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<u>LIST OF PRESENTERS</u>

The Balance Between Surface Heating and Advection on the U.S West Coast Inner Shelf.

Emily Lemagie, Woods Hole Oceanographic Institution; Anthony Kirincich, Woods Hole Oceanographic Institution; Steve Lentz, Woods Hole Oceanographic Institution

Thermal stresses play a key role in both organism function and community ecology, and small increases in inner shelf temperatures can lead to dramatic shifts in community structure. Inner shelf temperatures on the west coast of the United States are more moderate in summertime than predicted by surface heat flux alone. Without advection, the cumulative surface heat flux at a 15-meter mooring off the coast of Oregon would lead to warming over the inner shelf of 35 +/- 5 degrees Celsius from May to September. The monthly climatology over these 5 months is a depth-average temperature of around 10 +/- 2 degrees Celsius, with no significant trend (warming or cooling) over the summer season. Inter annual variability of only 1-2 degrees in the temperature is curious given the large changes in forcing conditions due to decadal and multi-year regional-scale variability such as ENSO and PDO-type regime shifts. Previous research indicates that advective processes likely have a buffering effect on temperature variability. Using 12 years of temperature and velocity profiles at a single site, we construct a local heat budget to examine the inter annual variability in the surface heating and advective cooling during the summer season. We also discuss the challenges in estimating surface heat flux from sparse data and in utilizing reanalysis products in the coastal ocean. An understanding of the inner shelf temperature variability could allow some predictive capacity for the potential changes in both ecologically and commercially important coastal marine species in future climate scenarios.

Influences of ocean weather on the episodic pulses of particulate organic carbon flux

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The biological carbon pump has been estimated to export ~5-15 Gt C yr^{-1} into the deep ocean, and forms the principle deep-sea food resource. Irregular, intense pulses of particulate organic carbon (POC) have been found to make up about one-third of the overall POC fluxes at a long-term deep-sea research station influenced by coastal upwelling, Station M. However, the drivers of these pulses have been challenging to quantify. It has long been recognized that ocean currents can result in particles being advected while sinking to the point of collection by a sediment trap. Thus, a sediment trap time series can incorporate material from a dynamic catchment area, a concept sometimes referred to as a statistical funnel. This concept raises many questions including what are the day-to-day conditions at the source locations of the sinking POC? And, how might such ocean weather and related ecosystem factors influence the intense variation seen at the seafloor? Here we analyzed three-dimensional ocean currents from a Regional Ocean Modeling System (ROMS) model from 2013-2017 to trace the potential source locations of particles sinking at 1000, 100, and 50 m/d. We then used regionally tailored satellite data products to estimate export flux of POC from these locations. The slower sinking speed particles had origins of over a range of up to ~300 km for the 100 m/d speed, and nearly 1000 km for the 50 km m/d, and occasionally at the location of highly productive upwelled waters coming from the coast. We found significant correlations between export flux from the estimated source

locations to trap-estimated POC fluxes. Particle source locations tended to originate from the east in the summer months, with higher export and POC fluxes. These results set the stage for further investigation into what conditions lead to flux pulses.

Mechanisms of pelagic red crab range expansion in the eastern Pacific

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The infrequent appearance of pelagic red crabs (Pleuroncodes planipes, PRC) on the beaches of Southern and Central California excites and puzzles oceanographers and beachcombers. In general, PRCs are abundant off the coast of Baja California, Mexico, and their arrival to central Californian waters and beaches is thought to coincide with anomalously warm surface waters, often in conjunction with El Niño events (e.g., 1982-1983, 2015-2016). The association of PRCs with abnormal ocean conditions has stimulated oceanographers to propose a number of hypotheses to explain the underlying bio-physical mechanisms associated with their periodic range expansions. However, no single hypothesis has acquired enough observational support to stifle alternative hypotheses. Motivated by an unprecedented number of strandings and at-sea observations of PRC in recent years, coupled with the fact that variability in PRC distribution remains poorly understood, we compiled a comprehensive dataset of adult and larval PRC records from 1950 to 2019 and summarized the most compelling hypotheses to explain the periodic northward expansion of PRCs. We found support for the hypothesis that PRC presence off Central California is associated with anomalous advection of waters from Baja California. Furthermore, it appears that after arriving off the central California coast PRCs are often able to remain in these northern waters for a year or more without additional anomalous transport from the south. Understanding the factors that drive PRC range expansions provides new information about the biological impacts of physical variability off the California coast and how it relates to broad-scale climate variability in the northeast Pacific.

Predicting Physical Drivers of Marine Ecosystems along the US West Coast Using a Linear Inverse Modeling Approach

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A Linear Inverse Model (LIM) is a stochastically forced damped linear dynamical model whose dynamical evolution operator and stochastic forcing amplitudes are estimated using the observed lag-covariances of the system state vector. We construct a LIM over a spatial domain extending from 30S to 70N and from 100E to 70W, including the entire tropical and North Pacific. Our system is described by monthly averages of sea surface temperature (SST) and sea surface height (SSH), two quantities that play a key role in ecosystem dynamics. In particular, SSH is dynamically linked to thermocline depth, and provides information on upper-ocean heat content and thermocline displacements related to upwelling. In this study, we use the LIM approach to examine the predictability of SST and SSH over the North Pacific and along the US West Coast. In particular, the predictability of the extreme and persistent warming that occurred in the northeast Pacific from the Winter of 2013/14 to the Winter of 2015/16, conditions that were poorly captured by operational forecast systems, is examined in the context of the LIM

framework. Our LIM results confirm that the sequence of events during 2014/15 in the northeast Pacific was indeed unusual and hard to predict, but the presence of an El Niño event toward the end of 2015 improved significantly the LIM skill. How unusual those conditions were, relative to the statistics of the previous 50 years, is also examined using long LIM integrations.

Interannual variability in the strength and structure of the poleward undercurrent: inferences from observations and a high-resolution regional ocean model

Alexander Kurapov, NOAA CSDL

Outputs from a 2-km resolution regional ocean model, the dynamical core of the NOAA West Coast Ocean Forecast System (WCOFS), are analyzed and compared against available multi-year CTD station and glider data with focus on seasonal and interannual variability in water properties at the level of the coastal undercurrent. The WCOFS domain extends along the west coast of the North American continent from 24N to 54N. The model is run continuously without data assimilation for a period of 2013-2017, which includes the 2015-16 El Nino event. The model is forced by the winds and atmospheric heat and freshwater fluxes at the surface plus subtidal and tidal boundary conditions along the open ocean boundaries. The non-tidal boundary conditions, from the global Navy HYCOM analyses, show interannual variability in the placement of isopycnal surfaces over the continental slope at the southern boundary of our domain, potentially forcing low frequency waves along the slope that may influence the undercurrent. The multi-year CTD profile time series at station NH25 off Oregon (J. Fisher) and glider data off Trinidad Head, California (Barth, Shearman, Erofeev) are utilized for comparative analyses. Analysis of the CTD station data off Oregon allows us consider the 5-year model record in the context of a longer, 20-year observation time series. Using the model and glider data, temperature (T) and background potential vorticity (PV) are analyzed near the level of the 26.5 kg/m3 isopycnal surface (about 200-300 m below the surface). In the T-PV diagrams, slope waters (inshore of the 2000 m isobath) exhibit relatively warmer T and lower PV compared to waters offshore (west of 127W). In 2016, both the glider data and the model show the undercurrent waters as more distinctive from the offshore waters in the T-PV diagram than in other years sampled. The model suggests that this condition corresponds to a relatively wider undercurrent area at the selected isopycnal surface.

