Eastern Pacific Ocean Conference 2017
Abstracts

Deep-water Renewal in the Strait of Georgia as an Effective Evaluation for SalishSeaCast

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Oral

ABSTRACT:
The Salish Sea, a semi-enclosed group of straits in the Eastern Pacific, acts as a large, stratified estuary. Many rivers flow into it. This freshwater then flows out toward the Pacific Ocean and is replaced by denser water inflows. However, particularly for the Strait of Georgia (SoG), the estuarine exchange flow is choked by strong tidal mixing in the narrow straits between the San Juan and Gulf Islands. The amount and depth of this exchange depends sensitively on the mixing and the densities of the waters on the two sides of the mixing region. Thus, the density, nutrient concentration, oxygen saturation, and dissolved inorganic carbon content of the incoming estuarine flow to the SoG depends on a number of difficult to model processes.
Ocean Networks Canada (ONC) has installed and maintains a series of four bottom-mounted, continuously recording, conductivity-temperature instruments in the correct place to capture this incoming flow. The combination of a sensitive process and the correct data make an effective process for model evaluation.
We will discuss the process, evaluate our model, SalishSeaCast, and present the model attributes that are required to simulate the deep water inflow accurately. SalishSeaCast is a NEMO (Nucleus of European Modelling of the Ocean) configuration with a coupled biogeochemical model for the Salish Sea (http://salishsea.eos.ubc.ca/nemo/). The model has a 500 m grid size with vertical partial z-levels from 1 meter near the surface to 20 meters at depth. It is forced by a 2.5 km weather model, over 150 rivers and eight tidal constituents. Boundary conditions come from NOAA sea surface height forecasts, Live Ocean for temperature and salinity at the western boundary and climatology for the northern boundary. The physical model has run operationally since 2014 and is currently used for storm surge prediction by stakeholders.

The complex seascape of harmful algal blooms in California before, during, and after the ‘Blob’-to-El Niño transition

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Session: The “Blob-to-El Niño” transition: what happened in the CCS?
Presentation Type: Oral

ABSTRACT:
The 2016 El Niño was flanked by massive toxic Pseudo-nitzschia blooms off the coast of California that coincided with the Pacific Warm Anomaly (a.k.a. “blob”) in 2015 and with ENSO-neutral conditions in 2017. This contribution examines blooms in three major hot spots: the Humboldt coast, Monterey Bay, and Santa Barbara Channel (SBC) over the span of three physically dynamic years in the California Current in an attempt to understand local and regional drivers. Variability in domoic acid concentration, the neurotoxin produced by Pseudo-nitzschia, is associated with various fishery closures and unusual mammal mortality events over the time period. While the warm temperature anomalies seen during the ‘blob’ were akin to those that resurged during the El Niño, HAB activity in 2016 did not approach anything like that seen from the Santa Barbara Channel to Alaska in 2015. Unexpectedly, HAB activity in 2017 was dramatic and mostly restricted to the Southern California Bight, with major ecosystem disruption occurring in the SBC region. This southern California bloom followed an unusually wet year along the coast that was decoupled from the ENSO event. Here we examine the similarities and differences in environmental drivers across years, to tease apart basin-scale factors from environmental stochasticity.

Growth and survival of coho salmon in the Northern California Current: the blob and beyond

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Session: The “Blob-to-El Niño” transition: what happened in the CCS?
Presentation Type: Oral

ABSTRACT:
Coho salmon have a relatively simple marine life history, juveniles enter the ocean in the spring at 1.5 years of age and adults return to freshwater in the fall after 18 months of marine rearing at age 3. As such, it is relatively easy to identify years in which differences in ocean conditions may have led to variation in marine survival of these fish. A long-standing hypothesis suggests that variation in marine survival of coho salmon is related to marine growth of juveniles soon after ocean entry. We have tested this hypothesis by measuring growth of juvenile salmon in June, soon after ocean entry, in a ocean survey conducted off the Oregon/Washington Coast since 2000 (2000 – 2016). In this presentation we report on juvenile abundance, juvenile growth and adult coho salmon returns over this time period. In addition, we examine relationships between these salmon metrics and common ocean indices, including temperature, up-welling, sea level height, PDO and NPGO. We report on a disruption of previous relationships between PDO, growth and survival of coho salmon in the years 2014 – 2015. In particular, we found abundant food resources and high growth of juvenile salmon during and after the blob, an unexpected result during periods of warm ocean temperatures. Finally, we will report on preliminary results from the June 2017 survey. The survey ship docked the day prior to the writing of this abstract but, initial reports suggest that the Northern California Current ecosystem continued to change in unexpected ways in 2017.

Internal Wave Dynamics in Barkley Submarine Canyon

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Session: Processes of the continental slope and shelf break
Presentation Type: Poster

ABSTRACT:
Submarine canyons are known to be sites of significant tidal energy conversion from the barotropic to baroclinic modes, with major implications for water mass mixing. This study characterizes the internal wave energy in Barkley Canyon, located off of Vancouver Island, utilizing a long-term dataset from three moored ADCP instruments operated by Ocean Networks Canada. This array provides a cross shelf view of internal wave beams as they progress from the thalweg of the canyon, to the upper slope. A long record of over a year (September 2013-December 2014) allows for comparison of different seasons and local oceanographic conditions on the internal wave field. A strong topographic steering effect is evident in the bottom 150 meters, and spectral analysis of the temperature and velocity data shows that semi-diurnal and diurnal frequencies dominate the energy spectrum. Harmonic analysis indicates that the amplitude and phase of M2 velocities change with depth, and that phase propagation is upward across all three locations. These observations are consistent with downward energy propagation and focusing of internal tidal beams. Enhancement of the energy spectrum close to the sea floor above the slope is also visible at higher frequencies, which is consistent with internal wave reflection. Submarine canyons are common bathymetric features, particularly along the shelf break of the eastern Pacific, and this study provides a detailed examination of the internal wave climate in one such canyon.

Biological Impacts of the 2013–2015 Warm-Water Anomaly in the Northeast Pacific: Winners, Losers, and the Future

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Session: The "Blob-to-El Niño" transition: what happened in the CCS?
Presentation Type: Oral

ABSTRACT:
A large patch of anomalously warm water (nicknamed "the Blob") appeared off the coast of Alaska in the winter of 2013–2014 and subsequently stretched south to Baja California. This northeastern Pacific warm-water anomaly persisted through the end of 2015. Scientists and the public alike noted widespread changes in the biological structure and composition of both open- ocean and coastal ecosystems. Changes included geographical shifts of species such as tropical copepods, pelagic red crabs, and tuna; closures of commercially important fisheries; and mass strandings of marine mammals and seabirds. The ecological responses to these physical changes have been sparsely quantified and are largely unknown. Here, we provide a bottom-up summary of some of the biological changes observed in and around the areas affected by the Blob.

Flow through the Northern Gap in the Santa Rosa to Cortez Bank Ridge

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Session: Processes of the continental slope and shelf break
Presentation Type: Poster

ABSTRACT:

Results of a hydrographic surveys in Santa Cruz basin and over the adjacent Santa Rosa to Cortez Bank Ridge in July 2002 and August 2004 are described. Data include CTD casts and vessel mounted ADCP results. Results agree with cyclonic flow pattern described by Bray et al., 1999, and showed strong westward flow along the northern boundary of the basin.

During the 2004 cruise, a current meter was moored at a depth of 337 m, about 22 m above the bottom, at the deepest point of the northern gap in the ridge. It was recovered two months later. Vector mean flow was 0.17 m/s and directed out of the basin, 250°T and the semi-major axis was 0.21 m/s. Variability was dominated by diurnal and semidiurnal tides. Flow into the basin was marked by large temperature change when the flood was strongest

Physical and biogeochemical variability at the head of Monterey submarine canyon

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Session: Processes of the continental slope and shelf break
Presentation Type: Poster

ABSTRACT:
Monterey submarine canyon extends from the mouth of Monterey Bay all the way to the coast, creating a dynamic connection between the deep ocean and nearshore environment. This study examines a long-term high-resolution time series of temperature, salinity, dissolved oxygen, pH and, recently, pCO2 from the Moss Landing Marine Labs seawater intake at the head of Monterey Canyon. Although the site is shallow at 17m depth, strong internal tides cause large vertical excursions at the semidiurnal frequency, allowing for the analysis of subsurface water properties. Over the period 2011-present, interannual variability of temperature and salinity over a wide density range is consistent with offshore observations; during the 2015-16 El Niño, conditions at this site are anomalously warm but not particularly spicy. At the tidal time scale, internal waves regularly expose this nearshore site to water that is low in dissolved oxygen, low pH, and high in pCO2, modulating the background seasonal variability associated with wind-driven upwelling and stratification.

