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Benthic Microplastic Distribution in Humbolt Bay, Northern California: A Comparative Study of Surface Sediments Based On Proxmity from the Shore

Annette J. Carlson[1]*, *Thomas Allie*[1], *Alexandra Baker*[1], *Kyle Dahlman*[1], *Jacob Evans*[1], *Jack R. Hawley*[1], *Karansingh M. Keislar*[1], *Randall S. Keys*[1], *Nathaniel V. Kristan*[1], *Eric Lawrence*[1], *Matthew T. Lopez*[1], *Freya N. Mitchell*[1], *Cory B. Monroy*[1], *Erick Ortiz*[1], *Katherine K. Panebianco*[1], *Daniel Raemer*[1], *Kezia F. Rasmussen*[1], *Wendy Raymond*[1], *Nicholas R. Schieferecke*[1], *Jennifer J. Snyder*[1], *Madeleine, J. Tervet*[1], *Carolyn, R. Westrick*[1], *Christine, J. Cass*[1], *Daniel C. O'shea*[1]

[1]*Humboldt State University*

Plastic production and use has increased steadily over the last century primarily because of plastic's resistance to corrosion and low production costs. Plastics enter the marine environment from non-point sources such as rivers, wind, and fishing activities, and point-sources like sewage treatment plants, dumping, and landfills. This research focuses on microplastics (MPs), specifically those within the size range of 0.335 to 5 mm, because of the uptake potential by detrital and filter feeding organisms. Quantifying the amount of MPs in the marine environment is crucial because bioaccumulation of plastics in marine life can affect humans who consume marine organisms. This study compares the concentration of MPs in sediments between the intertidal and subtidal environments of Humboldt Bay, California. We hypothesized that the intertidal samples would have higher MP concentrations due to their proximity to shore and increased anthropogenic activity. Sediment samples were collected using hand corers in the intertidal region and a Smith McIntyre grab in the subtidal region. Organic material in the samples was oxidized using 30% hydrogen peroxide, then a density differentiation technique was used to separate plastics for further microscope identification. Preliminary results show that about 95% of MPs found in sediment are microfibers and the remaining 5% of MPs are degraded hard plastic. To date, more MPs have been found in the subtidal region than the intertidal region, with 980 MP particles recovered in the subtidal region and 340 MP particles recovered in the intertidal region. This study confirms the presence of microplastics within Humboldt Bay, and defines their distribution with proximity to shoreline. These results can be used by the community to update recycling practices, wastewater treatment procedures to mitigate microfibers, and raise awareness about marine life ingestion of plastics.

*Student Presenter

Upwelling Jet Separation in the California Current System

Renato Castelao[1], *Hao Luo*[1]

[1] *University of Georgia*

The California Current System is characterized by summertime wind-driven upwelling, high biological productivity, and an intense equatorward upwelling jet. The upwelling jet is generally located close to shore to the north of Cape Blanco, but it separates from the coast at the cape during summer extending farther offshore downstream of the separation point. Jet separation results in a wider region influenced by cold, nutrient-rich upwelled waters, strongly affecting biological productivity, mesoscale activity, and air-sea interactions. Here, we use a high-resolution ocean model to investigate some of the mechanisms that influence jet separation in the California Current System, including interactions of the flow with topography and variations in wind stress. We will also discuss the implications of our results for jet separation in other Eastern Boundary Current Systems.

Submesoscale Currents in the Coastal Ocean

Daniel Dauhajre[1]*, *James C. McWilliams*[1]

[1] *University of California, Los Angeles*

Submesoscale dynamics, ocean currents less than 1 km in size with lifetimes of hours to days, are previously unexplored in the coastal ocean. No paradigms for continental shelf circulation predict the existence of these high Rossby number phenomena. However, high-resolution regional simulations of the Southern California Bight (SCB) reveal an active submesoscale regime on the shelf: fronts, filaments, and vortices characterized by strong vertical velocity, surface convergence, cyclonic vorticity, and horizontal density gradient. In the nearshore, generation and alignment of submesoscale structures is controlled by the shape of the coastline and local bathymetry. Analysis of fronts and filaments in the SCB uncovers a diurnal evolution in the convergence and downwelling of submesoscale fronts and filaments. The strong surface convergence and downwelling of submesoscale coherent structures preferentially traps surface material on the shelf. Preliminary analyses of Lagrangian particle trajectories in the SCB suggests that submesoscale physics need to be resolved to accurately predict coastal connectivity and the fate and transport of nearshore material. Estimates of transport and residence times from Lagrangian analysis in submesoscale-resolving simulations are applicable to a variety of interdisciplinary studies, e.g., improving predictions for the population dynamics of giant kelp and determining the efficacy of eDNA as a tool to measure local species distribution.

*Student Presenter

Characterizing Phytoplankton Production and Community Composition from Mid-Shelf to Slope Waters off Oregon During 2013-2017

Xiuning Du[1]

[1] *Oregon State University*

Phytoplankton data were collected from the approximately biweekly sampling of hydrography and plankton along the Newport Hydrographic Line (NH) off central Oregon at a shelf station, NH5 (9 km from shore), and at a slope station NH25 (46 km from shore) during 2013-2017. We examine spatial connections of phytoplankton community characteristics from seasonal and interannual perspectives. Some preliminary findings are: diatom, the major biomass contributor to the study system, showed coherent seasonal patterns at both NH5 and NH25, with higher abundance during upwelling season and low during downwelling season, except in 2015 when the highest diatom bloom was observed in January-February at NH25; dinoflagellate abundance did not present any consistent seasonality during the five-year study. Interannually, diatom bloom magnitude was higher in 2017 and 2014 at NH5 but high in 2014-2016 at NH25. Year-season crossed community structure analysis showed little variance during 2015-2017 at either shelf or slope however, upwelling mediated year-season analysis indicate higher interannual community variability. Regression analysis of all data found diatom and dinoflagellate abundance at NH5 were significantly ($p = 0.01$) correlated with that at NH25, and diatom had stronger correlation than dinoflagellate. Community structure was correlated at $p = 0.05$ between shelf and slope during the upwelling season. Local environment variability was predominantly determined by local nutrient and upwelling variability and secondly by remote forcing drivers represented by PDO and MEI. Correlations between phytoplankton production and community cross-shelf changes with local environment variations associated with upwelling and Ekman transport processes will be explored.

Modeling Flood Present and Future Flood Risk in the Portland, OR Metro Area

Lumas Helaire[1] *

[1] *Portland State University*

The Portland, OR metro area periodically experiences winter flood events (Dec âĂŞ Feb) due to storm events of relatively short duration (<7 days). When these rain events are combined with excessive snowmelt such as the February 1996 event, there is the potential for extensive flooding and property damage. An analysis of water levels in Portland shows a complex relationship, with water levels dependent on discharge from the Columbia River and Willamette River, and the tidal range at Astoria, OR. We have developed a Delft3D numerical model of the Lower Columbia River (LCR) to help us better understand flood impacts. The model contains inputs from Columbia River and five of the major tributaries (Sandy, Washougal, Willamette, Lewis and Cowlitz) and estimates of ungauged discharge. LCR discharge records indicate that in winter floods scenarios, the peak water level at Portland is highly dependent on upstream discharge from the Columbia River at Bonneville, and discharge from smaller tributaries. An analysis of discharge over the past 100 years shows that during these flood events, tributaries such as the Sandy River, which normally are too small to be considered as a significant contribution to water levels in the LCR, can spike to over 2 kCMS during winter floods. An analysis of the February 1996 event shows that the extreme water levels resulted from a large amount of Columbia River discharge coinciding with record Willamette River event. Future scenarios involve the incorporation of 0.5m - 1.4m of sea level rise along with a 10-20% increase in discharge from future climate projections. We will also examine the effect of coastal tidal range on upstream water levels. The model water levels and inundation projections will help planners understand and mitigate the effects of projected sea level rise and climate related increases in discharge.

*Student Presenter

Human Induced Changes to Freshwater Transport Pathways on the OR/WA Shelf

Joe Jurisa[1], *David Jay*[1], *Stefan Talke*[1]

[1]*Portland State University*

The construction of jetties and the dredging of navigation channels at the mouth of the Columbia River (MCR) since the late 1880âĂŹs have altered both outlet depth and width by nearly 50%. Prior to channel modifications the MCR was wide (8.6km) and shallow with multiple outflow channels that migrated every winter. The channel modifications have resulted in the modern MCR consisting of a single narrow (∼4.5km), deep channel (30m). Additionally, the construction of dams in the upper Columbia River and its tributaries have fundamentally altered the seasonal pattern of river flow feeding the Lower Columbia River Estuary (LCRE), with the modern LCRE having a larger background flow during the winter and spring freshets reduced by 40% relative to historical, pre-modification levels. To assess the historical changes in freshwater transport on the shelf a historical LCRE model and modern LCRE model are developed using the Delft3D-Flexible Mesh modeling suite. Preliminary results from the two models using the same idealized river and wind forcing suggest that for the historical model, stratification in the vicinity of the mouth is increased and northward freshwater transport is reduced compared to the modern model. The potential implications on larger scale coastal circulation and upwelling will also be discussed.

*Student Presenter

A Tale of Transition: Physical and Chemical Conditions of Kelp Forests and Urchin Barrens within a MPA

Kerry J. Nickols[1], *David A. Koweek*[2], *Sarah B. Traiger*[1], *David A. Mucciarone*[2], *Steven Y. Litvin*[3], *Paul R. Leary*[2], *Brian Cohn*[1], *Heidi K. Hirsh*[2], *Robert B. Dunbar*[2]

[1]*California State University, Northridge,* [2]*Stanford Unviersity,* [3]*Monterey Bay Aquarium Research Institute*

Changing ocean conditions can have drastic impacts on nearshore marine ecosystems. Kelp forests in Southern Monterey Bay experienced dramatic declines due to warm water conditions in 2014-2016 and a boom in the purple sea urchin (*Strongylocentrotus purpuratus*) population. Although cold water conditions have returned to the region, some areas remain devoid of kelp and with a robust urchin population, despite the presence of sea otters and protection as a no-take marine reserve. Here we compare and contrast the physical and chemical environment of a site that has remained a kelp forest, and one that transitioned from a kelp forest to an urchin barren using physical and biogeochemical data from 2013-2014 and 2018. The findings presented here highlight the physical and chemical ecosystem services provided by kelp forests (attenuated currents and increased surface pH) and quantify the environmental changes experienced by rocky reefs when they transition from kelp forests to urchin barrens. Adaptive management of MPAs should consider not only the value of kelp forests as habitat for ecologically and economically important species, but as important contributors to physical and chemical modification of the nearshore ocean.

*Student Presenter

Comparison of Microplastics in the Benthic Sediments of the Northern, Central, and Southern Regions of Humbolt Bay, Northern California

Katherine Panebianco[1]*, *Thomas Allie*[1], *Alexandra Baker*[1], *Annette Carlson*[1], *Kyle Dahlman*[1], *Jacob Evans*[1], *Jack R. Hawley*[1], *Karansingh M. Keislar*[1], *Randall S. Keys*[1], *Nathaniel Kristan*[1], *Eric Lawrence*[1], *Matthew Lopez*[1], *Freya N. Mitchell*[1], *Cory B. Monroy*[1], *Erick Ortiz*[1], , *Daniel Raemer*[1], *Kezia F. Rasmussen*[1], *Wendy Raymond*[1], *Nicholas R. Schieferecke*[1], *Jennifer J. Snyder*[1], *Madeleine Tervet*[1], *Carolyn R.Westrick*[1], *Christine J. Cass*[1], *Daniel C. O'Shea*[1]

[1]*Humboldt State University*

Plastics are durable, persistent, and have become deeply intertwined into the global economy. This research focuses on microplastics (MPs) that fall within the size range of 0.335 to 5.00 mm. Microplastics can bioaccumulate in marine organisms when consumed and eventually end up in human food sources. This size range of MPs found in the benthic environment are especially susceptible to consumption by the benthos. This study documents microplastic counts in the subtidal sediments of Humboldt Bay (HB) in northern California. This area supports a human population of about 47,000 people, and has a history of heavy industrial activities associated with lumber, shipping, and fishing. We hypothesized that the highest concentration of MPs would occur in the central portion of HB (Entrance Bay), where there is intensive use by humans, pollution point sources and a circulation pattern that concentrates flow towards Entrance Bay. Samples were collected from the northern (North Bay), central (Entrance Bay), and southern (South Bay) areas of HB using a Smith McIntyre grab sampler from the R/V Coral Sea. Organic material in subsamples was oxidized using 30% hydrogen peroxide, then isolated using a density separation technique and counted via optical microscopy. Preliminary counts of the MPs found in the subtidal region of HB are highest in Entrance Bay with 473 particles, lower in North Bay with 289 particles, and lowest in South Bay with 218 particles. Approximately 80% of these MPs were fibers, and the remaining 20% were degraded plastics. This information can be used to better understand the distribution of MPs within the soft-bottom, benthic ecosystem of HB, and to inform local communities and agencies as to the likely sources of these pollutants.

