Eastern Pacific Ocean Conference at Timberline Lodge

EPOC 2006: Abstracts

River and Freshwater Influences

Neil Banas, University of Washington

The Columbia River plume as mixer, barrier, and conduit

Authors: N S Banas and P MacCready (University of Washington School of Oceanography, Seattle, WA)

Abstract: A coupled circulation-and-ecosystem model, developed as part of the RISE (River Influences on Shelf Ecosystems) program, is used to examine the role of the Columbia River plume in shaping broad patterns of nutrient flux and primary production on the Washington and Oregon coasts. Realistic simulations of summer 2004 and 2005 in ROMS (Regional Ocean Modeling System) are forced by winds from the MM5 atmospheric model, Columbia riverflow, and climatological boundary conditions. The ecosystem model adds a budget for nitrate, ammonium, phytoplankton, zooplankton, and detritus to each grid cell. Model predictions are validated against surface chlorophyll distributions from SeaWiFS, the nitrate-salinity relationship observed during RISE cruises, and phytoplankton growth and grazing rates from dilution experiments in and out of the Columbia plume.

Preliminary results show vertical entrainment of nitrate into surface waters in the Columbia estuary and early plume, and also lateral entrainment of phytoplankton into the plume immediately north of the bulge region at the Columbia mouth. The fate of these upwelling-derived blooms once they encounter the plume—the fraction that pass through or beneath the plume onto the Oregon shelf, the fraction exported across the shelf in the plume itself, and the fraction retained on the Washington shelf—is examined using three-dimensional, diffusive particle tracking.

Ed Dever, Oregon State University

Observed Nitrate Variability off the Columbia River: June-August 2004

Authors: E. Dever (COAS, Oregon State University)

Abstract: As part of the RISE (NSF CoOP) program, 3 moorings were placed over the Oregon and Washington shelves in the Columbia River plume from June to September 2004. The moorings were deployed north, south and immediately offshore of the Columbia River mouth near the 70 m isobath. The moored array was designed to sample the plume under various synoptic conditions. The distances between the northern and central moorings was 31 km and that between the central and southern mooring was 14 km. All moorings included anemometers, temperature loggers, acoustic Doppler current profilers (ADCPs) and near-surface salinity, fluorescence, and light transmission. The moored instruments were concentrated near the surface in order to sample the plume, which can be trapped very closely (5 m or less) to the surface. Salinity, fluorescence, and light transmission were measured 1, 5, and 20 m beneath the surface. Temperature data was collected about every 5 m throughout the upper water column. Each mooring included 2 ADCPs, a downward looking 300 kHz unit in the surface buoy, and an upward looking 1200 kHz ADCP moored 15 m beneath the surface.

All moorings also had dissolved inorganic nitrogen (DIN, essentially nitrate) autoanalyzers at 1 m beneath the surface, however only the sensor on the central mooring returned useable data. In contrast to measurements of DIN over upwelling shelves, the DIN in the Columbia River plume shows lower overall values. The mean DIN from June 20 to Aug 23, 2004 was 2.5 uM, near the lower detection limit of the sensor. The peak DIN was 13.9 uM, and the standard deviation was 3.1 uM.

The surface DIN in the Columbia river plume is correlated with several other measured parameters. The strongest correlation is with temperature. For hourly interpolated measurements, the correlation with temperature is -0.51 (i.e., colder water is associated with higher DIN values). DIN is also negatively correlated with near surface fluorescence. If upwelling were the dominant source of nitrate, one might expect that DIN is positively correlated with salinity. Somewhat surprisingly, there is a weak negative correlation with salinity (-0.33). One possible mechanism for nitrate delivery to the surface is baroclinic tides. Velocity and subsurface temperature observations suggest a strong mode one internal tide. Between June and August, the strength of the baroclinic tide varies on time scales of weeks. Periods of high internal tide activity seem to be associated with elevated near-surface DIN.

Richard Dugdale, Romberg Tiburon Center

Nutrient and new production effects of the San Francisco Bay coastal plume

Authors: R. Dugdale, F. Wilkerson, A. Marchi, V. Hogue, and A. Paker (Romberg Tiburon Center, San Francisco State University, San Francisco, CA)

Abstract: San Francisco Bay is a river-driven, turbid estuary characterized by high ambient nutrient concentrations and low primary productivity. Although seasonal and strong

interannual changes in river flow modulate the exchanges of nutrients between estuary and coastal ocean, most primary nutrients of riverine source are exported to the coastal ocean. In heavy precipitation years, the salinity signal can be detected for more than 100 km from the Golden Gate. The nutrient plume is shortened by biological processes, primarily by phytoplankton uptake. The nutrient plume is dominated by Si(OH)4 with concentrations at the freshwater end of the estuary in excess of 200 μM, ensuring a good supply of that essential nutrient for near-shore diatoms. NO3 and NH4 are also exported through the Golden Gate, PO4 to a lesser extent. Enhancement of new production by the export of these nutrients will be especially important during non-upwelling conditions and may serve to promote diatom production year-round and aid in avoiding harmful algal blooms. Nutrient and new production data from the Gulf of the Farallones will be presented. Modification of NO3 uptake (new production) by NH4 is common in the estuary and has been seen during upwelling off Bodega Bay as a result of NH4 advected from the south near the coast.

Mark Halverson, University of British Columbia

The Fraser River plume's impact on the magnitude and spatial distribution of phytoplankton biomass

Authors: Mark Halverson and Rich Pawlowicz (University of British Columbia, Vancouver, BC)

Abstract: The Fraser River discharge forms a large, fresh, and often cloudy, buoyant plume upon entering the lower Strait of Georgia. The salinity, stratification, surface area, and optical clarity of the plume change dramatically because the Fraser River discharge varies by a factor of 10 throughout a year. Seasonal changes in the plume properties have a noticeable impact on the distribution and magnitude of phytoplankton biomass in the lower Strait of Georgia.

Utilizing a 3+ year high resolution surface water dataset based on an instrumented ferry and intermittent CTD casts, the seasonal changes in phytoplankton biomass are examined with respect to the Fraser plume. In three of (nearly) four years of ferry data, the average biomass in the plume exceeded that found out of the plume. Though the annual mean biomass is greater in the plume than out, the short time-scale behaviour shows that the non-plume biomass may exceed the plume biomass by up to a factor of ten. Inferences of integrated biomass taken from the ferry surface readings can be misleading. Vertical profiles of chlorophyll show that the depth-integrated biomass is typically lower inside the plume. Lower integrated values within the plume are partially due to the tendency for the chlorophyll profiles to be narrower than the profiles outside the plume, which is likely caused by differences in light penetration and stratification.

Diane Masson, Institute of Ocean Sciences

Spatial and temporal chlorophyll distribution in the Straits of Georgia and Juan de Fuca

Authors: Diane Masson and Angelica Pena (Institute of Ocean Sciences, Sidney BC)

Abstract: We investigate the spatial and temporal distribution of planktonic biomass along with some factors influencing its distribution within the Straits of Georgia and Juan de Fuca. These two straits are the main constituents of a large coastal estuary system on the southern coast of British Columbia. A large amount of freshwater enters the coastal basin, with the main source being the Fraser River, and drives a two-way estuarine circulation. Complex biological dynamics (responses to light, nutrients, grazing, etc) dictate complex biomass distribution. However, a unique data set from a relatively long duration (over 5 years) and systematic (every season, at the same 70 stations) sampling program allows us to accurately describe the chlorophyll distribution in both time and space within the coastal basin. Over the study area, the main features of the spatial distribution of chlorophyll are shown to be closely related to variations in upper water column stratification. In addition, it is shown that, during the summer, plankton growth is nutrient limited within the central Strait of Georgia. Finally, the possible role of light limitation of the plankton production within Juan de Fuca Strait is discussed.

Jonathan Nash, Oregon State University

Effect of discharge rate on the structure and mixing of Columbia River plume

Authors: Levi Kilcher, Jonathan Nash and Jim Moum (Oregon State University, Corvallis, OR)

Abstract: Observations of turbulence within the Columbia River estuary and plume were made during periods of low and high river discharge (August 2005 and May 2006). Dramatic differences in structure during these periods signify a regime change.

Within the estuary, turbulent energy dissipation rates (and vertical fluxes of freshwater) are similar during both low and high flow. As a result, plume waters are significantly fresher during high flows, approximately scaling with river discharge rate. In the plume nearfield, the freshness alters the dynamics, since the highly-stratified plume quickly detaches from the bottom, whereas the weakly-stratified plume exhibits top-to-bottom turbulence and high bottom stress. These differences extend well into the coastal ocean and have important implications for sediment transport, turbulent exchanges across plume boundaries, and cross-shelf transport.

Nikolva Nezlin, Southern California Coastal Water Research Project

Ocean-color satellite observations of stormwater plumes in Southern California

Authors: Nikolay P. Nezlin and Paul M. DiGiacomo (Southern California Coastal Water Research Project, Westminster, CA)

Abstract: Ocean-color observations from the satellite sensors SeaWiFS and MODIS provide synoptic information about spatio-temporal dynamics of stormwater plumes, including their direction of propagation, size, and persistence over time. In southern California, river discharge is a major source of pollutants and pathogens to coastal waters, and as such the knowledge of plume dynamics is important for management of coastal water quality. Plume size is a function of the total volume of precipitated water. This relationship is quantitatively different in different regions, and can be explained by the differences in watershed size, terrain, and land-use characteristics. The direction of plume propagation results from the near-shore circulation, which is modulated by local wind stress. Ocean surface geophysical and optical properties (e.g., salinity, transmissivity, and suspended particulate matter) can be used for direct or indirect assessment of water quality

parameters of interest (e.g., turbidity, toxicity, bacteria), and efforts were made in this study to examine the relationship from properties that can be examined from space and those observed in situ. Correlations between the remotely sensed and in situ measured parameters were different in different river systems and changed over the course of the after-storm period. This finding and others are discussed here.

Tim O'Higgins

Shifting nutrient pressures and eutrophication effects in Dublin Bay (Ireland)

Authors: Tim O'Higgins

Abstract: The Liffey Estuary in Dublin Ireland (pop. 1 million) has been subject to anthropogenic impacts for over 1000 years. Nutrients in the Liffye Estuary from agricultural and domestic waste flow into Dublin Bay. In recent decades the principal symptom of eutrophication has been the recurrent stranding of the nuisance brown algal species Ectocarpus siliculosis onto Dollymount Strand (a popular bathing beach).

The upgrade of Dublin's main sewage treatment plant from primary to secondary treatment has lead to a 25% reduction in Dissolved Inorganic Nitrogen since 2001. The composition of the effluent from the plant has shifted towards an increase in oxidised forms of nitrogen. The flux of Total Oxidised Nitrogen (TON) increased from 38 t N y-1 in 2001 to 1298 t N y-1 in 2004 while the flux of ammonia from the plant has decreased form 2147 t N y-1 to 450 tN y-1 over the same period.

Over the course of the upgrade of the sewage treatment plant there was a 42% reduction in the amount of Ectocarpus algae growing in the subtidal areas of the river Liffey plume off Dollymount Strand. Early in 2004 a brown dicoloration of the bathing waters off Dollymount Strand became apparent. From May to August of 2004 this discoloration persisted. Total phaeopigment concentrations reached a maximum of 220.2 mg.m-3. The high phaeopigment concentrations were caused by the diatom Odontella aurita and maximum cell concentration reached 7.4 million cells per litre. There was a positive corellation between mean total phaeopigment concentration and tidal range (r squares = 0.847, $p<0.001$) suggesting a link resuspension of phytobenthic cells.