Seasonal exchange flow in a Pacific Northwest estuary

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Presentation Type: Poster

ABSTRACT:
Estuarine exchange flow in the Pacific Northwest varies seasonally due to first-order changes in freshwater input and oceanic conditions on the shelf, which both influence water parcel residence time. Here, we quantify the time varying magnitude and mechanisms driving the exchange flow in Coos Bay, Oregon, a small, dredged estuary that typifies PNW estuaries outside of the Columbia River. We focus on the year 2014 to produce a validated numerical model hindcast to examine the along and across estuary salinity structure over multiple timescales, from tidal to synoptic to seasonal. Observational data include along-estuary hydrographic surveys, and time series of water velocity and salinity from a set of subsurface sensors located along-estuary. We find a complex spatial structure to the exchange flow that is partly due to the sinuous geometry of the estuary, its extensive tidal flats, and the multiple small sub-estuaries (i.e., sloughs) that connect into the main channel along its length. In particular, we focus on South Slough, the site of a National Estuarine Research Reserve, to explore how the salinity structure there interacts with the main channel.

Fine-scale physics and biology in the northern California Current

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
New oceanographic sampling technologies can convey significant, novel insights into physical-biological patterns and processes over a range of spatial scales. One exciting area of biological sampling that has evolved with considerable rapidity is in situ imaging technology. Our first effort deploying the In Situ Ichthyoplankton Imaging System (ISIIS) in the Northern California Current (NCC) in June 2016 yielded 44 TB of imagery data and necessitated development of a new automated image processing pipeline that uses a deep-learning Convolutional Neural Net algorithm. Nine ~60 km cross-shelf transects (centered on the 300 m isobath; extending over the shelf break) were sampled during daylight hours from Brookings to Astoria, Oregon. In addition, four 26-km alongshore transects intersecting the Columbia River Plume (CRP) and perpendicular to the cross-shore flow were sampled over an ebb and flood tide. The CRP signature of low salinity surface waters extended down the coast as far as Coos Bay. Dissolved oxygen reached almost hypoxic levels in the northern-most transects and large amounts of detritus were found associated within the oxygen minima. A total of ~65 taxonomic zooplankton groups were distinguished ranging from protists to larval fishes. Distinct distributions of zooplankton and larval fishes tracked nearshore hydrography and included several high density thin layers. New sampling efforts are planned to examine how cross-shelf mesozooplankton distributions and trophic relationships change with season in the NCC.

Examining the contribution of wave-induced transport to nearshore chlorophyll-a variability in Northern California.

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Poster

ABSTRACT:
The drivers of spatial and temporal variability in coastal phytoplankton blooms are complicated, making it difficult to predict events at an individual level. Recent research suggests that onshore wave-induced transport, or Stokes drift, may act as a forcing mechanism, resulting in periods of high nearshore chlorophyll-a in Northern California, by trapping buoyant phytoplankton in convergence zone that forms over the inner shelf. The accumulation of trapped phytoplankton results in a strong signal in fluorescence at shorter latencies than is expected from nutrient loading. The goal of this project is to elucidate the effects of surface gravity waves on nearshore phytoplankton temporal variability using the extensive remote sensing datasets that exist along Northern California. Utilizing high frequency radar derived surface currents, the offshore spatial patterns of surface flow preceding anomalously high chlorophyll-a events in the nearshore off of Bodega Bay, CA are examined for patterns of cross-shelf convergence. Lagrangian surface velocities are estimated using the high frequency radar derived Eulerian surface currents and adjusted with using Stokes drift calculated from offshore and mid-shelf in-situ spectral wave measurements. Surface particle trajectories are estimated using a 2D particle tracking model that reverse time steps from individual nearshore high chlorophyll-a events. This work has implications in other highly variable nearshore processes, such as larval transport and dispersion, where the inner shelf can act as a barrier to cross shelf transport and wave-induced transport can dominate.

Quantifying small-scale environmental gradients in coastal ecosystems.

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
One of the major challenges in understanding physiological and ecological processes is quantifying physical and biological patterns at appropriate spatiotemporal scales. Here we examine physical processes shaping environmental gradients on the inner shelf and nearshore coastal ocean using a distributed temperature sensing (DTS) system. A DTS system measures temperature continuously along the length of an optical fiber, resolving meter-to-kilometer spatial scales at 1-minute temporal resolution. This unique view of cross-shelf temperature structure allows us to characterize the landscape of temperature variability in benthic coastal environments.

A numeric modeling study of biogeochemical variables off Baja California during climatic anomalies

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Session: The "Blob-to-El Niño" transition: what happened in the CCS?
Presentation Type: Poster

ABSTRACT:

Climatic anomalies that occur at interannual scale have important consequences for the southern California Current system (CCS); most of them affect the entire North Pacific, sometimes extending into equatorial waters. One of these anomalous processes is El Niño or ENSO (El Niño Southern Oscillation), which plays a crucial role in understanding the CCS variability. The opposite phenomenon is La Niña, which is characterized by below average sea surface temperatures in the northern portion of the Pacific. The most recent phenomenon that affected the North Pacific Ocean is "The Blob", an anomalously warm water mass that formed in the Gulf of Alaska during the fall 2013 and spread across the North Pacific reaching as far south as Baja California, Mexico.
A biochemical model based on the nitrate cycle, coupled to a three-dimensional numerical hydrodynamic model, allows to simulate the response of nutrients, oxygen and phytoplankton off Baja California during the anomalous periods: 2010-2011, 2012-2013 and 2014-2015, characterized by La Niña, El Niño and The Blob conditions, respectively. Analyzing and quantifying these response processes due to climatic anomalies is important for the understanding of the regional biogeochemistry.

Model resolution necessary to study the impact of climate change on fisheries in the California Current System

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Oral

ABSTRACT:
The effects of global climate change on the California Current System (CCS) may have profound ramifications for the lucrative US-west coast fishing industry. However, the minimum resolution necessary to resolve processes that will drive changes in fish distributions and thereby affect fisheries is currently unknown.

Here we use a 4km Regional Ocean Modeling System (ROMS) model of the CCS to study changes in mean-state parameters such as temperature, circulation and water mass proportions. The reference model is forced with recent (1981-2010) climatological ocean (SODA) and atmospheric (ERA interim) conditions, while three end-of-century (2081-2100) model runs are additionally forced with climatological ocean and atmospheric anomalies derived from the NCAR Community Earth System Model (CESM), Large Ensemble Community Project (LENS). In order to capture the range of future CCS variability, we use three LENS end members exhibiting the warmest, average, and coldest mean California coastal SST under Representative Concentration Pathway 8.5.

In addition to comparing our historical and future model runs, we will discuss the skill with which 30-year averaged forcing fields reproduce present day CCS structure, as well as how end-of-century ROMS scenarios compare with coarser global model simulations.

Patterns of nutrient variability in the California Undercurrent

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Session: Processes of the continental slope and shelf break
Presentation Type: Oral

ABSTRACT:
The California Undercurrent is widely recognized as the source of nutrients for California coastal upwelling systems. However, very little attention has been paid to the nutrient concentrations and their variability within the undercurrent. We have made preliminary analyses of CalCOFI data-sets with hydrography and nutrient data, concentrating on shelf-break stations at depths of about 200m. CalCOFI Line 90 off southern California has been occupied and sampled for temperature and salinity more or less four times per year continually since 1950 with full nutrient data collected after 1981. This long time series shows temperatures with long period changes and little change in salinity that appear to be correlated with ENSO events. Consequently sigma theta follows the same pattern as temperature. Both nitrate and silicate concentrations closely track sigma theta. The range of sigma theta along Line 90 at 200m includes 26.5, the average for the equatorial component of the California Undercurrent. The nutrient concentrations associated with that sigma theta and their variability will be presented. Further analysis of this data will aid in predicting future changes in nutrient flux to the California upwelling centers that may result from perturbations in the Equatorial Pacific, specifically in the Equatorial Undercurrent nutrient regime that feeds the California Undercurrent.

Phytoplankton transport to the abyssal seafloor in the California Current observed over 30 years

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Session: General session: Oceanography of the eastern Pacific Ocean
Presentation Type: Oral

ABSTRACT:
The transport of surface phytoplankton to the deep ocean (4000 m deep) is a critical component of the marine carbon cycle and benthic ecosystem productivity. The transport of fresh organic material to the seafloor is likely driven by surface ocean ecosystems, and therefore we expect that the quantity and type of phytoplankton that reach the seafloor will be affected by climate-driven changes in the surface ocean. This study utilizes the deep ocean time-series study at Station M in the California Current to identify how the supply of phytoplankton to the deep ocean has changed across a 30-year observational record that spans variable climate regimes. Sediment trap samples were collected for 17-day periods nearly continuously since 1989. The phytoplankton within a subset of these preserved samples were quantified by microscopy to determine 1) how the species composition and relative abundance of phytoplankton within sinking particles changes during periods of high vs. low particulate organic carbon (POC) flux, and 2) how these measures have changed across multiple decades and periods of changing climate indices. Preliminary microscopy data will be presented, along with new observational strategies employed at Station M to further resolve the microbial contributions to POC flux at the seafloor. These data may be a valuable tool in the creation of more accurate biogeochemical models of the California Current system, improving our ability to predict how ecosystem links between the surface and benthos will be affect in a future climate.

