions to the local model. The high resolution model operates embedded in this intermediate grid. The nesting between the intermediate grid and the high resolution grid is a one way nesting, Peven et al. (2006).

The developed operative system provides a two day forecast of the ocean surface currents, temperature and salinity. A preliminary analysis shows a good agreement between computed and measured sea surface elevations.

Effects of Ocean-Atmosphere Coupling in a Modeling Study of Coastal Upwelling in the Area of Orographically-Intensified Flow

Natalie Perlin, **Eric Skillingstad**, and **Roger Samelson**
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Regional ocean-atmosphere model is used to study three-dimensional coastal circulation in the presence of coastline bend. Coastal promontories often introduce significant lower tropospheric flow disturbances, leading to spatial variations in wind forcing over the coastal ocean. Wind-driven seasonal upwelling along the West coast of the U.S. is an example of ocean-atmosphere interaction on regional to local scale that becomes very complex around coastal capes and points.

Model domain is designed to simulate a coastline with an idealized bay, formed by successive inland and seaward coastal bends. Horizontal domain has 3-km grid boxes, it extends about 630 km in the alongshore direction, about 480 km in the cross-shore direction including coastal land in the east. Results of the study show that this scale is large enough for orographic wind intensification to develop downstream of the inland bend during the simulation, while the grid is fine enough to resolve nearshore wind modification due to developing coastal upwelling. Sea surface temperature fields show temporal and spatial differences in upwelling development along the two sides of the simulated bay, the complexity of wind field over the area, and the importance for accurate wind representation for coastal ocean prediction. Atmospheric marine boundary layer exhibits features characteristic of the areas downwind of major capes and points along the West coast. This allows for the analysis of boundary layer details in regions of its rapid vertical and horizontal changes.

Data Assimilation in the IAS Using IS4DVAR in ROM

Brian Powell and **Andrew Moore**
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Hernan Arango
IMCS, Rutgers University, New Brunswick, NJ, USA

Emanuele Di Lorenzo
Georgia Institute of Techonology, USA

Ralph Milliff
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Dave Foley
NOAA/PMEL,USA

A brief introduction to using data assimilation in ROMS with an application in the Intra-Americas Sea. The Intra-Americas Sea is an interesting oceanic region comprised of deep basins with complex bathymetry and geometry. It is a well- constrained region of the North Atlantic with land mass boundaries along the western and northern extents. The Caribbean region is highly dynamic, but is well sampled by a long, overlapping time series of both satellite and in situ physical oceanographic measurements. Using the Regional Ocean Modeling System (ROMS), we have developed a real-time data assimilation system utilizing both satellite surface observations and in situ ship measurements to generate the best model state for the current day. Utilizing the numerous tangent-linear solutions from the data assimilation system, we generate a set of orthonormal perturbations to apply to the generated initial conditions to generate a forward, two- week predictive ensemble. This assimilative/prediction system is now running automatically in an experimental operational capability aboard a ship making regular trips across the region. We will be discussing the algorithmic setup and preliminary results from this experiment.

ROMS Web Sites

David Robertson and **Hernan G. Arango**
IMCS, Rutgers University, New Brunswick, NJ, USA

We will discuss the current status and capabilities of the ROMS web sites. A new domain https://www.myroms.org was acquired to host all ROMS web sites which including the forum (https://www.myroms.org/forum), developer's blog (https://www.myroms.org/blog), and wikiROMS (https://www.myroms.org/wiki). The ROMS source code is now distributed to the ocean modeling community under similar conditions to the MIT/X License (http://myroms.org/license), using Subversion (svn) revision control software.

A code managing web site, based on Trac, was developed to maintain the official realeases of the ROMS source code (https://www.myroms.org/projects/src). It can be used for version and bug tracking, code browsing, and development timelines and roadmaps.

