2010 ROMS/TOMS User Workshop

Hawaii Imin International Conference Center
University of Hawaii at Manoa, Honolulu, Hawaii, USA
April 5 - 8, 2010

Organized by: H. G. Arango, J. L. Wilkin, B. S. Powell, A. M. Moore

http://www.myroms.org/hawaii_workshop

Getting to the Workshop

From Honolulu Airport:

Via Car:

Follow the signs to interstate H1 east. Take exit 24B and merge onto University Avenue (Map 2). Turn right onto Dole Street then right onto Lower Campus Road. Parking costs $4 and is paid in advance at the entry kiosk. Once parked, proceed to Dole Street where you can catch free campus shuttle **J1** (in front of the Law Library) to Jefferson Hall where the Hawaii Imin International Conference Center is located.

Via Taxi:

The Hawaii Imin International Conference Center is located at 1777 East-West Road on the University of Hawaii at Manoa campus.

From Waikiki hotels:

Via Car:

Your route to the University of Hawaii campus will vary depending on your hotel location. However, once on campus, you will want to proceed to the public parking structure marked with P on Map 2. If you have a GPS device in your car, entering the intersection of Dole Street and Lower Campus Road should get you close enough to the parking entrance. Parking costs $4 and is paid in advance at the entry kiosk.

Once parked, proceed to Dole Street where you can catch the free campus shuttle **J1** (in front of the Law Library) to Jefferson Hall where the Hawaii Imin International Conference Center is located.

Via Bus:

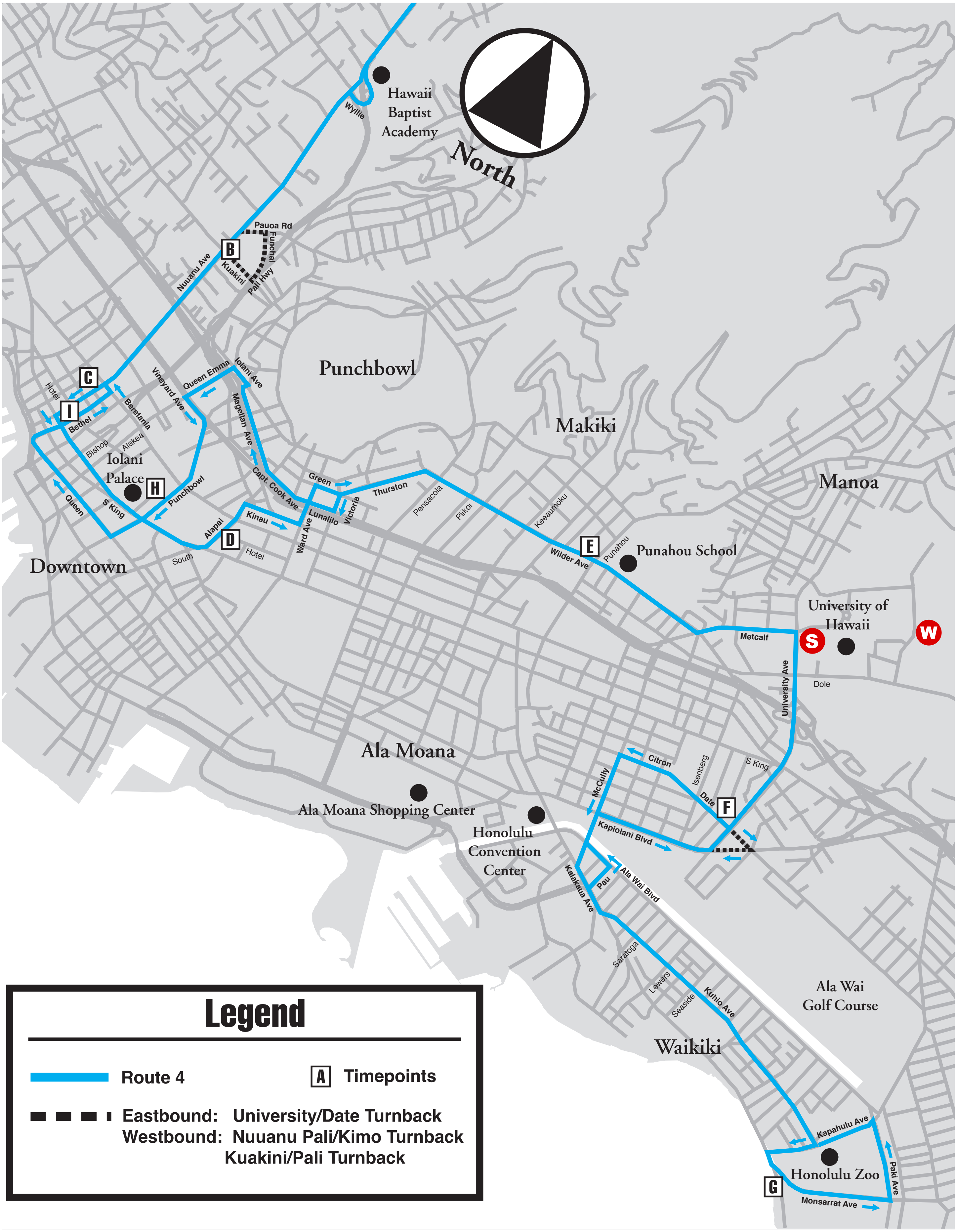
The city bus number **4** (Map 1) will bring you from Kuhio Avenue in Waikiki to the University of Hawaii Manoa campus S. The fare is $2.25 for adults, and $1 for students. There is also a 4-day city bus pass (unlimited rides) available for $25. Once on campus, you can catch the free campus shuttle **D1** (Map 2) near Sinclair Library to Kennedy Theatre across the street from Jefferson Hall (W) where the Hawaii Imin International Conference Center is located.

Via Taxi:

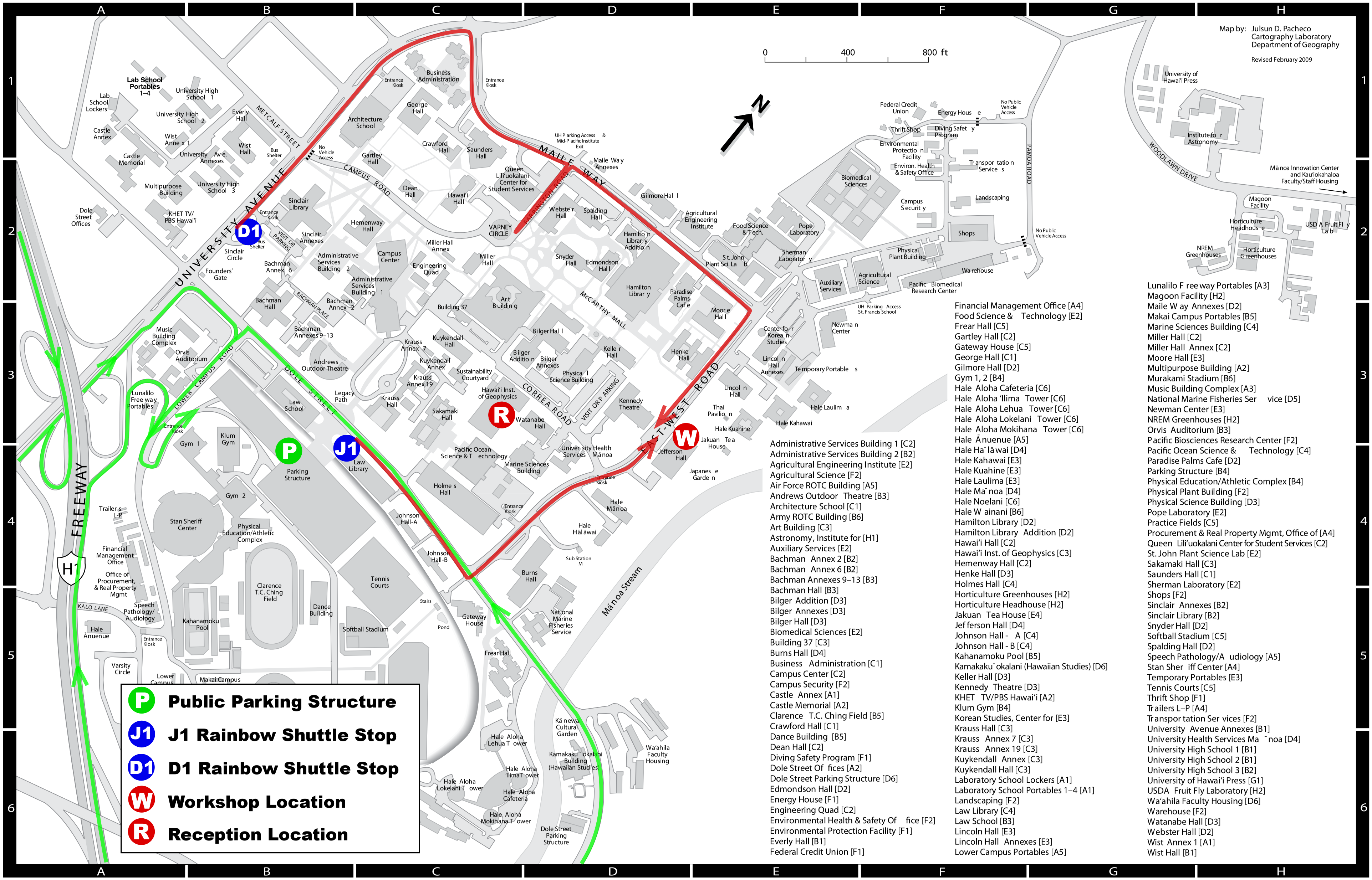
The Hawaii Imin International Conference Center is located at 1777 East-West Road on the University of Hawaii at Manoa campus. A taxi from Waikiki will cost $10 - $15.