Biogeochemical signatures of the recent warm blob and El Niño as obtained using a data assimilative reanalysis of the California Current System

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Session: The "Blob-to-El Niño" transition: what happened in the CCS?
Presentation Type: Poster

ABSTRACT:
Obtaining quantitative estimates of biogeochemical variables such as phytoplankton standing stock and processes such as primary production is challenging when desired over large spatial areas and sustained periods. Free running models of ocean circulation and biogeochemistry are limited by errors in model initial conditions, forcing, and model parameterizations. Satellite chlorophyll-a estimates and related quantities (e.g., primary production derived from chlorophyll-a) are limited by cloud cover. A data assimilative model offers data-constrained estimates of model state variables and dynamical processes that drive state variable changes.

We use a fully coupled data assimilative reanalysis of the California Current System to analyze the physical and biogeochemical state along the central California coast during the recent warm blob period (2014-2015) and the year following the 2015-2016 El Niño. We apply ROMS with 4-dimensional variational assimilation coupled to the NEMURO ecosystem model and assimilate satellite-derived sea surface chlorophyll-a along with extensive physical observations. Overall, the studied sequence of years is characterized by warm temperature anomalies, low phytoplankton biomass and low primary production. We find that springtime new production is not substantially altered by the blob but summertime new production is low. In contrast, spring 2016 following the El Niño exhibits low new production whereas summertime production is more typical. We quantitatively relate changes in new production to changes in vertical nitrate flux and stratification along the central California coast.

A quasi-dipole structure in the wind forcing over the California Current System helps interpret coastal water temperature anomalies during the marine heat waves of 2014–2016

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Session: The "Blob-to-El Niño" transition: what happened in the CCS?
Presentation Type: Oral

ABSTRACT:
The wind that sustains the California Current upwelling system (CCS) is quite variable. We characterized the wind forcing during 1981-present using Hilbert empirical orthogonal function (HEOF) analysis of buoy and satellite wind data. We found a large-- scale quasi-dipole structure in the wind forcing that spans the entire CCS coastline from Washington through California, indicating a tendency for wind fluctuations (upwelling and relaxation) north of Cape Mendocino and south of Cape Mendocino to be anticorrelated. When the northern half of the CCS is in a relaxation state, the southern half often experiences intensified winds, and vice versa. This pattern accounts for ~60% of the wind velocity variance on time scales of days to weeks, and is generated by fluctuations of the North Pacific High advecting the desert heat low pressure offshore.

The time series of the "activity" of the HEOF quasi-dipole allows us to place the wind forcing during the marine heat waves in the northeast Pacific in 2014-16 into the context of the typical wind forcing. The spatial pattern of the HEOF then helps us interpret the regional variations in water temperature along the coast. For example, in July 2015 there were strong SST anomalies from Capes Blanco and Mendocino southward, but not north of Cape Blanco, very similar to the spatial pattern of wind forcing captured by the HEOF analysis. Because the HEOF quasi-dipole is driven by local synoptic pressure systems, but El Niño signals come from the equator, this approach helps us disentangle the relative influences of local wind forcing and an advective El Niño signal on the SST anomalies. We are calculating HEOFs of the satellite wind stress curl and will discuss the role of wind stress curl anomalies and Ekman pumping in modulating the warm water anomalies along the coast.

A ratchet to shore: evidence of high-frequency internal waves transporting Quasi-Lagrangian plankton mimics.

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
Field studies have documented propagating slicks of flotsam and concentrated plankton, suggesting that high-frequency internal waves can induce net plankton transport. To quantify transport by internal waves and circumvent the difficulties of tracking plankton in situ, we deployed swarms of up to 16 mini Autonomous Underwater Explorers (m-AUEs) near Mission Beach, CA for periods of two to four hours over two weeks in June 2016. Hydrophones on the m-AUEs received signals from an array of acoustic pingers, allowing us to subsequently reconstruct their subsurface paths via triangulation. Inside the pinger array were several moorings, including a Wirewalker, to quantify the internal wave field. This presentation will focus on the results of a deployment in which two swarms of m-AUEs were programmed to hold depth at 3 and 12 m, respectively. The m-AUE tracks show that the shallower plankton mimics experienced increased shoreward transport when high-frequency internal waves propagated through the swarm, with measured Lagrangian velocities of up to 20 cm/s. This study provides direct evidence of subsurface transport by high-frequency internal waves.

Multiscale mixing dynamics in a transcritical, shelf-incising west coast canyon

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Session: Processes of the continental slope and shelf break
Presentation Type: Oral

ABSTRACT:
Submarine canyons are common features of the coastal ocean. Their complex topographies host dynamical processes on a variety of scales – enhancing upwelling, forcing hydraulic jumps over abrupt bends, and focusing internal waves, to name a few. Many of these processes are associated with small-scale turbulence so that canyons are also "hotspots" of energy dissipation and mixing. Globally, these processes contribute to diapycnal transport 2-3 times that of the open ocean. Regionally, this mixing influences the distribution of tracers such as nutrients, oxygen, carbon, and heat.

In order to elucidate dynamics driving mixing in a shelf-incising canyon (common off of California), a suite of observations were undertaken beginning in September 2016 in the La Jolla Canyon System in San Diego. Eight cross-canyon sections were occupied with a towed body for 24-hours apiece revealing enhanced dissipation driven by both tidal and mean flows. Turbulence occurs both near the bottom and in mid-depth regions where stratification is stronger and resulting mixing can significantly modify water mass properties. Turbulent mean flow separation occurs on offshore lines where along-shore flow is not blocked by the southern headland. Most dissipation, however, is tidally driven.

In addition to shipboard surveys, time series from 3 moorings along the canyon axis capture temporal variability of energetics and mixing patterns. Changes in stratification that occur over fortnightly timescales are linked to spring-neap cycles in energy and dissipation. These shifts alter the reflectivity of the system and thus the distribution of tidally driven mixing. The high-resolution, wave-powered WireWalker profiling mooring deployed at the head of the canyon has continued for the whole year, revealing
dynamics and biogeochemical signals on seasonal, event, tidal, and higher frequency timescales and proving novel insight into the canyon's role in the environment on the adjacent shelf.

Bias correction for seasonal dynamical downscaling of the Pacific Northwest

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Presentation Type: Oral

ABSTRACT:
JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE) features dynamical downscaling of regional ocean conditions in Washington and Oregon waters using a combination of a high-resolution regional model with biogeochemistry and forecasts from NOAA's global Climate Forecast System (CFS). The CFS forecast output, used for atmospheric forcing and boundary conditions of the J-SCOPE regional ocean model, has significant biases relative to the observed (reanalyzed) states. At coarse scales these biases have been quantified by the CFS group, through extensive reforecast experiments spanning multiple decades. Here, we explore possible methods for bias correction at regional scales in our seasonal forecasts. Specifically we consider: 1) subtraction of the coarse-scale bias, as a function of month, forecast lead time, and ENSO state, from CFS output prior to its application in regional forcing; 2) calculation of the regional bias based on our limited ensemble of J-SCOPE forecasts, each driven by uncorrected (hence biased) CFS output. Method 1 has the advantage of the biases being well sampled by the extensive set of CFS reforecasts, while method 2 has the advantage of using dynamically balanced (albeit biased) forcing timeseries from the coupled global atmospheric/oceanic models of the CFS. Results will be illustrated using immersive stereo visualization.

Shelf hypoxia in the Gulf of Farallones and Cordell Bank

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Presentation Type: Oral

ABSTRACT:
Upwelling of nutrient-rich water from the deep ocean to the continental shelf fuels productivity along the California Current System. Yet, these deep waters are also oxygen-poor and can be more corrosive than shelf water. While regional dynamics over an upwelling-relaxation cycle are fairly well described in the Bodega-Reyes region, shelf water off central California are understudied in terms of dissolved oxygen content and variability. Therefore, little is known on which mechanisms drive regional hypoxia (or when it occurs). Here we report continuous measurements of temperature, salinity, and dissolved oxygen collected at sites in the Gulf of the Farallones and on Cordell Bank during 2015 - 2017 upwelling seasons. And relate temperature, salinity and dissolved oxygen variability to forcing mechanisms to identify the importance of physical and biological drivers of hypoxia.