Phytoplankton carbon estimates and stocihiometric considerations indicate that the magnitude of the bloom was proportional to the shift in nitrogen supply form ammonia to TON. The high concentrations of cells and chlorophyll mean that these waters are unlikely to meet "good" water quality status required by European Union legislation.

Tawnya Peterson, UC Santa Cruz

Influence of the Columbia River on Algal Biomass and Primary Productivity Along the Washington and Oregon Shelves

Authors: T.D. Peterson (Institute for Marine Sciences, University of California, Santa Cruz, CA), R.M. Kudela and A.E. Roberts (Ocean Sciences Department, University of California, Santa Cruz, CA)

Abstract: Historical analyses and satellite data suggest that there is a higher standing stock of biomass (as estimated by chlorophyll a) in the Columbia River Plume and adjacent waters to the north (Washington) relative to coastal Oregon as far south as Heceta Bank. Based on four cruises with the CoOP RISE program that encompassed a variety of environmental conditions, we examined patterns of biomass and primary productivity in waters of the near-field and far-field plumes, as well as in waters not influenced by the Columbia River. We explored the problem of whether enhanced biomass resulted from in situ growth or advective processes. Our field observations reveal (1) that biomass-specific primary productivity was highest within plumes with sufficient nitrate and (2) that standing stocks were largest within aged plumes, particularly when they were found close to the coast. We consider far-field plume dynamics, including contributions made by other river plumes north of the Columbia River to productivity in this region. The data suggest that differences between the Oregon and Washington shelves are primarily due to enhanced biomass (reduced loss processes) rather than intrinsically higher rates of biomass-normalized productivity, which may be further magnified by the influence of river discharge north of the Columbia plume

Jay Peterson, Oregon State University

Influence of the Columbia River plume on regional zooplankton abundance and distribution

Authors: Jay O. Peterson (Oregon State University, Corvallis, OR) and William T. Peterson (NOAA/NWFSC)

Abstract: Surveys of zooplankton distribution and abundance were conducted off the Oregon coast, near the outflow of the Columbia River, as part of the River Influence on Shelf Ecosystems (RISE) project. During July 2004, June 2005 and June 2006, a Laser Optical Plankton Counter (LOPC) attached to a Triaxus tow body equipped with a CTD and fluorometer acquired a comprehensive data set on the physical and biological properties within the vicinity of the Columbia River plume. Results of the surveys provide new information on the influence of the river plume on zooplankton at temporal and spatial scales relevant to many physical and biological processes (i.e. hours to days, meters to kilometers). Results indicate that plankton are clearly influenced by physical and biological processes associated with the river plume. On small time and spatial scales, layered aggregations of zooplankton can be vertically displaced 5–30 m by internal waves propagating away from the plume front. Across larger spatial scales (10–100 km), zooplankton concentrate directly beneath the plume waters (especially 'aged' plume) and are often 2–5x greater in abundance and biovolume compared to surrounding waters. The magnitude and location of higher zooplankton abundance and biovolume will be discussed in relation to how physical and biological interactions associated with the Columbia River plume influence coastal biological processes.

Integrated Regional Oceanography Using In-Situ and Remote Observations and Models

Dudley Chelton, Oregon State University

SST influence on surface wind stress from Observations and the COAMPS model

Authors: Dudley B. Chelton, Tracy Haack, Julie Pullen, and Renato Castelao

Abstract: The influence of sea surface temperature (SST) on surface winds over the California Current System (CCS) identified recently from QuikSCAT satellite observations of surface wind stress and AMSR microwave measurements of SST is reinvestigated from higher-resolution infrared (IR) measurements of SST from the GOES-10 satellite. These newly available IR SST fields resolve scales down to ~10 km to within ~10 km of the coast, which are major improvements over the ~50 km resolution and ~75 km land mask of the AMSR data. The IR data thus reveal details in the coupling between SST and wind stress much closer to land and on much smaller scales than can be investigated from the microwave SST fields. These observational results will be compared with the SST and wind stress fields from the U.S. Navy Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) run in an uncoupled mode. Based on a preliminary analysis, the COAMPS model represents the SST influence on surface wind stress over the CCS region remarkably well compared with the NOAA North American Mesoscale atmospheric model. This is partly attributable to the high resolution of the SST boundary condition used in the COAMPS model. This air-sea interaction phenomenon will be investigated in detail to assess the accuracy of the parameterizations of surface and boundary layer processes in the COAMPS model.

Byoung-Ju Choi, Oregon State University

Evaluation of a regional model and nesting of a coastal model along the Oregon Coast

Authors: Byoung-Ju Choi, Scott R. Springer, John S. Allen, Gary D. Egbert, Alexander L. Kurapov, and Robert N. Miller (College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR)

Abstract: Proper boundary and initial conditions are required to make realistic simulations in a nested model. An Oregon Coastal Transition Zone (CTZ) model is being nested in the Navy Coastal Ocean Model-California Current System (NCOM-CCS) regional model to obtain reasonable model estimates for the physical fields in the region of the GLOBEC field experiments. Before we nest a high-resolution (3 km) CTZ model into NCOM-CCS, we evaluate NCOM-CCS (9 km) forcing and output. NCOM-CCS is forced by COAMPS atmospheric forcing. The magnitude and spatial patterns of COAMPS wind forcing have good correspondence with those from QuikSCAT. Qualitative and quantitative comparisons of NCOM-CCS output with satellite SST, hydrography data, mooring data, long range HF radar surface currents, and altimeter data show that NCOM-CCS model has good skill in reproducing major oceanic circulation features. While NCOM-CCS forcing does not include tides and river input, the Oregon CTZ model, also forced by COAMPS wind product, includes tides and Columbia River input. The Oregon CTZ model is currently running and effects of open boundary condition formulations have been tested. The model output from the Oregon CTZ model is being analyzed for the period of the GLOBEC field experiment in summer 2002.

Patrick Cummins, Institute of Ocean Sciences

Co-variability of the Alaska and California current systems

Authors: Patrick Cummins and Howard Freeland (Institute of Ocean Sciences / Fisheries and Ocean Canada, Sidney, BC)

Abstract: The North Pacific Current bifurcates approaching the west coast of North America into a northward flowing branch forming the Alaska Current, and a southward flowing branch forming the California Current. The variability of these current systems is discussed using in-situ data from Argo drifting buoys and a one-layer, reduced-gravity model. Maps of the regional geostrophic circulation are constructed from the Argo data at monthly intervals for the five year period 2002–2006. The circulation maps are used to determine the variability of the North Pacific Current and its bifurcation. In particular, the correlated and anti-correlated variability of the Alaska and California Currents are determined. This shows the dominant mode of variability to be a 'breathing' mode in which these current systems co-vary in response to fluctuations in the strength of the North Pacific Current.

These results are compared with 55 year model simulations driven by NCEP winds. The statistical properties of the transport of the Alaska and California Currents in the model are examined. A modal decomposition of these transports also shows dominance of the 'breathing' mode, suggesting that variability observed in the Argo circulation fields is consistent with large-scale, wind forced ocean variability.

Curtiss Davis, Oregon State University

GOES-R coastal waters imaging as a component of an integrated coastal observing system

Authors: Curtiss O. Davis (College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR), W. Paul Bissett (Florida Environmental Research Institute, Tampa, FL)

Abstract: As part of the Hyperspectral Environment Suite (HES) on the next generation Geostationary Operational Environmental Satellite (GOES-R, to be launched in 2014) NOAA is planning to include a Coastal Waters imaging capability (HES-CW). HES-CW is being designed to provide 375 m (at nadir) data in 9 ocean color channels at a frequency of once every 3 hours with selected sites hourly. The key advantage of a geostationary imager is frequency of revisit. Coastal waters are highly dynamic. Tides, diurnal winds, river runoff, upwelling and storm winds drive currents from one to several knots. Three hour or better sampling is required to resolve these features, and to track red tides, oil spills or other features of concern for coastal environmental management. The focus of this presentation is to outline plans for the use of HES-CW data together with IOOS in situ data and models to provide a more coherent picture of coastal ocean dynamics.

Sergio deRada, Naval Research Laboratory (JE)

High resolution ocean modeling for the Northeastern Pacific: Implementation and initial evaluation

Authors: Sergio deRada (Jacobs Engineering, Stennis Space Center, MS); John C. Kindle, Stephanie Anderson, Igor Shulman, and Brad Penta (Naval Research Laboratory, Stennis Space Center, MS); Jim Doyle (Naval Research Laboratory, Monterey, CA)

Abstract: A high-resolution (4Km) regional Navy Coastal Ocean Model (NCOM) for the Northeastern Pacific (California Current System (CCS) domain: 30–52N) has been implemented at NRL as an upgrade to the present 9Km version (30–49N) currently used in the real-time coupled bio-physical NCOMCCS model (see presentation by Kindle et al). The regional model receives boundary information from the operational 1/8-degree Global NCOM and provides boundary values to the sub-1Km resolution NCOM Monterey Bay nest. The ~4Km model is forced by high resolution surface fluxes from a regional COAMPS model with resolution as fine as 3Km. The global and regional NCOM models assimilate daily MCSST surface temperature along with 3D temperature and salinity obtained from the Modular Ocean Data Assimilation System (MODAS), which regresses satellite derived SST and SSH data to obtain T&S synthetic profiles.

Results from the 4Km model are presented, compared with the 9Km model, and evaluated relative to in-situ and remotely sensed observations, which include MODIS based bio-optical products processed by the NRL Ocean Color Section. Differences and similarities between 9Km and 4Km resolutions are shown, including assessment of the suitability of each model as a provider of boundary conditions to the finer NCOM Monterey Bay coastal models. Metrics on the merit of high-resolution modeling will be shown, including benchmarks and cost factors associated with each model.

John Farrara, NASA Jet Propulsion / Raytheon

A reanalysis of the regional ocean circulation for central California

Authors: Yi Chao (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA); Zhijin Li and John Farrara (Jet Propulsion Laboratory, California Institute of Technology, Raytheon ITSS, Pasadena, CA); Peggy Li (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA)

Abstract: A field experiment known as the Autonomous Ocean Sampling Network (AOSN) was conducted in and around Monterey Bay, California, during the summer of 2003. The Monterey Bay region was selected for this experiment because of its unique location at the center of the central California upwelling region which produces many rich oceanographic features, as well as the existing infrastructure for both in situ and remote sensing observations. The goal of AOSN was to develop an optimal sampling strategy using a combined approach using in-situ and satellite observations in 3-dimensional ocean circulation models, and adapting it in real-time. The core AOSN system consisted of instruments (both in situ and satellite), numerical models with data assimilation capabilities, and adaptive sampling tools to guide the deployment of observational assets for optimal performance.

This presentation describes the implementation and results produced by of one of the two the Regional Ocean Modeling System (ROMS) for this experiment. Recent results from an August 2006 field experiment in the same region will also be discussed. For the AOSN experiment, a three-level nested ROMS configuration is used including the U.S. West coastal ocean at 15-km resolution, the central California coastal ocean at 5-km, and the Monterey Bay region at 1.5-km. All three ROMS configurations have 32 vertical sigma layers, use atmospheric forcing produced by the Navy's COAMPS model and are integrated using a 3-dimensional variational data assimilation algorithm (3DVAR) to produce snapshots of the ocean states every 6 hours (the reanalysis).

The ROMS reanalysis will be briefly compared with the assimilated data for consistency. An extensive evaluation of the ROMS reanalysis against the independent measurements that are not assimilated into models will then be presented. This evaluation shows that the mean differences in temperature and salinity between reanalysis and observations to be less than 1 C and 0.2 PSU, respectively, with RMS differences of less than 1.5 C and 0.25 PSU. The reanalysis also shows good agreement with glider-derived depth-averaged velocities and HF radar surface currents.

