2015 Pacific Anomalies Science and Technology Workshop

Scripps Institution of Oceanography
La Jolla, CA, USA
May 5-6, 2015

Contributor Abstracts

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Recent NE Pacific Warming or: How I Learned to Stop Worrying and Love the Blob

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ABSTRACT

Strongly positive temperature anomalies developed in the NE Pacific Ocean during the boreal winter of 2013-14. Based on a mixed layer temperature budget (Bond et al. 2015), these anomalies were caused by lower than normal rates of the loss of heat from the ocean to the atmosphere, and of relatively weak cold advection in the upper ocean. Both of these mechanisms can be attributed to an unusually strong and persistent weather pattern featuring much higher than normal sea level pressure over the waters of interest. This anomaly was the greatest observed in this region since at least the 1980s. The region of warm SST anomalies subsequently expanded and reached coastal waters later in 2014 (Fig. 1). By early 2015, the temperature anomaly pattern in the NE Pacific Ocean was characteristic of a strongly positive phase of the Pacific Decadal Oscillation (PDO). It is found that sea surface temperature anomalies offshore affect air temperatures downwind in Washington state.

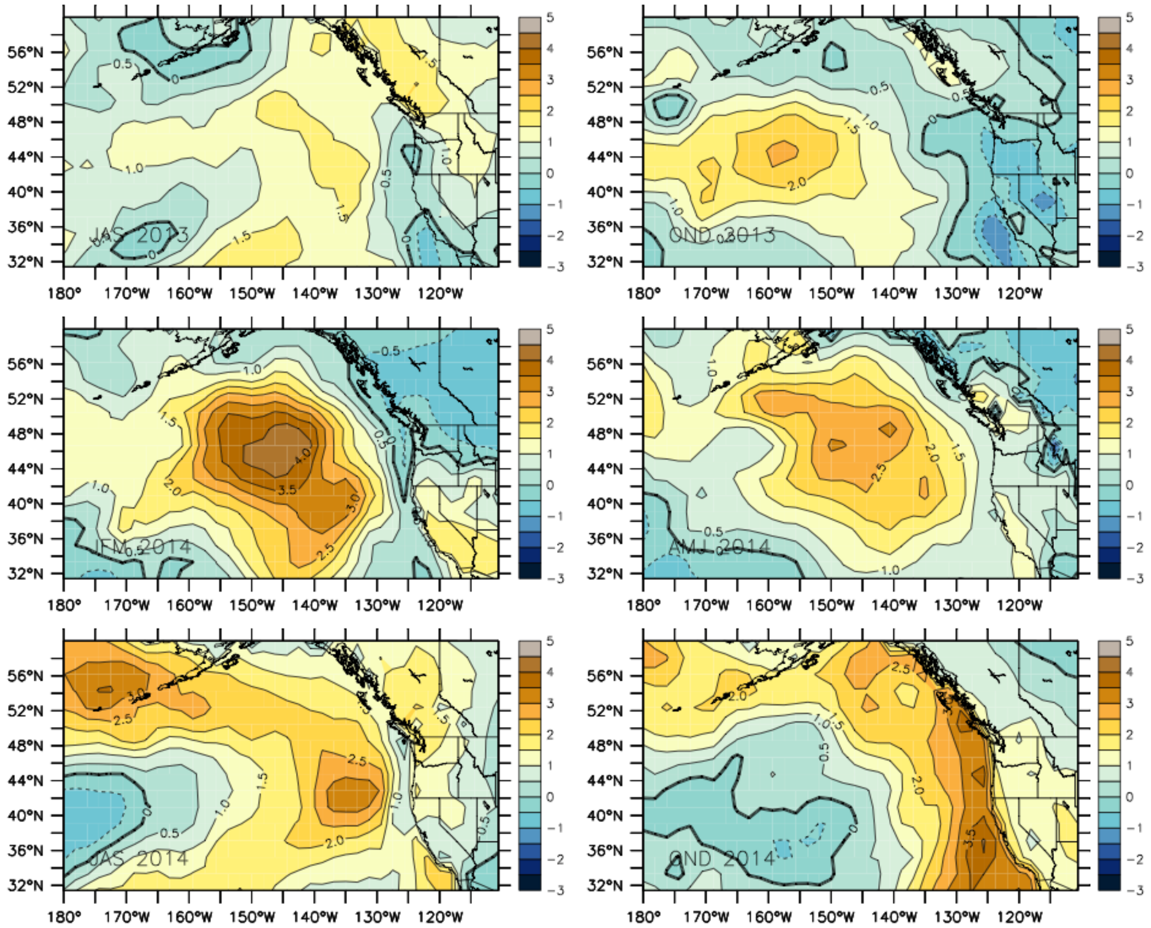

Figure 1. Skin temperature anomalies in units of standard deviations from the 1981-2010 climatological mean for JAS 2013 (upper left); OND 2013 (upper right); JFM 2014 (middle left); AMJ 2014 (middle right); JAS 2014 (lower left); and OND 2014 (lower right).

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Recent Climate Anomalies in Alaska

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ABSTRACT

Alaska has been remarkably, and sustainedly, mild since October 2013, a fact that has regularly captured national media attention. During January 2014, an extreme warm event late in the month established many new monthly, and in some cases winter high temperature records. Most notably, a high temperature of 62ºF (17ºC) was measured near Port Alsworth on January 27 that tied the all-time January record high temperature for the state. Reflecting anomalously warm sea surface temperatures, both Cold Bay and Saint Paul Island recorded the warmest summer (June-August, Cold Bay), or late summer (July-September, Saint Paul) of record. Calendar year 2014 was either the warmest or second warmest on record at most of the long-term climate observation locations west of a Barrow-to-Anchorage line. During 2014, Anchorage, for the first time on record, failed to record a subzero (Fahrenheit) temperature during a calendar year. This sustained warmth is quantified on a regional basis in Fig. 1, which shows the rank (warmest=1) of the October 2013 through March 2015 period for the thirteen Alaska climate divisions compared to all 18 month periods ending in March since October 1925-March 1927. This effectively captures anomalies in two consecutive cold seasons. During this period, 71% of days in Anchorage had an average daily temperature above the 1981-2010 normal.

Precipitation anomalies were, as usual, less coherent in space and time due to orographic effects, though both 2013-14 and 2014-15 featured similar patterns. Snowfall in both cold seasons was well below normal in South Central and Southwest Alaska and snowpack at higher elevations was well above normal. Alaska Range passes and areas just to the north had only intermittent snowcover during both cold seasons, resulting in the 2015 Iditarod Sled Dog Race being rerouted, following a disastrous 2014 race run over long stretches of bare ground. In general, snowfall anomalies were greater in 2014-15 than the previous winter. The combination of low snowpack and sustained warm temperatures during the winter and spring 2013-14 greatly contributed to the Funny River wildfire, which burned more than 195,000 acres (793km^2) in May and early June, the largest wildfire on the Kenai Peninsula since 1947. In contrast, the summer of 2014 was very wet across parts of Interior Alaska and in Southeast, with both Fairbanks and Juneau recording the wettest summer in more than a century of observations. The 2014-15 cold season brought Anchorage the lowest seasonal snowfall in the modern era, and the maximum daily snow depth of 8” (20cm) during the winter was the lowest in more than 30 years. Cold season anomalies were especially remarkable on windward aspects of the Gulf of Alaska coast and the Southeast Panhandle, where precipitation totals were generally close to normal, but snowfall (and snowpack) was far below normal, indicative of sustained far-above-normal freezing levels. Some generalized precipitation related highlights for the past 18 months are presented in Fig. 2.

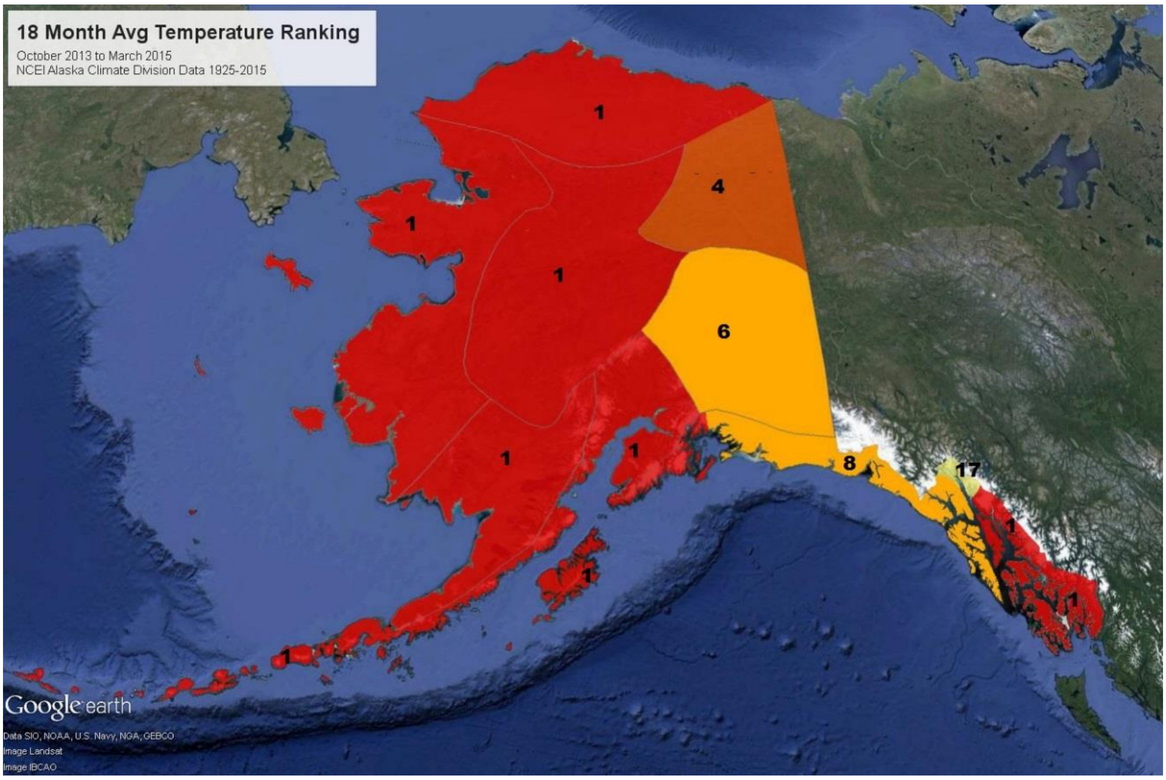

Figure 1. Rank of average temperature October 2013-March 2015 compared to other such 18-month periods since 1925-1927, by climate division. Source: NCEI.

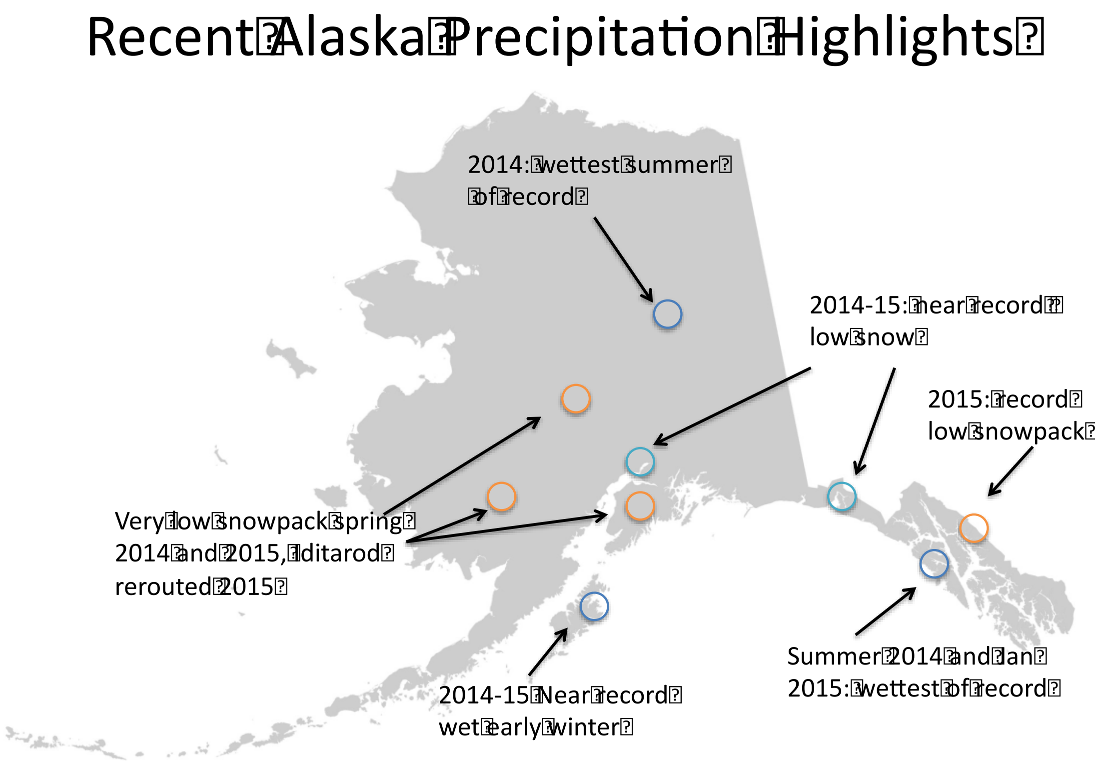

Figure 2. Precipitation-related highlights since Oct 2013. Source: NWS

Recent Climate Model Forecasts of Pacific Ocean SSTs

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ABSTRACT

The North American Multimodel Ensemble, NMME, (Kitman et. al. 2014) provides operational global sea surface temperature anomaly forecasts every month at monthly and seasonal timescales with lead times to seven months. Additionally, NOAA's operational fully coupled dynamic climate mode, the Climate Forecast System (Saha et. al. 2014) is run daily and provides continuously updated seasonal scale forecasts.

NMME forecasts are generally skillful even at the longest leads (as measured by anomaly correlations in the hindcast period 1982-2010) in forecasting North Pacific SST anomalies, through there is some seasonal variability in skill scores. By early 2014, NMME forecasts at a three month lead indicated something of an evolution in the warm mid-Pacific, with anomalies re-centering to the east, as seen in Fig. 1. Since mid-2014, most ensemble systems have consistently forecast a continuation of warm anomalies along the west and northwest North American coasts, and to a lesser extent a pool of negative anomalies in the mid-Pacific. The April 1, 2015 initialized NMME forecast, representing the grid point average of near 100 ensemble members from seven different ensemble system for the early summer season (May through July) and autumn (September through November) 2015 are shown in Fig. 2.

While the dynamic climate models have skill in forecasting SST anomalies in the North Pacific, forecasts by the CFS the PDO Index has not proved skillful. Figure 3 shows the CFS forecasts of PDO Index compared to the CPC derived observed PDO Index from mid-2013 through late 2014. Not only has the CFS mean failed to capture the strong positive projection of PDO Index, the CPC PDO Index has often been outside any of the constituent ensemble members.

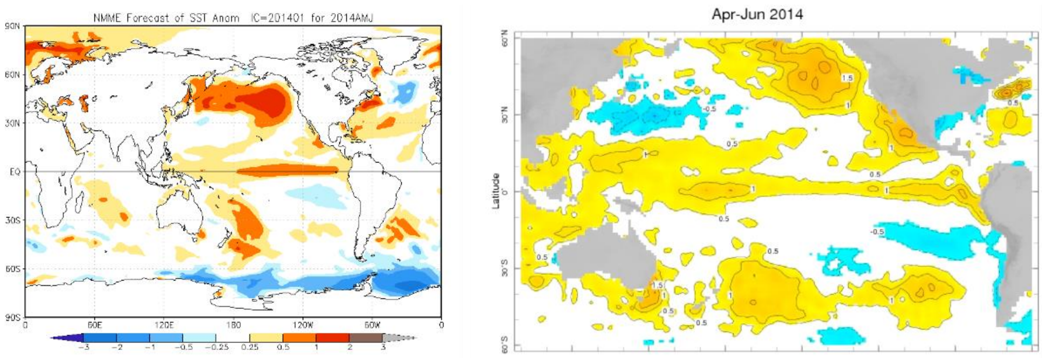

Figure 1. NMME January 1, 2014 SST anomaly forecast for April-June 2014 *(left)* and observed SST anomalies. Source: NMME forecast from NOAA/CPC, observed anomaly from IRI. doi: http://dx.doi.org/10.1175/JCLI-D-12-00823.1

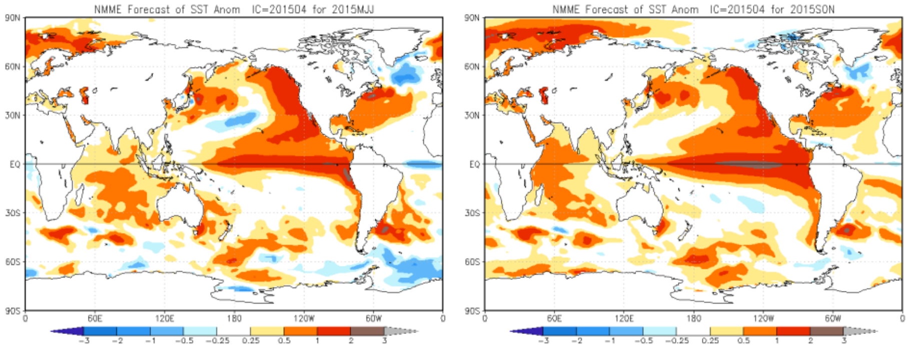

Figure 2. NMME April 1, 2015 initialized SST anomaly forecast for April-June 2015 *(left)* and observed SST anomalies. Source: NMME forecast from NOAA/CPC.

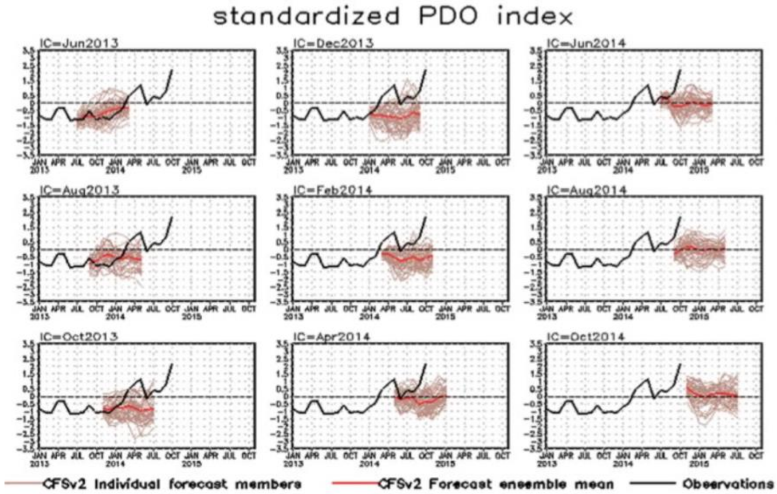

Figure 3. CFS PDO Index forecasts (ensemble members orange, mean red) vs. the CPC derived PDO Index (black). Source: Yan Xue, CPC, personal communication.

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Anomalous California Marine Stratus Frequency and SST during Summer 2014

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ABSTRACT
Surface and satellite observations reveal a marked decrease in the frequency of marine stratus clouds along a significant portion of the California coast during the summer months of 2014. These clouds are a common feature along the California coast, forming beneath the strong temperature inversion created between the warm descending air within the North Pacific High and the cool marine boundary layer near the surface. The inversion, typically strongest during the summer, caps the marine boundary layer, preventing the cool moist marine air from mixing with the overlying dry air.

Observations at many California coastal airports, particularly within the Southern California Bight, show a significant reduction in the frequency of low (<2500m) clouds during MJJAS 2014. Reductions of 10 and 11% (absolute) were noted at Los Angeles and San Diego, respectively, with the latter being the lowest value since the beginning of the record in 1950.

A new satellite-derived low cloud retrieval product (Schwartz et al, 2015) allows for a broader spatial examination of the marine stratus frequency. This cloud detection algorithm discriminates low liquid water clouds from high ice clouds and clear sky, through the use of the visible, shortwave infrared and longwave infrared channels on the Geostationary Operational Environmental Satellite (GOES). The dataset has a spatial resolution of 4km, a temporal resolution of 30 minutes and currently extends from 1996-2014.

Figure 1 shows the low cloudiness frequency anomaly (left panel) along the N.E. Pacific and U.S. West coast during MJJAS 2014 from this satellite derived product. The satellite data reveals a large area of negative anomalies over the Southern California coastal region extending south along much of Baja California. Along the central and northern California coast, slight positive anomalies are found trending toward negative values further offshore.

Also displayed (middle panel) is how the 2014 low cloudiness anomaly ranked among the 19 years of the satellite dataset. Over much of the west coast and offshore regions, the 2014 low cloudiness frequency was ranked near the bottom of the 19 years. The amount of 2014 summer low clouds was the lowest over the 19 years over nearly the entire Southern California Bight region, Northern Baja California and portions of the Pacific Northwest (right panel).

A recent study by Schwartz et al (2014) showed significant associations between large-scale sea surface temperature (SST) patterns and coastal low cloudiness along the North

American west coast. The SST strongly impacts the temperature of the marine boundary layer and the base of the inversion, and is thus a key component regulating the strength of the inversion. A higher SST leads to a weaker temperature inversion and thus an environment less conducive to both the formation and persistence of marine stratus clouds.

Strong positive SST anomalies, reaching at periods up to 2-3°C, existed along much of the California and Baja coastal waters during MJJAS 2014. Mean inversion strength during this period, as measured from 00Z radiosonde measurements at Miramar (San Diego) were on average about 1.2°C (22%) weaker than normal. It is reasonable to assume that the weakened inversion strength due to high SST values led, at least in part, to the reduction in marine stratus clouds over Southern California. It is important to note that reduced cloudiness would have a positive feedback on the SST, but due to the large spatial size of the SST feature, it is likely that in this case the SST led the clouds, at least at the onset. It is also possible that atmospheric circulation features associated with the large-scale SST anomaly patterns may have contributed to the reduced marine stratus.

