59TH ANNUAL EASTERN PACIFIC OCEAN CONFERENCE

EPOC 2012 ABSTRACTS

Timberline Lodge, Mt. Hood, OR
19-22 September 2012

Co-chairs: Sarah Giddings & Dave Sutherland
EPOC President: Albert Hermann
EPOC Treasurer: Noel Pelland

Please contact Sarah (sarahgid@uw.edu, 510.406.4574) with any questions

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Thursday, 20 September Morning Session: *How does basin-scale variability affect the connectivity of the California Current System (CCS): Its currents and ecosystems?*
Chairs: Chris Mooers and Bill Peterson

820 **Parker MacCready (UW School of Oceanography)** and Matthew Alford (UW Applied Physics Laboratory)

Modeling internal wave generation and propagation on the NE Pacific shelf

Internal gravity waves are known to be an important part of energy-carrying motions on the continental shelf globally, with the ability to cause turbulent mixing at sites remote from their generation regions. Using a realistic high-resolution (~1km) numerical hindcast simulation of the shelf and slope off Oregon, Washington, and British Colombia, we calculate the rate of conversion of barotropic tidal energy into baroclinic motions. The generation sites are localized near steep bathymetry, and are highly patchy in space and time. Internal wave energy fluxes show that the waves generated decay rapidly away from their sources, with decay scales on the order of 50 km. Comparing the IGW energy flux to observations from the NEMO mooring in 100 m of water on the Washington shelf just south of the mouth of the Strait of Juan de Fuca, the model energy flux is about 30% of that observed, and is coming from a different direction. This suggests that offshore low-mode internal waves, absent from the model forcing, may be of leading order importance here.

840 **Pavel A. Fayman (OSU College of Earth, Ocean and Atmospheric Sciences)**, A. L. Kurapov (OSU CEOAS), J. S. Allen (OSU CEOAS), R. K. Shearman (OSU CEOAS), and G. D. Egbert (OSU CEOAS)

Interannual variability in the northwest Pacific coastal ocean affected by basin-scale processes

A 2-km horizontal resolution model of the California Current System has been developed to study interactions of basin-scale ocean variability with coastal ocean circulation along the US West coast. The model is based on the Regional ocean model system (ROMS). The domain extends from 35°N to 50°N in the alongshore direction, with boundary conditions obtained from the HYCOM+NCODA Global 1/12° Analysis and atmospheric forcing from NOAA NAM. The model has been run (without assimilation) for the period of Sept. 2008 - Dec 2010. Model results have been compared against available data, including satellite SSH and SST, glider hydrographic transects near 45°N, mooring and tide gauge time series, and high-frequency radar surface currents. Considerable differences are found between 2009 and 2010, with the latter year showing influences of El Niño. In particular, winter downwelling conditions were stronger and extended farther south in 2010, and the start of summer upwelling in 2010 was delayed. The resulting stronger northward alongshore current in winter 2010 was associated with formation over the continental slope of a chain of large surface-intensified anticyclonic eddies that affected subsurface transports and formation of upwelling source waters on the mid-Oregon shelf. Stronger winds in winter 2010 resulted in deeper vertical mixing of near-surface waters than in 2009, providing conditions for substantially different vertical density structures over a shelf and slope during periods of summer upwelling in each year.

900 **Dudley B. Chelton (OSU College of Earth, Ocean and Atmospheric Sciences)**, P. Gaube (OSU CEOAS), R. M. Samelson (OSU CEOAS), and M. G. Schlax (OSU CEOAS)

Satellite Measurements of Mesoscale Eddies and Associated Air-Sea Interaction in the California Current System

An eddy detection algorithm applied to 18 years of altimeter measurements of sea-surface height identifies about 1600 mesoscale eddies with lifetimes of 8 weeks or longer in the California Current System (CCS). More than 95% of the eddies are nonlinear and can thus transport trapped fluid. Most form within 50–100 km of the coast and their amplitudes and nonlinearity are maximum about 200-300 km from the coast. Anticyclones outnumber cyclones by about 13%. About 125 eddies of each polarity propagated more than 500 km. Eddies of both polarities tend to be deflected equatorward, more so for anticyclones than cyclones.

Collocation of satellite measurements of sea-surface temperature (SST), wind speed and wind stress curl (Ekman pumping) to the eddy interiors reveals distinct eddy-induced variability. The SST response consists largely of rotational horizontal advection around the eddy interiors. The resulting SST anomalies generate positive and negative wind speed anomalies over warmer and colder water, respectively, that are consistent with the air-sea interaction observed globally over meandering SST fronts. The Ekman pumping associated with these wind anomalies tends to attenuate the eddies. Ekman pumping is also generated by the relative velocity between the surface winds and the surface currents in the rotating eddies. The polarity of this current-induced Ekman pumping is opposite that of the eddy polarity, thus attenuating eddies of both polarities. The surface current effects on Ekman pumping are generally stronger than the effects of air-sea interaction.

920 **Brian Beckman (NOAA NW Fisheries Science Center)**, M. Trudel (DFO Pacific Biological Station), and L. Rohrbach (NOAA NWFSC)

Variation in marine growth of juvenile salmon: relations to the NPGO and PDO

Marine growth of juvenile salmon has been assessed in a series of ocean surveys by measuring levels of the hormone IGF1. IGF1 has been validated as a growth index in laboratory studies and has been found to reflect growth rate over roughly a one-week interval. Early marine growth rate has been found to relate to subsequent survival rates of adult salmon in a number of samples. Determining the oceanographic mechanisms regulating early marine growth rate, and thus subsequent adult survival rates, is of substantial interest.

The PDO and NPGO are two indices of oceanographic structure in the NE Pacific Ocean. We will explore how inter-annual variations in these indices relate to variation in growth off the Washington Coast (2000 – 2011) and British Columbia Coast (2007 – 20011). Subsequently, we will down-scale the PDO and NPGO indices to local measures of temperature and sea surface height to begin to ascertain actual oceanographic mechanisms altering ocean productivity and salmon growth.

940 **Albert J. Hermann (UW Joint Institute for the Study of the Atmosphere and Ocean),** C. Ladd (NOAA Pacific Marine Environmental Laboratory), W. Cheng (UW JISAO), E. N. Curchiter (Institute of Marine and Coastal Sciences, Rutgers University), and K. Hedstrom (Arctic Region Supercomputing Center)

A model-based examination of multivariate physical modes in the eastern and western Gulf of Alaska

The Gulf of Alaska (GOA) supports major marine resources, and is governed by unique physical dynamics which include substantial tidal mixing, strong eastern and western boundary currents, seasonal downwelling circulation, along-canyon transport, and intermittent cross-shelf transport by eddies. Using multivariate EOF analysis, we have examined a suite of physical variables from circulation model output (wind stress, temperature, salinity, mixing, surface heat fluxes) to determine how these co-vary and to what extent we can summarize the combined physical state of the GOA using a limited set of spatial/temporal patterns. We also examine the correlation of large-scale atmospheric/oceanic patterns (PDO, ENSO, NPGO) on multivariate patterns in the GOA. These analyses indicate that El Niño (as represented by the Multivariate ENSO Index, MEI) is a

dominant contributor to variability of the region as a whole, being strongly correlated with the leading multivariate mode of the GOA. This leading mode includes stronger northeastward wind stress, stronger Alaska Gyre circulation, high coastal sea surface height anomalies, warm sea surface temperatures, deeper coastal mixed layer depths, enhanced shortwave radiation, and enhanced sensible heat losses. When the eastern and western halves of the GOA are analyzed separately, the North Pacific Gyre Oscillation (NPGO) is found to be significantly correlated with the leading multivariate mode of the eastern half. This leading mode contained higher coastal sea surface height and stronger coastal flows in association with intensified northwestward wind stress, but unlike the leading mode of the full GOA, had no significant SST signature.

1000 - 1020 *BREAK*

1020 **Jennifer L. Fisher (OSU Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center)**, W. T. Peterson (NOAA NWFSC), C. A. Morgan (OSU CIMRS), and J. O. Peterson (OSU CIMRS)

Basin-scale versus local-scale drivers of copepod community dynamics in the northeast Pacific

We have been exploring the relative effects of basin-scale forcing versus local upwelling on copepod community structure and biomass in the northeast Pacific at stations that represent the nearshore coastal upwelling zone, shelf break, and the open ocean out to 100 km from shore. Hydrographic and zooplankton data have been collected every two weeks for the past 17 years at the nearshore station, and this effort has shown that copepod species composition exhibits a strong seasonal cycle and that inter-annual variations in specific copepod communities are driven largely by basin-scale processes opposed to processes associated with local upwelling. Initial analyses also suggest that the community dynamics nearshore are in synch with those offshore, both at the shelf break (40 km from shore) as well as in the open ocean up to 100 km from shore. This suggests that large-scale transport processes control zooplankton species composition and community structure along the northern California Current and in the coastal upwelling zone off Oregon, USA, whereas upwelling itself may control only local productivity.

1040 **Curtiss O. Davis (OSU College of Earth, Ocean and Atmospheric Sciences)**, N. Tufillaro (OSU CEOAS), and J. Nahorniak (OSU CEOAS)

Eight years of Phytoplankton and Columbia River Plume dynamics from MERIS data

The European Space Agency's MERIS flying on ENVISAT (2002-2012) provides unique data for the coastal ocean. MERIS had additional spectral channels to separate suspended sediments from phytoplankton and to identify large plankton blooms. Where ground stations are available to acquire the data MERIS has a 300 m high resolution mode and special algorithms for the coastal ocean products. For the period 2004-2012 we have acquired and archived this 300 m MERIS for the west coast of the US from the Canadian Space Agency ground station and ESA archives. During this period the Pacific Decadal Oscillation (PDO) went from a warm phase (2004-5) to a neutral phase (2005-2007) and then a cool phase (2007-2012). Here we use the MERIS data to examine the dynamics of phytoplankton in the coastal upwelling, the California Current System and the Columbia River Plume looking for impacts and changes resulting from the shift in the PDO during this period.

1100 **Raphael M. Kudela (UCSC Ocean Sciences Department)** and M. Kahru (SIO)

Are Red Tides Linked to Basin Scale Oscillations?

We are witnessing a shift in marine phytoplankton communities within Eastern Boundary Current systems (EBCs), characterized by increasing biomass, increasing productivity, and potentially,

increasingly abundant dinoflagellates. Associated with these changes are increasing frequency and duration of negative impacts to both human and wildlife health since most organisms classified as Harmful Algal Blooms are also dinoflagellates. Time series from the US west coast suggest that true red tides have increased dramatically since 2005 coincident with mesoscale changes in depth and intensity of stratification and upwelling-favorable winds. Satellite ocean color can potentially provide an excellent tool for tracking these changes since a nearly 15-year record is available. However, intense blooms can create issues with standard processing of the imagery leading to a potential bias (underestimate) in coastal biomass and productivity. Here we explore both the technical challenges of extracting ocean color information from coastal time series and use these data in conjunction with long term records from shore and mooring platforms to link changes in bloom dynamics to the underlying physical processes dominating the California Current System. We show that dinoflagellate blooms, including true red tides, exhibit decadal-scale changes that appear to be linked to basin-scale restructuring of upwelling, stratification, and possibly land-sea connectivity.