Kris Karnauskas, University of Maryland

Interannual variability of SST and chlorophyll in the eastern Pacific warm pool: High-resolution satellite observations

Authors: Kristopher B. Karnauskas and Antonio J. Busalacchi (University of Maryland, Earth System Science Interdisciplinary Center, Cooperative Institute of Climate Studies, College Park, MD)

Abstract: The eastern Pacific warm pool (EPWP) is a body of water adjacent to the west coast of Mexico and Central America with sea surface temperature (SST) upward of 29°C. The spatial variability, seasonal cycle, and interannual variability of the EPWP are beginning to be defined within the context of a coupled system involving the ocean, atmosphere and land. Numerous prior studies explicitly state that further understanding of the interannual variability of precipitation in the Inter-Americas region depends on an improved understanding of what controls the SST variability in the EPWP. However, the role of the EPWP and its interactions with the atmosphere and land in ocean biology and the hydroclimate of the Inter-Americas is largely excluded from present research programs.

Infrared satellite measurements of SST and precipitation have been made for multiple decades and provide a suitable record for studying the interannual variability of the EPWP. More recently, the advent of high resolution microwave satellite remote sensing, altimetry, and scatterometry provide a means to understand the spatial structure and covariability of SST, sea level, ocean color, surface winds, precipitation, and land surface temperature in detail never before possible. The objective of the research described in this poster is to describe the interannual variability of SST in the eastern Pacific warm pool (EPWP), and to evaluate the impact of that variability on physical and biological systems on regional and global scales. Given that the EPWP is in the Pacific basin, careful attention must be given to the relative roles of local versus remote forcing.

Hey-Jin Kim, Scripps Institution of Oceanography

Decadal variability of stratification and nutrient supply in the California Current System with CalCOFI and ROMS

Authors: Hey-Jin Kim and Arthur Miller (Scripps Institution of Oceanography, La Jolla, CA)

Abstract: The 55-year in-situ dataset of CalCOFI in the southern California Current reveals significant surface-intensified warming and increased buoyancy frequency across the 1976–77 climate regime shift. However, the average thermocline depth, defined as the maximum gradient of temperature profile, did not change significantly across the regime shift. The maximum-gradient criterion for thermocline depth may be more appropriate than following isotherm because the isotherm necessarily deepens in the presence of surface-intensified warming. Both stratification strength and thermocline depth are associated with upwelling cell and coastal circulation, and consequently nutrient supply for primary production. Numerical modeling study with ROMS (Regional Ocean Modeling System) will be introduced to examine upwelled water quality and primary production changes due to different stratification.

John Kindle, Naval Research Laboratory

A multi-nested, near real time, coupled bio-physical model for the US west coast

Authors: John Kindle, Sergio DeRada, Igor Shulman, Robert Arnone, Bradley Penta, and Stephanie Cayula (Naval Research Laboratory, Stennis Space Center, MS); Jim Doyle (Naval Research Laboratory, Monterey, CA)

Abstract: Results from a near real-time modeling system for the US West coast are presented and evaluated relative to observations. The system presently includes a regional model (Navy Coastal Ocean Model—NCOM) at 9km resolution that receives boundary information from the operational global NCOM and provides boundary values to high resolution NCOM sub-nests for the Monterey Bay. The regional model and Monterey Bay nests include an embedded ecosystem model (COSINE) based on the formulation of Chai et al. (2002); these models are forced by high resolution surface fluxes from a regional COAMPS atmospheric model with resolution as fine as 3km. The global NCOM system and the regional NCOM assimilate daily MCSST surface temperature values and synthetic profiles of temperature and salinity obtained from the MODAS product, which regresses satellite derived SST and SSH values to obtain the synthetic profiles. The NRL Ocean Color Section processes the 1km resolution MODIS imagery using standard and newly developed algorithms to obtain a variety of bio-optical products. The high resolution Monterey Bay nests, which use curvilinear coordinate grids with resolutions of 1–4km and .5–1km respectively, can assimilate coastal observations using a multi-variate optimal interpolation scheme (NCODA). Results clearly reveal the close linkages between the spatial and temporal structure of the surface chlorophyll fields to the mesoscale variability of the California Current system and the Monterey Bay regions. Preliminary results are also shown from the MURI Adaptive Sampling and Prediction (ASAP) exercise in August 2006, during which the Monterey Bay nests will be assimilating temperature and salinity observations in real-time from gliders and ship-based ctd's. Presently, there is no assimilation of any bio-optical information into the system. Model results are used to identify both present capabilities and issues that will be addressed in future efforts. Daily results from this integrated system are posted on the Web (http://www7320.nrlssc.navy.mil/ccsnrt/) with approximately a 1-day delay.

Jan Newton, University of Washington-Applied Physics Laboratory

Assessing drivers of hypoxia in Hood Canal via observations and modeling

Authors: Jan Newton (University of Washington, Seattle, WA); Al Devol, Mark Warner, Matthew Alford, Mitsuhiro Kawase, Matt Wiley, Jeff Richey, Mike Brett, and Dan Hannafious (HCSEG)

Abstract: Hood Canal, a fjord-like side basin of Puget Sound, Washington, has been experiencing increasing frequency and duration of hypoxic conditions since the mid-1990s. The Hood Canal Dissolved Oxygen Program (HCDOP) was created to assess the underlying mechanism(s) of this change and to inform decision-makers on the efficacy of potential corrective actions.

Drivers may include ocean forcing via density changes or other influences as well as watershed forcing either via nutrient loading or alteration of freshwater input. The complexity of the issue and the supporting evidence for all of the drivers necessitated a modeling approach in which scenarios can be run controlling individual factors. HCDOP's science study, the Integrated Assessment and Modeling (IAM) study, is utilizing marine (ROMS) and watershed (DSHVM) modeling as well as observation networks in the marine (ORCA buoys, MMPs) and watershed.

Presented in this talk will be what information has been learned from the integrated modeling and observational effort after ~1.5 of its planned 3 years of study. The relation of the local condition in Hood Canal to regional forcings will be explored.

Brad Penta, Naval Research Laboratory

Coupling satellite derived ocean color and a coastal marine ecosystem model of the California Current System

Authors: Bradley Penta, ZhongPing Lee, Sergio Derada, Stephanie Anderson, Igor Shulman, and John Kindle (Naval Research Laboratory, Stennis Space Center, MS)

Abstract: We have incorporated the model by Lee et al. (2005) for the propagation of photosynthetically active radiation (PAR) through the water column into a coupled physical-ecological simulation model of the California Current System (NCOM-CCS). This model for the attenuation of PAR in oceanic and coastal waters is based upon inherent optical properties (IOP) - absorption (a490) and backscattering (bb490) at 490 nm - of the water column rather than its chlorophyll concentration. The a490 and bb490 coefficients are derived from ocean color observations, which provide large-scale, synoptic coverage of the upper layer of the ocean. Unlike the "standard" approach used for the absorption of PAR this method is not vertically constant - i.e., longer wavelengths are attenuated rapidly in the surface water while the blue wavelengths penetrate deeper. We have compared the "standard" and "new" PAR attenuation schemes, using a490 and bb490 computed from satellite observations as well as those computed from the model phytoplankton. This new approach has a large effect on the depth of the

euphotic zone and allows the model to form deep chlorophyll maxima.

Next, in a step toward assimilation of ocean color data into our model system, we have used the satellite derived IOPs to 'nudge' the model phytoplankton. We modify the (potential) maximum growth rate of our phytoplankton groups rather than altering the biomass directly. The realized growth rate also depends upon nutrient and light availability; consequently, we do not get unrealistic growth in regions of low nutrients. Also, by adjusting the growth rate rather than the phytoplankton directly, mass balance is maintained in the model.

Martin Saraceno, Oregon State University

Mesoscale events off the coast of Oregon (US): a satellite point of view

Authors: Martin Saraceno and P.T. Strub (College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR)

Abstract: Along track Sea Level Anomalies (SLA) derived from radar satellites measurements are combined with tide gauges time series to produce gridded fields of SLA in the west coast of North America (39–49oN, 123.5–127oW) for the period 1999–2004. The results do not show significant differences compared to the grid fields provided by AVISO-CLS in the region far from the coast, while in the near-shore region the derived geostrophic velocities show a more realistic pattern. Based on this new data-set, two examples of mesoscale events that contribute to a net transport across the shelf in the boreal winter-autumn are shown. The mechanisms responsible of these events are discussed.

Scott Springer, Oregon State University

A nested circulation model of the Oregon Coastal Transition Zone

Authors: Scott R. Springer, Byoung-Ju Choi, John S. Allen, Gary D. Egbert, Alexander L. Kurapov, and Robert N. Miller (College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR)

Abstract: The Oregon Coastal Transition Zone (CTZ) encompasses the California Current System (CCS) and shelf flow off the coast of Oregon. Global and basin-scale circulation models reproduce major features of the CCS but do not resolve details of the flow in the CTZ, which are highly dependent on small-scale topography and nonlinear interactions. We have developed a model based on ROMS for studying the circulation and the flow dynamics in this region. Information about the large scale flow as simulated by an assmilating ~9 km NCOM CCS model is communicated to the regional model via one-way nesting. Validity of the nesting strategy is demonstrated by faithful reproduction of the solution from the large scale model in the regional model at the same ~9 km resolution. At higher (3 km) resolution, the CTZ model develops a a more complex flow pattern. The realism of the flow is assessed by comparison with satellite observations and measurements made during the COAST and GLOBEC field experiments. Future development efforts include the incorporation of a variational data assimilation system that will give the CTZ model nowcast/forecast capabilities useful as part of a coastal ocean observing system.

Ted Strub, Oregon State University

Satellite estimates of transport and SST anomalies during the 2005 "Warm Event" in the Northern California Current

Authors: P. Ted Strub, Corinne James, Roberto Venegas (College of Oceanographic and Atmospheric Sciences, Oregon State University, Corvallis, OR)

Abstract: Several aspects of the unusually warm surface conditions in the ocean off Oregon and Washington during spring–summer 2005 are examined using satellite data. Large-scale (500km wide) alongshore surface transports along Oregon-Washington were poleward but weak during winter, producing equatorward anomalies. These winter conditions were followed by poleward transports in spring and early summer. A similar pattern is seen between Vancouver Island and the Queen Charlotte Islands. Off California, poleward transports were stronger than usual in winter and continued to be poleward into spring. This produced convergences of water from California off Oregon-Washington in winter and anomalous poleward transports from California to the Queen Charlotte Islands in spring and early summer. Considering the entire altimeter period of 1993–2005, the transports in winter–summer 2005 have some similarities to the poleward anomalies during the El Niño in 1997–98, although they were weaker and different in their timing. When these large-scale transports are broken into higher resolution components, the patters become more complex, as will be described. In addition to these moderately anomalous transports, highly anomalous wind forcing provided the dominant forcing, with downwelling-favorable April–June wind stress anomalies. Satellite-derived SST images show the development of SST anomalies between central California and Washington. SST values were 2–3°C warmer than average from 43°–49°N in the 300 km next to the coast during most of May–June. Off California, winds were upwelling-favorable in March–May (although weak) and cold upwelled water appeared by April, two months earlier than off most of Oregon-Washington. Cold, upwelled water appears in the satellite images to move northward from California in "fits and starts" during the alternating winds of April–July. After mid-July, strong upwelling-favorable winds expanded the band of cold upwelled water all along the west coast, providing more normal summer conditions!