10 Years of the ROMS Project: An Overview with Emphasis on what is Overlooked, Overdue, or Missing

Alexander F. Shchepetkin
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A review of physics, numerical methods and computer science associated with ROMS from the prospective of evolution/integration/interference of different pieces to add up to complete system. Selected subjects, such as mode splitting, compressibility effects in Equation of State, boundary conditions, and parallel code evolution are shown in more details.

Modeling of an Erosional Hot Spot at Ocean Beach, California

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Center for Applied Coastal Research, USA

Daniel M. Hanes
Pacific Science Center, Coastal and Marine Geology Program, USGS

Ocean Beach, California is an ocean-exposed beach adjacent to the mouth of the San Francisco Bay. The shoreline at Ocean Beach has been experiencing areas of erosion for decades with recent severe effects focused on an erosional hot spot near the reattachment point of the ebb tidal delta at Ocean Beach. In this study, we couple a wave model, a circulation model and a sediment model to predict waves, nearshore circulations and sediment transport at the mouth of the San Francisco Bay, with emphasis on Ocean Beach. Far-field motions are taken into account by incorporating large-scale forcing into the nearshore modeling system. The accuracy of the coupled model is demonstrated by comparisons with field measurements conducted in the summer of 2005 and the winter of 2006. The model results indicate that surface waves from a large range of incident wave directions tend to focus on a very narrow region at the hot spot location. The wave focusing pattern and the littoral transport are responsible for the hot spot evolution.

Modeling Sediment Dynamics of a Tidal Sand Bank

Richard P. Signell and **Erin R. Twomey**
US Geological Survey, Coastal and Marine Geology Program, Woods Hole, MA, USA

Using a combination of repeated swath bathymetry surveys and sediment transport modeling, we describe several aspects of the sediment dynamics on Middle Ground, a long linear sand bank in Vineyard Sound, Massachusetts. Middle Ground is approximately 6 km long, 800 m wide 16 m high in a water depth of about 20 m. It is comprised of coarse sand, and sits on a bed of gravel. The bank has existed for at least 400 years in dynamic equilibrium with the tidal currents, which are in the range of 1.2-1.8 m/s. Repeated high-resolution (1-m pixel) swath bathymetry surveys show that the bank is covered with large sand waves of up to 4 m height moving in a counterclockwise direction around the bank of up to 10 m/month. Remote sensing imagery suggests the tidal flow crosses the bank obliquely at a small angle such that counterclockwise residual tidal circulation should be generated through a frictional bottom torque mechanism.

Using the freely-available, open-source hydrodynamic model ROMS, with sediment transport capabilities developed under the Community Sediment Transport Modeling project, we have run 3D sand transport simulations on the bank using both suspended and bed load transport. The results confirm that tidal currents cross the bank at a small oblique angle, and the resulting residual counterclockwise circulation is consistent with the pattern inferred from the sand waves. The model results show a strong focusing of sediment transport on the bank, providing a mechanism for maintenance. Modeling work is currently underway to understand observed changes that occur to the bank during the winter, possibly due to strong mean currents and waves associated with storms.

The Non-Boussinesq ROMS and Its Applications

Y. Tony Song
Jet Propulsion Laboratory, Pasadena, CA, USA

Satellite-observed ocean-bottom-pressure (OBP) represents oceanic mass changes, while sea-surface-height (SSH) gives ocean volume changes; both are fundamentally important facts about ocean dynamics and climate changes. For the last several years, we have been trying to develop a non-Boussinesq (mass conserving) terrain-following ocean model to better represent these two satellite observations. In this talk, I will show how a stretched-pressure coordinate (sp-coordinate) can be used in ROMS for (1) directly applying GRACE-observed ocean-bottom-pressure (OBP) and altimeter-measured SSH in large-scale ocean modeling, (2) estimating inter-basin transports within Asian Marginal Seas, and (3) applications to earthquake tsunami genesis and simulations.