Hawaii Imin International Conference Center

Map 1: City Bus Route 4



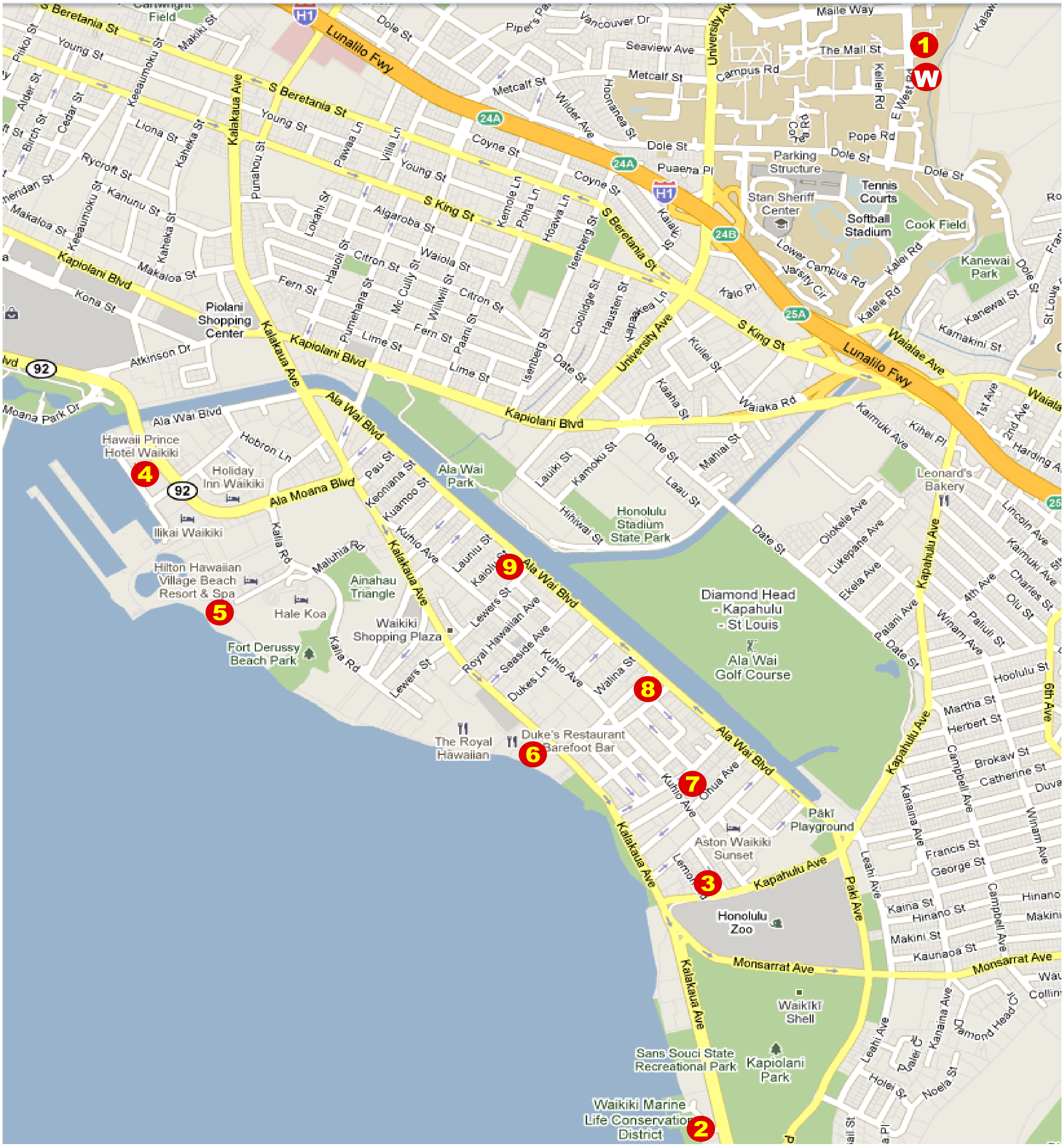
Map 2: Parking (P) and Meeting location (W)



Map 3: Waikiki Hotels and Workshop Location

1. East-West Center Housing
2. New Otani Hotel
3. Queen Kapiolani Hotel
4. Hawaii Prince Hotel
5. Hilton Hawaiian Hotel
6. Surfrider Moana Hotel
7. Hilton Waikiki Prince Kuhio Hotel
8. Aqua Aloha Surf & Spa Hotel
9. Coconut Waikiki Hotel

W. Hawaii Imin International Conference Center



Honolulu area attractions:

1. **Honolulu Zoo:** Located between the slopes of Diamond Head and Waikiki, the Honolulu Zoo is 42 lush tropical acres that include lions, tigers and bears! A children's zoo, African Savannah exhibit, playground and snack bar complete the visit.

2. **Diamond Head State Monument:** The unique profile of Diamond Head (Le'ahi) sits prominently near the eastern edge of Waikiki's coastline. Hawaii's most recognized landmark is known for its historic hiking trail, stunning coastal views, and military history. Diamond Head State Monument encompasses over 475 acres, including the interior and outer slopes of the crater.

3. **Waikiki Aquarium:** Located next to a living coral reef, the award winning Waikiki Aquarium brings guests face-to-fin with colorful tropical fish, reef sharks, living corals, endangered Hawaiian monk seals, sea jellies, squid, octopus and more!

4. **'Iolani Palace:** A Hawaiian national treasure and the only official state residence of royalty in the United States, `Iolani Palace was the official residence of the Hawaiian Kingdom's last two monarchs – King Kalakaua, who built the Palace in 1882, and his sister and successor, Queen Lili`uokalani.

5. **Honolulu Academy of Arts:** The Honolulu Academy of Arts is Hawaii's premier art museum, with a collection of more than 50,000 works. An encyclopedic museum where original works of art can be experienced in state-of-the-art galleries, it has major strengths in the arts of Asia, European and American painting, and graphic and decorative arts.

6. **Bishop Museum:** Considered the finest Polynesian cultural- and natural-history museum in the world, the Bishop Museum is Hawaii's version of the Smithsonian Institute in Washington, DC. The museum was originally founded in 1889 in honor of Princess Bernice Pauahi Bishop, a descendant of the Kamehameha family, and originally housed only Hawaiian and royal artifacts.

7. **USS Arizona Memorial Museum:** The USS Arizona Memorial Museum is a richly hued tapestry of memories and a moving testimonial to the bravery and honor of those who served and the thousands who died in the attack on Pearl Harbor, December 7, 1941. Be sure to visit the USS Bowfin, Arizona and Missouri memorials as well.

8. **Hanauma Bay Snorkeling:** Snorkeling in Hanauma Bay is truly experiencing paradise. The crystal blue ocean crater is full of bright and diverse species of fish, rays and turtles. Even the most inexperienced snorkeler can have a great time swimming with the Hawaiian wildlife in Hanauma Bay.

Oahu attractions:

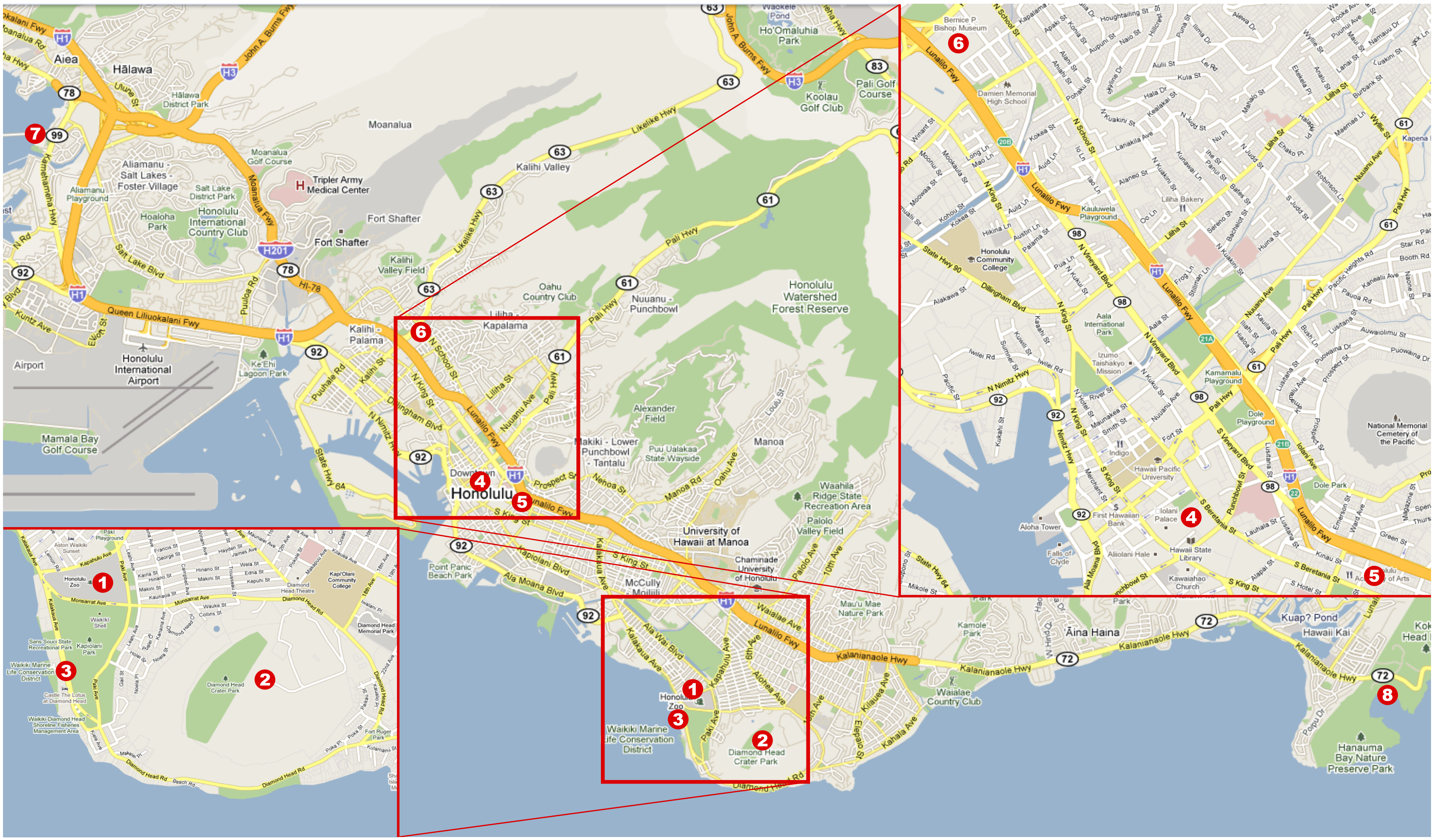
- **North Shore:** Home of Haleiwa, "Surf City, U.S.A." There are a plethora of activities and attractions on Oahu's north shore including: surfing, snorkeling, whale watching, golf, skydiving, hang gliding, the Polynesian cultural center, the Dole fruit plantation, art galleries, and more. Also, be sure to sample fresh shrimp from one of the many famous north shore shrimp trucks.

- **Oahu Beaches:** Oahu has many impressive beaches. Situated on the eastern coast are three of Hawaii's best beaches – Lanikai beach, Kailua Beach Park, and Waimanalo Beach Park.

- **Dole® Plantation:** The Dole® fruit plantation is located approximately 23 miles northwest of Honolulu along one of the routes to Oahu's north shore. The plantation garden tour is a walking tour through a garden of commercial species grown in O'ahu. You can explore on your own or on a guided tour. The Pineapple Express Train explores the entire complex, including the production portion of the plantation.