Milena Veneziani, Ocean Sciences, University of California Santa Cruz

Adjoint sensitivity analyses in the Central California coastal region

Authors: Milena Veneziani, Christopher A. Edwards, and Andrew M. Moore (Ocean Sciences Department, UC Santa Cruz, Santa Cruz, CA)

Abstract: The ocean circulation of the Northern and Central California coast is characterized by complex dynamics, which are driven both by internal instability processes and by external and boundary factors such as the wind forcing, the open boundary conditions, the steep bathymetry, the shape of the coastline, etc. We have investigated the sensitivity of some aspects of the Central California coastal circulation to different driving mechanisms, by using the adjoint model of the tangent linear version of the Regional Ocean Modeling System (ROMS). The adjoint model is particularly suitable for sensitivity analyses because it allows to determine how a certain metric, which is representative of a physical aspect of interest, evolves due

to linear variations of the system variables, the external forcing, the initial state, and the open boundary conditions.

We have identified a number of metrics that best represent the coastal upwelling processes of the Central California Current System, and studied their sensitivities to wind stress and wind stress curl forcing, other atmospheric forcings, advection mechanisms, open boundary conditions, etc. The three-dimensional sensitivity fields computed from a single integration of the ROMS adjoint model have been mapped, in order to investigate their spatial distribution.

Furthermore, more quantitative results have been obtained by comparing the sensitivities to the various driving mechanisms in particular case-study regions. The results for a geographical area centered around Monterey Bay will be shown and discussed here.

New Instrumentation, Technology and Applications

Chelsea Donovan, Turner Designs

Solid-state submersible active fluorometer used to monitor photosynthetic parameters and algal biomass

Authors: Chelsea Donovan (Turner Designs, Sunnyvale, CA)

Abstract: An in situ variable fluorescence system has been developed that will allow real-time measurement of the primary variable fluorescence variables; Fv, Fo and Fm. Advances in solid-state light detectors and the development of advanced signal processing circuitry have led to the development of a new generation of fluorescence instrumentation that can be used to measure photosynthetic parameters in a wider range of platforms and locations. Market pressures for smaller and more energy efficient sensors has been the primary motivation in the development of in situ variable fluorescence sensor and a line of small, filter fluorometers for algal and cyanobacterial biomass measurements. The variable fluorescence system is described and performance data presented. Variable fluorescence data is emerging as an important biological indicator and is being used for indicators of nutrient state, productivity, and algal bloom formation.

Dianne Greenfield, Monterey Bay Aquarium Research Institute

Field applications of the Environmental Sample Processor for remote detection of harmful algae: 2006

Authors: D.I. Greenfield, C.A. Scholin, S. Jensen, R. Marin III, B. Roman, E. Massion, C. Preston, and J. Jones (Monterey Bay Aquarium Research Institute, Moss Landing, CA); G. Doucette (Marine Biotoxins Program, NOAA/National Ocean Service, Charleston, SC)

Abstract: Molecular approaches for identifying harmful algal bloom (HAB) species and affiliated toxins are central to research and monitoring, but such methods require the return of discrete samples for laboratory analysis. This impediment is overcome with the Environmental Sample Processor (ESP), an instrument that detects remotely, subsurface, and in near real-time, a wide range of microorganisms and substances they produce (http://www.mbari.org/microbial/ESP). The "first generation" (1G) ESP was used to develop concepts for automating water sample collection, applying DNA probe arrays in an autonomous setting, and refining sample archival methods. The second-generation (2G ESP), a comparatively smaller, faster, and more robust version, was been deployed for the first time in Monterey Bay, CA (USA) during spring of 2006 for ~20 d per deployment. The 2G ESP has the capacity to carry out multiple tasks simultaneously (e.g., collect a sample for archival while developing a probe array) whereas the 1G ESP could only undertake one activity at a time. To date, the 1G ESP has successfully automated application of 3 DNA probe array classes in field deployments targeting bacteria, HABs, and invertebrate larvae. During the 2006 field season, the 2G ESP successfully automated detection of a number of harmful species, including diatoms of the genus Pseudo-nitzschia, some of which produce the toxin domoic acid. In addition to in situ detection, we attempted to ground truth instrument data by periodic water sampling and analyses using laboratory versions of molecular assays that are emulated within the ESP. Our long-term goal is to make ESP available to the oceanographic research and management communities at-large. Here we present our field findings to date, including planktonic species detected during 2006, domoic acid, environmental data, and our capability to ground-truth instrument data.

Kevin Hardy, Scripps Institution of Oceanography

The research enterprise: Infrastructure to accelerate innovation, foster interdisciplinary cooperation, and enable rapid response to emerging opportunities

Authors: Kevin Hardy (Scripps Institution of Oceanography/UCSD, La Jolla, CA)

Abstract: Recalling Thomas Edison's Menlo Park lab complex, many manufacturing concepts translate well to the academic community, helping maximize the return on investment (ROI) of limited research funding. Scientists constrained by fixed ship schedules understand the meaning of Just-in-Time Delivery and Critical Path scheduling. Similarly, rapid prototyping, crossover technology, development amortization, lean manufacturing, inventory control, incremental improvement, virtual groups, strategic partnerships, earned value accounting, and others have their place as adaptive strategies in the scientific enterprise.

Scripps Institution of Oceanography is experimenting with novel infrastructure enhancements, including the creation of the grassroots Scripps Technical Forum. The STF works on solving broad institutional problems common to individual research programs. This contributes to the Institution's ability to respond competitively to RFPs, enable new science through relevant emerging technologies, improve interaction between technical staff, and proactively seek new partnerships with researchers both on and off-campus.

Technology developments successfully brought on-line for Scripps researchers include: an untethered sediment sampler for biotechnology, ceramic spheres for deep sea flotation, autonomous hadal depth digital camera systems, underwater USB memory stick, an a advanced RDF. Others showing potential for development include a modular ROV, a short tether 8km ROV, blue tooth through glass, and a 10km AUV.

The presenter will discuss when and how matches are made between engineers and scientists, and a "distributed use" model for big ticket acquisitions. The speaker will cite examples of science posing challenges to engineers, and engineers anticipating research requirements.

The hybrid infrastructure provides support to large, small, and startup programs, speculative proposals, graduate students, and off-campus researchers, facilitated by interdepartmental interaction at UCSD, and partnerships with local industry.

The Scripps Technical Forum (STF) is sponsored by UCSD's new Center for Earth Observations and Applications (CEOA), headquartered at SIO, and directed by Scripps Deputy Director John Orcutt.

Benjamin Hodges, Scripps Institution of Oceanography

Glider measurements along a CalCOFI line: hydrography and chlorophyll

Authors: Benjamin A. Hodges, Daniel L. Rudnick, and Russ E. Davis (Scripps Institution of Oceanography, La Jolla, CA)

Abstract: Four deployments of an autonomous glider (Spray) were made along CalCOFI Line 93 between spring 2005 and summer 2006. In each case, the vehicle was programmed to follow the transect line from the California coast near San Diego to its end, approximately 700 km offshore, and then return along the same path. During each 2-month deployment, temperature, salinity, pressure, and chlorophyll fluorescence were measured along a 500-meter-deep section with occasionally interspersed 800-meter dives. With a dive completed every 3 hours, the horizontal resolution of the measurements was roughly 3 km. The observed seasonal cycle of large scale hydrography and chlorophyll fluorescence is consistent with historical CalCOFI data from Line 93, but the finer resolution of the glider measurements makes it possible to resolve smaller-scale features as well. Sharp, density-compensated temperature/salinity fronts are common, both within the mixed layer and in the thermocline. Fluctuations in the depth of the deep chlorophyll maximum closely track those of nearby isopycnals, and shoaling isopycnals are associated with enhanced chlorophyll concentrations. Near the surface, small scale horizontal variability in chlorophyll fluorescence is dominated by daytime nonphotochemical quenching, making a quenching model an important part of the understanding of the distribution of near-surface chlorophyll.

Kenneth Johnson, Monterey Bay Aquarium Research Institute

Applications of the ISUS optical nitrate sensor in the coastal ocean

Authors: Kenneth S. Johnson, Joe Needoba, Luke Coletti, Steve Fitzwater, Carole Sakamoto, and Hans Jannasch (Monterey Bay Aquarium Research Institute, Moss Landing, CA)

Abstract: The ISUS (In Situ Ultraviolet Spectrophotometer) nitrate sensor, developed in our laboratory at MBARI, provides a direct, optical measurement of dissolved nitrate concentration. A network of 7 to 10 ISUS optical nitrate sensors have been operated for as long as 4 years in Monterey Bay, and in the adjacent waters Elkhorn Slough, on moorings and autonomous underwater vehicles. These sensors are currently operated as part of the Land/Ocean Biogeochemical Observatory (LOBO, www.mbari.org/lobo), which is funded through the NSF Biocomplexity in the Environment program, and by the David and Lucile Packard Foundation. The sensors are used for a variety of applications, including observations of land/ocean nutrient fluxes and interannual variations of new primary production in the coastal ocean. This presentation will focus on examples of this work, including assimilation of the data into a real-time, diagnostic model that provides estimates of primary production, respiration and denitrification.

Shaun Johnston, Scripps Institution of Oceanography

Microstructure measurements from SeaSoar during AESOP

Authors: Shaun Johnston and Dan Rudnick (Scripps Institution of Oceanography, La Jolla, CA)

Abstract: In July and August 2006 as part of the Assessing the Effectiveness of Submesoscale Ocean Parameterizations (AESOP) field program, we conducted two separate surveys of a front and a region of internal tide generation. SeaSoar was towed behind a ship at 4 m/s measuring temperature and salinity from depths of 5-400 m at a vertical resolution of 8 m and a horizontal resolution of ~3 km. SeaSoar was also equipped with microconductivity probes and fast thermistors sampling at 2048 and 128 Hz. The ratio of temperature gradient variance measured by the microconductivity sensors to the large scale temperature gradient is the Cox number, where higher values indicate stronger turbulent mixing. Cox number was estimated during preliminary data analysis at a front and along an internal tidal beam.

From 30 July-6 August 2006 and about 100 km offshore of Monterey Bay, a front between upwelled water and warmer, fresher offshore water was surveyed twice with SeaSoar. Preliminary estimates of higher Cox number suggest enhanced mixing in regions of current shear between two different water masses. Also elevated levels of mixing are found along subducting isopycnals.

From 10-25 August 2006, SeaSoar was towed along 3 lines crossing Monterey Canyon, a region of internal tide generation. Velocity variance from 60 sections (20 repeat surveys of these 3 lines) suggests beams emanating possibly from a submarine fan, the canyon rim, and Sur Platform. The mean Cox number from these 60 sections shows elevated mixing along the beam.