A High-Resolution Nested Simulation on Non-Cohesive Suspended Sediment Transport Around Palos Verdes, California

Yusuke Uchiyama, **James C. McWilliams**, **Changming Dong**, and **Alexander Shchpetkin**
Institute of Geophysics and Planetary Physics, UCLA, Los Angeles CA, USA

We have developed a high-resolution (200 m) regional configuration with ROMS for non-cohesive suspended sediment transport simulation in Santa Monica and San Pedro Bays, CA, embedded in the parent Southern California Bight domain with 1 km resolution, along with a compatible nested wind-sea/swell prediction with SWAN. The extensive upwelling event occurred in March 2002 and associated sediment transport processes are well represented. In particular, submesoscale eddies are more actively generated in the high-resolution grid, and suspended sediments are partially trapped in these eddies and transported with them.

Modeling Tides in the Alaska Coastal Oceans

Xiaochun Wang, **Yi Chao** and **Hongchun Zhang**
Jet Propulsion Laboratory, Pasadena, CA, USA

Francois Colas and **James C. McWilliams**
Institute of Geophysics and Planetary Physics, UCLA, Los Angeles CA, USA

C. K. Shum and **Yuchan Yi**
Ohio State University, USA

With its complex coastlines, islands and shallow inlets, Alaska coastal region provides an extreme testing case for tide and ocean circulation modeling. A three level one-way nested model, configured from the Regional Ocean Modeling System (ROMS), is used to simulate tides of the Alaska region. The finest resolution for the focus area, Prince William Sound, is 1km and 40 vertical levels. The model tidal solution is validated against the multi-satellite altimetry in the open ocean and tide gauges along the coast. The accuracy of barotropic tides, as measured by the root of summed squares (RSS) of the RMS discrepancy of sea surface height amplitudes of eight major tidal constituents, is 11.5cm in the open ocean. Along the coastal region, the RSS of tidal amplitudes is 17.8cm, which is about 10% of the amplitude of the most energetic semi-diurnal constituent M2 of the region. The barotropic tidal energetics of the Alaska coastal region will also be discussed. The addition of tides to the three level nested model is the first step to build a data assimilation and forecasting system for the region.

Implementation of Grid Nesting: A First Look with Grid Mosaics

John C. Warner
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Hernan G. Arango
IMCS, Rutgers University, New Brunswick, NJ, USA

The nature of a single rectilinear grid provides limited flexibility to easily allow localized regions of increased resolution or local regions of grid curvature to follow topography or bathymetric features. To facilitate these abilities, we are investigating a methodology to implement grid nesting capabilities into ROMS. Grid nesting covers several types of grid assemblages: (1) grid mosaics which connect several grids along their edges, (2) grid refinement which provides increased resolution in a specific region, and (3) composite grids which allow overlap regions of non-aligned grids.

We will describe the current implementation of grid nesting by focusing on applications of grid mosaics. Exchanges are achieved by redefining the grid indices and provide a means for a natural continuation of each grid to extend into the adjacent grids. We describe the method, the implementation, and provide results for a simple test case. A method for grid development is presented and the grid mosaic capabilities are demonstrated on a realistic environment of the Hudson River Estuary.

Towards an Operational Satellite-Based Analysis/Prediction System Using ROMS: An Example for the East Australia Current

Javier Zavala-Garay, **John Wilkin**, and **Hernan G. Arango**
IMCS, Rutgers University, New Brunswick, NJ, USA

Assimilation of satellite observations into ocean models is a subject of intense research because of the obvious advantages for operational forecasting and hindcast analysis. A common procedure for incorporating such observations (mainly SST and altimeter data) into the numerical models is the use of empirical relationships, sometimes referred to as “Synthetic CTD”, that project to the subsurface what is seen by the satellites. The best examples where this procedure has been proved to work is in the areas of intense mesoscale variability associated with western boundary currents, such as the East Australia Current (EAC). However, the obvious limitation of such approach is the need of a large number of in situ observations (e.g., XBT and CTD soundings) from which a robust unbiased empirical relationship can be derived. In this talk we will introduce an alternative approach for vertically projecting the satellite information that is based on basic large scale dynamical balances. Comparison of this alternative approach for the EAC suggest that this technique can provide the same kind of information as Syntetic CTD, and therefore has great potential for improving mesoscale prediction in unsampled regions of the world ocean.