*Student Presenter

Simulating the Migration of Northern Fur Seal Pups through the Bering Sea and North Pacific Ocean

Noel A. Pelland[1], *Jeremy T. Sterling*[1], *Devin S. Johnson*[1], *Mary-Anne Lea*[2]

[1]*NOAA Alaska Fisheries Science Center*, [2]*University of Tasmania Institute for Marine and Antarctic Studies*

The northern fur seal (*Callorhinus ursinus*) is a highly migratory top predator that breeds in summer on island rookeries throughout the North Pacific Rim; the largest collection of these - roughly half of the breeding population - is found in the Bering Sea. In late fall, individuals embark on long oceanic migrations that last through the winter and spring. For newly-weaned pups, this migration is a period of highly variable cohort survival for reasons that are only partially understood. This study investigates environmental influences on migration using satellite-telemetered movement of Bering Sea northern fur seal pups in five separate years. Interannual differences in the direction of pup dispersal are evident, with pups from two years traveling much farther to the east than pups in the remaining years. These differences are qualitatively similar to the differences in the prevailing winds, and are apparent even when controlling for the effects of sex, departure time, and departure island. Evidence suggests that winds are a predictor of pup movement at time scales of at least 1-15 d. Individual-based simulations of pup movement that take into account the effects of wind, surface currents, movement persistence, and background drift by sex have skill in reproducing the observed interannual variability in the most densely-sampled years. These results suggest that prevailing winds can impact the habitat used by northern fur seal pups in the critical first few weeks of their migration. Simulations of pup movements in other unobserved years, and comparisons of these to historical or ongoing monitoring of cohort survival, are one potential tool for investigating the influence that these displacements and other environmental variability may have on pup mortality and northern fur seal demography.

*Student Presenter

Evaluation and Comparison of Microplastic Contents in Wild Mussels and Maricultured Oysters from Humboldt Bay, California Using an Enzymatic Digestion Method

Daniel Raemer[1] *, *Daniel O'Shea*[1], *Christine Cass*[1]

[1] *Humboldt State University*

This research evaluates the microplastic contents of commercially maricultured Pacific oysters (*Crassostrea gigas*) and wild mussels (*Mytilus edulis*) from Humboldt Bay (HB), California. Ten bivalves were collected from each of three different locations in HB: North Bay, Entrance Bay, and South Bay. Oysters were purchased directly from a commercial oyster farmer who cultivates them in the North Bay. Bivalves were digested with proteolytic enzyme complexes, vacuum filtered, and microplastics were quantified by microscopic examination of filters. All samples contained microplastics, with plastic fibers being the most abundant items. Significantly different concentrations of microplastic particles (plastic particles/g tissue wet mass) were found between mussels collected from different locations and from the cultured oysters ($p = 0.000$). Mussels from North Bay contained the highest average concentration of microplastics (6.29 ± 1.73 items/g) and were significantly different from all other groups. Microplastic concentrations in Entrance Bay (3.39 ± 1.19 items/g) and South Bay (2.29 ± 1.75 items/g) mussels were intermediate and not significantly different from each other ($p = 0.452$). Oysters contained the lowest microplastic concentrations (0.72 ± 0.34 items/g) and were significantly different from North Bay ($p = 0.000$) and Entrance Bay ($p = 0.001$) mussels, but not from the South Bay mussels ($p = 0.104$). Half of the samples from each location were digested using the enzyme complex Corolase 7089 and the other half were digested with Corolase 8000, both supplied by AB Enzymes Inc. All samples treated with Corolase 8000 digested completely, whereas some of the samples treated with Corolase 7089 did not achieve complete digestion, suggesting that Corolase 8000 is more efficient for this purpose. No significant difference in microplastic recovery was found between the two treatments ($p=0.253$).

*Student Presenter

Comparing Oceanographic Conditions Between Marine Protected Areas and Reference Sites Provides the Context Necessary to Interpret Ecological Patterns and Responses

H. Eve Robinson[1,2], *Eric P. Bjorkstedt*[1,3]

[1]*Humboldt State University,* [2]*California Ocean Science Trust,* [3]*NOAA Southwest Fisheries Science Center*

Along the California coast, marine ecosystems exist in a highly energetic and variable oceanographic environment that shapes the dynamics of populations and communities. Therefore understanding how ocean conditions vary over space and time is essential for interpreting ecological responses to spatial management. A diverse suite of ocean observations can be used to characterize historical conditions and spatial context to inform the design of adaptive management strategies for marine protected areas (MPAs) in a variable and changing ocean climate. During a baseline study period along the North Coast region, anomalous ocean conditions impacted estuarine and nearshore ecosystems, featuring warmer than usual temperatures, an intense drought, and a harmful algal bloom. In this region that extends from the California-Oregon border to Point Arena, we synthesized oceanographic information to determine the spatial and seasonal patterns of structures along the coast. Using a statistical clustering algorithm (k-means clustering) on temperature, chlorophyll, currents, fronts, and freshwater discharge, consistent patterns and structures were detected. Observations of the coastal ocean during baseline monitoring were also compared to historical observations to understand variation in the structure and dynamics in the region. Stable patterns during the study period despite anomalous conditions suggest persistent oceanographic regions that might impact marine ecosystems. Comparisons between MPAs and reference sites suggest that in most cases these sites share similar oceanographic influences across seasons, while also highlighting factors that may contribute to MPA-reference site differences as the ecosystem changes over time. Successful development of oceanographic context for the North Coast and its application, drawing on observation systems (e.g., CeNCOOS and NANOOS), can serve as a template for a statewide synthesis in support of broader long-term monitoring, evaluation, and adaptive management of California's MPA network.

*Student Presenter

Distribution of Microplastics at the Surface and Within the Water Column in Humbolt Bay, Northern Califoria

Nicholas R. Schieferecke[1] *, *Thomas Allie*[1], *Alexandra Baker*[1], *Annette J. Carlson*[1], *Kyle Dahlman*[1], *Jacob Evans*[1], *Jack R. Hawley*[1], *Karansingh M. Keislar*[1], *Randall S. Keys*[1], *Nathaniel V. Kristan*[1], *Eric Lawrence*[1], *Matthew T. Lopez*[1], *Freya N. Mitchell*[1], *Cory B. Monroy*[1], *Erick Ortiz*[1], *Katherine K. Panebianco*[1], *Daniel Raemer*[1], *Kezia F. Rasmussen*[1], *Wendy Raymond*[1], *Jennifer J. Snyder*[1], *Madeleine J. Tervet*[1], *Carolyn R. Westrick*[1], *Christine J. Cass*[1], *Daniel C. O'Shea*[1]

[1] *Humboldt State University*

Plastic is a commonly used, man-made material that is highly durable, easy to produce, and used widely throughout society. The persistence of plastics results in their introduction to the oceans via river runoff from urban and industrial areas, intentional dumping, and fishing practices. This study investigates microplastics (MPs) in the size range of 0.335 to 5 mm. MPs directly affect marine ecosystems, as they are mistaken for food by marine organisms and are then transferred to humans when we consume seafood. MP concentration in the water column can vary due to river input, tidal flux, and source proximity. We hypothesized that the highest concentration of MPs within Humboldt Bay (HB) in northern California would be found in the harbor entrance (Entrance Bay), which is adjacent to a sewage treatment plant and near a solid waste transfer station. We surveyed MP concentrations within the water column and surface layer in the three sub-basins of HB. Surface and water column samples were obtained using 0.335-mm mesh neuston and ring nets, respectively. Organic material in the samples was removed via oxidation with 30% hydrogen peroxide. Density separation techniques were then used to separate plastics for microscope analysis. Preliminary results do not support our hypothesis, as air-sea interface MP concentrations are highest in North Bay ($6.25 \times 10^{-5} \pm 4.03 \times 10^{-5}$ plastic particles per liter (ppL)) , followed by South Bay ($3.48 \times 10^{-5} \pm 1.04 \times 10^{-5}$ ppL), and lowest within Entrance Bay ($2.23 \times 10^{-5} \pm 0.87 \times 10^{-5}$ ppL). Within the water column, the highest average concentration of MPs was found in South Bay ($5.81 \times 10^{-5} \pm 11.89 \times 10^{-5}$ ppL), with lower concentrations in Entrance Bay ($1.46 \times 10^{-5} \pm 0.84 \times 10^{-5}$ ppL) and North Bay ($1.21 \times 10^{-5} \pm 0.87 \times 10^{-5}$ ppL). This study can help the public understand the quantity of plastic contained within HB, where it is most concentrated, and possible mitigation practices.

*Student Presenter

Bring the Noise: the Influence of Larval Recruitment Variability on the Adaptive Management of Marine Protected Areas

Will White[1], *Kirsten Grorud-Colvert*[1], *Jenn Caselle*[2]

[1]*Oregon State University,* [2]*University California, Santa Barbara*

Marine protected areas (MPAs) are an increasingly common conservation and management tool worldwide. Typically, managers expect that after fishing ceases inside an MPA, previously fished populations will steadily increase in abundance as they return to unfished levels. Hence adaptive management typically involves examining the ratio of fish density after:before MPA implementation or inside:outside MPAs (the latter is often more common because 'before' data are lacking). However, the expectation of a steady, positive increase in these response ratios is complicated by high variability in larval recruitment to populations in MPAs, both over time (pulses and droughts) and over space (hotspots and coldspots). We use a combination of theoretical models and data on kelp bass, *Paralabrax clathratus*, from southern California MPAs to show that a) realistic levels of recruitment variability produce huge uncertainty in response ratio calculations; b) including information on larval recruitment improves detection of decade-scale population trends; and c) the time scale of recruitment variability should influence the time scale over which MPA effects are expected to be measured. In general we show that variability introduced at the larval stage has a strong influence on the successful management of coastal populations.

*Student Presenter

Calanus marshallae and *Calanus pacificus* Egg Production in Relation to Environmental Variables in a Productive Upwelling Zone in the Northern California Current

Samantha Zeman[1], *Wiliam Peterson*[1], *Jennifer Fisher*[1], *Jay Peterson*[1]

[1]*Hatfield Marine Science Center*

Calanus pacificus and *Calanus marshallae* egg production rates (EPRs) were quantified from in situ incubations monthly between 2001-2016. These data represent a unique time series exploring zooplankton production in a coastal upwelling zone. EPRs (eggs female^{-1} day^{-1}) were similar for both *Calanus* species over years and season. Egg production was lowest in early summer (19 ± 12 eggs female^{-1} day^{-1}) and highest (38 ± 16 eggs female^{-1} day^{-1}) in April, before the onset of the upwelling season. The summer reduction in EPR for both species reflects a decrease in *Calanus* density. EPRs were negatively correlated with surface and deep temperature and positively correlated with oxygen. In transitional months (October and April), nutrient loads were positively correlated with higher EPRs. Chlorophyll a concentrations were correlated with higher EPRs, especially in the winter months when primary production was minimal. For *C. marshallae*, summer EPRs (May-Sept) were correlated with negative PDO years, but local-scale upwelling indices did not explain enhanced EPRs for either species. The lack of relationship between *Calanus* egg production and upwelling events suggests these species are not food limited, but instead the upwelling season, with an accompanying rise in primary production, creates ample nutrition for optimal egg laying

*Student Presenter

Offshore Transport of Coastal Water in the California Current System Due to Mesoscale Eddies

Caitlin Amos[1]*, *Renato M. Castelao*[1]

[1] *University of Georgia*

Nonlinear mesoscale eddies can have a significant impact on the distribution of coastal water in the California Current System (CCS). Upwelling along the coast results in nutrient rich coastal water that can be horizontally and vertically advected by eddies. Using satellite estimates of particulate organic carbon (POC) as a tracer of coastal water, this study quantifies the influence of eddies on the cross-shelf transport of water and the materials it contains in the CCS. Coastal water is initially pushed offshore by Ekman transport caused by the prevailing alongshore winds and then eddies trap and transport the water farther offshore. In the CCS, cyclonic eddies generally move westward and are characterized by positive POC anomalies. Cyclonic eddies found offshore that were generated near the coast contain higher POC concentrations on average in their interior than eddies of the same amplitude generated locally offshore, indicating that eddies are trapping coastal water near the coast and transporting it offshore. This analysis demonstrates that eddies play an important role in the cross-shelf transport of coastal water and the redistribution of materials, such as POC, in the CCS.

*Student Presenter

Is Humboldt Bay a Cryptic Hot Spot for Harmful Algal Blooms?

Clarissa Anderson[1], *Brett Stacy*[2], *Raphael Kudela*[2], *Kendra Hayashi*[2], *Greg Dale*[3], *Roxanne Robertson*[4], *Eric Bjorkstedt*[4,5], *Brian Tissot*[5]

[1]*Northern Hydrology,* [2]*University of California, Santa Cruz,* [3]*Coast Seafoods,* [4]*NOAA Southwest Fisheries Science Center,* [5]*Humboldt State University*

Harmful algal blooms (HABs) caused by the toxic diatom *Pseudo-nitzschia* have become commonplace in coastal California, with routine shellfish advisories and annual stranding events of protected marine mammals and seabirds. The largest shellfish disaster was in 2015 with an unprecedented HAB that closed the Dungeness and rock crab fishery in California for the entire season and resulted in $60M dollars in losses. A fundamental question affecting the mitigation of HAB events is how well the coastal oceanographic conditions that nurture these blooms explain the risk to estuarine environments where much of the commercial and recreational shellfish harvesting occurs. With the introduction of the "operational" California Harmful Algae Risk Mapping (C-HARM) system, coastal conditions conducive to blooms of *Pseudo-nitzschia* and its associated toxin, domoic acid, can be monitored in real-time. This kind of advanced warning has proven valuable to marine mammal resource managers given the tight connection between offshore toxins and animal stranding events. Where C-HARM provides less information is in major inlets such as the San Francisco Bay-Estuary and Humboldt Bay. The latter is the site of some of the highest commercial oyster production in the nation, which is very rarely affected by toxins even when the coastal region is experiencing a major HAB. The mystery deepens now that we have observed two seasons of periodic bursts of record high domoic acid in the waters surrounding shellfish growing sites in Humboldt Bay. Using a combination of particle tracking simulations and coincident measures of shellfish and water toxin levels, we explore the biological and physical controls that might underlie the mystery of Humboldt Bay. Our central aim is to improve model products for key stakeholders currently underserved by routine HAB forecasts and to identify the physical and biological factors affecting HAB risk in California estuaries.