Map 4: Oahu Tourist Attractions

1. Honolulu Zoo
2. Diamond Head State Monument
3. Waikiki Aquarium
4. ‘Iolani Palace
5. Honolulu Academy of Arts
6. Bishop Museum
7. USS Arizona Memorial Museum
8. Hanauma Bay Snorkeling



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PROGRAM

---------- Monday, April 5, 2010 AM ----------

08:00-08:50 Registration

08:50-09:00 Welcome and Logistics

Chairperson: Brian S. Powell

09:00-09:30 (30 min) John Warner, U.S. Geological Survey, USA
Development and application of a Coupled-Ocean-Atmosphere-Waves-Sediment Transport (COAWST) Modeling System

09:30-10:00 (30 min) John Osborne, COAS - Oregon State U., USA
The M2 Internal Tide over the Oregon Shelf

10:00-10:30 (30 min) Lionel Renault, OceanBIY/IMEDEA, Spain
Resonant coupling of oceanic gravity waves forced by travelling atmospheric disturbances with destructive effects in harbors: meteo-tsunamis in the Balearic Sea

10:30-11:00 Break / Posters (30 min)

Chairperson: Robert D. Hetland

11:00-11:30 (30 min) Ruoying He, North Carolina State U., USA
Modeling the Circulation, Coastal Connectivity, and Harmful Algal Blooms in the Gulf of Maine

11:30-12:30 (60 min) Alexander F. Shchepetkin, IGPP, UCLA, USA
Rethinking mode splitting, splitting in general, Boussinesq, non-Boussinesq, seawater EOS, and how it all comes together

12:30-14:00 Lunch / Posters

---------- Monday, April 5, 2010 PM ----------

Chairperson: John C. Warner

14:00-14:30 (30 min) Robert Hetland, Texas A&M University, USA
Modeling circulation on the Texas-Louisiana continental shelf

14:30-15:00 (30 min) Maitane Olabarrieta, USGS, USA
U.S. East Coast Storm Surge, Wind Wave and Runup Simulations During the Extratropical Remnants of Hurricane Ida

15:00-15:30 (30 min) Dian Putrasahan, Scripps, USA
Coupled Air-Sea Interactions in the Southeast Pacific

15:30-16:00 Break / Posters (30 min)

Chairperson: Richard P. Signell

16:00-16:30 (30 min) Andrei Natarov, IPRC, U. Hawaii Manoa, USA
A numerical study of the effects of wind and upstream conditions on the Hawaiian circulation

16:30-17:00 (30 min) Liejun Zhong, CSIRO, Australia
Seasonal variability of the Leeuwin Current on the west coast of Australia

17:00-17:30 (30 min) Frank Colberg, CSIRO, Australia
Pathways and Impact of Southern Ocean currents on Antarctic Ice Sheet melting in response to global warming

18:00-21:00 (3 hours) Reception
Oceanography Building Courtyard
Authentic Hawaiian Luau Menu

PROGRAM

---------- Tuesday, April 6, 2010 AM ----------

Chairperson: Hernan G. Arango

09:00-10:00 (60 min) Andrew M. Moore, UC Santa Cruz, USA
A Comprehensive 4D-Var Data Assimilation and Analysis System Applied to the California Current System using ROMS

10:00-10:30 (30 min) Alexander Kurapov, COAS, OSU, USA
Variational Assimilation of Satellite Observations in the Coastal Ocean

10:30-11:00 Break / Posters (30 min)

Chairperson: Andrew M. Moore

11:00-11:30 (30 min) Brian Powell, University of Hawaii Manoa, USA
Assimilation of HF radar: Raw or Cooked?

11:30-12:00 (30 min) Peng Yu, COAS, Oregon State University, USA
Variational Assimilation of HF Radar Surface Currents in the Coastal Ocean Circulation Model off Oregon

12:00-12:30 (30 min) Ivica Janekovic, U. of Hawaii Manoa, USA
Data Assimilation in a Shallow, Island Coastal Environment

12:30-14:00 Lunch / Posters

---------- Tuesday, April 6, 2010 PM ----------

Chairperson: Alexander L. Kurapov

14:00-14:30 (30 min) Zhijin Li, Jet Propulsioni Laboratory, USA
A Data Assimilation System for Costal Ocean Real-Time Predictions

14:30-15:00 (30 min) Dax Matthews, SOEST, U. Hawaii Manoa, USA
Data Assimilation in a high-resolution, sub-mesoscale regional model of Hawaii

15:00-15:30 (30 min) Gildas Cambon, LEGOS, France
Interannual to decadal upwelling variability in the Humboldt system: A downscaling experiment with ROMS designed for the period 1958-2005

15:30-16:00 Break / Posters (30 min)

Chairperson: Ruoying He

16:00-16:30 (30 min) Kate Hedstrom, ARSC, UAF, USA
Development of a climate-to-fish-to-fishers model: data structures and domain decomposition

16:30-17:00 (30 min) Diego Narvaez, CCPO, ODU, USA
Coupling an Individual-Based Model to the Regional Ocean Model System (ROMS): Application on larval dispersal studies

17:00-17:30 (30 min) Jeffrey Dorman, UC Berkeley, USA
Modeled population biology of *Euphausia pacifica* in the California Current using the Regional Ocean Modeling System Coupled with an Offline Individual-Based Model

PROGRAM

---------- Wednesday, April 7, 2010 ----------

Chairperson: Alexander F. Shchepetkin

09:00-09:30 (30 min) — Hernan Arango, IMCS, Rutgers University, USA
ROMS Framework and Algorithms

09:30-10:00 (30 min) — Florian Lemarié, IGPP, UCLA, USA
Towards the minimization of the spurious diapycnal mixing in sigma-coordinate ocean models

10:00-10:30 (30 min) — Yonggang Wang, FIO, SOA, China
The application of wave-induced vertical mixing to the KPP scheme

10:30-11:00 — Break / Posters (30 min)

Chairperson: Kate S. Hedstrom

11:00-11:30 (30 min) — Amy MacFadyen, OR&R/NOS/NOAA, USA
Use of Operational Forecast Systems in Oil Spill Trajectory Modeling

11:30-12:00 (30 min) — Aijun Zhang, CO-OPS/NOS/NOAA, USA
ROMS Applications in NOS Operational Forecast Systems

12:00-12:30 (30 min) — Paul Budgell, MUN, Canada
Simulation of Seasonal and Decadal-Scale Variability in the Caspian Sea

12:30-14:00 — Lunch / Posters

Chairperson: Hernan G. Arango

14:00-14:30 (30 min) — Richard P. Signell, U.S. Geological Survey, USA
Improving the process of getting data to drive models: The OOI-CI & IOOS-DMAC Intersection Development Project

14:30-15:00 (30 min) — David Robertson, IMCS, Rutgers U., USA
ROMS: NetCDF and Matlab

---------- Thursday, April 8, 2010 ----------

09:00-10:30 (90 min) — Andrew M. Moore, Tutorial I
ROMS 4D-Var: The Secrets Revealed

10:30-11:00 — Break (30 min)

11:00-12:00 (60 min) — Tutorial II
TBD

12:00-13:30 — Lunch

13:30-14:30 (60 min) — Tutorial III
TBD

14:30-15:30 (60 min) — Tutorial IV
TBD

PROGRAM

Posters

1. Abouali, Mohammad, San Diego State University, USA
General Curvilinear Ocean Model: Next Generation (GCOM-NG)

2. Armstrong, Brandy, USGS, Woods Hole, MA, USA
A real-time forecasting system to predict coastal storm impacts

3. Cambon, Gildas, LEGOS, France
New features in ROMS_AGRIF 2.0 release and in the ROMSTOOLS pre- and post-processing toolbox

4. Chang, Nicolette, CSIR, South Africa
ROMS model application south of Africa

5. Colberg, Frank, CSIRO, Australia
Assessing current and future storm surge risk in the South Pacific and Southern Australia

6. Dukhovskoy, Dmitry, COAPS, Florida State U., USA
Modeling wave characteristics in the North Eastern Gulf of Mexico

7. Hsu, Marcia, University of Hawaii Manoa, USA
Hawai'i Ocean Observing System: The Role of ROMS

8. Huang, Ho-Shuenn, National Kaohsiung Marine U., Taiwan
Numerical Prediction and Correction of Tidal Forcing for Kaohsiung Second Harbor Using ROMS

9. Liang, Junhong, University of California Los Angeles, USA
Oceanic responses to mountain gap winds in the Northeastern Tropical Pacific

10. Manyilizu, Majuto Clement, U. of Cape Town, South Africa
Numerical modelling of the East African Coastal Current (EACC)

11. Masson, Diane, Institute of Ocean Sciences, Canada
A regional ocean model of the Canadian Pacific Coast

12. Moon, Jaehong, RIAM, Japan
Estimation of freshwater transport and dispersal pathway discharged from the Changjiang River in the East China Sea

13. Morey, Steve, COAPS, Florida State University, USA
Variability of wind-driven transport in the Florida Big Bend Region

14. Oleynikov, Igor, Pac. Ocean. Inst. of the FEBRAS, Russia
Integration ROMS in OIAS (Oceanological information-analytical system) of Pacific Oceanological Institute of FEBRAS

15. Renault, Lionel, OceanBIT/IMEDEA, Spain
Coupled Ocean/Atmosphere regional simulation of Coastal Jet off Central Chile: A case study for the October 2000 event

16. Setou, Takashi, NRIFS, Fisheries Research Agency, Japan
Application of a 3D-var data assimilation scheme to an eddy-permitting North Pacific Model based on ROMS

Talk Abstracts

ROMS Framework and Algorithms

Hernan G. Arango
IMCS, Rutgers University, USA

An overview of ROMS framework in terms of new algorithms and developments. The model diagnostic terms were revisited to allow term decomposition in all coordinate directions. The biology and sediment model interfaces were redesigned to allow customization and addition of new models. The vertical, terrain-following coordinate transformation now allows additional equations and numerous vertical stretching functions. The transformation is generic and the formula_terms, which are independent of the stretching functions, are registered with the CF Conventions Committee and the NetCDF-Java group. The diapycnal mixing associated with the advection schemes is analyzed in terms of T-S properties and term diagnostics in a coarse resolution North Atlantic application.

The full suite of 4D-Var data assimilation algorithms are very mature in ROMS and include sophisticated conjugate gradient solvers, spectral and Ritz preconditioning, additional state variables to adjust, and observation sensitivity drivers. The theory and technical considerations behind these algorithms will presented in Andrew M. Moore's lecture and tutorial.

A preview of future ROMS developments will be discussed.

Simulation of Seasonal and Decadal-Scale Variability in the Caspian Sea

W. Paul Budgell
Dept. of Physics and Physical Oceanography,
Memorial University of Newfoundland, Canada

Ralf Toumi, **Catherine Reifen**, **Andrew Singleton**, and **James Farley Nicholls**
Department of Physics, Imperial College, United Kingdom

The Caspian Sea, the world's largest enclosed water body, has exhibited dramatic variations in sea level over the past century. Future climate projections from IPCC AR4 model results indicate that the Caspian Sea Level (CSL) may fall by as much as 8 m. Such a drop in the CSL would dry nearly the whole Northern Basin of the Caspian, with dire environmental implications.