Poster Abstracts

Implementing Posidonia Oceanica Effects in ROMS_SED

Jacopo Chiggiato, **Mauro Sclavo** and **Sandro Carniel**
CNR-ISMAR, Venice, Italy

John C. Warner and **Richard P. Signell**
US Geological Survey, Coastal and Marine Geology Program, Woods Hole, MA, USA

Understanding the effect of posidonia oceanica on near-shore dynamics is a challenging area with no devoted research before the late 80ies-early 90ies. Even now many processes have not been discerned. Major impacts identified are the reduction of flow speed, the modification of flow and turbulence structure, attenuation of wave energy; all of which affect local modification of sediment transport. The usage of numerical models to simulate such impacts is still at an early stage. Most available parameterizations rely on few laboratory experiments with very few sensitivity analyses and with very idealized situations, which makes them hardly generalizable.

The approaches used up to now are basically two, and both work on tuning the drag coefficient of the bottom friction: Kobayashi-type models (dealing with waves only) and Nepf-type models (dealing with currents only). Very recently, a few papers addressed the issue of modeling, in a realistic way, seagrass meadows impact on flow-wave-sediment dynamics in the near-shore (Chen et al., Estuaries and Coast 2007, US Army CEM, 2006). The approach used is basically Nepf-type, and it is focussed on the estimate of the bottom drag coefficient for current and, with similar formalism, for waves. We have implemented the possibility to activate a modified bottom roughness in the bottom boundary layer of ROMS_SED in order to simulate the presence of posidonia oceanica. Sensitivity analyses based on an idealized case study as well as a realistic case study along the western Italian coastline will be presented and discussed.

ROMS Operational in the Adriatic Sea: The AdriaROMS System

Jacopo Chiggiato
CNR-ISMAR, Venice, Italy

Marco Deserti, **Stefano Tibaldi**, **Tiziana Paccagnella**, and **Andrea Valentini**
ARPA-SIM, Bologna, Italy

AdriaROMS is the operational ocean forecast system for the Adriatic Sea running at the HydroMeteorological service ARPA-SIM in Bologna, Italy.

It is based on ROMS version 2.2 (3.0 now being implemented). The Adriatic configuration has a variable horizontal resolution, ranging from 3 km in the north Adriatic to ~10 Km in the south, with 20 s-coordinates levels. The model (originally AdriaROMS 1.0) has been initialised in September 2004 from MFS (general circulation model for the Mediterranean Sea) fields optimally interpolated onto AdriaROMS grid, then run in preoperational configuration until June 2005 when the first forecast were published on the web. The current version, AdriaROMS 2.0, has been instead re-initialized in order to reset some biases, with optimal interpolation mapping of CTD casts collected during the August 2006 oceanographic cruise DART06b Dynamics of the Adriatic in Real Time (NR/V Alliance).

Surface forcing are provided by the Limited Area Model Italy (LAMI), non hydrostatic numerical weather prediction model with 7 km horizontal resolution, that provides tri-hourly shortwave radiation, 10m wind, 2m temperature, relative humidity, total cloud cover, mean sea level pressure and precipitation. All of them are used to compute momentum and heat fluxes. MFS data are used at the open boundary to the south with relaxation-radiation boundary conditions with superimposed four major tidal harmonics (S2, M2, O1, K1). Forty-eight rivers (and springs) are included as well, using monthly climatological or persistence of NRT available measurements.