Physical Controls on Extremes of Oceanic Carbon and Oxygen at the Northern End of the California Current System

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In coastal upwelling regions, wind driven upwelling brings carbon-rich, oxygen-poor subs-surface water to shallow regions. The winds driving the upwelling are usually local. However, there are evidences of local upwelling variability driven by winds in remote locations. Local winds do not show strong coherence with proxies of upwelling in the highly productive water in the west coast of southern Vancouver Island, the northern limit of the California Current System. Biogeochemical models used to study this region have not been properly quantifying the relative contributions of local and remote wind forcing of upwelling. Our data analyses show significant influence of remote winds on local upwelling in the region. Building on these results, we force a biogeochemical model with a thousand-year long, stochastically generated, present-day condition physical forcing to include both local and remote wind forcing. Including remote wind forcing in the model improved the model-observation agreement by intensifying modelled carbon and oxygen extreme events. The long daily-resolved simulations allowed us to calculate robust statistical estimates of modelled carbon and oxygen extreme events. Exceedance probabilities show that in the upper shelf carbon and oxygen extreme events can occur at different rates (and so are decoupled). In the model upper layers, both carbon and oxygen extremes are controlled by physics, while biological processes appear to control the extremes in the lower layers. These findings are supported by sensitivity experiments, of which we will present a selection of results.

Variability in SST frontal activity in the California Current System due to the El Niño-Southern Oscillation

Caitlin M. Amos, UGA; Renato M. Castelao, UGA

In the California Current System (CCS), sea surface temperature (SST) fronts are important for circulation dynamics and promoting biological activity. Prevailing equatorward winds during the summer result in offshore Ekman transport and upwelling along the coast, where SST fronts often form between the cold, upwelled water and the warm, offshore waters. Interannual variability in wind patterns, coastal upwelling, SST and sea level anomalies have been linked to the El Niño-Southern Oscillation (ENSO), however the role that ENSO plays in SST frontal variability has received less attention. Using daily satellite SST data, SST fronts are detected from SST gradient maps using an edge-detection algorithm. Initial analyses reveal SST fronts are most frequently observed to the north of 22N within 300 km of the coast. Frontal activity generally decreases during El Niño and increases during La Niña periods, indicating that ENSO is likely influencing the variability of SST fronts in this region. We are also comparing sea level anomalies and winds with SST frontal activity and investigating the forcing mechanisms by which ENSO influences SST frontal variability in the CCS.

The Return of "The Blob" — A Near Real-Time Assessment of the 2019 North Pacific Marine Heat Wave

Dillon J. Amaya, Arthur J. Miller, and Shang-Ping Xie, Scripps Institution of Oceanography.

In the Winter of 2013-2014, sea surface temperature anomalies (SSTAs) in the Northeast Pacific exceeded three standard deviations above normal. Over the course of several months, these anomalies migrated onto the North American coastline where they were then able to devastate coastal marine ecosystems. These warm ocean anomalies, referred to as "The Blob", have since sparked significant scientific interest in the physical mechanisms governing similar marine heat waves. Since June 2019, a similar patch of extreme warm ocean anomalies have been building in the Gulf of Alaska, leading many to wonder if "The Blob" and its coastal impact has returned. In this study, we conduct a near real-time analysis of the atmospheric forcing mechanisms behind the summer 2019 North Pacific warm anomalies. We show that a significant multi-month weakening of the North Pacific subtropical high has led to a sharp reduction in surface evaporation and surface ocean mixing, generating prolonged warm conditions throughout the North Pacific. We then force an atmospheric model with observed SSTAs over the past year and find that this anomalous atmospheric circulation is partly the result of remote forcing from the tropical and subtropical Pacific. These results highlight the importance of remote forcing in generating extratropical marine heat waves, and suggests that summertime tropical teleconnections may play a larger role in North Pacific climate variability than previously thought.

The blob in 3D: Interactive analysis of a warm anomaly and its impact on the Pacific Northwest

Albert Hermann, UW/JISAO; Nicholas Bond, UW/JISAO; Samantha Siedlecki, UConn; Sulagna Ray, UConn; Emily Norton, UW/JISAO

A warm surface and subsurface anomaly in the Northeast Pacific (aka the blob) spanned multiple years (2013-2016) and created unique conditions with persistent biological impacts, which have included the displacement of commercially important fish species along broad stretches of the North American coastline. Considering the waters offshore of the Pacific Northwest, global climate model simulations used for seasonal predictions generally indicated warmer than normal upper-ocean temperatures, but predicted anomalies were of lesser magnitude than observed. The anomaly is believed to have been largely driven by anomalous atmospheric conditions over the Northeast Pacific, and possibly by anomalous oceanic advection into the region. Here we employ immersive 3D graphics to interactively explore multiple drivers of the anomaly and its coastal impacts, using oceanic/atmospheric reanalyses which include ARGO data. This analysis may help to identify which aspects of the regional dynamics (e.g. local vs. remote forcing of the region) were mis-represented in the seasonal forecasts.

Composite biophysical ENSO over California Current System using ROMS-NEMURO

Nathalí Cordero Quirós, Arthur J. Miller, Yunchun Pan, and Lawrence A. Balitaan

In this study we present a biophysical composite ENSO over the California Current System between the period of 1959 to 2007 using the ROMS coupled to the ecosystem model NEMURO. Our results show composite El Niño and La Niña events for anomalies of SST and velocity fields. Biogeochemistry is represented by composite anomalies of nitrate, silicates, and biomass from two phytoplankton groups (nanophytoplankton and diatoms), and three zooplankton groups (predators, meso, and micro) averaged from 0 to 100 m. Our results show that the CCS response associated to La Niña events is stronger than the response related to El Niño events. This asymmetry is consistent with results from a previous analysis using the CESM1- POP2-BEC, and with findings from other studies that use observations. We further explore the source of this asymmetric response of the CCS to ENSO and examine whether it arises in the tropical Pacific or is locally generated by the CCS winds. Histograms of SSTa over the Niño-4 region, where the teleconnections to the PNA pattern originate, show that La Niña are in fact more consistently cold than El Niño conditions are warm. This result suggests that teleconnections during La Niña will more consistently drive cold conditions in CCS than warm conditions during El Niño. This is also consistent with the meridional wind stress over CCS being more upwelling favorable during La Niña than downwelling favorable during El Niño.

Skillful Multiyear Predictions of Ocean Acidification in the California Current System

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The California Current System (CCS) is an Eastern Boundary Upwelling System that is characterized by high primary productivity supported by the upwelling of nutrient-rich waters from depth. These waters are also naturally corrosive, with relatively high pCO2 and relatively low pH. The compounded effects of corrosive upwelling and the diffusion of anthropogenic CO2 into surface waters has already begun to cause shell degradation in pteropods along the continental shelf. Thus, skillful seasonal to decadal forecasts of carbonate chemistry parameters, such as pH, are crucial for the proper management of living marine resources in the CCS. Here we utilize output from the Community Earth System Model Decadal Prediction Large Ensemble (CESM-DPLE), a forecasting system that initializes 40 ensemble members annually from a forced ocean sea-ice reconstruction, to consider the potential to predict surface pH in the CCS. We show that CESM-DPLE has statistically significant predictability in annual surface pH anomalies out to five years over a persistence forecast, with some regions exhibiting predictability out to eight years. Further, we find that CESM-DPLE can skillfully predict surface pH anomalies for multiple years when compared to the available pH observations. Predictability in CCS surface pH is driven by the multiyear persistence of dissolved inorganic carbon (DIC) anomalies, with some contribution from the forecasting system's ability to predict sea surface temperature and surface alkalinity anomalies. The anomalous DIC is accumulated by vertical and lateral advective fluxes from the North Pacific basin. Our results demonstrate the utility of an initialized decadal prediction ensemble for managing the onset and impacts of ocean acidification in the CCS.