Towards a climatology of the California Undercurrent at Trinidad Head (41N)

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Session: Processes of the continental slope and shelf break
Presentation Type: Poster

ABSTRACT:
The California Undercurrent (CU) is a narrow, subsurface, countercurrent in approximate geostrophic balance that transports warm, salty (high spice), low oxygen water from the tropical eastern Pacific poleward. Previous studies in other regions of the California Current System have found that the CU reaches maximum velocity during spring upwelling above the shelf break at the 26.5 isopycnal. Due to its location and timing the CU has the potential to impact heat transfer between the equatorial and polar regions and it remains an open question as to whether it can act as source waters for upwelling systems along the broader California Current. Outside of Central and Southern California, little is known about the seasonal timing and variability of the CU. From 2006 to present, monthly hydrographic surveys along the Trinidad Head Line (41N) collected CTD profiles at five cross-shelf stations that span the breadth of the inner shelf to beyond the shelf break. Underway ADCP measurements were also conducted. Since 2015 a Seaglider operated by Oregon State University and archived by CenCOOS has provided high-frequency transects of temperature, salinity, and depth-averaged currents (DAC). In this study, we plan to objectively map the available data along the Trinidad Head Line to a regular grid so that the geostrophic method can be applied to quantify along-shore geostrophic currents in both datasets. The goals of this project are to attempt to resolve the seasonal timing and progression of the CU in the northern California Current, validate existing and new glider observations in the region with the long-term climatology of the CU, and to put the glider transects into seasonal context.

Role of submesoscale processes on the biogeochemistry of the California Current Ecosystem

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Oral

ABSTRACT:
Seasonal wind-driven upwelling supports phytoplankton blooms that turn the California Current into one of the most productive ecosystem of the ocean. This upwelling is confined to a narrow near-shore band that is poorly resolved by current physical-biogeochemical models. Further offshore, mesoscale eddies counteract the upwelling by removing surface nutrients through subduction. However, the impact of submesoscale motions on upwelling and "eddy quenching" of productivity has not been quantified yet. Here, we present results from two sets of simulations with a regional physical-biogeochemical model of the California Current run at the resolution of 4 and 1 km respectively. We evaluate the effects of submesoscale processes on upwelling and turbulent fluxes of nutrients and other material properties, and how they reverberate through the biogeochemistry and ecosystem of the region, from the cycling of carbon and oxygen, to the spatial and temporal patterns of primary production and phytoplankton community size structure.

The NOAA West Coast Ocean Forecast System: new analyses and data assimilation tests

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Oral

ABSTRACT:
The status of the West Coast Ocean Forecast System (WCOFS), under development at the NOAA National Oceanographic Service, will be discussed. New analyses of oceanic variability, using multiyear model runs without assimilation, have been focused on the near-surface salinity signal, details of the surface boundary layer, and connectivity of the slope and offshore waters. In particular, several model outputs have been verified against the Oregon glider data (data courtesy J. Barth et al.). The WCOFS run without evaporation and precipitation (E-P) develops a positive salinity bias of up to 1 psu near the surface. In the Navy global HYCOM-based data assimilative forecast system, the surface salinity is nudged to climatology, but shows strong negative bias in the top 100 m. Inclusion of E-P in WCOFS yields a smaller salinity bias in the top 100 m than in the two above-mentioned model estimates. Comparisons of WCOFS against Argo profiles off Vancouver Island and Washington suggest that including precipitation can make the model winter stratification stronger than observed. In our ongoing effort, we are learning if the Craig-Banner parameterization for the wave-induced near-surface turbulence has an effect on the near-surface salinity or temperature in winter or summer. Along with the model skill assessments, we have run initial data assimilation tests. These have shown the positive impact of the SST, SSH, and HF radar assimilation on the shelf currents.

Effects of coastal biophysical processes on the spatial structure of intertidal communities along the Southeastern Pacific coast

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Poster

ABSTRACT:
Understanding the influence of environmental variability on the biogeographic structure of ecological communities is a central challenge in ecology. We hypothesize that the geographic range of coastal species with different larval dispersal strategies is influenced by the distribution of different regimes of biophysical variability along the coast. To test this hypothesis, we examine how the spatial distribution of different modes of biophysical variability is related the biogeographic structure of a diverse assemblage of 65 rocky intertidal species sampled over ~2,600 km along the South East Pacific (SEP) coast. Our results show that biogeographic breaks, evaluated using multivariate classification trees, are consistent with classic biogeographic units. Distributional breakpoints for species with non-feeding planktonic larvae clustered around 30°S, a known biogeographic limit. On the other hand, we observed a previously unreported break in the distribution of species with both lecitotrophic and planktotrophic larval dispersal strategies around 35°S. Using wavelet coherency analysis of physical-biological time series derived from MODIS satellite data, we show the existence of significant multiscale temporal coherence in the spatial structure of sea surface temperature, chlorophyll-a, and riverine outflow along the SEP. Regions with coherent regimes of biophysical variability, and the breaks between them, are in striking agreement with the biogeographic patterns revealed by the multivariate classification trees, and reconcile similar biogeographic patchiness reported for other groups of species along the SEP. Our results suggest that riverine outflow, an overseen coastal environmental processes, may play an important role on the geographic distribution of rocky shores species through its effects on larval dispersal patterns.

Transport Processes and Patterns for Small-Scale Land Runoff: Defining a "Zone of Impact"

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Oral

ABSTRACT:
Nearshore pollution patterns are recognized, but not well studied. Through an improved knowledge of small-scale plumes, better policy and management decisions can be made. Whether pollution is due to nutrients, pathogens or toxins, the highest concentrations of pollutants occurs in the near-field, where transport and mixing processes dominate (biogeochemical decay is secondary). Data on shoreline salinity and fecal indicator bacteria exhibit coherent space-time patterns – and a coherent "zone of impact" can be determined, which we define as a time-varying spatial zone in which the constituent of concern exceeds a reference concentration (level of concern). The zone of impact can be determined empirically and conceived as a probability of exposure in a risk-assessment framework. However, the zone of impact can also be modeled or data can be analyzed to determine dominant processes – thus allowing forecast of high-risk zones at future times. Small-scale plumes have been largely ignored in the literature, although there is a growing argument that they may pose the greatest risk to water quality in coastal waters. These small plumes occupy a different parameter space than larger plumes. For example, wind and wave forcing are often key factors in plume behavior and associated pattern of pollution. Our preliminary work suggests that coherent spatio-temporal patterns can explain (apparently) not-so-well-behaved patterns of pollution that are reported when concentrations are under-sampled. And this environmental issue challenges coastal oceanographers to better explain transport and mixing in small-scale plumes.

Just how unusual was the "Blob"?

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Session: The “Blob-to-El Niño” transition: what happened in the CCS?
Presentation Type: Oral

ABSTRACT:
The marine heatwave (MHW) of 2014-2015, aka “the blob” was an extreme event of high sea surface temperatures across a vast portion of the north east Pacific. Here, we examined the breadth, strength, longevity of the event, and distance from the shore of the MHW and compared it to similar events for the NE Pacific from 1984-2016, based on satellite measurements of sea surface temperature. An algorithm was created to characterize anomalous events, based on their strength compared to a climatology of the standard deviation in SST anomaly. We chose +2 stdev as the cutoff for “blob-class” anomalies. We then measured the area, duration, and closest distance of the middle and edge of the feature to the coast for all patches of water with values > this threshold. Based on this analysis, the marine heat wave, which began in late 2013, and continued through 2016, stands out in several aspects compared to past events. The recent MHW lasted > 6 months at a time, whereas the nearest similar event lasted only 3 months. The MHW covered an area roughly 16 times the area of Alaska (AK), whereas the closest similar event covered only 3 AKs. Events such as the 97-98 El niño do appear as large blob-class events, however, their areal extent and duration is much smaller. The only other event from the analyzed time period that is close in extent occurred in late 2004, lasting 4 months, and covering approximately 4 AKs.

Downwelling wind impacts on a buoyant coastal current from an idealized small discharge river

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Poster

ABSTRACT:
In order to explain the transport of water masses alongshore in buoyant coastal currents from low discharge rivers there is a demand for an increased understanding of the role of downwelling-favorable winds and river discharge in the transport and mixing of buoyant plumes. Winds can increase the propagation speed of the plume, but also can increase dilution from turbulent mixing. We investigate how these responses impact the plume for different river discharge conditions representative flows from the small mountainous rivers along the Oregon coast. We used observations of the Oregon coast as the basis for a suite of Regional Ocean Modeling System (ROMS) simulations with an idealized domain forced by different combinations of tidal, wind, and river forcing. We found that increasing downwelling wind speeds and increasing discharge lead to greater propagation speeds of the buoyant plume. As winds increase, the dependence on discharge is decreased and there is less alongshore variability in offshore plume extent. For high discharge scenarios, the dependence on wind speeds is decreased. An increased understanding of how the coastal current responds to winds under low discharge conditions will advance our ability to predict transport of water properties, suspended nutrients, or larvae in coastal systems.

Development, Testing, and Application of a Regional Forecast Model

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Poster

ABSTRACT:
The LiveOcean modeling system produces daily short-term forecasts of circulation and biogeochemical properties in the NE Pacific and Salish Sea. It is soon to be used by shellfish growers to adapt to the presence of corrosive waters from Ocean Acidification. It will also be used by regional managers to help manage the razor clam fishery as it is affected by Harmful Algal Blooms.