*Student Presenter

Late Summer Observations of Turbulent Nutrient Flux in the Chukchi Sea

Nick Beaird[1]

[1] *Oregon State University*

We present unique simultaneous observations of turbulent diffusivity and nutrient concentrations collected via a towed platform on the Chukchi Sea shelf. In 2017 a towed sled capable of high resolution, full water column, nutrient observations was fitted with fine scale shear (aquadopp and 500 kHz ADCP) and temperature microstructure instruments. Repeat occupations of Distributed Biological Observatory transects on the Chukchi shelf were made, targeting regions of high productivity, biodiversity, and rates of biological change. Occupations spanned a strong wind-driven upwelling event in which Atlantic Waters from the Arctic halocline intruded onto the shelf via Barrow Canyon. Here we present the distribution of turbulent diffusivity on the shelf in relation to bathymetry and the upwelling event. Rates of vertical turbulent nutrient flux into the nutrient poor euphotic zone are quantified.

Validation of Rip-Current Driven Cross-Shore Exchange Simulations

Christine Baker[1]*, *Melissa Moulton*[1], *Nirnimesh Kumar*[1]

[1] *University of Washington*

Both transient and bathymetrically controlled rip currents affect the exchange of contaminants, pollutants, and larvae between the surf zone and the inner shelf along shorelines of the Eastern Pacific. Transient rip currents, hypothesized to be generated by coalescence of surfzone eddies, are stochastic, and their locations are not known a priori. In contrast, bathymetrically controlled rip currents are driven by radiation-stress and pressure gradients from bathymetrically induced alongshore variations in breaking waves, and often occur at fixed locations. Together these processes lead to complex, time-varying, three-dimensional patterns of exchange between the surf zone and the inner shelf.

Here, a phase resolving, non-hydrostatic numerical model, Simulating Waves At the Shore (SWASH), is used to simulate wave propagation and three-dimensional circulation patterns on an alongshore-inhomogeneous barred beach in the Atlantic Ocean near Duck, North Carolina. Observations of surf zone waves and currents are compared to simulated nearshore velocities. The field-validated model is used to explore the dynamics of eddy coalescence and cross-shore exchange of transient and bathymetrically driven rip currents.

*Student Presenter

Where Estuarine Inflow Originates on the Shelf

Elizabeth Brasseale[1]*, *Parker MacCready*[1]

[1] *University of Washington*

An idealized 3D estuary model is used to examine the pathways by which shelf water becomes estuarine water. On the Pacific Northwest coast, the most ecologically active regions are the estuaries, where rivers meet the Pacific Ocean. The unique mixture of freshwater and seawater provides a home for oysters and a nursery for salmon. Of the water in the Puget Sound, a fjord-like estuary in the Pacific Northwest, 90% originated in the ocean rather than the rivers which demonstrates the importance of the shelf-estuary pathway in maintaining estuarine ecology. The idealized model used in this study was built in Regional Ocean Modeling Systems (ROMS) and features an estuarine channel with a river on a rectangular coastline adjoining a stratified continental shelf with tides. Exchange flow develops as river output is mixed with the coastal ocean by a single frequency 12-hour tide. Two methods of analysis are used to highlight the shelf-estuary path within the idealized model: the first technique is Lagrangian particle tracking and the second technique is Total Exchange Flow (TEF) isohaline calculation of inflow and outflow across cross-sections of the model. Particle tracking shows that shelf water comes from the Kelvin direction (from the right in the Northern Hemisphere) and from deeper in the water column. TEF shows that exchange flow spins up on the shelf and increases with distance from the estuary mouth.

Fate of Internal Waves on a Shallow Shelf

Kristen A. Davis[1], *Robert S. Arthur*[2], *Justin Rogers*[3], *Oliver Fringer*[3], *Emma Reid*[1], *Thomas DeCarlo*[4], *Anne Cohen*[5]

[1] *University of California, Irvine,* [2] *Lawrence Livermore National Labs,* [3] *Stanford University,* [4] *University of Western Australia,* [5] *Woods Hole Oceanographic Institution*

Internal waves strongly influence the physical and chemical environment of coastal ecosystems worldwide We report observations from a distributed temperature sensing (DTS) system that tracked the transformation of internal waves from the shelf break to the surf zone over a shelf-slope region. The spatially-continuous view of temperature fields provides a perspective of physical processes previously available only in laboratory settings or numerical models, including internal wave reflection off a natural slope, shoreward transport of dense fluid within trapped cores, internal "tide pools" (dense water left behind after the retreat of an internal wave), and the transport of internal wave upwelled water on to a shallow reef. Analysis shows that the fate of internal waves on this shelf - whether transmitted into shallow waters or reflected back offshore - is mediated by local water column density and shear structure, with important implications for the distribution of energy, heat, and nutrients on the shelf.

*Student Presenter

Headland Recirculation in a Wind-Driven System

Connor D. Dibble[1]*, *Steven G. Morgan*[1], *John L. Largier*[1], *Brian P. Gaylord*[1]

[1]*Bodega Marine Laboratory*

Recruitment hotspots, where larvae of benthic organisms reach adult habitat in greater numbers, have been associated with nearshore oceanographic processes including fronts, internal waves, surfzone dissipation, and eddy recirculation. These larval transport mechanisms play an important role in population dynamics, which has motivated research to understand hydrodynamic structures that retain or accumulate larvae near benthic habitats. We measured currents around a coastal headland known to operate as a recruitment hotspot using an array of six stationary profilers to document flow dynamics between the leeward bay and the outer coast. Using real-vector empirical orthogonal functions (EOF), we captured circulation structures consistent with flow separation and eddy formation in the lee of the headland. However, the predominant mode of circulation was a sheared eddy with recirculation confined to a dynamic bottom layer while surface waters were displaced downwind. The relationship between leading EOF structures and forcing mechanisms, including local and remote winds and the alongshore coastal current, were explored using generalized linear models in a Bayesian framework. This approach quantified the magnitude of forces driving flow structures in the system while also allowing for the analysis to be extended using simulated and historical wind data. Our detailed analysis of wind-driven recirculation dynamics provides a basis for understanding larval entrainment around headlands, including the effect of the interaction of larval behaviors and depth-distributions on exposure to retentive conditions. We will extend this work by simulating circulation dynamics according to the bounds set by historical wind data in our system and predicting retention rates for organisms based on accompanying larval distribution data. This study contributes to our understanding of the operation of wind-driven headland recirculation and serves as a basis to improve our understanding of recruitment hotspots associated with the small and mid-sized headlands that are common throughout the California Current System.

*Student Presenter

Modeled and Observed Internal Tidal Variability in the Santa Maria Basin

David Fertitta[1] ***, *Sutara Suanda*[2], *Christopher A. Edwards*[3], *Kevin Haas*[4], *Emanuele Di Lorenzo*[4], *Art Miller*[5], *Nirnimesh Kumar*[1]

[1] *University of Washington,* [2] *University of Otago,* [3] *University of California, Santa Cruz,* [4] *Georgia Institute of Technology,* [5] *Scripps Institution of Oceanography*

The Santa Maria Basin (SMB) is a part of the Eastern Pacific coastal ocean extending from Pt. Arguello to Pt. Buchon, CA. This region is subjected to strong internal tidal variability leading to complex three-dimensional circulation patterns, density evolution on synoptic and shorter time scales, and material exchange. Previous studies in this region indicate that during summer the semidiurnal internal tidal activity onshore of the shelf break is from internal tidal generation on the continental slope at water depths of h=1000-3000m, with no local generation occurring at the shelf break. Furthermore, from the shelf-break to the mid-shelf, about 50% of internal tidal energy fluxes are phase-locked to astronomical tides (coherent), while the other 50% is incoherent. However, the length scales over which semidiurnal internal tidal energetics vary within the SMB, along with temporal variability on seasonal and longer time scales, are not yet known.

Here, we use the Regional Ocean Modeling System to simulate semidiurnal internal tidal dynamics in the SMB. The model grid with varying horizontal resolution optimally resolves the coastal and inner-shelf dynamics. Model hindcasts for 2017 are validated against velocity and temperature measurements from the mid- and inner-shelf observations from September to October, 2017. At 50m water depth, modeled internal tidal energy fluxes are stronger offshore of Pt. Sal and Pt. Purisima but decrease north of Pt. Sal. Energy fluxes strongly dissipate from 50 to 30m, indicating a region of strong vertical mixing, which has implications for stratification and cross-shore circulation. The year long simulation is also used to investigate seasonal variability in internal tidal generation pattern, and transition from coherent to incoherent fluxes. The dependency of the seasonal variability in internal tidal energetics to changes in local stratification, wind-driven circulation, submesoscale eddy activity, and nonlinear interactions are investigated. Funded by the Office of Naval Research.

*Student Presenter

A Ratchet to Shore: How Background Flow and Nonlinear Internal Waves Can Interact to Enhance Transport of Quasi-Lagrangian Plankton Mimics

Jessica C. Garwood[1]*, *Peter J. S. Franks*[1], *Perry Naughton*[2], *Paul L. D. Roberts*[1], *Andrew J. Lucas*[1,2], *Jules S. Jaffe*[1]

[1]*Scripps Institution of Oceanography,* [2]*University of California, San Diego*

Because larvae are at the mercy of horizontal currents and must return to their adult habitats, shoreward transport in the nearshore region is necessary for the recruitment of many coastal benthic populations. High-frequency physical processes, such as nonlinear internal waves, can enhance this transport, but obtaining reliable estimates of internal wave-induced transport relevant to organisms that can swim vertically is challenging. Without the option to track individual organisms in situ, we rely on measurements collected by a swarm of 16 mini Autonomous Underwater Explorers (m-AUEs) with programmable behavior, paired with simple simulations, to gain insight on how plankton behavior, internal waves, and background flow can interact and influence transport in shallow ocean waters (< 50 m). Preliminary results from plankton mimic deployments off Mission Beach, CA show that internal waves propagating in a vertically structured background flow can lead to depth-keeping plankton experiencing bursts in cross-shore velocities that are an order of magnitude (up to 20 cm/s) higher than background (< 2 cm/s).

The Influence of Diurnal Wind Forcing on Internal Waves Over the Inner Shelf

Matt Gough[1], *Tucker Friesmuth*[1], *Jamie MacMahan*[1], *Jacqueline McSweeney*[2], *Jack Barth*[2], *Jim Lerczak*[2], *Nirnimesh Kumar*[3], *Falk Feddersen*[4]

[1]*Naval Postgraduate School,* [2]*Oregon State University,* [3]*University of Washington,* [4]*Scripps Institution of Oceanography*

110 thermistor strings and 50 ADCPs were deployed along a 60 km stretch of coastline in central California at water depths 50 m to 7 m between August-October 2017 as part of the Inner Shelf Dynamics DRI. Temperature and current profiles reveal an abundance of internal waves (IWs) in the form of internal bores and solitons at semidiurnal and shorter timescales which exhibit considerable longshore and temporal variability. During periods of diurnal cross-shore afternoon wind forcing, inner shelf temperature profiles exhibit a distinctive diurnal pattern at water depths 25 m and less where the combination of turbulent mixing, surface heat flux, and cross-shore heat flux cause the entire water column to becomes mixed and heated. During these periods of time there is an observed suppression of IWs in the afternoon. Mechanisms responsible for the suppression of IW propagation are explored which include IW wave guide modification by a shoaling or deepening of the pycnocline, changes in the buoyancy frequency, and wind-induced shear. Because IWs drive cross-shore transport over the inner shelf, these findings have important implications towards understanding how diurnal wind-forcing modifies cross-shore transport through the suppression of IW propagation.