A High-Resolution Global Ocean Model of ROMS and its Application to GRACE

Frank Colberg and **Y. Tony Song**
Jet Propulsion Laboratory, Pasadena, CA, USA

We report on a high-resolution global ocean modeling effort using the regional ocean modeling system (ROMS-Rutgers version). This study is motivated by the availability of increasingly accurate measurements of the earth gravitational field (e.g. GRACE), which allow for the deduction of ocean bottom pressure and hence an estimation of the total oceanic mass flux. Since ocean models using Boussinesq approximation a priori inhibit the calculation of ocean bottom pressure signals our effort is directed towards developing a global ocean model with non-Boussinesq formulation.

At the current developing stage we are able to present preliminary results from the initial spin-up phase of the hydrostatic model version. The model resolution is on average ¼ degree horizontally, with highest resolution over the equatorial belt decreasing towards the subtropics to midlatitudes. To overcome the north-pole singularity the grid has been rotated following Madec and Imbard (1996). The ocean model is then coupled to a Sea-Ice model at the poles, hence allowing for a more realistic representation of fresh water fluxes there and for the investigation of possible Ocean-Ice interaction. The model is spun-up with monthly climatologies of the NCEP/ NCAR

Reanalysis and then run with monthly means of NCEP/ NCAR windstress and fluxes from 1948 to present.

The Effects of Spatially Variable Wind Forcing on Freshwater Transport in a Buoyancy-Driven Coastal Current

John Rogers-Cotrone and **Alexander Yankovsky**
Department of Geological Sciences, University of South Carolina, Columbia, South Carolina, USA

Tom J. Weingartner
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The Alaska Coastal Current (ACC) is located in a region with prevailing downwelling favorable winds, flows over a long stretch of coastline (over 1000 km), and is driven by multiple sources of freshwater discharge totaling 23000 m3 s-1 along its length. Previous studies of wind effects on buoyancy-driven coastal currents have focused on single sources of freshwater and spatially-uniform winds. Using the Regional Ocean Modeling System (ROMS) we attempt to determine how spatially variable winds affect the downstream transport of freshwater along a long coastline with nearly continuous sources of freshwater.

Our model domain is 500 km long and extends 80 km offshore with a bottom topography representative of the ACC region. Ten sources of freshwater are evenly spaced at 25 km intervals along the middle 225 km of the domain, each with a discharge of 200 m3 s-1. This domain represents a fraction of the total length of the ACC and we use periodic boundary conditions, allowing water flowing through the downstream boundary to re-enter the domain at the upstream boundary, to mimic a continuous buoyant flow from outside of our domain. Both constant and spatially varying, predominantly downwelling favorable winds are applied over the domain. The spatial variations of wind are introduced as one period of a harmonic function. Freshwater gain in the coastal current through the buoyancy forcing region is calculated by taking a 30-day averaged difference between freshwater fluxes at the downstream and upstream edges of this buoyancy forcing region.

Results from several runs are split into two categories based on this freshwater gain. Values of gain are relatively high (between 1000 m3 s-1 and 1300 m3 s-1) for all runs with moderate average wind stress (~ 0.05 pa), regardless of its spatial variations, as well as for the case of no wind forcing. Values of gain are nearly 50% lower (ranging from 500 m3 s-1 to 800 m3 s-1) for runs with average wind stresses of about 0.025pa, especially when wind varied spatially along the coast line. Thus light and variable downwelling favorable winds can result in substantially lower freshwater gain than under no wind conditions. The reversal of wind to upwelling favorable conditions over limited fraction of coastline effectively blocks the downstream freshwater transport as expected. Possible mechanisms for this reduction in freshwater gain under lighter wind conditions are identified.

Using the GST Tools to Study Island Wake Sensitivity to Upstream Flow Perturbation

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Oceanic currents flowing around topographic features such as an island, headland, reef or even a shallow seamount, usually involve strong wakes in which there is vigorous re-circulation after separation of the stream from the topography. The wake flows govern the dispersion of pollutants and nutrients, they generate vertical transport of nutrients from deeper water, and they influence the scouring and deposition of sediments. In fluid dynamics, flow separation and wakes have been extensively studied for smooth incident flows. However, geophysical flows are characterised by high incident levels of turbulence, and this strongly influences both the flow separation and the wake structure. In the coastal ocean, the incident turbulence can come from other topographic features, tidal currents, wind stress variability, larger scale current variability, etc..