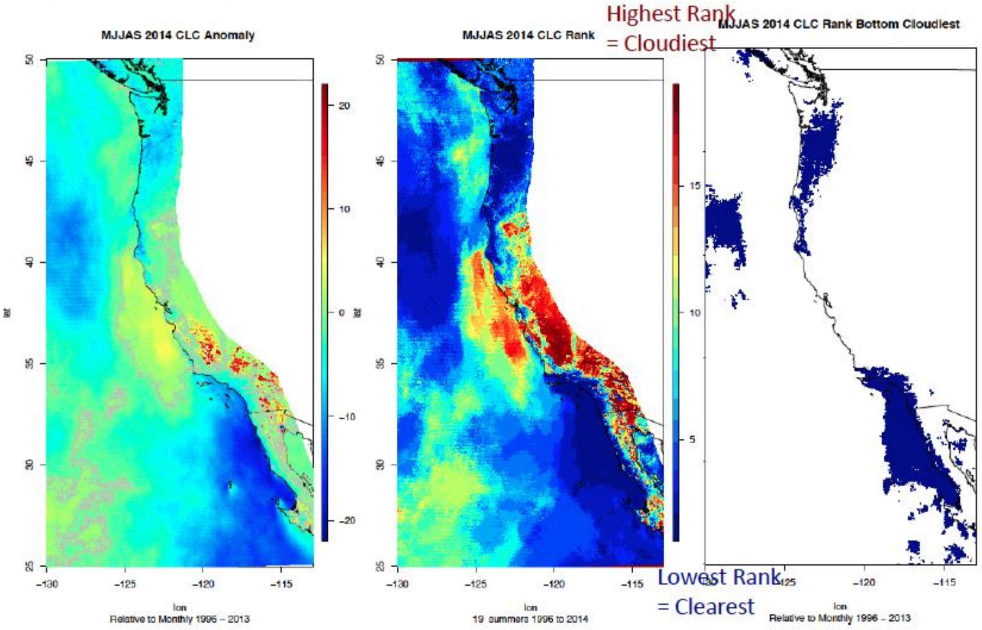

Figure 1. Satellite-derived coastal low cloudiness frequency anomaly during May-Sept 2014 is shown in the left panel, gray contour denotes zero. The ranking of the 2014 anomaly within the 19 years of data is displayed in the middle panel while those pixels for which the 2014 year had the lowest anomaly are denoted in the right panel.

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Identifying anomalous climate conditions in the Northeastern Pacific Ocean

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ABSTRACT

In this work we are showing the increase of positive anomalies in monthly atmospheric pressure (station level) between Anchorage, Alaska and San Diego, California, from September 1959 to February 2015. Trends are revealing long term atmospheric pressure changes in the eastern Pacific Ocean, especially these occurring during 2014 and 2015 (Figure 1). Atmospheric pressure anomalies at San Diego have remained positive since 1999. In order to keep a reference of what happens in the northeastern region, a new climate index for the west coast of North America is proposed called North Eastern Index (NEI), as a tool for understanding some trend in short, medium, and long term scales (Figure 2). The index was drawn as differences in atmospheric pressure (at the station) between San Diego, CA/Ensenada, Baja California and Anchorage, Alaska, obtained from 1960-2015. The NEI captures signals from high latitudes and larger scales, in the central and southern portions of the California Current, strongly diminishing the last two years. Figure 3 shows the Ekman transport (Ekty, north-south component) from January 1986 to July 2014 in three locations off the North America coast. Ekty trend is northward since 2010, not just at one point, but apparently all along the Pacific coast. This situation may have occurred before in the past, but the northward component had not stayed so long. This may reflect the tendency of warm subtropical conditions over temperate and subpolar regions, as an increase in surface air temperature in Anchorage (not shown) and SST since April 2013 (not shown).

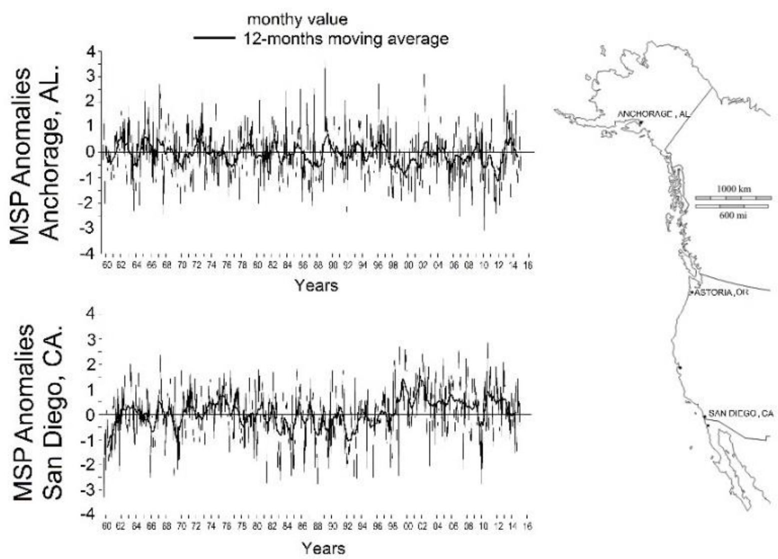

Figure 1. Mean Station Pressure anomalies from Anchorage, AK, and San Diego, CA, from September 1959 to February 2015. Thin line monthly value, thick line 12 months moving average.

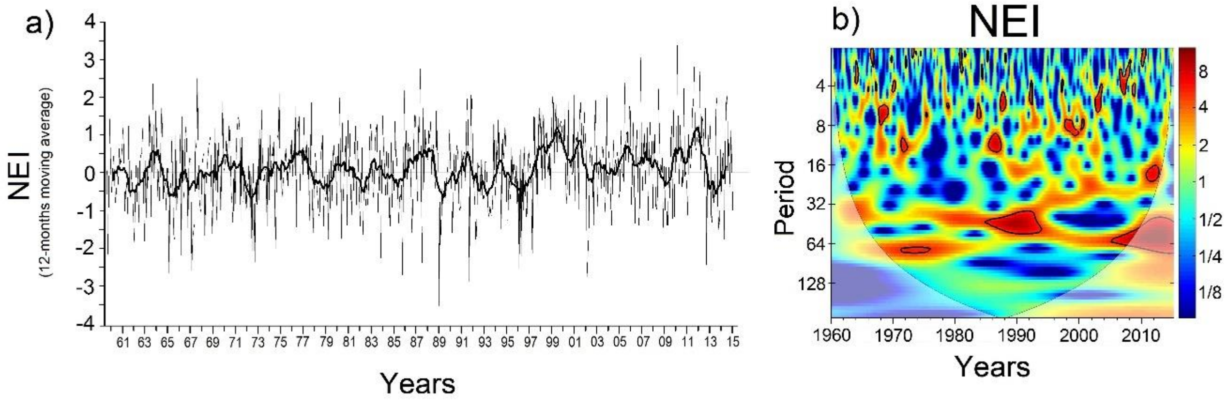

Figure 2. a) NEI time series from September 1959 to December 2014, thin line monthly values; thick line 12-month moving average; (b) Wavelet spectra of the NEI. Contours are in variance units, and black thick lines are 95% confidence levels using the red noise model. Solid line indicates the cone of influence. The color bar represents normalized variance.

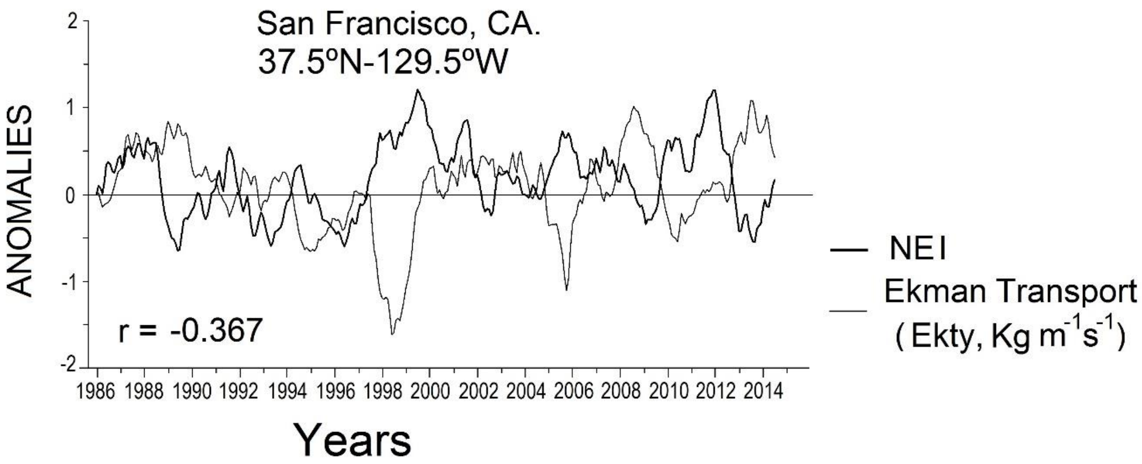

Figure 3. Time series of NEI and Ekman Transport (Ekty, north-south component) and NEI in from off San Francisco, CA.

References

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Data of Ekman Transport:
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The Pacific Blob and California Drought

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ABSTRACT

The media has widely reported on the large Gulf of Alaska warm sea surface temperature (SST) anomaly, nicknamed 'The Blob' (Bond, 2013). The Blob first appeared in November 2013 and has since spread down along the West Coast to mid-Mexico and out towards Hawaii. Also, California is in the 4th year of an exceptional drought that is now impacting Southern Oregon and Nevada as well. This drought has resulted from the 'Ridiculously Resilient Ridge' (RRR) of high pressure that has prevented storms from reaching the West Coast during the winters of 2013-2015.

The general trend in sea surface temperature (SST) over the first decade of the 21st Century had been towards more La Nina-like and negative Pacific Decadal Oscillation (PDO) conditions (Hilburn and Wentz, 2014). This pattern is characterized by strong trade winds in the central Equatorial Pacific that produced a cold anomaly on the Equator. That cold anomaly extended up into the middle latitudes and along the west coast of North America. The strong trade winds produced moisture convergence in the west Pacific where heavy precipitation occurred. This left negative precipitation anomalies in the central Pacific, and the anomalous latent heating was mainly responsible for quasi-stationary wave patterns in the mid-latitude atmosphere associated with cold winters over Europe and Asia (Trenberth et al., 2014).

In 2014, we began to see the tropics shifting into a more El Nino-like pattern with a weakening of the trade winds in the central Pacific. SSTs have been warming in the central Equatorial Pacific, and with it, the precipitation anomalies in the central Pacific are positive. When latent heating from precipitation is located in the central Pacific, it is more likely to force a quasi-stationary pattern with a ridge over the Gulf of Alaska and western U.S. with a trough over the Midwest and East Coast of the United States. This has been responsible for the most recent cold winter on the East Coast.

The California drought began in 2012 when the RRR began preventing winter storms from reaching our coasts (Swain et al., 2014). During spring and summer 2013, the area of California covered by severe drought increased from 20% to 80%. Meager wintertime precipitation in 2013-2014 and 2014-2015 has not been enough to counteract the drought. Thus, the current drought actually began before the current El Nino-like and positive PDO conditions; however since establishment of the conditions, the drought has dramatically worsened.

Bond et al. (2015) find that the anomalously high SSTs in the Gulf of Alaska resulted from lower than normal rates of heat loss from the upper ocean and relatively weak cold advection. Both of these processes are controlled by the quasi-stationary weather pattern forced by El Nino in the tropics. Fig. 1 shows the close correspondence between the location of the blob and the location of the blocking ridge in the atmosphere, and examination of other months in 2014 confirm that they move together. Monitoring of the blob and any predictions about the future of the blob depend on the processes controlling PDO (Newman et al., 2015). This requires monitoring the state of El Nino, the intense winds of the Aleutian low, and processes controlling the Aleutian low, which include tropical cyclone recurvature and the location and stability of the Kuroshio-Oyashio Extension.

Monitoring of PDO, hence the blob, requires knowledge of SST, surface wind, and rain rate. Microwave satellite data provide accurate information about these parameters. The scientific work needed is to determine the proper spatial domains and seasonality considerations in interpreting the satellite data to provide a comprehensive picture of the processes relevant to controlling the intensity and location of the blob. We have created a webpage that provides images enabling monitoring of storm conditions over the Pacific Ocean: http://www.remss.com/about/projects/atmospheric-river-watch.

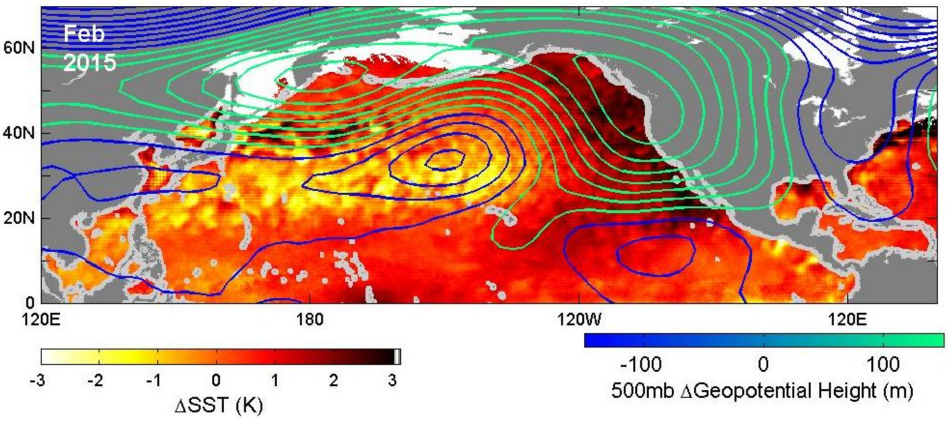

Figure 1. SST anomaly (color) and 500 mb geopotential height (contours) for February 2015 (top).

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Seabird Responses to Unusual Oceanographic Conditions in the Northeast Pacific, 2014-2015: Breeding Failures, Spikes, and Mass Mortality

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ABSTRACT
We collated measurements of breeding success, phenology, and mortality from Baja California, Mexico to Alaska to investigate regional and species-specific seabird responses to the unusual oceanographic conditions in the Northeast Pacific Ocean in 2014-2015. Large-scale "blobs" of exceptionally warm waters were observed in the Gulf of Alaska and off Baja California early in 2014; these blobs coalesced, and by late 2014 the entire Northeast Pacific was warm. The canonical ENSO does not explain this North Pacific warming. In response, near-zero reproductive effort and breeding success was observed for seabirds in the Gulf of California and southern California Current, and poor to average breeding success was observed for most species in the northern California Current, Gulf of Alaska, and in the western Aleutian Islands. In contrast, there was exceptionally early breeding and elevated breeding success found for seabirds in the southeastern Bering Sea and associated northern realms. Following the summer 2014 breeding season, a mass-mortality event of Cassin's auklet (a planktivorous species), affecting perhaps 100,000 individual birds, was observed in the northern California Current-Gulf of Alaska transition zone, with mortality concentrated off Oregon and Washington. While the large-scale ocean warming undoubtedly affected seabird food webs, forcing regional and species-specific variation in responses, different mechanisms probably affected breeding effort, success, and mortality. High productivity of auklets in previous years may have contributed to the mass auklet mortality event which affected young birds more so than adults, but changes in their prey base in the fall 2014-winter 2015 is the primary explanation. Large-scale Northeast Pacific seabird responses have been observed previously in conjunction with major El Niño events (e.g., 1982-1983, 1997-1998), but the variation and mortality observed in 2014-2015 is unprecedented in over 3 decades of seabird studies in this area.

Improving Oceanographic Anomaly Detection Using High Performance Computing

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ABSTRACT
Anomaly detection is a process of identifying items, events or observations, which do not conform to an expected pattern in a dataset or time series. Current and future missions and our research communities challenge us to rapidly identify features and anomalies in complex and voluminous observations to further science and improve decision support. Examples abound in oceanographic satellite imagery of sea surface temperature, sea surface height, and ocean color, and atmospheric measurements of ocean wind and pressure, for example. Given this data-intensive reality, we are developing an anomaly detection system, called OceanXtremes, powered by an intelligent, elastic cloud-based analytic service backend that enables execution of domain-specific, multi-scale anomaly and feature detection algorithms across the entire archive of ocean science datasets. OceanXtremes will be equipped with both web portal and web service interfaces for users and applications/systems to register and retrieve oceanographic anomalies data. The OceanXtremes web portal will allow users to define their own anomaly or feature types where continuous backend processing will be scheduled to populate the new user-defined anomaly type by executing the chosen data mining algorithm (e.g. differences from climatology or gradients above a specified threshold). A parallel analytics platform will be implemented to demonstrate new technology concepts including:

- An adaption of the Hadoop/MapReduce framework for parallel data mining of science datasets, typically large 3 or 4-dimensional arrays packaged in NetCDF and HDF
- An algorithm profiling service to efficiently and cost-effectively scale up hybrid Cloud computing resources based on the needs of scheduled jobs

The key idea is that the parallel data-mining operations will be run “near” the ocean data archives (a local “network” hop) so that one can efficiently access the thousands of (say, daily) files making up a decade-long time-series, and then cache key variables and pre-computed climatologies. Using this platform scientists can efficiently search for anomalies or ocean phenomena, compute data metrics for events or over time-series of ocean variables, as well as efficiently find and access all of the data relevant to their study. This work has been funded by a recent NASA ROSE AIST proposal with an expected start date in June 2015.

A warm and weird central California in 2014 and 2015

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ABSTRACT

In spring 2014 a strong downwelling Kelvin wave crossed the equatorial Pacific, prompting predictions of a large El Niño and a great deal of press coverage. It had been 18 years since the last large El Niño and as a result of the cool eastern Pacific that had been prominent since, California had been mired in one of the most significant droughts on record. It is rather paradoxical that a cool and productive ocean results in stress on land. The news of a large El Niño, normally thought of as a catastrophic event, brought cheers to most Californians. It also brought thoughts of a change in regime; was this the end of almost 20 years of cooler than average eastern Pacific sea surface temperatures (SST), and were we looking at 20 or more years of warmer SSTs? The large El Niño however, never materialized. What did materialize was an unusually warm North Pacific during the second half of 2014. The patterns observed were extremely similar to those during an El Niño but they happened without one. These unusual North Pacific conditions helped make 2014 the warmest year ever observed during the 120 year instrumental record in California and globally. Numerous temperature records were broken in western North America, from Alaska to Arizona. The long-term trend in ocean warming is about 0.1°C/decade, and therefore cannot by itself explain the anomalous warmth that exceeded several degrees in many places. The exceptionally warm waters in the eastern North Pacific may then be related to a natural shift in climate. The Pacific Decadal Oscillation (PDO) index varies between mostly positive (warm) and mostly negative (cool) on periods between 40 and 70 years and became sharply positive in 2014.

The North Pacific anomalies were captured beautifully by the sensors on the M1 mooring in Monterey Bay. An SST of 18°C was observed in late August 2014, the warmest ever measured during the 25-year record at M1, warmer than the 1997-98 El Niño of the century. The warmer than average North Pacific SSTs were enhanced in Monterey Bay and the California Current during summer, as the cold ocean-hot land gradient was lessened, weakening upwelling-favorable winds. Less wind resulted in calm conditions after July, with little upwelling and a warm, clear and relatively unproductive coastal upwelling system. Warm water at the surface indicates lower nutrient availability for the most important primary producers in the ocean, phytoplankton. Nitrate is a key nutrient that enables the production of high phytoplankton biomass in upwelling systems. MBARI scientists have developed novel sensors for nitrate, allowing it to be measured hourly at 1 m depth at the M1 mooring since 2002. The mean monthly values measured during the second half of 2014 are the lowest of any year in the record. During normal years nitrate concentrations at the mooring are characterized by frequent upwelling events that increase concentrations to values from 5 to 30 µM. For the four months from August through November, the daily average nitrate did not exceed 1 µM. This was an unprecedented string of low nitrate concentrations. Such low nitrate concentrations must have significant impact on the marine ecosystem by limiting primary production. The lower than average chlorophyll fluorescence values observed at M1 during 2014 support this decrease in primary production. The decreases in fluorescence were significant but not as large as what

one would surmise from SST and nitrate. Another indication of the unusually warm 2014 was the increase in warmer water southern species in Monterey Bay. John Pearse and colleagues documented a dramatic increase in the colorful rose nudribranch (*Hopkinsia rosacaea*) in the rocky intertidal of Hopkins Marine Station in Pacific Grove. And MBARI staff reported the recruitment of the medialuna or half-moon (*Medialuna californiensis*) beneath the M1 mooring during servicing visits. The medialuna has a symbiotic relationship with *Mola mola*, feeding on its parasites. In sharp contrast to the decreased productivity, for the second summer and fall in a row inshore Monterey Bay attracted enormous schools of feed fish and their predators --- birds, sea lions, dolphins and whales.

What can explain these paradoxical observations? The observations of an ecosystem that has been deprived of its fuel, nitrate and other nutrients normally provided by upwelling, and the observations of significant numbers of marine wildlife. We offer two hypotheses, neither exclusive from the other. One significant difference between the warm 2014 conditions in Monterey Bay and El Niño was the lack of a strong anomaly at depth. During El Niño, remotely forced waves deepen the thermocline, nutricline and mixed layer. During 2014 the lens of warm water overlay a shallow and strong thermocline. It is likely that some nitrate was supplied to the surface waters but consumed immediately. Lower than atmospheric concentrations of sea surface carbon dioxide provide support to some nitrate supply. However, even though there was some fuel provided in 2014, it was clearly much less than during other years, so other processes must also have contributed to the bonanza in marine wildlife, whales in particular. One such process is the collapse of an ecosystem that normally occupies an area of about a hundred kilometers next to the coast to one of a only a few 10s of kilometers along the coast and in Monterey Bay. Bays in particular act as refugia for wildlife during difficult times. The large numbers of wildlife are then a consequence of an increase in concentration over a small area rather than an actual increase in numbers. We have no information about the nutritional state of the wildlife but one has to think that body fat or other indicators of condition would show the effects of the decreases in primary production.

The warm and weird 2014 leads us to a final and more speculative topic: what will be in store for Monterey Bay and the North Pacific in coming years? Is the beginning of a new climate and ecosystem regime and will the PDO remain mostly positive for 20 years or more? Or will we go back to the cool eastern Pacific we have lived with since the late 1990s, or feel a whole new set of conditions?