*Student Presenter

Challenges of Understanding and Managing Disease Outbreaks in the Sea

Sarah Gravem[1], *Jennifer Burnaford*[2], *Amy Henry*[3], *Laurel Field*[1], *Elliot Jackson*[4], *Noah Jaffe*[5], *Malina Loeher*[6], *Bruce Menge*[1], *Melissa Miner*[7], *Emil Aalto*[8], *Sean Bignami*[9], *Jenn Burt*[10], *Cynthia Catton*[6], *Tim Carpenter*[11], *Benjamin Dalziel*[1], *Mike Dawson*[12], *Christopher Derito*[4], *Corey Garza*[13], *Maurice Goodman*[14], *Cassandra Glaspie*[1], *Drew Harvell*[4], *Lenaig Hemery*[1], *Ian Hewson*[1], *Brenda Konar*[15], *Diego Montecino-Latorre*[16], *Monica Moritsch*[7], *Priya Nanjappa*[17], *Melissa Pespeni*[18], *Jonathan Robinson*[1], *Laura Rogers-Bennett*[6], *Steven Rumrill*[19], *Cascade Sorte*[3], *Lauren Schiebelhut*[12], *Jenna Sullivan*[1], *Dannise Ruiz-Ramos*[12], *Allison Tracy*[4], *Piper Wallingford*[3]

[1]*Oregon State University*, [2]*California State University, Fullerton*, [3]*University of California, Irvine*, [4]*Cornell University*, [5]*San Francisco State University*, [6]*California Department of Fish and Wildlife*, [7]*University of California, Santa Cruz*, [8]*Stanford University*, [9]*Concordia University*, [10]*Simon Fraser University*, [11]*Seattle Aquarium*, [12]*University of California, Merced*, [13]*California State University, Monterey Bay*, [14]*California State University, San Luis Obispo*, [15]*University of Alaska Fairbanks*, [16]*University of California, Davis*, [17]*American Association of Fish and Wildlife Agencies*, [18]*University of Vermont*, [19]*Oregon Department of Fish and Wildlife*

A number of infectious diseases have affected animals in the California Current Large Marine Ecosystem in recent years, most notably sea star wasting syndrome. SSWS was one of the largest marine epizootics on record and severely affected multiple sea stars species from Mexico to Alaska. Compared to terrestrial diseases, SSWS and many marine diseases have unique qualities that are often fundamentally linked to life in the aqueous environment. The water medium allows pathogens to survive longer and travel further and more quickly than pathogens in air. Further, the water medium can make direct contact between individuals unnecessary for disease transmission. Pelagic larval phases, which are made possible by the water medium, result in relatively open populations that can either promote or hinder inter-generational and inter-site transmission depending on whether larvae carry pathogens. Pelagic larvae are also potentially beneficial for population recovery after disease, because they can repopulate disparate areas, their large numbers can replenish populations rapidly, and their large numbers have a high adaptive potential. On the other hand, remediation strategies like captive breeding, vaccination, antibiotic therapy, quarantine, culling, and the development of resistant populations are challenging or unfeasible for most marine species.

Because of the unique features of life in the water, terrestrial (typically vertebrate) models and management strategies are not often sufficient for understanding or addressing outbreaks in the sea. An integration of current knowledge in oceanography and particle transport with disease ecology is necessary if we are to understand, predict, or mitigate marine disease outbreaks in the future.

*Student Presenter

Idealized Simulation of Cross-Shore Tracer Exchange Nearshore with Transient Rip-Currents, Stratification, and Diurnal Heat-Flux

Derek Grimes[1]*, *Falk Feddersen*[1], *Nirnimesh Kumar*[2], *Sarah Giddings*[1], *Geno Pawlak*[3]

[1]*Scripps Institution of Oceanography,* [2]*University of Washington,* [3]*University California, San Diego*

Rip-currents are ubiquitous along nearly all open coastlines, and are important for tracer exchange between the surf-zone (SZ) and the inner-shelf (IS). Transient rip-currents are stochastic, generated by coalescence of surfzone eddies, and lead to ejection of SZ water and vorticity onto the IS. Previously, three-dimensional numerical simulations with an initial stratification and surfzone eddy forcing show generation of transient rip currents, which eventually leading to a mid-water well-mixed column of offshore flow that transports SZ source tracers offshore. Essentially, the SZ eddies enhance the vertical mixing just offshore of the surfzone, producing an intermediate density fluid and a quasi-three layer baroclinic exchange flow, with on-shore flow near the surface and bottom, and offshore flow in between. This exchange flow is energetic up to 8 surfzone widths offshore, and relies crucially on the interaction of transient rip currents and stratification.

These prior simulations do not include any surface heat flux. The solar-heating cycle can also drive exchange in shallow reservoirs, and may exhibit complex spatiotemporal phasing and variability. Previous surfzone tracer releases have observed both a much warmer surfzone (for mid-day release) to a colder surfzone (for early morning release) relative to the inner-shelf. Thus, the timing of a shoreline sourced pollution event, with respect to the solar day may result in different tracer evolution and different cross-shore exchange pathways. The coupled influence of diurnal heat flux, inner-shelf stratification, and transient rip currents on cross-shore exchange is not understood. On a natural, open alongshore uniform coastline these processes operate in tandem, motivating the study of their coupling. Here, a set of idealized ROMS simulations with tracer releases at different times of the day are used to examine how rip-currents and diurnal heat fluxes influence exchange.

*Student Presenter

Morphologic and Transient Rip Current Dynamics: ISDRI Observations and Model Simulations

Annika O'Dea[1], ***Merrick C. Haller*** [1], *Nirnimesh Kumar*[2]

[1]*Oregon State University,* [2]*University of Washington*

Rip currents, offshore-oriented currents generated in the surf zone, are important sources of exchange between the surf zone and inner shelf. Rips can be classified as either bathymetrically-controlled (morphologic) or transient, depending on their dominant forcing mechanism. Adequate measurements that fully capture transient rip events are difficult to obtain, and questions still remain regarding transient rip dynamics and the conditions under which they form.

Here, we present X-band radar observations of both morphologic and transient rip currents, collected as part of the Inner Shelf Dynamics DRI, a coordinated field and modeling study conducted in September and October 2017. The experimental site was in central California on a relatively straight section of coastline with frequent rip currents. Measurements from ADCPs and temperature sensors deployed by our collaborators (MacMahan *et al.*, NPS) and co-located within the X-band radar footprint are used as validation. The radar image time series will be used to assess the temporal and spatial dynamics (e.g., alongshore spacing, cross-shore extent, frequency of occurrence, and duration) of rips as observed over the two-month study period.

Finally, a phase-resolving Boussinesq model funwaveC will be used to characterize the potential interactions and co-existence of transient and morphologic rips. Past studies have shown that funwaveC is capable of adequately simulating the nearshore eddy field that drives transient rips. Here, funwaveC will be used to simulate transient and morphologic rip generation and dynamics over an alongshore-variable bathymetry, with channels oriented perpendicular to the shoreline. A range of wave conditions (wave height, period, directional spread) will be simulated to determine the types of rips and temporal scales of rip pulsations seen in different conditions. Model results will be compared to ISDRI observations to determine if similar trends and variability are simulated.

Multi-Platform Observations of Headland Eddy-Internal Wave Interactions

Michael Kovatch[1] *, *Falk Feddersen*[1], *Ken Melville*[1], *Luc Lenain*[1], *Jen MacKinnon*[1], *Amy Waterhouse*[1], *André Palóczy*[1], *Jack Barth*[2], *Jim Lerczak*[2], *Jacqueline McSweeney*[2], *Jim Thomson*[3], *Melissa Moulton*[3], *C. Chris Chickadel*[3], *Jamie MacMahan*[4], *John Colosi*[4], *Joe Calantoni*[5]

[1]*Scripps Institution of Oceanography,* [2]*Oregon Sate University,* [3]*University of Washington,* [4]*National Park Service,* [5]*Naval Research Laboratory*

In the fall 2017, observations were collected around Point Sal, one of a series of small headlands north of Point Conception, CA. As with other headlands, the rapid change in coastline results in flow separation and recirculation, the impact of which is two-fold. First, the changing bathymetry results in a transition from along-shore to cross-shore flow causing enhanced upwelling in the lee. This differential upwelling has been studied for larger headlands, such as Pt. Arena, CA, but is not as well studied for smaller headlands. Second, the recirculation has the potential to release from the coast and advect away in the form of a headland eddy. In addition to the headland processes, the greater Point Sal region is consistently inundated with nonlinear internal waves. Shipboard and drifter observations have shown that convergent wave fronts trap and advect tracers toward the shoreline. Increased mixing is also observed at the leading edge of the impinging waves. While internal wave and eddy impacts have been studied separately in the past, these two processes occur in unison at Point Sal, resulting in a novel and complex study area. Moored observations provide long records of high temporal resolution but the lower spatial resolution makes observing the spatial variability of small-scale phenomena challenging. However, with the addition of vessel-, airplane-, and radar-based measurements, the details can be more clearly resolved. Flow separation fronts have noticeably different cross- and along-front structure, as well as propagation behavior, compared to internal wave fronts. The behavior and structure of each respective front before and after interaction with the other will be characterized using the vast array of available measurements.

This project is part of the Office of Naval Research funded "Inner-Shelf Departmental Research Initiative" involving many institutions and investigators.

*Student Presenter

A model investigation of Larval Transport for Shallow-Water Rockfish Populations in Carmel Bay and Southern Monterey Bay

Anna B. Lowe[1]*, *Christopher A. Edwards*[1], *Patrick T. Drake*[1]

[1]*University of California, Santa Cruz,*

Motivated by empirical evidence, this study identifies common transport pathways of self-recruitment and connectivity between Carmel Bay and southwest Monterey Bay populations of kelp rockfish (Sebastes atrovirens) and develops a mechanistic understanding of recruitment around the Monterey Peninsula. This research uses the Regional Ocean Modeling System (ROMS) with realistic atmospheric and tidal forcing to simulate the oceanographic environment. An offline nesting configuration resolves the region surrounding Monterey Bay at 120 m resolution. Lagrangian particle trajectories were calculated from the model output using OpenDrift. Particles were released daily during the 2014 spring upwelling season from suitable habitat in Carmel Bay and southwest Monterey Bay. Particles were released at 2 m and recruit if they reach suitable habitat (5-40 m bottom depth) in Carmel Bay or southwest Monterey Bay within the competency period 30-60 days. Both populations record higher levels of self-recruitment than connectivity (Carmel Bay: 3.2%, 1.7% of particles released, southwest Monterey Bay: 2.7%, 0.2% of particles released, respectively). Carmel Bay self-recruits remain close to release locations (97% stay within 10 km). Whereas Monterey BayâĂŹs characteristic counter-clockwise circulation entrains many self-recruits before returning to suitable habitat in southwest Monterey Bay (69% stay within 10 km). Connectivity between the two populations typically follows a direct route around the Monterey Peninsula; northward connectivity is 6x more common than southward connectivity. Particles that do not recruit in either region typically move southwestward. These recruitment pathways are related to the alongshore wind and fronts that develop off the Monterey Peninsula. Northward connectivity occurs when the alongshore wind relaxes and the upwelling front, off the Monterey Peninsula, disappears. These results demonstrate that nearby populations (and thus MPAs) do not have homologous recruitment or exchange. Nearshore dynamics may cause different transport pathways or develop transient barriers to connectivity. These results have important implications for MPA management.

*Student Presenter

Effects of Winds, River Discharge and Tides on Shelf-Estuary Coupling in Coos Bay, OR

Maria Jose Marin Jarrin[1]*, *David Sutherland*[1]

[1] *University of Oregon*

The Coos Estuary typifies the small, seasonally-forced estuarine systems found along the relatively narrow Oregon continental shelf and other eastern boundary ocean basins worldwide. During 2014, we recorded velocity data from an upward-looking ADCP located mid-estuary to examine the influence of winds, tides and river discharge on the subtidal flow in the main estuarine channel, and in particular how shelf waters enter the estuary. These velocity time series show that during high and moderate discharge, the exchange flow deepens and strengthens in the classical sense: seaward flow at the surface and landward flow at depth. However, we find reversals where landward flow occurs for periods of more than a day across the water column. These reversal events coincide with neap tides and downwelling-favorable northward winds. Here, we further explore these in situ data in combination with idealized numerical simulations of the shelf-estuary system to quantify the effect of winds, tides and coastal currents on the observed flow. The exact partitioning of how shelf waters enter the estuary, and what forces modulate that coupling, is important to investigate since it influences larval recruitment, dissolved oxygen levels, contaminant transport, and other biophysical processes in the heavily-used Coos Estuary.

*Student Presenter

Observations of Internal Tides on the Inner Shelf: A Three Dimensional Look at Propagation and Shoaling

Jacqueline McSweeney[1], *Jim Lerczak*[1], *Jack Barth*[1], *Amy Waterhouse*[2], *Jen MacKinnon*[2], *John Colosi*[3], *Jamie MacMahan*[3]

[1]*Oregon State University*, [2]*Scripps Institution of Oceanography*, [3]*Naval Postgraduate School*

Internal tides and non-linear internal waves (NLIWs) are major contributors to changes in stratification and mixing throughout the inner-shelf. Generated offshore, internal tides propagate shoreward and dynamically evolve as the NLIWs interact with shoaling bathymetry. Though shoaling NLIWs have been a topic of interest for some time, it is a difficult process to observe because shoaling NLIWs are highly non-linear, evolve very quickly, and may have along-shelf spatial variability. In this project, we use mooring and shipboard observations from a 2017 ONR-funded field campaign offshore of central California to describe internal tides as they propagate shoreward and shoal. Our mooring array includes ∼30 moorings that span from 150m depth (∼40km offshore) to 5m depth (right outside the surfzone) and include 2 parallel across-shelf lines (∼3 km apart) as well as an along-shelf line on the 25m isobath. The moorings were deployed September - October 2017 and overlap with 2 week-long shipboard surveys. Our project focuses on observations offshore of a relatively-straight coastline, which provides a quasi-idealized context to study these processes. We present a 3-dimensional look at the internal wave transformation during shoaling and describe the underlying dynamics modulating internal waves in this region.

