

Progress Report

A. Grant Number: NA11NOS0120032

B. Amount of Grant: \$2,322,414 (Year 5); \$10,245,630 (Cumulative Y1-5)

C. Project Title: CeNCOOS: Integrating Marine Observations for Decision Makers and the General Public

D. Grantee: MBARI, David M. Anderson (PI)

E. Award Period: From: June 1, 2011 To: May 31, 2016

F. Period Covered by this Report: From: June 1, 2015 To: Nov 30, 2015

1) Project Summary

The project goal is to serve the region's needs for sustained observing, data, and information products, and to contributing to the national scale Integrated Ocean Observing System by operating the Central and Northern California Ocean Observing System (CeNCOOS). Data and information, including observations, model now-casts, and forecasts, are streamed real-time and made available via the Internet, web services, and other access points. The observing system contributes to solving regional issues including ocean acidification, hypoxia, water quality, and also national-priority issues including marine commerce and transportation, public health and safety, natural hazards, climate, environmental, and ecosystem change, and sustainable marine living marine resources. Users of CeNCOOS data and information products include scientists, resource managers, decision-makers, students, and interested citizens. Founded in 2004, CeNCOOS functions as one of eleven IOOS regional associations (RA's) and as a regional coastal ocean observing system (RCOOS). CeNCOOS works closely with the Southern California Coastal Ocean Observing System (SCCOOS), guided by a Joint Strategic Advisory Committee; both are responsive to the California Ocean Protection Council and the Ocean Science Trust. CeNCOOS, SCCOOS, and NANOOS (Northwestern Association of Networked Ocean Observing Systems) conduct many observing and product development efforts jointly, guided by a memorandum of understanding and advice from the West Coast Governor's Alliance.

CeNCOOS is a collaborative that enables sustained and coordinated measurements, model nowcasts and forecasts, and integrated products to inform decisions about the ocean in its region. CeNCOOS's vision is to be a leader within U.S. IOOS, and be recognized and relied upon regionally and nationally as a trusted source of data, information, and expertise to inform wise use of the ocean off central and northern California. To accomplish this vision, CeNCOOS engages nearly fifty investigators and students at fifteen institutions, in four strategies: 1) continue long-term measurements of meteorological, and ocean physical, chemical, and biological parameters, 2) provide a publicly accessible data portal to integrate

real-time and historic time-series measurements together with geospatial and other data, 3) develop, implement, and operate data-assimilating coupled ocean physical-biogeochemical ecosystem models, and 4) utilize data to create products to inform policy and decision-making. Progress on each of these strategies is enabled by the substantial contributions made by partners that contribute, time, effort, observing assets, and resources towards common goals, quadrupling the investment made by this project, and engaging invaluable scientific skill and expertise. Beyond the value of the observations and forecasts and value of the archived data that can be re-used for other purposes, the observing systems also serve as a technology-incubator, as a resource promoting STEM education (science, technology, engineering, and math) and U.S. technology leadership, and as a knowledge-base for wise stewardship of our nation's coastal resources.