Future changes in the California Current Upwelling System

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Future changes in the California Current System (CCS) are investigated by dynamically downscaling CMPI5 climate projections using the Regional Ocean Modeling System (ROMS) with 0.1˚ horizontal resolution. To capture the spread of projections in the CMPI5 ensemble, we select three global climate models (GCMs) that span the CMIP5 range for future changes in both the mean and variance of physical and biogeochemical CCS properties: GFDL-ESM2M, HadGEM2-ES, and IPSL-CM5A-MR. To debias the model forcing obtained from the GCMs (i.e., correct for their systematic offsets with observed climate), we apply a "time-varying delta" method in which the regional model's surface and lateral boundary conditions are constructed by adding the transient (1980-2100) GCM anomalies to the observed historical (1980-2010) climatology. Relative to a "fixed delta" method that compares a historical period to a future one, the time-varying delta method has advantages of (1) capturing projected changes in interannual variability, and (2) resolving intermediate time frames (e.g., 2010-2070), when climate changes will have considerable impacts on the CCS ecosystem. We investigate spatial differences between

the downscaled projections as well as differences between downscaled projections and the GCM projections that force them. This analysis sheds light on the uncertainty that results from insufficient resolution in GCMs relative to the uncertainty due to spread among the GCMs themselves. Until large ensembles of eddy-resolving global or regional models are computationally feasible, we suggest that a fruitful approach is to combine coarser resolution large ensembles with dynamical downscaling of select runs informed by analyses like the one here.

Seasonal to decadal scale phytoplankton community variations in the Santa Barbara Channel, CA, are associated with decadal climate oscillations and changes in regional ocean circulation

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Although critical to our understanding of marine ecosystem structure and function, large-scale phytoplankton community variations and their forcings are poorly understood, primarily due to difficulties quantifying phytoplankton species and groups and a lack of available long-term data sets. Bio-optical algorithms provide a cost-effective method to extend the spatiotemporal coverage of phytoplankton community observations, and thus to better understand large-scale phytoplankton community variations and how they may be impacted by anthropogenic climate change. Here, we present an analysis of seasonal to decadal scale phytoplankton community variations in the Santa Barbara Channel, CA (SBC) derived from ~12 years of monthly High Performance Liquid Chromatography (HPLC) biomarker pigment concentrations. The HPLC data set is merged with an additional ~10 years of modeled biomarker pigment concentrations derived from a recently developed bio-optical algorithm to create a ~22 year monthly time series of surface ocean phytoplankton biomarker pigment concentrations in the SBC. We use this extensive time series to demonstrate long-term changes in the response of the phytoplankton community to the upwelling-driven seasonal cycle. We also find an association between pronounced decadal-scale dinoflagellate blooms and the alignment of specific phases of the North Pacific Gyre Oscillation and El Nino Southern Oscillation, and link these observations to variability in regional ocean circulation patterns assessed by ROMS particle trajectory modeling. The linkages between decadal-scale climate variations and dinoflagellate blooms may explain decadal observations of unusual red tide events in the broader California Current System. Our results have important implications for parsing apart the impacts of natural and anthropogenic climate change on phytoplankton communities, and suggest that advection plays an important role in local realizations of phytoplankton community composition.

Climate-related variability in assemblage and size-structure of euphausiids in coastal waters off northern California

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We analyzed an 11-year time series of zooplankton collections made at roughly biweekly to bi-monthly intervals along the Trinidad Head Line (41Â°N) to assess effects of climate forcing on coastal euphausiids off northern California, with specific attention on the effects of the 2014-16 marine heatwave and 2015-16 El Niño. Cold-water species (Thysanoessa spinifera and T. inspinata) both declined during warming events while warm-water species (e.g., T. gregaria) increased in abundance. Euphausia recurva and Nyctiphanes simplex occurred exclusively during the marine heatwave 2015-16 El Niño, and the timing of their arrival off northern California corroborates anomalous onshore transport during the early â€˜Warm Blobâ€™ phase of the heatwave and strong poleward transport following the onset of the 2015-16 El Niño. In contrast to many other taxa, the dominant species Euphausia pacifica exhibited relatively little variability in numerical abundance over the course of our study. However, length of adult and juvenile E. pacifia in coastal waters off northern California declined sharply during years affected by unusual warming events. Early life history stages exhibited an opposite response, in which warming shifted the population towards larger size classes. Changes in body size suggest dramatic declines in biomass of this critical and dominant forage species. Results from this work suggest that time series of euphausiid community composition and size have strong potential to serve as informative ecosystem indicators.

Climate controls on zooplankton composition and ocean-estuary exchange in the Strait of Juan de Fuca, USA

Julie E. Keister; Bethellee Herrmann; Andrew Mondavi; Parker MacCready, University of Washington

In the Northeast Pacific, the Strait of Juan de Fuca (SJF) connects the Northern California Current upwelling system to the Salish Sea between the U.S. and Canada. Multiple physical influences including advection of hydrographically different water masses from three regions the Strait of Georgia, Puget Sound, and the Northern California Current upwelling system create a complex environment in the SJF, strongly influenced by ocean-estuary exchange. Climate influences on the physics are reflected through changes in temperature, river flow, and circulation. These factors also affect zooplankton community structure. The largest temporal changes in the SJF zooplankton community are strong seasonal shifts from a summertime community dominated by warm-water species with Puget Sound affinities, to a winter community dominated by cold-water species that are rare in Puget Sound, but dominate on the coast during summer upwelling. The shifts in composition, and opposite cycle of dominance in the SJF compared to the coast, suggest that changes in water mass advection are important controls on species composition, and likely also drive interannual variability. We used data from a zooplankton time series sampled monthly since 2003 in the eastern SJF, and particle-tracking experiments in a high-resolution ROMS model of the Salish Sea, to explore climate-related changes in species composition and advective pathways, with a focus on understanding the climate-mediated role of ocean-estuary exchange. The mechanisms that control the SJF species composition differ from those that control California Current zooplankton, illustrating the importance of regional ecosystem monitoring.

Regional wind patterns and the spatial structure of marine heat waves off the western United States

Melanie R. Fewings, Oregon State University; Kevin S. Brown, Oregon State University

Marine heat waves (MHWs) in the northeast Pacific during 2014–2016 caused major economic and ecological damage. The strength of the SST anomalies showed strong spatial variability within the California Current System (CCS). Similar regional variability in MHW intensity is observed along coastlines worldwide, but is not well understood. Our previous work showed that the coastline shape dictates regional wind patterns that can either alleviate or intensify a MHW. The spatial pattern of sea-surface temperature (SST) anomalies during the July 2015 "split MHW" off the western continental U.S., previously described as "flummoxing" climate scientists, was similar to the spatial pattern of the preceding wind stress anomalies. This relationship between wind stress and SST anomalies existed because (1) where SST warmed, the net air-sea heat flux anomalies were small due to increased cloudiness and (2) the wind stress anomalies were unusually persistent, presumably due to the atmospheric ridging associated with the large-scale MHW. The result was a stronger MHW offshore of California than offshore of Washington/Oregon during July 2015. Here, we discuss whether the above relationships between wind, air-sea heat flux, and SST anomalies hold during other MHW events in the CCS region. We discuss the contribution of short and long-time scale SST anomalies to the occurrence of a MHW. We use satellite ocean vector wind data and reanalysis products, objectively analyzed air-sea fluxes from SeaFlux and OAFlux, and radiative forcing from CERES. SST anomalies related to wind variability are among the aspects of CCS MHWs least well predicted by existing models (Jacox et al., 2019). The relationships between coastline shape, wind, and SST anomalies we discuss here may guide efforts to better predict the spatial pattern of future MHWs in the CCS.