PO.DAAC & "The Blob": Discover and Visualize NASA Physical Oceanographic Data

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ABSTRACT

The Physical Oceanography Distributed Active Archive Center (PO.DAAC) is responsible for the management and distribution of NASA's physical oceanographic data. It distributes over 500 datasets spanning gravity, ocean wind, sea surface topography, salinity, and sea surface temperature satellite missions. PO.DAAC supports the physical oceanography user community by offering a suite of data access and visualization tools and services. Such capabilities will be highlighted to improve user understanding of "the blob" including the web portal and several GUI based tools. Examples include:

1. PO.DAAC's State Of The Ocean (SOTO) tool, which provides visualization of near-real-time satellite data.
2. PO.DAAC's High-level **T**ool for **I**nteractive **D**ata **E**xtraction (HITIDE), which enables subsetting, extraction, and visualization of swath satellite data.
3. PO.DAAC's Live Access Server (LAS) tool, which provides subsetting, extraction, and visualization of gridded satellite data.
4. PO.DAAC's Consolidated Web-Services for search, image, and extract of swath and gridded satellite data.

Role of ocean temperatures in Arctic tundra vegetation productivity

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ABSTRACT
This study investigates the links between large-scale climate variability and Arctic tundra vegetation productivity focusing on the Pacific sector. Vegetation productivity has been overall increasing in the Arctic over the satellite record however, since about the late 1990s productivity in many parts of the Arctic has been flat or even declined. We hypothesize that large-scale climate variations are in part responsible for recent vegetation trends. Variations in available summer warmth, the limiting factor for Arctic tundra, are correlated with sea surface temperature in the North Pacific. We will also examine the link between summer warmth and warm anomalies in the Gulf of Alaska.

Introduction
Three decades of remotely sensed Normalized Difference Vegetation Index (NDVI) displays an overall increase of Arctic tundra vegetation greenness (**Fig. 1**) but with considerable spatial variability of the trends. NDVI represents vegetation productivity as measured by above-ground biomass and has a universal relationship with biomass throughout the pan-Arctic tundra. Pan-Arctic tundra vegetation greening is responding to increases in available summer warmth (**Fig. 1**) that are, in large-part, driven by summer sea-ice retreat along Arctic coasts (Bhatt et al. 2010). Since 80% of Arctic tundra is within 100-km of the coast, its variability is closely linked to that of the Arctic Ocean (Bhatt et al. 2013). Summer sea level pressure changes since 1998 resemble the negative phase of the Arctic Oscillation, suggesting the need to examine links with the North Pacific and North Atlantic Oceans.

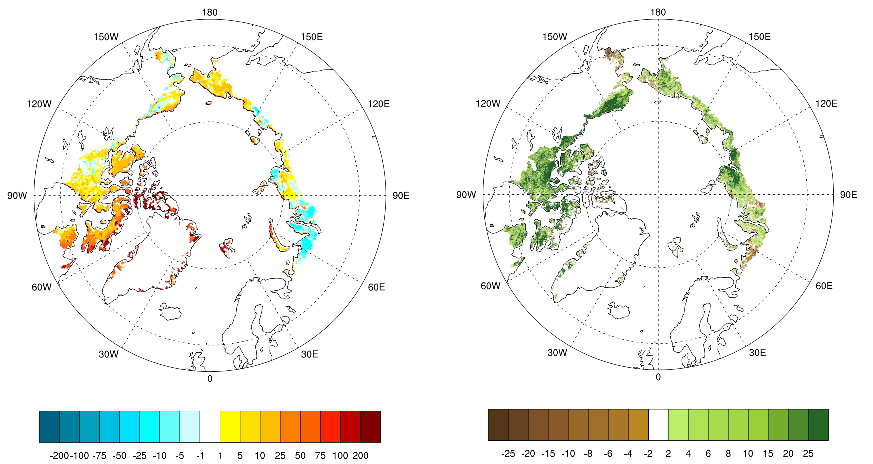

Figure 1. Percent change from 1982-2013 for May-August SWI (sum of degree months above freezing) *(left)* and maximum NDVI (MaxNDVI) *(right)*. Units of percent change in all panels.

Data and Methods
This study employs several

remote sensing data sets: Special Sensor Microwave Imager (SSM/I) sea-ice concentrations, Advanced Very High Resolution Radiometer (AVHRR) radiometric surface temperature (Ts), and NASA GIMMS AVHRR maximum NDVI. Summer Warmth Index (SWI) is calculated from Ts as the sum of May to September monthly surface temperatures above freezing, in units of ˚C months. The sea surface temperature data are from NOAA/OAR/ESRL PSD in Boulder, Colorado. Standard climate analysis is employed.

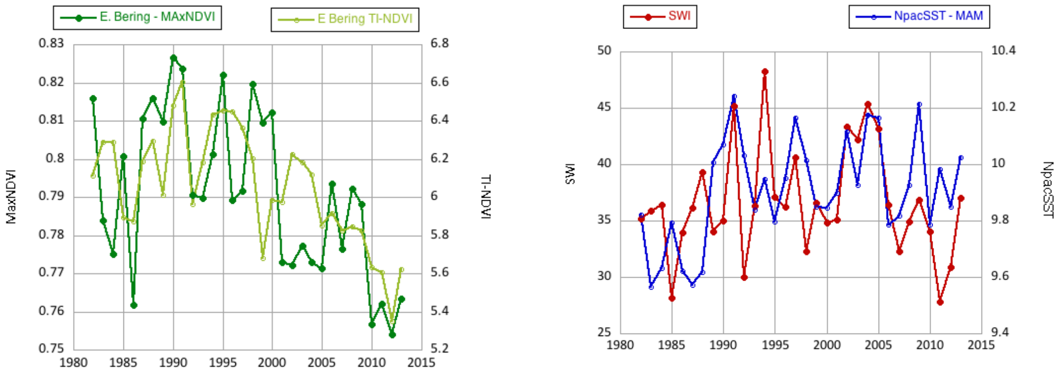

Figure 2. E. Bering MaxNDVI and time integrated NDVI (right) and Pacific (30-60N, 120-240E) MAM SST (blue) with E. Bering SWI (red) (right).

Results

Tundra in the Arctic and Alaska is overall increasing but there is considerable heterogeneity. Here we focus on Alaska and its three tundra regions: Beaufort, East Chukchi and East Bering. Trends of NDVI in the East Bering region display declining trends while the E. Chukchi and Beaufort show positive trends (Fig. 1). Vegetation productivity in the E. Bering has declined since about 2000 (Fig. 2, left) shown by the MaxNDVI and time integrated NDVI (TI-NDVI: sum of biweekly maxNDVI) trends. SWI displays large variability but is significantly (95%) correlated (R=0.36, linearly detrended) with MAM N. Pacific SSTs (Fig. 2, right). MAM N. Pacific SSTs are significantly correlated with the E. Chukchi region (0.39) but uncorrelated with the Beaufort region. Correlations with winter (JFM) are weaker. Further analysis is underway to identify important regions in the North Pacific Ocean that influences SWI.

Conclusions

Tundra vegetation which is largely warmth limited has increased over 1982-2013, however, since about 1999 productivity has declined is southwestern Alaska. Declines are linked to generally cooler temperatures in the North Pacific, a delay in the retreat of sea ice in the Bering Sea, and possibly to changes in available moisture during summer.

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Historical linkages between Alaska seasonal temperature, river ice breakup and Pacific sea surface temperatures

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ABSTRACT

Alaska climate anomalies have been shown to be linked to Pacific sea surface temperatures (SST). The climate variable most strongly linked to Pacific SSTs is temperature on the monthly to seasonal-scale, which has been specifically linked with the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) teleconnection índices (e.g. Papineau 2001; Hartmann and Wendler 2005). Understanding these linkages is especially important as they can be exploited to improve the seasonal predictability of Alaska climate, which is important as much of the economy and human health is driven by weather and climate in Alaska.

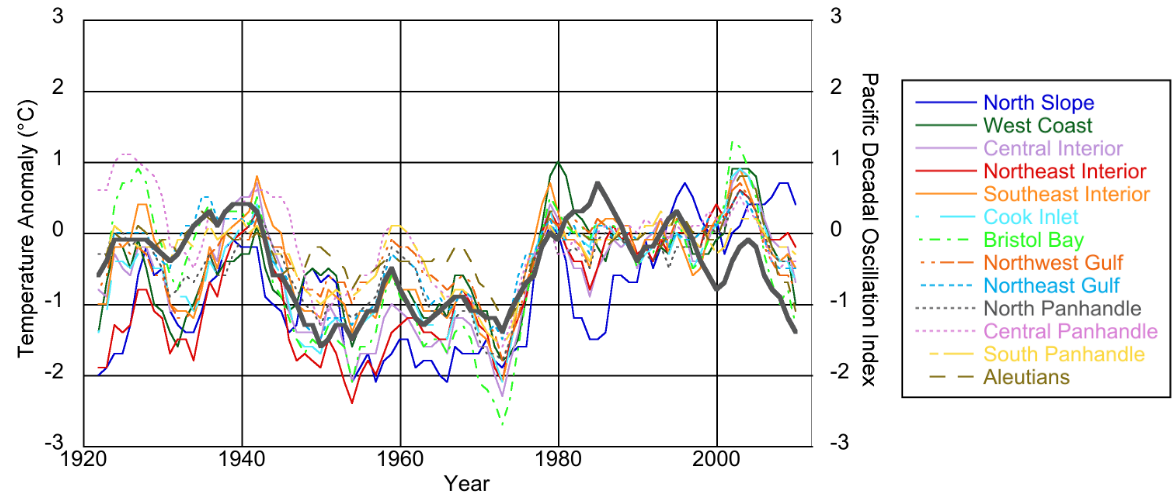

Figure 1. Annual 5-yr running averaged divisional temperature anomalies for the 13 Alaska climate divisions. The Pacific decadal oscillation index (PDO) is shown in dark gray and has also been smoothed by 5-yr running average. The mean of the PDO has been adjusted to match the average mean of the 13 Alaska climate divisions for ease of comparison. Figure reproduced from Bieniek et al. 2014. The 13 Alaska climate divisions are described in Bieniek et al. (2012).

The annual historical temperatures for all of Alaska's 13 climate divisions (based on meteorological station data) display broadly similar variability between a 5-yr running average of the PDO and annual temperatures over the last 90+ years (Figure 1; Bieniek et al. 2014). A long-term trend to warmer temperatures has also occurred with this low-frequency variability superimposed upon it in Alaska. Understanding the linkages between Pacific SST anomalies and temperature/precipitation anomalies over terrestrial Alaska is a necessary step in evaluating past and future climate variability.

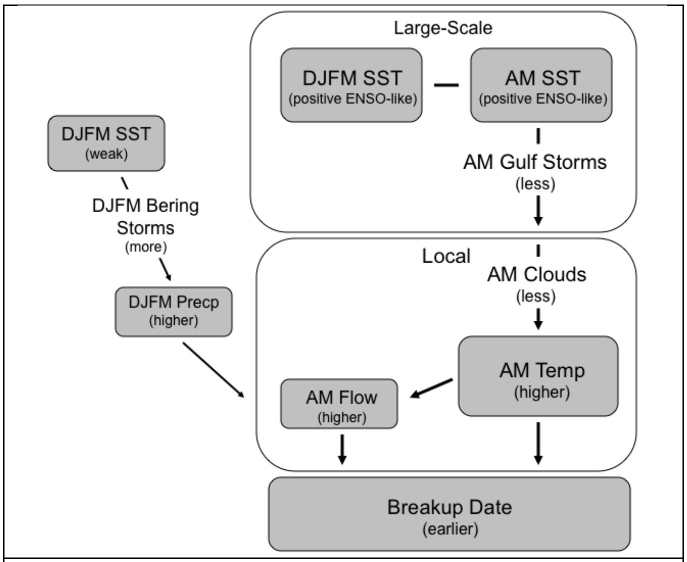

Figure 2. Summary of the Alaska breakup–climate mechanism highlighted for early breakup. The primary mechanism is outlined within the boxes, with the secondary mechanism shown on the left. DJFM represents the December–March period while AM signifies April– May. Later breakup can be described by opposite sign anomalies. Figure reproduced from Bieniek et al. (2011).

River ice breakup in April-May poses a flood risk to Alaskans who live along the many rivers in the region. Breakup has been shown to occur earlier when temperatures are warmer in spring (Bieniek et al 2011). A mechanism that relates early breakup with positive ENSO-like SST anomalies in the Pacific and Gulf of Alaska storm tracks is demonstrated (Figure 2) based on a statistical analysis of reanalysis, meteorological and hydrological station data. Identifying and investigating similar mechanisms is greatly needed in Alaska to better understand the drivers of month, seasonal and annual climate variability and trends. Such mechanisms will help to identify the potential of future climate change in the many regions of Alaska that are especially vulnerable to change. This will further help stakeholders to better plan and prepare adaptations if projected changes in future climate are better understood.

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Linking warm temperature anomalies between nearshore and shelf waters in the Gulf of Alaska

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ABSTRACT

The multi-agency Gulf Watch Alaska ecosystem monitoring program includes oceanographic data collection at multiple sites within the *Exxon Valdez* Oil Spill (EVOS)-affected region (www.gulfwatchalaska.org). Data from these sites are used to determine if oceanographic changes in Gulf of Alaska shelf waters are synchronous with near-shore conditions measured in Cook Inlet and Prince William Sound. Coastal waters of the Gulf of Alaska are connected by the wind and freshwater-driven Alaska Coastal Current. Cook Inlet and Prince William Sound are large estuaries in the northern Gulf that experience upwelling of shelf waters and are locally influenced by freshwater input (precipitation and snowpack and glacier melt), large tides, and topographically steered winds. Ocean conditions drive the timing and magnitude of primary production through changes in light, temperature, nutrients, and stratification, which are influenced by local (e.g. upwelling, topographic wind forcing) and basin-scale (e.g. variability in Aleutian Low wind patterns) processes in the Gulf of Alaska (Mundy 2005). Comparisons of temperature time series between Cook Inlet, Prince William Sound and the GAK1 mooring on the shelf near the mouth of Resurrection Bay show consistent warm anomalies in coastal areas during 2014, with a magnitude similar to those observed in 2005.

DATA AND METHODS

Oceanography and plankton monitoring are conducted across the Gulf of Alaska shelf at the GAK1 hydrographic station, along the Seward Line, and along the Continuous Plankton Recorder transect, as well as at oceanographic stations and continuously sampling shore stations in lower Cook Inlet/Kachemak Bay and Prince William Sound (Fig. 1). Water temperature anomalies were calculated from time series (2004-2014) at the Kachemak Bay National Estuarine Research Reserve water quality station in Seldovia Alaska and GAK1 mooring (2004-2014) and from conductivity-temperature-depth (CTD) profiler stations in central Prince William Sound (1975-2014).

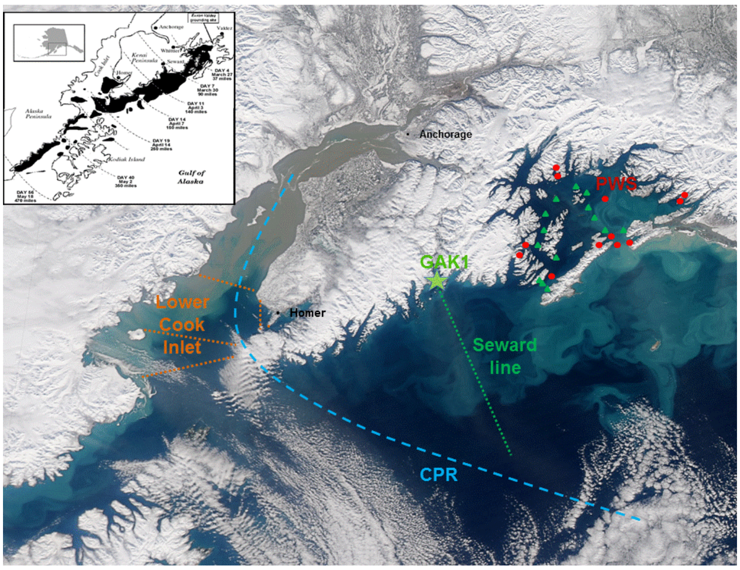

Figure 1. Gulf Watch Alaska monitoring program oceanographic sampling locations

Coherence was calculated between the Seldovia and GAK1 time series.

RESULTS

Monthly average temperature anomalies were calculated from the 11 year time series at the Seldovia harbor water quality station (Fig. 2). Average monthly water temperatures were above normal for all months in 2014 and warmer than any time since 2005, averaging a high of 12°C in July in each year. Coherence calculated between temperatures at Seldovia and the GAK1 mooring (Fig. 3) show that the time series are coherent for periods greater than 3 months and independent at shorter time scales. Prince William Sound had similar warm temperature anomalies (Fig. 4) in 2014 and 2005.

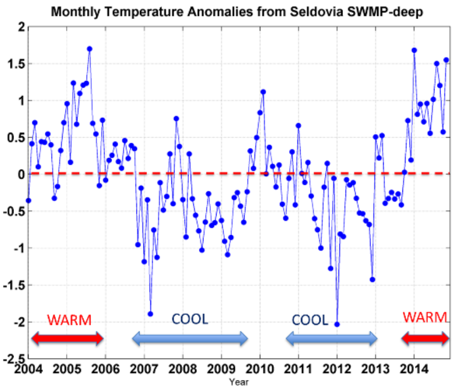

Figure 2. Monthly average temperature anomaly (degrees C) for Seldovia water quality station.

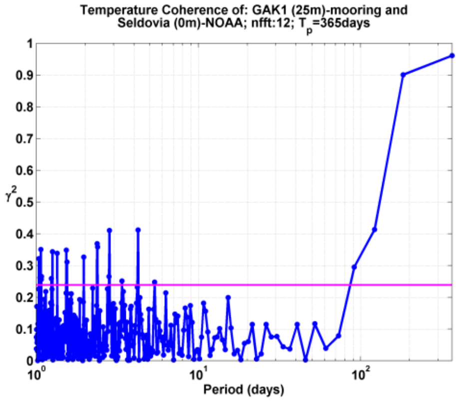

Figure 3. Coherence between water temperature time series at the Seldovia NOAA tide gauge and the near-surface

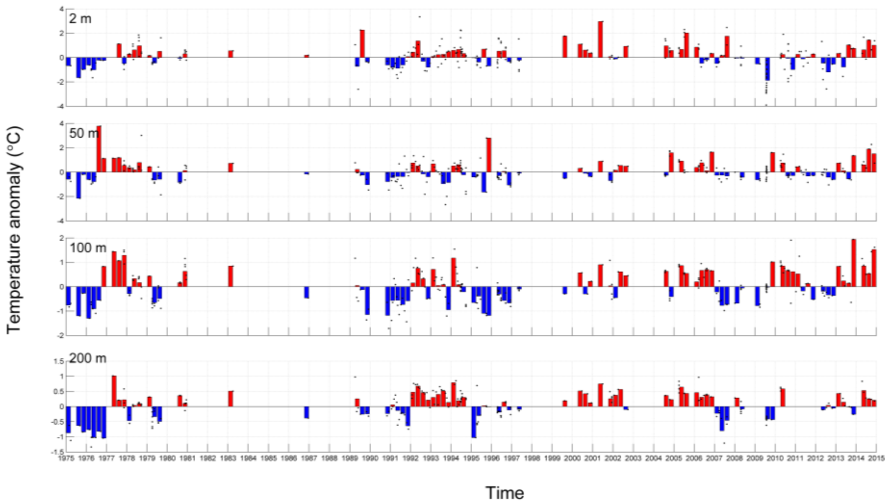

Figure 4: Temperature anomalies from central Prince William Sound CTD stations (1975-2014). Warm temperature anomalies were present at all depths in 2014, a pattern also observed in 2005.

Near-surface water temperature time series constructed from NOAA National Water Level Observation Network tide gauge station data (not shown) also show consistently warm temperature anomalies for 2014 across the entire Gulf of Alaska coast.

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Observations from Alaska: Potential effects of the warm blob on the pelagic ecosystem of the Gulf of Alaska

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ABSTRACT

The Alaska Fisheries Science Center's Auke Bay Laboratories division conducts a variety of pelagic ecosystem monitoring surveys annually. The "Warm Blob" began forming in the North Pacific during fall 2013 and observations from surveys conducted during 2014 suggest that some species may have benefited from the warm conditions while others may have not. Six of the most common zooplankton species consumed by juvenile marine fish and salmon had significantly higher energy reserves in 2014; and information on the timing, magnitude, and species assemblage of the 2014 phytoplankton bloom could provide insight into why zooplankton lipid content was atypically high. Juvenile salmon and herring appear to have benefited from consuming energy-rich prey, as both species exhibited high levels of lipid stores. However, the 2014 cohort of age-0 herring experienced high levels of over-mortality despite being in good energetic condition. Warm water pelagic fishes were relatively high in abundance in the Gulf of Alaska during 2014 and likely increased predation pressure on juvenile fish.

A Comparison of the Anomalous Ocean Conditions observed off the West Coast of Canada in 2014 and 2015 from three monitoring systems.

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ABSTRACT

Sea surface temperature (SST) data collected at several locations off the West Coast of Canada are used to examine the timing and extent of anomalously warm water observed in 2014 and 2015. SSTs collected from lighthouse stations and weather buoys (Figure 1) are examined as time series of daily anomalies from the long-term averages. The SST observations from the lighthouses are taken by the lighthouse keepers at the first daylight high tide using a handheld electronic instrument. The buoy data are provided by Environment Canada from a network of ODAS (Offshore Data Acquisition Systems) buoys that collect weather data hourly. The times series of lighthouse data and the buoy data span about 80 and 25 years, respectively.

The 1500 km Line P water properties survey includes 26 monitoring stations from the continental slope near southern Vancouver Island to Ocean Station PAPA (OSP, 50^{o}N, 145^{o}W). Surveys are carried out using a Seabird 911 CTD in February, June and August/September of each year. Vertical profiles of temperature, density, and oxygen from seven recent surveys are presented as anomalies from the baseline data collected from 1980 to 2010.