Wake structure depends mainly (but not only) on the Reynolds number Re. Classical stability theory fails to predict the correct Re regimes in most geophysical contexts. Field observations and laboratory experiments show that instability and transition to turbulence occur at lower Re. Wakes can be enhanced by incident turbulence through a property of the system known as non-normality (modes are not orthogonal). This means that linear interference of the modes can lead to significant transient growth of stochastically induced perturbations and an elevation of the system variance. This aspect of stochastically forced systems is embodied in the ideas of Generalised Stability Theory (GST) developed by Farrel & Ioannou (1996). For example GST allows to compute initial perturbations which maximize linearly the energy over a given period.

With a shallow water model Aiken et al (2002, 2003) have shown the relevance of using GST to study the wake sensitivity to upstream turbulence. The latest version of ROMS which contains tools for invoking GST (Moore et al, 2004) has been used to "reproduce" some Aiken et al experiments and to expand on these works with the addition of more realistic scenarios. A preliminary result on the addition of a varying bottom topography is presented.

Representation of Near-Bed Sediment Gravity Flows within the Regional Ocean Modeling System (ROMS)

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Within the past decade, data from several continental shelf and deltaic environments has shown near-bed sediment gravity flows to be an important component of across-shelf sediment transport. Both observational and theoretical work has concluded that stratification at the top of the wave-boundary layer can trap sediment within this thin layer (~10 cm thick), creating fluid muds whose density anomaly is sufficient to cause downslope transport. This transport process, however, can not be represented within standard vertical grids (z-, s-, or sigma-coordinate) used within ocean models because the thickness of the wave boundary layer typically increases as water depth decreases, and because it is usually too thin to be resolved. Additionally, standard wave-current interaction modules used within ocean models do not resolve velocities and turbulence at the vertical resolution of the wave boundary layer. These considerations motivated previous work within ECOM-SED (Estuarine and Coastal Ocean Model – SEDiment) to represent near-bed sediment gravity flows using a separate grid cell underneath of the model's sigma-grid (Harris et al., 2004; 2005). A similar component is being implemented within the Regional Ocean Modeling System (ROMS) and being tested using an idealized continental shelf / river plume test case.

Development of the Four-Dimensional Local Ensemble Transform Kalman Filter (4D-LETKF) for Coastal Oceans

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A four-dimensional (4D) Local Ensemble Transform Kalman Filter (LETKF) system is being developed for the estimation and forecast of the coastal oceans using the Regional Ocean Modeling System. We present the methodology for the data assimilation system with the feature-tracking capabilities for the mesoscale eddies and the Lagrangian analysis system that runs in parallel with the data assimilation system.

Variation of Residual Currents in Kyunggi Bay of Korea

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The residual current, defined as the flow averaged over the tidal cycle, plays an important role in estuarine and coastal processes. The macro-tidal river environment, the Great Han Estuary has three main channels through which the riverine sediment load is discharged into the Kyunggi Bay. It is generally accepted that the magnitude and direction of the residual current at each channel would determine the dispersal and deposition processes in the macro-tidal flats of varying composition of grain size. However up until now, it is far from clear whether the residual flows in this area are flood- dominant or ebb-dominant. There are numerous factors for the residual flows to be created and modified. In estuarine and coastal environments such as the Kyunggi Bay, the shallow water depth, interaction among multiple tidal constituents, river discharge and surface wind and wave effects would be the factors among others.