David Kaplan, University of California Santa Cruz

Improved interpolation and extrapolation of HF radar data based on modal current decomposition

Authors: David M. Kaplan (Institute of Marine Sciences, University of California Santa Cruz, CA), Francois Lekien (Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ)

Abstract: HF radar measurements of surface currents provide a unique and powerful tool for looking at coastal circulation. Nonetheless, the data they produce often have significant spatial gaps and data close to shore are generally limited. A technique, here referred to as modal current decomposition, has been developed to produce continuous 2-dimensional current fields by fitting available data to a set of spatial modes defined on a finite domain. This technique has the advantages of incorporating the coastal boundary condition of no-flow through the boundary into the fit and including a controllable level of spatial smoothing. While the basic technique has been well explained by Lipphardt et al. [2000] and Lekien et al. [2004], the details of the fitting process and many of the limitations of the technique have not been fully explored. Here we explore the theoretical basis of the technique in more detail. We then proceed to expand on the basic technique to incorporate directly the radial current data produced by each HF radar instrument. This method has the advantages of making maximal use of available data and avoiding the additional step and associated error of

creating total vector currents from HF radar radial current data. We also develop techniques for dealing with spatially-nonuniform data and data gaps. Error propagation is used to incorporate measurement error into an estimate of the error associated with the final interpolated current field. We explore this exhanced modal current decomposition technique by applying it to HF radar data from the Bodega Bay region. Patterns of surface divergence and vorticity are compared with prior results from the same region based on the original total vector current data. Modal current decomposition results agree favorably with these more traditional results. Nonetheless, care must be taken when using the technique as limited data can produce erroneous results. Despite these limitations, the technique provides a robust mechanism for interpolating and spatially filtering 2-dimensional velocity measurements.

Joseph Needoba, Monterey Bay Aquarium Research Institute

In situ chemical instruments address the problem of sample aliasing in estuaries

Authors: Joseph Needoba (MBARI, Moss Landing, CA), Gage Dayton (Moss Landing Marine Labs, Moss Landing, CA), Ken Johnson (MBARI, Moss Landing, CA)

Abstract: Monitoring of the chemical constituents of aquatic environments presents numerous logistical and technical challenges that include sample collection, preservation, and accurate analyses. These challenges mean that few samples are collected and under-sampling of the environment becomes a significant obstacle to furthering biogeochemical understanding of coastal systems. In situ instrumentation allows for high resolution observations that illuminate – and avoid – the problem of sample aliasing caused by high frequency variability. The tidal cycle, in particular, has an impact on the concentration and variability of many estuarine biogeochemical properties, due to the mixing of water masses and the presence of chemical gradients between end-member sources. Therefore, monitoring frequencies that do not resolve the daily environmental variability can impact the interpretation of time series data or the optimization of numerical models. We will present measurements of nitrate, oxygen, and related variables from the LOBO sensor network (www.mbari.org/lobo) in the Elkhorn Slough estuary (California) that resolve the variability associated with the semi-diurnal tidal cycle. Our understanding of the data is significantly improved by interpreting rate measurements in the context of tidal vectors, water residence time, and the interactions with diel rhythms. Compared to traditional chemistry sampling methods, the ocean observatory data significantly improves our model validation ability and our understanding of ecosystem nutrient cycling in estuarine environments.

Steve Ramp, Naval Postgraduate School

A Seaweb Implementation for the Adaptive Sampling and Prediction (ASAP) Program

Authors: Steve Ramp, Joe Rice, and Fred Bahr (NPS); Chris Fletcher (SPAWAR)

Abstract: Seaweb is an undersea communications system based on Benthos telesonar modems and networking software developed at SPAWAR Systems Center, San Diego. Fixed and mobile assets on the bottom and in the water column communicate with the laboratory either directly via acoustic transducers on a surface gateway buoy, or indirectly via bottom-mounted repeaters that in turn relay information to the gateways. Networks may be small or large, with just a few repeaters and a single gateway, or as many as sixty repeaters and several gateways, called Racom (radio/acoustic communications) buoys. With some compromises in availability, autonomous gliders can also serve as gateways eliminating the need for a moored buoy. The systems are robust in that communications pathways can be re-routed on the fly to compensate for system losses/failures. During August 2006 off Santa Cruz, CA, a two-Racom, six-repeater network was implemented to move data in near-real time from two ADCPs in trawl-resistant bottom mounts (TRBMs) on the 60 m and 100 m isobaths. Vertical profiles of horizontal ocean currents were transmitted every ten minutes from both instruments, staggered so that transmissions were five minutes apart. Three different communications paths were used successfully, most commonly with both instruments talking through one buoy, one directly and the other via three hops on the bottom. Once at the buoy, the data were transmitted to NPS using Iridium satellite communications, and placed onto the Internet where an automated script created several graphical displays in real time. System performance was flawless through the first three weeks, whence some problem with the Iridium link developed at the buoys which will remain undiagnosed until the equipment is recovered on September 1, 2006. A complete report will be available at the meeting.

Daniel Rudnick, Scripps Institution of Oceanography

The underway CTD

Authors: Daniel L. Rudnick and Jochen Klinke (Scripps Institution of Oceanography, La Jolla, CA)

Abstract: The development of the Underway Conductivity-Temperature-Depth instrument (UCTD) is motivated by the desire for inexpensive profiles of temperature and salinity from underway vessels, including volunteer observing ships (VOS) and research vessels. The UCTD operates under the same principle as an expendable probe. By spooling tether line both from the probe and a winch aboard ship, the velocity of the line through the water is zero, line drag is negligible and the probe can get arbitrarily deep. Recovery is accomplished by reeling the line back in. Recovering the UCTD has some advantages: (1) the cost per profile decreases with increasing use, (2) sensors can be calibrated post-deployment, (3) the UCTD carries a pressure sensor so depth is measured directly, (4) no hazardous materials are left behind. The design goal for UCTD was to obtain profiles deeper than 100 m at 20 knots (typical of a VOS). This goal has been surpassed, as we are able to profile to over 150 m at 20 knots, and to over 400 m at 10 knots. The first operational use of UCTD occurred during a cruise May–June 2004, whose purpose was to examine the effect of internal waves and spice on long-range acoustic propagation. Over 160 UCTD casts were completed, resulting in a hydrographic section with resolutions of 10 km horizontally and 5 m vertically.

R. Kipp Shearman, Oregon State University

Autonomous Glider Observations from the Newport Hydroline, The New Vagaries of Fortune

Authors: R. Kipp Shearman, John A. Barth, Anatoli Erofeev, and Tristan Peery (Oregon State University, Corvallis, OR)

Abstract: We describe our fledgling glider operations at OSU. Begining in April 2006, we have more-or-less continuously maintained an autonomous glider, sampling a cross-shelf transect along the Newport Hydroline (44 39.1 N). A section runs from the 20 m isobath (NH-01) out about 90 km (NH-45), and takes 3-7 days to complete (longer coming back in than going out). The glider undulates from the surface to 2-3 m above the bottom (200 m maximum) with an along-track resolution ranging from 100 m in shallow water to 400 m in deep water. The glider is equipped with a CTD and several optical instruments (chlorophyl fluorescence, CDOM Fluorescence, backscatter, and dissolved oxygen). The benefits of autonomous sampling are well known - the cost relative to comparable ship-time is miniscule and you can be a sea-going oceanographer without the seasickness; the other benefits come by maintaining a continuous presence in the ocean - just by being there your chances of observing intermittent, unpredictable (possibly important) processes are increased. For example, our glider observations along the Newport Line show an apparently large convergence in the bottom boundary layer just inshore of the upwelling jet during a wind reversal early in the 2006 season. Finally, we invented the nose-bag which has revolutionized glider recovery at sea.

G. Jason Smith, Moss Landing Marine Laboratories / ACT-Pacific Coast

The Alliance for Coastal Technologies (ACT) – A national partnership supporting coastal monitoring efforts

Authors: G. Jason Smith, Kendra Hayashi, Traci Conlin, and Kenneth Coale (Moss Landing Marine Laboratories, Moss Landing, CA)

Abstract: The ACT program seeks to develop and maintain partnerships between research institutions, state and regional resource managers, and private sector companies to disseminate information on, as well as foster development of innovative sensor and sensor platform technologies for the monitoring and surveillance of coastal environments. ACT was developed in 2001 with encouragement by the National Oceanic and Atmospheric Administration (NOAA) to support the technological requirements of state, national and international efforts on integrated and sustained ocean and coastal observations for managing marine and coastal resources, mitigating natural hazards, safeguarding public health and safety and ensuring safe and efficient maritime transportation and commerce. ACT – Pacific Coast is headquartered at the Moss Landing Marine Laboratories and serves as one of seven partner institutes nationwide. The partner institutes work together to foster regional involvement and meet ACT's broad programmatic goals of providing: (1) an unbiased, third-party testbed for evaluating new and developing in situ sensor and sensor platform technologies for environmental monitoring, (2) a comprehensive data and information clearinghouse on coastal observing technologies and (3) a forum for capacity building through annual workshop series, seminars and newsletters on specific technology topics. This poster will highlight ACT-Pacific Coast achievements in each of these activity areas with particular emphasis on our water quality sensor performance verification activities. We encourage everyone to support their regional Ocean Observing System (OOS) activities and make use of the ACT program to foster information exchange on monitoring technologies and needs.

Pete Strutton, Oregon State University

Bio-optical observations of carbon cycling in the equatorial Pacific

Authors: Pete Strutton (COAS, Oregon State University, Corvallis, OR)

Abstract: Recent observations from the equatorial Pacific highlight the potential importance of non steady state processes in the carbon cycle of this globally important region. First, cruise observations of biogenic silica production and dissolution suggest that tropical instability waves (TIWs) may be important for generating sporadic fluxes of biogenic material to depth. Second, analysis of the NOAA/PMEL CO2 database reveals a different relationship between surface CO2 and SST during the time of the year (July to December) that TIWs are most active. Taken together, these observations suggest that TIWs may modulate the relationship between surface productivity, air-sea CO2 flux and carbon export to depth. This hypothesis will be investigated using a year of bio-optical data spanning the basin. Suggestions for future observations on autonomous platforms will also be discussed.

Calvin Teague, CODAR Ocean Sensors

River surface velocity measurement using a UHF RiverSonde

Authors: Calvin C. Teague, Donald E. Barrick, and Peter M. Lilleboe (CODAR Ocean Sensors, Ltd., Mountain View, CA)

Abstract: Recently a UHF radar system called RiverSonde has been developed and used to measure the surface velocity of fresh-water rivers 100–200 m wide. The system is based on the SeaSonde which is used to measure ocean surface currents using radar frequencies in the HF band. Like the SeaSonde, the RiverSonde employs direction finding using three antennas, but instead of the crossed loops and monopole used in the SeaSonde, the RiverSonde uses three yagi antennas displaced from each other and oriented in different directions. The transmitted power is less than 1 W, the radar wavelength is on the order of one meter to couple to the shorter water waves expected on a river, and operation normally is over fresh water. Data are processed using an angular resolution of one degree, and range cell sizes as small as 5 m. Maximum range typically is 200–300 m.

After several short-term initial deployments, a prototype RiverSonde was used for periods of about six months on the Cowlitz River at Castle Rock, Washington and at Threemile Slough in central California, and for several weeks at a salt marsh at Oyster Landing near Georgetown, South Carolina. The Cowlitz River site was about 30 km upstream from the Columbia River, and the water velocity typically was about 1 m/s, but it reached about 3.5 m/s during a flood event. The radar velocity was highly correlated with river stage observations made by the USGS about 150 m downstream from the radar site. The flow in Threemile Slough, which connects the Sacramento and San Joaquin Rivers, is tidally-driven, with flow reversals twice a day and a peak velocity of about 1 m/s in each direction. An ultrasonic velocity meter (UVM) operated by the USGS recorded the average water velocity across the channel at a depth of approximately 4.5 m, and the radar velocities agreed with the UVM velocities with a correlation coefficient of 0.988. Finally, the experiment at Georgetown was conducted to see how the RiverSonde would function in an environment with several tidally-driven meandering water channels among marsh grass. The system

performed quite well, with the available echo energy dependent on the local wind but at times visible to the 300 m maximum range sampled by the hardware. Although two of the sites were well inland from the coast, ocean influences were clearly seen at all of the sites.