The time series data (from the lighthouses and weather buoys) show that the date when there is a change from negative to positive temperature anomalies, and again when the 2014 and 2015 observations values exceed the historical maximum daily temperature, varies by location. Observations from the Strait of Georgia show a delayed influence of the warm Pacific Ocean water.

The transition from cooler to warmer than normal SST conditions along Line P is seen to vary with distance. Warming of the offshore section is evident in August 2013 while a band of cooler surface water along the coast is present until the February 2015 survey. The oxygen profiles show a similar surface layer of negative oxygen concentration, as well as deeper vertical excursions of water with a negative oxygen anomaly.

Density profiles show that starting in 2013 the Line P transect was characterized by a well-defined surface layer with waters of lower than normal density that penetrates to a depth of about 100 m. The strength of this stratification, and the mechanisms that control it, will likely determine the duration of the warm pool of water in the North Pacific (Freeland, 2015).

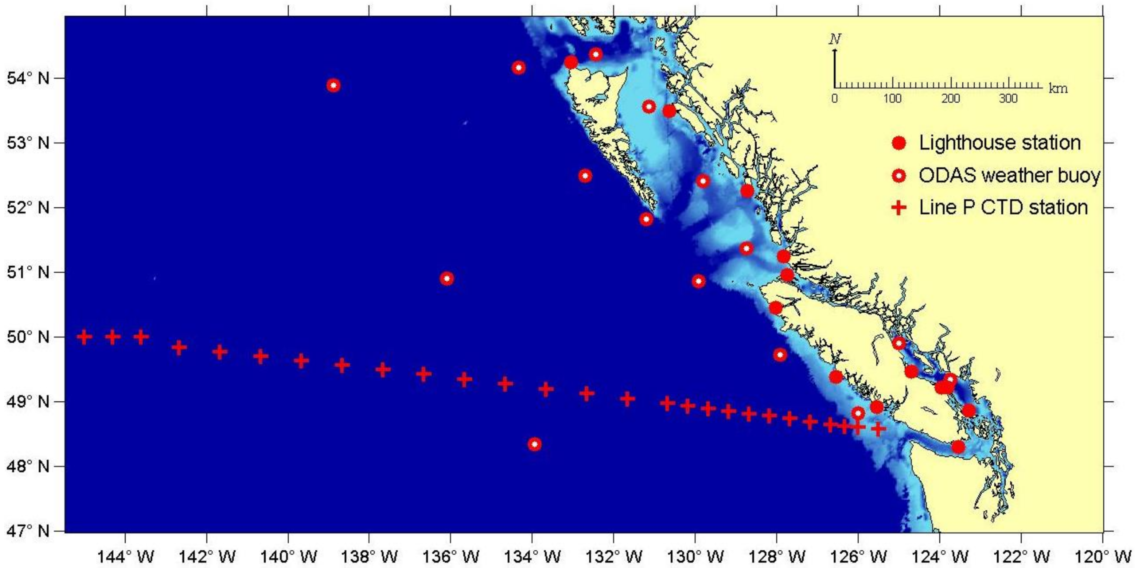

Figure 1. Monitoring locations: Red dots show the locations of 12 stations in the lighthouse shore station network. Red dots with white centers show the locations of 14 ODAS buoys in the Canadian weather buoy network. Red crosses show the sampling stations along Line P.

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Observations of the "blob" from NANOOS: info over depth and over time

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ABSTRACT
A new Climatology app by NANOOS shows the SST at several NDBC buoys is well above 2 standard deviations outside the 39 year mean (Fig. 1). A data-rich set of observations on the NW Washington Coast from the UW-NANOOS Cha'ba and NEMO-subsurface moorings positioned mid-shelf recorded over the full water column the movement of the unprecedentedly-warm water of the North Pacific "blob" onto the shelf following the fall transition to downwelling-favorable winds, resulting in temperature anomalies greater than 6°C above past records, and reveal information on the link between variations of shelf dissolved oxygen and local wind forcing.

Observations spanning late June through late October 2014 from two NANOOS/UW moorings mid-shelf on the NW Washington Coast indicate that upper ocean conditions (T, S, DO, chlorophyll) in this region were similar to previous observations (2011-2013) for most of this period with a two notable exceptions: summertime deep oxygen and early fall temperature (Fig. 2a, c).

Deep DO was on average about 1 mg l^{-1} lower than previous (albeit limited) observations, starting at roughly 3 mg l^{-1} and dropping to 1 mg l^{-1} before rising again in mid-September (Fig. 2a). Unlike 2013, however, the 2014 record does not show any rapid and short-lived (<week) extreme drops in DO.

There was typically a robust correlation between shelf wind direction, the resultant currents, and changes in deep DO. Somewhat counter-intuitively, upwelling favorable winds (from NW), resulted in local increases in deep DO, and downwelling-favorable winds (from SE) resulted in local decreases (Fig. 3a, b, d). This appears to be a consequence of the advection of a north-south DO gradient with lower DO to the south that moves northward to the mooring site, consistent with past observations (Connolly et al., 2010). The relationship between winds/currents and DO reversed to the expected pattern after extended downwelling and a pulse (> week) of very strong, nearly full-depth northward currents (>0.3 m s-1) in late September (Fig. 3b, d). A potential explanation is that the extended, strong northward flow may have flushed the low-DO water past the mooring site. Thus, during this strong downwelling event, DO levels at the mooring site first dropped, then increased again, presumably as the low DO patch advected past. The measured current speed and duration relative to the expected low-DO patch size support this mechanism.

For much of the summer, temperatures were not particularly anomalous, despite the much warmer water offshore apparent from satellite images, highlighting the complex interplay between ocean basin-scale anomalies (the "blob") and local oceanographic

processes (upwelling). Near-surface (3 m) temperatures remained near the average of past mooring records, staying below 1°C for much of the summer (Fig. 2c). However, following a strong, extended downwelling-favorable wind event driving northward currents in late September (Fig. 3a, b), upper ocean temperatures rapidly increased from ~9°C to more than 14°C (Fig. 3c). Then following a 2-week period of weak and variable winds, another return to strong downwelling-favorable winds brought the "blob" further ashore, thickening this layer to >50 m and elevating temperatures above 15°C, more than 6°C above 2013 observations from this period at mid-depths (20-60 m) (Fig. 3a, c).

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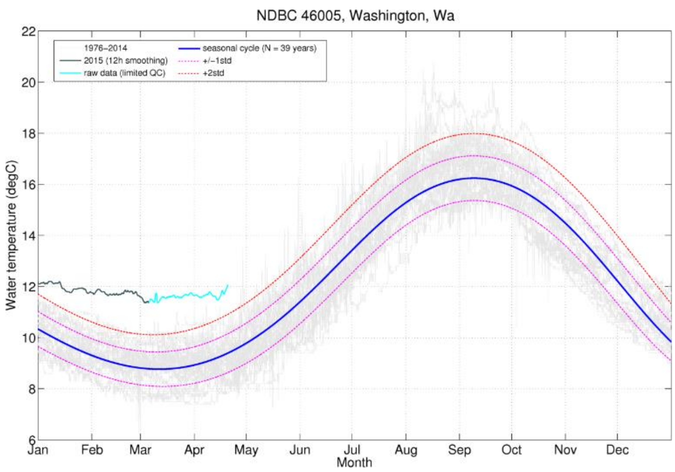

Figure 1. *(above)* NDBC Stations 46005 sea surface temperature data for 2015 (cyan and black lines), which are currently over two standard deviations above normal (blue line). The light grey lines show all of the data collected between 1976 and 2014.

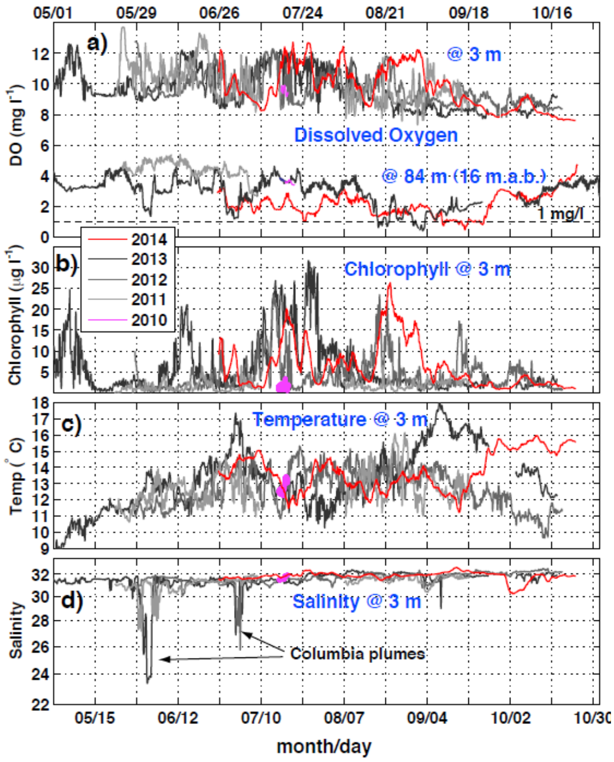

Figure 2. *(above)* Interannual comparison of observations at the Cha'ba mooring, 13 nautical miles WNW of La Push at 47°, 58' N, 124°, 57' W.

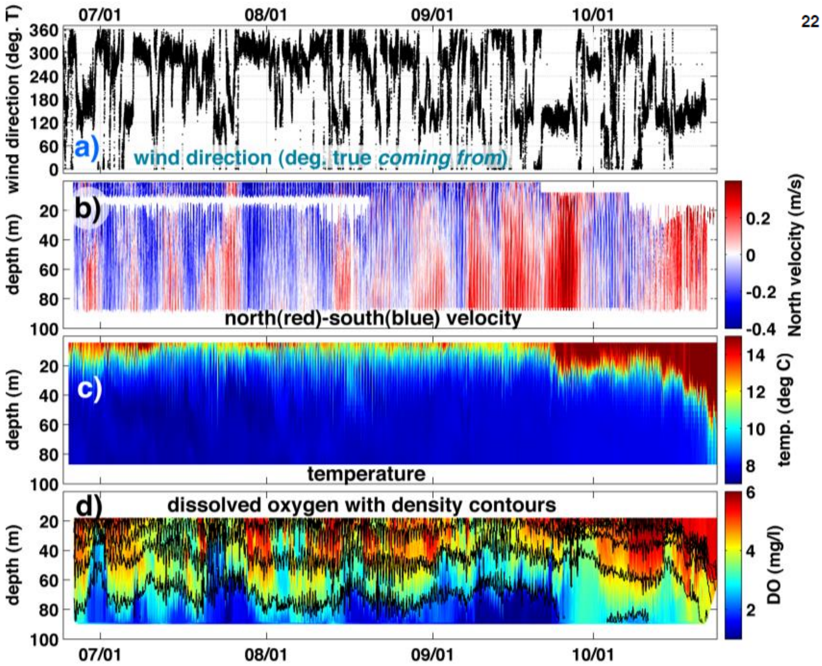

Figure 3. *(left)* 2014 NEMO/Cha'ba observations: a) wind direction showing the direction the wind is blowing from, b) north (red)/south (blue) current velocities, c) temperature, d**)** dissolved oxygen with density contours overplotted.

Time series observations of nearshore water conditions in the Columbia River estuary during the 2014-2015 NE Pacific temperature anomaly

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ABSTRACT
Extraordinarily warm sea surface temperatures were present in the NE Pacific starting in the winter of 2013-2014 and continued into the spring of 2015 (Bond et al. 2015). The extent and impact of this anomalous ocean condition on nearshore environments of the West Coast is of ecological concern, since previous warm SST anomalies in 1997 and 2005 led to decreased primary productivity and impaired or unusual habitat conditions for aquatic animals throughout the California Current Ecosystem (Chavez et al. 2002, Kudela et al. 2006). Here we report evidence of the 2014 anomaly moving onshore and entering the Columbia River mouth, as measured by in situ instruments deployed in the salt-wedge region of the estuary. Time series measurements of temperature from 1997-2015 provide evidence that the anomaly reached the estuary in Fall 2014, following the end of the upwelling season (Fig. 1).

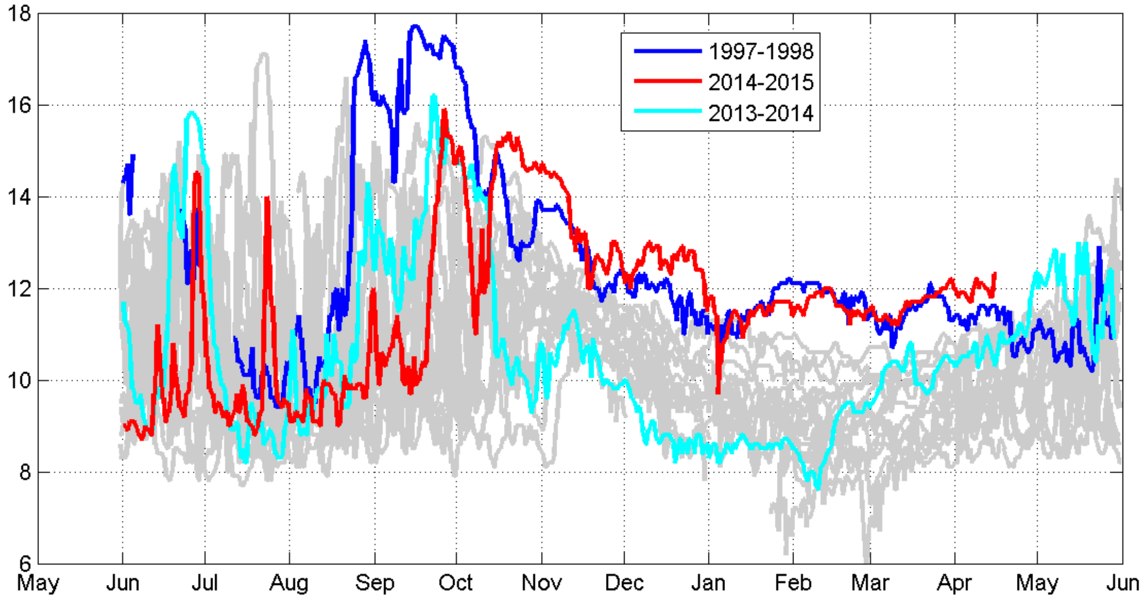

Figure 1. Ocean water temperature (°C) estimated from sensors in the Columbia River estuary for every year between 1997 and 2015. Specific years are highlighted (see text).

Temperatures remained high from October 2014 through April 2015. Table 1 summarizes 2014-2015 temperatures compared to previous years for the six-month period between October and April (185 days). Relative to the average of all years, 2014 was warmer on 184 out of the 185 days, with an average difference of +2.1°C. Relative to the El Niño conditions of 1997-1998, 2014 was warmer on 135 out of the 185 days, with an average difference of +0.6°C. The summers associated with the El Niño and 2005 warm anomalies had periods of poor primary productivity on the continental shelf as a result of reduced upwelling conditions and high temperatures. However for the period shown in Table 1, neither of those years reached comparable temperatures to 2014-2015. If conditions persist into spring and summer 2015, the anomaly may lead to conditions similar to 2005 yet unprecedented in the temporal persistence at the nearshore environment.

Table 1. Number of days between October and April 2014-2015 that temperatures exceeded selected comparison years (data shown in Figure 1), and compared to the 1997-2015 average temperature.

	average	1997	2005	2013
# of days	184	135	179	185
□ temp	+2.1	+0.6	+1.8	+2.8

The temperature data shown in Fig. 1 is complemented by a variety of biogeochemical sensors that were deployed beginning in 2008 as a part of the NSF Science and Technology Center for Coastal Margin Observation & Prediction. Phytoplankton blooms from the coastal ocean can be easily detected in the saline waters of the estuary (Roegner et al. 2011). To date, there is evidence that phytoplankton blooms in the near shore region were reduced in Fall 2014, but no other obvious trends in biogeochemical parameters have been noted. Planned continued monitoring of biogeochemical parameters throughout the upwelling period of 2015 will help determine the extent of changes in ocean conditions at the nearshore coastal margin that result from the continued presence of this large scale temperature anomaly.

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Measurements from NH10, a long time series on the Oregon shelf

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ABSTRACT

A mid-shelf mooring has been maintained 10 nm off Newport, Oregon, for more than 15 years. The seasonal variation is very strong, but the length of the record allows extraction of non-seasonal anomalies. The longest records are for the vertical distribution of currents from an ADCP, but substantial records exist also for temperature and salinity at multiple depths. We will examine these records for anomalous behavior coincident with the Warm Blob.

Changes to the hydrography and zooplankton in the northern California Current in response to 'the blob'

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ABSTRACT
The northern California Current supports a lipid-rich food chain composed of copepods, krill and small pelagic fish. Disruptions to this food chain result in reduced productivity and poor survival of pelagic and benthic fishes; major disruptions are often associated with warm ocean conditions during years of positive Pacific Decadal Oscillation (PDO) and positive El Niño events. Fortnightly measurements of hydrography and zooplankton have been sustained along the Newport Hydrographic line since 1996. These efforts have shown that the response of local hydrography and zooplankton species composition is modulated by the sign of the PDO and El Niño. Five El Niño events (1997-98, 2002-03, 2004-05, 2006-07 and 2009-10) have been sampled since 1996 where warm water and anomalously high biomass of subtropical copepods were observed at 44.6°N, regardless of the magnitude of the event at the equator or the sign of the PDO. We compare the local hydrography and species composition across 20 years of positive PDO and five El Niño events in comparison to the anomalously warm event of 2014-15. During this past warm event, the waters off Newport were seasonally warm (+2°C anomaly) and fresh (by 0.2 salinity units) and the biomass anomalies of warm (cold) water copepods increased (decreased) dramatically as was observed during other positive PDO and ENSO years. However, the copepod species richness on the shelf has been the highest in the past 20 years, indicating source waters from offshore. In fact, seventeen copepod species, many of which have tropical affinities, have been recorded on the Oregon shelf that have not been observed at any time over at least the past 50 years, making this extreme event unlike any other.

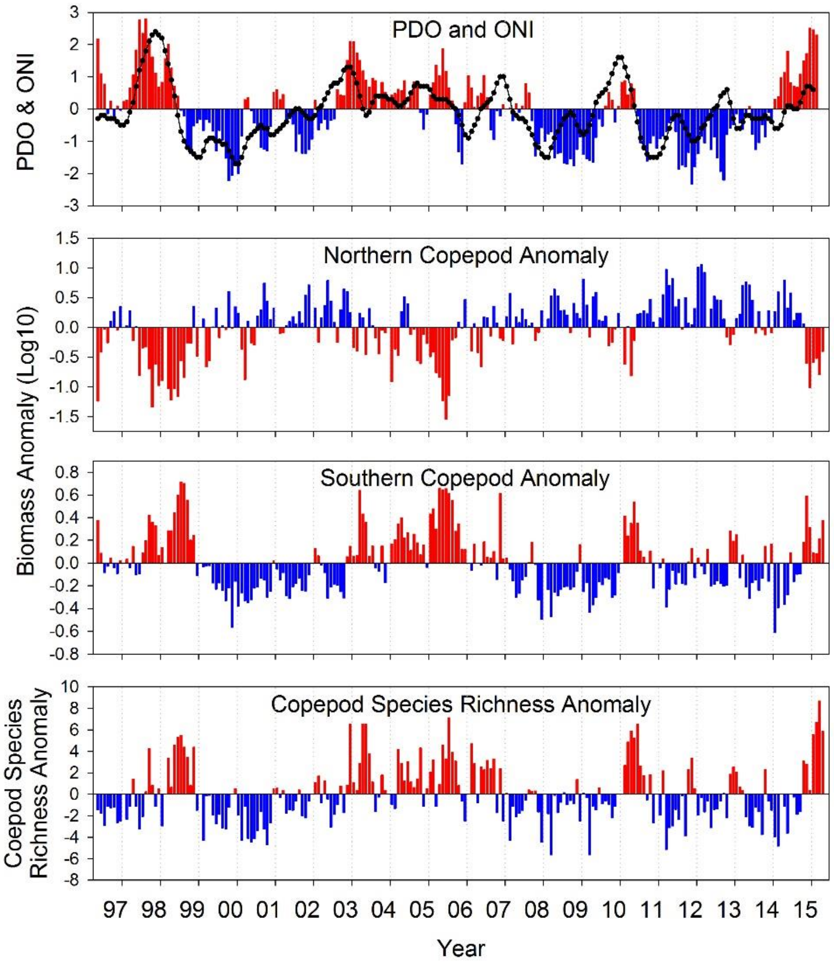

Figure 1. Basin-scale and local ocean ecosystem indicators collected off Newport Oregon from 1996 to present. Pacific Decadal Oscillation (bars top panel) Ocean Niño Index (line top panel) and the northern and southern copepod biomass and species richness (number of species) anomalies from fortnightly sampling at a shelf station in 60 m of water.

Glider Observations of the 2014–2015 Temperature Anomalies in the Southern California Current System

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ABSTRACT

Initiated in 2006, the California Glider Network provides sustained subsurface observations of the coastal ocean. Spray underwater gliders have continuously occupied CalCOFI lines 66.7, 80 and 90 for nearly eight years. Repeat sections along the three lines extend to a 350-500 km across-shore distance and 500 m depth. Following a sawtooth trajectory, the gliders complete each dive in 3 hours and over 3 km, approximately. Measured variables include pressure, temperature, salinity, and velocity (depth-averaged and depth-dependent). With a sampling pattern that is well resolved both spatially and temporally, autonomous Spray gliders are a pragmatic observational platform for long-term surveying of the southern California Current System (CCS) structure and variability.

For each of the three lines, a comprehensive climatology has been constructed from the multiyear timeseries. The climatology is comprised of objectively mapped fields, uniformly spaced in depth, time and offshore distance. It facilitates the analysis of mean structures, annual cycles and interannual anomalies. Periodically updated, the climatology includes recent observations and allows for sustained monitoring of mesoscale and large-scale features in the CCS. The largest interannual signal in the glider climatology is the ongoing surface-intensified warming anomaly, which began in early 2014 and persists through present (Fig. 1a). Positive temperature anomalies are strongest in the upper 50 meters of the water column (Fig. 1b) and reached up to 5°C during the last 16 months.