Before attempting to downscale future climate scenarios for the Caspian, we wish to understand previous swings in the CSL and to develop confidence that we can reproduce the variability in the Caspian Sea physical environment under existing climate conditions. To examine seasonal and decadal-scale behaviour of the Caspian Sea, a hindcast simulation is conducted for the period 1958-2001 using the coupled ice-ocean Regional Ocean Modelling System (ROMS) forced with ERA40 atmospheric reanalysis data. Using available river disharge data and a conventional bulk flux algorithm for latent heat transfer produced a bias in CSL trend of +6 cm/yr. The sensitivity of the Caspian water balance to evaporation of river runoff downstream of gauging stations, enhanced evaporation due to wave action, mesoscale variability in air-sea fluxes and changes in Caspian surface area are addressed.

Interannual to decadal upwelling variability in the Humboldt system: A downscaling experiment with ROMS designed for the period 1958-2005

Gildas Cambon[1], **Boris Dewitte**[1,3,4], **Katerina Goubanova**[1,3], **Francois Colas**[5], **Vincent Echevin**[2], **Ali Belmadani**[2], **Christophe Hourdin**[2], **Timothée Brochier**[2]

1. LEGOS/IRD, Toulouse France
2. LOCEAN/IRD, Paris France
3. IMARPE, Lima, Peru
4. IGP, Lima, Peru
5. IGGP/UCLA, Los Angeles, USA

The biogeochemical response to wind forcing in the waters off southeast Australia have been investigated with a coupled physical-carbon chemistry-NPZD model. The model shows that upwelling favourable winds bring DIC rich slope waters to the surface causing an outgassing. As the water is advected, downstream phytoplankton production consumes carbon resulting in absorption of CO_2. The net effect of upwelling, in a region of the global ocean that is generally absorbing, is reduced absorption. This result is further investigated using a biogeochemical shelf budget, analysis of terms, and the use of an age tracer. In this talk, I will concentrate equally on general analysis techniques (i.e., using the age tracer) and the scientific conclusions themselves.

Pathways and Impact of Southern Ocean currents on Antarctic Ice Sheet melting in response to global warming

Frank Colberg[1], **Nathan Bindoff**[1,2,3]

1. CSIRO Marine and Atmospheric Research, Aspendale, Australia
2. Antarctic Climate and Ecosystems CRC, Hobart, Australia
3. University of Tasmania, Hobart, Australia

Results are presented from high resolution ocean model simulations using ROMS encompassing the whole of Antarctica taking into account ocean ice shelf interaction. Simulations are run under present day climate conditions and are then compared with simulations forced with the projected atmospheric state as predicted by the IPCC emission scenario A2. Model results and diagnosed analyses of gravity and height changes of the Antarctic Ice Sheet are discussed and compared to observational data such as GRACE. The model's capability to adequately represent the Southern Ocean mean state will be discussed.

Modeled population biology of *Euphausia pacifica* in the California Current using the Regional Ocean Modeling System Coupled with an Offline Individual-Based Model.

Jeffrey Dorman and **Thomas Powell**
University of California Berkeley, Berkeley, CA, USA

William Sydeman
Farallon Institute, Petaluma, CA, USA

Steven Bograd
NOAA, Southwest Fisheries Science Center, Pacific Grove, CA, USA

Euphausia pacifica is the dominant krill species on the West coast of the United States and an important trophic link in the food web of the coastal upwelling ecosystem. Understanding the impacts of physical forcing on their spatial distribution and biological condition will enable a better understanding of the productivity of those predators that rely on them as a food source. We have chosen to use an individual-based model (POPCYCLE) to simulate *E. pacifica* as there are known aspects of their life-history that are difficult to model using a traditional concentration based model or other available individual-based models. Those aspects include, diel-vertical migration, discreet reproductive events, and stage-specific mortality and growth. The IBM POPCYCLE is run offline from ROMS, allowing multiple population simulations without the computational expense of running ROMS. However, interpolation between saved forcing data must be implemented. We present results of the spatial and temporal distribution from the winter/spring of 2001 and 2005 in the California Current. The year 2001 was chosen as a fairly "standard" year for the California Current; and the year 2005 was simulated as an anomalous year, i.e., upwelling was delayed much later in the year than on average. Results show that changes in advection and phytoplankton abundance impact the spatial and temporal peaks of *Euphausia pacifica* abundance and reproductive effort. These model results provide information on the factors that control important prey species productivity in the California Current.

Modeling the Circulation, Coastal Connectivity, and Harmful Algal Blooms in the Gulf of Maine

Ruoying He
North Carolina State University, USA

The Gulf of Maine (GOM) is a continental shelf sea that supports productive shellfisheries that are frequently impacted by *Alexandrium fundyense* blooms and outbreaks of paralytic shellfish poisoning (PSP). To monitor and predict harmful algal blooms abundance and distribution in the GOM, we have coupled a population dynamics model for *Alexandrium* into a GOM ROMS. In the wake of the historic bloom of 2005 in the western GOM, this coupled model was used to diagnose the underlying causes, including 1) high abundance of resting cysts in fall 2004 that provided a large inoculum; 2) storms with strong northeast winds that carried toxic cells towards, and along the coast; and 3) abundant fresh water runoff, providing macro- and micro-nutrients, a stratified water column, and an alongshore transport mechanism. Sensitivity experiments show that simulations initiated from *A. fundyense* cyst distributions capture large-scale seasonal patterns in the distribution and abundance of *A. fundyense* cells. We proposed that cyst abundance is a first-order predictor of regional bloom magnitude in the following year, and that cyst abundance may hold the key to interannual forecasts of PSP severity. The coastal ocean transport and connectivity in the GOM and Georges Bank (GB) are further quantified using the Lagrangian probability density functions (PDFs) based on ROMS circulation simulations and numerical particle trajectory calculations. We focus on the spring and summer seasons when toxic *A. fundyense* blooms often occur. The seasonal-averaged PDFs highlight the mean circulation patterns in the GOM. On the interannual time scale, Lagrangian PDFs do show significant variability.

Development of a climate-to-fish-to-fishers model: data structures and domain decomposition

Kate Hedstrom
Arctic Region Supercomputing Center, University of Alaska, Fairbanks, USA

Jerome Fiechter
University of California, Santa Cruz, USA

Kenneth A. Rose
Louisiana State University, USA

Enrique N. Curchitser and **Miguel Bernal**
Institute of Marine and Coastal Sciences, Rutgers University, USA

We are developing a model for examining the long-term population cycles of anchovy and sardine in the California Current system. This presentation will focus on the numerical methods and computing considerations for dynamically coupling the physics, lower trophic level, and upper trophic level models. The physics is represented by the Regional Ocean Modeling System (ROMS), which has been designed to run on parallel architectures using the Message Passing Interface (MPI) that is common on the current generation of supercomputers. The lower trophic level model is a version of the NEMURO nitrogen-phytoplankton-zooplankton model. The fish community is represented using a full life cycle, individual-based approach. When combining the models, which are a mix of Eulerian and Lagrangian approaches, care must be taken to ensure that the modeling system continues to function on tens of processors with many thousands of individuals without running into resource limitations – or worse, results that depend on the number of processors. We will describe several of the numerical algorithms we are using in our dynamically-coupled model, including those for spatially-locating eggs from spawning and scaling the predator-prey interactions among the fish species represented in the model and between the fishers and the fish.

Modeling circulation on the Texas-Louisiana continental shelf

Robert Hetland and **Xiaoqian Zhang**
Texas A&M University, USA

The physical processes on the Texas-Louisiana continental shelf and slope are examined using a high-resolution domain. The model domain covers all the Texas- and Louisiana- bays and estuaries and extend to past the 500 m isobath. The model is forced with the observed freshwater fluxes from the eight major Texas and Louisiana rivers, surface winds, and heat fluxes. This model is used to study seasonal hypoxia over the Texas-Louisiana shelf, and examine the origins of harmful algal blooms that occur sporadically along the Texas coast. This model will be transitioned to an operational model used to predict oil spill trajectories.

Data Assimilation in a Shallow, Island Coastal Environment

Ivica Janekovic and **Brian Powell**
University of Hawaii at Manoa, USA

Data assimilation techniques are well established in global and regional modeling systems with spatial resolution of order 10-100km and temporal scales on the order of days. However, applying the methods in the near-shore coastal regions, usually resolved with high spatial resolution (~100m) grids simulating complex and highly dynamical environments, remains a novel approach. We present our ongoing research related to the Western Oahu regional model, based on ROMS, by using variational data assimilation with limited observations (CTD and ADCP). The Modeling system is characterized by a variable mesh grid resolution of 600m in deeper regimes and 200m near the coast. Validation of TLM approximation used in variational methods for a such region is evaluated revealing that initial perturbations are quickly dissipated by the boundary conditions. With dominating tidal circulation, adjustment to the boundary conditions requires careful attention to avoid removal of the tidal signal. We present preliminary results from the assimilation of ADCPs recovered at the end of February, 2010 in this highly nonlinear regime.

Variational Assimilation of Satellite Observations in the Coastal Ocean

Alexander L. Kurapov[1], **David G. Foley**[2], **P. Ted Strub**[1], **Gary D. Egbert**[1], and **J. S. Allen**[1]

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2. NOAA-NESDIS-JIMAR, NOAA-SWFSC, Pacific Grove, CA, USA

Nonlinear ROMS is combined with the AVRORA tangent linear and adjoint codes developed at OSU, to facilitate implementation of the variational representer-based method in the coastal ocean model off Oregon (U.S. West Coast). Satellite observations of alongtrack SSH and SST maps are assimilated using the ROMS-AVRORA system at 6-km horizontal resolution to learn about the utility of satellite information in the context of coastal ocean prediction and forecasting systems. The study period is June-October 2005 when observations (AVISO absolute dynamic topography) from 3 satellites, Jason, Topex, and Envisat are available. Assimilation proceeds in a series of 6-day time windows. In each window, initial conditions are corrected using iterations of the adjoint and tangent linear AVRORA and a multivariate initial condition error covariance. The nonlinear ROMS is then run with the corrected initial conditions for the 6-day analysis period plus the 6-day forecast period. The forecast is a background solution for assimilation in the next window. Since the mean SSH in the alongtrack altimetry and the Boussinesq ROMS are not directly comparable, we assimilate the SSH slope along each track (or, scaled appropriately, the surface geostrophic velocity component in the direction normal to the tracks). SSH assimilation improves the model-data RMS difference of SSH forecasts and also corrects the geometry of the SST front compared to the unassimilated SST. Combined SSH and SST assimilation further improves accuracy of near-surface transports and SST. The horizontal offshore transport of momentum and heat in the assimilative solution is more uniform along the coast than in the free-run prior model, in which the transport was dominated by separation at Cape Blanco (43°N). Also, the assimilative solution helps reveal the existence of a front at 127°N, about 200 km offshore in addition to the inshore front that is usually clearly seen in SST images. This outer front is not reproduced by the limited-resolution prior model, and is characterized by a strong along-front current and strong subsurface horizontal gradient of temperature, but weak SST contrast.