The RiverSonde system will be described briefly, and representative data from the three experiments above will be summarized. Finally, plans will be outlined for a deployment of several RiverSonde units to map total flow vectors at the confluence of two channels where the complicated flow patterns affect juvenile fish migration.

Multidisciplinary Modeling

Susan Allen, University of British Columbia

Physical controls on the timing of the spring bloom in the Strait of Georgia

Authors: Susan Allen, Kate Collins, and Rich Pawlowicz (University of British Columbia, Vancouver, BC)

Abstract: A coupled biophysical model of the Strait of Georgia, British Columbia, Canada has been developed and successfully predicts the timing of the spring phytoplankton bloom. The physical model is a one-dimensional vertical-mixing model that uses a K-Profile Parameterization of the boundary layer and is forced with high frequency meteorological data. The biological model includes one phytoplankton class (microphytoplankton), two nutrient classes (nitrate and ammonium) and detritus. The coupled biophysical model was used to determine what physical factors are controlling the arrival of the spring bloom. Wind was found to control the bloom time arrival, with strong winds delaying the bloom and weak winds causing the bloom to arrive earlier. Solar irradiance had a small effect on the arrival time, and freshwater input (primarily Fraser River discharge) was insignificant to the arrival time of the bloom. Including ammonium in the model was necessary to successfully reproduce the magnitude of the bloom.

Bénédicte Ferré, U.S Geological Survey

Estimates of sediment transport rates on the Palos Verdes (CA) Shelf

Authors: Bénédicte Ferré and Christopher R. Sherwood (U.S. Geological Survey, Woods Hole, MA), Patricia Wiberg (University of Virginia, Charlottesville, VA) and Christopher J. Murray (Pacific Northwest National Laboratory, Richland, WA)

Abstract: The Palos Verdes (PV) Shelf has been studied for decades because of concerns about the ecological consequences of DDT discharged from the Whites Point outfall. The Los Angeles County Sanitation Districts (LACSD) deployed upward-looking acoustic-Doppler current profilers (ADCPs) on the Palos Verdes and San Pedro shelves from late 2000 to mid-September 2004 and has collected sediment cores at PV Shelf stations every other year since 1981. We have used a one-dimensional (vertical) sediment transport model to estimate sediment transport rates and infer rates of erosion or deposition at these sites, which are located on the 35 m and 60 m isobaths.

Current data from the ADCPs and wave data from an offshore buoy were used to force the model. Sediment characteristics were determined from analyses of grain size distributions from both disaggregated and naturally aggregated samples. Erodibility (amount of cohesive sediment available for erosion at various shear stresses) was determined from geostatistical analyses of camera penetration depths and erosion chamber measurements made during a 2004 field program. Field measurements were used to check the timing of modeled resuspension events and the threshold (critical shear stress) for resuspension.

Sediment-transport rates were calculated at the ADCP sites and differences between them (flux divergences) were computed to infer erosion/deposition rates. Our best estimates were calculated using sediment characteristics for each site based on samples obtained by LACSD during their monitoring program, the USGS in 1992, and the participants of the 2004 geotechnical measurement program. Sensitivity to uncertain model parameters was evaluated by conducting sets of calculations for the following conditions:

1) Reduced wave forcing to determine how frequently currents alone were responsible for transport at each site.

2) Uniform sediment properties, allowing us to isolate the influence of horizontal current variations.

Because waves are responsible for most of the sediment resuspension, only small amounts of sediment were transported in the first case. Variations in sediment characteristics indicated that transport rates may vary by a factor 3 between the least and most mobile sediments in the study area. Along isobaths, the most important differences in transport rates were caused by variations in current speeds, which were generally higher south of the outfalls. Sediment transport ranged from 76 metric tons m-1 yr-1 near from the outfall to 340 t m-1 yr-1 on the San Pedro shelf. Calculated flux divergences between adjacent stations suggest that, in the absence of other sediment sources, erosion occurs north of the outfalls and deposition occurs in the region immediately south of the outfalls.

Albert Hermann, University of Washington - JISAO/PMEL

Relative merits of Eulerian vs. individual-based models of fish dynamics in patchy habitats

Authors: Albert J. Hermann (Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA)

Abstract: A fundamental equivalence was established by Taylor (1921) between Eulerian and Lagrangian approaches to turbulent diffusion; an ensemble of particles, each subjected to a random walk (the Lagrangian approach), can generate statistics equivalent to turbulent eddy diffusion (the Eulerian approach). This equivalence is relevant to the construction of statistically meaningful Individual-Based models of fish, and their Eulerian counterparts. Spatially explicit Individual-Based models offer great flexibility in the specification of behaviors, especially those based on past history (e.g. gut fullness). However, when the circulation or prey fields are patchy in space and time, such models may require a large ensemble of realizations, to attain a statistically meaningful result. These patchy situations include eddy-rich circulation fields, as well as prey fields locked to a particular bathymetric feature. Eulerian models have less flexibility in the specification of history-dependent behaviors, but a single run may naturally integrate over some (yet not all) possible Lagrangian realizations of individuals in patchy environments. Here an attempt is made to determine which approach could be expected to be superior, based on the statistics of the circulation and prey fields, and given a finite computational resource to generate realizations of either type of model.

Chris Murray, Pacific Northwest National Laboratory

Geostatistical mapping of sediment erodibility on the Palos Verdes (CA) Shelf using multiple data sets

Authors: Christopher J. Murray and Yi-Ju Chien (Pacific Northwest National Laboratory, Richland, WA), Patricia L. Wiberg (University of Virginia, Charlottesville, VA), Christopher R. Sherwood (U.S. Geological Survey, Woods Hole, MA), Robert A. Wheatcroft (Oregon State University, Corvallis, OR)

Abstract: Sediment transport modeling requires input fields that describe the spatial distribution of bottom sediment properties. One of the most important of those properties is the erodibility of the sediment as a function of bottom shear stress. However, measurements of sediment erodibility are difficult and expensive, so that few direct measurements are normally available. We mapped the spatial distribution of sediment erodibility on the Palos Verdes Shelf, off Southern California, using a combination of direct and indirect measurements. Direct measurements of sediment erodibility were performed using the Gust technique at ten sites. Those measurements were used to estimate the slope and intercept of a log-log regression of cumulative mass eroded as a function of shear stress at each of the ten locations. Average sediment porosity in surficial sediment (~ 0.2-1.0 cm) was estimated for 48 locations using resistivity data and Archie's Law. In addition, the camera penetration depth (CPD) for a Sediment Profile Imaging (SPI) device was available for 160 locations. This CPD provides a simplified measure of sediment shear strength, similar to that available from a cone penetrometer. The CPD had a higher correlation with the slope of the sediment erodibility functions than porosity (0.84 vs. 0.66) and was available in many more locations, so we decided to use it as the main supplementary data set in mapping the sediment erodibility functions.

We used geostatistical methods to examine the spatial continuity of the sediment property data. Variogram models fit to the CPD and porosity data showed a consistent range in the alongshore direction of approximately 6,400 – 7,000 m, and a shorter range of 1,600 – 3,000 m in the cross-shelf direction. We generated 1,000 realizations of the CPD on a 50-m rectangular grid across the Palos Verdes Shelf using Gaussian simulation methods conditioned on the CPD variogram model and the 160 CPD data. We then generated 1,000 realizations of the slope of the sediment erodibility functions using the collocated cokriging simulation algorithm. Each realization of sediment erodibility was conditioned on the 10 Gust data and one of the previously generated realizations of CPD. The median simulated value of the slope at each grid node provides a central estimate of sediment erodibility that will be used as the base-case input for the sediment transport model. We also ranked each realization of sediment erodibility based on the proportion of the area containing highly erodible sediment and identified realizations having both low and high proportions of highly erodible sediment. Modeling of those realizations will provide a preliminary estimate of the uncertainty in sediment transport predictions on the Palos Verdes Shelf related to spatial uncertainty in sediment erodibility.

Marlene Noble, U.S. Geological Survey

Rapid variations in the temporal and spatial structures of barotropic and baroclinic currents associated with tidal processes on the Los Angeles shelves

Authors: Marlene Noble, Kurt Rosenberger, and Richard Signell (U.S. Geological Survey), Carmen White (U.S. Environmental Protection Agency), Joe Meistrell (Los Angeles County Sanitation District, Whittier, CA)

Abstract: The San Pedro Bay portion of the continental shelf south of the port of Los Angeles CA is about 20 km wide. Just west of the port, the shelf narrows to 2–3 km wide within a distance of about 7 km off Palos Verdes (PV) peninsula. This variable bathymetry forces rapid changes in the structures of surface tides, internal tides, and the associated nonlinear baroclinic currents that occur at approximately tidal frequencies in the region. Since 2001, the Los Angeles County Sanitation Districts (LACSD) have deployed ADCP and thermistor moorings to monitor vertical structure in current and temperature fields over the narrower portion of the shelf off PV and within the transition zone between the PV shelf and the wider San Pedro shelf. About a year after the initial deployment, four more moorings were deployed on the San Pedro shelf southwest of the main array. In addition, a heavily-instrumented cross-shore array of moorings was deployed in the transition region of the shelf for four months in the late winter of 2004 by a consortium of agencies to gather further detail on the rapid spatial variations in continental shelf processes.

The principal semidiurnal tide, M2, tends to be the largest tidal constituent. Sea level deflections associated with the M2 tide tend to be independent of local topographic variations; sea level oscillations are about 50 cm on both the wider and narrower sections of the shelf. However, M2 barotropic tidal current amplitudes are enhanced in the transition region, changing from about 5 cm/s over the San Pedro shelf to 6–10 cm/s in the southern PV transition region. They are then reduced to less than 2 cm/s over the narrowest section of the PV shelf. These variations in amplitude occur over a distance of less that 15 km along the shelf and are larger than that predicted by the high-resolution (but depth-integrated, barotropic) ADCIRC tidal model for this area.

The internal tides and bores at tidal frequencies often present in this region may have significant vertically-averaged mean amplitudes and stable phases over periods of several months. Hence, they can interfere with barotropic tidal currents and cause significant increases (or decreases) in estimated barotropic tidal current amplitudes. The estimated barotropic amplitudes can change by more than 80% when current records are shorter than 6 months. The interference in the calculated barotropic tidal current amplitude would be even larger if the major axes of surface and internal tidal currents were not nearly perpendicular. Surface tidal currents are oriented alongshelf; internal tides are oriented cross-shelf. The slope of the seabed over the narrow portion of the shelf, 2–3 degrees, is roughly critical for internal tides. Hence, some portion of the internal tidal current field becomes nonlinear. Near-bottom current fluctuations associated with these bores are very asymmetric, oriented primarily offshore and are significantly enhanced with respect to internal tidal amplitudes. These asymmetric internal tides or bores are strongest in the transition region of the shelf. These internal motions contribute a significant amount of

variance to near-bottom currents and bed stresses. The partial rectification of the oscillatory flow field near the bed causes a net movement of resuspended material off the shelf and onto the slope.

Christine Petersen, National Marine Fisheries Service / University of California Santa Cruz

Exploration of influences of shoreline topography and season on nearsurface transport with a 3-d model in central California

Authors: Christine H. Petersen (NOAA-SWFSC/University of California Santa Cruz, Santa Cruz, CA), Chris Edwards (University of California Santa Cruz, Santa Cruz, CA), Steve Ralston (NOAA-SWFSC)

Abstract: Members of the rockfish species complex in the NE Pacific may be broadly categorized into winter and summer-spawning subgroups. Relatively little is known about the capabilities by groundfish spp. in the larval stages to control alongshore position or resist offshore advection via active depth choice. In order to project the significance of spawning season, and the influence on alongshore displacement by shoreline topographical features, we investigate dispersion in a 3km nested ROMS configuration for the central California coast. The model is driven at the surface by COAMPS regional wind forcing for the year 2002. Randomized releases of nearsurface lagrangian floats are monitored over realistic periods of groundfish pelagic larval duration. Cross-shore position (shelf/slope) of initial larval release had a relatively small influence on the integrated yearly probability distribution of alongshore displacement for timescales greater than 2-weeks. Episodes of longer-term retention were observed in southern Monterey Bay and south of Point Reyes. We will discuss the statistics of the dispersion, net transport, and seasonal alongshore connectivity over the course of the modeled year.