*Student Presenter

"Robot larvae" Test the Effects of Behavior on Larval Transport in a Retentive Upwelling Shadow

Steven G. Morgan[1], *Connor D. Dibble*[1], *M. Grant Susner*[1], *Tom G. Wolcott*[2], *Donna Wolcott*[2], *John L. Largier*[1]

[1]*Bodega Marine Laboratory*, [2]*North Carolina State University*

Microscopic larvae of marine animals are still largely thought of as being at the mercy of currents, despite evidence of their ability to exert some behavioral control over transport. The question remains open because we cannot track larvae while they develop for weeks and months in a dynamic ocean. We developed a robotic larval mimic, Autonomous Behaving Lagrangian Explorer (ABLE), to experimentally test the ability of larvae to regulate transport by vertically swimming between sheared currents flowing at different rates or directions. ABLE senses its environment, simulates the vertical swimming responses of larvae and reveals transport trajectories by periodically relaying its location. We programmed ABLEs to mimic three larval behaviors: remaining near surface, remaining near bottom and diel vertical migration. We repeatedly deployed groups of replicates for 24 h in the complex flow of an upwelling shadow in the lee of Bodega Head. The behaviors had profound consequences for larval transport and retention matching our predictions based on known circulation patterns and larval behaviors. During prevailing winds, ABLEs simulating each behavior stayed together with those 1) near bottom staying put in an eddy, 2) near surface traveling far south alongshore and 3) undertaking a DVM traveling south alongshore an intermediate distance. During relaxation events, ABLEs simulating each behavior spread apart more than those deployed during prevailing winds with those 1) near bottom staying put, 2) near surface traveling out of the bay and far north and 3) undertaking a DVM traveled north an intermediate distance. Wind stress had little effect on the differences exhibited among ABLEs with the three simulated behaviors. The overall dispersion of ABLEs near surface was far greater than those at near bottom while those undertaking a DVM were intermediate. Thus, ABLEs provided direct evidence for the effectiveness of behavior in regulating larval transport under challenging conditions.

*Student Presenter

Vertical Structure of Cross-Shore Flow in the Inner Shelf in the Southern California Bight

Geno Pawlak[1], *Ajinkya Desai*[1], *Madison Zamora*[1], *Ed Parnell*[2], *Kristen Davis*[3]

[1]*University of California, San Diego,* [2]*Scripps Institution of Oceanography,* [3]*University of California, Irvine*

Cross-shore flow on the inner continental shelf is important for transport and dispersal of nutrients, larvae and pollutants between the nearshore zone and the outer shelf. Analysis of velocity time series from a bottom-mounted ADCP at Point Loma, CA for 2013 indicates that baroclinic motion at tidal frequencies represents a dominant mechanism for cross-shore exchange on the inner-shelf. Exchange is predominantly manifested via a bottom-intensified two-layer mode with the bulk of the variability for this mode associated with the $M2$ frequency. The exchange flux driven by the $M2$ accounts for approximately 35% of the net cross-shore exchange flux. Variability at diurnal timescales is relatively weaker. The vertical asymmetry of the cross-shore mode is accounted for by the phase relationship between the barotropic and baroclinic $M2$ tide. The vertical extent of the bottom intensification varies with seasonal shifts in the depth of the thermocline. A shift to a surface-intensified vertical structure was observed in the $M2$ cross-shore flow for Sept/Oct 2013, coincident with a phase shift in the baroclinic flow. It is hypothesized that this shift results from seasonal changes in the local propagation of $M2$ internal tide energy. We examine this hypothesis and compare with velocity and stratification observations from a second inner shelf location at Newport, CA.

*Student Presenter

Reduced Barnacle Larval Abundance and Settlement in Response to the "Blob" and El Niño: Patterns, Nearshore Thermal Stratification, and Potential Mechanisms

Jesús Pineda[1], *Nathalie Reyns*[2], *Steve Lentz*[1]

[1] *Woods Hole Oceanographic Institution,* [2] *University of San Diego*

We assessed the effects of the 'Blob' and El Niño on the settlement rate of an abundant intertidal barnacle. Daily or weekly settlement, nearshore temperature, currents, and abundance of early-stage barnacle nauplii and Chthamalus fissus cyprids were measured in La Jolla, California, from the inception of the large-scale warm-water anomaly known as the 'Blob' in 2014, to one year following the 2015/2016 El Niño. We also measured over two years of weekly settlement rates during the 1997/1998 El Niño in La Jolla and in two Mexican sites. Settlement was low during the Blob and the 2015/2016 El Niño, but increased dramatically after its eclipse, and rates remained high through spring 2017. Barnacle nauplii and C. fissus cyprid abundances were also low during the Blob and El Niño. Nearshore water column thermal stratification and variability of the high-frequency cross-shore currents, a measure of internal wave activity, declined during the Blob and El Niño, but increased at the end of El Niño. Similarly, settlement rates in the Mexican sites were low during the 1997/1998 El Niño. The reduction in settlement during the Blob and El Niño may be related to two factors: a decrease in water-column stratification, which can influence internal bore larval transport and the cross-shore distribution of larvae, and also to lower early-stage larval abundance, potentially related to reduced reproductive output or high nauplii mortality during the disturbances.

*Student Presenter

Thermal Stratification and Nearshore Larval Accumulation and Transport

Nathalie Reyns[1], *Jesús Pineda*[2], *Steven Lentz*[2]

[1] *University of San Diego,* [2] *Woods Hole Oceanographic Institution*

Larval transport in the nearshore plays a central role in larval dispersal and connectivity of shallow water species; however, few studies have resolved the relevant scales of larval transport and patterns of larval distribution in this region. To better understand the physical-biological mechanisms that determine larval transport, we combined high-resolution physical measurements (temperature, currents and pressure) with vertically-stratified sampling of barnacle larval distributions in a nearshore region, in water 4-12m deep (within 1km from adult, rocky intertidal habitat, La Jolla, California, USA). We sampled larvae during 2014 and 2015, using a semi-vortex pump to determine how larval vertical distributions varied spatially and temporally with changing hydrodynamic conditions. Barnacle cyprids were most abundant in depths 2-3 m above the bottom, and were distributed closer to shore when regional thermal stratification was greatest. Our data suggests that cyprids are transported by the internal tide and accumulated at a well-mixed nearshore station, where stratification breaks down. Cyprid vertical distribution shifted to surface waters, however, in response to high-frequency alongshore current reversals, and their associated warm fronts. Some of these episodic events also occurred during downwelling conditions, and were associated with large peaks in settlement, suggesting that larval transport from the nearshore zone of accumulation to the rocky intertidal results from the interaction between low- and high-frequency dynamics.

*Student Presenter

A Detailed Nearshore Heat Budget

Gregory Sinnett[1]*, Falk Feddersen*[1]

[1]*Scripps Institution of Oceanography*

Temperature is a critical component in the ecologically sensitive nearshore region ($<$ 8 m depth, containing the surfzone). A previous month-long (summer-time) study at Scripps Beach in Southern California closed a primitive nearshore heat budget, with the principal result that the previously unconsidered "wave heating" term (due to viscous dissipation of breaking-wave generated turbulence) was significant, on average 23% of incoming solar radiation. A subsequent study found elevated albedo from the bubbly whitewater of breaking surface waves reduced surfzone solar radiation on average by 14%. These competing wave-heating and albedo-related solar heat flux reduction components vary with wave height and solar radiation. Additional heat flux variability exists at time scales from minutes to hours due to advective processes such as internal waves and rip currents. Here, new observations from a dense thermistor array ($\approx$ 1 m vertical resolution and $\approx$ 10 m cross-shore resolution), three ADCPs, a co-located solar radiometer and other instruments are used to track temperature variability and heat flux components on time scales from minutes to months. Wave heating, the new albedo-related solar heat flux reduction, and advective internal wave and rip-current processes affect the nearshore heat budget and are quantified for the first time in a full nearshore heat budget.

Mixing and Frontal Action in the Outer Southern California Bight

Jerry A. Smith[1]

[1]*Scripps Institution of Oceanography*

Analysis of data from the Langmuir Circulation DRI continues. The multi-investigator experiment was carried out in the area between Catalina, San Clemente, and St. Nicolas islands, in the South California Bight. Last year, I presented some preliminary analyses of data from our "Phased-Array Doppler Sonar," which led to some interesting statistics concerning Langmuir circulation. This year, analysis is focusing on the continuous time-series of vertical profiles of temperature, salinity, and density from the wave-powered "WireWalker" profiler. Thorpe-scale analysis is employed to estimate dissipation rates, which I hope to relate to the LC statistics and other meteorological data. With profiles extending to as close as 10 cm below the surface, the diurnal-cycle of heating and night-time remixing is quite clear. We also observe depth-uniform changes in T and S that can only be explained as fronts advecting past the R/P FLIP. Future collaborations with other involved investigators will explore this spatial variability.

Long-Distance Transport and Dilution of Tracers Released from Multiple Shoreline and Estuarine Sources

Xiaodong Wu[1], *Falk Feddersen*[1], *Sarah N. Giddings*[1], *Nirnimesh Kumar*[2], *Derek Grimes*[1], *Geno Pawlak*[3]

[1]*Scripps Institution of Oceanography,* [2]*University of Washington,* [3]*University of California, San Diego*

The surfzone is vulnerable to pollution from contaminated coastal and estuarine discharges. Along the San Diego- Tijuana (SDTJ) coast, multiple pollution sources (e.g., the Tijuana River, Punta Bandera in Mexico, and the South Bay Ocean outfall) deliver various pollutants to the region. For example, in Punta Bandera, just 10 km south of the US Mexico border, approximately 20 million gallons a day of partially treated sewage is released onto the beach. During favorable wind and oceanic conditions, the contaminated plume travels northwards, potentially as far as across the U.S. border. Poor water quality within the hotspot impact region causes beach closures and threatens the ecological health of coastal regions, highlighting the need for an improved understanding of tracer transport and dilution from the surf zone to the inner shelf along the coast.

Here, we employ a high-resolution wave-current-coupled model to simulate the transport and dispersion of tracers released from multiple potential sources. This model includes realistic temperature, salinity, offshore currents, waves and atmospheric forcing for the study region and it resolves the current and wave fields from the inner shelf to surf zone and within the estuary. The model boundary conditions are nested from a series of solutions that scale up to the CA Current. The model is first validated using in-situ hydrographic measurements that were conducted in 2015 as part of the CSIDE (Cross Surfzone/Inner-shelf Dye Exchange) project. Following model validation, the transport and dilution of tracer released from the Tijuana Estuary, Punta Bandera and the South Bay Ocean outfall are simulated using a numerical passive dye tracer. The effects of winds, waves, stratification and discharge magnitude from the point source on the distribution of the impact region are investigated. We hypothesize that, under south swell conditions, the tracer is transported northward. In this case, the development of stratification on the inner shelf may confine the plume transport close to the shoreline and even relatively small amounts of discharge may travel long distances alongshore. Under well mixed inner shelf conditions, the plume may be transported offshore to the inner shelf, a region where the wind and tidal forcing dominate the circulation.

*Student Presenter

Responses of Biological Populations to Different Time Scales of Environmental Variability

Louis W. Botsford[1], *Lauren Yamane*[1], *Mikaela M. Provost*[1]

[1]*University of California, Davis*

Physical variability in the Eastern Pacific Ocean occurs on a broad range of time scales. The human impact of such variability depends how biological populations respond. Age structured populations (e.g., fish, mammals and birds) respond differently to different time scales of physical variability. They are most sensitive to time scales near their generation time and to very long time scales, so their responses vary from species to species and they are affected by fishing. Fishing increases the selective sensitivity at both the long time scales and the generational time scales. This creates some ambiguity when fished populations show greater variability at long time scales: is that due to a change in the environment or increased sensitivity to long time scales (termed a "cloaking effect"). Shorter lived species such as Pacific salmon are more sensitive to environmental variability in general, and are most likely to show a peak in sensitivity to generational time scales as well as long time scales. Longer lived species such as Pacific hake are less sensitive, and usually only have a peak at long time scales. Our group has recently shown that surprisingly, a future increase in the frequency of ENSOs would actually benefit the population status of Brandt's cormorants that breeds on the Farallon Islands. We are currently investigating what life history characteristics lead to peaks in sensitivity to both generational and very long time scales vs. only generational time scales, using Pacific salmon and Atlantic cod as examples.

*Student Presenter

Transitions and Recovery in Ocean Structure and Plankton Assemblages Associated with the 2009-10 El Niño and the 2014-16 Marine Heatwave off Northern California

Eric P. Bjorkstedt[1,2], *Roxanne R. Robertson*[2]

[1]*NOAA Southwest Fisheries Science Center,* [2]*Humboldt State University*

Physical and biological observations along the Trinidad Head Line (THL) span a decade marked by significant climate variability, and provide a basis for examining how this variability has affected coastal ecosystems in the transitional region of California Current between Cape Blanco and Cape Mendocino. Synthesis of changes in physical conditions (e.g., water column structure) and biological time series for copepods, euphausiids, and selected meroplankton (larval fish, cephalopods) capture the dramatic effects of the 2014-16 marine heatwave (MHW) off northern California, but also suggest a step-change from cooler conditions (and concurrent ecosystem responses) following the 2009-10 El Niño. In contrast to the cool conditions observed in 2008 and early 2009, the period between the 2009-10 El Niño and the onset of the MHW is marked by a juxtaposition of warm- and cool-water taxa in coincident with stronger seasonal warming of surface waters overlying waters upwelled onto the shelf than was observed prior to the 2009-10 El Niño. With the onset of the 'warm blob' and subsequent 2015-16 El Niño, sharp changes were observed in the plankton community: many cool water taxa declined sharply as warm water taxa increased in abundance and diversity. Concurrent novel observations of unusually high larval densities of several larval fishes and market squid, whether by advection of planktonic taxa or by poleward shifts in spawning distributions several fishes and market squid. Shifts in the cross-shelf distributions of several taxa appear to be related to displacement of cool water from the shelf and reduced cross-shelf transport. These changes in the plankton assemblage were mirrored in the size structure of euphausiids, marked by a shift to intermediate sizes during the El Niño-MHW interval and a sharp reduction in size during the MHW. Since the dissipation of the MHW, the plankton community appears to have recovered towards conditions observed following the 2009-10 El Niño; some transitions have been more gradual than others, reflecting interactions between species? life histories and physical drivers of variability.