Expanding the biophysical ensemble: hybrid dynamical-statistical downscaling methods based on spatial/temporal scale.

Albert Hermann, UW/JISAO

While coupled global models of the atmosphere and ocean have demonstrated significant skill in predicting broad-scale SST patterns on seasonal timescales, they typically lack the fine resolution necessary to capture biophysical details which strongly impact fish recruitment (for example, regional prey biomass and regional subsurface temperatures). Dynamical downscaling - the use of coarse-scale global predictions to force fine-scale regional dynamical models - can be used to bridge this gap, and to generate useful predictions for biogeochemical variables not included in the global simulations. However, the computational expense of dynamical downscaling has strongly limited its wider use. Indeed, at present, readily available ensembles of coarse-scale global output are far larger than what can be affordably downscaled. Given this computational barrier, statistical relationships derived from a limited set of downscaling output can be used as a proxy to generate a much larger ensemble of regional predictions from the global forcing. Here we review several related hybrid statistical-dynamical methods to expand dynamically-generated regional ensembles on both seasonal and multi-decadal timescales. These methods are based on dominant spatial/temporal correlations between the global forcing and the regional response, and can include correlations across different biophysical variables. Depending on the spatial and temporal scale of the target predictand, time-lagged correlations may be a crucial element in these hybrid methods. Examples include the use of hybrid methods for projecting the short- and long-term future of the Bering Sea cold pool, a feature with strong connections to major fisheries of the Bering Sea.

Pelagic seascape community ecology: Assessing and predicting the surface community composition in the northern California Current

Caren Barceló, Richard D. Brodeur, Lorenzo Ciannelli, Elizabeth Daly, Craig Risien, Gonzalo Saldías, Jameal Samhouri, P. Ted Strub

A current interdisciplinary challenge is to effectively track multiple facets of biodiversity of the marine ecosystem from a remote perspective with the ultimate goal of developing ecosystem indicators for management. In this study, we use generalize additive mixed models to quantify the relationship between spatially and temporally explicit community data using both in-situ and remotely sensed oceanographic data spanning 10 years during 3 different months during the spring-summer season. Using these community gradients and the modeled functional relationships, we predict one community gradient (warm-cold) onto satellite data from 2003-2012 and based on community predictions outside of sampled species data, between 2013-2015. With the modeling, and concurrent satellite data summarized for species-specific positive catch only locations, a particular remote sensing reflectance data field from MODIS (Rrs555) that captures a turbidity signal indicative of freshwater influence, was also a significant predictor of community differences, indicative of its usefulness in understanding higher trophic level biology associated with freshwater input in this region. Further, from these spatial maps of community composition projected onto satellite data, we develop a new community-level, temporally and spatially explicit indicator that assesses variations in the epipelagic community. This index of community differences is useful for regional ecosystem condition reports and could be useful within a broader ecosystem-based fisheries management context.

Environmental variability introduces time lags into the fishery benefits of marine protected areas

White, Will, Oregon State; Barcelo, Caren, UC Davis; Nickols, Kerry, CSU Northridge; Hastings, Alan, UC Davis; Botsford, Louis, UC Davis

Implementation of marine protected areas (MPAs) to benefit biodiversity and fishery yield is becoming more widespread globally, and there is now a network of MPAs spanning California and Oregon. One of the anticipated (or hoped-for) benefits of MPAs is subsidies to nearshore fisheries, as larvae produced inside MPAs spill over into fished areas. However, that spillover has proven difficult to detect empirically, and evidence for fishery benefits remains elusive as well. Within an adaptive management framework, a first step in assessing whether MPAs are or will produce this desired effect is to quantify the magnitude of the fishery benefit, and the time scale over which it could be expected to manifest. Focusing on the second of these, we use age- and size-structured models of rockfish populations to show that there is a decade-scale time lag in the expected full realization of fishery benefits, corresponding to the time taken for fish inside MPAs to mature and for their (dispersed) offspring to enter the fishery. However, the timing of any large benefit to the fishery is further affected by nearshore environmental variability (e.g., ENSO, NPGO) that affect productivity and thus the magnitude of annual cohorts of larval recruits. Our analysis shows that the timing of MPA implementation relative to the phase of environmental variability (i.e., was the MPA preceded by a period of very high or very low larval recruitment) has a major effect on the timing of realized fishery benefits. This effect must be accounted for in the adaptive management of these populations and fisheries.

Management implications of differences in frequency responses of California Current fished species

Louis Botsford, UC Davis; Mikaela Provost, UC Davis; Lauren Yamane, UC Davis

At EPOC 2018 we described how cohort resonance determines the frequency responses of fish species to environmental variability, based on differences in life history. This year we will describe the consequences of that for fishery and ecosystem management. Cohort resonance consists of greater sensitivity of age structured populations to two frequency bands: 1) cohort frequencies (1/(generation time) and 2) low frequencies. Fishing sharpens that pattern in a way that increases variance. Also, population persistence depends on how much variance is in each band. Fishery management is responsible for specifying the allowable catch each year in a way that maintains a sustainable population. They do this in a precautionary way which reduces catch based the level of environmental variability. To date, this is done assuming white noise (equal variance at all frequencies). We will need to account for the fact that the California Current has a non-white environmental spectrum, for many species dominated by the ENSO signal. We now know that the relative sensitivity in the two bands depends on species longevity and spawning age distribution. We will present describe the different approaches appropriate for species ranging from 4 y to 100 y longevity.

Integrated ocean observing systems for assessing marine protected areas across California

Clarissa Anderson, Southern California Coastal Ocean Observing System (SCCOOS), Scripps Institution of Oceanography, University of California San Diego; Christopher Edwards, Ocean Sciences Department, University of California Santa Cruz; Henry Ruhl, Central and Northern

California Ocean Observing System (CeNCOOS), Monterey Bay Aquarium Research Institute (MBARI)

Marine protected areas (MPAs) have been established as a tool to improve sustainability of fisheries, habitats, and their socio-economic value. MPAs face many pressures, from resource use to climate variations and long-term change. These factors operate from local to global spatial scales over daily to decadal timescales. This wide range of variance in space and time presents serious challenges to understanding how ocean weather, climate, MPA management practices and other factors converge to shape MPA conditions. Given the range of possible influences and their scales, there is risk of interacting factors becoming indistinguishable without sufficient context (e.g. aliasing). In addition to issues with measuring such phenomena, big challenges remain in improving the timeliness and reproducibility of assessments. This presentation will introduce objectives and preliminary results from a newly funded California Ocean Protection Council and California Sea Grant project that aims to leverage existing capacity at the IOOS Regional Associations for California to employ: 1) large scale satellite data and models to develop regularly updating curated data views and products that quantify relationships between large scale phenomena, features, and variations and conditions at each of the Tier I MPA locations across the state, and 2) fine-scale models nested in larger scale simulations to develop regularly updating information products that quantify changing conditions at selected MPA and reference locations across the state, and 2) fine-scale models nested in larger scale simulations to develop regularly updating information products that quantify changing conditions, including MPA connectivity, at finer scales, and integrate results into our products and our multi-scale curated data views. We will also describe our plan to work with others collecting MPA relevant data to: 1) format and assemble in situ MPA monitoring data for inclusion in the multi-scale curated data views, including data for key performance measures and metrics, and 2) evaluate an emerging suite of operational, ecological models that can be synthesize data into a multivariate, multi-stressor description of regional ecosystem state to produce statewide quantitative, indicator-based assessments.