James Pringle, University of New Hampshire

Upwelling is not a local phenomena: Examples from Pt Reyes & the WEST and CODE regions

Authors: James M. Pringle (University of New Hampshire, Durham, NH)

Abstract: Upwelling is not a local phenomena: Examples from Pt Reyes & the WEST and CODE regions.

Analysis of wind-driven upwelling in the WEST region near Pt. Reyes and the CODE region between Pt. Reyes and Pt. Arena have traditionally concentrated on the local bathymetry and wind fields. Modeling of the circulation, either with quasi-analytical models [e.g. Brink et al. 1987] or numerical models [Gan & Allen 2002, Kuebel Cervantes & Allen 2006] over-estimates the strength of the alongshore equatorward flow and the temperature changes associated with upwelling. This overestimate is often O(1) or more, and is more pronounced to the south.

Using a series of numerical and analytical models, I argue that these issues arise from insufficient consideration of alongshore variation in the winds and bathymetry. High resolution wind fields produced by Koracin and Dorman find that the alongshore windstress field weakens considerably south of Pt. Reyes, and that this alongshore variation weakens wind-forced currents north of Pt. Reyes. As importantly, the dramatic narrowing of the shelf to the south of Monterey Bay significantly reduces the alongshore currents in the WEST region, and to a lesser extent in the more northerly CODE region.

Both the wind and bathymetric variation cause an O(1) reduction in the upwelling of cold, nutrient rich water to the mid-shelf in these regions. Including the alongshore variability in winds and the bathymetry south of Monterey Bay produces large along-isobath pressure gradients. These pressure gradients offset the alongshore windstress, as observed in momentum balances calculated from mooring data.

This analysis illustrates that upwelling is not a local phenomena, and that any modeling of the coastal ocean must resolve wind and bathymetric variation for several hundred kilometers or more. This lengthscale is defined further in Pringle (2002).

Chris Sherwood, U.S. Geological Survey

Evolution of the contaminated sediment deposit on the Palos Verdes (CA) Shelf: physical, chemical, and biological processes

Authors: Christopher R. Sherwood and Benédicté Ferré (U.S. Geological Survey, Woods Hole, MA), Robert P. Eganhouse (U.S. Geological Survey, Reston, VA), Patricia L. Wiberg (University of Virginia, Charlottesville, VA)

Abstract: A deposit of contaminated sediment has accumulated on the continental shelf of the Palos Verdes (PV) peninsula southwest of Los Angeles since the first of a series of ocean outfalls was constructed near Whites Point. The sediment is a combination of sewage particles and natural sediment and contains DDT (primarily in the form of DDE), PCBs, and other contaminants. The deposit has been repeatedly sampled by the Los Angeles County Sanitation District (LACSD) since 1981 and was mapped in detail by the U. S. Geological Survey (USGS) in 1992 and by the U. S. Environmental Protection Agency (EPA) and collaborators in 2004. The effluent-affected deposit has a maximum thickness of about 80 cm and is more than 30 cm thick over an area of more than 10 km2. Improvements in wastewater treatment and a ban on the manufacture of DDT have reduced effluent contamination since 1971, and the most-contaminated sediments have been buried by relatively cleaner sediment. Now almost no solids are released from the outfalls, and LACSD data indicate that sediment deposition rates near the outfalls are near zero. Total DDT in fish tissues still exceeds Federal standards, but inventories of DDE are falling in most of the deposit. DDE is being transformed to DDMU at varying rates by reductive dechlorination throughout the deposit and, in surface sediment (top 15 cm) over most of the deposit, physical processes are also acting to reduce DDE inventories. However, the concentration of DDE is increasing in surface sediment near the outfalls, a region with the highest concentrations of buried DDE and the lowest deposition rates. We think this indicates that bioturbation is mixing more-contaminated sediment into the surface layer, a process that if coupled with erosion, could maintain or even increase the amount of DDE entering the food web. We hope to answer the question: how will DDE concentrations in surface sediment change over the next few decades as erosion and bioturbation transport buried DDE to the surface and inventories fall through chemical transformation and other loss mechanisms? We have implemented a box model to represent the relevant biological, physical, and chemical

processes and predict future concentrations of DDE in surface sediment. We used analyses of the LACSD sediment cores and sediment-transport calculations to set key parameters and test the model. The results indicate that forecasts are most sensitive to assumptions about erosion rates which, in turn, depend on subtle variations in sediment mobility, spatial variations in near-bottom currents, and changes in local sediment supply.

Xiaochun Wang, Jet Propulsion Laboratory / Caltech

Modeling tides in Monterey Bay, California

Authors: Xiaochun Wang, Yi Chao, John Farrara, and Zhijin Li (JPL/Caltech, Pasadena, CA); James. C. McWilliams (UCLA, Los Angeles, CA); Jeffrey D. Paduan and Leslie K. Rosenfeld (NPS)

Abstract: In the process of developing a tide-permitting coastal forecasting system, tidal signal is added to an oceanic general circulation model for the Monterey Bay, California. The model, which is configured from the Regional Ocean Modeling System (ROMS), is three-level nested with the finest resolution of 1.6 km. As the first step to develop such a system, the tide simulation is validated against tide gauges,

Topex/POSEIDON along-track altimetry observation, and high frequency coastal radar observation. The model tidal energetics is then analyzed and compared with the available observations. Though the barotropic tide energy flux generally propagates northward, the baroclinic tide energy of semidiurnal frequency can penetrate into the Monterey

Submarine Canyon. The baroclinic tide energy of diurnal frequency is much smaller than the energy of semidiurnal frequency and trapped around the generation sites. The lessons learned from the MB06 real-time tide-permitting prediction experiment will also be presented.

The Eastern Pacific Ocean: Ecosystems and Dynamics

Jack Barth, Oregon State University

Intraseasonal wind oscillations and their influence on northern California Current coastal ecosystems

Authors: John A. Barth (College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR) and John M. Bane (Department of Marine Sciences, University of North Carolina, Chapel Hill, NC)

Abstract: Intraseasonal oscillations (ISOs) are fluctuations in the atmosphere-ocean-climate system with periods between 20 and 40 days, that is longer than the typical 2-6 day "weather-band" wind fluctuations that drive coastal upwelling and downwelling. We show how wind ISOs directly influence the coastal ocean ecosystem in the northern California Current System, the eastern boundary current of the North Pacific. During summer 2001 in the Oregon coastal upwelling system, ecosystem variations were due to 20-day ISOs in wind stress. Upper-ocean temperature, phytoplankton and zooplankton varied principally on the 20-day time scale and correlated with the stress, showing the importance of the stress ISOs in driving the oceanic ecosystem. The stress ISOs were driven by variations in the north-south position of the atmospheric Jet Stream, which were generated by an interaction between the Jet Stream and the western U. S. mountain ranges. In 2005, the spring transition to upwelling-favorable wind stress was delayed by over a month in the northern California Current Large Marine Ecosystem by 20-40 day wind ISOs associated with a southward shift of the Jet Stream. Early in the upwelling season (May-July) off Oregon, the cumulative upwelling-favorable wind stress was the lowest in 20 years, nearshore surface waters averaged 2°C warmer than normal, surf-zone chlorophyll-*a* and nutrients were 50 and 30% less than normal, respectively, and mussel and barnacle densities were reduced by 83 and 66%, respectively. The negative impact of these changes propagated up the marine food web.

David Ainley, Harvey & Associates

Variability in ocean climate and prey availability affecting seabird occurrence off Oregon, 2000–2002

Authors: David Ainley (Harvey & Associates, San Jose, CA), Steve Pierce (Oregon State University, Corvallis, OR), Katie Dugger (Oregon State University, Corvallis, OR), Glenn Ford (RGFord Consulting, Portland, OR)

Abstract: We assessed the occurrence patterns of seabirds against the spatial variability in frontal features, as well as the abundance of prey, during four cruises in 2000 and 2002. Data were gathered from the OSU SeaSoar and a towed, 4 channel acoustic vehicle, coincident with strip transects of birds. Previously, we had published on the 2000 results, but without full analysis of acoustic data. In this paper, we compare 2000 with 2002, including acoustic data that have been used to provide actual estimates of potential prey in various size classes. As of this writing, we don't have any results to highlight.

Vincent Combes, Georgia Institute of Technology

The role of surface winds in the seasonal and interannual variability of large-scale eddies in the Gulf of Alaska

Authors: Vincent Combes and Emanuele Di Lorenzo (Georgia Institute of Technology, Atlanta, GA)

Abstract: Eddies in the open ocean are primarily generated through instability processes associated with regions of strong horizontal shear or upper ocean baroclinicity. However in the Gulf of Alaska interior, the largest (D ≥200km) and longer lived (T ≥4 yr) eddies originate in coastal areas along the eastern boundary, where the generating dynamics are strongly dependent on the interaction between coastal flows and the complex geometry.

In this study, a high resolution regional oceanic model is used to explore the seasonal and interannual variability of eddy statistics. It is shown that most of the variance in the Gulf of Alaska basin is explained by interannual variability associated with the eddy field. During El Niño the eddy activity in the eastern basin is stronger. For example, consistent with observational records, the model captures a strong Haïda eddy in the winter 1982–83. However in contrast with previous findings by Melsom et al. (1999), who report on the important role of equatorial coastally trapped waves and enhanced baroclinic instability during El Nino years, we find that the baroclinicity of the flow field is not stronger during El Nino years and that local changes in the wind field, typical of the El Nino atmospheric teleconnection, play a bigger role in the generation of stronger eddy fields. Specifically along the eastern basin the eddy field results from a large scale geostrophic adjustment of the coastal flow field in response to a positive perturbation in sea surface height forced locally by poleward winds. The positive sea level anomaly corresponds to enhanced poleward buoyancy flow around the cape. The interplay of the coastal buoyancy flow with the complex coastal geometry is shown to be important in the generation and detachment of the larger eddies. The initial adjustment involves the excitation of nonlinear Rossby waves.

This study leads to a better understanding of the exchanges between inshore and offshore waters in regional oceans characterized by complex geometry at seasonal and interannual time scale. A correct representation of cross-shelf mixing is relevant for biogeochemical cycle in climate models. Also, given the long lived life of eddies generated along the eastern boundary, we hypostatize that these coastal dynamics may play a more important role in basin wide climate variability than previously recognized.

Leah Feinberg, Oregon State University

Temporal and spatial variability in brood size in relation to euphausiid egg distributions off northern Oregon and southern Washington

Authors: Leah R. Feinberg and C. Tracy Shaw (Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, Newport, OR); William T. Peterson (NOAA-NWFSC, Hatfield Marine Science Center, Newport, OR); Jesse F. Lamb (Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, Newport, OR)

Abstract: The euphausiids, Euphausia pacifica and Thysanoessa spinifera, are critically important species in the northeast Pacific food web and thus their recruitment can be seen as an overall indicator of potential ecosystem productivity. Several years of surveys between La Push, Washington and Newport, Oregon showed that euphausiid egg concentrations were highly variable from year to year, but were generally found in greater concentrations off Washington. Brood size incubations conducted on 4 RISE cruises (2004-2006) gave us the opportunity to investigate whether euphausiid brood sizes are larger off the Washington coast.