11:20 H. Song (SIO), **Art Miller (Scripps Institution of Oceanography)**, S. McClatchie (NOAA NMFS), E. Weber (NOAA NMFS), K. Nieto (NOAA NMFS), and D. Checkley (SIO)

Application of a data-assimilation model to variability of Pacific sardine spawning and survivor habitats with ENSO in the California Current System

The Pacific sardine (Sardinops sagax) showed significant differences in spawning habitat area, spawning habitat quality and availability of survivor habitat as the Pacific Ocean went through the La Niña state in April 2002 to a weak El Niño in April 2003. During another El Niño/Southern Oscillation transition period in 2006/2007 when the El Niño state retreated and the La Niña returned, a similar pattern in spawning habitat quality was seen. The coupling between the atmospheric forcing, the physical ocean states and the properties of the sardine egg spawning are investigated using dynamically consistent data assimilation fits of the available physical oceanographic observations during these months. Fits were executed using the Regional Ocean Modeling System four-dimensional variational assimilation platform along with adjoint model runs using a passive tracer to deduce source waters for the areas of interest. Analysis using the data-assimilation model runs reveals that unusually strong equatorward wind forcing drives offshore transport during the La Niña conditions, which extends the spawning habitat for sardine further offshore. A statistical model of sardine spawning habitat shows better habitat quality during the El Niño conditions, which is associated with higher egg densities and corresponded to higher daily egg production. Concentration of eggs is also increased by convergence of water. The results of the source waters analysis using the adjoint data assimilation model support the idea that offshore transport extends the spawning habitat, and show that higher levels of nutrient are brought into the spawning habitat with high concentration of sardine eggs.

11:40 **Ariane Verdy (Scripps Institution of Oceanography)**, M. R. Mazloff (SIO), and B. Cornuelle (SIO)

State Estimate and sensitivity for the California Current System

Satellite measurements of the surface ocean and sensor-based measurements of the interior ocean are used to constrain the solution of a general circulation model for the southern California Current System (CCS). The resulting state estimate is a dynamically-consistent, eddy-resolving hindcast covering the period January 2007 to December 2010. Using the adjoint (4DVar) method, observations are used to adjust "controls" consisting of atmospheric state, open boundary conditions, and initial conditions. The state estimate is a free forward simulation using those optimized controls, largely consistent with available observations.

The adjoint provides a useful tool for quantifying the sensitivity of the ocean state to underlying processes. As an example, we present an analysis of the sensitivity of coastal sea surface height (SSH) to local and remote forcing. Sensitivities are attributed to alongshore and cross-shore wind stress, heat fluxes, and freshwater fluxes. Our results suggest that (i) the short-term response to local wind forcing dominates; (ii) the effect of non-local winds is carried by coastally-trapped waves and near-inertial waves; (iii) there are significant seasonal variations due to changes in stratification.

A state estimate of the carbon cycle in the CCS is being produced by coupling the physical model to a simplified representation of ocean biogeochemistry. The adjoint of the coupled model is used to adjust biogeochemical controls and bring the state estimate into consistency with measurements of ocean color, pCO2, pH, oxygen, and nutrients. We present initial results from the 4-year biogeochemical model-observation synthesis.

12^{00} - 16^{00} *BREAK - lunch & afternoon free time, snacks served starting at* 15^{45}

Thursday, 20 September Afternoon Session: *Upwelling intensification: fact or fiction?*
Chairs: Bill Sydeman and Marisol Garcia-Reyes

1600 **Marisol García -Reyes (Farallon Institute for Advanced Ecosystem Research)** and W. J. Sydeman (Farallon Institute)

Geostrophic and measured winds: on trends, similarities and differences

The effect of increasing green-house gases concentration on the eastern boundary upwelling systems (EBUS), as proposed by A. Bakun in 1990, is due to the deepening of the thermal low pressure systems in the adjacent continents. The lower pressure over land would lead to a greater cross shore pressure gradient between the continental pressure systems and the ocean high pressure cells, strengthening the resultant alongshore geostrophic winds. However, geostrophic winds are not the only driver of winds at coastal areas since they are regional-scale winds in an equilibrium state easily modified by local conditions. Furthermore, other processes also drive upwelling winds; for example, the trade winds at lower latitudes or the low pressure systems, not associated with continental warming, at higher latitudes (v. gr. northern Canary Current). At the core of the EBUS geostrophic and coastal winds are well correlated (40-80%) during the upwelling season, except for the Humboldt system where upwelling is driven mainly by the trade winds. Therefore, if an increase in cross shore pressure gradient is occurring due to the effect of green-house gases, the next question is if and how this change is transferred to the coastal winds. Here, based 64 years of NCEP data, we analyze the seasonality and trends in geostrophic and coastal winds at the four EBUS. We show that there are differences in the coastal wind trends among and within systems and that these trends are not easily related to the trends in geostrophic winds, except at certain regions.

1620 ***Keith E. Leffler (PSU Civil and Environmental Engineering)** and D. A. Jay (PSU CEE)

An Examination of Long-Term Upwelling Intensity and Transition Dates on the Oregon/Washington Coast

The date of onset of coastal upwelling and upwelling intensity are important ecological parameters for the Columbia River Estuary and neighboring coastal region. Previous high-resolution estimates of upwelling transition dates have generally been limited to 1967-present by the availability of the Coastal Upwelling Index (CUI). This work estimates dates of spring transition and upwelling intensity from 1871 with a combination of novel techniques. First, using the recently completed 20th Century Climate Reanalysis, Version 2, the Coastal Upwelling Index is computed for the years 1871-2008, extending the CUI record by 96 years. Long term behavior of the surface wind stress may be estimated directly from the longer CUI record. Second, height variations from seasonally varying river flow are removed from the Astoria tide record, using an enhanced version of the models of Kukulka and Jay, an efficient method for long data sets. Correction for flow allows Astoria to be added to the small set of tide stations with 50+ years of data, a necessity for examining long-term upwelling behavior from sea level records. Finally, a wavelet-based method, specifically designed to detect step-like changes, is used to estimate transition dates. For the years 1925-present, CUI and flow-adjusted sea level are used in combination, while CUI alone is used prior to 1925. Using these techniques, estimates of the spring transition and upwelling intensity are developed from 1871 to present. An analysis for trends and correlations with climate signals will be presented.

1640 **Brian Wells (NOAA Southwest Fisheries Science Center, Fisheries Ecology Division)**, R. Mendelssohn (NOAA SWFSC Environmental Research Division), I. Schroeder (UCSC Applied Math and Statistics), J. Santora (Farallon Institute), and V. Brown (UCSC Applied Math and Statistics)

Coastal turbulence, upwelling, and wind shear time series examined 1946-2012: Extending Schwing and Mendelssohn (1997)

In central California, it has been well documented that wind strength and structure are the exogenous factors that largely determine the production of krill, salmon, rockfish, and seabirds. For this region, we extend the physical time series analysis of Schwing and Mendelssohn (1997, JGR 102:3421-3438) by nearly 20 years. As well, we examine not just upwelling specifically, but also time series of turbulence and wind shear which each, in distinct ways, affect the biology of the region: coastal and open ocean production, wind mixing, and advection (sensu Bakun and Parrish 1982, CalCOFI 23: 99-112). Using state-space models we demonstrate a secular increasing trend in wind shear, as well as a modest seasonal amplification in wind shear, turbulence, and upwelling intensity. Following, we demonstrate a reduction in the likelihood of optimal winds occurring in the region during the upwelling season (sensu Cury and Roy 1989, CJFAS 46:670-680). Inclusion of basin-scale variables (eg, NPH, ENSO) did not explain secular trends nor seasonal amplification patterns indicating that they likely derived from the interaction of the land mass and coastal ocean. Finally, as a real-world examples of the probable consequences of these changing wind patterns, we examine our results in the context of Santora et al (2011, Prog Ocean 91:397-409) and Wells et al (2012, MEPS 457:125-137) wherein krill distributions were related to wind patterns along the coast.

1700 **James A. Johnstone (UW Joint Institute for the Study of the Atmosphere and Ocean)**, N. J. Mantua (UW JISAO)

A history of NE Pacific SST and atmospheric circulation, 1900-2011

Northeast Pacific sea surface temperatures (SSTs) are strongly influenced by large-scale atmospheric circulation anomalies that have undergone substantial trends and variations since 1900. Using century-long gridded records of sea-level pressure (SLP) and SST, we demonstrate that the dominant pattern of surface temperature variation for the coastal NE Pacific can be modeled as a direct product of regional atmospheric circulation. Using a first order autoregressive model, we show that a simple metric of atmospheric pressure combined with a persistence term accounts for over 60% of the historical monthly- to century-scale SST variations over the past 112 years. SST variations from monthly to century scales can be largely attributed to incremental changes produced by upper ocean heat flux anomalies that are sensitive to the regional atmospheric circulation. Our SLP-SST analysis indicates that circulation-driven changes are substantial over the past century, including strong coastal warming from ~1910 to 1940 and recent multidecadal shifts associated with the Pacific Decadal Oscillation (PDO). We also show that summer coastal upwelling winds at 45°N, 125°W are sensitive to more localized variations in the NE Pacific atmosphere. We illustrate a long-term (1900-2011) index of coastal upwelling based on SLP data, and find no clear evidence for a secular increase. It is notable, however, that upwelling winds have been relatively strong since 1998. The Pacific and global climate patterns associated with this 1998 increase are discussed and placed in the historical context of the past century.

1720 **Ryan R. Rykaczewski (USC Marine Science Program)** and J. P. Dunne (NOAA GFDL)

Response of upwelling winds to a warming climate: IPCC model projections

Given the general expectation of increased heating of landmasses relative to the oceans under increased greenhouse-gas concentrations, it has been suggested that continental thermal lows, the ocean-continent atmospheric pressure gradient, and the magnitude of upwelling-favorable winds will intensify. Evaluating the importance of this mechanism relative to other atmospheric processes which may also influence upwelling winds (e.g., the position of the North Pacific High and the static stability of air masses given long-term changes in temperature and specific humidity) is

challenging. In order to assess the upwelling intensification hypothesis in a comprehensive fashion, we examined the strength and seasonality of alongshore winds in the California Current region using a suite of different coupled ocean-atmosphere models assembled for the Fifth Assessment Report by the Intergovernmental Panel on Climate Change. In contrast to the general expectation of intensified upwelling winds in summer, the magnitude of summer winds is projected to weaken. However, these models do consistently project and earlier seasonal onset of upwelling-favorable winds in spring. This change in seasonality is related to the poleward migration of the major atmospheric pressure cells that is projected as a consequence of global warming, and these changes may be more important in structuring the coastal wind characteristics than the intensification mechanism. The lack of an increased pressure gradient during summer with global warming is related to the changing interactions among temperature, pressure, and specific humidity.

17^{40} **Andrew Thomas (UMaine School of Marine Sciences):** , R. Weatherbee (UMaine SMS), and R. Mendelssohn (NOAA SWFSC)

13-year Trends in California Current Chlorophyll Concentrations

Data from the thirteen-year (1997 – 2010) SeaWiFS satellite mission covering the California Current region (23°N – 50°N) are analyzed to isolate and quantify dominant time/space patterns of overall chlorophyll trends. We use state-space models to separate the time-varying chlorophyll signal at each location into 3 components: a time-dependent slowing varying trend, a non-stationary seasonal component, and a stationary, normally distributed residual or "error" term that includes many episodic anomaly events. We use k-means clustering to group time series whose trends behave similarly over the 13-year period. Silhouette analysis suggests 5 major groups. Mapping these groups shows the resulting spatial geography of trends, with latitudinal differences in cross-shelf zonation. Two groups, one representing coastal upwelling regions from WA to Point Conception, and the other the Southern California Bight area south to Punta Eugenia, show increasing trends over study period, even when the El Nino period of 1997-98 is not included. Other regions representing a) offshore temperate water (north of ~ 35°N), b) the coastal upwelling region of southern Baja California and c) subtropical offshore regions off southern Baja have significant interannual variability but no overall trend. Trends in each region are compared to those evident in simple least squares regression models and loess filtering. Trends are then compared to variability over the same region in wind forcing and SST, and to previously described basin-scale climate signals important to forcing in the California Current such at the MEI.