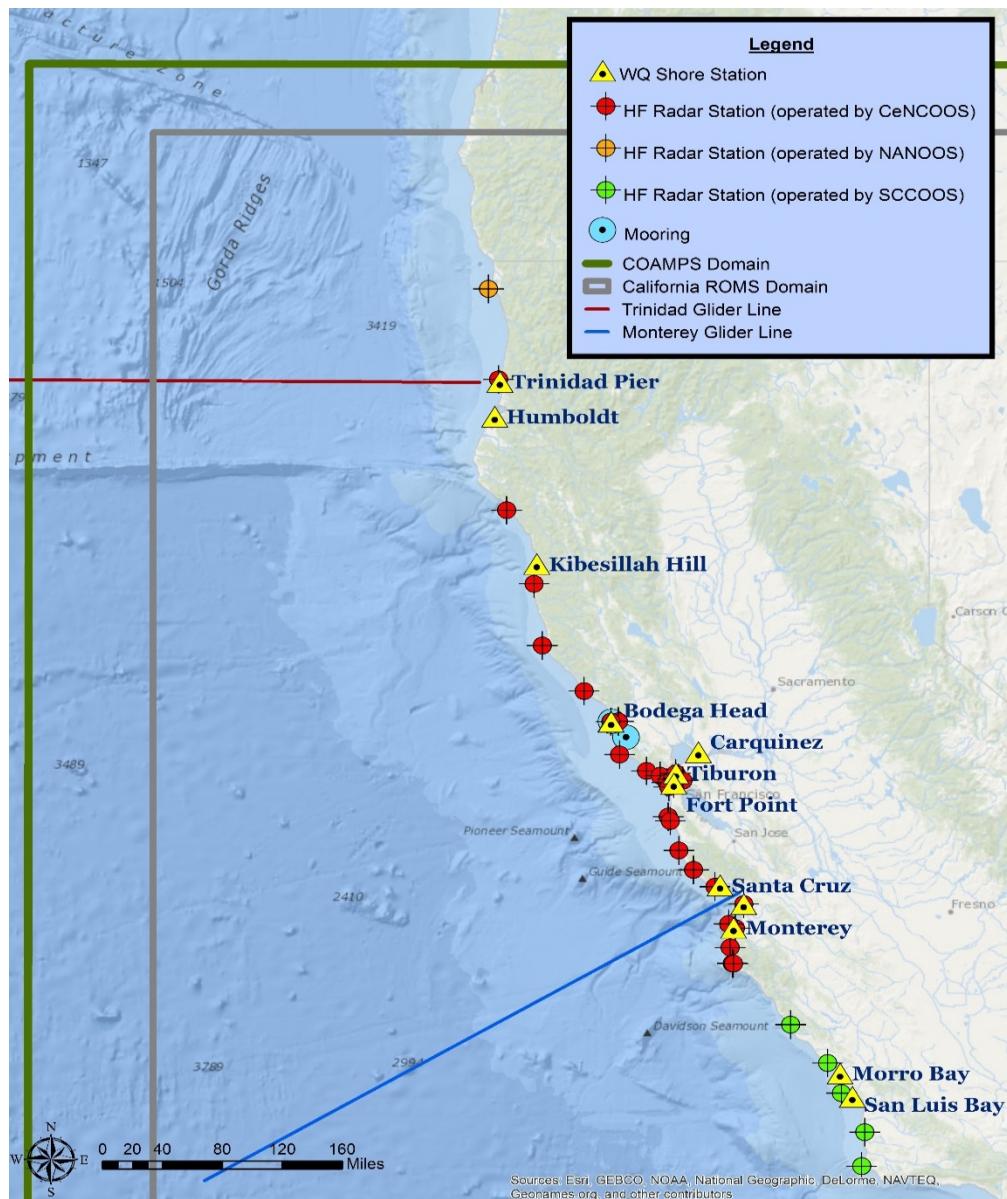


Figure 1: CeNCOOS Supported Observing Assets as of Dec 2015

2) Progress and Accomplishments

The CeNCOOS collaborative made significant progress on all four strategic plan elements (observing, data, modeling, products), and is on track to meet year 5 milestones. Four milestones specific to year 5 were originally proposed. “New stations added” was proposed, and we will add a shore station in South Humboldt Bay this Spring. “Acquiring new hardware” was proposed, and sensors were added during the period, including a pCO₂ sensor (MLML) in Monterey Bay, and three animal tags to be deployed this winter. We will spend \$50,000 on shore station capital equipment between now and May. “Begin Bodega line” was proposed. This activity (cruises with water sampling, CTD casts, and net tows) is occurring as an episodic, when-funding-allows activity at Bodega (CeNCOOS remains unable to support this). “Study larval connectivity” was proposed, and both UCSC and UCLA are using some of their CeNCOOS modeling support to improve estimates of larval flow (and particle trajectories). Throughout the period CeNCOOS operated 13 shore stations, 27 high frequency radars, 2 gliders, a data portal, 3 nowcast/forecast models, and produced a broad suit of data and information products described below and in the supplemental information. The shore stations collected over 2 million observations, the HFR produced 93,000 radial observations, and the two gliders made a dozen sections across the California Current. Data were streamed real-time, made available on the CeNCOOS data portal and via web services. Glider data were provided to the glider data assembly center, high frequency radar data were provided to the Coastal Observing Research and Development Center, and other sites (cencalcURRENTS.org, norcalCURRENTS.org, bml.ucdavis.edu/boon/). Catalog-level data descriptions were served to the IOOS catalog and the West Coast Ocean Data Portal.

Significant coastal phenomena observed during the period included ongoing severe drought in California (observed in stations in San Francisco Bay); the persistence of an unusually warm pool of water in the surface eastern Pacific that extended to the coast (observed by CeNCOOS stations and gliders); the seasonal cycle in upwelling and California Current strength (observed by stations, gliders, HFR). A massive harmful algal bloom (observed in weekly sampling and forecast by models) that began in the end of May continued through the period, resulted in fish and shellfish warnings and closures, and the delay of the opening of the Dungeness crab season (scheduled to open November 2015). CeNCOOS investigators conducted both basic and applied research to understand these phenomena, responded to the media, and responded to requests for data and information. Results from CeNCOOS investigators were presented at the biennial Eastern Pacific Oceanography Conference in September, the 2015 Coastal and Estuarine Research Federation Meeting (CERF) in November in Portland, the Western Society of Naturalists meeting in November in Sacramento, the annual CalCOFI science meeting in December 2015, and at the Fall American Geophysical Union Meeting in December 2015.