Previous interannual temperature anomalies in the dataset were linked to ENSO events (Todd et al., 2011), however, those anomalies had weaker magnitudes and subsurface maxima (Fig. 1b). The timing and strength of the recent warming is consistent along each glider line (Fig. 2) and concurrent with weakening northerly winds and a deepening of isopycnals. Our ongoing analysis of the glider climatology and atmospheric data aims to understand the cause, and ultimately the fate, of the warm surface waters in the southern CCS.

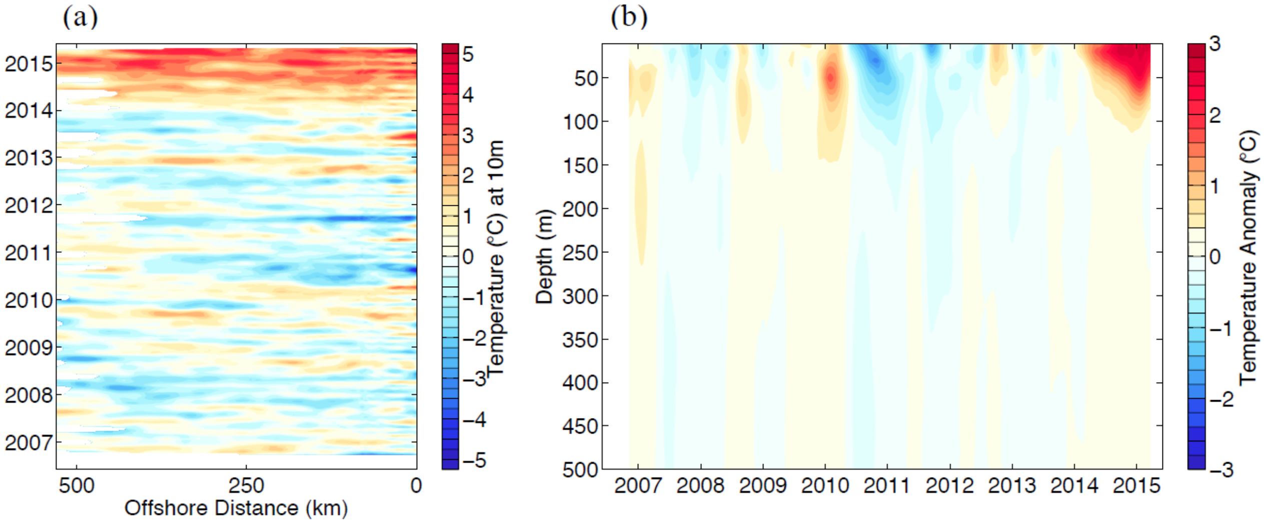

Figure 1: Hovmöller plots of: temperature anomalies at 10 m along Line 90 *(a)* and temperature anomalies at all depth levels along Line 90, averaged over the inshore 200 km and filtered with a 3-month running mean *(b)*.

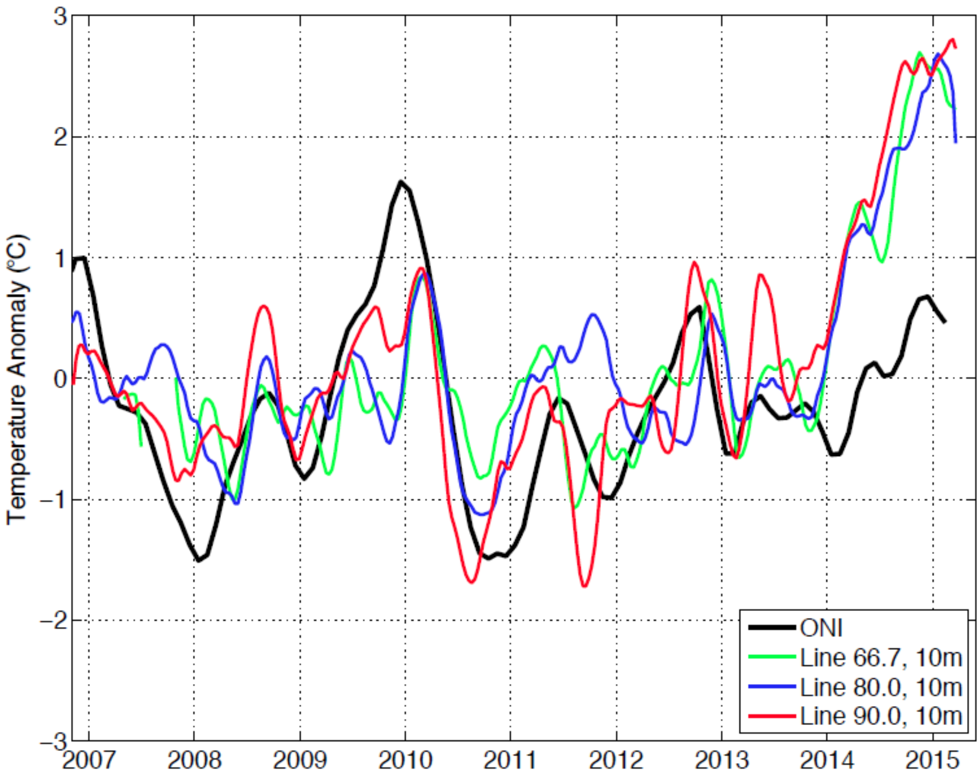

Figure 2: Temperature anomalies at 10 m along Line 66.7 (green), Line 80 (blue) and Line 90 (red), averaged over the inshore 200 km and filtered with a 3-month running mean. "Oceanic Niño Index" (black) filtered with a 3-month running mean.

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Physical-chemical anomalies and associated ecological responses in southern California kelp forests

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ABSTRACT

The Santa Barbara Coastal LTER (SBC LTER) is an interdisciplinary research and education program established in April 2000 with funding from the National Science Foundation. Its principal research objective is to gain a predictive understanding of the importance of land and ocean processes in structuring coastal ecosystems altered by disturbance and climate. The focal ecosystem of SBC LTER is giant kelp (*Macrocystis pyrifera*) forests, a diverse and highly productive system that occurs on shallow rocky reefs at the interface of the land-sea margin in California and other temperate regions throughout the world. An important element of SBC's research involves characterizing spatial and temporal dynamics of a diverse array of physical and chemical drivers and their associated ecological responses over the long-term (data since 2002 are publically available at http://sbc.lternet.edu//data/dataCollectionsPortal.html). We are analyzing these time series data: (1) to characterize the magnitude of "blob-associated" changes in the physical and chemical properties of inner shelf waters (8-30 m water depths) of the Santa Barbara Channel, and (2) to determine whether there were corresponding changes in the ecological characteristics of giant kelp forest communities.

The first signs of anomalous warming of bottom waters within kelp forests of the Santa Barbara Channel may have appeared in early 2013 when anomalies turned mainly positive. Apart from spring upwelling in 2013 when temperature anomalies were neutral, positive anomalies have been recorded every month since early 2013 with deviations ranging as high as 3.8°C above the 14-year monthly mean. This is unprecedented in the time series (Figure 1a). Positive anomalies in salinity (ΔS) were also observed every month since late 2012 and ΔS exceeded 0.3 for several months in 2013 and 2014. Positive ΔS values occurred in previous years, but were weaker and shorter in duration. Apart from 1-2 months, anomalies in nitrate, phosphate, and silicate turned consistently negative in late 2012. However, comparable anomalies in these nutrients occurred earlier in the record, especially before 2008 for nitrate and phosphate (Figure 1a). We are currently investigating the source waters of the positive ΔS and the causes of decreased nutrients.

Large anomalies in key ecological characteristics of giant kelp forests associated with the large positive temperature anomalies have not been observed. Water column chlorophyll *a*, the standing biomass of giant kelp and reef fish, and the nitrogen content of giant kelp were lower, and densities of recently settled sea urchins were higher than normal, but not markedly so compared to prior years (Figure 1b). Shorter time series data on pigment

concentrations in kelp revealed a declining trend in recent years consistent with the below-normal levels observed in kelp tissue nitrogen. The most dramatic change in kelp forests that coincided with the onset of the "blob" was observed in sea star species, which first showed signs of a wasting disease in fall of 2013. The disease spread rapidly from north to south and by spring 2014 infections were prevalent throughout southern California.

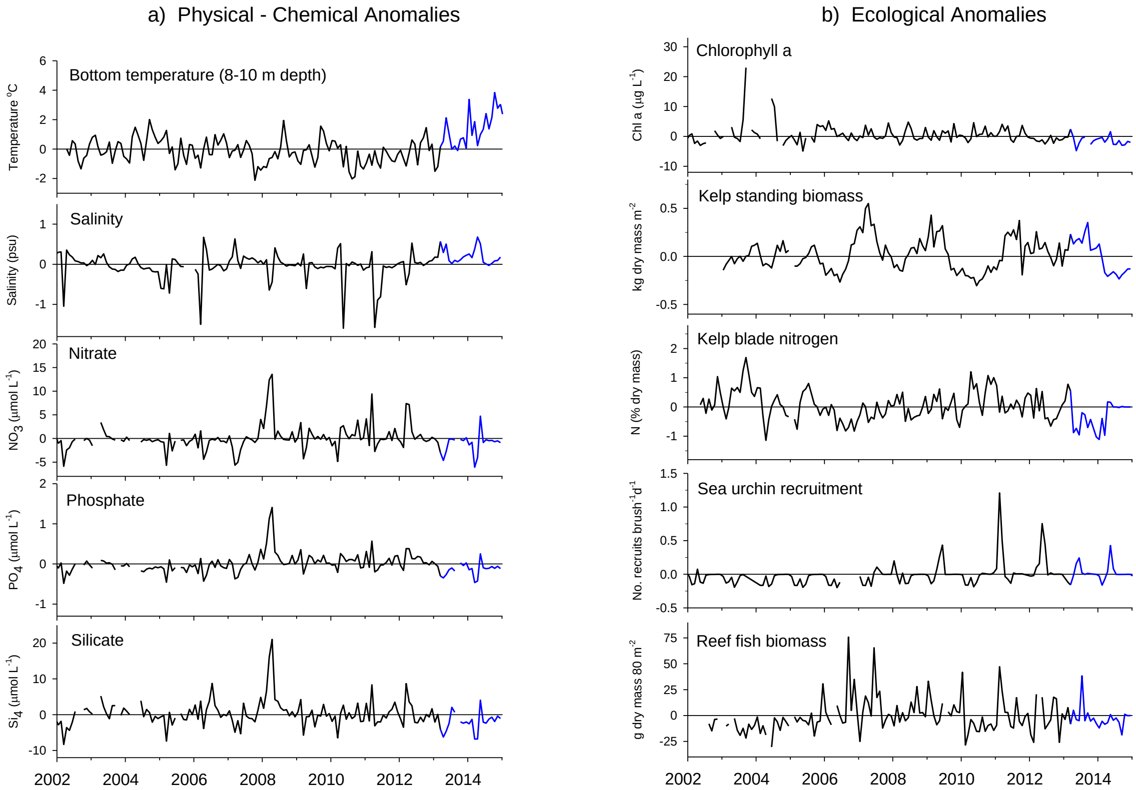

Figure 1. Mean monthly anomalies of: (a) temperature, salinity, and nutrients of inner shelf waters of the Santa Barbara Channel and (b) ecological characteristics of giant kelp forests in the Santa Barbara Channel for the period 2002-2014. Values beginning in March 2013 are shown in blue. Monthly values for bottom temperature and salinity represent the mean of measurements recorded every 10-20 minutes at five kelp forest locations. Monthly values for nitrate, phosphate, silicate and chlorophyll *a* represent depth-averaged means obtained from monthly water samples at five kelp forests. Monthly values for kelp standing biomass and reef fish biomass represent the mean of monthly measurements collected at 3 kelp forests. Mean monthly values for the nitrogen content of kelp blades is based on a composite sample (n=15 blades) obtained from three kelp forests. Monthly values for sea urchin recruitment represent the depth integrated mean of the number of recently settled sea urchins on standardized collectors (i.e., brush) deployed at two week intervals at two locations.

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Anomalous biotic conditions in the California Current System in August 2014 in the context of basin-scale forcing

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ABSTRACT

In August 2014 the CCE-LTER group set out for Pt. Conception on the *R/V Melville* in the next in a series of process cruises intended to understand the effects of (sub)mesoscale fronts on nutrient fluxes, grazing, export fluxes, and predator-prey interactions in the California Current Ecosystem. Prior to the cruise, it became apparent that conditions off the Central/Southern California coast were anomalous in many respects. The *Melville* cruise immediately before us had intended to analyze responses to Fe availability in the strong upwelling zone off Central California, but upwelling winds were so weak they had to move much farther north to the Pacific Northwest to find the conditions of interest. The CalCOFI cruise in July 2014 showed that temperature anomalies at 10 m depth exceeded +5º C off Pt. Conception and that Chl-*a* concentrations were anomalously low. *Spray* gliders demonstrated a coherent warming at 10 m depth along 3 sampling lines in Central-to-Southern California. Satellite imagery revealed a broad zone along the California Coast of anomalously high SST (in 12 of 12 regions analyzed) and low Chl-*a* (in 11 of 12 regions), extending ca. 100-150 km offshore. Horizontal gradients in Sea Surface Height were weak.

Subsequent basin-scale satellite analyses reveal that positive temperature anomalies were discernable in the Subarctic Pacific as early as April 2013, persisting through calendar 2013 and extending southward off the west coast of North America by May 2014. Over this same time period, basin-scale Chl-*a* anomalies showed different signs in the Subarctic Pacific and off the west coast of the continental U.S., with generally positive anomalies in high latitudes in spring-summer, concurrent with negative Chl-*a* anomalies in mid-latitudes. This leads to a pattern of positively correlated SST and Chl-a anomalies in high latitudes, but negatively correlated anomalies in mid-latitudes. These results will be discussed in relation to hypothesized forcing of the NE Pacific.

Anomalous flow and ecosystem conditions off southern California during the 2014 Pacific Anomaly

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ABSTRACT
Our mooring off Pt. Conception (CCE2, on the slope in 800m water depth) shows clear signatures of the anomaly starting in summer 2014. The warming seems to reach only to 30m depth, but anomalously low nitrate and chlorophyll is also found in the upper layer. This suggests less intense or less effective upwelling activity. In the preceding spring of 2014, there is some upwelling, but the densities and nitrates remain lower, oxygen higher, CO_2 outgassing is much reduced, and the few chlorophyll blooms are only found later than usual (May/June) (Fig. 1).

Our moored time series show that already at the beginning of the year, unusual conditions exist, with less dense and lower nutrient water in the upper layer. We believe this is related to anomalous poleward flow which already pre-existed in 2013 and early in 2014, as multi-year ADCP data suggest.

The absence of effective upwelling, as evidenced by the biogeochemical data, allows surface heat fluxes and alongshore advection to dominate the heat balance. Surface heat flux alone can explain much of the warming, and poleward flow typically advects warmer water from the south, thus amplifying the local heat gain. We hypothesize that the combined effect of these leads to the anomalous warming.

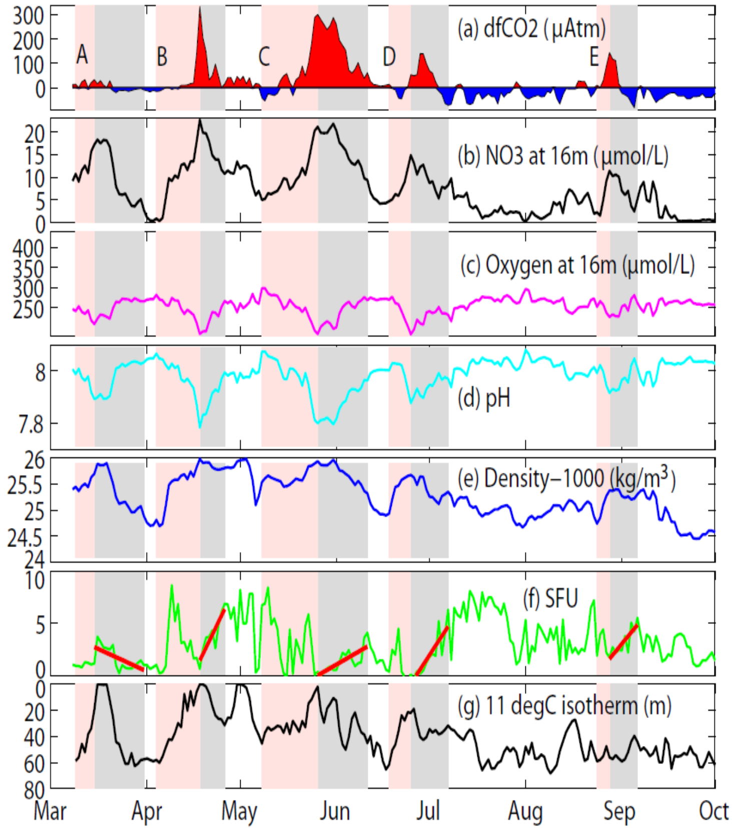

Figure 1a. Time series from the CCE2 mooring from a typical year (2011), with upwelling events marked in pink and subsequent chlorophyll blooms marked in gray.

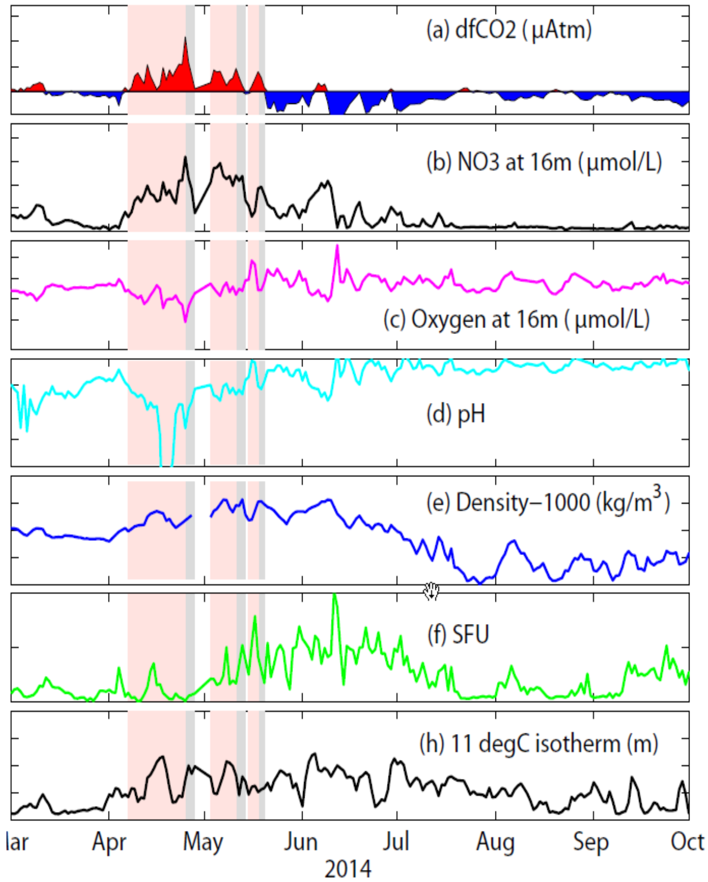

Figure 1b. Time series from the CCE2 mooring from 2014, variables, axes, and shading as above.

The 2014/15 Warm Anomaly in the Southern California Current

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ABSTRACT

The CalCOFI program has been carrying out ocean observations in the California Current System (CCS) since 1949. Since 1984 these observations have centered on the southern CCS. Observations are carried out quarterly, covering a grid of 75 stations. Measurements for the winter of 2014 and the spring of 2015 are not, or, respectively, not yet, available. Measurements that will be presented here are the basic hydrographic properties, concentrations of nutrients and chlorophyll, a proxy for phytoplankton biomass. Measurements are presented either as maps or as the average value of any one property across the 66 standard CalCOFI stations. Values are presented mostly as anomalies (Anom) or anomalies standardized by the standard deviation of the property (StAnom). An extensive set of other measurements, made by the CalCOFI group and California Current Ecosystem Long-Term-Ecological-Research program over the last 12 months, is not yet available.

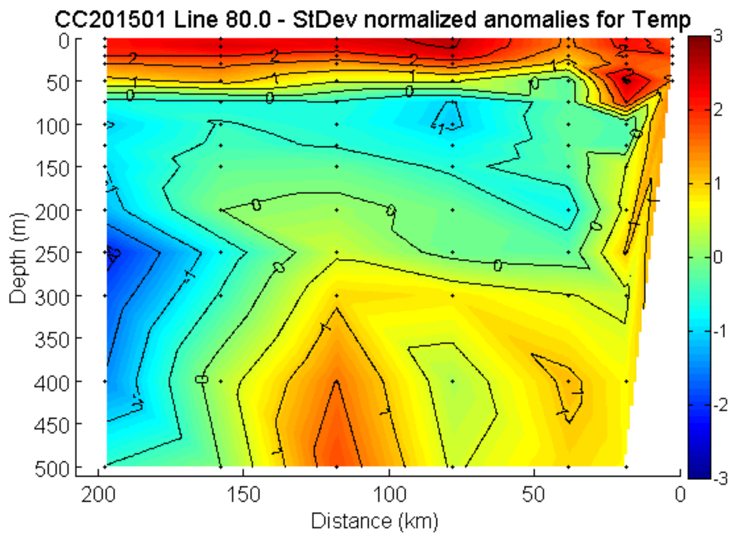

Fig. 1. Standardized temperature anomalies CalCOFI Line 80 (off Pt. Conception) during the winter of 2015.

Significantly positive mixed layer temperature anomalies were already observed during the spring of 2014, when positive anomalies were present throughout the study domain; StAnoms reached values of 1.5. The warming continued through January 2015 when values of StAnoms throughout the domain were larger than 1.5, reaching in some areas values of 3 or higher. Domain averages were almost as high as those observed during the peak of the 1998 El Nino event.

The warming was mostly confined to the upper 50 to 100 m of the ocean (e.g., Line 80, Fig. 1). Temperature anomalies below a depth of 100 m were mostly neutral. Thus, the stratification of the upper 100 m was greatly increased during the fall and winter. These variations as a function of depth are in strong contrast to those observed during the 1998 El Nino, when the strongest anomalies were observed in the thermocline of the eastern part of the domain, leading to a weakening of the stratification in the upper

100 m. Isopycnals in the thermocline were displaced downward during both, the 1998 El Nino and the 2014/5 Warm Event.