Preliminary results suggest that increased brood sizes can not explain higher egg concentrations off the Washington coast. Highest average brood sizes were found near the mouth of Astoria canyon and off of Cape Meares, Oregon. There was a great deal of seasonal and interannual variability in both brood size and in the prevalence of spawning females in net tows. Cruises in July of 2004 and August of 2005 yielded far more spawning females per unit effort than the 2005 or 2006 June cruises. The highest average brood sizes were also seen on the July and August cruises suggesting that June is not an ideal time to study the productivity of euphausiids. Our results will be presented in the context of changing ocean conditions through the timeframe of the cruises. We will also explore alternate hypotheses as to why egg concentrations are higher off of Washington, such as whether canyons might play a role in concentrating eggs and adult euphausiids

Melanie Fewings, Massachusetts Institute of Technology/WHOI Joint Program

Observations of cross-shore flow driven by cross-shore winds on the inner continental shelf

Authors: Melanie Fewings (Woods Hole Oceanographic Institution/Massachusetts Institute of Technology Joint Program, Woods Hole, MA), Steven J. Lentz, and Janet Fredericks (Woods Hole Oceanographic Institution, Woods Hole, MA)

Abstract: On continental shelves, cross-shore circulations influence the water column density structure and the distributions of heat, salt, phytoplankton, nutrients, and pollutants. The mechanisms that drive cross-shore flow over the inner shelf are not well-understood. Five-year-long time series of winds, waves, and water velocity profiles from an underwater cabled coastal observatory in 12 m water south of Martha's Vineyard, Massachusetts are used here to determine the separate dependence of the cross-shore velocity profile on waves, cross-shore winds, and along-shore winds.

During small waves, cross-shore wind stress is the dominant mechanism driving the cross-shore circulation and exchange on this inner shelf. The along-shore wind stress does not drive a substantial cross-shore circulation. The cross-shore circulation has a two-layer structure, with shoreward near-surface flow for shoreward winds, and vice versa. This circulation is consistent with an along-shore uniform velocity field. The observed cross-shore transport in the surface layer agrees with a simple numerical model of cross-shore wind stress forcing. The cross-shore surface layer transport is stronger in summer than winter, for a given wind stress. When waves are large, the Eulerian cross-shore circulation is a shallow downwelling cell, with onshore flow above the wave troughs and an offshore return flow immediately below, regardless of wind forcing. Waves also lead to a large difference between the Eulerian circulation during combined wind and wave forcing, and the Lagrangian transport of nutrients, plankton, heat, salt, and pollutants. However, the relative importance of wave, cross-shore wind, and along-shore wind forcing will depend on water depth and wind strength.

The forcing mechanisms for cross-shore exchange on this inner shelf are fundamentally different from those at mid-shelf. This is likely true in a wide variety of inner-shelf locations, including those on the west coast of the United States.

Stephanie Henson, University of Maine

Phytoplankton scales of variability in the California Current System: A wavelet analysis

Authors: Stephanie Henson and Andy Thomas (School of Marine Sciences, University of Maine, Orono, ME)

Abstract: Eddies and meanders are ubiquitous features of the CCS coastal jet and are thought to play an important role in the productivity of the region. However, characterising the spatial and temporal variability of phytoplankton remains a challenge. A method commonly employed to extract the dominant frequencies from a time series of data is the Fourier transform, but it contains no information on the temporal evolution of a signal's spectral characteristics. A technique recently introduced in oceanography is wavelet analysis. This method allows the dominant modes of variability – AND how they change in time or space – to be determined. We apply the analysis to over seven years (October 1997 – December 2004) of SeaWiFS chlorophyll-a concentration data. Maximum variance in chlorophyll occurs with periods of ~ 100–200 days, and varies with distance offshore. Interannual variability in the magnitude of chlorophyll variance is also observed, with maxima in 1999, 2001 and 2002. A seasonal cycle in the timing of the peak variance occurs, with maxima in the spring/summer close to shore and in autumn/winter further offshore, which we associate with the migration of the coastal jet. Peaks in the latitudinal distribution of chlorophyll variance are found to correspond to topographical features of the coastline.

Anthony Kirincich, Oregon State University

Spatial and temporal variability of inner-shelf circulation along the central Oregon coast during summer

Authors: Anthony R. Kirincich and John A. Barth (College of Oceanic & Atmospheric Sciences, Oregon State University, Corvallis OR)

Abstract: The nature and variability of inner-shelf circulation along the central Oregon coast are examined using

measurements obtained in water depths of 15 m during the summer of 2004. Although wind forcing and bathymetry are spatially uniform in the inner-shelf, distinct differences in circulation existed among four along-shelf stations. Upwelling circulation at the northernmost station, north of an offshore submarine bank, is similar to classic two-dimensional (2D) upwelling with bottom stress and acceleration balancing the along-shelf wind stress. In contrast, onshore of the bank at the southern three stations, the 2D balance is poor and inclusion of the pressure gradient and nonlinear terms improves the momentum balance. During downwelling events the 2D balance holds well at the southern sites, but poorly at the northern site. The dominant mode of variability, found using EOF analysis of pressure, along-shelf velocity, across-shelf surface transport, and density, was correlated to the local wind forcing and seen at all stations. A second mode, seen only off the bank, drives additional upwelling or downwelling. The temporal and spatial differences observed result from region-wide flow-topography interactions which leave the on-bank stations in a lee. By late summer, inner-shelf flow during upwelling is strong and southward north of the bank, weak onshore of the northern part of the bank, and increasingly southward to the south. These results agree favorably with previous outer- and mid-shelf studies conducted in the region, while offering new insight into physical and ecological interactions in the inner-shelf.

Eric Kunze, University of Victoria

Observations of biologically-generated turbulence in Saanich Inlet

Authors: John F. Dower, Ian Beveridge, and Richard Dewey (University of Victoria, Victoria, BC)

Abstract: Measurements in Saanich Inlet, B.C., reveal elevated turbulence levels during the dusk and dawn vertical migration of the acoustic scattering layer of krill. Although these intense turbulence events only last about 10 minutes, they raise daily-averaged eddy diffusivities in the inlet to (4–40) cm2/s as compared to the 0.02 cm2/s average without them. Since vertically migrating layers of swimming organisms are found in much of the ocean, biologically-generated turbulence may impact (i) transport of inorganic nutrients into the depleted surface layer from underlying stratified waters to affect biological productivity, and (ii) the exchange of atmospheric gases with the stratified ocean interior. Sampling to date shows sensitivity to weather conditions.

Murray Levine, Oregon State University

Momentum balance off the Oregon coast

Authors: Murray D. Levine, Timothy J. Boyd, and P. Michael Kosro (Oregon State University, Corvallis, OR)

Abstract: We explore the vertically-integrated momentum balance using observations of the wind-driven circulation off the Oregon coast during the 2001 COAST experiment. The results are very sensitive to the orientation of the horizontal coordinate defining alongshore and cross-shore directions. A small rotation of the horizontal coordinate can result in large changes in the "alongshore" balance due to contamination by the dominant "cross-shore" near-geostrophic balance. We compare and contrast the momentum balance for an upwelling and a downwelling-favorable wind event.

Bill Peterson, NOAA-Fisheries

An investigation into time lags between recent high-frequency changes in the PDO and response of various components of the ecosystem in the northern California Current

Authors: William T. Peterson and Robert I. Emmett (NOAA-Fisheries, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR)

Abstract: Decadal variability in the climate of the North Pacific Ocean, as indexed by the Pacific Decadal Oscillation (PDO), has recently shown high-frequency variability: a 20-year warm phase which ended in 1998 was followed by a 4-year cold phase (1999–2002) and a 4-year warm phase (2003–2005), and now perhaps a switch back to cold phase (2006). Shifts to cold (warm) phase in the northern California Current (NCC) resulted in increased (decreased) biomass of zooplankton and baitfish such as osmeriids, anchovies and sardines, dramatic increases (decreases) in survival rates of both coho and Chinook salmon, and increased (decreased) reproductive success of marine birds. This high-frequency climate variability has handed us a grand experiment that allows us determine in what ways and how quickly hydrographic properties, plankton, and fish respond to short term climate variability. We explore the time lags between PDO phase changes and changes in temperature, salinity, the spring transition, zooplankton, baitfish, salmon abundance and species composition in the NCC. We will also briefly review the biological impact of warm ocean conditions in the NCC observed in 2005: zooplankton stocks were reduced by half, baitfish stocks crashed, salmon returns declined, and seabird deaths were extraordinarily high for common murres, cormorants and Cassins' auklet populations. Evidence suggests that the 2005 oceanic warm event was as devastating to the NCC coastal marine ecosystem as the El Niño of 1998.

Stephen Pierce, Oregon State University

Observations of the poleward undercurrent in the California Current System, 1995–2005

Authors: S. D. Pierce, P. M. Kosro, C. D. Wilson, B. Hickey, G. W. Fleischer, P. H. Ressler, and J. A. Barth (Oregon State University, Corvallis, OR)

Abstract: As one of the oceanographic components of the joint US-Canada hake survey cruises in recent years, velocities were observed with shipboard acoustic Doppler current profiler. A series of velocity sections extending from mid-shelf to mid-slope at about 18 km meridional spacing were collected in 1995, 1998, 2001, and 2003 from Monterey to Vancouver Island (Monterey to Cape Mendocino in 2005). Tidal velocities are estimated and removed using OSU Tidal Inversion Software. Survey-means of all the cross-shore sections reveal significant subsurface poleward flow with a core >0.1 m/s for each survey. The depth of the maximum poleward velocity varies from 200-300 m. Mean poleward transports range from 0.6-1.0 Sv. The undercurrent core is centered 20-30 km (10-15 km) off the shelf break in 1995 and 1998 (2001 and 2003). These observations generally confirm previous Eulerian as well as Lagrangian studies of the poleward undercurrent, increasing confidence in the robustness of the feature.

Andrew Thomas, University of Maine

Comparisons of interannual variability in chlorophyll between four Eastern Boundary Current regions

Authors: Andrew Thomas (University of Maine, Orono, ME), P. Ted Strub (Oregon State University, Corvallis, OR), Peter Brickley (University of Maine, Orono, ME)

Abstract: Eight years (Sept 1997 – Dec 2005) of SeaWiFS data, remapped over the 4 global Eastern Boundary Current regions as monthly composites, are used to quantify the interannual variability of chlorophyll concentrations. Climatological seasonal cycles are removed. As a function of latitude, concentrations averaged over the 100km closest to the coast capture the majority of upwelling-related chlorophyll variability. In the 2 Pacific regions, maximum negative anomalies are associated with the 97–98 El Nino, strongest off Peru, central Chile and the Pacific Northwest. Strongest positive anomalies are in 2001–02 and in 2005 in the California Current, and in 2002–04 off Peru and 1998–2000 off central Chile. Negative anomalies of magnitudes similar to the Pacific El Nino signals are evident only episodically in the 2 Atlantic systems, and then only over restricted latitudinal ranges, strongest off Namibia and Western Sahara in 1998, off Namibia in 2002 and South Africa in 2005. Maximum positive anomalies are strongest through most of 2000 and 2003–04 in the Benguela but restricted to the winters of 1997–98 and 2000–01 off North Africa – Iberia. Overall patterns are summarized as EOF decompositions and compared first to each other statistically and then to wind forcing and circulation signals derived from altimeter data.