Shelf-estuary coupling: a case study of the Coos Bay estuary in southern Oregon

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Session: Processes of the continental slope and shelf break
Presentation Type: No preference

ABSTRACT:
Although the Pacific Northwest coast is relatively straight, variations in shelf width, bathymetry, wind strength, and freshwater input, produce significant along-coast variability in circulation and water properties. For example, on portions of the Oregon coast, a narrow shelf combined with seasonally-modulated river discharge can produce conditions where oceanic forcing primarily controls circulation and water properties inside estuaries. The Coos estuary, located south of Heceta Bank inshore of a relatively narrow continental shelf in Oregon, has an observed estuarine exchange flow that ramps up during the wet winter months, particularly after storm events, and decreases dramatically during dry summer months. However, we have a poor understanding of how external ocean conditions affect the water properties and exchange within the estuary throughout the year. Here we use oceanographic and meteorological observations to understand when and how shelf-estuary coupling occurs over interannual and seasonal time scales near the Coos estuary. We examine possible oceanographic variations on interannual timescales that might imprint on to the seasonal hydrography of the estuary, such as the PDO, ENSO, or NPGO. Changes on the shelf that could influence estuarine dynamics include a depression of the thermocline or any variability in stratification, a modification in the strength of seasonal upwelling, and/or advection of distinct water masses across the estuary mouth. Ultimately, an improved understanding of shelf-estuary coupling will inform studies on ecosystem functioning inside these critical estuarine habitats.

River discharges and their influence on phytoplankton biomass in coastal areas off central Chile (32°-37°S) during a drought period (2010-2014)

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Oral

ABSTRACT:
This study explores the impact of rivers discharge variability, including a period of extended drought (2010-2014), on phytoplankton biomass and nutrient exportations in the coastal waters of Central Chile. The seasonal and interannual variability of the rivers discharge, plume area extension, phytoplankton biomass as well as N and P exportation were determined in coastal areas under the influence of Maipo, Mataquito, Maule, Itata and BioBio rivers using 15 years (2000-2014) of MODIS-SeaWiFs ocean color images and hydrological rivers data. A strong positive correlation was found among river discharge, plume area, and nutrient export, during winter when precipitation reaches a maximum. Analysis of the inter-annual variability shows that the increase/decrease in the annual river plume magnitude coincides with "El Niño/La Niña" events; however, after 2010 this connection seems to disappear. During the Megadrought period (2010-2014) river discharge and plume area reduced from 43% to 61%, and from 41% to 65%, respectively. This Megadrought caused a major impact on the phytoplankton biomass (with a 86% to 88% decrease) in the northern coastal areas influenced by the Maipo and Mataquito rivers. The influence of rivers on these coastal ecosystems is discussed, including sensitivity to changes in river discharge due to natural (e.g. rainfall, snow) and anthropogenic factors (e.g. change in land-use, river water demand).

Joint assimilation of physical and chlorophyll observations into a model of the California Current System

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Oral

ABSTRACT:
Biogeochemical numerical models coupled to physical ocean circulation models are commonly combined with data assimilation in order to improve the models' state or parameter estimates. Yet much still needs to be learned about important aspects of biogeochemical data assimilation, such as the effect of model complexity and the importance of more realistic model formulations on assimilation results. We present the application of 4D-Var data assimilation to two biogeochemical ocean models: a simple NPZD model with 4 biogeochemical variables (1 phytoplankton, 1 zooplankton) and the more complex NEMURO model, containing 11 biogeochemical variables (2 phytoplankton, 3 zooplankton). Both models are coupled to a 3-dimensional physical ocean circulation model of the U.S. west coast based on the Regional Ocean Modelling System (ROMS). Chlorophyll satellite observations and physical observations are assimilated into the model, yielding substantial improvements in state estimates for the observed physical and biogeochemical variables in both model formulations. We assess whether additional complexity in biogeochemical model formulation leads to improved results and better forecasting abilities of the data assimilation system.

Relationship between biological variables and surface water origins in Monterey Bay, CA based on water-trajectory analysis

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
Changes in biological variables such as fluorescence are intermingled with advection and mixing of water masses, which make it difficult to discern the underlying biological processes at play. Organisms in Monterey Bay are sensitive to changing water masses. Is there a correlation between the origins of water masses and the biological response? We use surface current data from the high frequency radar (HFR) network in central California to produce 4-day backward trajectory statistics in Monterey Bay between 2006 and 2010. Increases in fluorescence at the M1 mooring lag upwelling favorable wind conditions by 7 days (Service et al., 2009) and we associate increases in fluorescence in Monterey Bay with 4-day particle trajectories to locate a common source water location. We investigate whether increases in fluorescence are most correlated with water a source centered in proximity to Año Nuevo, testing the hypothesis of Rosenfeld et al. (1994) that upwelled waters of Monterey Bay stem primarily from Año Nuevo.

Seasonal and interannual variation in growth and condition of larval and juvenile northern anchovy (Engraulis mordax) in relation to the biochemical and species composition of lower trophic levels

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Session: General session: Oceanography of the eastern Pacific Ocean
Presentation Type: Oral

ABSTRACT:
Northern anchovy (Engraulis mordax) is an important forage fish throughout the California Current although much less is known about the northern subpopulation off Oregon and Washington than the central subpopulation. Prior studies indicate that the growth of early stage northern anchovy within the northern California Current is greater when a boreal copepod community dominates, which suggests that growth variation may be related to the lipid quantity or fatty acid composition of their prey. However, this hypothesis has not been tested. Therefore, we determined the age, hatch date, body condition, and daily growth rate of larval and juvenile northern anchovy collected in coastal Oregon in 2012 and 2013. We also compared anchovy growth and condition with data on the species composition, lipid quantity, and fatty acid composition of the copepod and phytoplankton communities collected in the same years in order to test this hypothesis. Anchovy averaged 35 mm standard length (SL) in 2012 and 45 mm SL in 2013, and hatch dates were distributed throughout mid-May to August. Mean daily growth rate and body condition (mass-length residuals) at capture varied within and between years. Mean growth ranged from 0.30 to 0.70 mm/day, declining each fall. The lowest condition was observed in October 2012 and the highest in July 2013. Although body condition and growth within and across years were significantly correlated with the copepod species composition ($r > 0.500$), phytoplankton species composition and the fatty acid composition of copepods displayed much stronger relationships with body condition ($r > 0.837$) in both years. Growth and condition were also positively correlated with certain essential fatty acids indicative of diatom production, specifically eicosapentaenoic acid (EPA: 20:5ω3). However, there were no significant relationships between anchovy growth or condition and total lipids present in the copepod community. These results highlight the important role that phytoplankton species and copepod fatty acid composition play in regulating growth variation of early stages of northern anchovy.

Surf zones regulate subsidies of planktonic food and larvae to nearshore communities

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
We tested the hypothesis that surfzone hydrodynamics plays a key role in regulating subsides of food and larvae to nearshore communities by 1) comparing entire zooplankton communities inside and outside of the surf zone daily while monitoring physical conditions for one month each at two shores with different surf zones and 2) conducting a coastwide survey of barnacle recruitment relative to surfzone type. Opposite cross-shore distributions of zooplankton and phytoplankton occurred at the two sites: zooplankters were more abundant inside the wide surf zone at a moderately sloping shore with a system of rip currents, and they were more abundant outside the narrow surf zone at a steep shore where water exchange was reduced by half. Modeled larvae recruited onshore in two ways: benthic streaming near the bottom when winds are calm and wind-driven transport of surface-dwelling larvae to the turbulent surf zone followed by sinking to the bottom boundary layer. Recruitment varied predictably with surfzone hydrodynamics regulating communities coastwide.

Simulating Ocean Acidification in the Bering Sea

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Presentation Type: Oral

ABSTRACT:
Anthropogenic emissions have been causing a rise of carbon dioxide in the atmosphere, which is partly taken up by the world's oceans. This carbon influx changes the chemistry of the ocean and leads to a process known as ocean acidification (OA). Dissolved carbon dioxide reacts with seawater, leads to a decrease in pH, and indirectly favors dissolution of calcium carbonate, which is crucial for shelled marine organism survival and local marine food webs. The vastness of the Bering Sea in the Northern Pacific makes it difficult to gather data on OA and capture the causes and effects on calcium carbonate dissolution, measured as aragonite saturation (Ωar). Therefore, computational regional modeling is a useful tool for predicting and understanding OA and Ωar. This is essential due to the high biological productivity of the Bering Sea and its importance as a critical U.S. fishery. This project looks at key variables (e.g. alkalinity, temperature, salinity, and the dissolved inorganic carbon) that are known to affect Ωar in the Bering Sea. The model is used to understand how these mechanisms impact the spatial and temporal variability of Ωar. The results demonstrate that freshwater fluxes from nearby major river systems (e.g. Yukon, Kushokwim) are a substantial driver of Ωar along the inner shelf, illustrating the importance of resolving these inputs in regional OA models.