Towards the minimization of the spurious diapycnal mixing in sigma-coordinate ocean models

Florian Lemarié and **James C. McWilliams**
IGPP, University of California, Los Angeles, USA

Laurent Debreu
INRIA and Laboratoire Jean Kuntzmann, France

High-order diffusive advection schemes are now widely used in numerous state-of-the-art ocean models. However, as suggested by (Griffies *et al.*, 2000), the diffusion associated to this type of scheme may be large enough to produce excessive diapycnal mixing. In terrain-following coordinate models like ROMS, a strong horizontal mixing along iso-sigma surfaces can thus lead to spurious diapycnal fluxes of heat and salt (and hence density) when it is applied in regions with sloping isopycnals.

This problem has been recently highlighted in regions with steep topographic features (Marchesiello *et al.*, 2009). We are currently attempting to diagnose, as accurately as possible, the damages done to the stratification due to this additional spurious mixing. In parallel, a modified version of the ROMS tracer advection scheme is under consideration in order to restore the adiabatic property of advection. This can be done essentially by rotating the diffusion tensor from the horizontal/vertical directions to the isopycnal/diapycnal directions (Marchesiello *et al.*, 2009).

Up to now special care has been given to the design of an accurate discretization of the rotated diffusion as well as to the numerical stability analysis of the ROMS time stepping algorithm when the modified scheme is used.

A Data Assimilation System for Costal Ocean Real-Time Predictions

Zhijin Li and **Yi Chao**
Jet Propulsion Laboratory, California Institute of Technology, USA

James C. McWilliams
IGPP, University of California, Los Angeles,USA

Kayo Ide
University of Maryland, College Park, USA

A coastal ocean observing system generally consists of sparse conventional observations and high resolution satellite and radar remote sensing measurements. Difficulties arise when observations from such an observing system are assimilated into high resolution models. In particular, into those regional and coastal ocean models that have been using spatial resolutions approaching 1 km and thus have the capability of representing flow systems over a wide range of spatial scales. A multi-scale three-dimensional variational data assimilation (MS-3DVAR) scheme has been formulated. This scheme is characterized by constructing error covariance at different spatial scales and implementing data assimilation sequentially from large to small scales. The application of this scheme to real-time coastal ocean observing systems will be presented.

Use of Operational Forecast Systems in Oil Spill Trajectory Modeling

Amy MacFadyen and **Glen Watabayashi**
NOAA OR&R Emergency Response Division, Seattle, WA, USA

Thousands of incidents occur each year in which oil or chemicals are released into the environment as a result of accidents or natural disasters. Spills into our coastal waters can harm people and the environment and cause substantial disruption of marine transportation with potentially widespread economic impacts. The Emergency Response Division (ERD) of NOAA's Office of Response and Restoration (OR&R) provides scientific expertise to support an incident response — a key part of which is trajectory forecasting to predict the movement of oil spills.

The movement of oil (and other substances) on the water surface is driven by a combination of winds and ocean currents. Forecasting this movement requires environmental data that has traditionally been either sparse or unavailable. However, more recently, operational nowcast and forecast hydrodynamic model systems are increasingly being implemented in critical inland and coastal waters of the United States. In order for these systems to be incorporated in incident response, the forecast datasets must be readily available in a form that can be utilized immediately so that model predictions may be quickly evaluated. We highlight several such regional systems that have recently been utilized in spill response.

Data Assimilation in a high-resolution, sub-mesoscale regional model of Hawaii

Dax Matthews and **Brian Powell**
School of Ocean and Earth Science and Technology, University of Hawai'i at Manoa, USA

We utilize the incremental strong constraint four-dimensional variational data assimilation (IS4DVAR) method to study the circulation and dynamics around the Hawaiian Islands. In this system we assimilate observations from satellite radiometry and altimetry, as well as *in situ* data from Argo floats, surface drifters, autonomous gliders, and shipboard CTD (conductivity, temperature, depth) and ADCP (acoustic Doppler current profiler) instruments. We present results from a 2-year spin-up of the IS4DVAR model performed in preparation for the operational real-time system. Model-observation difference is reduced by over 70%; however, large reductions in misfit are only seen in sea surface temperature (SST). This is due to the vast difference in the relative number of observations of the various products, with satellite SST accounting for over 99% of all observations assimilated. Results are presented from experiments that focus on increasing the contribution of non-satellite SST observations.

A Comprehensive 4D-Var Data Assimilation and Analysis System Applied to the California Current System using ROMS

Andrew M. Moore[1], **Hernan G. Arango**[2], **Gregoire Broquet**[3], **Chris Edwards**[1], **Milena Veneziani**[1], **Brian Powell**[4], **Dave Foley**[5] and **Jim Doyle**[6]

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5. Environmental Research Division, NOAA Southwest Fisheries Science Center, Pacific Grove, California, USA
6. Naval Research Laboratory, Monterey, California, USA

The ROMS 4D-Var data assimilation platforms have been applied extensively to the California Current System (CCS), and have provided a wealth of valuable experience with regard to the challenges of data assimilation in a mesoscale ocean circulation environment. ROMS currently supports three 4D-Var data assimilation systems, and a suite of powerful diagnostic tools. In this talk we will present results from a 2.5 year period during which 4D-Var was applied sequentially to the CCS. During this period, a variety of data were assimilated from various platforms. Example analyses will be presented, including estimates of the expected analysis error, and quantification of the level of redundancy and efficiency of the observing array. The impact of correcting for uncertainties in the initial conditions, surface forcing, and open boundary conditions on various different aspects of the CCS circulation estimates will also be presented. In addition, the impact of each observation platform on circulation estimates during the analysis and forecast cycles will also be explored.

ROMS 4D-Var: The Secrets Revealed (Tutorial)

Andrew M. Moore
University of California, Santa Cruz, USA

ROMS is one of the few community ocean models for which a 4-dimensional variational (4D-Var) data assimilation capability has been developed. The ROMS 4D-Var system, however, is by far the most comprehensive of all those currently available. ROMS 4D-Var comprises three different 4D-Var platforms: one that searches for the best estimate of the ocean circulation in the full space spanned by the model, and two that search in the sub-space spanned by the observations. In all cases, the best estimate circulation can be identified by adjusting the model initial conditions, surface forcing, and open boundary conditions. In the case of 4D-Var in observation space, model errors can also be admitted, leading to the so-called weak-constraint problem. Several powerful 4D-Var post-processing algorithms have also been develop for ROMS, including an observation sensitivity driver. This talk will be a follow-on to the talk entitled "A Comprehensive 4D-Var Data Assimilation and Analysis System Applied to the California Current System using ROMS," and the focus will be a review of the fundamental ideas that underpin the entire 4D-Var package for ROMS.

Coupling an Individual-Based Model to the Regional Ocean Model System (ROMS): Application on larval dispersal studies

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Most physiological processes in marine organisms are controlled by environmental parameters such as temperature, salinity, food, etc., which can be estimated from hydrodynamic models with appropriate processes. Individual-Based Models (IBM) are used to study dispersal of freely drifting marine organisms, such as larvae, which are affected by growth and behavior in response to environmental conditions. In this study we convert the particle-tracking module in the ROMS code into an IBM representing eastern oyster larvae which has growth and vertical migration. ROMS was configured for Delaware Bay to calculate the estuarine circulation in response to winds and river discharge. Larvae are released from a number of points (reefs) at several times and tracked for 2 to 4 weeks which is sufficient for them to mature (attain a length of 330 micron), at which point they sink and attach to the bottom. The results show that variations in temperature and salinity have a large impact in the larval survival, dispersal and settlement. Increased larval mortality is associated with areas having low salinity or low temperature. Simulations show that behavior is important and favors settlement of larvae within the Bay; particles without behavior are mostly exported to the shelf. A recirculation in the lower Bay is important in retaining larvae, increasing the settlement in this area. River discharge variation also affects the dispersion pattern, causing a shift between middle and lower Bay settlement. These results confirm that both physical and biological processes influence the dispersion pattern of larvae, and thereby, the pattern of recruitment and genetic dispersal over Delaware Bay. We are able to map which reef is the source of recruits to each oyster bed based on the results of this work. Finally the modification of ROMS drifters into an IBM provides a new tool for studies of larval dispersion and other individual-based studies.

A numerical study of the effects of wind and upstream conditions on the Hawaiian circulation

Andrei Natarov
IPRC, University of Hawaii, USA

Brian Powell
University of Hawaii at Manoa, USA

We compare the effects of varying both boundary conditions and wind forcing resolution on a high-resolution Regional Ocean Modeling System (ROMS) designed for the Hawaiian Islands. This regional model uses both Navy Coupled Ocean Model (NCOM) and Hybrid Coordinate Ocean Model (HYCOM) lateral forcing. We find that the resulting circulation is sensitive to both wind and lateral boundary conditions. Higher resolution wind products drive stronger overall circulation in the upper ocean. While the eastward current in the lee of the islands is driven directly by the wind stress curl. Westward currents north and south of this flow are enhanced due to mismatch in the velocity prescribed at the western boundary of the domain and the velocity of the wind-driven flow.

Accompanying the differences in the mean circulation patterns are the differences in sea surface temperature (SST), surface salinity (SSS) and surface heat fluxes. Experiments driven by the higher resolution winds have higher heat fluxes and SSTs in the lee of the Islands than lower resolution wind driven counterparts. The surface salinity is lower on the lee side of the Islands, and higher on the windward side for the higher resolution winds. Validation tests consist of comparing the means and variances of SST and SSH fields, as well as temperature and salinity fields with ARGO and Hawaii Ocean Time-Series (HOT) hydrography, and computing standard rms and correlations statistics between the observations and experiments.

The comparison with AVHRR data shows that all four experiments are good at capturing the seasonal cycle; however, there is a warm bias in the monthly means of the model runs during winter months. There is a shift of warmer SST in the Lee of the Big Island with the higher resolution wind forcing, which is different from observations. It is found that HYCOM-driven models generally have a better comparison to Aviso SSH, with higher-resolution winds improving the comparison. The vertical T/S profiles compare favorably with hydrographic observations, especially the temperature profiles. For salinity profiles it is found that runs with NCOM boundary conditions capture salinity profiles in the upper portion of the thermocline very well, while overdiffusing water masses at the base of the thermocline. In contrast, runs with HYCOM boundary conditions do not capture the salinity structure in the uppermost part of the ocean, but capture the stratification at the base of thermocline very well.