Detailed accomplishments below are organized by strategic plan element (observations, data portal, modeling, and products).

1. Observing Systems

- Harmful Algal Bloom (HAB) and phytoplankton monitoring and forecasting
 - CeNCOOS continues to support the statewide HAB monitoring and alert program through Raphael Kudela’s lab at UCSC. CeNCOOS-supported HAB monitoring at the Santa Cruz and Monterey wharves (and analysis at several other sites) alerted state health officials to a HAB event that began on May of this year and persisted into the fall. The repercussions of the bloom **are still being felt** in the

region, as important commercial and recreational fisheries have been closed due to high toxin levels that continue to accumulate in some species. During this interval, in particular, we expanded sampling to include Humboldt State University/SFWSC (Trinidad Head line) and the NOAA R/V Shimada west coast survey in an effort to better monitor the bloom event and validate the predictive model.

- Work is progressing on transitioning the experimental UCSC HABs predictive model which uses a novel approach to blend coastal satellite and numerical model data to forecast toxic algal blooms to be run operationally at the CeNCOOS Program Office (ultimately, the model will be run by NOAA). Additional funding for this activity has been secured from NASA, with Clarissa Anderson (UCSC) as lead PI and including Rick Stumpf (NOAA) as a collaborator. The experimental model outputs are publically available on the CeNCOOS site at: <http://www.cencoos.org/sections/conditions/blooms/habforecast/>. Tests of the multivariate DINEOF code were made, and the code was transferred to the HAB project wiki for sharing (<https://sites.google.com/site/habforecastingforcalifornia/home>).
- Water Quality
 - CeNCOOS PIs continue to operate 13 water quality shore stations in the region. Specific information on the network of station can be found on our [website](#). UC Davis sites at Bodega Head achieved 100% uptime, Fort Point 99%, and Tomales Bay 70%. The Tomales Bay telemetry continues to be interrupted during periods of extended fog when the solar-powered battery charge is depleted. Bodega Head received a new anemometer. At the MLML subsurface mooring at 16m in Monterey Bay, MLML installed a Turner C-Sense pCO₂ sensor in November. This site samples high-frequency variability related to the internal tides present at 16m depth. An example plot from the subsurface mooring operated by Moss Landing Marine Labs can be seen below in Figure 1:

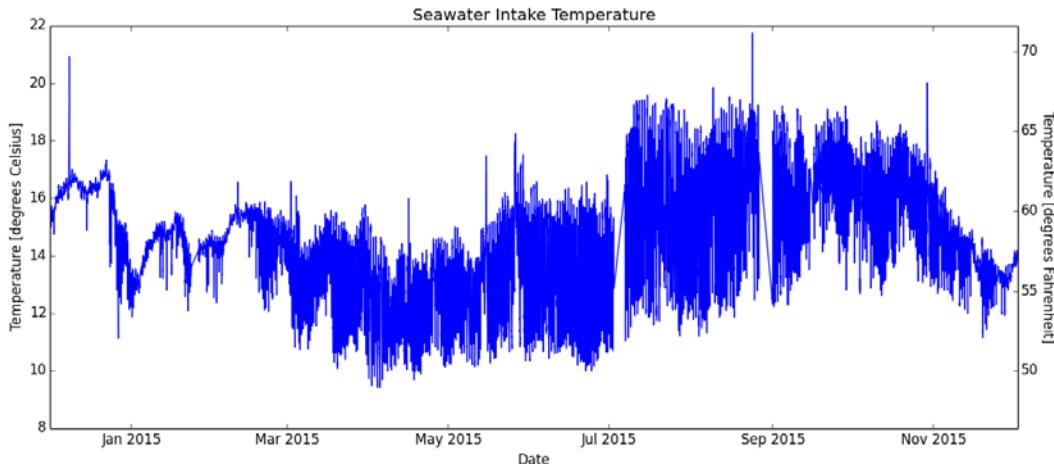


Figure 1: Timeseries (5-min sample interval) of seawater temperature from the MLML intake pipe over the period 2014-12-01 to 2015-11-30.

- SFSU facilitated the provision of new intertidal chl-a fluorometer data (non-realtime) for Hopkins Marine Station.
- A new Humboldt Oyster Conditions webpage went live on 9/28/15 using data from the HSU Chevron Station, upwelling data based on NOAA buoy 46022 located just offshore from the entrance of Humboldt Bay. The site's construction and content has been the product of a collaboration between the region's mariculture representatives, academic community and other stakeholders. The page can be found on the [CeNCOOS website](#).