Spatial and Temporal Patterns of Chlorophyll Concentration in the Southern California Bight

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Session: General session: Oceanography of the eastern Pacific Ocean
Presentation Type: No preference

ABSTRACT:
Distinguishing between local, anthropogenic nutrient inputs and large-scale climatic forcing as drivers of coastal phytoplankton biomass is critical to developing effective nutrient management strategies. Here we assess the relative importance of these two drivers by comparing trends in chlorophyll-a in coastal (0.1–16.5 km) to offshore (17–700 km) areas, hypothesizing that coastal regions influenced by anthropogenic nutrient inputs would have different spatial and temporal patterns in chlorophyll-a concentration from offshore regions where coastal inputs are less influential. Quarterly CTD fluorescence measurements collected from three southern California continental shelf regions since 1998 were compared to chlorophyll-a data from the more offshore California Cooperative Fisheries Investigations (CalCOFI) program during the same period. We found the trends in the coastal zone were comparable to those offshore, with a gradual increase in total chlorophyll-a and a shallowing of the subsurface chlorophyll-a maximum depth since the beginning of observations, followed by declining chlorophyll-a and deepening of the maximum depth from 2010 to present. An exception was the northern coastal part of SCB, where chlorophyll-a continued increasing after 2010. The observed trends appear to be strongly related to ocean physical environment. The long-term increase in chlorophyll-a prior to 2010 was correlated with increased nitrate concentrations in deep waters, while the recent decline was associated with deepening of the upper mixed layer. The observed trends in chlorophyll-a appear to be linked to the low-frequency climatic cycles of the Pacific Decadal Oscillation and North Pacific Gyre Oscillation. These large-scale factors affecting the physical structure of the water column may also influence the delivery of nutrients from deep ocean outfalls to the euphotic zone, making it difficult to distinguish the effects of anthropogenic inputs on chlorophyll along the coast.

Impact of riverine turbidity on modelled primary productivity within a west coast river plume and its associated region of freshwater influence

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Oral

ABSTRACT:
Turbidity due to suspended sediments from mountain rivers can make an important contribution to light attenuation in plumes and surrounding regions of freshwater influence (ROFIs). We investigate this phenomenon in the context of the Fraser River and Southern Strait of Georgia using a three dimensional coupled physical-biological model (SalishSeaCast) with an observation-based turbidity-light attenuation relationship. Whereas previous models in this region have represented riverine turbidity effects through a constant relationship to salinity or freshwater input (Peña et al., 2016, Collins et al., 2009) , our parameterization includes an additional tracer representing Fraser River turbidity. This turbidity is input according to data from the Fraser River Water Quality Buoy and and is removed through a constant sinking rate. We will discuss the impact of turbidity on primary productivity in the plume and ROFI as well as on physical characteristics of the plume. In doing so we demonstrate a simple yet powerful representation of this important process applicable to modelling the biology of river plumes in Eastern Boundary Current Systems.

“Seals travel with a fair wind”: The influence of marine winds on the migration of newly-weaned northern fur seal pups

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Session: General session
Presentation Type: Poster

ABSTRACT:
Small, inexperienced, newly-weaned pups of the “depleted” Pribilof and Bogoslof Islands northern fur seal (Callorhinus ursinus; NFS) population migrate through the Bering Sea and North Pacific Ocean to more southerly winter foraging habitat during their first fall and winter at sea. Survival of pups during this migration is low, relative to adults, and highly variable year-to-year, for reasons that are not fully understood but may include storm conditions, prey availability, and the ability of pups to reach profitable foraging grounds. Here, we describe ongoing investigations into the effect of interannual variability in marine winds on the migratory dispersal of NFS pups using satellite tagging. Satellite-telemetered movements support traditional knowledge that the timing of pup dispersal varies in years of contrasting atmospheric forcing, and that winds influence movement speed within the Bering Sea. Comparison of pup movement to reanalysis surface winds throughout the migration demonstrates that, as wind speed increases, pup movements are increasingly concentrated downwind and to the right, consistent with wind-forced surface currents. Simple correlation analyses of wind vectors and pup movements imply that winds could influence an individual pup’s displacement by hundreds of kilometers during the first fall-winter migration. Of the 4 mostly densely-sampled years of satellite tagging, 2 captured migrations in which a strong El Nino signal was present, showing differences in mean pup position within the Gulf of Alaska and central North Pacific Ocean that are qualitatively consistent with forcing by anomalous atmospheric patterns. The idea that anomalous winds can alter pup dispersal is also supported by historical NFS stranding data during the 1950s and 1960s suggestive of interannual variability in the location of pups along the North American coast during some winters. We summarize ongoing work that will use novel statistical methods to quantify the mean and individual variability in the wind effect on pup movement, simulate year-to-year pup displacement over the more than 60-year reanalysis wind record, and investigate any possible effect of interannual variability in prevailing winds on pup survival and NFS demography.

Intermittent Breaching of the Carmel River, CA

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Oral

ABSTRACT:
Carmel River, near Carmel, CA, is a seasonally open, ephemeral river that has a basin of approximately 640 km^2. During the dry summer months, the barrier beach is built across the river mouth, limiting water exchange. Precipitation during the winter months increases the discharge within the river until water levels are sufficiently high to breach the barrier beach. Upon breaching, the sediment concentration is often high and can greatly impact the surrounding coastal waters. However, the offshore extent of the plume is highly variable, owing to intermittent opening and closing of the river. Here, observations during the 2016-2017 winter allow for a dynamic balance between discharge, wave forcing, and tidal exchange, that led to several distinct breach events. These winter months were particularly wet, leading to a fully-developed breach that remains open to date. During the initial breach formation, offshore water characteristics, specifically sediment concentration, were affected within the entire Carmel Bay. In addition, the initial breach that occurred after the first major precipitation event was insufficient to keep the river open, owing to wave forcing at the mouth. Wave penetration to the estuary through overtopping and upstream propagation are routinely observed during this stage. It is hypothesized that a critical discharge is required to maintain an open river mouth that depends on offshore wave forcing.

Temporal variability in thermally-driven cross-shore exchange: the role of M2 tide

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
We examine temporal variability of baroclinic cross-shore exchange in the context of a tropical fringing reef system focusing on the role of tidally driven along shore flow. Ensemble diurnal phase averaging of cross-shore flow at the Kilo Nalu Observatory (KNO) in Oahu, Hawaii shows a robust diurnal signal associated with an unsteady buoyancy/diffusive dynamic balance, although significant variability is observed at sub-diurnal time scales. In particular, persistent fortnightly variability in the diurnal flow is consistent with modulation by the semidiurnal alongshore tidal flow. The alongshore flow plays a direct a role in the cross-shore exchange momentum balance via Coriolis acceleration but also affects the cross-shore circulation indirectly via its influence on vertical turbulent diffusion. An idealized linear theoretical model for thermally driven cross-shore flow is formulated using the long-term time-averaged diurnal dynamic balance at KNO as a baseline. The model is driven at leading order by the surface heat flux, with contributions from the alongshore flow and cross-shore wind appearing as linear perturbations. Superposition of the idealized solutions for Coriolis and time-varying eddy viscosity perturbations are able to reproduce key aspects of the fortnightly variability. Modifying the model to consider a more realistic along-shore flow and considering effects of nightly convection lead to further improvements in comparisons with KNO observations. The ability of the theoretical approach to reproduce the fortnightly patterns indicates that semi-diurnal variations in the along-shore flow are effective in modulating the cross-shore flow via Coriolis and vertical turbulent transport mechanisms.

Temporal scales of variability in nearshore larval transport

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ABSTRACT:
Population dynamics and connectivity of marine organisms is dependent on larval transport, yet resolving larval transport is challenging because it is episodic, and because biological and physical processes involved in larval transport vary at multiple scales. Observations of barnacle settlement in a Southern California rocky shore from 2014 to 2017 indicate multiple scales of variability, and time series of water temperature, circulation, and pressure in the nearshore zone suggests this variability relates to a suite of processes, including internal tides, downwelling, seasonal stratification, and El Niño. Moreover, our results suggest coupling among temporal scales. Previous observations in a location ~7 km distant, with a more abrupt bottom slope, indicate that whereas small- and large-scale processes had similar effects on larval transport and settlement, the response to mesoscale processes is different. Resolving larval transport in the nearshore requires multiple approaches addressing a variety of temporal scales and their coupling, including settlement and physical time series, as well as observations of larval distribution.