U.S. East Coast Storm Surge, Wind Wave and Runup Simulations During the Extratropical Remnants of Hurricane Ida

Maitane Olabarrieta
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During 13th -15th of November a powerful extra-tropical storm developed from the remnants of tropical storm Ida and affected the East coast of the USA causing severe flooding in some areas, damaging buildings and eroding beaches. Ida's low pressure cell was located off the U.S. East coast while a high pressure area was located in New England, resulting in strong winds blowing toward the southwest all along the coasts of Virginia, Delaware and New Jersey resulting in coastal setup and high waves along the coast between Cape Hatteras and New Jersey. From the Carolinas north to New England beach erosion appears to have rivaled that which occurred during Hurricane Isabel in 2003. One of the most critical factors affecting the potential for beach and dune erosion, overwash, and breaching is the total wave runup. The extent of runup is controlled by a range of factors. The most significant being tidal levels, storm surge heights and the height of waves incident to the coast. The present study focuses on hindcasting and analyzing the spatial and temporal distribution of these parameters. We use results derived from a modeling system for wind, waves, and circulation currently applied by the USGS to the U.S. East coast. The system is run here in a hindcast mode with a 5 km resolution grid for both the SWAN wave generation and propagation model and the three dimensional ROMS hydrodynamic model. Model simulations computed a maximum storm surge of approximately 1.1 m (not including wave-induced setup), a value that was also measured by several coastal tidal gauges. Model results also indicate that the most energetic waves, with significant wave heights up to 7 m, occurred in coastal Virginia, decreasing to 4.5 m at Cape Hatteras. Computed significant wave heights and sea levels are compared with wave data and tidal levels measured along the East U.S. coast. The models performance is analyzed computing the RMSE, the correlation coefficient (R) and the model skill (S) in each considered station. Results showed that there is a high agreement between the measurements and the models outputs, although some discrepancies are observed in specific areas.

The M2 Internal Tide over the Oregon Shelf

John J. Osborne, **Alexander L. Kurapov**, **Gary D. Egbert**, **P. Michael Kosro**
COAS, Oregon State University, USA

Interactions of the internal tide and wind-driven upwelling on the Oregon shelf are studied using a 1-km horizontal resolution ocean circulation model based on ROMS. The study period is May-August 2002, when data from the GLOBEC field program are available for model verification. Realistic time- and space-varying atmospheric forcing is provided by COAMPS. Open boundary conditions are a combination of a solution from a larger scale, 3-km resolution ROMS model (run without tidal forcing) and barotropic tide from a data-assimilating shallow-water model. Three cases are compared, forced by the tide only, winds only and the tide and winds in combination. Modeled subtidal and tidal variability on the shelf is in good agreement with time-series of mooring velocity observations.

The solutions have revealed "hotspots" of the M2 internal tide generation on the Oregon slope, as well as areas of intensified tidal energy dissipation. Despite day-to-day variability in the baroclinic tidal energy fluxes on the slope and shelf, the alongshore average flux on the shelf does not vary much. Resolution of bathymetry affects the area-integrated generation and dissipation of the internal tide energy on the slope more than the integrated baroclnic tidal energy flux from the slope to the shelf.

Assimilation of HF radar: Raw or Cooked?

Brian S. Powell, **Dax Matthews**, **Ivica Janekovic**
University of Hawaii at Manoa, USA

HF radars cover much of the coastal United States, and many of these data are now being used in modeling activities. Through measuring the doppler shift of the returned signal, the surface ocean current along the radial line from the radar is derived. When two or more radars sample a near-orthogonal patch of ocean, simple statistical inversion techniques are used in an attempt to calculate ocean currents. Most modeling groups working with HF radar assimilate these artificially generated ocean currents. Variational data assimilation, which relies upon the physics of the model to generate the covariances, is ideally suited for working with data close to its source. To this end, we present a method in ROMS for assimilating direct radials generated in real-time by HF radars and compare the results with the assimilation of the artificial current vectors. Due to the temporal and spatial overlapping requirement, assimilation of radials will provide a larger constraint to the assimilation than the vectors, and we explore the results of the two.

Coupled Air-Sea Interactions in the Southeast Pacific

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Hyodae Seo
International Pacific Research Center, University of Hawaii at Manoa, USA

We examine the air-sea interactions in the Humboldt Current System (HCS) using the Scripps Coupled Ocean-Atmosphere Regional (SCOAR) model. The oceanic component for this model uses Regional Ocean Modeling System (ROMS) and the atmospheric component uses the Regional Spectral Model (RSM). Recent studies based on satellite observations suggest that there is a tight coupling between summertime SST gradients and wind stress derivatives. The SCOAR model has reproduced many aspects of the observed coupled processes. In this study, we compare the HCS wind stress and SST fields in SCOAR to those obtained from satellite observations such as QuikSCAT and TMI-AMSRE. The coupled processes that occur between the surface flux fields and the SSTs are diagnosed. We also examine the correspondence between the crosswind SST gradient and wind stress curl, along with the downwind SST gradient and wind stress divergence, in both the SCOAR model and NCEP/DOE Reanalysis II. Particular emphasis is being given to the effect of atmospheric feedback processes on the stability of the coastal upwelling and understanding the processes that control the mean and eddy circulation in the HCS, which contributes to the overall heat balance in the upper ocean and the resulting mean ocean-atmosphere circulation of the Eastern Tropical Pacific region.

Resonant coupling of oceanic gravity waves forced by travelling atmospheric disturbances with destructive effects in harbors: meteo-tsunamis in the Balearic Sea

Lionel Renault[1,2], **Guillermo Vizoso**[1], **John Wilkin**[3], and **Joaquin Tintore**[1,2]

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Meteo-tsunamis are long-period oceanic waves that possess tsunami like characteristics but that are meteorological in origin. In the western Mediterranean, travelling atmospheric gravity waves and/or convective pressure jumps generate long surface waves in the ocean that are amplified and produce strong seiche oscillations in some inlets and harbors. This results in a sudden drop of sea level inside the harbor that can be repeated cyclically from a few hours to several days. These high amplitude oscillations can produce significant hazards with social and economic consequences. In particular, they affect recreation and fishing in Ciutadella harbor, southwest of Menorca Island.

In this presentation, we focus on this phenomenon locally known as *Rissaga*. Ciutadella is a natural elongated inlet about 1 km long, 100 m wide and approximately 5 m deep, with a free period of oscillation (Helmholtz mode) of 10 minutes. This specific geometry confers to the harbor a large Q-factor, which results in significant resonant amplification of long waves from the open sea. *Rissaga* events typically occur in summer and last from a few hours to several days with sea level oscillations of approximately 0.5 m on average. Extreme oscillations have also been observed. On June 15, 2006, wave heights of 4–5 m were reported inside the harbor resulting in very strong and destructive currents.

We have used ROMS to study the propagation and coupling between the atmospheric and the oceanic waves and the amplifications occurring in different regions travelled by the atmospheric forcing disturbance (open ocean, shelf, channel and harbor).

First, we analyze the problem using a simple idealized basin from which the major physical processes can be identified. The parent domain is a 1 km resolution, 100 m depth rectangular basin sloping up to 10 meters depth. The child domain is an idealized harbor with similar dimensions to Ciutadella with 20 m spatial resolution. Results show that ROMS can adequately reproduce the main features of the *Rissaga* events described in the literature. Sensitivity analysis to different atmospheric forcing conditions (intensity, travelling direction, etc.) and bathymetries is also carried out.

Second, we study two real cases: one using ROMS forced by WRF regional atmospheric model (three embedded domains with 30km, 6km, 1.5 km spatial resolution) and another using realistic atmospheric conditions from July 2006 (extreme event) and May 2008 (normal oscillations). A sea level travelling atmospheric wave train of 5 hPa, which is in good agreement with observations, is adequately reproduced by WRF. The associated inverse barometer wave front in the open ocean is progressively amplified in the different regions of the domain reaching almost 50 cm at the mouth of Ciutadella and more than 3 m inside in the extreme case. This is also in reasonable agreement with observations.

We analyze theses findings and the feasibility of establishing an operational forecasting system that can, in the near future, result in the establishment of an early warning system of meteo-tsunamis in the Mediterranean.

ROMS: NetCDF and Matlab

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

A quick review of the tools and information available on the ROMS web sites will be presented.

Nowadays, almost all the pre- and post-processing of ROMS NetCDF files is done with Matlab. As we presented at the Sydney Workshop, we will navigate the various ways to access NetCDF data inside Matlab. There is a lot of interest and confusion in the forum about this topic. We will attempt to clarify issues like: the NetCDF library version (NetCDF-3, NetCDF-4), file type (classic, HDF5), compression, and OpenDAP. Matlab's native NetCDF interface (starting with R2008b) adds yet another layer of complexity. Currently, we have mexcdf, mexnc, snctools, NetCDF-java, and native Matlab potentially available and interacting with each other. We will attempt to explain the hierarchy of these interactions.

Rethinking mode splitting, splitting in general, Boussinesq, non-Boussinesq, seawater EOS, and how it all comes together

Alexander F. Shchepetkin
IGPP, University of California, Los Angeles, USA

A convoluted story about how code writing work comes long before an understanding of how and why it works leads to re-discovery of old knowledge. Essentially a unified approach to mathematical splitting of stiff operators, not just for barotropic-baroclinic mode, but overall throughout the oceanic solver. A perturbational analysis helps to derive two- or three-way splits involving several components of the model. Barotropic mode, compressible EOS, implicit bottom drag can peacefully co-exist without overwriting computational efforts of each other.

Improving the process of getting data to drive models: The OOI-CI & IOOS-DMAC Intersection Development Project

Richard P. Signell
U.S. Geological Survey, Woods Hole, MA, USA

This project is intended to improve the automated processing and transfer of data needed by regional models for forcing and assimilation. Currently research modelers spend a good portion of their time first determining where to access data, such as observations or other models' output for initialization, and then creating and maintaining automated methods to retrieve the data. In the process they create *ad hoc* connections through various organizations. Through this project, NSF's Ocean Observatories Initiative - Cyber Infrastructure (OOI-CI) and NOAA's Integrated Ocean Observing System - Data Management and Communications (IOOS-DMAC) will provide a standardized, reliable and efficient system for research modelers to access the data they need freeing them to do actual research. At the same time, this project will enhance the methods used to manipulate and disseminate the data to the scientific community and provide format conversions so research modelers can more readily use the data.

This project will improve the process by which research modelers access data to drive their models. We will do this in two ways:

1. We will transfer observations and model output from the World Meteorological Organization's (WMO's) Global Telecommunication System (GTS) into the OOI-CI infrastructure. OOI-CI will in turn present these data to the modelers via a Unidata Thematic Real-time Environmental Distributed Data Services (THREDDS) catalog and subscription service.
2. We will enhance the methods used to access data using ingestion and transformation services to support new data streams.

The application of wave-induced vertical mixing to the KPP scheme

Yonggang Wang
First Institute of Oceanography, SOA, China

A surface, wave-induced vertical mixing is incorporated to modify the K-profile parameterization (KPP) scheme available in ROMS. The effects of this modified KPP scheme on a quasi-global oceanic general circulation model are examined by carrying out four test cases. To evaluate simulated upper-layer temperature and surface mixed layer depth (MLD), the model seasonal cycle of temperature and MLD are compared with those from Levitus climatology. In this study, the MLD is defined as the depth that the temperature has changed 0.8°C from the reference depth of 10 m. Statistic analysis shows that test cases with the addition of wave-induced vertical mixing can reduce the root-mean-square difference of upper-layer temperature and increase the correlation with Levitus climatology. Based on comparison with Levitus climatology, the surface wave-induced mixing improves the simulation of MLD in summer time for both hemispheres. Comparison with other seasons reveals that MLD is most significantly improved during the summer. The simulation results are sensitive to the weight of wave-induced mixing coefficients and suggest that the preferred weighting coefficient is between 0.1 and 0.3 in the modified KPP scheme.