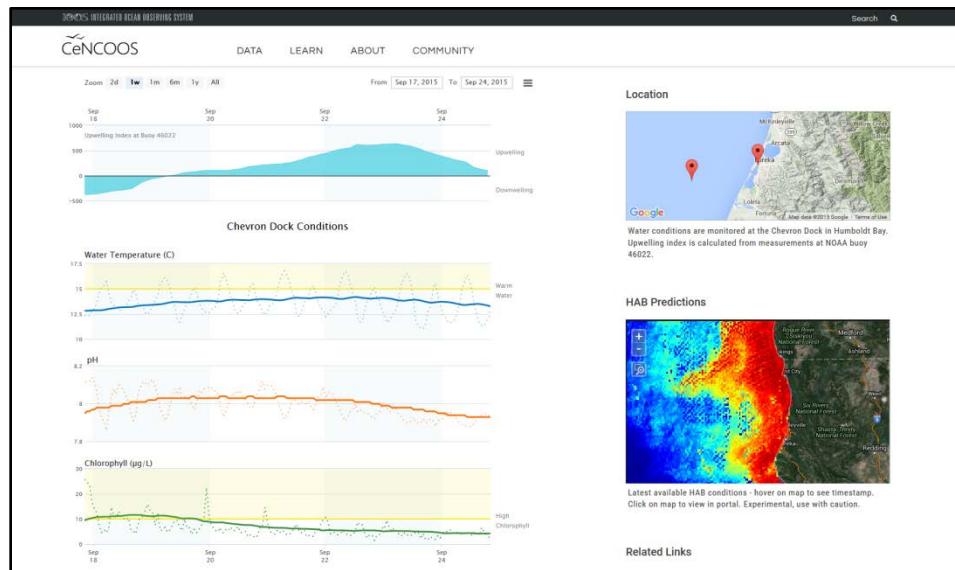


Figure 2: a screen shot from the new Humboldt Oyster Conditions dashboard

- Gliders and Moorings
 - Beginning in early December, 2014, the Oregon State University glider research group is obtaining vertical sections of ocean properties from off Trinidad Head, CA ($41^{\circ} 3.5'N$) using a 1000-m capable Seaglider equipped with the following sensors: CTD, dissolved oxygen (Aanderaa 4831 optode), light backscatter (700 nm), chlorophyll fluorescence and Colored Dissolved Organic Matter (CDOM) fluorescence (WET Labs Ecopuck). The gliders also measure depth-averaged velocity which can be combined with geostrophic estimates of relative velocity to get absolute velocity and hence transport. The glider is flying from approximately the 100-m isobath (~10km offshore) to 130W (~500 km offshore), repeating the line every 30 days. This effort is jointly funded by NANOOS, CeNCOOS, and SWFSC. Data are being sent in near real-time to the IOOS Data Acquisition Center and, simultaneously, to the CeNCOOS and NANOOS data centers. When an individual glider deployment is complete, the data is submitted to NODC.

The glider data show Starting in mid-April 2015, the warm upper –ocean water was held offshore by coastal upwelling. From mid-June to October 2015, the glider captured the formation of a warmer than average California Undercurrent

Eddy being shed offshore from the continental slope region.

- The Chavez lab at MBARI, in conjunction with the Rudnick lab at Scripps, continues to operate a Spray glider making continuous measurements of temperature, in the following activities from which data were made available to CeNCOOS:salinity, fluorescence, currents, and acoustic backscatter from the surface to 600-700 m along CalCOFI Line 67. In addition, with support from CeNCOOS, the Chavez lab has:
 - periodically deployed two Spray gliders owned by NPS in support of CeNCOOS partner needs, including the collection of background/animal sound information
 - developed and applied an ocean acidification payload on the Liquid Robotics wave glider
 - deployed two UCSC-owned Webb-Teledyne gliders in support of harmful algal bloom studies
 - updated displays (and underlying data connections for MBARI OA moorings in Monterey Bay.
 - performed quality control (reformat) of fluorescence data from Nielson shore stations.
 - computed daily climatologies for shore stations with more than two years of data. The climatologies will be used for an El Nino 2015 data product, and eventually for data presentations similar to the NANOOS Explorer (which provides long-term mean for mooring time series).
 - prepared and quality controlled non-real time glider data for submission to the glider DAC.
- High Frequency Radar
 - CeNCOOS maintains 27 HFR stations. Most of the HF radar effort during this reporting period has been directed at the challenge of maintaining continuous operations and data capture. Most, but not all, stations have remained in service through the reporting period.
 - UC Davis continues to operate eight existing HFR sites (Point Reyes, Bodega Head (2), Gerstle Cove, Point Arena, Fort Bragg, Shelter Cove, Trinidad), with high data returns (92.3-100% hourly radials submitted). Data are transferred to CORDC for all sites (IOOS archive) and are processed and archived at Bodega Marine Lab (providing regional access with graphics on the BOON website). A site assessment report for all UC Davis operated sites (similar to that done for the CODAR sites during the last period) was completed.
 - Maintenance by UC Davis included antenna repair at Point Arena, replaced power supply at Shelter Cove, improved power and communications at Point Reyes, relocated antennas at Fort Bragg to accommodate new public trail, installed new antenna at Point Bonita.
 - UC Davis participated in HFRnet diagnostics discussion, led the CenCOOS monthly tech calls, established new site agreements for some of the former SFSU sites, updated the UC Davis –BML agreements.