The present study investigates the characteristics and variability of the residual flows at major points of the channels. We use two types of flow data; flow data measured in the field and the data simulated using the ROMS with dry and wetting nearshore module. One-month long current data have been used to estimate the residual currents using three methods; Time average over varying periods, digital filtering of subtidal components and the tidal harmonic method.

In this study, comparison of spatially and temporally varying residual currents estimated by different methods is presented to elucidate a prospecting mechanism responsible to the tidal flat dynamics in Kyunggi Bay, Korea.

Ocean Carbon Cycling in Eastern Boundary Current Systems: The Canary Versus the California Current System

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Eastern Boundary Currents Systems (EBCs) are major oceanographic features that are well known for their high productivity and for playing an important role in the marine carbon cycle. Yet, the quantitative understanding of the mechanisms driving biological production, air-sea CO2 fluxes, and offshore transport of organic matter in these systems is limited. Through a comparative study of the Canary Current System (CanCS) and the California Current System (CalCS), we investigate here the major environmental factors and the leading physical processes that control the biological production rates and the fate of the organic matter in each EBC. Our analyses are based on a series of Regional Oceanic Modeling System (ROMS) simulations in both EBCs, enhanced with analyses of remotely observed quantities such as chlorophyll and net primary production. In order to ensure that the coastal ocean dynamics is optimally represented, a first set of simulations was conducted to characterize the model sensitivity to resolution, atmospheric forcing, topography, and the open boundary conditions. A first validation of the simulated mean circulation and the seasonal cycle was realized by comparing model outputs with climatologies from satellite and in-situ data. It shows the skills of the model to reproduce the regional circulation and the seasonal cycle of coastal upwelling. In this presentation, we will describe the details of the implementation of the ROMS Canary Current model and will discuss the first preliminary results from the CanCS and CalCS comparison.

ROMS Implementation for the British Columbia Coastal Waters

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ROMS has been implemented on a 3 km grid for the entire coast of British Columbia, extending from the Columbia River to the south and to the Alaska border to the north. The model is forced by tides, winds, river runoff and atmospheric heat flux. It is initialized with mean climatology and run through a complete annual cycle, with seasonal winds (NCEP), river discharge, and boundary conditions. The model results will be validated against available observations. Of particular interest is the simulation of the seasonal change in the coastal regime from upwelling to downwelling, as well as the formation of eddies along the continental margin.

Ocean Carbon Cycling and CO2 Air-Sea Exchange Along the U.S. West Coast

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We investigate the coastal ocean carbon budget for the U.S. West Coast on the basis of a coupled physical-biogeochemical model, with a focus on the central upwelling region off California. This region is dominated by intense coastal upwelling, highly turbulent flow, and a high biological production. The ocean model is based on the Regional Oceanic Modeling System (ROMS), coupled to an NPZD-type ecosystem model including a formulation of the ocean carbon cycle, which is driven by climatological mean forcing. Our analyses suggest that the air-sea flux of CO2 constitutes only a small component of a very active and dynamic carbon cycle in the euphotic zone. The central California upwelling region is nearly balanced with regard to CO2 air-sea gas exchange, overall constituting a weak source of CO2 to the atmosphere of roughly 0.2 mol C m-2 yr-1. This is the consequence of upwelling-driven CO2 outgassing nearshore and biologically-driven CO2 uptake offshore, often associated with filaments originating at capes and other prominent topographical features along the coast. The net CO2 flux is small compared to e.g. photosynthesis that fixes approximately 8.8 mol C m-2 yr-1. New production amounts to 3.3 mol C m-2 yr-1 and thus accounts for 37% of total production. Spatially averaged export production nearly equals averaged new production, but locally new and export production are substantially decoupled in this dynamic ocean region. This is due to lateral transport associated with mean horizontal fluxes induced by persistent meso- and submesoscale circulation structures and to lesser degree by the mean lateral offshore transport induced by Ekman transport. We will report on these budgets as well as ongoing efforts to estimate the magnitude of the lateral transport of carbon and nutrients between the coastal and open ocean, which we expect to be substantial.

domain, we have also ranked the sensitivies to different factors with respect to each other.