*Student Presenter

Low-frequency Isopycnal Variability in the Alaska Gyre from Argo

Patrick Cummins[1], *Diane Masson*[1]

[1]*Institute of Ocean Sciences, Fisheries and Oceans Canada*

Gridded fields of hydrographic data from Argo are used to examine the low-frequency variability of representative isopycnal surfaces over the Alaska Gyre in the eastern subpolar North Pacific. Anomalies in the depth of isopycnal surfaces and spice anomalies on these surfaces are considered over the 14 year period, 2004-2017. The vertical displacement of isopycnals at large scales is described and related to atmospheric forcing. Evidence is presented for the propagation of isopycnal depth anomalies in the Subarctic Current. In particular, it is shown that anomalies in the depth of deep isopycnal surfaces propagate westward at approximately twice the speed of first mode, long baroclinic Rossby waves, consistent with altimetric observations of sea surface height variability. Conversely, spice anomalies in the upper ocean are advected eastward by the mean flow. However, the dominant subsurface spice signal is a large-scale positive anomaly that forms locally on isopycnals below the main pycnocline. This anomaly develops due to the downward diffusion of heat associated with the marine heatwave of 2013-14 over the northeast Pacific.

Variable Trends in Pteropod Abundance between the Shelf and Slope from Two Decades of Observations off Newport Oregon, USA

Jennifer Fisher[1], *Bill Peterson*[2], *Jay Peterson*[3], [4]*Hongsheng Bi*

[1]*Oregon State University,* [2]*NOAA Northwest Fisheries Science Center*, [3]NOAA Office of Science and Technology, [4]University of Maryland

Waters which upwell nearshore in the northern California Current have low pH and aragonite saturation values < 1.0 which may impair the ability of the planktonic snail *Limacina helicina* to produce aragonite or may lead to shell dissolution, resulting in mortality. Here, we present data on the abundance of *L. helicina* over 22 years from two stations located on the continental shelf and slope that are exposed to upwelled waters differentially. Over the 22 year time span, the seasonal peak abundance of *L. helicina* followed a negative trend in the nearshore coastal upwelling zone where waters are corrosive. In contrast, the seasonal peak abundance increased offshore where aragonite saturation values are generally » 1 year round. Further, the long term trend nearshore in the coastal upwelling region was variable while the long term trend offshore was inversely correlated with the North Pacific Gyre Oscillation.

*Student Presenter

Climate and Bottom up Forcing of Phytoplankton Biomass and Primary Production in the Southern California Current System

Ralf Goericke[1]

[1]*Scripps Institution of Oceanography*

The CalCOFI program has made systematic observations of water column structure, concentrations of inorganic nutrients, phytoplankton biomass and primary production in the southern California Current System for the last 35 years. Across our study domain, these variables show consistent variations with each other and indices of ocean climate, suggesting close links between these. However, the strength of links varies spatially, i.e. in the oligotrophic offshore, the region of the California Current, the coastal upwelling and the Southern California Bight. These differences suggest that even in a small area such as our study domain links between forcing and oceanographic variables vary dramatically. Over the last 35 years three time periods can be distinguished based on basin-wide forcing: 1984 to 1998 when the PDO was in a positive phase, 1999 to 2014 when the PDO was in a negative phase and 2014 to the present when the region experienced the marine heatwave and the most recent ENSO. We asked if the responses of oceanographic variables (phytoplankton biomass, mixed layer nitrate, nitracline depth) to each other and climate forcing differed between these three periods. Work carried out so far does not show changing responses of variables to forcing during the three time periods in spite of the strong forcing of the system and large variations of the variables. These results suggest that the characteristics of the mechanisms that mediate responses did not change across the three time periods and that established relationships could be used to gauge the response of the system to future climate change.

*Student Presenter

Characterizing Pacific Ocean Regime Shifts

Matthew Newman[1], *Sanjiv Kumar*[2]

[1] *University of Colorado*, [2] *Auburn University*

The Pacific Decadal Oscillation (PDO), the dominant year-round pattern of monthly North Pacific sea surface temperature (SST) variability, and the related basin-wide Interdecadal Pacific Oscillation (IPO), undergoes relatively rapid changes in phase every few decades or so. Such "regime shifts", which have been related to many regional and global climate impacts including variations in the global mean temperature and the recent warming hiatus, are often thought to represent sudden nonlinear changes between relatively stable climate states. We suggest instead that these regime shifts could result from a linear superposition of different key Pacific physical processes, which operate on different timescales to drive similar PDO/IPO-like SST anomaly patterns. The combination of these processes can be represented by a low-order multivariate autoregressive model (multivariate Ornstein-Uhlenbeck process) known as a linear inverse model (LIM), empirically determined from the zero- and one-season lag covariance of observed seasonal Pacific SST anomalies. In the LIM, variations in the superposition of randomly forced processes alone can result in both Pacific regime shifts and a PDO power spectrum resembling 1/f noise. Key aspects of observed Pacific regime shifts since 1890, including the dominant pattern, its amplitude, and the probability distribution of regime durations (time intervals between phase changes) can all be reproduced by this simple LIM.

Moreover, the LIM captures details of Pacific regime shifts significantly better than do all the CMIP5 coupled GCM simulations of the 20^{th} century, perhaps because Pacific variability simulated by these models is often based on a different balance of processes than in nature. This is illustrated by a LIM constructed from one historical run of the NCAR CESM (one of the CMIP5 models), which is also able to reproduce the regime shift behavior found within a 40-member ensemble of the same model even as its regime behavior exhibits typically larger amplitudes and shorter durations than observations.

*Student Presenter

Exploring the Deterministic Dynamics of the Generation and Propagation of Decadal Subsurface Water-Mass Anomalies in the North Pacific

Mercedes Pozo Buil[1], *Emanuele Di Lorenzo*[2]

[1]*University of California, Santa Cruz,* [2]*Georgia Institute of Technology*

Given the strong recent interest in the decadal timescale variability and the potential for its predictability, it is critical to identify dynamics that carry inherent decadal-scale predictability. Using basin-scale reanalysis and an ensemble of the Regional Oceanic Modeling System (ROMS) in an eddy-permitting resolution, preliminary results suggest that the advection of subsurface anomalies originated in the subduction regions of the western North Pacific influence the low-frequency variance of the source water properties that feed the main upwelling systems of the eastern North Pacific. Although previous studies have shown that the subsurface anomalies propagate by mean advection, the anomalies in the ensemble model are also transformed from the generation region (western North Pacific) to the eastern boundary, implying that the anomalous advection term (i.e., eddy-scale variability) plays some role in the transformation and propagation of the anomalies. Here, we will use the ROMS ensemble and a Lagrangian offline numerical tool (Arianne) to (1) examine the contribution of the propagation dynamics (anomalous advection of anomalies vs. advection by the mean currents) to the low-frequency character of the subsurface water-mass anomalies, and (2) diagnose the atmospheric forcing mechanisms that drive the deterministic and predictable low-frequency variability of the subsurface anomalies. Preliminary results suggest that the decadal-scale variability associated with the subsurface water-mass anomalies originated in the western North Pacific may be driven by basin-scale wind stress curl forcing with a delay of approximately 3 years.

*Student Presenter

Water Level Trends in the North-Eastern Pacific Since 1853

Stefan A. Talke[1], *D. A. Jay*[1]

[1]*Portland State University*

Using records obtained from the US National Archives, we analyze sea-level and tidal trends in the North-East Pacific since 1853. After digitizing records, a careful reanalysis of meta-data, data quality, and leveling information enables us to assess time-variable uncertainty and tie historical records to a modern datum. Results from Astoria (1853-1876), San Diego (1853-1872) and Port Townsend (1873-1877) confirm inter-annual variability observed in the San Francisco sea-level record (1854-present), increasing confidence in long-term patterns. Records from Sitka (1893-1894) and Kodiak Island (1881-1890; 1906-1909) confirm that sea-level is dropping in Alaska, while comparison of available records from CA to WA highlights the strong local variability in sea-level rise caused by plate tectonics, glacial isostatic adjustment, and other factors such as trends in river flow. Significant local variability is observed in SF Bay and the Columbia River Estuary; for example, an approximately 0.2 m/century difference in relative sea-level rise trends is observed in Fort Stevens (OR) and Astoria (OR) over the past 100 years, though the locations are separated by less than 10 miles. Also in the Columbia Estuary, altered river flow and changed channel depths have altered the seasonal cycle of water level and the mean water level; in upriver locations, a drop in water level of greater than 0.5m has occurred. An 30% reduction in the flow out of the Golden Gate also contributes to the sea-level signal in San Francisco Bay. Anthropogenic changes to depth, river flow, and estuary planform also drive trends in tidal statistics, with both SF Bay and the Columbia River estuary exhibiting an increasing tide range on the order of 5-10% per century. Nearby coastal stations show much less change in tidal statistics, suggesting that any trends in oceanic conditions (sea-level, stratification, winds) have a minor or negligible effect on measured tides.

*Student Presenter

Thirty-Five Year Trends of Eastern North Pacific SST and SST Phenology

Andrew Thomas[1], *Nick Record*[2], *Karen Stamieszkin*[2], *Kathy Mills*[3], *Lisa Kerr*[3]

[1]*University of Maine*, [2]*Bigelow Laboratory for Ocean Science*, [3]*Gulf of Maine Research Institute*

Thirty-five years (1982 - 2016) of OISST data, subset over the 3 NOAA Large Marine Ecosystems (LMEs) that encompass the North American west coast (Gulf of Alaska, California Current, Gulf of California) are used to quantify decadal trends in both SST and 3 metrics of summer SST phenology. Monthly OISST data provide maps of the 35-year trends in SST, characterized by warming over most of the study region, strongest in the Gulf of California, but cooling within the California upwelling region. Self-organizing maps (SOMs) group the interannual structure behind these trends, presented as a map of similarly behaving regions and the structure within each grouped region. The dominant feature of all regions is strong negative, then positive, SST anomalies in the 2007-2016 period. Daily OISST data are then used to extract 3 metrics of summer phenology (summer start, end and duration) within each year. Thirty-five year trends in these three metrics are mapped over the study region, showing mostly earlier trending start dates, strongly spatially variable end dates and increasing summer duration, especially over the Gulfs of Alaska and California, although few regions have statistically significant trends. SOMs are used to group the interannual structure behind the phenology trends, presented as maps of similarly behaving regions and the temporal structure dominating each region.

*Student Presenter

Blue Whales and Greenwaves: Oceanographic Determinants of Migration Phenology

Briana Abrahms[1], *Elliott Hazen*[1], *Ellen Aikens*[2], *Steven Bograd*[1], *Mike Jacox*[1], *Jeremy Goldbogen*[3], *Matt Savoca*[3], *Ladd M. Irvine*[4], *Daniel M. Palacios*[4], *Bruce Mate*[4]

[1]*NOAA Southwest Fiseries Science Center,* [2]*Wyoming Cooperative Fish and Wildlife Research Unit,* [3]*Stanford Hopkins Marine Station,* [4]*Oregon State University*

In the California Current, the movements and life histories of many top predators are closely tied to the phenology of upwelling-driven coastal productivity. For migratory species, tracking resources that propagate across space and time (i.e. 'resource waves') can theoretically enhance energy gains during migration. To track resource waves, animals may rely on proximate cues and/or memory of climatological phenologies to forecast conditions beyond their immediate perceptual ranges. While studies have linked the phenology of marine migrants with the phenology of resources in a single location, no empirical investigation of tracking of resource waves among migratory marine megafauna exists. We investigated the role of resource tracking, both contemporaneously (response to local conditions) and climatologically (memory), in shaping the phenology of blue whales, Balaenoptera musculus, during spring/summer migrations in the eastern North Pacific. We combined a 10-year blue whale telemetry dataset with the timing of the springtime chlorophyll-a bloom, a demonstrated proxy for krill availability. We did not find a significant relationship between the contemporaneous date of peak productivity and date of blue whale use (linear regression $p=0.23$), including when chlorophyll-a was lagged up to 3 months. However, blue whale use had a significant association with the climatological phenology of peaks in chlorophyll-a ($p < 0.001$), and blue whales matched their movements to the average timing of the spring bloom over three times better than random simulated migrants. This suggests that blue whales target the timing of their migrations to exploit the seasonal green-up of predictable, geographically-fixed productivity hotspots. Moreover, reliance on climatological phenologies has important conservation implications given potential future changes in upwelling that may disrupt resource waves. Understanding the local- and/or basin-scale drivers of coastal productivity is critical for assessing the trophic effects of environmental changes, as we show that such drivers indirectly influence the migration patterns of an emblematic and endangered marine mammal species.

*Student Presenter

What Time and Space Sampling is Needed to Resolve the California Undercurrent?