- UC Davis updated a tool to extract/plot time series from the US West Coast data set for a given locations, enabling time series to be calculated for a broader geographic region (previously could only use the BML data set).
- CODAR Ocean Sensors continues to operate 14 HFR sites for CeNCOOS (93-99.74% hourly radials delivered).
- CODAR staff removed the Treasure Island HFR site in San Francisco Bay. The infrastructure at the site degraded so that the power was gone and equipment was in serious risk of being stolen. Site scouting for a new site has been underway at Point Richmond. The proposed location is 37°54'34.34"N 122°23'23.64"W at the Miller/Knox Regional Shoreline Park.
- The Naval Post Graduate School continues to operate nine HFR sites for CeNCOOS. The real-time connection to Point Pinos was removed when the nearby NOAA NMFS office closed.

2. Data Management and Data Portal

- Axiom and CeNCOOS staff continued to operate the CeNCOOS data management system, including web services, web site, and data portal; each element complies with the IOOS guidance for standards and interoperability. The CeNCOOS DMAC activities were overseen by a committee that met monthly. Additionally two half-day committee meetings were held to develop the strategic operating plan and guidance documents needed for certification. CeNCOOS participated in the annual IOOS DMAC meeting, and participated in quarterly teleconferences with AOOS, who also utilize Axiom Data Science in DMAC. CeNCOOS staff participated in a three-day marine biodiversity planning meeting, which will lead to the acquisition of new biological data, and inclusion of the Darwin Core metadata standard for some CeNCOOS biological data (for acquisition and dissemination). We installed and tested the IOOS Compliance Checker. The checker is used to identify problems with metadata, leading to improved metadata. Data continued to be provided to the CORDC HFR node, and submitted to NDBC for archive, and metadata updates were contributed to the IOOS catalog.
- Axiom added new functionality to the catalog and portal, ingesting and serving new datasets, and working to establish data interoperability with external agencies. New search/catalog functionality includes improved user pathway for loading of data layers onto the integrated map providing a cleaner and more powerful data discovery experience. The CeNCOOS data team tested a prototype viewer and integrated mapping layer for glider data sets. The new tool enables glider trajectory data streams to be visualized as curtain plots, two dimensional maps and three dimensional visualizations. Axiom staff also developed a system to submit sensor data to NDBC for archival and discovery. Staff worked with contacts at NDBC to submit and validate data, and CeNCOOS sensor data streams are now flowing from Axiom's systems to NDBC's.

3. Modeling

- The Naval Research Laboratory Marine Meteorology Division (NRL-MMD) has continued to provide high-resolution real-time atmospheric forecasts for marine using the COAMPS model. The significance of this CeNCOOS-supported effort is to provide forcing boundary conditions for the regional ocean circulation models. The forecast results continue to be disseminated at a web site (<http://www.nrlmry.navy.mil/coamps>)

[web/web/cencoos](#)) and an anonymous ftp site in real time. The forecasts fields continue to be made available on the U.S. Global Ocean Data Assimilation Experiment (USGODAE) server, which is accessible to researchers and end users in the community (<http://www.usgodaе.org/>). The archive of surface fields and 3-dimensional atmospheric fields from the present to 2003 are contained within the USGODAE server as well. The fields are also disseminated in real-time on the USGODAE server. The forecasts continue to be disseminated on the web servers with both graphical and binary file information available. Limited verification has been carried out as well, including comparison of the forecast fields with observations such as buoys along the coast.

- In the past year, a fully coupled (air-ocean) model configuration continues to be tested in real time in a Beta mode (not fully operational) to provide more consistent air-sea fluxes leveraging FNMOC computational resources. The COAMPS 36, 12, 4 km meshes are tightly coupled with an NCOM 4 km mesh in the current configuration. FNMOC and NRL are currently working on ocean verification for the coupled domain. NRL and FNMOC are currently discussing the details of possibly implementing this system in the Navy operational suite.
- The UCSC Ocean Modeling Group has continued to operate the near real-time nowcast 4D-Variational Data Assimilation system for the broad California Current. The data assimilative system runs every four days, providing a hindcast state estimate for the prior four days using the variational approach. Between formal ocean state estimates, fields from a non-data constrained model are calculated and served on a daily basis. Outputs from the model can be found on the CeNCOOS [website](#).
- Yi Chao's group at UCLA continues to run the 3-km California state-wide ROMS model with data assimilation and real-time forecasting capabilities. This state-wide ROMS model is assimilating both the HF radar surface current data and the vertical profiles of temperature and salinity from four Spray gliders as well as other available observational data sets including satellite sea surface temperature and vertical profiles of temperature and salinity from moorings, ships and floats. On a daily basis, they are making on the order of 20 ensemble model forecast in order to quantify errors. The model output is provided to CeNCOOS through an OpenDAP THREDDS server that can be directly accessed from the CeNCOOS web site. A systematic effort has been carried out to validate the 3-km state-wide ROMS model. A manuscript describing this validation effort is in progress and expected to be submitted early 2016. Three validation products have been developed and are being tested on the PI's web site (Fig.3).