Anomalies of salinity in the mixed layer and spiciness on isopycnals at depth did not respond to the Warm Anomaly. In contrast, nitracline depths (the depth where concentrations of nitrate reach values of 1 uM) were unusually high and concentrations of nitrate, and other macronutrients were unusually low in the mixed layer, similar to observations during the 1998 El Nino.

Phytoplankton biomass, which is likely limited by the availability of inorganic nitrogen over large areas of the domain, was unusually low during the last 9 months. Low concentrations of nitrate and phytoplankton biomass are usually due to weak upwelling-favorable winds in the region. This was not the case for most of 2014/15 when upwelling favorable winds were normal, with the exception of July and August of 2014.

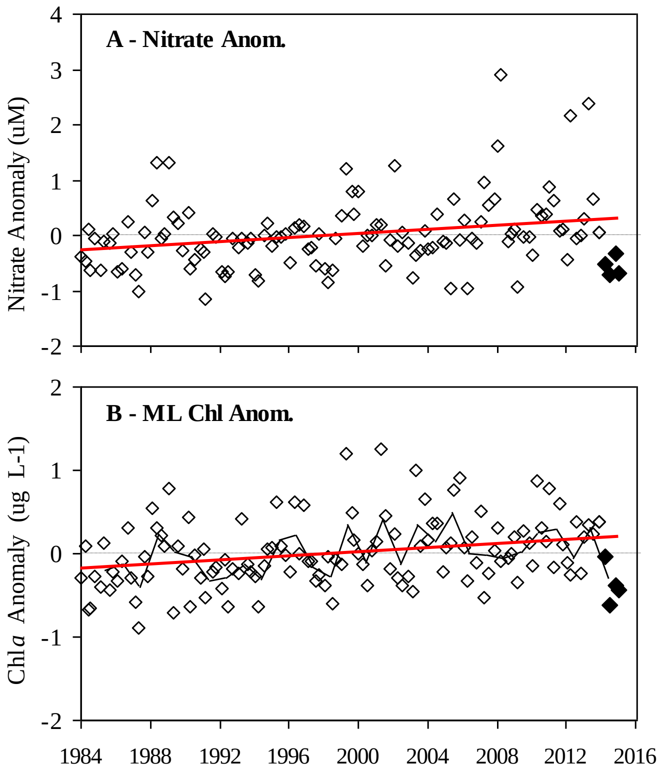

Fig. 2. Mixed layer nitrate (A) and Chl a anomalies for all CalCOFI cruises since 1984. The data from the last four cruises, spring of 2014 to winter of 2015 are shown as solid black symbols. Increasing trends for both data sets (red line) are significant.

To conclude, the limited perspective provided by the CalCOFI data and time series suggests that the 2014/15 warm anomaly was due to a change in the water masses advected into the region. The anomalously warm surface layer that has been present since the middle of 2014, serves as a cap on the system, inhibiting the transport of nutrients from depth into the euphotic zone. This lack of nutrients reduces the productivity of the system with likely significant effects on the rest of the ecosystem.

Changes in Temperature, Salinity and Chlorophyll at Coastal California Stations

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ABSTRACT

The idea of anomalous events elicits the question: "change as compared to what?" That is, some background or baseline information is required to define the meaning of the word change. Using long-term data sets of temperature, salinity and chlorophyll as baseline observations, we can determine the sign, magnitude and frequency of change. Beginning in 1916 at Scripps Institution of Oceanography Pier (La Jolla, CA), daily measurements of sea surface temperature and salinity provide a context to evaluate the recent and most rapid temperature increase event since the generalized warming of the late 70's. Chlorophyll concentration at this location has declined strongly since November 2012. Warm temperatures and low chlorophyll have also been observed at other Southern California Bight stations.

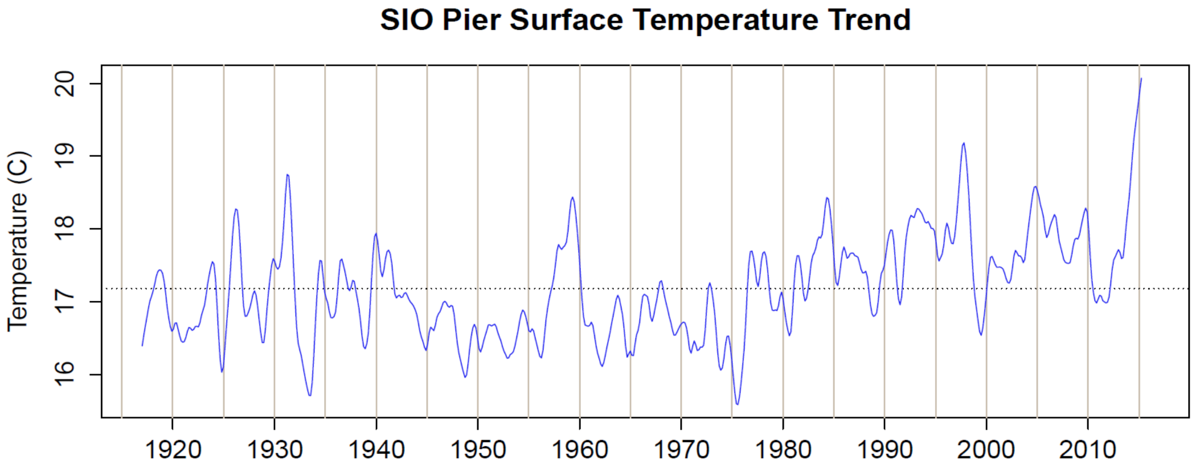

Figure 1. Scripps Institution of Oceanography Pier Sea Surface Temperature 1916- Feb 2015. Temperature data are loess smoothed with a quarterly window to remove seasonality

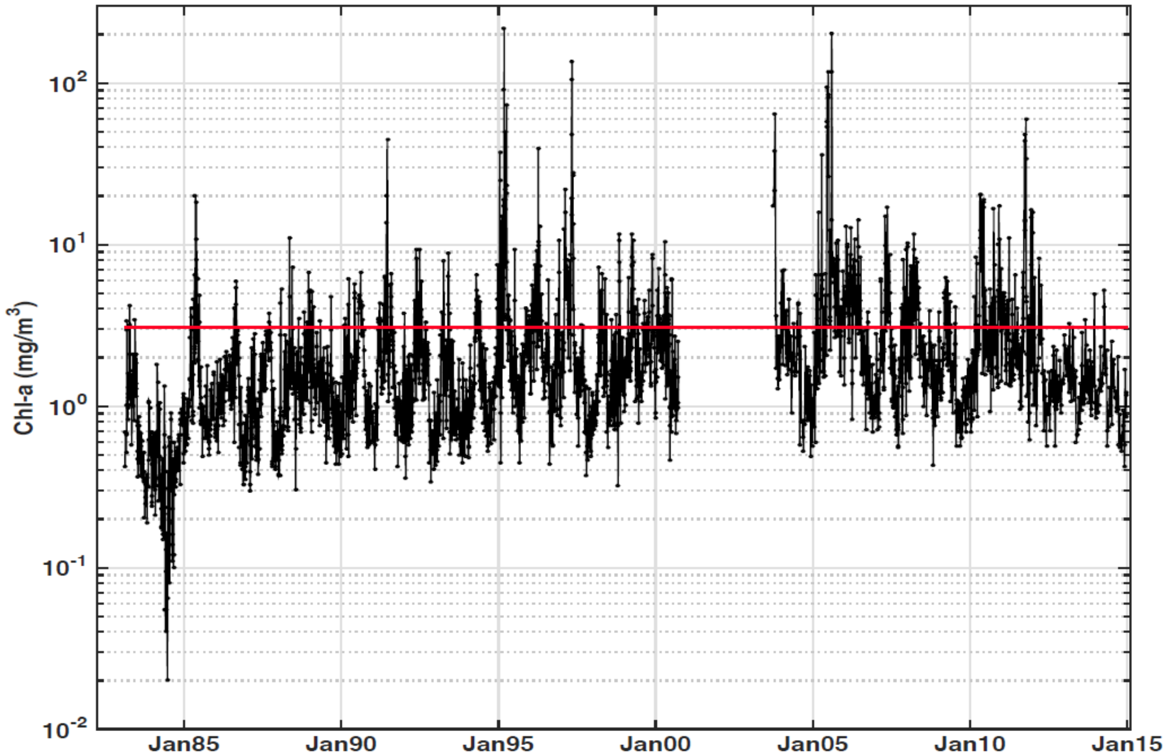

Figure 2. Scripps Institution of Oceanography Pier Chlorophyll Timeseries (1983-2000, 2004-2014)

Response of mid-shelf zooplankton assemblages off northern California to warming event of 2014

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ABSTRACT
Since early 2008, we have sampled zooplankton and their environment along the Trinidad Head Line (THL; 41° 3.5’ N) at approximately monthly intervals throughout the year, with the goal of characterizing ecosystem state at the base of the food chain. Here, we present evidence that the coastal zooplankton community present off northern California was strongly influenced by the arrival of unusually warm water in 2014.

We analyze copepod community structure at a mid-shelf station (TH02; 75m depth) based on samples taken with a vertical tow from 100 m (or within a few meters of the sea floor) of a 0.5 m diameter ring net fitted with 202 µm mesh and a TSK flowmeter. We also characterize the euphausiid community based on analysis of zooplankton sampled with oblique tows (max. depth of 100 m) of a standard CalCOFI bongo net fitted with 505 µm mesh on one side and 335 µm mesh on the other. CTD casts measuring temperature, salinity, fluorescence, transmissivity, PAR, and dissolved oxygen are conducted at each station.

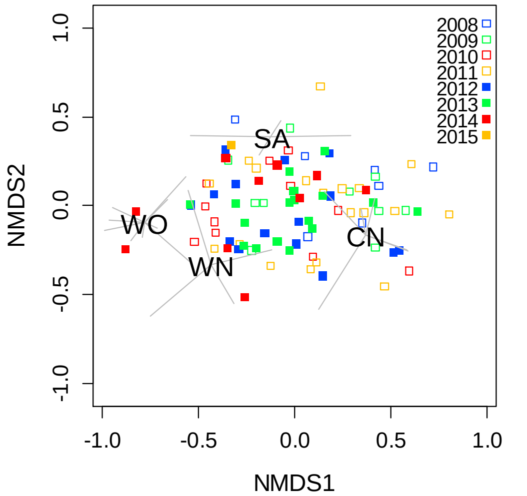

Figure 1. NMDS ordination of mid-shelf copepod assemblages, relative to position of cold-neritic (CN), sub-arctic (SA), warm-neritic (WN) and warm-oceanic (WO) species (following Hooff & Peterson, 2006).

We applied non-metric multi-dimensional scaling (NMDS) to discern structure within the copepod assemblage observed at the mid-shelf station (TH02, 41° 3.5’ N, 124° 16’ W, 75m depth). The first axis of this ordination (NMDS1) distinguishes assemblages with abundant cold-water, neritic species from those dominated by species with warm-water or oceanic affinities (Figure 1). Seasonal transitions between cold-water and warm-water assemblages occur each year, with variability in assemblage structure corresponding to water mass characteristics and reflecting unusual transport patterns or the influence of climate events (e.g., the 2009-10 El Niño) (Figures 2 and 3, Bjorkstedt et al. in prep). In the second half of 2014, reduced upwelling and the subsequent arrival of unusually warm waters associated with “The Blob” caused an earlier than usual decline in the prevalence of cold-water copepods—which began in July—and observation of an assemblage dominated by warm-water, oceanic copepods to an extent not previously observed (Figures 1-3). Moreover, we observed several species of copepod not previously reported in the THL time series. Changes were also observed in the euphausiid assemblage, with the appearance of a warm-water species (e.g., *Euphausia recurva*) not previously observed in our record.

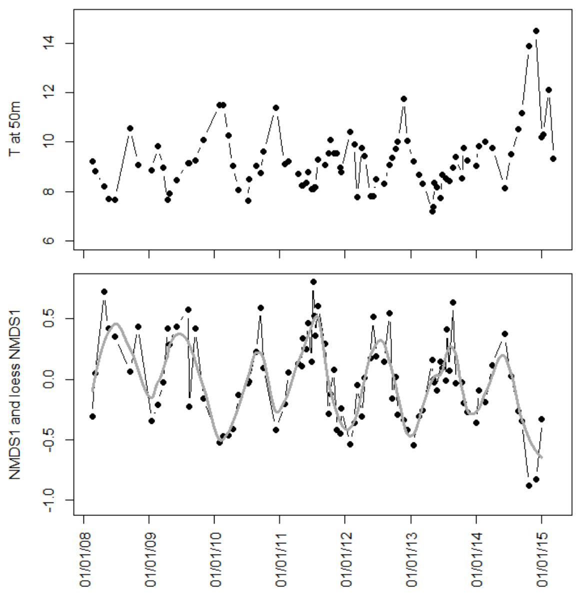

Figure 2. *Upper panel:* Time series of temperature measured at 50 m depth at TH02. *Lower panel:* Time series of NMDS1 for the copepod assemblage at TH02,with loess fit to the time series.

References

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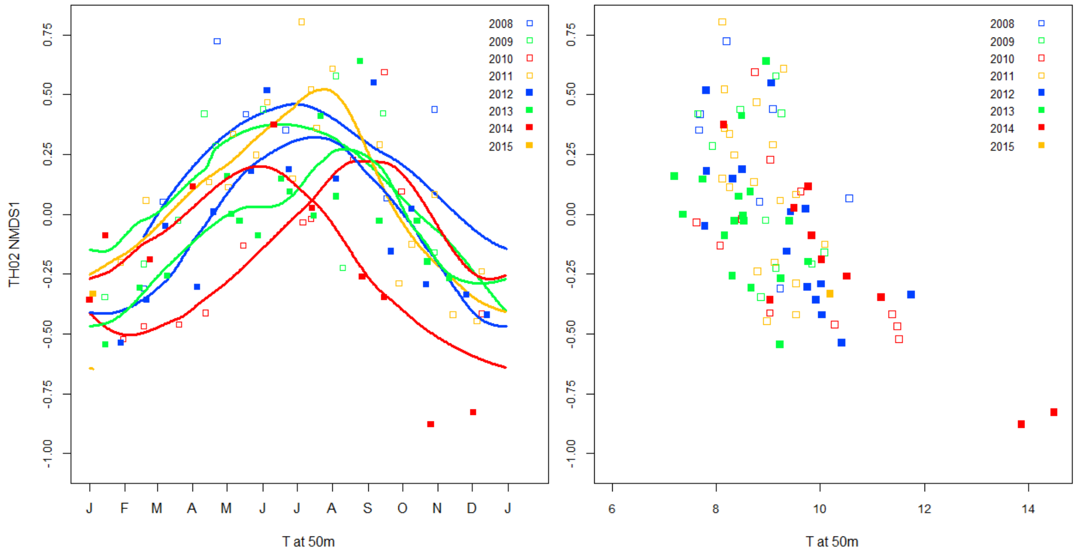

Figure 3. Left panel: Year-by-year series of NMDS1 for copepod assemblage at station TH02 along the Trinidad Head Line, with loess fit to the (full) time series. Right panel: NMDS1 in relation to temperature at 50m depth at station TH02.

Conveying the 2014-2015 warm anomaly environmental and ecological conditions to fishers, regulators, legislative staffers and federal employees

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[3]Over fifty NOAA, academic and NGO scientists contribute to creating the CCIEA documents and web content.

ABSTRACT

The NOAA Integrated Ecosystem Assessment (IEA) program promotes ecosystem-based management at five large marine ecosystems around the United States. The California Current IEA (CCIEA)[1,2] is the most mature program and provides annual ecosystem updates to the Pacific Fishery Management Council to assist them with regulating West Coast fisheries. The March 2015 presentation[3] to the PFMC focused on the evolution of the "warm blob" (http://www.washingtonpost.com/news/energy-environment/wp/2015/04/10/the-pacific-ocean-may-have-entered-a-new-warm-phase-and-the-consequences-could-be-dramatic/), the warm anomaly off Baja California and the leading indicators on how the marine environment was responding to these unprecedented conditions. The goal of the CCIEA is to synthesize the ecological state into knowledge that will assist regulators in their decision-making for setting fishery limits. The result of this year's presentation is that two of the Council subcommittees that report on ecosystem issues have been tasked with working with the CCIEA team to identify those indicators from environmental, ecological and human dimension factors that will best assist the Council.

The recent presentation included discussion of the large-scale indicators: (PDO, NPGO, ENSO), the three phases of the "blob," coastal upwelling, the warm air temperatures and lack of snow pack. The leading indicators are the switch to southern copepod species along the Newport line, the starving sea lion pups and the huge numbers of dead Cassin's Auklets. The associated indicators of ecological integrity were represented by time series discussions of forage fish, Chinook salmon escapement status, and groundfish status. Human activities and human wellbeing indices related to the fishing industry were presented, followed by a synthesis of the indicators and a presentation of conceptual models to tie it all together.

Publicity from this integrated story to the Council raised considerable interest in the ongoing conditions and the IEA program. Variations of the presentation have been given to federal congressional staffers, NOAA management and multiple news outlets.

This presentation will focus on the material presented to these regulators, staffers and federal managers and will discuss those elements which best conveyed the material on how the environmental condition impacts propagate through the ecosystem up to human activities.

[1] The full CCIEA report can be viewed at: http://www.noaa.gov/iea/CCIEA-Report/pdf/index.html

[2] The CCIEA Summary/Introduction is viewed at: http://www.noaa.gov/iea/Assets/iea/california/Report/pdf/A.CCIEA%20Phase%20III%20Introduction_2013.pdf

[3] The two presentations to the Pacific Fishery Management Council are available at: http://www.pcouncil.org/wp-content/uploads/2015/03/E1b_Sup_IEA_PPT1_ElectricOnly_Werner_Stein_MAR2015BB.pdf and http://www.pcouncil.org/wp-content/uploads/2015/03/E1b_Sup_IEA_PPT2_ElectricOnly_Garfield_Harvey_MAR2015BB.pdf

Southern California Coastal Fish Community Response to the 2014 Anomaly

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ABSTRACT

Using three unique long-term time series of nearshore fish abundance and biomass, the response of southern California coastal fishes to the anomalous conditions of 2014 was investigated. Since at least 1980, demersal fish and invertebrate surveys have been conducted with otter trawls during summer offshore of Sam Clemente (6, 12, and 18 m isobaths) and offshore of Huntington Beach (6 m). In addition, fish impingement has been monitored at the Huntington Beach Generating Station (multiple times per year). These data provide robust resolution on species-specific abundance, biomass, diversity, and size of the fish communities at these locations. Prior studies affirmed the fish impingement at Huntington Beach Generating Station represents patterns in coastal midwater fishes throughout the Southern California Bight (Miller and McGowan 2013). Utilizing these data, this investigation examined what, if any, changes in the juvenile and adult fish communities occurred. Furthermore, using the impingement monitoring data, an assessment of recruitment was made to determine how the 2014 year class (for select species) compares with the prior 40 years.

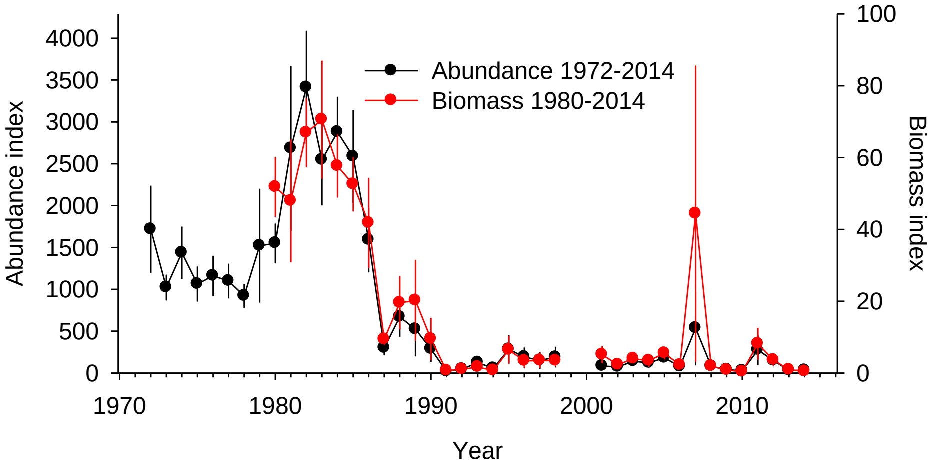

Figure 1. Mean annual abundance and biomass indices for fishes entrapped at the Huntington Beach Generating Station.

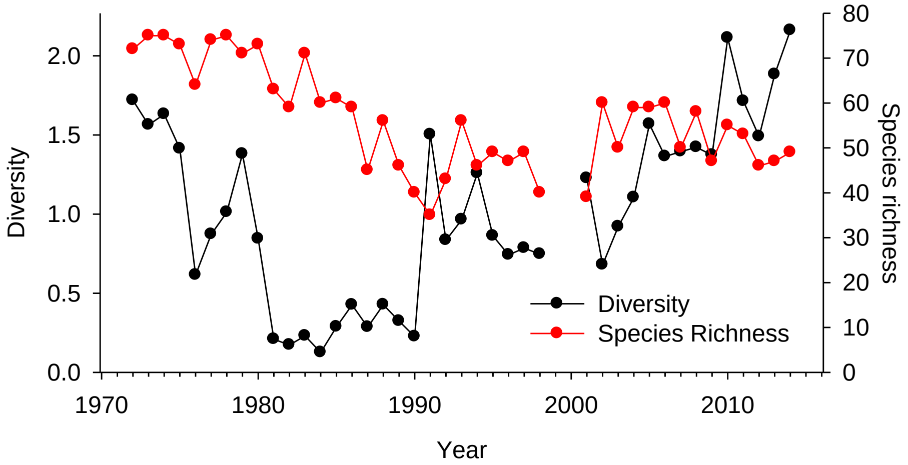

Figure 2. Annual species diversity (H´) and species richness of fishes entrapped at Huntington Beach Generating Station.