Exploring the Deterministic Dynamics of the Subsurface Anomalies in the North Pacific Using an Ensemble Modeling Approach: An Update

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Session: Advances and applications of ocean modeling in the eastern Pacific
Presentation Type: Oral

ABSTRACT:
Subsurface water properties propagating along isopycnals surfaces have been shown to play an important role in modulating ocean and climate variability. Preliminary results using basin-scale reanalysis products suggested that the advection of subsurface water anomalies influence the low-frequency variability of the surface water properties in the Gulf of Alaska and the California Current System by mean upwelling. However, the characterization of these subsurface anomalies and the forcing dynamics that drive their low-frequency variability are still unclear. In this study, we examine this subsurface low-frequency variability using an eddy-resolving ensemble of the Regional Oceanic Modeling System (ROMS) for the North Pacific. The ROMS model is configured at a resolution between 16 km (south) to 7 km (north) with 40 terrain following vertical layers. We analyze 6 ensemble members forced by ECMWF ORA-S3 reanalysis wind stress and heat fluxes, and NCEP-NCAR reanalysis freshwater fluxes for 51 years (1959-2009). Each member in the ensemble contains slightly different initial conditions derived from the last Januaries of the spin-up control run. We will use the North Pacific ROMS ensemble to establish the robustness of our previous results and to separate and quantify the deterministic (i.e., forced) vs. intrinsic (i.e., unforced) forcing dynamics that modulate low-frequency changes in subsurface circulation and subsurface water-mass properties anomalies.

The combined effect of submarine canyon dynamics and geometry of tracer concentration profiles on the cross-shelf exchange of tracers

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Session: Processes of the continental slope and shelf break
Presentation Type: Oral

ABSTRACT:
The exchanges of water, nutrients and oxygen between the coastal and open ocean are key fluxes in on-shelf nutrient budgets and biogeochemical cycles. On a regional scale, submarine canyons are known to enhance physical processes such as shelf-slope mass exchange and mixing. There is good understanding of the flow around upwelling submarine canyons; however, the flux of biologically relevant tracers is less understood. The objective of this work is to characterize the combined effect that upwelling dynamics and enhanced mixing within a submarine canyon have on the spatial and temporal distribution, and cross-shelf exchange of passive tracers having different initial concentration profiles. A scaling scheme for diffusive mixing and transport of tracers within an idealized canyon during upwelling favourable conditions is proposed. Parameter space was explored with numerical experiments simulating an upwelling event near an idealized canyon with locally enhanced vertical diffusivity and smooth initial tracer profiles based on nutrient profiles taken at Barkley Canyon, BC during the Pathways Cruise 2013.

This work presents results from the numerical experiments using the community model MITgcm and suggests a physical mechanism through which each final tracer distribution is reached. We find that for all tracers, the depth of strong gradients is key to the exchange process, allowing more tracer transport when located deeper than the shelf break. Added to this, enhanced mixing within the canyon further increases the concentration near canyon rim depth and thus the tracer flux upwelled through the canyon, while the lower background diffusivity allows relatively unmixed ocean water onto the shelf, near the bottom. Taken together, our work shows that the tracer pathways developed by the canyon dynamics, locally enhanced mixing and initial tracer profile have significant implications for the final tracer distribution on the shelf.

Changes in nearshore hydrodynamic conditions, larval concentration, and the importance of vertical scales

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
Larval transport in the nearshore plays a central role in larval dispersal and connectivity of shallow water species; however, few studies have resolved the scales of larval transport 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 measures of barnacle larval distributions in a nearshore (within ~400m from adult, rocky intertidal habitat, in water 6-4m deep) region in La Jolla, California, USA. We sampled larvae during 2014 and 2015, using a semi-vortex pump sampling from 5 depth intervals every 1-2 hours to determine how larval vertical distributions varied spatially and temporally with changing hydrodynamic conditions. Barnacle cyprids were most abundant in mid-depths, and did not correspond with the thermocline depth. Cyprid abundance increased and became more concentrated in surface waters, however, in response to along-shore current reversals. Some of these episodic reversals corresponded with cross-shore flow and large peaks in settlement, suggesting that nearshore larval transport may be associated with downwelling conditions. Resolving vertical scales of distribution is critical for understanding larval transport mechanisms.

Euphausiid size distribution off northern California in response to the marine heatwave of 2014-2016

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Session: The “Blob-to-El Niño” transition: what happened in the CCS?
Presentation Type: Poster

ABSTRACT:
Euphausiids commonly dominate assemblages of plankton and micronekton that underpin the transfer of energy and material to higher trophic levels. Changes in euphausiid populations can alter trophic pathways and ecosystem functioning, often with dramatic consequences for higher trophic levels. In the California Current Ecosystem euphausiids are known to respond strongly to climate variability. We analyzed plankton samples collected along the Trinidad Head Line off northern California from fall 2007 - summer 2017 to examine variation in the size distribution of dominant krill species Euphausia pacifica, Thysanoessa spinifera, and Nematoscelis difficilis and how length distributions responded to recent climate events, i.e. the Blob and the 2015-2016 El Niño. Length measurements of E. pacifica adults collected in 2014-2017 indicated a departure from normal size frequency distributions and a smaller mean length. This pattern extended to E. pacifica juveniles but was not apparent in furcilia stages. Similarly, T. spinifera adults collected during the marine heatwave were relatively small compared to previous years. This pattern was not observed in earlier life history stages, in fact some T. spinifera furcilia stages were larger during 2015 compared to previous years. These patterns were not apparent in N. difficilis adults or larval stages. Observed changes in length of adult E. pacifica and T. spinifera are consistent with expected responses to warming temperatures. Variation in length patterns among species and stages may reflect different metabolic needs, distribution, and/or life history strategies. These observations highlight the importance of detailed data extraction, especially when resolving euphausiid response to climate variability and their trophic roles in a changing environment.

Satellite-imagery spatio-temporal patterns associated with a Gymnodinium catenatum harmful bloom in the northern Gulf of California in early year 2015.

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Poster

ABSTRACT:
From the point of view of remote sensing, a harmful algal bloom (HAB) is a spatio-temporal anomaly of chlorophyll a (chl-a) characterized by a sudden increase in its surface concentration in a certain place. To locate the origin and extent of the harmful bloom of G. catenatum ocurred in early 2015, a satellite-imagery time series of the Upper Gulf of California was constructed with daily data of chl-a from September 2014 to March 2015. The statistical technique of orthogonal empirical functions (EOF) was applied to isolate the signal associated with the bloom, which is apparently explained by modes 3 and 4 (13% of the variance), where a significant positive anomaly was observed in January which coincides with the G. catenatum abundance observed in-situ during the bloom. The development of the bloom was apparently related to the passage of two category-3 hurricanes (Saffir-Simpson scale) along the gulf whose winds may have eutrophized the study area by inducing vertical mixing of the water column and the transport of limiting nutrients, such as Fe, from the continent to the ocean. Coupled with this, a transport of particulate matter from the south to the northern portion of the gulf was corroborated by comparing wind vectors and geostrophic currents with satellite-images of color dissolved organic matter (CDOM). This nutrient input into the northern gulf, together with the onset of winter conditions (enhanced coastal upwelling, sea surface temperature change and increase of the mixed layer thickness), could have favored the formation and proliferation of the G. catenatum bloom.

Satellite-measured interannual variability of turbid river plumes off central-southern Chile: Spatial patterns and the influence of climate variability

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Poster

ABSTRACT:
Ocean color imagery from MODIS (Moderate Resolution Imaging Spectroradiometer) onboard the Aqua platform is used to characterize the interannual variability of turbid river plumes off central-southern Chile. Emphasis is placed on the influence of climate fluctuations, namely El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Antarctic Oscillation (AAO). Additional satellite data on wind, boat-based hydrographic profiles, and regional climate indices are used to identify the influence of climate variability on the generation of anomalous turbid river plumes. The evolution of salinity at a coastal station on the 90 m isobath between the Itata and Biobío Rivers shows a freshwater surface layer with salinity 32.5 and 5–10 m thick during major plume events in 2002, 2005 and 2006. Surface salinity minima are correlated with peaks in turbidy from the normalized water leaving radiance at 555 nm (nLw(555)), both representing turbid river plumes. EOF analysis reveals that major turbid plume events occurred primarily during warm phases of the ENSO and PDO, and negative phases of the AAO, when storm tracks are further north. Anomalously large turbid plumes extend long distances offshore (70–80 km), and individual plumes coalesce into a continuous plume along the coast that covers the entire continental shelf. Season-specific correlation analyses reveal an increased influence of the AAO on river plumes south of Punta Lavapié in spring-summer (negative correlation). North of this major cape, ENSO and PDO indices have a dominant influence on plumes with positive correlations with the nLw(555) signal in winter (and negative in summer). We discuss the biogeochemical implications of plume events and the importance of long-term and high-resolution ocean color observations for studying the temporal evolution of river plumes.