Friday, 21 September Morning Session: *General Session*
Chairs: Jeff Paduan and Jim Lerczak

820 **Jun-Hong Liang (UCLA)** and J. C. McWilliams (UCLA)

The impact of high-frequency mountain gap winds on the northeastern tropical Pacific

The wind jets funneling through the three mountain gaps of Central America have a substantial impact on the mean state and variability of the northeastern tropical Pacific (NETP). Oceanic responses to high-frequency synoptic gap winds include nearshore surface cooling, nearshore chlorophyll bloom, and the spin-up of asymmetric dipole circulations. These responses are explained and quantified by a synthesis of satellite observations and simple models. In order to assess the contribution of synoptic wind events on regional mesoscale variability, we construct a series of numerical solutions for the NETP using the regional ocean modeling system (ROMS). Different eddy generation mechanisms are represented by different lateral and surface boundary conditions in these solutions. The combined large-scale circulation and low-frequency wind forcing is the dominant generation mechanism for eddies in NETP, both synoptic wind forcing and remote equatorial Kelvin wave forcing play an addition role. The synoptic events contribute to 8% to 20% of the regional eddy activity in different seasons.

840 ***Cheryl Harrison (UCSC)**, D. Siegel (UCSB/ERI), and S. Mitarai (OIST)

The role of filamentation and eddy-eddy interactions in marine larval accumulation and transport

A coupled particle-tracking/ocean circulation model of an idealized eastern boundary upwelling current is used to explore the mesoscale pathways of larval transport. We find that simulated larvae are often organized into filaments found between mesoscale eddies that correspond to attracting Lagrangian coherent structures (LCS). LCS are material curves that map filamentation and transport boundaries, often corresponding to the locations of sea surface temperature fronts. Filamentation and eddy-eddy interactions aggregate larvae from many source regions and release times into small, highly dense packets that can be transported back to the shelf. Larval densities in these packets can be up to two orders of magnitude greater than initial release densities near the coast and are robust to strong levels of random "swimming" perturbations. This study suggests that coherent flow structures play an important role in pelagic transport of marine larvae.

900 **Jeffrey Paduan (Naval Postgraduate School)**, S. Frolov (MBARI), M. Cook (NPS) and J. Bellingham (MBARI)

Improved statistical prediction of surface currents based on historic HF-radar observations

Accurate short-term prediction of surface currents can improve efficiency of search-and-rescue operations, oil-spill response, and marine operations. We developed a linear statistical model for predicting surface currents (up to 48 hours in the future) based on a short time-history of past HF-radar observations (past 48 hours) and an optional forecast of surface winds. Our model used empirical orthogonal functions (EOFs) to capture spatial correlations in the HF-radar data and used a linear autoregression model to predict the temporal dynamics of the EOF coefficients. We tested the developed statistical model using historical observations of surface currents in Monterey Bay, California. The predicted particle trajectories separated from particles advected with HF-radar data at a rate of 4.4 km/day, which represents an improvement over the existing statistical model (drifter separation of 5.5 km/day). We found that the minimal length of the HF-radar data required to train an accurate statistical model was between one and two years, depending on the accuracy desired.

920 **Angelica Peña (DFO Institute of Ocean Sciences)** and D. Masson (DFO IOS)

Plankton ecosystem dynamics on a coupled physical-biological model of the Strait of Georgia

The Strait of Georgia is a highly productive, semi-enclosed sea with strong estuarine circulation connected to the North Pacific by the Juan de Fuca Strait. Significant geographical and temporal variability has been observed in this region, making it challenging to understand and detect ecosystem changes based on observations only. In order to better understand the key links between physical and biological processes determining lower trophic levels, a coupled plankton/circulation model (ROMS-Regional Ocean Modeling System) has been developed. The lower trophic level ecosystem component is a nine-compartment Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) model that includes two types of phytoplankton and zooplankton. Model results from simulations of the mean annual cycle will be presented. Modeled phytoplankton biomass shows pronounced seasonal variability consistent with observations. Model and observations indicate maxima phytoplankton abundances in April, when the increase in solar radiation and abundance of nutrients provide optimal growing conditions. In the model, physical variability plays an important role in maintaining the high spatio- temporal variability of plankton abundance. In particular, freshwater inflow and tidal mixing greatly influence the stability of the water column and the distribution and production of phytoplankton and zooplankton.

9^{40} C. Risien (OSU CEOAS), **Murray Levine (OSU College of Earth, Ocean and Atmospheric Sciences)**, and P.M. Kosro (OSU CEOAS)

The Annual Cycle of Temperature on the Oregon Shelf at NH-10

Time series observations from moorings have been made since 1999 (with some gaps) 10 nautical miles off Newport, Oregon on the Newport Hydrographic Line (NH-10) through NANOOS (Northwest Association of Networked Ocean Observing Systems) and GLOBEC (Global Ocean Ecosystem Dynamics) programs. This 80 m deep location on the shelf is often well-mixed vertically for 2 to 3 months during winter. Then the stratification of the water column begins in the spring and intensifies into summer, as the upper ocean warms due to solar heating and the deeper water cools due to upwelling circulation. The temperature at depth usually begins to increase by mid-summer followed by fall storms that continue the reduction of the stratification. This annual temperature cycle is discussed in the context of upwelling, downwelling and solar radiation.

10^{00} - 10^{20} *BREAK*

10^{20} **Stefan Talke (PSU)** and D. A. Jay (PSU)

Mean sea-level, tidal properties, and extreme events in Astoria, OR from 1853-present

In this presentation we describe our efforts to recover, digitize, and analyze the continuous tide gauge record from Astoria, OR from between 1853 to 1876. We have digitized hourly data (1870-76) and High/Low data (1853-54, 1860-1874, 1876) found in the NOAA archives. An additional twenty years of tide rolls were photographed at the National Archives in Kansas City from 1853 to 1875. The tide rolls depict a continuous pencil trace from which water levels are extracted at 6 minute resolution using software line-finding techniques, after rectifying images to remove camera distortion.

Initial gauge results obtained from 1861-1862 describe perhaps the harshest recorded winter in Northwest history, with occasional water temperatures below 0ºC. Using a power-law relationship between tidal properties (e.g., tidal admittance) and Columbia river data from 1876, we reconstruct the historical hydrograph and show that the catastrophic Dec. 1861 rain-on-snow flood produced a 32-day average flow of nearly 17,000 m3/s. Hence, this flood was approximately 35% larger than the largest 20th century winter flood in December 1964. Analysis of the 19th century tide data also suggests that (a) tidal phases were more than half an hour earlier, (b) the primary constituents such

as M2 were up to 10% smaller and (c) frictional overtides such as M4 were up to five times larger than the present. These changes are primarily caused by local anthropogenic activity but are also influenced by riverine and oceanic boundary conditions. Using benchmark data to be recovered in August 2012, we also compare historical and modern sea-level.

10^{40} ***Piero Mazzini (OSU College of Earth, Ocean and Atmospheric Sciences)** and J. A Barth (OSU CEOAS)

Freshwater observations from underwater gliders off the Oregon coast during fall-winter

Off the Oregon coast, a high contrast in the thermohaline structure is seen between the spring-summer and fall-winter seasons. The well studied and surveyed summer and spring seasons, are forced by upwelling favorable winds, bringing saline cold water near the coast and pushing warmer and fresher water offshore in the surface layers. Due to rough weather conditions, fall and winter seasons have not been as well surveyed until after 2006, when the OSU Glider Research Group began to use autonomous underwater gliders to survey the Oregon continental shelf and slope, allowing operations in nearly any weather conditions. During this time of the year the wind field is more variable, often downwelling favorable, and a significant amount of freshwater is discharged into the coastal ocean, from several mountainous rivers along the Oregon coast. As result of both wind-forcing and freshwater input, a well-marked low-density front is observed off Newport-OR, throughout these seasons. Over 50 of those fronts were identified in the glider data record, and their basic characteristics and response to the wind-forcing are being analyzed and preliminary results will be presented.

11^{00} **Carlos Moffat (University of Concepción)**, C. Nittrouer (UW), K. Boldt (UW), and A. Rivera (Centro de Estudios Científicos)

Warm water supply to a rapidly retreating Patagonian Glacier (Jorge Montt, Chile)

Understanding supply of heat to the terminus of melting glaciers is key to elucidate the role the ocean is playing in modulating loss of freshwater from the continents and to appropriately estimate present and future sea-level rise. Here, hydrographic and current velocity surveys conducted in the summer of 2010 and 2011, winter of 2011 and fall 2012 are used to study the dynamics of a fjord adjacent to Jorge Montt, a rapidly (1 km/year) retreating glacier in the southern Patagonian Ice Fields. During Summer, freshwater is carried from the glacier in a relatively thick (8-20m) surface layer with salinities of 5 or less, but active submarine melting/runoff is also observed at depth, identifiable as a number of horizontally coherent lateral intrusions extending through the deepest section of the channel, which lead to the overall cooling, freshening and oxygenation in the deep layer. During the winter, warmer waters occupy the deep basin while the surface layer is thinner and saltier, suggesting drastically reduced submarine melting and runoff. A shallow (<40 m) sill separating the 350-m fjord from the channel connecting the fjord to the Pacific Ocean leads to input of warm, shallow water to the fjord, while also restricting the renewal of the deep water next to the terminus. The effects of these competing factors, as well as the evolution of the offshore Pacific waters are discussed in the context of their potential to modulate the further retreat of Jorge Montt Glacier.

11^{20} **Leslie Rosenfeld (MBARI CeNCOOS)**, J. Scianna (MBARI CeNCOOS), F. Bahr (MBARI CeNCOOS), and J. Patterson (MBARI CeNCOOS)

An Update on CeNCOOS, the Central and Northern California Ocean Observing System

CeNCOOS is one of 11 regional ocean observing systems that together with a Federal backbone and national program office make up the Integrated Ocean Observing System (U.S. IOOS®), the U.S. contribution to the Global Ocean Observing System. The CeNCOOS region extends from Pt. Conception to the Oregon border, from the coast through the Exclusive Economic Zone. CeNCOOS coordinates closely with the regional ocean observing systems to its north and south, NANOOS and SCCOOS, respectively. CeNCOOS is a consortium of 50 members, and currently provides support to 15 principal investigators at 13 institutions. CeNCOOS supports a dozen automated shore stations, more than 20 high frequency (HF) radars, a continuously operating profiling glider, atmosphere and ocean numerical models, and a data management system. Most importantly, CeNCOOS serves data and information products to aid in informed decision-making concerning ocean ecosystems, fisheries, and water quality; climate change; maritime operations; and coastal hazards. For example, CeNCOOS water quality stations provide measurements of dissolved oxygen, pH, chlorophyll, and harmful algal blooms which are used by shellfish growers to aid in maximizing their yield. CeNCOOS is assisting in the evaluation of Marine Protected Areas by characterizing the physical environment, including winds, currents, temperature, and waves, of these areas over time. CeNCOOS is also participating in the development of methods for monitoring acidification in the coastal ocean. The surface currents derived from the HF radar measurements are used to inform, among other things: ship navigation and safety of maritime operations, search and rescue operations, and oil spill response.

11^{40} **Richard Dewey (University of Victoria VENUS)**, V. Tunnicliffe (UVic VENUS), and P. Macoun (UVic VENUS)

VENUS: An Update on Observatory Expansions

VENUS is one of two ocean observatories operated by Ocean Networks Canada of the University of Victoria. As the coastal network, VENUS has resources deployed in the Salish Sea east of Vancouver Island, while the NEPTUNE network extends westward from Vancouver Island out to the Endevour Ridge. Phase I of VENUS (2006) included the cabled network, with three bottom Nodes located in both Saanich Inlet and the Strait of Georgia. We are now half way through our Phase II expansion, which includes the installation of CODAR stations, Ferry systems, Gliders, a water column profiler, and a number of specialized experimental packages. An update on the science and observations, as well as the newest installations will be presented.