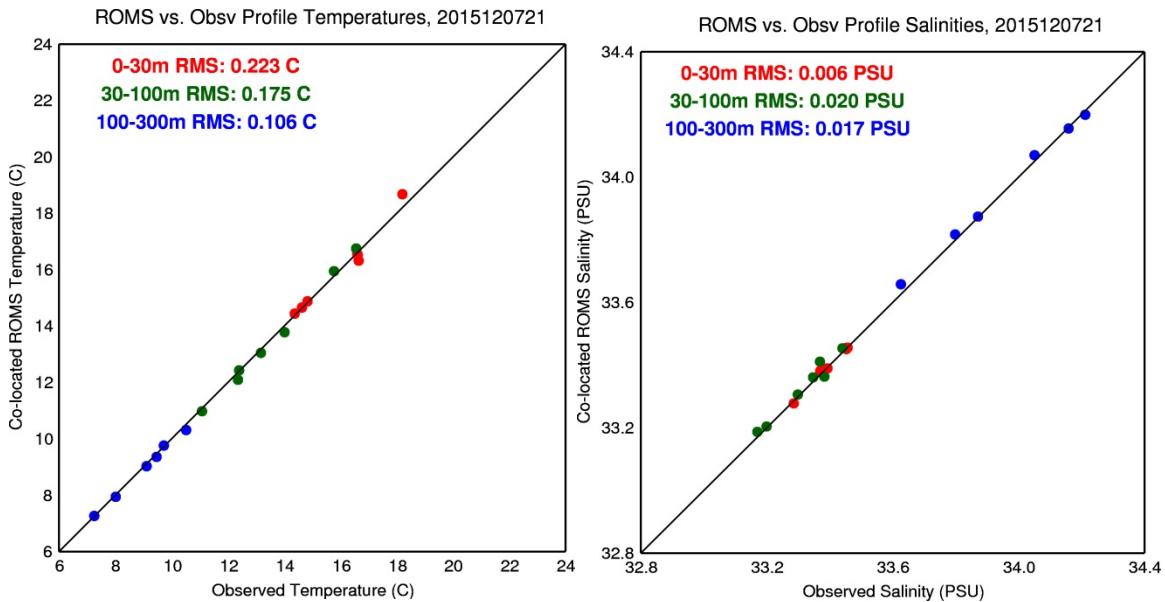


Figure 3: Good agreements found in these comparisons reflect a consistency between the observational data and CA ROMS nowcast/analysis.

The UCLA group is also maintaining the back-end engine for the drop-a-drifter tool, where users can track the movement of a particle of water (the trajectory) at selected depths of the upper 400 meters during the past two weeks and future (72-hrs into the future).

- The NCEP global forecast system model fields were added to the data portal by Axiom.
- HAB modeling activities were described in a previous section.

4. Products, including significant education and outreach

- The web site and the data portal remain the primary access for users for information and data respectively. The site (cencoos.org) averaged 800 sessions/day (1,500 page views) in July 2015.
- Marine Biodiversity Observation Network (MBON) data portal developed. Currently a stand-alone view to cross-project MBON data, this portal will eventually be integrated with the CeNCOOS data portal. CeNCOOS and partner Axiom are working with MBARI investigators, and cross-MBON collaborators from three MBON projects to provide access to biodiversity data. The efforts range from the synthesis of information from ongoing programs to IOOS compatible data systems, to development of novel methods, to the generation of products for stakeholders (<http://axiomdatascience.com/maps/ioos/mbon/#module-search>).
- Oyster Conditions Dashboard created (Ocean Acidification). Working with investigators at Humboldt State University and Humboldt Bay oyster growers, CeNCOOS developed the Oyster Conditions Dashboard, which provides access to real-time water quality, and productivity information and forecasts (<http://www.cencoos.org/data/humboldt/oyster>).
- Contributed data to IOOS Pacific Ocean Acidification (IPACOA) web portal, joint with AOOS, NANOOS, PacIOOS, SCCOOS (<http://www.ipacoa.org/>). This product organizes and improves access to ocean seawater carbonate chemistry data related to saturation state changes.

- Two videos describing IOOS data portals produced. We initiated a project to produce short (2 minute) videos describing IOOS data portals, and completed videos for CeNCOOS and SECOORA. The video introduces the observing assets in the region and introduces data access via a portal. We may produce eleven videos working with the regional associations and the IOOS office.