References

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Temperature Anomalies in the Waters near Two San Diego Ocean Outfalls

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ABSTRACT

The City of San Diego (City) collects a suite of oceanographic data at permanent (fixed) sampling stations in the coastal waters off San Diego as part of its two National Pollutant Discharge Elimination System permits that govern the discharge of wastewater to the ocean via the Point Loma and South Bay ocean outfalls. These stations range in location from offshore of Mission Bay southward to near Los Buenos Creek in northern Baja California, Mexico, and span depths from about 9-100 m (Figure 1). Sampling is conducted on a variety of timescales from weekly to quarterly. Stations in the Point Loma Ocean Outfall (PLOO) monitoring region have been sampled since 1991, while stations for the South Bay Ocean Outfall (SBOO) monitoring region have been sampled since 1995. Historically, data collected have included temperature, conductivity (salinity), dissolved oxygen, pH, transmissivity, and chlorophyll *a*. Colored dissolved organic matter (CDOM) has also been measured at selected stations since 2010. Additionally, the City has had moored instruments in place near the PLOO since mid-2006 to measure currents and temperature in order to model and track the outfall plume (Parnell and Rasmussen 2010, Rogowski et al. 2012). In 2014, moored instruments were also deployed near the SBOO. Temperature data at these moorings are collected every 10 minutes from strings of thermistors spaced every four meters starting from 2 m above the bottom to 6 m below the surface.

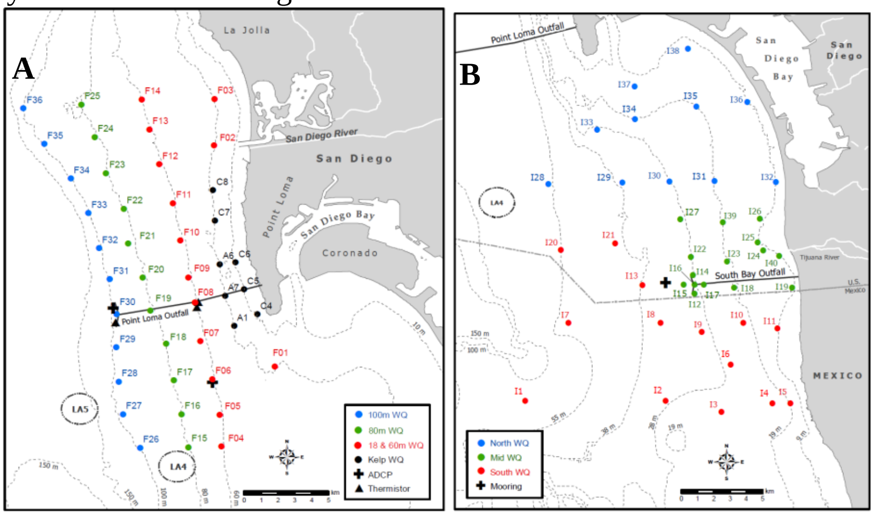

Figure 1. Long term CTD sampling stations and moored instrument locations near (A) the Point Loma Ocean Outfall and (B) the South Bay Ocean Outfall.

Mooring data highlight 2014 as being particularly warm with deviations above the mean of 3-4°C throughout the water column during the year (Figure 2A & 2B). Data from CTD measurements, which have a longer time frame but a coarser time scale, show that positive anomalies as high as 7°C were present in 2014 (Figure 2C).

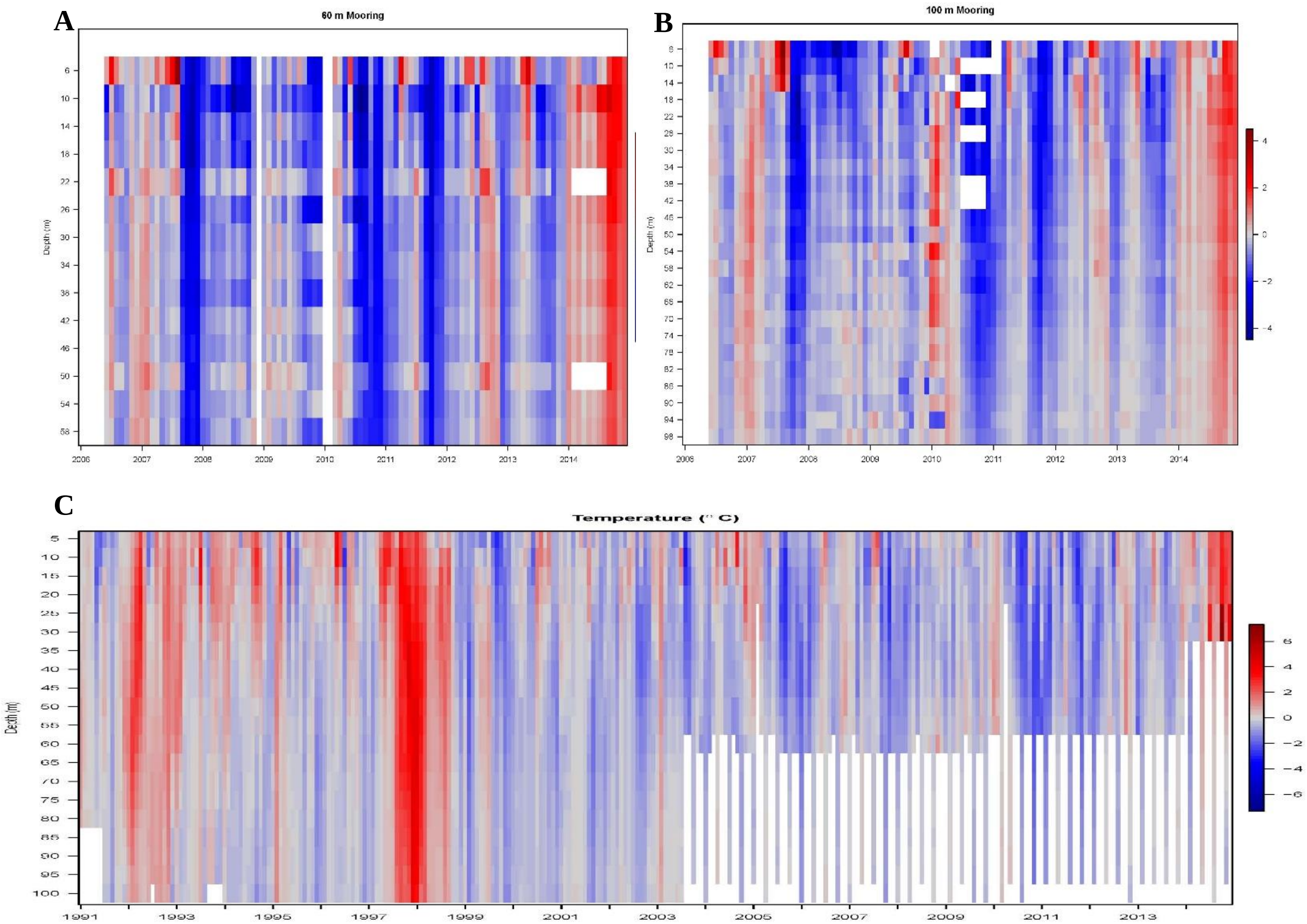

Figure 2. Temperature anomalies from 2006 through 2014 at the PLOO 60m (A) and 100m (B) moorings, and from 1991 through 2014 at all PLOO and SBOO CTD stations combined. White spaces indicate missing data.

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Trends in forage and implications for California sea lions

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ABSTRACT
In the last decade off central and southern California, fishery independent surveys have shown that sardine and anchovy greatly decreased in biomass, while market squid and rockfish abundance increased. The 2014 sardine stock assessment estimated the lowest biomass since 1993. Sardine and anchovy egg counts were extremely low in Spring 2015 compared to 1997 to 2014. Emaciation of California sea lion pups increased in early 2015, suggesting that declining forage may play a role. The trends in biomass of commercially important fish species are not simply related to trends in sea lion abundance or pup weight. We hypothesized that sea lion pup weights were related to the nutrition they received through the mothers' milk, and that the mothers' foraging success would be related to the relative abundance and quality of forage. The observed shift in relative abundance of forage taxa changed the food quality of forage in terms of calories and fats. Sardine and anchovy are both higher in fat and calorie content than rockfish or squid. The quality of forage has declined over the last decade as a result. Sea lion pup weights fell as forage food quality declined associated with the shift in the relative abundances of forage species. Derived variables representing the abundance of high and low quality forage can predict the temporal pattern of emaciation in sea lion pups (correlation between observed and modeled estimates is ~95%). The large sea lion population combined with shifting forage composition and consequent reduction in food quality off south-central California and southern California near breeding colonies suggests that pup emaciation may become the norm until high-quality forage increases again in the southern California region.

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Recent anomalies in pinniped stranding trends along the Central California Coast

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ABSTRACT
Marine mammals are exposed to numerous stressors that can result in changes in their health and mortality, including ship traffic, noise, fisheries interaction, localized prey depletion, biotoxins, pathogens, and pollutants. Consequently, marine mammals are classified as sentinel species that can provide insight into the overall health of marine ecosystems. As highly mobile organisms with long generation times, large body sizes, and protected status, marine mammals often are difficult to study. However, marine mammals that wash ashore (“strand”) provide greater access to these wild animals, and spatiotemporal trends in marine mammal strandings have been correlated with anomalous oceanographic conditions (Melin et al. 2010) as well as harmful algal blooms (Torres de la Riva et al. 2009) in California.

Since 1975, The Marine Mammal Center (TMMC) has been authorized by the National Marine Fisheries Service to respond to and collect data from marine mammals that strand along the California coast from San Luis Obispo (SLO) to Mendocino (MEN) County. TMMC’s range expanded to include Santa Barbara (SB) County in 2014. For this study, pinniped stranding data was compiled for 2014 and 2015, and these data were compared to previous stranding trends. Total stranding numbers for 2014-2015 were calculated for MEN-SB and MEN-SLO Counties, with California sea lions (CSL; *Zalophus californianus*) representing 93% of the stranded pinnipeds admitted to TMMC from SB County. Statistical comparisons excluded data collected before 1997, the year when consistent recovery efforts began (Melin et al. 2010).

Overall, a greater number of pinnipeds stranded in 2014 ($n_{MEN-SB} = 985$, $n_{MEN-SLO} = 803$) to date in 2015 ($n_{MEN-SB} = 1061$, $n_{MEN-SLO} = 736$) compared with mean annual strandings from 1997-2013 (685 ± 78). Specifically in 2014, a greater number of CSL, most of which were adult females, stranded with signs of acute domoic acid toxicosis (n = 163) compared with previous years (41 ± 8), and there were increased northern elephant seal (*Mirounga angustirostris*; $n_{2014} = 154$, $\bar{x}_{1997\text{-}2013} = 126 \pm 9$) and northern fur seal (*Callorhinus ursinus*; $n_{2014} = 28$, $\bar{x}_{1997\text{-}2013} = 12 \pm 3$) strandings. In the spring of 2015, a majority of the stranded pinnipeds were CSL that are less than two years old (n = 664). In addition, although Guadalupe fur seals (GFS; *Actocephalus townsendi*) infrequently strand in California, with zero to five stranding annually from 1977-2014, 12 GFS stranded and were admitted to TMMC in the first four months of 2015.

The timing of pinniped strandings, and specifically of CSL less than two years old, also has been anomalous in recent years. Whereas a majority of young CSL typically strand in the summer (May-July, 53 ± 3%), the peak in strandings for CSL age 0-2 years shifted to the spring (March-May) in 2013 and 2014 and even earlier in 2015 (Figure 1).

The increased number of pinnipeds that stranded on California beaches in 2014 and the spring of 2015 was similar to previous years in which anomalous oceanographic conditions were observed in the California Current System (CCS). Greater numbers of pinniped strandings have occurred in the summer following strong El Niño events (1992 and 1998) and when strong negative upwelling persisted in the summer (2009). The summer is when CSL pups are weaned at approximately one year of age, which likely makes them particularly vulnerable to these environmental perturbations. Furthermore, CSL are the most abundant year-round marine mammal residents in the CCS. In recent years, the shifted peak in strandings of young CSL to the spring months indicates lactating females are unable to adequately provision their pups, rather than pups failing to thrive after weaning. Because adult female sea lions are experienced foragers, failure by mothers to find enough food to nurse their pups may indicate greater depletion of or changes to fish stocks than previous years with persistent, large-scale oceanographic anomalies in the CCS. The increase in females with domoic acid toxicosis in 2014 also may reflect a further contribution to lactational failure in affected animals. Thus, marine mammal stranding data adds another layer to improve the overall understanding of the CCS and ecosystem health.

Despite marine mammals being an integral component of marine ecosystems and sentinel species that generate considerable public interest, marine mammal health and stranding data currently are not readily accessible or integrated with biogeochemical and physical oceanographic parameters. Therefore, efforts are underway to collate existing marine mammal data into a database (the “Marine Mammal Health Monitoring and Analysis Platform”, or MMHMAP) compatible for integration with environmental datasets and accessible by the public within the Integrated Ocean Observing System (IOOS), which will facilitate research collaborations, science-based management, and public awareness.

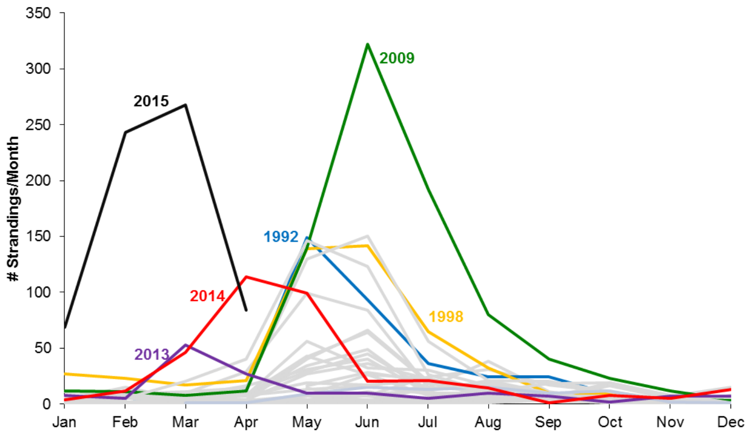

Figure 1. Monthly number of California sea lions less than two years old that stranded along the California Coast from Mendocino to Santa Barbara County, 1975-2015. The three most recent years and three previous years with anomalous oceanographic conditions are highlighted.

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The warm winter of 2014 in the entrance to the Gulf of California

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ABSTRACT

The southern Gulf of California and the region of the entrance experienced weaker than normal wind forcing during the winter of 2014. We present evidence of its impact on sea surface temperatures (SSTs), upwelling and primary productivity. The entrance to the Gulf of California is the region where all the exchange with the neighboring Pacific Ocean takes place. It is a large oceanic region roughly delimited by Cabo San Lucas, at the tip of the Baja California Peninsula (22º 49' N, 110° W), Cabo Corrientes in the Mexican mainland (20º 25' N, 105° 40' W) and offshore by the Revillagigedo Archipelago (18º 45' N, 111º W). Wind forcing has a monsoonal seasonal variability in the Gulf of California (Douglas et al, 1993), winter winds blow from the northwest and in summer from the southeast. Intense northwesterly wind events lasting several days are common. Pares-Sierra et al. (2003) attribute this pattern to the mountain chains over both coasts, which cause the wind to be funneled along the longitudinal axis of the Gulf. Biological productivity is greatly enhanced by wind-driven coastal upwelling along the eastern coast of the Gulf (Lluch-Cota, 2000). During the winter of 2014 drastic departures from the climatic mean occurred in the lower atmosphere and upper-ocean of the entrance to the Gulf of California. Our discussion will focus on comparing winds, sea surface temperature and primary productivity in successive winter seasons (2013 and 2014). From January-March 2013, during a typical winter, the entrance to the Gulf registered at least three northerly wind events. In contrast, the winter of 2014 only registered one late event around March 16. This is consistent with the relaxation of the winter wind field throughout the Gulf of California, with important consequences on surface temperatures and productivity of the Southern Gulf and the entrance region. In the left panel of Fig. 1a we compare monthly mean SST values in 2013 (left column) with those in 2014 (center column). The column to the right contains anomalies, taken as the difference pixel by pixel (2014 -2013). For January-March 2013 the SST maps show typical winter conditions with lower SSTs in February and March. The warmer waters (>25°C) in February and March are found south of the Marias Islands (21°N) due to the outflow of cool waters from the Gulf. One year later, in January 2014, the position of the 25°C isotherm is located north of the Marias Islands, at about 23°N, and positive anomalies on the east coast of the Southern Gulf reach 3°C. By February 2014 positive anomalies persist at the entrance and the southern Gulf of California continues to warm up (SSTs are 3 to 4°C warmer than in 2013). By March most of the entrance remains about 2°C warmer than 2013 and the southern Gulf contains even larger areas with positive anomalies (up to 4°C). In 2014 the shape of the 25°C isotherm seems to indicate the early advance of the poleward tropical flow into the Gulf (Lavin et al., 2006). The relaxation of the wind forcing in 2014 appears to be directly responsible for the observed warming. Upper-ocean chlorophyll concentrations for 2013 and 2014 are presented in Fig. 1b. Again the winter of 2013 shows typical values with chlorophyll concentrations of 2 mg m^{-3}, or higher (in red). This includes the upwelling region

off Cabo Corrientes. In 2014 upper-ocean chlorophyll concentrations progressively diminish from January to March. This is the opposite tendency to that observed in 2013 when March was the more productive in terms of chlorophyll. In the anomaly maps the southern Gulf and its entrance are shown to be chlorophyll-deficient from January 2014 onwards. In March the region shows no sign of recovery. Even considering the activation of the upwelling zone off Cabo Corrientes, the region as a whole remains low in chlorophyll content.

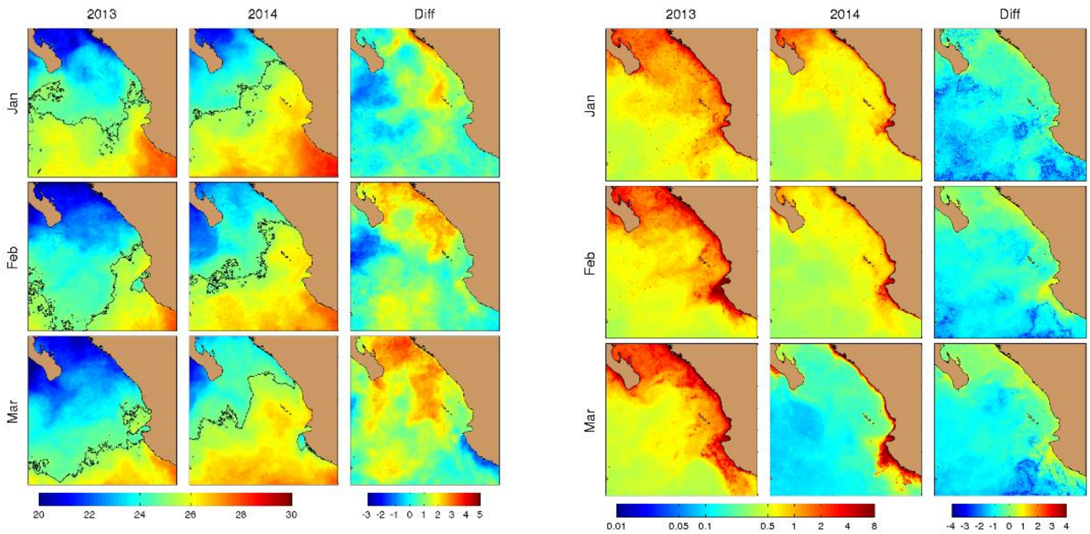

Figure 1. Monthly mean maps comparing the winter of 2013 and 2014; a) SST maps for 2013, 2014 and the anomaly (2014-2013) with positive values indicating warmer temperatures in 2014; b) Chlorophyll concentration (mg m^{-3}) maps for 2013, 2014 and the anomaly (2014-2013) with negative values indicating a deficiency in chlorophyll upper-ocean concentrations for 2014.

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Temperature and Salinity Anomalies on the Northern Gulf of Alaska Shelf

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ABSTRACT

Hydrographic data collected on the northern Gulf of Alaska shelf reveal multi-decadal trends and seasonal to multi-annual fluctuations around these trends (Royer et al., 2005; Janout et al, 2010). Water column stratification is increasing over time, the springtime onset of stratification may be starting earlier, and temperatures are increasing. All of these changes may precipitate adjustments within the biological components of the ecosystem but actual consequences are still as yet unknown.

At station GAK1 on the inner shelf, long-period trends (Figure 1) include warming (~ 0.2 °C decade^{-1}) and freshening (0.15 decade^{-1}) at the surface, while subsurface waters exhibit increases in both temperature (0.15 °C decade^{-1}) and salinity (0.025 decade^{-1}) over waters 100-200 m below the surface. Relationships are found with the PDO (3 month lead, r^2 = 0.38 for temperature and r^2 = 0.15 for surface salinity) and SOI (8-9 month lead, r^2 = 0.20 for temperature and r^2 = 0.20 for salinity).