12^{00} - 16^{00} *BREAK - lunch & afternoon free time, snacks served starting at* 15^{45}

Friday, 21 September Afternoon Session: *Deoxygenation and acidification in waters of the Eastern Pacific*

Chairs: Samantha Siedlecki and Ryan Rykaczewski

1600 **Jay O. Peterson (OSU Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center)**, C. A. Morgan (OSU CIMRS), and W. T. Peterson (NOAA NWFSC)

Seasonal and interannual variability in the extent of hypoxia in the northern California Current from 1998 – 2011

Hypoxia within the northern California Current is highly seasonal, occurring during the period of active upwelling (May – Oct), and is patchily distributed in both time and space. We use 14 years of data to illustrate the seasonal and inter-annual variability in the timing and distribution of hypoxia off Oregon and Washington, identify regions of highest susceptibility, and look at potential contributing factors to the development of hypoxia over the shelf. We estimate that the area of hypoxia over the shelf has been as large as 15,600 km2 in some years, covering 62% of the shelf and the lower 30% of the water column. Regions of more persistent and severe hypoxia occur north of 42° N latitude where the shelf width is greatest. The average oxygen content of source-waters ranged from 1.9 – 2.5 ml L-1 inter-annually with the low values coincident with years of greatest extent and severity of hypoxia.

1620 **Alexander van Geen (Columbia University Lamont-Doherty Earth Observatory)**, W. Berelson (USCalifornia Earth Sciences), C. Deutsch (UCLA Atmospheric and Ocean Sciences), R. Thunell (USCarolina Earth and Ocean Sciences), T. Baumgartner (Centro de Investigación Científica y de Educación, Oceanografía Biológica), V. Ferreira (Centro de Investigación Científica y de Educación, Oceanografía Biológica), J. Mey (LDEO), O. Yajimovich Gonzalez (Superior de Ensenada), C. Tems (USCalifornia Earth Sciences), J. McManus (Universidad Autónoma de Baja California, Facultad de Ciencias Marinas), and J. Crusius (OSU CEOAS)

Variations in ocean hypoxia and thermocline depth over the past 120 years inferred from sediment 15N/14N at three sites along the western margin of North America

Climate warming is widely expected to reduce the oxygen supply to the ocean interior, leading to an expansion of the suboxic zones. To provide some paleoceanographic context, we measured bulk organic 15N/14N in 210Pb-dated sediments of three suboxic basins at 24°N (Pescadero), 25°N (Soledad), and 33°N (Santa Monica) to reconstruct past variations in the intensity of denitrification in the eastern Pacific that are closely linked extent and intensity of the oxygen-minimum zone. All three records indicate a 1 per mil increase in bulk 15N/14N over the past 30 years. This trend tracks an intensification of the oxygen minimum zone recorded by the CalCOFI hydrographic time series (McClatchie et al., 2010). According to a coupled atmospheric-ocean circulation model, the recent trend was driven by a deepening of the tropical and subtropical thermocline (Deutsch et al., 2011). Between 1900 and 1980, all three records show a more gradual but steady decrease in 15N/14N and, therefore, weakening of the oxygen-minimum zone during this interval. According to ensemble-mean model simulations from the IPCC, this trend appears to be driven by a shoaling of the thermocline linked to the increase in concentrations of anthropogenic greenhouse gases. Observations and modeling therefore confirm a close link between climate and the intensity oxygen-minimum zone in the northeast Pacific, although the direction of change is opposite to what is commonly assumed.

1640 **Jeffrey Abell (Humboldt State University)**, A. G. Dickson (SIO), V. J. Fabry (CSU San Marcos), and E. P. Bjorkstedt (HSU, NOAA SWFSC)

Documenting the frequency and intensity of exposure to aragonite corrosive water on the northern California continental shelf

Hydrographic surveys conducted in July 2007 and 2011 have identified aragonite corrosive waters on the western continental shelf during periods of intense upwelling. These surveys have documented the aragonite saturation horizon at depths of 60 m along much of the California coast and have found it at the very surface near Point St. George in northern California. Here, we present data from repeat hydrographic surveys near this region to ascertain the frequency and intensity of the shelf's exposure to corrosive waters. Since March 2010, hydrographic, DIC and alkalinity measurements have been made at quasi-monthly intervals along a transect extending 50 km offshore from Trinidad Head, CA. Results from the first two years of the survey indicate typical upwelling patterns associated with northerly winds beginning in May and peaking in August. Water column pH reaches its minimum during peak upwelling as evidenced by the shoaling of the pH = 7.75 isopleth from 100–175 m up to 25–65 m. This pH isopleth (which corresponds to the depth of the aragonite saturation horizon) was not observed at the surface. This may be due to the timing of sampling, which came after phytoplankton had already responded to the upwelling event and begun to photosynthesize (thus elevating local pH). Nonetheless, 50 – 90% of the water column was considered under-saturated with respect to aragonite during peak upwelling. Over an annual cycle, some fraction of the shelf is exposed to aragonite under-saturated waters over a longer period: from early May to late October.

1700 **Bill Crawford (DFO Institute of Ocean Sciences)** and N. Bolingbroke (DFO IOS)

Trends in oxygen on constant-density surfaces of the Northeast Pacific Ocean

We examined NODC observations of water properties, as well as those at the Institute of Ocean Sciences, to search for decadal changes in oxygen concentration in the upper thermocline of the Northeast Pacific Ocean. These archives extend back in time to the early 20th century. Where possible, we interpolated oxygen concentration onto constant sigma-theta surfaces. An initial examination of the results reveal a general decline in oxygen concentration since the 1980s throughout the Northeast Pacific, on both constant-depth and constant-density surfaces. This decline is also present in previous decades except off southern California, where oxygen concentration was lower in the 1960s than in the 1980s as noted in previous studies. Trends in oxygen concentration in sub-surface waters along the continental margin north of California seem to have been influenced by both deep-sea and California Undercurrent waters. As a result, the decline in oxygen concentration along the British Columbia continental margin has been greatest since the 1980s, with smaller decrease in previous decades. Additional results from this on-going project will be presented at EPOC.

1720 **Antonio Baptista (Oregon Health & Science University, Center for Coastal Margin Observation & Prediction)**, J. Needoba (OHSU, CMOP), C. Roegner (NOAA NWFSC), M. Wilkin (OHSU, CMOP), C. Seaton (OHSU, CMOP), S. Riseman (OHSU, CMOP), P. Welle (OHSU, CMOP), Y. Spitz (OSU, CMOP), C. Llebot (OHSU, CMOP), J. Lopez (OHSU, CMOP), B. Li (OHSU, CMOP), and W. Evans (U Alaska Fairbanks)

Estuarine hypoxia and acidification in the Columbia River

Shipboard observations of low dissolved oxygen in the Columbia River estuary (Roegner et al. 2011) led to high-resolution measurements of DO at selected stations of the SATURN observation network, starting 2010. These high-resolution measurements:

- reveal a systemic pattern of ocean-induced summer deoxygenation of estuarine waters, during sustained periods of upwelling;

• suggest (based on current understanding of source mechanisms) the likelihood of synoptic occurrence of estuarine acidification;

• suggest the possibility of estuarine hypoxia events being, under certain circumstances, mitigated by co-occurring blooms of Mesodinium rubrum.

As a consequence:

• we initiated in summer 2012 high-resolution measurements of pH and pCO2 at selected SATURN stations;

• we are exploring the use of high-resolution Phycoerythrin fluorescence measurements for surrogate detection and characterization of M. rubrum blooms;

• we began developing and exploring ecological models that might better explain the processes at play, thus allowing us to move from correlation to causation.

In this presentation we will provide a status report on our high-resolution observations and simulations, will describe an emerging conceptual model for Columbia River estuarine hypoxia and acidification, and will offer an early analysis of the possible role played by river discharges and M. rubrum blooms.

1740 **Samantha A. Siedlecki (UW Joint Institute for the Study of the Atmosphere and Ocean)**, N. Banas (UW JISAO), K. A. Davis (UW APL), S. N. Giddings (UW Oceanography), P. MacCready (UW Oceanography), T. Connolly (UW Oceanography), and B. Hickey (UW Oceanography)

Seasonal Oxygen Decline in an upwelling regime – A closer look at oxygen variation in the Pacific Northwest

Hypoxic regions (< 1.5 ml/l) exist over the shelf and slope of Washington and Oregon. Recent observations show the importance of both source water chemistry as well as local biogeochemical processes in determining seasonal hypoxia on continental shelves (Connolly et al, 2010). Using the external forcings and framework set up by the MoSSea (Modeling the Salish Sea) project, ROMS, and NCOM, realistic hindcasts of 2005, 2006, and 2007 are performed. Oxygen is modeled and coupled to the biogeochemical model from Banas et al (2008). Data from the ECOHAB PNW-RISE database is used to ground-truth the model. Results from 2005 indicate fresh nutrients from the slope are introduced in the spring when the slope currents are primarily equatorward, and then, over the course of the upwelling season, the nutrient source becomes more recycled, coincident with the emergence of the poleward undercurrent. As a result, oxygen concentrations in the spring source waters set the initial condition for hypoxia to develop as a result of biochemical interactions with organic matter and the sediments. Remineralization occurs mostly at the sediment interface on the Washington coast, while in Oregon and in the Juan de Fuca Eddy region, remineralization occurs primarily in the water column. Processes influencing the spatial variability in remineralization will be discussed.

Saturday, 22 September Morning Session: *Nearshore physics and biology*
Chairs: Kerry Nickols and Brock Woodson

820 **Fabian J. Tapia (Universidad de Concepción, Oceanography and** Estación Costera de Investigaciones Marinas, P. Universidad Católica de Chile**)**, S. A. Navarrete (ECIM P. Universdidad Católica de Chile), J. Largier (UC Davis Bodega Marine Laboratory), D. Storch (ECIM P. Universdidad Católica de Chile and Alfred Wegener Institute), M. Fernández (ECIM P. Universdidad Católica de Chile), and M. Parragué (ECIM P. Universdidad Católica de Chile)

Influence of mesoscale atmospheric forcing and local thermal regimes on recruitment variability of kelp crabs (Taliepus dentatus) at two intertidal sites in central Chile

Disentangling the complex physical-biological interactions that drive spatial and temporal variability in recruitment is a major challenge for the conservation of many coastal species. Physical processes that mediate larval dispersal do not necessarily determine patterns of recruitment, as sources of physiological stress for planktonic larvae, such as transient increases in water temperature, may alter recruitment patterns that would be expected from dispersal alone. Here we assess the extent to which recruitment variability in the kelp crab Taliepus dentatus, recorded monthly over 11.5 years at 2 intertidal sites in central Chile, may respond to changes in coastal wind forcing and local regimes of thermal variability characterized through in situ temperatures recorded in the shallow subtidal.

Recruitment of T. dentatus showed a strong seasonal pattern, beginning in early spring (September) and continuing through late summer (February-March). Monthly recruitment rates were highly coherent and positively correlated between sites. When integrated over each season, recruitment at both sites was positively correlated with cumulative alongshore wind stress, indicating that recruitment improved on years with stronger upwelling. Although daily surface temperatures at both sites were negatively correlated with the intensification of upwelling-favorable winds, hourly variability in local temperatures as a function of changes in synoptic wind differed substantially among sites. Integrated recruitment at one of the sites was strongly and negatively correlated with an index of transient heating (hourly temperature increases). Thus, high-frequency fluctuations in thermal conditions encountered by larvae nearshore may alter both the intensity and spatial structure of recruitment in coastal benthic invertebrates.

840 **Falk Feddersen (Scripps Institution of Oceanography)**

Surfzone eddies in strong alongshore currents: Forced or Instabilities?