3) Scope of Work

No changes to the scope of work were made during this reporting period. CeNCOOS met all milestones and successfully operated all components of the observing and modeling systems. Data collection was routine and complete except for brief downtimes noted above related to instrument problems and calibrations.

4) Personnel and Organizational Structure

No changes to staff were made. In September Governing Council elections Luke Beatman, Turner Designs, was elected to an industry seat, and Liz Whiteman, Ocean Science Trust, was elected to a non-profit seat, replacing Skyli McAfee. Raphe Kudela will remain executive committee (EC) chair. Dean Wendt was elected to EC Chair elect. Francisco Chavez and John Largier remain on the EC. Elections for the one-year EC terms will be held in April 2016.

5) Budget Analysis

The Year 5 award of \$2,222,414 (includes \$91,000 sent directly to NPS and \$52,500 sent directly to NRL) was received in June 2015. The Year 5 amount is de-scoped from the original \$4M request. As directed we will spend at least \$648,000 in support of HFR operations and maintenance. Included in the year 5 award is \$109,862 allocated to CODAR for a national radar spare parts program. With an award start date of June 1 2011 and end date of May 31, 2016, a total award amount of \$10,245,630, and a balance remaining of \$631,127, CeNCOOS spending is on track with full draw down of funds anticipated by the conclusion of this 5 year funding agreement. Of the total award, \$6,672,599 was distributed to 14 sub-awards. There was \$1,484,858 in sub-award funds remaining as of Dec. 23, 2015. Capital expenses exceeding \$5,000 were three expendable CTD tags for elephant seals (\$21,137.85 for three tags), and \$5,870.14 for an Econet data communications unit.

Progress Report Addendum

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Supplemental Information:

1) Products and Services

- Continued work on the IOOS Pacific Region Ocean Acidification data portal (IPACOA). CeNCOOS contributed to the IPACOA data portal developed this Fall (with PacIOOS, AOOS, NANOOS, and SSCOOS). The aim of the portal is to simplify and coordinate access to regional ocean acidification data. The CeNCOOS sensors at the Hog Island Oyster Company are one of five sites monitoring the full seawater carbonate chemistry (using the “Burkolator” system).
- California Current state estimates (nowcast) improved. Physical and biological fields are estimated continuously in near real-time using a new 4D-Variational Assimilation system by UCSC. The system assimilates more data than previously, uses a global ocean state estimate (HYCOM) for lateral boundary conditions instead of climatology as used previously, and assimilates surface chlorophyll observations and estimates biogeochemical fields using a fully coupled physical-NPZD model. We believe this to be the first fully coupled physical-biogeochemical data assimilation system operating in near real-time. Data (nowcasts) are provided on the CeNCOOS and UCSC web sites.
- Regional atmospheric and ocean circulation nowcasts and forecasts are improved by a new configuration of the COAMPS model (run by NRL), which includes 36, 12, and 4 km grids (operational at Fleet Numerical Meteorology and Oceanography Center since 25 September 2013). The forecast results are disseminated at a new web site (<http://www.nrlmry.navy.mil/coamps-web/web/cencoos>) and an anonymous ftp site in real time. The design of the web interface has been modified and includes additional cloud products and additional zoomed in areas. Products are created that display winds over the sub-domains of Northern, Central, and Southern California. Additional surface products of great importance to the ocean community, such as sea surface temperature and surface moisture fluxes, are available as well. Other products that summarize the

forecasts for various locations of interest in a compact graphical format, often referred to a meteogram, are accessible from the COAMPS web page.

- West Coast Ocean Data Portal participation: the CeNCOOS Information Manager is a member of the West Coast Ocean Data Portal Action Coordination Team, a west coast wide effort to provide an ocean data registry to meet the needs of the marine planning community. As a member of the team, our Information Manager provides guidance on registering relevant IOOS data sets in the portal and coordinates with stakeholders from the marine planning community.
- CSU Monterey Bay will make its State-wide high resolution bathymetric data publicly accessible by the end of the fiscal year.
- [Humboldt Oyster Conditions dashboard](#). This site presents a set of parameters that aid oyster growers in understanding the factors affecting the growth of the oysters outplanted to northern Humboldt Bay. There is an upwelling index built from the actual (not modeled) wind directions and speeds occurring offshore to Humboldt Bay (NOAA buoy 46022), which shows the growers how the future potential for oyster food (phytoplankton) to be arriving in the Bay; there is the amount of oyster food actually in the Bay (chlorophyll fluorescence, CeNCOOS); there is water temperature with threshold indications for when temperatures become high enough to promote Vibrio outbreaks; there is pH data so that growers can see when conditions become corrosive (i.e. ~ pH 7.75). All of these variables are presented as running averages to emphasize trends, and the website is constructed so that it is easy to view these variables over short or long time scales.