Stuart Bishop[1], *Jasen Jacobsen*[2], *Eric Bjorkstedt*[3]

[1]*North Carolina State University,* [2]*University of California, Santa Cruz,* [3]*NOAA Southwest Fisheries Science Center*

The California Undercurrent (CUC) is a subsurface thin ribbon of poleward flowing warm, salty, and low PV water at the shelf break along the Eastern Boundary of the North Pacific. It is thought to be important for a number of potential impacts, including facilitating cross-shelf exchange and transport of low oxygen from the south. Gliders have routinely been used to observe the cross and along-shore variability of the broader California Current System, including the CUC. In addition to glider transects NOAA has been running semi-regular weather-permitting monthly cruises at Trinidad Head (41N). Five stations span the inshore region to beyond the shelf break where CTDs are cast to 450 m have been performed since 2010. The nominal spacing between sites is approximately 5 km. In addition, as a part of CenCOOS there was a Seaglider that continuously monitored the TH line from 2015-2017. The surface spacing between 1000 m Seaglider dives is approximately 6 km every 4 hours, but the Seaglider can capture higher subsurface resolution due to the saw-tooth sampling pattern. In this study the Seaglider data is subsampled using a random generator in space and time to coarsen the data to investigate the time and space scale dependence of CUC's along-shore geostrophic velocity. The goal is to determine how well the TH line of discrete monthly CTDs can resolve the CUC transport strength.

*Student Presenter

Influences of Local and Large-Scale Processes on the Body Composition of Northern California Current Euphausiids

Christine J. Cass[1], *Eric P. Bjorkstedt*[1,2], *Roxanne R. Robertson*[1,2]

[1]*Humboldt State University,* [2]*NOAA Southwest Fisheries Science Center*

Euphausiids play an important role in the northern California Current (NCC) food web, serving as a prey source for marine birds, baleen whales, and commercially important fish species. To better understand what leads to seasonal and interannual variability in euphausiid prey quality, adult Euphausia pacifica and *Thysanoessa spinifera* have been collected since May 2013 off the coast of Trinidad, CA, USA (∼41°N, THL). Individuals are collected approximately monthly from the upper 100 m, and their protein, lipid, and calorie content is determined. During July 2013 to May 2014, small numbers of these species were also collected off of Newport, OR (∼44.5°N, NHL) to assess spatial variability in these parameters. Our generated time series reveals the importance of both local and large-scale oceanographic processes in determining body composition of NCC euphausiids. During summer 2013, euphausiids, particularly the shelf-dwelling *T. spinifera*, had significantly higher concentrations of lipids off of Newport than Trinidad (*T. spinifera* mean values of 22-26% versus 4-6% of dry mass (DM), respectively). This was likely due to variability in local euphausiid prey, as surface chlorophyll concentrations during this time were highest at nearshore NHL stations where *T. spinifera* were most abundant. Responses of euphausiids to large-scale oceanographic events were also evident in the time series. A warm water anomaly called "the Blob" occurred in the northeastern Pacific Ocean from fall 2013-winter 2015/16. It started offshore, and reached the northern California and Oregon coast in September 2014. Temperatures within the Blob were 2-4 degrees Celsius above average and anomalously warm conditions extended up to 100 m depth. During the Blob (fall 2014 to summer 2015), lipid content (%DM) of THL E. pacifica was significantly lower (33-66%) than during the same time period a year prior.

*Student Presenter

Seasonal Variability and Dissolved Oxygen Trends in the California Undercurrent Off Northern California

Jasen Jacobsen[1] *, *Stuart Bishop*[1], *Eric Bjorkstedt*[2,3]

[1]*North Carolina State University,* [2]*Humboldt State University,* [3]*NOAA Southwest Fisheries Science Center*

The phenology of coastal upwelling in the California Current System (CCS) changes in the vicinity of the Cape Mendocino: upwelling is more persistent to the south and exhibits stronger seasonality to the north. Moreover, recent modeling work has shown a similar geographic shift in the phenology of the California Undercurrent (CU) and seawater properties on the 26.5 $\sigma\theta$ surface (Kurapov *et al.*, 2017). Temperature, background potential vorticity (PV), and geostrophic velocity exhibit a smaller seasonal amplitude south of Cape Mendocino compared to farther north. In this study we aim to use monthly cross-shelf observations along the Trinidad Head Line (41N) to assess the phenology of the CU 70 km north of Cape Mendocino from 2010-2017. During this period the climate modes shifted from a "cool-productive" phase to a warmer, less-productive phase. We develop a seasonal climatology of the hydrography and along-shore geostrophic velocity in the region and subsequently assess whether there are any trends in CU properties and dissolved oxygen (DO) related to shifting climate modes. This analysis shows that the CU is only present in this region in the fall when upwelling favorable winds subside. These results corroborate the strong seasonality of the CU north of Cape Mendocino (and regions farther north) in contrast to the dynamics observed farther south. Along density surfaces deeper than 26.5 $\sigma\theta$ increases in DO appear to be associated with reduction in apparent oxygen utilization (AOU). This increase may be explained by either a local decline in the supply of organic substrate available for microbial respiration, or by a change in the characteristics of source water related to increase in the strength of the North Pacific gyre. In the broader context of the long-term decline in DO across the CCS, this study highlights the potential for temporary trend reversals at local scales that may not be coherent between geographic regions.

*Student Presenter

Detection and Characterization of Submesoscale Coherent Vortices from Argo Float Observations in the Northeast Pacific

Daniel McCoy[1]*, *Daniele Bianchi*[1], *Andrew Stewart*[1]

[1]*University of California, Los Angeles*

Submesoscale coherent vortices (SCV) are ubiquitous throughout the ocean, but their frequency and role in large-scale ocean circulation are poorly understood. Cuddies are a form of Eastern boundary upwelling system SCVs that are generated within the poleward flowing California Undercurrent (CU), a consistent feature of the California Current System. The characteristically warm and salty CU water, originating along the equator, can occasionally become trapped within these long-lived anticyclonic cuddies, propagating westward across the Pacific. Sinking as they travel along isopycnal surfaces, the lack of an observational surface expression with subthermocline SCVs makes them difficult to detect and study using satellite altimetry. Here, we take advantage of the network of Argo floats to identify occurrences of these vortices due to their warm, salty, and weakly stratified signatures, which contrast against the surrounding ocean. We develop a general algorithm to detect SCVs based on spiciness and stratification anomalies and apply it to the array of Argo profiles. The method results in hundreds (check order of magnitude) of detections from 20+ years of observations in the North Pacific. This allows us to develop robust statistics of SCV properties at different stages of their life cycle, including size, shape, and intensity. We further use reconstructed eddy properties to investigate their formation mechanism and life cycle, and to estimate their contribution to the transport of material properties from the Eastern boundary to the North Pacific's interior.

*Student Presenter

Linking Phytoplankton Biomass and Wind Patterns Using Satellite Data in the Northern California Current System

Hally B. Stone[1]*, *Neil S. Banas*[2], *Parker MacCready*[1]

[1]*University of Washington,* [2]*University of Strathclyde*

Eastern Boundary Upwelling Systems like the California Current System (CCS) are highly productive regions due to the abundant nutrients largely supplied to the euphotic zone through coastal upwelling. However, previous studies suggest that productivity is limited in the presence of extremely high winds because phytoplankton are swept off of the shelf before they can utilize the upwelled nutrients. There have been numerous studies into the relationship between productivity and wind patterns, using both models and observations, that suggest an optimal wind speed to ensure the most productivity on the shelf, and this optimal wind speed is related to both the shelf width and the degree of wind intermittency. However, there have been few studies that apply this relationship between productivity and wind patterns to the Northern California Current System (north of 42°N; NCCS), an unusually productive region with highly variable upwelling-favorable and downwelling-favorable winds, and many studies largely ignore phytoplankton once they leave the shelf. Using ocean color derived from GlobColour, a merged satellite data product, and NCEP Reanalysis winds, we examine the relationship between phytoplankton biomass and wind patterns in the CCS. Results from this analysis suggest that there is an optimal wind speed for peak productivity, though this relationship varies throughout the domain. In addition to upwelling indices to characterize wind intermittency, results from a particle tracking experiment using a ROMS model of the NCCS are used to map retention times with respect to wind patterns. This analysis focuses on both the shelf region (within 75 km of the coast) and the offshore region (75 - 300 km from the coast) to characterize the effects of wind stress, wind intermittency, and retention times on phytoplankton biomass, including both spatial and temporal variability.

*Student Presenter

Coastal winds and poleward undercurrents

***Roger M Samelson*[1]**

[1]*Oregon State University*

A time-dependent, inviscid, linear theory for the generation of poleward undercurrent flow under upwelling conditions along mid-latitude ocean eastern boundaries is proposed. The theory relies on a conceptual separation of timescales between the rapid, coastal-trapped wave response to upwelling winds and the subsequent slow, interior quasi-geostrophic evolution. Solutions are obtained under idealized conditions in which the coastal boundary and the continental slope topography are independent of alongshore, meridional coordinate, and the time-dependent wind-stress forcing is spatially uniform and directed alongshore. A time-dependent coastal boundary condition on the slow-timescale interior flow, consisting of the low-frequency, geostrophically balanced sea-surface height disturbance over the outer shelf, is obtained from consideration of the fast-timescale, coastal-trapped response. A quasi-geostrophic potential vorticity equation is then solved to determine the interior response to this time-dependent boundary condition. Under upwelling conditions, the results show the formation of a localized region of subsurface poleward flow over the upper continental slope that is qualitatively consistent in amplitude, location, and timing with observations of poleward undercurrents on eastern boundaries. Despite its origin as a sea-surface height anomaly, the coastal boundary condition drives a baroclinic planetary wave response, in which the poleward subsurface flow evolves in planetary vorticity balance with induced subsurface upwelling.

*Student Presenter

Seasonal and Interannual Transports of Water Into the California Current from the South

Ted Strub[1], *Corinne James*[1], *Craig Risien*[1]

[1] *Oregon State University*

Twenty-five years of altimeter data are used to examine the connection between the southern boundary of the California Current and regions to the south off Mexico and the tropics. On seasonal time scales, connections between the equatorial and coastal wave guides demonstrate a moderate annual signal that travels north from the tropics to the southern regions of the California Current, where the seasonal cycle of circulation in the California Current carries this signal farther north during fall and winter. 'Progressive displacemments' are calculated from the large-scale altimeter-derived alongshore currents (in the 150 km next to the coast). On interannual time scales, anomalous poleward transports and displacements along the Mexican mainland and Baja California coast were strongest in mid-year during the 1997 El Niño, continuing along the U.S. coast in late 1997. They were also moderately strong along mainland Mexico during the mid-year 'marginal' 2014 El Niño, continuing along the Baja and U.S. coast during the second half of 2014. During the 'strong' 2015 El Niño, transports were only moderately poleward during the second half of 2015 along mainland Mexico and Baja California, weak along the U.S. coast. From this viewpoint, the 2014-2015 period can be interpreted as a two-year transport and displacement event. During most other years, the anomalous large-scale alongshore transports are not well enough coordinated between the different regions along the eastern Pacific basin in a manner that would bring water into the California Current from great distances to the south. 1997 and 2014-2015 are the anomalies.

*Student Presenter

A Composite Physical-Biological ENSO in the California Current System

Nathali Cordero-Quiros[1]*, *Arthur J. Miller*[1], *Aneesh C. Subramanian*[1], *Matthew Long*[2], *Jessica Luo*[2]

[1]*Scripps Institution of Oceanography,* [2]*National Center for Atmospheric Research*

El Niño Southern Oscillation (ENSO) drives important changes in the upwelling region of the California Current System (CCS). Local and atmospheric patterns associated with the ENSO induce variability of the physical state. These changes are linked to the biogeochemical response of the ecosystem and represent a good source of predictability. In this study we use a 67-year long simulation by NCAR to build a framework for understanding ENSO-related variability of the CCS. The model uses oceanic component from POPv2 with biogeochemistry from the Biogeochemical Elemental Cycling model (BEC). Our results represent the first attempt to composite El Niño (La Niña) events using anomalies of SST, pycnocline depth, chlorophyll, zooplankton, oxygen and nutrients. Each of the 24-month composites shows the temporal and spatial evolution of ENSO over the CCS. We found that the model is delayed by 1 to 3 months with respect to observations and that its coarse resolution is a limiting factor for capturing some of the observed trends. The signature of the ecology in the model is coherent with the variability of the pynocline depth. Both the physical and biological states exhibit the strongest response during the winter, with chlorophyll blooms that persist throughout the summer. The model produces stronger and more significant La Niña events. The probability distribution of SSTa over the CCS region is skewed toward warm values in both the model and in observations. Future work is necessary to elucidate the mechanisms that lead to this distribution and for understanding the dynamics behind stronger La NiÃśa events. However, we found the composite approach useful to identify changes in the physical state that are driven by ENSO and their link to the biogeochemical response of the CCS. This will help us to quantify the ENSO-related variability and to measure the uncertainty of these predictions.

*Student Presenter

Physical-Biological Predictability Along the California Coast Arising from Large-Scale Pacific Climate Dynamics

Emanuele Di Lorenzo[1], *Antonietta Capotondi*[2], *Aneesh Subramanian*[3], *Arthur J. Miller*[3]

[1]*Georgia Institute of Technology,* [2]*Earth System Research Laboratory, NOAA,* [3]*Scripps Institution of Oceanography*

Large-scale surface dynamics of Pacific climate are known to have predictable impacts on the circulation and ecosystem dynamics of the Northeast Pacific coasts. Examples of these are large-scale modes such as the El Niño Southern Oscillation (ENSO) (lead predictability 6 months), the Pacific Meridional Modes (PMM) (lead predictability ∼8-9 months), and the winter to winter coupling between the North Pacific Gyre Oscillation (NPGO) and the Pacific Decadal Oscillation (PDO) (lead predictability ∼12-16 months). Recent studies also explore the role of predictability associated with ocean subsurface dynamics, specifically the advection of biogeochemical subsurface anomalies along the North Pacific Current that feed the regional upwelling systems of the California Current System and Gulf of Alaska (lead predictability ∼5-10 years). Here we present a review of the mechanisms underlying these different sources of large-scale predictability and quantify the resulting prediction skill on key regional marine ecosystem drivers such as upwelling nutrient fluxes, alongshore and cross-shore transport.