Beaches throughout the United States are chronically impacted by poor water quality, making swimmers sick and affecting coastal economies. Run-off pollution often drains directly into the surfzone and the mechanisms dispersing and diluting pollution or other tracers (e.g. larvae) are not clear. Surfzone 2D turbulent eddies are the dominant mechanisms for surfzone dispersion and dilution, and these eddies are generated either from a shear-instability of the alongshore current (“shear-waves"), from finite-crest length breaking of individual waves, or from alongshore gradients in wave-group forcing, which have distinct length-scales. SandyDuck based observations of surfzone eddies are compared to funwaveC model simulations. Finite-crest length breaking induces energy at much larger frequencies and wave-lengths than a NSWE model. The relative contributions of shear instabilities and finite-crest length breaking on the momentum and vorticity dynamics are examined. The results will have implications for modeling the dispersion and dilution of surfzone tracers (whether fecal indicator bacteria, sediment, or larvae).

900 **Melissa M. Omand (Woods Hole Oceanographic Institution)**, F. Feddersen (SIO), R.T. Guza (SIO), and P. J. S. Franks (SIO)

Episodic vertical nutrient fluxes and nearshore phytoplankton blooms in Southern California

In Southern California, intense phytoplankton blooms localized in the nearshore (< 20 m depth) appear intermittently, particularly during summer and fall. The underlying drivers of these blooms are poorly understood. Three distinct phytoplankton blooms lasting 4–9 days were observed in approximately 15 m water depth near Huntington Beach CA between June - October of 2006. Each of these blooms was preceded by a vertical nitrate flux event. The first vertical nitrate flux event in June contained both advective and turbulent fluxes, whereas the later two events were primarily turbulent, driven by shear in the lower part of the water column. A simple local Nitrate-Phytoplankton (NP) model using a linear uptake function and driven with the nitrate flux captured the timing, magnitude, and duration of the three Chla blooms (skill= 0.61). These results suggest that the vertical nitrate flux was a primary control on growth, and that estimation of both the advective (upwelled) and turbulent fluxes is necessary to best predict these episodic blooms.

9:20 **Steven Morgan (UC Davis Bodega Marine Laboratory)**, A. Shanks (UO Oregon Institute of Marine Biology), J. MacMahan (NPS), A. Reniers (RSMAS), J. Brown (NPS), and C. Griesemer (UC Davis)

Differential transport across the surf zone of reflective and dissipative shores as a determinant of larval supply

We determined whether differences in water exchange across the surf zone on dissipative and reflective shores regulates larval supply to intertidal populations. We surveyed zooplankton daily for one month relative to physical conditions inside and outside the surf zone at a dissipative and reflective beach near Monterey, California. Larvae of some species completed development nearshore while larvae of other species migrated offshore and back. Concentrations of zooplankters were much greater outside than inside the surfzone at the reflective beach, indicating that the surf zone may block onshore transport. Barnacle cyprids were an exception, suggesting that ontogenetic changes in larval behavior may facilitate penetration of the surf zone. In contrast, zooplankters were 1 to 2 orders of magnitude more concentrated inside the surf zone of the dissipative beach. Settlement of barnacles on rocks at both beaches was low, and settlement of sand crabs, Emerita analoga, was abundant only on the dissipative beach. Different hydrodynamics of surf zones at dissipative and reflective beaches together with larval behavior may play a major role in regulating larval supply along the West Coast.

9:40 ***Ata Suanda (OSU College of Earth, Ocean and Atmospheric Sciences)**, J. A. Barth (OSU CEOAS)

Contrasting regimes of high-frequency internal wave activity on the Oregon inner shelf

High-frequency internal waves are intermittent and energetic events that affect the mixing and transport of nutrients, larval invertebrates and pollutants on continental shelves. However, there is significant temporal and spatial inhomogeneity in wave form, strength, and occurrence on the inner shelf - the shallowest stratified continental shelf region outside the surfzone. On the Oregon coast, the presence of a large submarine bank (Heceta bank) provides contrasting environments for the propagation of internal waves by varying the strength of background stratification, energy of tidal-band internal waves, and distance from wave generation sites. We present observations of velocity from bottom-mounted Acoustic Doppler Current Profilers and temperature from thermistor chains to contrast high-frequency internal activity at both on- and off-bank inner-shelf sites. At all sites, various forms of intermittent internal activity are recorded including packets and singular waves of depression and elevation, as well as sharp bore-like features. Subtidal and tidal-band background oceanic conditions are both shown to influence the number and form of wave events that occur. High-frequency wave events are more abundant at on-bank sites though they have less internal tidal

energy, suggesting the influence of multiple sources of internal waves or increased wave dispersion over the extended propagation distance from shelf-break generation sites.

1000 - 1020 *BREAK*

1020 ***Robert S. Arthur (Stanford CEE Environmental Fluid Mechanics Laboratory)**, R. K. Walter (Stanford CEE EFML), C. B. Woodson (Stanford CEE EFML), O. B. Fringer (Stanford CEE EFML), and S. G. Monismith (Stanford CEE EFML)

Field and Numerical Investigation of Nearshore Internal Bores

We investigate the dynamics of shoaling internal waves in the nearshore environment using both field and numerical modeling results. In southern Monterey Bay, we observed transient stratification and mixing events ("internal bores") associated with shoaling internal waves using an array of instruments with high spatial and temporal resolution. The arrival of the observed bores is characterized by surging masses of dense (cold) water that tend to stratify the water column. This is followed by a gradual drop in the temperature throughout the water column over several hours until a sharp warm-front relaxation, followed by high frequency temperature fluctuations, after which the water column nearly returns to its original state. From this data, we describe the general characteristics of the bores and their effect on local mixing dynamics. The dynamics of the bores is further examined using the fully nonlinear, nonhydrostatic numerical model SUNTANS, and is shown to depend on the nearshore bathymetric slope. We quantify the bathymetric slope relative to the internal wave slope with the internal Iribarren number. By varying this parameter in the model, we show its effect on internal bore dynamics and scalar transport associated with bore events. Our results suggest that nearshore internal bores interacting with local bathymetry dramatically alter local dynamics and mixing in the nearshore environment with important ecological implications.

1040 **Karina J. Nielsen (Sonoma State University)**, T. C. Gouhier (OSU), B. A. Menge (OSU), F. T. Chan (OSU), E. E. McPhee-Shaw (MLML), J. L. Largier (UC Davis BML), and P. T. Raimondi (UCSC)

Synoptic forcing and local scale dynamics of surfzone phytoplankton in the northern California Current Ecosystem over 9 years and 8 degrees of latitude

Despite advances in our understanding of the dynamics of oceanic primary production, nearshore waters are optically complex and the accuracy of satellite-based chlorophyll-a close to shore is questionable. We used nine years of daily fluorometer-based chlorophyll-a (chl-a) measurements at fourteen sites in Oregon and California to investigate the coupling between offshore (remote sensed) and surfzone (in situ) chl-a, and variation across large spatial domains and years of varying climatic conditions as indexed by SST, indices for local upwelling, MEI, PDO and NPGO. We assessed intra-annual variability and phenology using wavelet analyses and assessed larger spatio-temporal patterns with non-metric multidimensional scaling. We found strong gradients in chl-a concentration and variability with distance from shore (negative) and latitude (positive). Surfzone chl-a was correlated with remote sensing chl-a among years, but the relationship changed temporally with distance from shore. Local-scale physical forcing explained more variance in surfzone chl-a at northern sites, while ocean-scale forcing had more explanatory power for southern sites. Bloom phenology also varied with potential consequences for higher trophic levels. A single high chl-a period in mid-late summer characterized northern sites, while southern sites tended to have a bimodal or single early peak. Our results highlight the role of ocean-scale physical forcing in the surfzone, but also its variable expression among regions. Furthermore, the repeated observations of surfzone chl-a being higher than shelf waters reflect a growing body of evidence that nearshore waters are characterized by distinct physical and biological properties that may challenge existing paradigms.

1100 **John Ryan (Monterey Bay Aquarium Research Institute)**, J. Harvey (MBARI), Y. Zhang (MBARI), and B. Woodson (Stanford CEE EFML)

Aggregation of plankton: perspectives from a thinking / sampling AUV

Plankton aggregation in regions of convergent flow has been observed in many coastal environments. This process strongly influences coastal marine ecology by structuring plankton trophic dynamics, transport, connectivity, and recruitment. Physical phenomena conducive to convergent circulation, such as fronts and internal waves, are highly dynamic, and they influence processes at small scales, making them challenging to observe effectively. Understanding these complex phenomena and their ecological consequences is consequently aided by observations with certain attributes: high-resolution multidisciplinary sensing that resolves physical-chemical-optical relationships at fine scales, rapid surveying for quasi-synoptic description, onboard algorithms for real-time feature recognition and response, and algorithm-mediated sample acquisition. The Dorado autonomous underwater vehicle (AUV) was developed to host these integrated capabilities, and it has been applied extensively to multidisciplinary research in Monterey Bay, California. Using perspective from studies in the last decade, we illustrate some of the small-scale physical phenomena found to be ecologically influential in the Monterey Bay region. Using data from Dorado's autonomously targeted sampling, followed by shore-side molecular screening, we describe variability in the abundance of targeted marine zooplankton observed across a range of time scales – from interannual to episodic. At the episodic end of the spectrum, we use detailed information from Dorado to illustrate the apparent aggregation of larvae in convergence zones generated by frontal and internal wave dynamics.

1120 ***Katherine Adams (Oregon State University)** and J. Barth (OSU)

Who's driving – physics or biology? Interannual variation of near-bottom continental shelf dissolved oxygen during upwelling

During upwelling the productive ecosystem on the central-Oregon continental shelf is dependent on the supply of nutrients carried onshore and up onto the shelf by source water, characterized by a cold, salty, oxygen-poor signature. Dissolved oxygen (DO) concentrations of source water along the Newport-hydrographic (NH) line during upwelling are lower than wintertime concentrations on the shelf (~ 6 ml L-1) but are above the hypoxic (< 1.43 ml L-1) levels observed on the shelf each summer. Previous studies during the upwelling season indicate an interannual variability in oxygen levels on the central-Oregon shelf but have yet to quantify this variability or relation to physical and biological drivers. Here we analyze three years (2009 – 2011) of continuous time series of near-bottom temperature, salinity, dissolved oxygen and currents from mid-shelf (70-m isobath) and inner-shelf (15-m isobath) moorings over Stonewall Bank (44.25°N, 124.25°W) along with glider-measured source water (NH25; 100 – 200 m in 250-300 m of water) and NDBC buoy 46050 wind data to quantify the interannual variation of the moored time series, source water and wind forcing. Spring transition dates based on wind-forcing are compared to the moored time series. A second spring transition date, based on in situ temperature and salinity data, is defined as the convergence of source and shelf water properties. Respiration rates are compared to the rates of decline calculated by linear regression fits of dissolved oxygen time series. We find near-bottom oxygen dynamics on the shelf during the upwelling season is modulated by consumption via microbial respiration and replenishment via advection and mixing processes.

1140 **Olav Ormseth (NOAA Alaska Fisheries Science Center)**

Nearshore fish ecology and oceanography in the Gulf of Alaska: internal dynamics and external connections

An interdisciplinary marine ecological study underway in the Gulf of Alaska (GOA) includes a consideration of nearshore and offshore dynamics and connections between the two. The GOA Integrated Ecosystem Research Project is a 4-year effort to better understand ecosystem function in the GOA through coordinated fish and seabird studies linked with extensive oceanographic research and nested physical and biological models. A central aspect of the project is conducting parallel field studies in nearshore and offshore areas during spring, summer, and fall of 2011 and 2013. These studies are using nets and hydroacoustics to describe the distribution and abundance of fishes, CTDs and water samplers to determine water column characteristics, and plankton nets to define zooplankton distributions. The goals of the nearshore work are twofold. Extensive oceanographic work in the nearshore will provide us with information regarding habitats, habitat utilization, and the potential prey fields available to fishes, as well as how habitats change over time. Because the work is paralleled offshore, we will also gain a better understanding of the connectivity between nearshore and offshore waters. I will present preliminary data from the nearshore work and hope to contribute to the discussion regarding these important but inadequately explored regions.