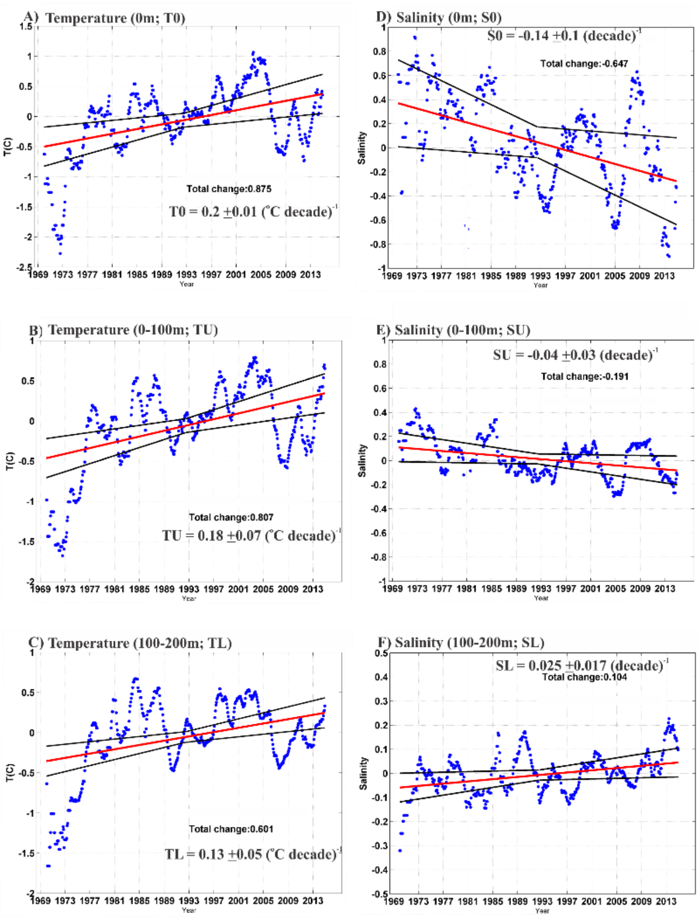

Figure 1. Temperature (left) and salinity (right) trends from station GAK1 over 1970-2014 from the surface (top) and integrated over 0-100m (middle) and 100-200m (bottom).

Temperature and salinity variations are nonuniform across the shelf and with depth (Figure 2). Changes in density (and stratification) are moderated by compensating changes in the temperature and salinity at times but at other times the two parameters work to increase or decrease density together. For example, from 2013 to 2014 the density in the upper 300 m of the water column declined, with temperatures increasing by 2-4 °C near the surface and by up to 0.5° at 200-300 m depth. Over the same time period, salinities tended to decrease at slope and mid-shelf stations, with the largest decrease (> 1) observed at 100m depth at stations beyond the shelf break. Inner shelf station stations salinities decreased from 2013 to 2014 below 100 m depth.

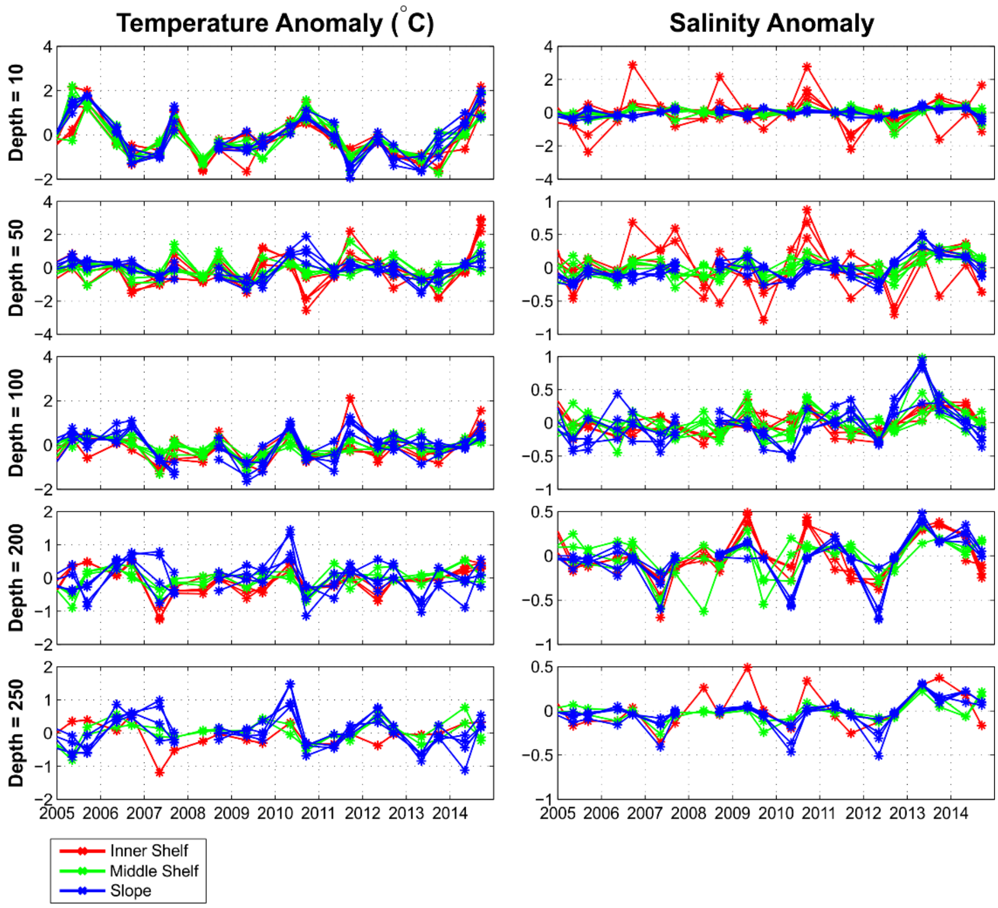

Figure 2. Temperature and salinity anomalies from twice-annual (May and September) hydrographic surveys on the Gulf of Alaska shelf for the 10-year period 2005-2014 at 10, 50, 100, 200 and 250 m depths. Anomalies are color-coded by shelf domain: red = inner shelf (GAK Stations 1-4), green = middle shelf (GAK stations 5-9) and blue = continental slope (GAK stations 10-13). Note change in y-scale amongst panels.

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Plankton on the Northern Gulf of Alaska Shelf during 2014

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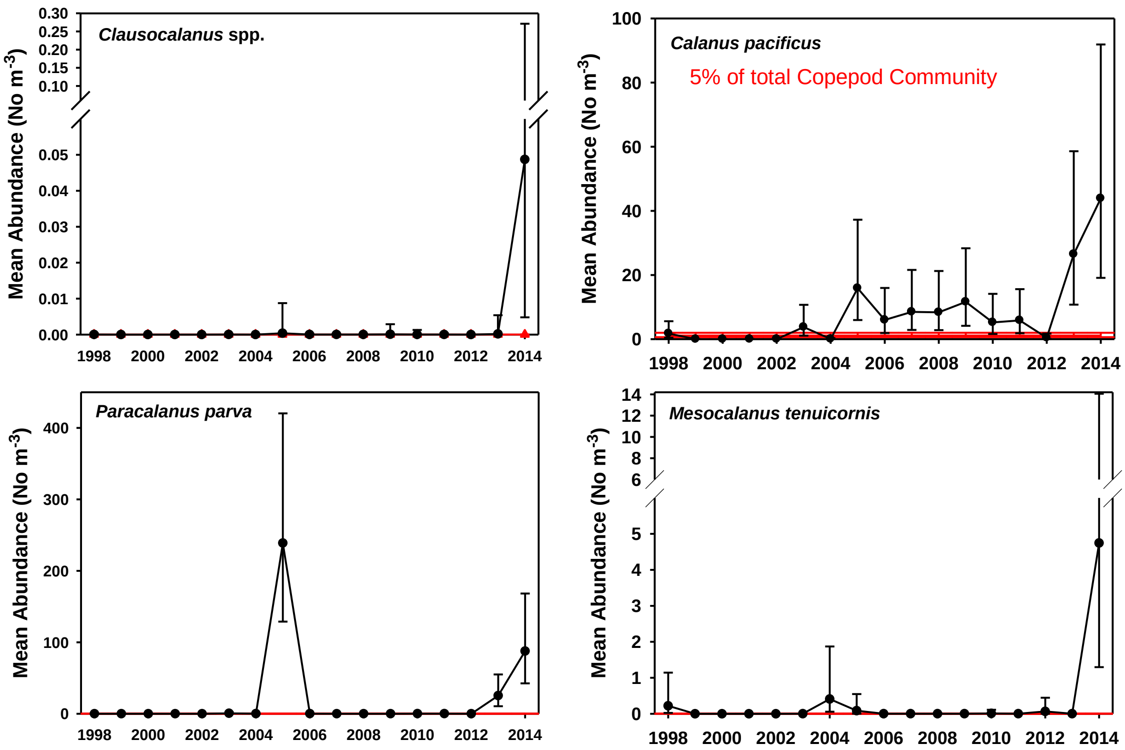
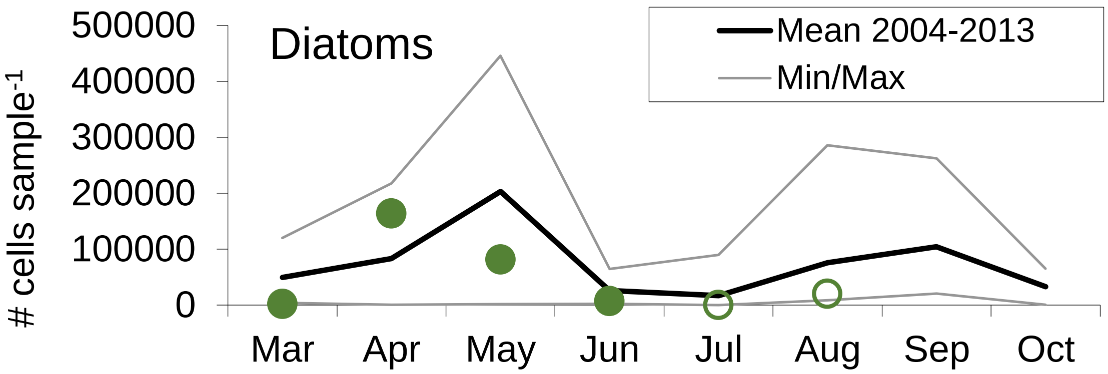
ABSTRACT

The warm conditions of 2014 were evaluated for the plankton times in the Gulf of Alaska: The Seward Line, the Pacific Continuous Plankton Recorder (CPR) program, and the Prince William Sound (PWS) Monitoring program. All three programs show that spring conditions on the shelf and within PWS, were relatively normal, but signals emerged over the summer and through the fall. Monthly observations on the shelf by the CPR program suggest zooplankton abundance was enhanced in summer and fall, although biomass was much less impacted or not altered at all. The September cruise along the Seward Line was relatively normal in terms of total community abundance and biomass across the shelf. Nonetheless, the Seward Line showed significant increases in the four copepods taxa normally associated with southern influence: *Clausocalanus* sp., *Calanus pacificus*, *Mesocalanus tenuicornis*, and *Paracalanus parva*. For all but the last species, values were the highest observed in the 17-year time series. While these same 4 species were observed within PWS, the signal was more muted and/or less atypical.





Diatoms
Mean 2004-2013
Min/Max
cells sample-1
500000
400000
300000
200000
100000
0
Mar
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May
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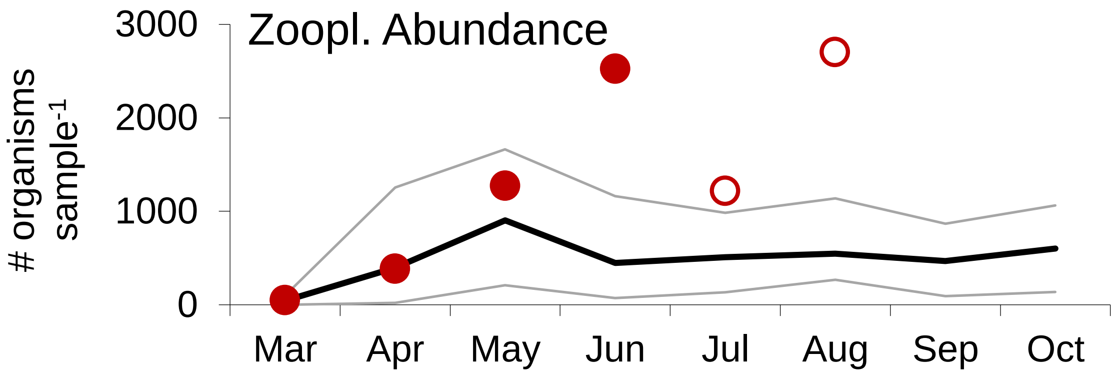

Zoopl. Abundance
organisms sample-1
3000
2000
1000
0
Mar
Apr
May
Jun
Jul
Aug
Sep
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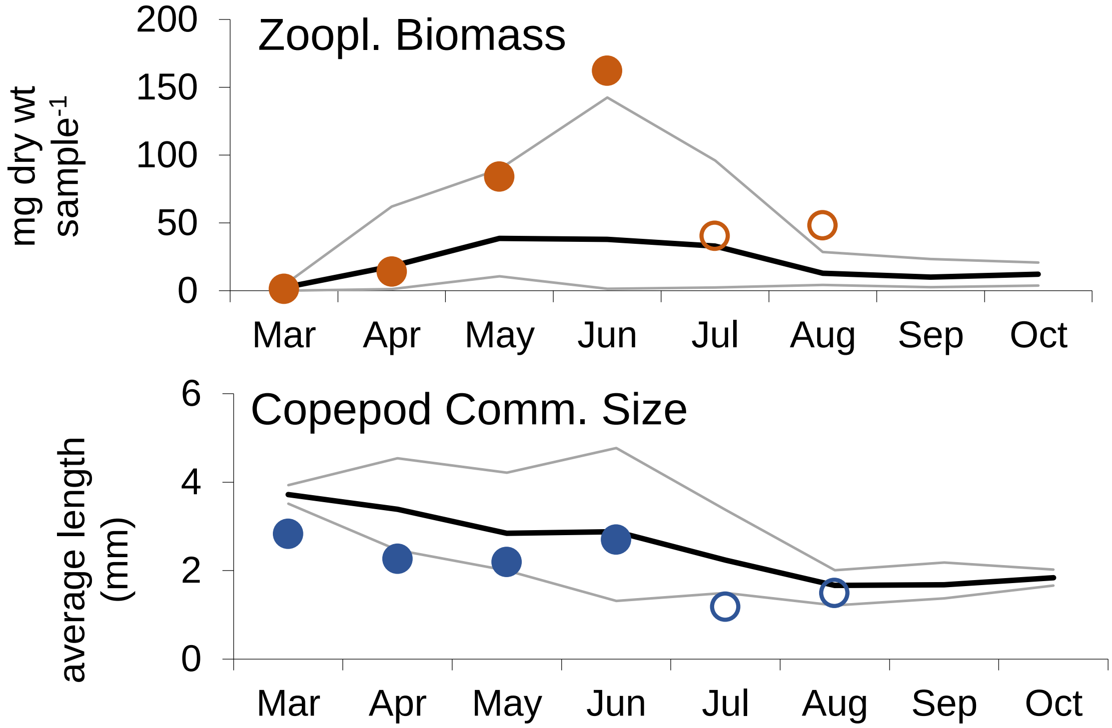

Figure 2. Four plankton indices from the CPR sampling of the Alaskan shelf. The points in each graph show 2014 monthly means values. Filled values are finalized, unfilled values are provisional. The solid line is long-term (2004-2013) monthly mean, with long-term monthly minima and maxima shown by the grey lines.

Tracking Sea Surface Temperature Anomalies along the U.S. West Coast using Coastal Data Information Program (CDIP) Nearshore Buoys

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ABSTRACT

Summer 2014 produced anomalously warm ocean temperatures offshore California, raising questions from both researchers and the general public about how these temperatures compare to previous years, and whether this was an isolated event or part of a larger cycle.

Multi-year time-series of sea surface temperature (SST) along the U.S. West Coast were examined using data from Coastal Data Information Program (CDIP) nearshore buoys, plotted as climatological comparisons (Fig. 1), monthly-averaged boxplots (Fig. 3) and single-day cross-year comparisons (not shown). All stations examined had at least 8 years of data, with some records starting in the early 1990s.

Climatological comparisons reveal that SSTs for Summer 2014-Winter 2015 are the highest temperatures recorded at each station (Fig. 1, Fig. 3) since CDIP monitoring began, although Mission Bay, CA and Point Reyes, CA, had similarly high SSTs during the 1997-1998 El Nino event (October ‘97-March ‘98). California stations south of Cape Mendocino (southern California Current System) began registering anomalously warm SST in June 2014. Stations offshore Oregon and Washington (northern CCS) began registering warm anomalies in October 2014. SST values ranging from 1-5^{o}C above all previous years have persisted through March 2015 at all stations examined.

Monitoring long-term SST variations provides valuable information about physical oceanographic parameters, which can influence the biology and climate of the region, and

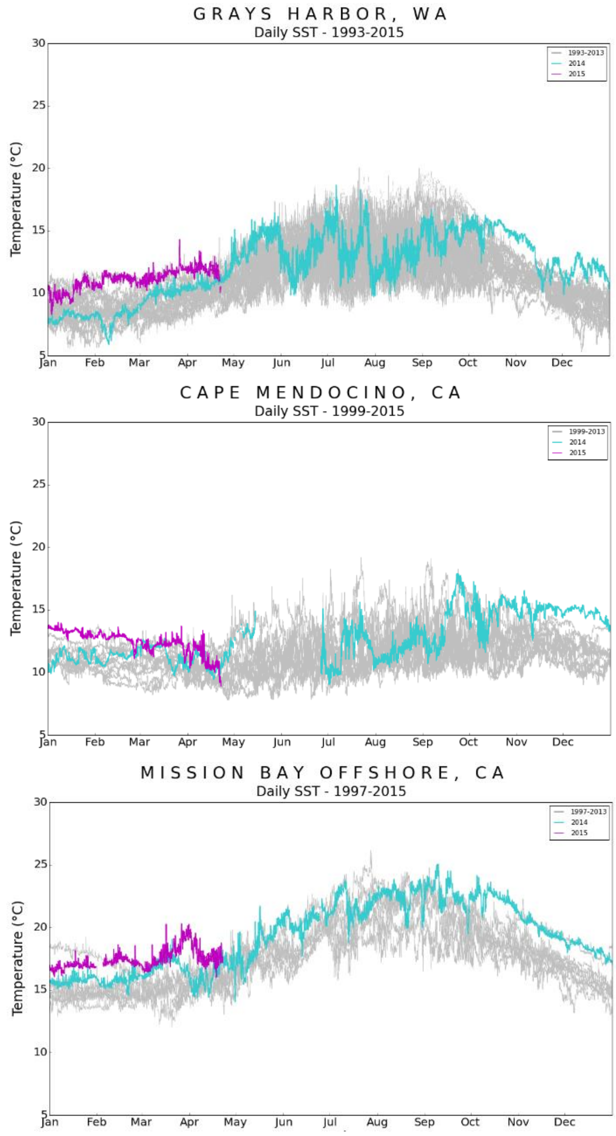


Figure 1. Climatological comparisons of SST at three CDIP buoys. Grey lines represent past years (through 2013), turquoise is 2014, and magenta is 2015. Mission Bay shows anomalously high SST values starting in June 2014, and all three stations show high SST for Fall 2014-Winter 2015.

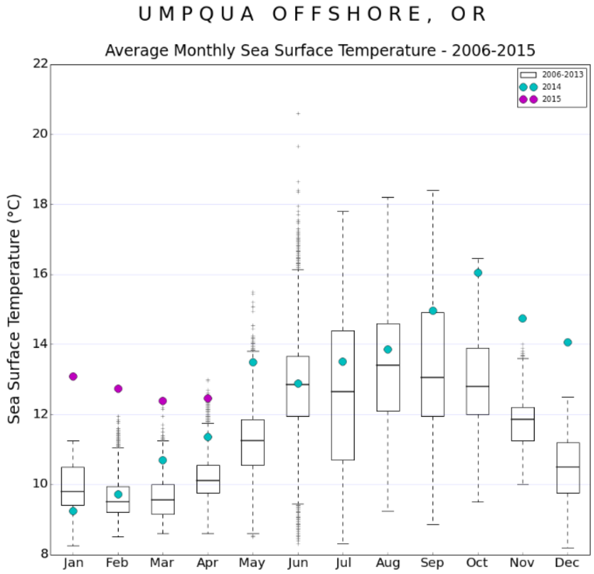
larger-scale processes. Accurate observation and analysis of temperature trends can help inform recreational ocean users and the general public about present ocean conditions and related physical and biological changes (e.g. unusual species sightings, fishing stock status, coastal ocean health, atmospheric changes).

Data Source

Coastal Data Information Program (CDIP) buoys measure nearshore wave parameters and SST. Buoy temperature sensor is located at the hull mooring eye, approximately 45 cm below the water surface. Buoys collect SST data every 30 minutes. Data are transmitted in near-real-time to NDBC servers, disseminated to the National Weather Service, and also available through the CDIP website. Primary CDIP sponsors are the U.S. Army Corps of Engineers and the California Department of Parks and Recreation.

Station Name	Offshore (nm)	Depth (m)
Grays Harbor, WA	4.5	42.4
Umpqua, OR	15.5	183
Cape Mendocino, CA	17.5	334
Point Reyes, CA	21.5	575
Harvest, CA	15.5	549
San Nicolas Island, CA	15.5*	307
Mission Bay, CA	5.5	192

Figure 2. U.S. West Coast CDIP buoy stations and distance offshore. SST climatology stations are labeled and marked in orange.
*Offshore west of San Nicolas Island, Channel Islands.



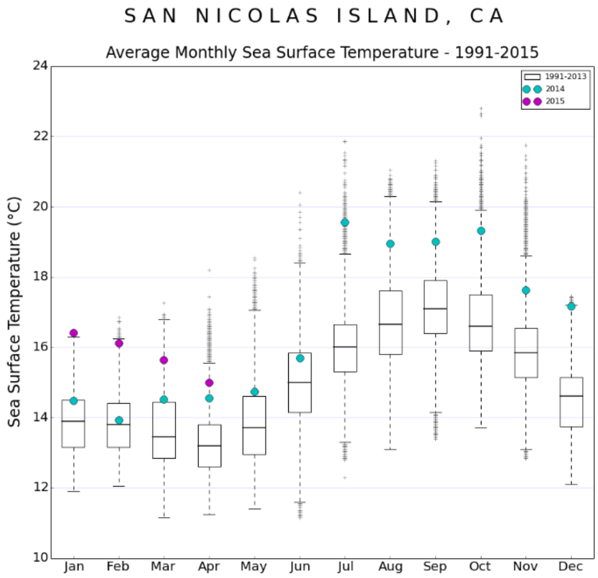


Figure 3. Monthly-averaged boxplots of SST at CDIP buoys Umpqua, OR *(top)* and San Nicolas Island, CA *(bottom)*. Turquoise represents 2014 and magenta represents 2015.