What is ecologically relevant when considering deoxygenation trends?

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Temperature and oxygen variability on upwelling margins occurs at both shorter (semidiurnal, diurnal, event-based, and seasonal), and longer timescales (interannual and multidecadal). Considering the magnitude and characteristics of variability is important for understanding when climate-driven changes, such as ocean deoxygenation, become discernible and ecologically relevant. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) is a long-term ecosystem monitoring program, which is now in its 70th year. This time series provides an opportunity to characterize the natural variability of oxygen, test for the presence of a statistically significant deoxygenation signal, and examine how oxygen variability and deoxygenation trends vary from inshore to offshore and across the upper 500 m of the water column. We use generalized additive models to test how oxygen and temperature variability are explained by different modes of variability: seasonal, interannual, multidecadal, and secular. Preliminary results indicate that dominant temporal models of variability vary with depth and distance offshore. At nearshore stations, oxygen is seasonally variable, has a positive relationship with the Oceanic Nino Index (ONI) at 50-150 m and with the Pacific Decadal Oscillation Index (PDO) at 50-400 m, has no relationship with the North Pacific Gyre Oscillation Index (NPGO), and shows a significant secular deoxygenation trend across most depths. In contrast, at offshore stations the seasonal signal is weak or absent at depths below 50 m, the ONI signal is weak or absent, PDO has a weak negative relationship with oxygen at 0-30 m and a weak positive relationship at 150-400 m, NPGO has a strong positive relationship with oxygen at 0-50 m and a negative relationship at 200-500 m, and a significant deoxygenation signal is only consistently observed at 500 m. To consider the ecological relevance of combined temperature and oxygen variability, we also examine how the metabolic index of the habitat changes through time.

Fishes as mobile monitors of hypoxic conditions across ocean basins

Leticia Cavole, Scripps Institution of Oceanography, University of California San Diego; Gallo Natalya ,Scripps Institution of Oceanography, University of California San Diego; Salvanes Anne Gro Vea, Department of Biological Sciences, University of Bergen; Ramirez-Valdez Arturo, Scripps Institution of Oceanography, University of California San Diego; Levin Lisa, Scripps Institution of Oceanography, University of California San Diego; Aburto Octavio, Scripps Institution of Oceanography, University of California San Diego; Limburg Karin, Department of Environmental and Forest Biology, State University of New York College of Environmental Science and Forestry

Oxygen minimum zones (OMZs) contain the largest reservoirs of hypoxic waters in the world, comprising around 7% of total ocean volume. Climate change is expanding OMZs worldwide through a process known as deoxygenation, which is expected to have cascading effects throughout the open ocean and in to the deep sea. For example, deoxygenation can alter the distribution and decrease the biodiversity of fishes, ultimately affecting fisheries yields. The OMZ expansion and shoaling have already compressed the habitat for midwater fish in the southern California Current ecosystem, but the extent to which increasingly-low levels of oxygen affect fish growth and microchemistry remains poorly understood. We hypothesize that the hypoxic conditions found in different OMZs (both the Southern California Bight and the Benguela current ecosystem) will lead to unique elemental signatures in fish otoliths, which are similar to earbones and grow to reflect the surrounding environmental conditions much like the rings of a tree. Through the analysis of different fish species, we were able to detect common elemental patterns in the otoliths of those species living inside OMZs, across different ocean basins. This unique elemental signature was significantly different from that of a shallow marine fish species living outside the OMZs. By using fish as mobile monitors of hypoxic conditions, we seek to elucidate how the past, current, and future deoxygenation processes are likely to affect fish growth.

Characterizing marine heatwaves in British Columbia waters

Charles Hannah, Fisheries and Oceans Canada; Peter Chandler, Fisheries and Oceans Canada; Stephen Page, Fisheries and Oceans Canada

Since the Blob event in 2013-2015, warmer than normal seems to have become the norm for the surface waters of the Gulf of Alaska. However dramatic warming of the surface waters of the shelf and coastal regions of British Columbia does not seem to have occurred. We use the Marine Heatwave classification of Hobday et al (2018) as a framework for analysis of sea surface temperature statistics for the nearly 30 years of sea surface temperature data from 13 weather buoys around British Columbia. We also explore the use of the Heatwave classification to the coastal sea surface temperature from the BC Lighthouse program; many of these records start in the 1930s. The goal is to characterize the spatial and temporal patterns of Marine Heatwave statistics for British Columbia waters. We also introduce the analogous Coldwave classification.

Turbulent dissipation and diffusion - have we been chasing a red herring?

Jerome A. Smith, Scripps Institution of Oceanography, UCSD

A crucial aspect of our understanding of the oceans is when, where, and how things mix. This brings nutrients into the light, and balances the salt and heat budgets in the long run. But it is very hard to measure: it's small-scale, and occurs erratically. An early approach, pioneered by Steve Thorpe, and then Tom Dillon and Tom Osborn, was to look at profiles of density, and identify "patches" where the density is momentarily upside-down - unstable. Comparing this to a "sorted profile" (swapping each sample with another some distance away to make a stable profile) led to the "Thorpe scale", hypothesized to be proportional to a theoretical length scale balancing the dissipation of turbulent kinetic energy against stratification, and so indicating the strength of turbulent mixing in the patch. Then Jim Elliot and Neil Oakey devised a way to use a stereo phonograph needle to measure the vertical shear of the horizontal currents directly - the "shear probe". So the focus changed to measuring micro-scale shear, and estimating the diffusion from that, assuming an average value for the "mixing efficiency" - how much density is mixed for a given amount of velocity (shear) variance as measured by the shear probe. But now, modern micro-scale-resolving computer simulations have indicated that this "mixing efficiency" varies quite a bit, depending on whether the turbulence is driven primarily by shear or by buoyancy (gravity acting on density differences). I propose that the contrast between the unsorted and sorted profiles provides guidance as to whether the driving force at the time of the profile is tilted more towards buoyancy or shear. Also, this contrast provides an estimate of the amount of potential energy available from the density field to drive mixing, and this is more directly related to the diffusion of density (and everything scalar too) than is the dissipation of turbulent kinetic energy, with no need for a mixing efficiency to be known. So, did we get distracted?