Thursday, 20 September Poster Session: *How does basin-scale variability affect the connectivity of the California Current System (CCS): Its currents and ecosystems?*

- **Frank Aikman III (1, NOAA NOS Coast Survey Development Laboratory) presented by Chris Mooers**, Z. Yang (NOAA NOS Coast Survey Development Laboratory), and A. Zhang (NOS Center for Operational Oceanographic Products & services)

  Development of a National Ocean Service West Coast Operational Forecast System

  NOAA/NOS is working toward development of a U.S. West Coast Operational Forecast System (WCOFS), intended to provide forecast guidance of 3-D hydrodynamical fields to support marine navigation, emergency response and ecological applications and to provide boundary conditions to more local models. We propose to have a WCOFS that will encompass the entire CCS regime with a horizontal grid resolution of 3-10 km and a vertical coordinate consisting of ~50 levels. Modeling runs of WCOFS will be driven at the open ocean boundary with an NWS operational global scale model and operational model-derived surface atmospheric forcing. River discharges will come from USGS gauges and NWS River Forecast Centers. WCOFS will be implemented with a data assimilation capability. It is expected to be able to assimilate ocean state variables from satellite remote sensing, HFR and in-situ data. We adopt a community approach to facilitate the WCOFS development that will involve building up and maintaining close communications with the West Coast oceanographic community, including the formation of a scientific advisory board. We are currently at a preparation stage for the WCOFS development. We have reviewed various coastal ocean community models (e.g. ROMS and FVCOM) and existing regional modeling systems in the West Coast hyper-region and are about to make a decision on the one to be used. NOS will begin the WCOFS development in 2013 with operational products available in 2016-17. WCOFS will provide accurate and timely 1 day nowcast and 5 day forecast guidance of the 3-D, baroclinic ocean state.

- **Susan E Allen (2, UBC Earth, Ocean and Atmospheric Sciences)**, M. A Wolfe (UBS Earth, Ocean and Atmospheric Sciences)

  Hindcast of the Timing of the Spring Phytoplankton Bloom in the Strait of Georgia, 1968-2010

  Using a one-dimensional coupled bio-physical model, the spring phytoplankton bloom in the Strait of Georgia was hindcast for years 1968 to 2010. Relative to the long term mean (March 25), the timing of the bloom was later in the early 1970's (about April 2), earlier in the early 1990's (about March 18) and later again in recent years (about March 30). These long term shifts are related to shifts in the intensity of winter storms and cloudiness. A more dramatic shift is seen in the interannual variation in timing with the standard deviation over seven consecutive years doubling during the timeseries. Since the early 1990's there have been a few, very early blooms leading to a large interannual spread in bloom times. We show that this change is related to warming and therefore we project that this level of variation may continue under climate change.

- **Eric P. Bjorkstedt (3, NOAA SWFSC and Humboldt State University)**, W. T Peterson (NOAA NWFSC), and J. Largier (UC Davis BML)

  Copepods, connectivity, and curly currents: observations of a potential transport barrier in the northern California Current

  Copepod abundance and community structure at mid-shelf stations off Oregon and northern California have exhibited a remarkable degree of coherence during the late 2000s and early 2010s, despite substantial geographical separation, and differences in the character of the local upwelling system associated with intervening headlands, differences in bathymetry, etc. In early 2012, this general pattern was disrupted: the copepod community off northern California retained a

southern/offshore flavor even as the copepod community off Oregon regained northern, neritic species as expected during periods of negative PDO. Surface circulation patterns observed with HF radar offer a possible mechanism for this disruption. During winter 2011/2012, mean surface currents indicate persistent anticyclonic flow inshore of an equatorward jet extending southwest from Cape Blanco and north of offshore flows near Cape Mendocino. This feature, which appears to dominate coastal waters between the two capes, represents a plausible mechanism for the retention of copepods with southern or oceanic affinities in coastal waters off northern California, and be part of a broader circulation pattern that can temporarily disrupt alongshore connectivity of coastal populations. Because this feature lies directly off the mouth of the Klamath River, understanding the causes, frequency and consequences of similar circulation patterns for nearshore productivity and prey fields may have important implications for elucidating how marine survival of Klamath River salmon responds to environmental variability captured in large scale indices.

- **David A. Jay (4, PSU Civil & Environmental Engineering)**, S. A. Talke (PSU CEE), A. Devlin (PSU CEE), and E. Zaron (PSU CEE)

  Decadal and Sub-Decadal Scale Fluctuations in Pacific Tides – Local or Regional or ?

  Extraction of secular trends in tidal constituents from tidal records has more in common with determination of mean sea level (MSL) trends than simply use of the same data. Both require 30-50yrs of data, and both suffer difficulties in trend/acceleration extraction due to the presence of instrumental noise and multiple-scale fluctuations. The latter likely have several causes within the ocean-atmosphere system. Sub-decadal scale fluctuations in tidal properties in San Francisco and Astoria are correlated with El Nino-Southern Oscillation (ENSO) variations, while the Seattle record shows little ENSO-correlated variation. Exploration of fluctuations in tidal properties on these time scales is vital, because their removal improves trend extraction may provide insight into the causes of secular trends. Both local and regional factors drive fluctuations in tidal constituents. From the terrestrial side, tidal amplitudes in many ports are inversely related to river flow, due to quadratic bedstress – higher river flow damps tides, and there are triadic frictional interactions between constituents, e.g., M2, K1 and O1. Similar changes could occur on a regional scale due to changes in shelf stratification and variations in internal tides. In this case, one would expect to see, at temperate latitudes, M2 much affected more than K1, but this is not always the case. On a basin scale, ENSO related changes in MSL could, by changing tidal dissipation in shelf areas or large-scale windstress patterns, alter wave propagation and shift amphidromic positions. A component of amplitude and phase fluctuations also appears to be due to variable timing errors.

- **Alan Shanks (25, UO Oregon Institute of Marine Biology)**

  Predicting the Commercial Catch of Dungeness Crabs from the Annual Return of Their Larvae

  For 11 years (1997-2001, 2006-2011) daily abundance of [Cancer magister] megalopae has been measured in Coos Bay, Oregon. From 1997 through 2006, settlement season catch (April through September) varied from 2000 to 80,000 megalopae. In 2007, the settlement season catch jumped by > 10 times and has varied from 164,000 to 2.3 million megalopae. The step change from lower to much higher catches appears to be related to the regime shift in the Pacific Decadal Oscillation (PDO), higher annual returns tend to occur during periods of negative PDO. During periods of both lower and higher catches, the annual return of megalopae was significantly negatively correlated to the day of the year of the spring transition and positively correlated to the amount of upwelling during spring and early summer. The size of the commercial catch lagged four years to allow for growth of the megalopae into the fishery is set by larval success as measured by the number of returning megalopae; the relationship is parabolic. At return rates between ~2000 and 100,000, the population is recruitment limited; the commercial catch varies directly with the number of returning megalopae. At higher return rates, density dependent effects predominate and set the size of the

commercial catch. If the recent very high return rates are due to a PDO regime shift, then for years to decades the commercial catch may be set by density dependent effects following settlement and the huge numbers of returning megalopae may impact benthic community structure.

- **Andrew Thomas (5, UMaine School of Marine Sciences)**, P. T. Strub (OSU CEOAS), R. Weatherbee (UMaine), and C. James (OSU CEOAS)

  Satellite views of Pacific chlorophyll and physical variability: comparisons of basin-scale with eastern boundary current patterns and links to climate indices

  Concurrent chlorophyll (CHL), sea surface temperature (SST), sea level anomaly (SLA) and wind vectors over the 13+ year SeaWiFS period (1997 – 2010) quantify time and space patterns of phytoplankton variability and its links to physical forcing over the Pacific Ocean and its two eastern boundary current (EBC) systems, the California and Humboldt Currents. EOFs capture dominant modes of variability over the whole basin, over the equatorial corridor and over EBC upwelling regions. Non-seasonal variability along the equatorial corridor is highly correlated with basin-scale variability, more weakly with EBC variability, and the strongest signal across all regions is the 1997-1999 ENSO cycle. Results quantify the magnitude and geographic pattern with which dominant basin-scale signals are expressed in the EBC upwelling areas, stronger in the Humboldt than the California Current. In both EBC regions, wind forcing has weaker connections to non-seasonal CHL variability than SST and SLA, especially at mid and lower latitudes. Dominant physical and biological patterns over the basin and each sub-region are compared to indices of Pacific climate variability (the MEI, PDO and NPGO). We map and compare the local CHL footprint associated with each index and those of local wind stress curl, showing the dominance in most areas of the MEI and its similarity to the PDO. Principal estimator patterns quantify the linkage between dominant modes of forcing variability (wind, SLA and SST) and CHL response, comparing local interactions within EBC regions with those imposed by equatorial signals.

Thursday, 20 September Poster Session: *Upwelling intensification: fact or fiction?*

- **Nikolay P. Nezlin (6, SCCWRP)**, M. A. Sutula (SCCWRP), R. P. Stumpf (NOAA NOS), and A. Sengupta (SCCWRP)

  Upwelling-driven near-shore phytoplankton blooms in the Southern California Bight

  Short-term upwelling events look like a primary factor driving near-shore phytoplankton blooms in the Southern California Bight (SCB). A 10+ year dataset of daily satellite remotely-sensed observations of sea surface temperature (SST) and ocean color transformed to chlorophyll concentration (CHL) were used to detect: (1) upwelling events associated with abrupt drops in SST; and (2) phytoplankton blooms associated with an increase of the offshore extension of the zone of high CHL. In the SCB, blooms were most frequent in spring and associated with the spring transition to upwelling regime, in contrast to the regions to the north, where blooms persisted from spring to autumn during stable seasonal intensification of upwelling. At interannual scale, the periods with highest frequency of upwelling events coincided with maximum bloom intensity. Standard upwelling index (UI) derived from large-scale atmospheric circulation was decoupled from the frequencies of both upwelling events and phytoplankton blooms. Significant intensification of blooms was observed during the observed period, although neither the frequency of upwelling events nor UI demonstrated evident interannual trends. The effect of other than upwelling nutrient sources for phytoplankton growth, including stormwater and wastewater discharge, appeared to be limited to the areas in close proximity to major river mouths and wastewater outfalls.

- **Stephen D. Pierce (7, OSU)**, and J. A. Barth (OSU)

  Upwelling-season winds off Oregon: long-term increase in variability, not strength?

  Some climate change models predict long-term intensification of coastal upwelling-favorable wind stress, while others do not. Such intensification could have significant effects on upwelling-based ecosystems. Wind time series measured by NDBC buoys (generally starting in the 1980s) tend to be too short for trend analyses. The NCEP/NCAR reanalysis project, however, provides daily wind stress extending back to 1948. The NCEP/NCAR wind is well correlated with NDBC buoy winds off Oregon, when the buoy winds are available. Prior to this, the NCEP/NCAR analysis assimilates all available historical data back to 1948 in a dynamically consistent manner.

  We determined total cumulative upwelling-season wind stress for each year. Over the 64 years 1948-2011, there is NO significant trend in the total wind forcing. We also explored the variance of the wind stress within each upwelling season, and in this case there IS a significant long-term trend: over 64 years the within-season variability increases by about 30%. We also note an increase in variance in an 8-35 day (intraseasonal) band. A long-term change in the variance structure of winds during the upwelling season may have important ecosystem implications.