Interannual variability and climate modulation of freshwater turbid river plumes along the Oregon coast

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Oral

ABSTRACT:
The influence of climate variability on the Northeast Pacific (NEP) ocean has been mainly attributed to the impact of ENSO, PDO, and NPGO because of their role modulating coastal circulation, upwelling, and ecosystem response - their impact on freshwater river plumes, and their interannual variability, has been poorly studied. An analysis based primarily on 14.5 years of ocean color imagery is used to study, for the first time, the interannual variability of freshwater turbid plumes off the Oregon coast. EOF analysis reveals two dominant modes associated with (i) the winter plumes of coastal rivers which are merged along the entire Oregon shelf (EOF1) and flowing in the downstream direction as coastal-attached buoyancy-driven flows, and (ii) the offshore Columbia River plume occupying most of the coastal ocean off Oregon (EOF2) as it is transported south and offshore during spring-summer upwelling. Major plumes are found to correspond mainly with ENSO cycles, but longer time series are needed to better evaluate the influence of PDO and NPGO because of their dominant decadal variability. Anomalously large coastal plumes (EOF1) lagged primarily the canonical El Niño during fall and La Niña during winter (e.g. 2005-2006, 2011-2012). Major events for the offshore Columbia River plume occurred after intense and persistent La Niña conditions (e.g. 2008, 2011, 2014). We discuss the likely atmospheric teleconnection for these anomalous events and their biogeochemical repercussions.

Variations in Langmuir circulation in response to spatially and temporally inhomogeneous forcing

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
In March and April 2017, a multi-investigator experiment was carried out in the area between Catalina, San Clemente, and St. Nicolas islands, in the South California Bight. As part of this effort, a 200 kHz Phased-Array Doppler Sonar was deployed to assess the strength, spacing, and orientation of the surface expressions of Langmuir circulation as conditions varied. A WireWalker was also deployed to continually monitor changes in stratification over the top 90m. Nature complied, with 3 distinct wind-events approaching or exceeding 20 m/s. Other investigators, on the R/V Sproul, R/V Sally Ride, and by airplane, documented spatial variations in conditions; this talk will focus on the temporal variations measured at R/P FLIP, which was held in place with a 3-point mooring in ~1000 m deep water. While the first wind-event engendered significant deepening of the mixed layer, the subsequent two mainly 'reset' the mixed layer depth to roughly the same maximum as after the first.

On subsurface cooling associated with the Biobio River Canyon (Chile)

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Session: Processes of the continental slope and shelf break
Presentation Type: Oral

ABSTRACT:
Submarine canyons cutting across the continental shelf can modulate the cross-shelf circulation being effective pathways to bring water from the deep ocean onto the shelf. Here, we use 69 days of moored array observations of temperature and ocean currents collected during the spring of 2013 and winter-spring 2014, as well as shipboard hydrographic surveys and sea-level observations to characterize cold, oxygen poor, and nutrient-rich upwelling events along the Biobio Submarine Canyon (BbC). The BbC is located within the
Gulf of Arauco at 36º 50'S in the Central Chilean Coast. The majority of subtidal temperature at 150 m depth is explained by subtidal variability in alongshore currents on the canyon with a lag of less than a day (r2=0.65). Using the vertical displacement of the 10º and 10.5ºC isotherms, we identified nine upwelling events, lasting between 20 h to 4.5 days, that resulted in vertical isothermal displacements ranging from 29 to 137 m. The upwelled water likely originated below 200 m. Majority of the cooling events were related with strong northward
(opposite Kelvin wave propagation) flow and low pressure at the coast. Most of these low pressure events occur during relatively weak local wind forcing conditions, and were instead related with Coastal Trapped Waves (CTWs) propagating southwards from lower latitudes. These cold, high-nutrient, low-oxygen waters may be further upwelled and advected into the Gulf of Arauco by wind forcing. Thus, canyon upwelling may be a key driver of biological productivity and oxygen conditions in this Gulf.
This research has been recently published in JGR Oceans (doi:10.1002/
2016JC011796).

Spatial heterogeneity in dominant scales of near-bottom oxygen variability in the inner shelf of central Chile

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Session: Multiple scales in nearshore physical and biological processes
Presentation Type: Oral

ABSTRACT:
Shelf habitats in central Chile are seasonally exposed to low-oxygen waters of Equatorial origin. This seasonal occurrence of hypoxic waters on the continental shelf is understood as a consequence of the spring-summer intensification of upwelling-favorable winds. However, little is known about other factors that may modify the shoreline manifestation of hypoxia, thus producing a mosaic of local regimes in terms of the timing and intensity of low-oxygen episodes in near-bottom waters. To test whether shoreline complexity, bathymetry, and exposure may induce spatial heterogeneity in the dominant scales of near-bottom oxygen variability, continuous records of dissolved oxygen, temperature, and conductivity were gathered from 8 inner-shelf sites (20-25 m depth) along ca. 200 km of the central Chile coast (36-37.5°S) over a spring-summer season (October 2016 – March 2017). Concurrently, coastal wind variability and water-column temperature structure were recorded at various sites along the region. Our analyses revealed striking differences in the periodicity of near-bottom hypoxia among sites separated by less than 50 km. Contrary to our expectation, not all exposed sites exhibited a dominance of synoptic-scale variability in near-bottom oxygen levels. At least one site located close to the north rim of the Biobio submarine canyon exhibited a strong diurnal signal in near-bottom oxygen concentration. Conversely, sustained near-bottom hypoxia for periods of up to 3 weeks was observed at protected sites in the Gulf of Arauco, which is comparable in terms of size and geomorphology to Monterey Bay. By incorporating coastal exposure and local bathymetry to the interpretation of local regimes of near-bottom oxygen variability, we expect to identify the alongshore spatial scales at which they may differ, and contribute to the current understanding of physical factors that structure benthic communities in upwelling regions.

Seasonal and synoptic-scale dynamics of a Patagonian river plume - variability in ocean-river balance

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Session: River and tidal plumes in Eastern Boundary Current Systems: Dynamics, variability, and biogeochemical impacts in the coastal ocean
Presentation Type: Poster

ABSTRACT:
Hydrographic structure, circulation, and productivity regimes in fjords are strongly modulated by freshwater inputs and their interaction with oceanic forcing. Assessing the extent to which temporal changes in the river-ocean balance determine the scale and sharpness of hydrographic gradients, and the associated productivity patterns, is of particular interest in Patagonian fjords given their potential role as sinks for atmospheric carbon. We used hydrographic profiles and time series collected since 2009 along the Baker fjord in central Patagonia (47.5°S) to assess the dominant scales of variability in the river–ocean interaction, as well as temporal changes in the relative importance of ocean vs. river forcing. In particular, we focused on the periodicity and extent of along-fjord excursions of a near-surface salinity front indicating the transition between river-dominated and ocean-dominated conditions. The scale of along-fjord front displacements changed seasonally, in a way that is consistent with seasonal changes in river outflow. The salinity front was found farther from the river mouth during months of high river discharge (summer). Non-seasonal variability in salinity front displacements was significantly correlated with synoptic variability in the main component of oceanic wind forcing. Incursions of up to 30 km were observed within 1 week after an intensification of eastward winds off the Penas Gulf, although the response was maximal at 1 day lags. The front's position along the fjord was often associated with maxima in near-surface chlorophyll-a concentrations, suggesting that productivity patterns could be strongly modulated by these seasonal and synoptic-scale interactions.

Glider Observations and a Numerical Simulation of the 2014 – 2016 Warm Anomalies in the Southern California Current System

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Session: The "Blob-to-El Niño" transition: what happened in the CCS?
Presentation Type: Oral

ABSTRACT:
Anomalous oceanic conditions persisted in the southern California Current System during 2014-2016. In our two-part study, we (1) use measurements from autonomous underwater gliders to describe the magnitude, timing and extent of the spatiotemporally-varying anomalies and (2) use the California State Estimate (CASE) to determine which physical processes caused the observed heat anomalies. Our observations come from the California Underwater Glider Network (CUGN), in which Spray gliders have continuously monitored subsurface physical and biological variables along CalCOFI lines 66.7, 80 and 90 for over ten years. Data from the CUGN were recently processed into a comprehensive regional climatology (Rudnick et al. 2017) that gets updated monthly and captures the recent "Blob" and El Niño events. The distinct warm anomalies of the two events peaked near the change of the calendar year in 2014-2015 and 2015-2016, respectively, with a lull in warming between. The "Blob" warm anomaly waned but did not disappear before the beginning of the El Niño, leading to the warmest water observed off southern California in the instrumental record. Along the three glider lines, the "Blob" warming was characterized by a shallow, surface-intensified warm pool caused by an increase in solar heating and decrease in wind-driven mixing. In contrast, the El Niño warm anomaly penetrated deeper and coincided with anomalous poleward advection. Downwelling anomalies, as inferred from deeper-than-normal isopycnals, lasted through the entire 2014-2016 time period, with the deepest excursions occurring at the peak of the El Niño. To understand the physical forcing of anomalies during the "Blob" period, the El Niño period and the transition in between, we turn to the four-dimensional CASE. It allows us to compute a regional heat budget that quantifies the contribution of all relevant processes (atmospheric heat flux, horizontal and vertical advection, mixing) to the observed changes in heat content.