Cross-shore energy and heat transport by nonlinear internal waves in shallow water

Jim Lerczak, Oregon State University

Nonlinear internal waves, propagating toward the coast, have been shown to transport a significant amount of energy and drive cross-shore water mass and heat exchange near the coast. Here we utilize observations and a nonhydrostatic numerical model to quantify energy and heat transport by nonlinear internal tides and high-frequency internal waves propagating to the coast in water depths ranging from 50 to 10 m. The data set is an extensive array of moored ADCPs and temperature, salinity and pressure sensors collected off of central California in 2017 as part of the Inner Shelf Dynamics Experiment, sponsored by the Office of Naval Research. Simulations of shoaling internal tides were conducted using the nonhydrostatic Stratified Ocean Model with Adaptive Refinement (SOMAR). Based on the central California measurements, when averaged over a tidal cycle, energy transport is dominated by hydrostatic fluxes, with non-hydrostatic and nonlinear fluxes accounting for less than 10% of the total onshore flux. Energy flux can exceed 100 W/m toward the coast and varies sub-tidally without an obvious correlation with the spring/neap cycle. We analyze the cross-shore heat flux driven by internal waves in temperature space in order to diagnose water mass transformations and identify water temperature classes that significantly contribute to net cross-shore heat flux by internal waves. This analysis reveals adiabatic fluxes of heat - for example, bottom water masses of the same temperature class being advected back-and-forth by internal waves at a location that do not contribute to the net heat flux. It also demonstrates changes in temperature class of waters being transported cross-shore by internal waves. For example, the onshore flux of surface waters by internal waves tend to be at a lower temperature than the surface waters advected offshore.

Wind-driven circulation and upwelling may enhance particle transport by internal waves

Connor Dibble, UC Davis; Gerardo Fernandez, CICESE; Steven Morgan, UC Davis; John Largier, UC Davis; Anatoly Filonov, University of Guadalajara; Lydia Ladah, CICESE

Internal waves, particularly those generated by tides, are important and widespread forces for cross-shelf exchange and mixing in the oceans. They can drive significant mass transport on continental shelves and entrain, accumulate, and deliver larvae and other planktonic particles to nearshore habitats. They also have the potential to drive local adaptation or acclimation to extreme events. A complex set of factors affect the characteristics, propagation, and particle transport potential of internal waves. We examined internal wave run-up events in Bahia Todos Santos near Ensenada, B.C., Mexico, identifying and characterizing them by their leading cold fronts, currents, and subsequent vertical excursions of the thermocline. We present evidence that wind stress modified internal wave events. Upwelling introduced dense bottom water into the bay system and wind-driven surface currents interacted with internal waves as they shoaled in the bay. Internal wave run-up that co-occurred with wind-driven onshore currents had greater: stratification in the bay, potential energy change across fronts, baroclinic surface and bottom currents, downward vertical currents surrounding fronts, and particle accumulation potential. Wind may have caused internal waves to break and form bores sooner. Internal waves were known to enhance nutrient and larval delivery in the northern bay prior to our study, but we have examined evidence suggesting the effect is augmented by the addition of wind-driven currents and the presence of upwelled water masses in and near the bay. We are evaluating this new finding in light of larval concentrations from the field to test the impact of variation in internal wave characteristics related to wind stress on larval accumulation and transport.

Nearshore Lagrangian Connectivity: Submesoscale Influence and Resolution Sensitivity

Daniel P. Dauhajre, UCLA Atmos. and Oceanic Sci.; James C. McWilliams, UCLA Atmos. and Oceanic Sci.

Realistic simulation of nearshore (from the shoreline to approximately 10 km offshore) Lagrangian material transport is required for physical, biological, and ecological investigations of the coastal ocean. Recently, high-resolution simulations of the coastal ocean have revealed a shelf populated with small-scale, rapidly evolving currents that arise at resolutions less than dx~100 m. However, many historical and recent investigations of coastal connectivity utilize circulation models with approximately 1 km resolution. Here, we show a resolution sensitivity to simulated Lagrangian transport and coastal connectivity with a hierarchy of Regional Oceanic Modeling System (ROMS) simulations of the Santa Barbara Channel at dx=1, 0.3, 0.1, and 0.036 km. At higher-resolution (dx<=100 m), rapid along-shore and vertical transport occurs in regions less than 1 km from the shoreline due to submesoscale shelf currents that open up new transport pathways on the shelf: submesoscale fronts and filaments, topographic wakes, and narrow along-shore jets. Shallow-water fronts and filaments induce early-time downwelling and subsequent dispersal at depth of surface material; this is not captured at coarser-resolution (dx=1 km). Differences in three-dimensional (3-D) and two-dimensional (2-D) transport are explored in a higher-resolution simulation: in general, 3-D trajectories are more dispersive than 2-D, due to a separation in their respective trajectories.

Using dual numbers for automatically differentiating complex functions -- a simple way to create biogeochemical data assimilation code

Jann Paul Mattern, UCSC Ocean Sciences; Edwards, Christopher A, UCSC Ocean Sciences

The computation of derivatives of complex, high-dimensional functions is fundamental to a wide variety of scientific applications. Dual numbers (which are similar to complex numbers) allow for automatic, exact evaluation of the numerical derivative of high-dimensional functions at an arbitrary point with minimal coding effort. We use dual numbers to construct tangent linear and adjoint model code for a biogeochemical ocean model and apply it to a variational (4D-Var) data assimilation system based on a coupled physical-biogeochemical model of the California current system. The resulting data assimilation system takes modestly longer to run than its hand-coded equivalent but is considerably easier to implement and updates automatically when modifications are made to the biogeochemical model, thus making its maintenance with code changes trivial.

Managing Uncertainty: Strategic Downscaling of Climate Change Impacts on CCS Oceanography and Fisheries

Elizabeth Drenkard, NOAA GFDL; Arthur Miller, Scripps Institution of Oceanography; Charles Stock, NOAA GFDL; Sam McClatchie, NOAA SWFSC

Anthropogenic climate change poses an unprecedented challenge for marine resource managers: rising temperatures, and altered ocean chemistry and circulation patterns will affect habitat suitability for many living marine resources (LMRs), including valuable U.S.-west coast fisheries. Downscaled global projections are useful for anticipating regional changes in ocean conditions. However, computational limitations necessitate frugality in designing experiments that comprehensively represent uncertainty across factors such as emission scenarios, global and regional model configurations, and internal climate variability. As an example, we briefly present findings regarding a northward shift in sardine spawning habitat suitability and discuss our methodology in the context of proposed "best practices" for dynamical downscaling. Specifically, we used output from climatologically forced historical (1981-2010) and future (2071-2100; NCAR LENS delta-addition) simulations of a Regional Ocean Modeling System (ROMS) model of the California Current System (CCS) to inform a general additive model that predicts probability of sardine egg-presence. These findings will be compared with preliminary results from a similarly configured regional Modular Ocean Model (MOM6) of the CCS to illustrate important considerations in generating strategic ensembles of downscaled climate change projections for the purpose of managing living marine resources.

A Meridionally Averaged Model of Eastern Boundary Upwelling Ecosystems: An Inter-ecosystem Model Comparison.