Thursday, 20 September Poster Session: *General Session*

- ***Kerstin Cullen (8, University of Maine, School of Marine Sciences)**, A. Thomas (UMaine SMS), and R. Campbell (Prince William Sound Science Center)

  Temporal and spatial variability of chlorophyll and turbidity on the Alaska shelf: links to dominant forcing

  Nine years of MODIS satellite data (2002-2011) covering the Alaska shelf from Kodiak to Yakutat are analyzed to quantify temporal/spatial variability of chlorophyll and turbidity. Remote sensing reflectance at 555 nm is used as a qualitative proxy for turbidity. Areas flagged for high turbidity are masked within chlorophyll images to remove questionable values. Monthly climatologies are presented for both metrics. We use EOF's to quantify dominant modes of both eight-day and monthly patterns for both metrics from March to October, the period of sufficient light for visible-range remote sensing. The dominant mode of chlorophyll variability shows distinctive spring blooms extending away from the shelf and weakening into the interior Gulf of Alaska, stronger on the western half of the shelf, near Kodiak Island. Weaker fall blooms occur across the shelf in most years. The dominant mode of turbidity variability shows a strong seasonal cycle of turbid plumes from the Copper River as well as other glacial discharge sources that account for 21% of the variance. Peak turbidity at the mouth of these discharge sources occurs in July/August, followed by a two pronged turbidity plume extending from the discharge sources from October to March. EOF modes of both chlorophyll and turbidity are compared to freshwater discharge metrics and wind forcing. Hovmöller plots quantify variability of the shelf through the Copper River turbidity plume over time. Lastly, we compare satellite data to cross-shelf in situ data to examine similarities and present a view of vertical structure not evident in the satellite data.

- **Leah Feinberg (9, OSU Cooperative Institute for Marine Resources Studies)**, C. T. Shaw (OSU CIMRS), W. T. Peterson (NOAA NWFSC)

  A synthesis of reproductive rates for Euphausia pacifica from several regions of the Northeastern Pacific Ocean

Euphausia pacifica is a dominant euphausiid species in most areas of the Eastern North Pacific. They are important browsers of phytoplankton and microzooplankton and are prey for many marine mammals, seabirds, larval fishes and bait fish. However, we are only recently assembling a clearer picture of their life history and bioenergetics. In this synthesis, we bring together new and previously published data sets on brood size from short-term (24-48h) incubations from 5 regions ranging from southern California to the Gulf of Alaska. These results are compared by region and the relationships between body size and brood size is analyzed using quantile regression. We also compare longer-term incubations of females (2-9 months) from 7 regions from Santa Barbara to the Gulf of Alaska in order to look at differences in brood size and inter-brood period while females are maintained under identical light, water, temperature and feeding environments. Despite a consistently wide range in brood size and inter-brood period within all areas, there are still some significant differences and trends among regions. Median inter-brood periods increase slightly with increases in latitude. Median (and maximum) brood sizes are significantly largest off of central Oregon and the smallest median broods were from Puget Sound, Washington and Southern California. Quantile regression allows us to determine whether maximum brood size is primarily limited by female size, or other factors such as food availability in several dynamically different regions of the North Pacific.

- ***Nicholas Foukal (10, University of Maine School of Marine Sciences)** and A. Thomas (UMaine SMS)

  Satellite-measured phytoplankton phenology in the California Current: time and space patterns and a comparison of metrics

  Interannual variability in the seasonal timing of phytoplankton concentrations affects the structure of the marine ecosystem through bottom-up forcing. We analyze 13 years (1997-2010) of NASA SeaWiFS chlorophyll data in the California Current (23˚N-51˚N, extending 800 km offshore) to present the space patterns and interannual variability of timing and duration of both blooms and low-chlorophyll periods. The data are divided into individual years at every location and then normalized to the annual amplitude and mean to focus on differences in timing rather than magnitude. To track spatial and interannual variability, we use the k-means clustering algorithm to group locations in which the individual annual cycles are similar over the 13 year time period. We then examine each cluster's time series with respect to a series of phenology metrics. These include the dates of the annual maximum and minimum concentration, metrics based on annual running chlorophyll sums, as well as measures of the duration and intensity of periods above or below subjectively chosen thresholds. Results from these metrics for each cluster are analyzed for overall trends and compared to indices of physical forcing such as ENSO, PDO and NPGO as well as local-scale variability in SST and wind.

- **Sarah N. Giddings (11, UW Oceanography)**, P. MacCready (UW Oceanography), N. S. Banas (UW JISAO), K. A. Davis (UW APL), S. A. Siedlecki (UW JISAO), B. M. Hickey (UW Oceanography)

  The influence of the Columbia River Plume on transport to the nearshore region and along-coast estuaries

  Large river plumes are known to influence coastal dynamics substantially. In the Pacific Northwest, the Columbia River, with substantially greater outflow than other coastal rivers, exerts a strong influence on the region. As part of a joint hydrodynamic and ecosystem modeling project to understand the generation and transport of harmful algal blooms (HABs) in the Pacific Northwest, we present realistic hindcast simulations of the Salish Sea and the nearshore coastal ocean along the Washington and Oregon shelf. The ROMS simulation was forced with realistic bathymetry, tides, climatology, river forcing, and open boundary conditions. Numerical experiments in which we turn

off the Columbia River along with particle tracking and inert dye tracers are used to identify the influence of the Columbia River plume on nearshore transport pathways and exchange flow in along-coast estuaries. The Columbia River plume front often blocks transport to the coast, however, when particles become entrained in the plume during downwelling winds, the Columbia can become a strong along-shore conduit. This enhances connectivity between the Columbia and along-shore estuaries to the north as well as between the coastal ocean and the nearshore region. This enhanced along-shore connectivity during downwelling winds has broad ranging impacts including the creation of an important transport pathway for HABs from Heceta Bank off of the Oregon coast to the Washington coast as well as significantly altering exchange flow in along-coast estuaries. Hindcast simulations from 2005-2007 will be used to describe interannual variability in these processes.

- **Albert J. Hermann (12, UW Joint Institute for the Study of the Atmosphere and Ocean)**

  Interactive 3D exploration of biophysical model projections for the Bering Sea

  As one element of the Bering Sea Integrated Ecosystem Research Program (BSIERP), IPCC model projections of global climate change have been downscaled to the physics and biology of the Bering Sea, using a 3D primitive equation hydrodynamic model (ROMS) which ice and tides, embedded NPZ, and stage- and age-structured fish. This work entails 3D ensemble runs of a high resolution regional model, and the volume of multivariate output produced by such an endeavor poses unique challenges for both storage and interpretation. In this live demonstration, both global and regional predictions will be explored using stereo-immersive 3D techniques which simultaneously display both locally and remotely hosted datasets, and include both Eulerian and Lagrangian information. We demonstrate how this approach leads to a more efficient exploration of the biophysical dynamics, as compared with standard 2D graphics.

- **Jeffrey Paduan (13, Naval Postgraduate School)**, S. Frolov (MBARI), M. Cook (NPS) and J. Bellingham (MBARI)

  Improved statistical prediction of surface currents based on historic HF-radar observations

  Accurate short-term prediction of surface currents can improve efficiency of search-and-rescue operations, oil-spill response, and marine operations. We developed a linear statistical model for predicting surface currents (up to 48 hours in the future) based on a short time-history of past HF-radar observations (past 48 hours) and an optional forecast of surface winds. Our model used empirical orthogonal functions (EOFs) to capture spatial correlations in the HF-radar data and used a linear autoregression model to predict the temporal dynamics of the EOF coefficients. We tested the developed statistical model using historical observations of surface currents in Monterey Bay, California. The predicted particle trajectories separated from particles advected with HF-radar data at a rate of 4.4 km/day, which represents an improvement over the existing statistical model (drifter separation of 5.5 km/day). We found that the minimal length of the HF-radar data required to train an accurate statistical model was between one and two years, depending on the accuracy desired.

- ***Noel A. Pelland (14, UW Oceanography)**, J. T. Sterling (NOAA/NMFS National Marine Mammal Laboratory), M. Lea (University of Tasmania Institute for Marine and Antarctic Studies), N. A. Bond (UW JISAO), R. R. Ream (NOAA/NMFS National Marine Mammal Laboratory), C. C. Eriksen (UW Oceanography), and C. M. Lee (UW Oceanography and APL)

  Oceanographic Conditions, Movement, and Diving Behavior in Pelagic Winter Habitat of the Adult Female Northern Fur Seal (Callorhinus ursinus)

  Adult female northern fur seals (Callorhinus ursinus) from the Pribilof Islands annually migrate long distances to winter foraging habitat located primarily in the California Current (CC) and Gulf

of Alaska (GA) coastal marine ecosystems. Despite the importance of this winter phase to the adult female life cycle, the degree to which variability in the Eastern Pacific surface ocean environment affects female movement, diving behavior, and winter foraging success is poorly understood. This study examines the winter foraging behavior of satellite-tagged adult females from the Pribilof Islands during 2002-2010, and compares the behavior of a subset of these to surface ocean conditions measured by Seagliders off the Washington coast, in the northern CC, from 2003-2009. Adult females in this study concentrated their effort within 200 km of the shelf break and near prominent coastal features such as capes or inlets. Females increased their daytime diving effort in the CC in comparison to the open North Pacific, and the depth patterns of day dives suggest that females feed on prey congregated immediately below the mixed layer during this time. Of three females who foraged in close proximity to Seagliders, one spent ~2 months within a productive freshwater plume from the Columbia River, while others recorded dive bouts near eddy edges, regions of potentially enhanced productivity and prey aggregation. The seasonal, geographical, and small-scale patterns of behavior observed in this study indicate that mesoscale variability in the coastal transition zone can strongly influence adult female northern fur seal movement and diving, likely by affecting the abundance and accessibility of their prey.

Thursday, 20 September Poster Session: *Deoxygenation and acidification in waters of the Eastern Pacific*

- ***Ben Moore-Maley (15, University of British Columbia)**, S. Allen (UBC), and D. Ianson (IOS)

  The effects of physical processes on pH in the Strait of Georgia

  A one-dimensional vertical mixing model coupled to an NPZD biological model is used to investigate the range and variability of pH in the Strait of Georgia: a semi-enclosed coastal sea in British Columbia, Canada with a large, seasonally variable freshwater input dominated by the Fraser River. Two-dimensional processes such as estuarine circulation are parameterized. The model is initialized in fall using rosette casts from two long-running sampling programs taken directly north of the Fraser River plume, and run for 1 year with continuous forcing from local wind, air temperature, cloud fraction, relative humidity, incoming solar radiation, and river discharge observations. The model has been previously used to successfully hindcast the timing of the spring phytoplankton bloom in the Strait, with a primary bloom date sensitivity to wind. The nitrogen-based NPZD model has recently been modified to include dissolved inorganic carbon (DIC), total alkalinity, and dissolved oxygen equations, and an air/sea gas exchange module has been developed for oxygen and carbon dioxide. Local observations of DIC, alkalinity, and pH are used to constrain the 40 m boundary conditions and freshwater concentrations for these new variables, and to verify the model outputs. Hindcasts are run for bloom years from 2000 to the present, and sensitivity analyses are performed for several physical forcing and biological parameter variation scenarios. Model results quantify the sensitivity of pH and aragonite saturation state to the major forcings and processes in the Strait.

- ***David R. Munro (16, UW Oceanography)**, P. D. Quay (UW Oceanography), and S. Dickinson (UW APL)

  Multi-decadal record of net biological production in the Southern California Current System based on dissolved O2 and nutrient budgets

  The relationship between biological O2 saturation from O2:Ar dissolved gas ratio measurements and routinely measured O2 saturation during six CalCOFI cruises from 2005 to 2008 allows estimation of potential net community production (NCP) rates from the multi-decadal CalCOFI

dataset. Interannual variations in NCP estimated from surface O2 agree well with NCP variations based on nitrate budget estimates (r2 = 0.6) from 1984-2010. O2-based and nitrate-based NCP estimates are compared with estimates based on satellite algorithms coupled with empirical export-ratio algorithms for four different regions within the CalCOFI grid. We explore several possible causes of variability in NCP within the CalCOFI region including variability in coastal upwelling, upwelling driven by wind stress curl, and stratification. Agreement between our O2-based NCP estimates, previous nutrient budget estimates, and sediment trap studies within the CalCOFI grid suggest that remineralization rates beneath the photic zone may be surprisingly low in the Southern California Current System.