Numerical modeling of Upwelling Filaments in the Gulf of Finland

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Coastal upwelling and upwelling filaments are common phenomenon in the Gulf of Finland. Observations show that locations of upwelling centers and filaments are repeatable. We use ROMS to reproduce a coastal upwelling event that occurred in the Gulf of Finland at August 2006.

The model area is Gulf of Finland (from 21N to 30N and from 59E to 61E). Grid resolution is 1/20 degrees in the respect for longitude. In vertical direction there are 20 sigma coordinate layers. The model is forced by winds from Kalbadagrund weather station for time period from 25.07.2006 to 31.08.2007 (with three hour time resolution). The model results are validated against available sea surface temperature satellite pictures.

Adjoint Sensitivities to Local and Remote Forcing in the Central California Region

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We have used the ROMS adjoint model to study the sensitivity of the Central California circulation to different driving mechanisms. The region is characterized by complex dynamics driven both by internal instability processes and by external and boundary factors such as the wind forcing, open boundary conditions, steep bathymetry and coastline shape. Understanding the relative contribution of these factors is relevant not only for theoretical reasons, but also for planning observational strategies and for data assimilation purposes.

We have defined a number of metrics that best represent the coastal upwelling processes and the energetics of the California Current System, and we have used the adjoint model to determine the sensitivity of these metrics to the model initial conditions and external forcing. The spatial distribution of the sensitivity fields has allowed us to investigate the relative contribution of local versus remote forcing, while the sensitivity temporal changes have identified the periods of major influence. By averaging the appropriately weighted sensititivity results over the whole model

Wet/dry Model Application on Gyunggi-Bay Tidal Flat

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In the estuary where tidal flat is well developed, a stable and accurate wet/dry scheme is one of the most imporant factor for reasonable model simulation. In this study, the moving boundary schemes in different models are applied to Gyunggi-bay estuary, Korea, and the model results are compared with several observed data.

The Infuence of Wind Stress and Topogrpahy on the ACC Frontal Locations in Drake Passage

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The Antarctic Circumpolar Current (ACC) features three major fronts: the Subantarctic Front (SAF), the Polar Front (PF), the Southern ACC Front (SACCF). The locations of these fronts are not stable. The PF can shift away from its historical mean locations on the order of 100 km. The ACC transport in Drake Passage varies over a large range (50 to 60 Sv). Numerical simulations with the Regional Ocean Modeling System are carried out to study the frontal variability under the influence of local wind stress and bottom topography in Drake Passage.

Different surface wind stress are applied in the model, the 6 hourly QSCAT/NCEP blended wind stress,monthly running mean filtered wind stress and no wind situtation. With 6 hourly wind stress, the PF location is more variable than that with the monthly running mean filtered wind stress. The mean PF location changes with different wind stress. This change is different at different locations in the model. The surface elevation to each side of PF changes with the wind forcing. The peak frequencies at which the wind stress is correlated to the surface elevation above 95% confidence level in the south are the 8 and 30 days with the wind stress change leading the surface elevation change. The peak frequencies to the north of the PF are 8, 15 and 40 days. The positive phase lag at some frequencies might be due to the contamination from the local baroclinic instabilities.

The mean 500~m temperature tracked PF location is consistent with mean surface PF location. The surface PF tends to be south of the 500~m PF front. This difference between the surface and 500~m PF locations is modulated by the wind stress and the topography. With stronger wind stress, the difference is reduced.

The Shackleton Ridge is reproduced in the model using a Gaussian type function. Compared to model results with smoothed topography, the SACCF path behaves more realistic with the northward intrusion. It indicates, in the middle of drake passage, the Shackleton ridge affects the pathway of the SACCF, among other reasons, such as the cold water intrusion and the PF instability. This tells us the importance of realistic representation of bottom topography in simulating the ACC fronts.