Development and application of a Coupled-Ocean-Atmosphere-Waves-Sediment Transport (COAWST) Modeling System

John C. Warner, **Brandy Armstrong** and **Maitane Olabarrieta**
U.S. Geological Survey, Woods Hole, MA, USA

Ruoying He and **Joseph Zambon**
Marine, Earth & Atmospheric Sciences, North Carolina State University, USA

George Voulgaris and **Nirnimesh Kumar**
Department of Earth & Ocean Sciences, University of South Carolina, USA

Kevin Haas
Dept. of Civil and Environmental Engineering, Georgia Institute of Technology, USA

Understanding the processes responsible for coastal change is important for managing both our natural and economic coastal resources. The current scientific understanding of coastal sediment transport and geology suggests that examining coastal processes at sub-regional to regional scales can lead to significant insight into how the coastal zone evolves. In the coastal zone, storms are one of the primary driving forces resulting in coastal change. Understanding the processes that drive coastal change will increase our capability to predict impacts of storms on coastal systems.

Here we describe a numerical modeling approach to investigate the dynamics of coastal storm impacts. We use the newly developed Coupled Ocean – Atmosphere – Wave – Sediment Transport (COAWST) Modeling System that is based on the Model Coupling Toolkit to exchange prognostic variables between the ocean model ROMS, atmosphere model WRF, wave model SWAN, and the Community Sediment Transport Modeling System (CSTMS) sediment routines. The models exchange fields of sea surface temperature, ocean currents, water levels, bathymetry, wave heights, lengths, periods, bottom orbital velocities, and atmosphere radiation fluxes, winds, atmospheric pressure, relative humidity, precipitation, and cloud cover. Data field exchanges are regridded using sparse matrix interpolation with weights from SCRIP.

We describe the modeling components and the model field exchange methods. As part of the system, the wave and ocean models are run with cascading, refined, spatial grids to resolve nearshore processes driven within a larger, coarser-scale coastal modeling system. This facilitates seamless modeling from the shelf break across the inner shelf and through the surf zone. The modeling system is applied to the U.S. East coast with a focus on the Carolinas coastal region to investigate nearshore and inner-shelf processes and how these are connected. The importance of utilizing larger-scale forcing to drive nested models is identified by showing the spatial variability of the forcing and how that interacts with coastal orientation. Because the waves are a dominant mechanism for sediment mobility and the currents are then responsible for the transport, a coupled system is necessary. Also presented will be some of the challenges faced to develop the modeling system.

Variational Assimilation of HF Radar Surface Currents in the Coastal Ocean Circulation Model off Oregon

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Sea surface velocity fields observed by a set of high-frequency (HF) radars have been assimilated into a three-dimensional ocean circulation model configured along the Oregon coast for the period of June-July 2008. The nonlinear model is based on the Regional Ocean Modeling System (ROMS), and the data assimilation (DA) on the indirect representer-based variational algorithm using tangent linear and adjoint codes AVRORA developed by our group. Daily averaged surface velocity maps used for assimilation are a blend of data from several standard- and long-range HF radars in an area that extends 150 km offshore between 42-47°N. Assimilation proceeds in a series of 3-day windows. In each window, AVRORA is implemented to obtain improved initial conditions, and then the nonlinear ROMS is run for a period of 6 days (3-day analysis plus 3-day forecast). Both the analyses and forecasts are evaluated against the surface velocity data as well as satellite SST daily composites and satellite altimetry data that were not assimilated. Throughout the 60-day experiment, the DA system improves the area-averaged model-data RMS difference and correlation, with respect to both the assimilated surface velocity and validation SST, for both the analysis and forecast periods. Experiments with two different initial condition error covariances are compared. The first is based on the use of a balanced operator that yields the correction to the initial condition in approximate geostrophic and thermal wind balance; the second is multivariate, but not dynamically balanced. Both experiments show similar analysis and forecast skill with respect to the sea surface velocity. However, the case with the balanced error covariance yields better model-data difference statistics for SST, particularly during the forecast periods.

ROMS Applications in NOS Operational Forecast Systems

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The National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) has selected two core ocean models for development of NOS Operational Forecast Systems (OFS). One is ROMS developed by Rutgers University for curvilinear structured model grid choice, and the other is the Finite Volume Coastal Ocean Model (FVCOM) developed at the University of Massachusetts, Dartmouth (UMASSD) for unstructured model grid choice. All NOS OFSs are implemented and operated within an NOS standardized functional framework called the Coastal Ocean Modeling Framework (COMF), and will be run on NOAA's operational High Performance Computing (HPC) System. COMF is a set of standards and tools for developing and maintaining NOS's hydrodynamic model–based operational forecast systems. The goal of COMF is to provide a standard and comprehensive software infrastructure to enhance ease of use, performance, portability, and interoperability of NOS's OFS. COMF will increase time-and-cost efficiency for OFS development, transition, operations and maintenance, while enabling the community-sharing of validated improvements and minimizing redundant parallel efforts.

Three new ROMS based NOS OFSs are being developed for the Chesapeake Bay (CBOFS), Delaware Bay (DBOFS), and Tampa Bay (TBOFS). These OFS have been developed to provide maritime community users with real-time operational products which include nowcasts and short-term forecast guidance of water levels, currents, water temperature, and salinity for the next 1 to 2 days. These parameters are fundamental physical variables for other applications such as emergency response (e.g. oil spills; search and rescue) and ecological forecasting.

Seasonal variability of the Leeuwin Current on the west coast of Australia

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The Leeuwin Current System was simulated using a high-resolution ROMS covering the west coast of Australia. The Leeuwin Current System consists of the Leeuwin Current, the Leeuwin Undercurrent and the Capes current in the inner shelf moving opposite to the Leeuwin Current. ROMS was nested in a global model, the Bluelink ReANalysis (BRAN) and forced by ERA-interim surface fluxes data. ROMS simulation results are compared with satellite SST and other field data. Seasonal variations of the Leeuwin Current System will be presented in this study.

Poster Abstracts

General Curvilinear Ocean Model: Next Generation (GCOM-NG)

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The ocean has a strong impact on the atmosphere and thus on the nearly two thirds of the world's population that live by the coast. Therefore, studying the ocean and understanding its human impact is inevitable. The goal of GCOM-NG, is to deliver a forecast coastal model that will be more accurate and computationally efficient than other available models. GCOM-NG differs in many aspects from other commonly used coastal models. Using general curvilinear coordinate is the most important feature of this model. Traditionally, coastal models make use of sigma-coordinate which cannot represent non-convexity in the vertical and it is well documented that it affects the calculation of different oceanic variables, particularly on steep slopes. Furthermore, the majority of the commonly used ocean models make use of hydrostatic assumptions to calculate pressure. In the coastal regions and on the fast varying slopes, this assumption will lead to considerable errors in pressure calculation which affect the entire flow system of the ocean. Moreover, there is a need for high-resolution ocean models for detailed studies of different subjects, including biogeochemical studies, where hydrostatic assumptions will fail in the refined resolutions. This has motivated us to develop GCOM-NG, which uses general curvilinear and non-hydrostatic equations to address current and future needs of the oceanographic community and the study of ocean-human impacts.

A real-time forecasting system to predict coastal storm impacts

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In the coastal zone, storms are one of the primary environmental causes of coastal change. These discrete events often produce large waves, storm surges, and flooding, resulting in coastal erosion. In addition, strong storm-generated currents may pose threats to life, property, and navigation. The ability to predict these events, their location, duration, and magnitude allows resource managers to better prepare for the storm impacts as well as guide post-storm survey assessments and recovery efforts.

As a step towards increasing our capability for prediction of these events, we have developed an automated system to run the Coupled Ocean – Atmosphere – Wave – Sediment Transport (COAWST) Modeling System as a daily forecast. Management of the system is controlled by the Windows Scheduler to start Matlab® and run scripts and functions. Data required by the modeling system include daily modeled wave, wind, atmospheric surface inputs, and climatology fields. The Unidata Internet Data Distribution/Local Data Manager is used to download NCEP GFS global 5 degree data and NCEP NAM Conus 12km data to a local server. The Matlab "structs" tool and NJ-Toolbox are used to access these large data sets on the local server as well as data sets available on the Nomads http://nomads.ncep.noaa.gov site. The data are used to create the required inputs for the WRF, ROMS and SWAN models. Currently the output from the coupled ROMS-SWAN system is displayed at http://woodshole.er.usgs.gov/project-pages/cccp/public/COAWST.htm. We will describe the modeling system, data acquisition, and visualization methods required for the forecasting system.

New features in ROMS_AGRIF 2.0 release and in the ROMSTOOLS pre- and post-processing toolbox

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We present here the new features implemented in the ROMS_AGRIF V.2.0 and ROMSTOOLS new versions recently released on the website http://roms.mpl.ird.fr.

The main new features in ROMS_AGRIF 2.0 code release are the implementation of a 2-ways AGRIF nesting (Debreu *et al.*, 2010, submitted; Debreu *et al.*, 2008), a new rotated advection-diffusion scheme, and a RSUP3 scheme, (Marchesiello *et al.*, 2009) designed to limit excessive diapycnal diffusion. Concerning computing efficiency, a procedure to determine the optimal sub-domain partition (the ''auto-tiling'' procedure) in case of OpenMP parallelization. Moreover, two more NPZD type biological models are available and the PISCES biogeochemical model has been coupled to the ROMS_AGRIF (Aumont *et al.*). Other capabilities that have been introduced since version 1.0 are: on-line momentum and tracer equation diagnostics, on-line atmospheric forcing diagnostics, HBL smoothing, and additional outputs variables etc.. Special efforts have resulted in increased robustness through parallel computing: MPI and OpenMP parallelization and sub-domain partitioning. For this purpose, an automatic testing

procedure (called Roms Validation ToolKit (RVTK) have been developed to check many test cases and realistic configurations in different sub-domains (tiles) and parallelization configurations.

Concerning pre- and post-processing ROMSTOOLS toolbox, new features have also been introduced, particularly the processing of the nested grid forcings (oceanic and atmospheric) and the interannual forcing preparation.

Exhaustive lists of the new features available for the ROMS_AGRIF v2.0 code and the ROMSTOOLS 2.0 processing toolbox, with detailed descriptions, will be presented.

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ROMS model application south of Africa

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ROMS is applied to the oceans south of Africa in order to investigate the oceanic processes and the variability of these processes which impact the biogeochemistry of the region. Immediately off southern Africa, physical processes of the shallow Agulhas Bank may have impacts on the chokka squid and the spawning of anchovy. The ROMS configuration over the Agulhas Bank shows that the Agulhas Current plays a dominant role in the circulation and vertical structure over much of the shelf. South of this region, the dynamics of the upper layer of the Southern Ocean are explored with the eventual goal of studying the biogechemical cycle. The Southern Ocean region is important as a sink for atmospheric carbon, particularly that of anthropogenic origins. Changes to the forcing and/or upper ocean dynamics will impact this through the solubility and biological pump. Important processes in the region are related to eddies and fronts which are investigated. The modelling approach to address the disparity of scales in the region is to configure a larger domain to support a fine-scale nested model over localized regions of interest.