Thursday, 20 September Poster Session: *Nearshore Physics and Biology*

- ***Megan J. Demcak (17, Humboldt State University),** C. Hoyle, B. Stacy, R. Bauer, V. Crandell, J. Fernandez, J. Lavell, A. Nelson, M. Porter, D. Rode, S. Ramirez Jr, M. Walker, L. Williams, J. Wilson, J. Abell, C. J. Cass, E. Bjorkstedt, R. Robertson (all authors affiliated with Humboldt State University)

  A comparison of the Eel River Submarine Canyon to a typical northern California shelf during an upwelling and a non-upwelling event

  Submarine canyons comprise a fifth of the continental shelf along the North American west coast. Canyons incise the continental slope creating dramatic bathymetric differences that can result in atypical circulation features. The steepness of the canyon (up to 45° compared to typical shelf slopes of 0.2°) helps it act as a conduit for water exchange between the deeper canyon and the adjacent shelf. It has been suggested that this exchange may dramatically affect the transport of nutrients and organisms at the shelf, and ultimately influence productivity there. Here, we test this hypothesis by comparing nutrients, chlorophyll, dissolved oxygen, and zooplankton biomass between the Eel River Submarine Canyon (ERSC) and a typical shelf near Trinidad Head, CA (45km north of the ERSC). During a non-upwelling event the ERSC had lower dissolved oxygen concentrations in the upper water column, colder surface waters, decreased integrated zooplankton biomass, and higher surface concentrations of nitrate, silicate, and ammonia. Preliminary results suggest that the ERSC surface waters maintain properties more similar to deeper water when compared to a typical shelf. These waters may be primed for enhanced productivity once upwelling begins. Collected data will serve as a baseline for ongoing sampling to assess how the ERSC impacts the water column in association with wind-driven coastal upwelling. Under these conditions, we expect to see an increase in productivity over the canyon. Results should improve our understanding of the impacts of submarine canyons on coastal processes that influence nearshore ecosystems.

- **Todd Mitchell (18, UW)**, and N. Mantua (UW)

  Chlorophyll distributions and variability along the North American West Coast

  A provocative 2012 study by Suryan et al. contrasted monthly chlorophyll-a variability in the mid- to outer-continental shelf regions with the greater chlorophyll-a concentrations over the inner shelf. The present study uses 5-day mean chlorophyll-a estimates to further document how the distributions vary regionally and across the shelf, and to relate the seabird "hotspot" regions defined by Suryan et al. to spatially coherent patterns of chlorophyll-a variability derived by rotated principal component analysis.

- **Kerry J. Nickols (19, UC Davis Department of Wildlife, Fish, and Conservation Biology)**, S. H. Miller (UC Davis BML), B. Gaylord (UC Davis BML), J. L. Largier (UC Davis BML), and S. G. Morgan (UC Davis BML)

  Spatial differences in larval abundance within the coastal boundary layer and adjacent to the surfzone

  The dynamics of very nearshore waters are a missing piece in understanding larval transport and delivery to suitable habitats. The distribution and abundance of larvae in the coastal ocean is variable in time and space, and depends on physical processes and larval behavior, leading to biophysical interactions that effect larval retention and delivery to adult habitat. While recent evidence suggests that larvae are retained within 1-3 km of the shore, few studies have obtained measurements further inshore to assess supply immediately adjacent to shoreline habitats. We measured cross-shore distributions of crustacean larvae between 250 and 1100 m from shore within the coastal boundary layer (CBL), a region of reduced flow, as well as physical factors that may influence larval distributions within the CBL. We found high larval abundance within the CBL that increased shoreward, peaking at 850 m from shore. Larval abundance decreased closer to shore at the innermost station, which appears to be on the interface between the CBL and the wave-driven nearshore zone. These regions also had distinct larval communities. These patterns persisted across sample dates, suggesting that the spatial structure of nearshore larval communities is robust to changes in physical conditions. While larval supply appears to be high within the CBL, a narrow band of water adjacent to the surf zone was largely unoccupied by larvae. Low larval supply adjacent to suitable habitats has important implications for the coupling of supply and recruitment, and for the dynamics of shoreline populations.

- **Travis A. O'Brien (20, Lawrence Berkeley National Lab)**, W. D. Collins (LBL), L. C. Sloan (UCSC), P. Y. Chuang (UCSC), and I. C. Faloona (UC Davis)

  Sea surface temperatures drive coastal fog variability but not the long-term trend

  Western coastal fog is nearly ubiquitous during the summer months, and it has influences ranging from societal to ecological; it impacts air and land traffic, it supplies moisture to terrestrial coastal ecosystems during the driest parts of the year, and it reduces temperatures in coastal rivers by reducing insolation. Changes in coastal fog could dramatically change the nature of the North American west coast. Bakun (1990) hypothesized that intensification of coastal upwelling, caused by an increased land-sea temperature contrast, would cool sea-surface temperatures and increase the occurrence of fog. We use a combination of satellite observations and climate model simulations to show that cooler SSTs do cause an increase in coastal fog; much of the interannual variability of coastal fog over the last 25 years can be directly attributed to variability in SSTs. These results verify the hypothesized SST-fog connection, but the lack of a strong trend in near-coastal SSTs over the last 100 years, in conjunction with a relatively strong decline in coastal fog, indicates that other factors presently control the long-term trend. A climate model projection, in which near-coastal SSTs are warmer, indicates that warming SSTs may contribute to a further decline in fog. This indicates that the future of coastal fog may still be controlled by coastal SSTs, and so the future of fog is uncertain due to uncertainties in the future of coastal SSTs.

- **G. Curtis Roegner (21, NOAA NWFSC)**, E. A. Daly (OSU CIMRS), R. D. Brodeur (NOAA NWFSC)

  Surface distribution of brachyuran megalopae and ichthyoplankton in the Columbia River plume during transition from downwelling to upwelling conditions

  In the California Current coastal boundary zone, the spring transition between downwelling and upwelling conditions, along with the fluctuating structure of the Columbia River plume, creates

highly dynamic interactions. In this study we measured biophysical properties of surface water during the spring transition from downwelling to upwelling conditions in 2010, when the transition was delayed and Columbia River flow was substantially higher than average. Plume waters that were trapped in a northward flowing coastal boundary current during downwelling conditions were advected offshore after several days of upwelling favorable winds. Neustonic collections of brachyuran larvae and ichthyoplankton varied in response to this large seaward advective event. Megalopae of cancrid crabs exhibited patterns of both offshore transport (Cancer oregonensis/productus) and nearshore retention (C. magister). Additionally, abundant numbers of large juvenile widow (Sebastes entomelas) and yellowtail (S. flavidus) rockfish of a size appropriate for settlement were sampled during a period when ocean conditions favored high recruitment success. These results demonstrated that the response of planktonic crab larvae and ichthyoplankton to large scale advection varied by species, with larger and more vagile fish exhibiting less evidence of passive transport than smaller crab larvae. Importantly, portions of the planktonic fish and crab community were able to maintain nearshore distributions in favorable settlement habitat, despite physical advection offshore.

- **Sherry E. Scott (22, Marquette University)**, A. Gharzaryan (Miami University), D. Rivas (CICESE), I. Rypina (WHOI), and A. Wert (Benedictine College)

  Analyzing upwelling flow via individual trajectory complexity

  We consider some preliminary results from the analysis of upwelling flow data from the Oregon coast during 2005 using a relatively new technique that focuses on individual trajectory complexity. The method- called ergodicity defect- has been used successfully in the context of several other test flows and may have advantages over more traditional analysis techniques. The goal is to use the complexity of the fluid particle trajectories to reveal structures resembling Lagrangian coherent structures. Such an analysis has implications for a better understanding of transport and transport barriers in the flow.

- **Alan L. Shanks (24, UO Oregon Institute of Marine Biology)**, M. Jarvis (UO Oregon Institute of Marine Biology), S. G. Morgan (UC Davis BML), C. Griesemer (UC Davis BML), J. MacMahan (NPS), J. Brown (NPS), J. H. M Reniers (RSMAS), and A. Fujimura (RSMAS)

  Surf zone hydrodynamics and the delivery of larvae to the shore

  Larvae of intertidal species that development offshore must return to shore to complete their life cycle; they must migrate across the surf zone. We are investigating the effects of surf zone hydrodynamics on larval delivery. The surf zone may be a barrier to shoreward migration or, if water is readily exchanged, facilitate shoreward transport. Barnacle settlement on rocks at dissipative beaches was orders of magnitude higher than in similar habitats at reflective shores. Dissipative surf zones readily exchange water due to rip currents and surf zone larval concentrations were correlated to concentrations seaward of the surf zone; dissipative surf zones do not act as barriers to shoreward larval migration. Dissipative surf zones are always associated with sandy beaches while surf zones associated with rocky shores are reflective. At reflective shores, while the surf zone is narrow, because they lack rip currents water is less readily exchanged and they can act as a barrier to larval migration; surf zone larval concentrations were not correlated to concentrations offshore. At reflective shores, the concentration of competent larvae in the surf zone was significantly correlated with the concentration of detritus and both competent larvae and detritus were both more abundant during periods of small waves suggesting that larvae enter the surf zone during these periods and that migration into the surf zone is somehow analogous to the movement of detritus. Surf zone hydrodynamics does effect the ability of larvae to migrate to shore.

- **Matthew Spydell (23, Scripps Institution of Oceanography)**, F. Feddersen (SIO), R. T. Guza (SIO), and J. MacMahan (NPS)

  Determination of Surfzone Lagrangian Stochastic model parameters from Eulerian measurements

  In order to understand and model surfzone/shelf exchange processes, the transport and dispersion of surfzone tracer (pollution, larvae, etc.) needs to be known. Although the depth- and time-averaged surf zone currents that largely determine tracer transport are well known, less is known about the dispersion and mixing. Recently, dispersion by surfzone eddies has been estimated using observations of Lagrangian drifters and dye.

  A Lagrangian Stochastic Model (LSM) reproduced the dispersion statistics of the Huntington Beach 2006 (HB06) experiment GPS-tracked surfzone drifters. Thus, an LSM could be used to model (i.e. predict) the transport and dilution of surfzone tracers. However, in this study the LSM model parameters (cross- and alongshore velocity variance and Lagrangian time-scale) were determined from the in-situ drifter data. As Lagrangian surfzone observations are not typically available, LSM parameters would need to be determined from Eulerian observation (current meter) or simulation (numerical model) data in order for the model to be used in an operational sense (ie. to predict the dilution of an actual surfzone pollution spill).

  Here the relationship between surfzone Eulerian and Lagrangian velocity statistics is examined for the surfzone drifter field experiments. In order to determine velocity variance and decorrelation times, Lagrangian and Eulerian velocity frequency spectra and autocorrelation functions are calculated. These Eulerian and Lagrangian statistics are compared and the question of whether Eulerian statistics can be used as parameters in a LSM model of dispersion is addressed.

Additional EPOC scientists attending

John Allen (OSU)
*Rosalie Bauer (HSU)
Peter Bromirski (UCSD)
Christine Cass (HSU)
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*Jennifer Lavell (HSU)
*Amanda Nelson (HSU)
Jan Newton (UW APL)
*Michael Porter (HSU)
*Salvador Ramirez (HSU)
*Dylan Rode (HSU)
Roger Samelson (OSU)
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