Jordyn E. Moscoso, UCLA; Daniele Bianchi, UCLA; Andrew L. Stewart, UCLA; James C. McWilliams, UCLA

Eastern Boundary Upwelling Systems (EBUSs) exhibit strong coupling between atmospheric wind forcing, biogeochemical cycles, oceanic transport and mixing. This interplay of physical and biological dynamics leads to differences between EBUSs, notably in overall biological productivity. Recent studies have highlighted the response of primary productivity to mesoscale eddies, which induce an overturning circulation that opposes wind-driven upwelling, subsequently burying nutrients below the euphotic zone via stirring along isopycnals. To better understand the impact of these physical processes on biology, we developed a Meridionally-Averaged Model of Eastern Boundary Upwelling Systems (MAMEBUS) a quasi-2D physical model cast in terrain following coordinates, coupled with biogeochemical models ranging from a single nutrient-cycling model to more complex NPZD models with size structured ecosystems. This idealized model configuration allows us to explore the physical and biogeochemical dynamics of EBUS across a wide range of parameters, while circumventing the computational limitations associated with eddy resolving regional models. Specifically, we focus on the ecosystem sensitivity to variability in the surface wind stress, the bathymetry, and the diffusion of buoyancy and tracers due to mixing by mesoscale eddies. We also use MAMEBUS to compare the response of various NPZD models to a range of physical forcing. Known for their inherent chaotic behavior, large variations between the simple and complex NPZD models gives a variety of different solutions making modeling the ecosystem correctly rather ambiguous. With our solutions, we compare the zonal and vertical distributions of phytoplankton and zooplankton between NPZD models. We find that changes in modeling the predator-prey interactions, which determine the top-down control of phytoplankton, support different responses in zonal chlorophyll patters.

Temporal variability and environmental forcing of surface, midwater and benthic communities in the California Current System

Monique Messié, MBARI; Rob Sherlock, MBARI; Christine Huffard, MBARI; J. Timothy Pennington, MBARI; Anela Choy, SCRIPPS; Reiko Michisaki, MBARI; Kevin Gomes, MBARI; Francisco Chavez, MBARI; Bruce Robison, MBARI; Kenneth Smith, MBARI

Long-term marine biological time series are rare, and even more so are time series that monitor ecosystems through the water column, from surface to seafloor. Here, we present an unprecedented dataset integrating three time series (1997-present) spanning the surface, midwater and benthic habitats. Data were obtained from surface microscopic counts, video observations of midwater animals and benthic imaging of the seafloor. Taxon-specific time series of plankton biomass and midwater and benthic animal densities were analyzed using principal component analysis (PCA) and non-metric multidimensional scaling (nMDS) to highlight temporal changes in ecosystem structure. The first mode of variability for each time series, as identified from PCA, was compared to environmental forcing including Pacific climate variability indices and local upwelling. We demonstrate how upwelling forcing propagates through the three time-series communities, which provides important understanding of how climate variability impacts ecosystems across the water column.

Disentangling potential global change trends from low frequency climate oscillations in marine environments

Tom Bell, Earth Research Institute, UC Santa Barbara; James Allen, Dept. of Geography, UC Santa Barbara; Kyle Cavanaugh, Dept. of Geography, UC Los Angeles; David Siegel, Dept. of Geography, UC Santa Barbara

Giant kelp (Macrocystis pyrifera) is a highly dynamic, globally distributed, marine foundation species which supports a diverse community of ecologically and economically important species. Therefore, understanding the drivers of kelp biomass variability is vital for fisheries, ecology, and conservation research. We have developed a multidecadal (35+ years) time series of giant kelp canopy biomass across much of the NE Pacific and have used this dataset to identify several important abiotic and biotic drivers which operate over various time scales. Low frequency climate oscillations, such as the El Niño-Southern Oscillation and the North Pacific Gyre Oscillation are the principal drivers of interannual giant kelp variability along the coast of California. However recent unprecedented marine warming events have been implicated in kelp declines and have challenged our ability to distinguish whether these decreases are part of a natural cycle in kelp abundance. Here we use our multidecadal scale dataset to examine kelp biomass patterns over multiple spatial and temporal scales to tease apart fluctuations associated with marine climate cycles from longer-scale trends. We also investigate whether these trends exist at local scales (1km) or manifest as regional scale changes which may be more indicative of global change effects.

Using Local Ecological Knowledge to Infer Climate Variability in Galapagos Fisheries

Leticia Maria Cavole, Daniela Faggiani Dias, Scripps Institution of Oceanography; Maria José Barragán, Solange Andrade, Charles Darwin Foundation; Jose Jarrin Marin, Charles Darwin Foundation and Humbolt University.

Galápagos is blessed with the abundance of marine life and high levels of endemism, but it naturally experiences high climate variability during El Niño events that disturb the entire marine food web, which ultimately affects the artisanal fishing activity. In this study, we were able to detect the main impacts of El Niño events on artisanal fishing and marine life using the local ecological knowledge provided by the interviews spanning four generations of fishers on the three most populated islands in Galápagos. Anecdotal information and perceptions coincided with the current scientific literature and provided novel insights about: (i) the positive and negative effects of the El Niño years on artisanal fisheries and marine animals, (ii) differences in species caught during warm and cold seasons and (ii) current interactions among artisanal fisheries, tourism and industrial fisheries activities within the 40 nautical miles that surround the Galápagos Marine Reserve. In addition, fishers have provided valuable information for managing resources under climate change by identifying sites that function as natural refuges for fish and invertebrates during intense El Niño events that behave similarly to the 8.5 IPCC climate scenario. Our interviews highlight an urgent need for a novel bottom up and collaborative approach between the artisanal fishing sector and the Galápagos National Park Directorate. Working together with local users and one of the groups that first inhabited the Galápagos is essential to achieving sustainable and long-term use of natural resources and to increasing and anticipating human and environmental resilience under continued long-term global warming.

Development of a Generalized Transmission and Proliferation Model for Withering Syndrome for Species of Farmed and Wild Abalone

Laura Solinger, University of Southern Mississippi; Carolyn Friedman, University of Washington; Eileen Hofmann, Old Dominion University; Eric Powell, University of Southern Mississippi; John Klinck, Old Dominion University; Leanne Poussard, University of Southern Mississippi; Kathleen Hemeon, University of Southern Mississippi

Overharvesting and disease outbreaks have led to a decline in abundance for many of the seven abalone species of the US West Coast, including two of which are currently listed as endangered pursuant to the US Endangered Species Act of 1973 and 3 of which are listed as species of concern. While management actions have been taken in the recent past to limit harvest of abalone, the emergence of Withering Syndrome (WS) in 1985 has since exerted strong influence on already declining wild populations of abalone and on the culture of red abalone. WS is caused by the intracytoplasmic rickettsia-like organism (RLO), which disrupts functioning of the digestive gland, leading to catabolism of the foot muscle, and eventually death. El Niño conditions and elevated seawater temperatures have been associated with increased prevalence of WS-RLO infections. Understanding the characteristics of RLO transmission and proliferation (e.g. sinks and sources of infective elements, thermal thresholds, origins of species-specific susceptibility) and how they may impact population dynamics of abalone are important to promote stock rebuilding. Here, a SLIP (susceptible, latent infection, patent infection, waterborne infective particle) modelling approach is presented to simulate disease progression and subsequent population dynamics of three species of abalone as influenced by temperature, species assemblage, host susceptibility, and proximity to sources/sinks of RLO. This work will inform management plans for restoration of wild populations and sustainability of farming operations to disease incidence in projected near-future climate change conditions.

Wind Forcing and Physical and Bio-optical Variability over the Washington and Oregon shelves

Edward Dever, Oregon State Univ.; Craig Risien, Oregon State Univ.; Raelynn Heinitz, Oregon State Univ.; Kristin Politano Oregon State Univ.