Assessing current and future storm surge risk in the South Pacific and Southern Australia

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We are discussing two different approaches to analyze and assess climate change and associated sea level extremes in the South Pacific and along South Australia including Tasmania.

Modeling wave characteristics in the North Eastern Gulf of Mexico

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The FSU Big Bend Region coupled modeling system was developed to support NOAA Northern Gulf Institute related research projects in the area. A critical component of the system is a wave model. The primary goal of the wave modeling component is to investigate the role that waves play in physical and biological processes in the region, including flux parameterization for the air-sea interaction, ocean mixing, larvae transport by Stokes drift, and others. For the simulation of waves, the SWAN (Simulating WAves Nearshore) model, version 40.68, is used. The wave model is coupled to the ocean component based on the Regional Ocean Modeling System (ROMS) and the Advanced WRF (Weather Research and Forecasting) atmospheric model. The wave-ocean coupling is two-way. The ocean model exports sea surface height and vertically integrated current to the wave model. The wave model sends the following fields to the ocean model: wave direction, wave amplitude, wave length, surface wave relative peak period, bottom wave period, and wave bottom orbital velocity. Wave-atmosphere coupling is currently one-way in that the wave model receives wind stress components from the atmospheric model. However, two-way coupling through modification of the air-sea turbulent fluxes is under development. Preliminary results from the simulation are presented.

Hawai'i Ocean Observing System: The Role of ROMS

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The NOAA-funded, Hawai'i Ocean Observing System (HiOOS) focuses on ecosystem monitoring and prediction in the Hawaiian Islands with a focus on the south shore of Oahu. HiOOS is part of the larger Pacific Islands Ocean Observing System (PacIOOS). The School of Ocean and Earth Science and Technology at the University of Hawai'i Manoa (SOEST) works with various government agencies and organizations to provide both nowcasts and forecasts for Hawaiian coastal and open ocean conditions. ROMS plays an integral role within HiOOS, and we present a brief overview of the ROMS modeling component in the Hawai'i Ocean Observing System (HiOOS).

Numerical Prediction and Correction of Tidal Forcing for Kaohsiung Second Harbor Using ROMS

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This study uses ROMS to investigate and predict the ocean dynamics near the Kaohsiung Second Harbor in Taiwan. The effects of simulated tidal forcing and currents are compared to the observed sea level data from the NKMU buoy and other measurements.

The actual bathymetry of the Kaohsiung Second Harbor area is used to generate a nearly orthogonal grid (139 x 139 x 20) using either SeaGrid or EasyGrid. Tidal forcing is specified at the southern boundary using a combination of Chapman (free-surface) and Flather (2D momentum) open boundary conditions. Radiation boundary conditions are used for 3D momentum and tracers.

The simulated sea level and currents in the harbor are in good agreement with the observations. The Kaohsiung Second Harbor is affected by diurnal and semi-diurnal tides.

Oceanic responses to mountain gap winds in the Northeastern Tropical Pacific

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The wind jets generated by the three mountain gaps of Central America have a substantial impact on the mean-state and variability of the northeastern tropical Pacific. The oceanic responses to the gap winds is examined and interpreted by combining satellite data and ROMS solutions. We used two levels of nested grids encompassing a domain from 15ºS to 40ºN and from the west coast of the American continents to 140ºW, with open-boundary conditions at its western and alongshore edges. An equilibrium solution and a semi-idealized gap wind response test were carried out. Analysis shows that sea surface cooling under the gap winds is mainly due to mechanically forced vertical turbulent mixing. Mesoscale eddies from the gap-wind region are the combined consequences of direct forcing by high-frequency wind jets and indirect forcing by lower-frequency wind jets via barotropic and baroclinic instability of the wind-jet-forced unstable currents.

Numerical modelling of the East African Coastal Current (EACC)

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To date, there has been very little modelling of the East African coastal ocean in the Western Indian Ocean. ROMS is configured to study the monthly variability of the East African Coastal Current (EACC) during the monsoonal transitional seasons (April/May and October/November). The grid extends from 5°N-15°S to 38°E-55°E. The initial and lateral boundary conditions were derived from the World Ocean Atlas (WOA). The model is forced with monthly wind stress and heat flux climatologies (COADS) from January, 1945 to December, 1989. The results show that the EACC exhibits a large temporal and spatial variability throughout the year. The lowest mean currents (0.63 m/s) are observed in February while the maximum (1.13 m/s) occur in July off the East African coast. The monthly mean speeds increase rapidly northward in April and through the austral winter, then decrease slowly through the rest of the year. During both monsoon transitional periods (April/May and October/November), the EACC attains speeds greater than 1m/s north of 6°S.

A regional ocean model of the Canadian Pacific Coast

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A high resolution (3 km) application of ROMS has been implemented for the Canadian Pacific Coast. The model domain extends from the Columbia River to the southern Alaskan Coast. It is driven by atmospheric forcing provided by the CORE (Coordinated Ocean Reference Experiment) as well as the NARR (North American Regional Reanalysis) datasets. Lateral boundary conditions have been implemented to simulate realistic tides as well as the variability of the water properties both from monthly Levitus climatology and from the output of a larger North-East Pacific ROMS implementation (NEP4-Globec). A series of 8 year (1997-2004) numerical simulations have been performed to examine the seasonal and year to year variability of the coastal ocean as well as the sensibility of the results to the various forcing types. Special attention has been given to the simulation of certain ubiquitous features such as: seasonal reversal of the shelf break current, seasonal changes in the mixed layer depth, upwelling and downwelling transitions in the spring and in the fall, and buoyancy-driven coastal currents.

Estimation of freshwater transport and dispersal pathway discharged from the Changjiang River in the East China Sea

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We examine the offshore transport and dispersal pathway of the freshwater discharged from the Changjiang River in the East China Sea (ECS) using an interannual simulation of regional ECS model with ROMS. Atmospheric forcing is obtained from the NCEP reanalysis-II 6-hourly data from 1995 to 2005 (10 m wind, temperature, surface pressure and radiation). Surface fluxes of momentum and heat are calculated using bulk formulations. The KPP parameterization is also used. Comparison between the results of 1996 and 1998 clearly demonstrates that the summer monsoon winds play a critical role in spreading freshwater offshore and determining the structure and pathway of the freshwater in the ECS. Analysis of the hindcast simulation also shows that a northeastward freshwater pathway to Jeju Island across the northwestern shelf of the ECS, dominates during the summer period due to the along-shore wind. On the other hand, there is virtually no relationship between the amount of discharge from the Changjiang River and the freshwater transport toward Jeju Island. The analysis also suggests that relatively weak along-shore wind allows an additional pathway to the central region of the ECS along the ambient current between the Taiwan and Korea/Tsushima Straits.

Variability of wind-driven transport in the Florida Big Bend Region

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A high-resolution application of ROMS for the Florida Big Bend Region (BBR) of the northern West Florida Shelf is used to examine the variability of wind-driven transport. Comparisons between *in situ* data, satellite-derived wind fields, and atmospheric model analysis products describe the scales of variability in the region. ROMS simulation results are compared to ADCP data in order to give an Eulerian description of the flow variability. Lagrangian particle tracking methods are applied to investigate cross-shelf transport mechanisms important to reef fish larvae in the BBR. Interannual modulation of the synoptic scale atmospheric forcing leads to large differences in the important onshore transport pathways.

Integration ROMS in OIAS (Oceanological information-analytical system) of Pacific Oceanological Institute of FEBRAS

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OIAS accumulate significant amounts of data about the far-eastern seas of Russia, and some method of its analysis. Since 2006 we have been developing a system of continuous monitoring of Peter the Great Bay. This system includes data from weather stations on Shults and Popov foreland, video cameras on the same territories and a set of sea buoy experiments. We are going to integrate this data into the ROMS modeling system, and compare modeling results with the real data. We will present the preliminary results of this integration.

Coupled Ocean/Atmosphere regional simulation of Coastal Jet off Central Chile: A case study for the October 2000 event

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The cool waters off central Chile (26°S-36°S) are principally maintained by coastal upwelling, which is driven by persistent low-level along-shore southerly winds. Satellite data, marine reports, and coastal *in situ* observations off central Chile indicate that those along-shore winds intensify at intraseasonal timescales leading to Coastal Jets (CJs). The southerly jet events off central Chile occur year round but are more frequent during the summer upwelling season (over 60% of the time). The jet is characterized by an elongated maximum of surface wind speed (10m s^{-1}) with its axis at about 150 km off the coast and a cross-shore scale of about 500 km. The available observations (essentially remote sensing) show the CJ activity is seasonally phase locked with SST, with a peak season in August–October. They suggests that the statistically dominant forcing mechanisms of the SST cooling during CJ events is a combination of seaward advection of temperature resulting from Ekman transport, air-sea heat exchange, and Ekman-driven coastal divergence.

Coupled high-resolution ocean (ROMS) and atmophere (WRF) regional models are used to study the October 2000 Coastal Jet event (Garreaud *et al.*, 2005, Renault *et al.*, 2009). Our aim is to investigate the forcing mechanisms of CJ events. The model variability is validated against the observations. Then, the main statistical 3D characteristics of the oceanic response to a CJ event are analyzed. In particular, a complete heat budget within the mixed layer during this CJ event is estimated, in both the coastal and offshore areas in the vicinity of the CJ core. In the coastal area, the results show that upwelling is the main contributor to the observed cooling. However, in the neighbourhood of the CJ core, cooling is a combination of advection, heat fluxes and mixed layer entrainment.

Application of a 3D-var data assimilation scheme to an eddy-permitting North Pacific Model based on ROMS

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A three-dimensional variational (3D-var) data assimilation scheme has been developed and applied to an eddy-permitting North Pacific model based on ROMS. Our final goal is to study fisheries resource/recruitment variation and proper marine/fisheries environment management using the reanalysis or forecast products. The 3D-var scheme is founded on the MOVE system developed by the Japan Meteorological Research Institute (e.g. Fujii and Kamachi, 2003). This scheme is characterized by the following three steps: (1) minimizing the nonlinear cost functions by using a pre-conditioning method, (2) analyzing temperature-salinity profiles by using vertical coupled EOF modes, and (3) assimilating the data analyzed into an ocean model, namely, making reliable reanalysis data by using the Incremental Analysis Updates method. As the first step, we apply this scheme to the 1/2-degree ocean model covering the whole of the North Pacific. Satellite SSH/SSTs and *in situ* temperature-salinity data from GTSPP and WOD2009 are assimilated into the model. It was found that the 3D-var scheme works well and significantly improves simulated results. That is, the reanalysis data is in better agreement with some of the observed data than the simulation without the data assimilation. For example, eddy activities west of the date-line in the mid-latitude are well reproduced in the reanalysis data.