*Student Presenter

Seasonal to Decadal Predictions of Northeastern Pacific Sea Surface Temperatures: a Linear Inverse Model and Multimodel Ensemble Study

Daniela Faggiani Dias[1] *, *Aneesh Subramanian*[1], *Laure Zanna*[2], *Arthur J. Miller*[1]

[1]*Scripps Institution of Oceanography,* [2]*University of Oxford*

A suite of statistical linear inverse models (LIMs) are used to understand the remote and local SST variability that influences the SST predictions over the Northeastern Pacific Ocean from seasonal to decadal time scales. Observed monthly SST anomalies are used to construct different regional LIMs along the Pacific sector (between 15°S and 60°N): Tropics plus Western and Eastern Extra-tropics, Western and Eastern Extra-tropics only, and Eastern Extra-tropics only. Seasonal to decadal predictions are made separately for each of those regions and the forecast skill for the Northeastern Pacific is compared between those different regional LIMs. Moreover, the skill from the seasonal forecasts made with the LIMs are compared to the that from operational forecast systems in the North American Multi-Model Ensemble (NMME), revealing that the LIM has better forecast skill in the Northeastern Pacific than the NMME models. Regarding different regional influences, at seasonal time scales the inclusion of the Tropics in the LIM acts to worsen the forecast skill for the Northeastern Pacific and it seems that regional variability plays a more important role than remote influences in the seasonal predictability. The data was also bandpassed into interannual and decadal time scales to identify the interactions between time scales using the structure of the propagator matrix. This analysis reveal that the regional interactions for the low frequency components occurs the other way around: the inclusion of the Tropics in the model considerably improve the forecast skill throughout the Extra-tropics on decadal time scales, especially along the coast of Canada and Alaska. These results indicate the importance of temporal scale interactions in improving predictability on decadal timescales. Hence, we show that LIMs are not only useful as benchmarks for estimates of statistical skill, but also to isolate contributions to the forecast skills from different timescales, spatial scales or even model components.

*Student Presenter

Toward Predicting the Spatial Pattern of Mid-Latitude Marine Heat Waves Based on the Imprinting of Regional Wind Anomalies

Melanie Fewings[1], *Kevin Brown*[1]

[1]*Oregon State University*

The northeast Pacific marine heat wave (MHW) of 2014-2016 was among the largest recorded MHWs. This MHW was caused by persistent mid-level atmospheric ridging and affected ecosystems from Alaska to Mexico. However, there was strong regional variability along the coast in the timing and strength of the MHW. By summer 2015, the MHW split in two parts, one in the Gulf of Alaska and one from central California to Baja. Similar regional variability within MHWs is common globally, but not well understood.

Here, we show that the split MHW structure is explained by a regional, synoptic wind dipole mode we described in previous work. Satellite wind stress anomalies during the two weeks preceding the splitting of the MHW displayed an unusually persistent "southern wind relaxation" state. The unusual persistence of this state is consistent with the atmospheric ridging that caused the large-scale MHW.

To determine whether changes in surface heat flux or wind-driven mixing were more likely responsible for the SST anomalies, we examined the heat budget for the surface mixed layer. The atmosphere-ocean heat flux anomalies off southern California were too small and/or the wrong sign to explain the SST anomalies during the splitting of the MHW. This suggests that changes in wind-driven vertical mixing and mixed-layer depth were more likely the cause of the splitting of the MHW.

There is a systematic relation between the mid-level ridging that caused the MHW and the regional wind dipole with its associated SST anomaly dipole. This suggests that the spatial pattern of mid-latitude MHWs off western North America may be predictable, even if the timing is not. We suggest that future MHWs in the California Current System are likely to also develop a "split" structure.

*Student Presenter

A Hybrid Dynamical-Statistical Downscaling Method for the Rapid Generation of Regional Ocean Forecasts

Albert J. Hermann[1], *Wei Cheng*[1], *Georgina A. Gibson*[2], *Ivonne Ortiz*[1], *Kerim Aydin*[3]

[1]*University of Washington,* [2]*University of Alaska Fairbanks,* [3]*NOAA/Alaska Fisheries Science Center)*

Dynamical downscaling is a powerful technique for generating regional forecasts from coarse-scale global ones, yet is computationally expensive at fine spatial and temporal scales. Statistical downscaling trained on present local conditions is computationally fast, yet can be misleading as dominant spatial patterns and processes shift through time. Typically, the number of available (and demonstrably skillful) global forecasts on seasonal or multi-decadal timescales far exceeds the number that can be affordably downscaled to any region through purely dynamical methods. Here we describe a hybrid dynamical-statistical scheme, based on covariance analysis, which quickly generates a large ensemble of forecasted regional futures. The method proceeds through statistical (EOF) analysis of a small ensemble of output from both the (forcing) global models and the (dynamically downscaling) regional models; this establishes characteristic multivariate patterns of regional response to both present and future large-scale forcing. Once established, these statistical relationships are applied to a much larger ensemble of global model realizations, using the large-scale multivariate patterns as predictors of the multivariate regional response. This affordably generates a large ensemble of regional futures, helping to establish the statistics of such regional forecasts (e.g. the probability of extreme events). Ideally, this vastly reduces the need to dynamically downscale each global realization of the future. We have successfully applied this technique using annual averages from multi-decadal biophysical projections of a regional ocean (the Bering Sea); here we consider its potential for use in seasonal and multi-decadal biophysical predictions of the Pacific Northwest.

Immersive 3D Visualization of Regional Model Output

Albert J. Hermann[1]

[1]*University of Washington*
E-mail: albert.j.hermann@noaa.gov

A portable immersive 3D display will be set up to illustrate regional model output from the Bering Sea, the Pacific Northwest, the Gulf of Alaska, and any other regional models that EPOC participants wish to provide for visualization on this hardware. Gridded files in netcdf format, with regular latitude-longitude-depth-time axes, are best for this purpose.

Contact me by email if you are interested in visualizing your model results at EPOC!

*Student Presenter

Submesoscale Circulation and Vertical Flux in the California Current System

Delphine Hypolite[1], *Fayçal Kessouri*[1], *James McWilliams*[1]

[1] *University of California, Los Angeles*

Submesoscale features, such as fronts, filaments and vortices, characterized by small horizontal scales $\mathcal{O}$(0.1 - 10)km and high Rossby numbers Ro ∼1, can alter the vertical distribution of materials in the water column and the vertical tracer fluxes. In particular, submesoscale fronts, showing strong surface convergence and downwelling currents, induce the accumulation and subduction of materials and they are expected to regulate the exchanges between the surface mixed layer and the ocean interior properties. In that direction, comparisons of different resolutions of regional ocean numerical simulations in Central California show that the onset of the submesoscale leads to an intensification of the vertical and cross-shore nutrient and organic matter fluxes.

To build upon our current understanding of the role of the submesoscale dynamics all over the US West coast, we compare submesoscale permitting numerical simulations in Central California [30-39°N] and in the North West US [39-50°N] coast. By decomposing all model variables between mean, mesoscale and submesoscale contributions, we quantify the role of the submesoscale dynamical features on the thermal fluxes, increasing our predictive capability of the California Current System ecosystem dynamics with a new understanding of previously un-resolved biophysical processes.

Processes Affecting Water Properties in Washington Coastal Estuaries

Parker MacCready[1], *Samantha Siedlecki*[2], *Ryan McCabe*[1]

[1] *University of Washington,* [2] *University of Connecticut*

Oyster growth in Willapa Bay and Grays Harbor depends critically on phytoplankton imported from the shelf. But the same processes that fuel high productivity can also bring corrosive waters to the estuaries, fatal to larval oysters. In this talk we explore the processes controlling the biogeochemistry of water delivered to the estuaries, including the effects of upwelling and the Columbia River. Results come from new, high-resolution simulations using the LiveOcean model framework.

*Student Presenter

Increasing the Biological Resolution of a Regional Ocean Model for the California Current System

J. Paul Mattern[1], *Christopher A.Edwards* [1], *Stephanie Dutkiewicz*[2], *Oliver Jahn*[2]

[1]*University of California, Santa Cruz,* [2]*Massachusetts Institute of Technology*

Marine ecosystem models are commonly coupled to physical ocean circulation models in order to simulate the biological and chemical processes occurring in complex physical environments. In regional model applications, the improvements brought by increasing the physical resolution of the model (reducing the grid size) have been thoroughly demonstrated. Some attention has also been paid to the biological resolution of the model, i.e. the number of plankton groups and nutrients included in the ecosystem model. Yet, the biological resolution of typical regional ecosystem models has remained relatively low and a notable increase in resolution has only been applied to ecosystem models aimed at global applications; one example is the DARWIN ecosystem model that in some configurations simulates more than 50 phytoplankton groups. We implemented DARWIN for our regional model of the California Current System and examine if its benefits carry over from the global into a regional setting: we assess whether the inclusion of more plankton groups lead to improved model results and if dominant phytoplankton groups are self-emergent.

Patterns of Residence Time, Eutrophication, and Ecosystem Metabolism in Coastal Ecosystems

Nicholas Nidzieko[1]

[1]*University of California, Santa Barbara*

Coastal ecosystems are eutrophic when rates of primary production exceed a threshold value. Although the carbon-equivalent nitrogen load (using a Redfield ratio of 106:16) to many estuaries and coastal shelf seas is more than sufficient to drive these systems towards a eutrophic state, many estuaries with "high" nutrient loads are no more productive than systems with "low" nutrient loading. The pivotal role that residence time plays in controlling the metabolic state has long been noted: many systems are not eutrophic simply because they have high flushing rates and, thus, the residence time of terrestrial nutrients entering the system is short. Here, we present a novel quantitative approach to residence time based on allometric scaling, using a synthesis of published ecosystem metabolism rates and coastal ecosystem sizes. We derive estimates of residence time by applying ideas from the metabolic theory of ecology, in which the metabolism is controlled by the rate at which nutrients can be efficiently moved throughout the system, and compare these estimates to published values of residence time. This work has the potential to provide a unifying framework for comparing apparently heterogenous systems.

*Student Presenter

Predicting Ecosystem Response to Shifting Drivers in San Francisco Bay

Emma Nuss[1], *Rusty Holleman*[2], *David Senn*[1], *Zhenlin Zhang*[1], *Jian Zhou*[3], *Mark Stacey*[3]

[1]*San Francisco Estuary Institute,* [2]*University of California, Davis,* [3]*University of California, Berkley*

Ambient nutrient concentrations in San Francisco Bay are high relative to many other urbanized estuaries, yet eutrophic conditions are typically not observed. Stratification dynamics, suspended sediment concentrations, and abundance of benthic grazers provide strong controls on phytoplankton dynamics. With projected changes in freshwater fluxes and declining sediment loads, a future shift toward eutrophic conditions and frequent harmful algae blooms in the Bay is plausible. Probabilistic graphical models, such as Bayesian network models, have been increasingly used in ecological modeling studies to answer ecosystem scale and management questions. Probabilistic graphical models synthesize information from observations, deterministic models, and expert knowledge into a representative network of conditional probabilities in which questions of likelihood can be answered. We apply this methodology to the San Francisco Bay ecosystem to determine the likelihood of an ecosystem shift towards eutrophication under future scenarios. In addition to determining likelihood, understanding how the dynamics of nutrients, hydrodynamics, and biology interact under a rich set of future scenarios will be crucial for mitigation and forward-looking stewardship of the Bay. We analyze available observations and carry out hydrodynamic modeling studies to expand the understanding of these dynamics and build a representative graphical model. We present the results of our observational data analysis and hydrodynamic modeling studies and the development of our probabilistic model.

*Student Presenter

Salish Sea Model Ecosystem-Lower Trophic: Tidally Driven Nutrient Supply to Surface Waters in the Northern Strait of Georgia

Elise Olson[1], *Susan Allen*[1], *Ben Moore-Maley*[1], *Doug Latornell*[1]

[1] *University of British Columbia*

Salish Sea Model Ecosystem - Lower Trophic (SMELT) is a three-dimensional biogeochemical model coupled to a NEMO-based physical model of the Salish Sea, run operationally at UBC as part of the SalishSeaCast system. In this presentation, we will discuss semiperiodic nitrate supply to the surface waters of the northwest Strait of Georgia diagnosed from SalishSeaCast output. The nutrient supply pattern is identified as a region of elevated mean (March-November) and standard deviation (April-September) of surface nitrate stretching from Discovery Passage to Baynes Sound in a monthly climatology based on simulations from fall 2014 to present. We will analyze the relative contributions of southward advection of nitrate supplied through tidally-enhanced mixing in and near Discovery Passage, transport of nitrate from the northeastern Strait under eastern upwelling conditions, and local upwelling. We will discuss the importance of the phenomenon as a source of nutrients to the euphotic zone, fueling primary production in the northern Strait of Georgia. Finally, we will explore the degree of predictability of the primary production response in the context of the predictability of the physicial drivers of the nitrate supply, wind and tidal currents. We will interpret our study within the context of similar networks of narrow fjord-like passages found throughout the British Columbian coast.

*Student Presenter