As part of the NSF Ocean Observatories Initiative (OOI) Endurance Array, six surface moorings have been deployed over the Oregon and Washington shelves since April 2015. The moorings are deployed off Grays Harbor, Washington and Newport, Oregon at inner shelf, shelf and slope depths. The moorings include surface meteorology, physical oceanographic, chemical and biological sensors. Here we report on seasonal variability in wind forcing, temperature, velocity, and chl-a fluorescence. The Oregon and Washington shelves are part of the northern California Current Marine Ecosystem. They exhibit characteristic responses to spring and summer upwelling winds and winter storms. We describe the spring and summer variability in physical parameters and fluorescence and contrast it to that in fall and winter. During spring and summer, cold recently upwelled water is associated with high chlorophyll fluorescence. However, off Washington, local wind forcing is not strongly correlated with temperature variability. Off Oregon, there is a stronger relationship between local wind forcing and temperature and salinity. In both regions, there is a significant correlation between chlorophyll fluorescence and optical backscatter in spring and summer. By way of contrast, in winter and early spring, relatively low fluorescence occurs, and there is often no relationship between the weak chlorophyll fluorescence signal and the optical backscatter.

Can we detect spring-neap variability of San Francisco Bay Plume from space?

Cassia Pianca, Estuary & Ocean Science Center - San Francisco State University; Piero L.F. Mazzini, Estuary & Ocean Science Center - San Francisco State University.

San Francisco Bay is the largest estuary on the US west coast, located on the north central coast of California. It receives water from the Sacramento-San Joaquin river system, which drains approximately 40% of the California area. Discharge magnitudes are highly variable, ranging between 1,000-10,000 m^3/s during winter and early spring and between 100-300 m^3/s during summer and fall. The tides are mixed semi-diurnal with 1.3 meters of average tidal range, with a spring-neap variability. As changes in tidal amplitude affect mixing and estuarine hydrodynamics, as well as sediment resuspension and transport, it is expected that river plume dynamics and optical water properties will also be impacted. Using a 17-year long time series of daily ocean color data from the Moderate Resolution Imaging Spectroradiometer (MODIS), we investigate the potential changes in size and turbidity of San Francisco Bay Plume as a result of changes in tidal amplitude modulated by the spring-neap cycle, and whether these changes can be detected within the influence of time variable discharge and wind-forcing.

Space-time variability of San Francisco Bay Plume from MODIS imagery

Piero L. F. Mazzini and Cassia Pianca Estuary & Ocean Science Center, San Francisco State University

San Francisco Bay Plume (SFBP) is an understudied, human-impacted river plume, which influences an extremely complex and ecologically important region, the Gulf of the Farallones, located in the California north central coast. Waters originated in the San Francisco Bay estuary, which are potentially contaminated by sewage, oil spills, toxins from harmful algal blooms, and other anthropogenic introduced pollutants, are delivered to the adjacent coastal ocean, particularly in ecologically relevant areas, such as the Greater Farallones, Cordell Bank and Monterey National Marine Sanctuaries. Understanding the reach of influence of SFBP, and how this plume varies in time, is therefore crucial for the proper management of these Sanctuaries. A 17-year long time series of daily ocean color data from the Moderate Resolution Imaging Spectroradiometer (MODIS) is combined with historical in situ salinity data from oceanographic cruises to create an empirical synthetic surface salinity (SSS) product for this region. Preliminary analysis of the space and time variability of the SFBP using the SSS are presented.

Heat Waves in the San Francisco Bay Estuary

Alyssa Ells, San Francisco State University; Piero Mazzini, San Francisco State University; Chelle Gentemann, Earth and Space Research; García- Reyes, Farallon Institute

Marine heat waves (MHWs), much like atmospheric heat waves, are prolonged anonymously warm events that take place in the ocean. MHWs can have significant impact in marine ecosystems; harmful algal blooms, hypoxia, declines in subtidal kelp beds, mass mortalities of pinnipeds and common mures have been documented effects of MHWs. While the time variability and trends in MHWs have been previously addressed in the northeastern Pacific Ocean, few studies have focused on MHWs within estuarine environments. This study analyzes a 30-year long time series obtained from 15 temperature sensors installed in piers and buoys to investigate trends in MHWs in the San Francisco Bay (SFB) estuary, the largest estuary in the west coast of the U.S. Characteristics such as frequency, magnitude, duration and rate of evolution will be addressed. Understanding MHWs and their temporal variability within the SFB estuary can give scientists and resource managers the tools to help protect and try to prevent loss of habitat in marine life.

Measuring turbulent stress and tke profiles in the osbl using an autonomous underwater vehicle

Alexander W. Fisher, UCSB; Nicholas J. Nidzieko, UCSB

Surface gravity waves are fundamental to the exchange of momentum, energy, heat, and gases between the atmosphere and the ocean. While considerable advances have been made in understanding wave-driven turbulent mixing in recent years, the specific nature of momentum exchange within the wave-affected surface layer remains a key gap in our understanding of the physical response of a coastal ocean to wind forcing. However, direct measurements of turbulent Reynolds stresses and dominant terms in the TKE budget in the oceanic surface boundary layer (OSBL) are rare owing to constraints associated with buoy-, ship-, and tower-based observations. Consequently, the inclusion of surface wave effects in turbulence closure schemes relies heavily on numerical modeling results due to the limited availability of direct observations. Using a Hydroid-Kongsberg REMUS 600 autonomous underwater vehicle equipped with microstructure probes and fast velocimeters, measurements of the turbulent Reynolds stress, TKE, and dissipation were collected within the OSBL during a series of deployments carried out in the Santa Barbara Channel. Preliminary estimates of turbulent fluxes will be presented and analyzed in the context of boundary layer scaling relations. An analysis of vehicle response to wave orbitals and the subsequent correction and validation of turbulence measurements made from a propelled platform will also be discussed.

Observations and simulations of interannual variability in the first migration of Bering Sea northern fur seal pups

Noel Pelland; Marine Mammal Laboratory (MML), NOAA-AFSC; Jeremy Sterling, Marine Mammal Laboratory (MML), NOAA-AFSC; Devin Johnson, Marine Mammal Laboratory (MML), NOAA-AFSC; Mary-Anne Lea, Institute for Marine and Antarctic Studies, University of Tasmania

Survival of young animals is an important ‘bottleneck’ or population regulatory mechanism in marine mammal species. In northern fur seals (NFS; Callorhinus ursinus), understanding and prediction of early survival is complicated by the species’ long winter migration across a wide range of habitats in the North Pacific Ocean. Further quantitative understanding of this migration for naïve, newly-weaned pups is critical for the development of environmental metrics that may explain their first winter survival and aid in NFS conservation. We describe efforts to simulate the migration of NFS pups from the Bering Sea using statistical models of animal movement, which are developed from satellite telemetry observations of five separate migrations. Observed pups show differing dispersal directions by year, with differences greatest between 10-50 days at sea. These differences are similar in character to the prevailing winds – prominently, strong westerly winds in 1997 and 2015 were associated with pup displacements to the east. This is consistent with previous evidence of wind-influenced dispersal and movement of pups within the Bering Sea. To facilitate simulation of pup migration, movements are modeled as a combination of background, wind-associated, and random components, where the background movements vary spatially; simulations based on these models have realistic spatial distributions and good skill in reproducing the observed differences by year. These results are consistent with the hypothesis that observed interannual differences in pup habitat use are largely due to the winds, or more specifically, the interaction between winds and the background mean movement. The exact mechanisms underlying either the background or wind-associated movements are not presently known. The simulations’ skill in reproducing observed migratory patterns indicates that they are a valid tool for hindcasting dispersal and habitat use in years without satellite tracking, which would allow for comparison to historical and ongoing time series of NFS pup survival estimates.