2) Data Management

We continued to operate the CeNCOOS data management system, including web services, web site, and data portal, each which comply with the IOOS guidance. All CeNCOOS data services are standards-based, data are freely available, and the system is service-oriented and uses a common vocabulary. Services described on the data access page include THREDDS, ERDDAP, SOS, nCWMS, and GeoServer (<http://www.cencoos.org/data/access>). The CeNCOOS DMAC activities were overseen by a committee that met monthly. Additionally two half-day meetings of the committee were held to develop the strategic operating plan and guidance documents needed for certification. We participated in the annual IOOS DMAC meeting, and participated in quarterly teleconferences with AOOS, who also utilize Axiom Data Science in DMAC.

CeNCOOS staff participated in a three-day marine biodiversity planning meeting, which will lead to the acquisition of new biological data, and inclusion of the Darwin Core metadata standard for some CeNCOOS biological data (for acquisition and dissemination). We installed and tested the IOOS Compliance Checker. The checker is used to identify problems with metadata, leading to improved metadata. Data continued to be provided to the CORDC HFR node, and submitted to NDBC for archive, and metadata updates were contributed to the IOOS catalog. NDBC makes CeNCOOS available via the WMO GTS.

3) Observing Assets

Current Inventory of CeNCOOS-supported Ocean Observing Assets (see appendices) Notable additions in the last year are the Seaglider that is being deployed by Jack Barth's lab at OSU and the Humboldt Bay Indian Island shore station collaboratively operated by HSU and the Wiyot Tribe:

- CeNCOOS supports 27 HF radar stations.
- At present, CeNCOOS supports 15 automated shore stations.
- Other assets: CeNCOOS supports the continuous operations of a Spray glider (owned and flown by Scripps) along a line extending through, and offshore of, Monterey Bay. A new glider line off Trinidad commenced operation in December 2014 (operated by OSU; supported by both NANOOS and CeNCOOS). CeNCOOS also supports seasonal operations of gliders run by the Naval Postgraduate School and UCSC. Additionally, CeNCOOS supports a mooring in Tomales Bay at 50ft depth to collect oceanographic data.

4) Ocean Acidification Platforms:

- The CeNCOOS region includes at least 25 non-federal platforms which collect water quality variables relevant to ocean acidification chemistry, 20 of which directly measure pH (though not necessarily with high accuracy) and/or carbon variables. CeNCOOS has also been involved in maintenance and data management aspects of the prototype pCO₂ and DIC instrument installed at Hog Island Oyster Company, designed by Burke Hales.

Appendix A. CeNCOOS HF Radars								
CeNCOOS HF Radars	Operator	Location	Latitude	Longitude	Range	Purchased by	National Priority	Notes
Trinidad Head	UC Davis	Northern CA	41.07	-124.16	long	COCOMP	1	
Shelter Cove	UC Davis	Northern CA	40.03	-124.08	long	COCOMP	1	
Fort Bragg	UC Davis	Northern CA	39.44	-123.81	long	COCOMP	1	
Point Arena Field Station	UC Davis	Northern CA	38.94	-123.74	long	COCOMP	1	
Gerstle Cove	UC Davis	Northern CA	38.57	-123.33	standard			Does not report in real-time
Bodega Marine Lab	UC Davis	Northern CA	38.32	-123.00	long	COCOMP	1	
Bodega Marine Lab	UC Davis	Northern CA	38.32	-123.07	standard		1	
Point Reyes	UC Davis	Northern CA	38.05	-122.99	standard		1	
Commonweal Center, Bolinas	CODAR	Northern CA	37.91	-122.73	standard	COCOMP	1	
Slide Ranch	CODAR	Northern CA	37.87	-122.60	standard	COCOMP		
Point Bonita Fog Station	CODAR	Northern CA	37.82	-122.53	standard	COCOMP	1	
Sausalito Marin Sanitary District	CODAR	SF Bay	37.84	-122.48	short	COCOMP		
Romberg Tiburon Center 1	CODAR	SF Bay	37.89	-122.45	short	COCOMP	1	
Angel Island, Point Blunt	CODAR	SF Bay	37.85	-122.42	short		1	
Treasure Island	CODAR	SF Bay	37.83	-122.38	short	COCOMP	1	Down, radar to be relocated Spring 2016
San Francisco Exploratorium	CODAR	SF Bay	37.80	-122.40	short			
Crissy Field	CODAR	SF Bay	37.81	-122.47	short	COCOMP	1	
Land's End, Sutro Baths	CODAR	Central CA	37.78	-122.51	standard	COCOMP	1	
Montara Water and Sanitation	CODAR	Central CA	37.53	-122.52	standard	COCOMP	1	
Pillar Point	CODAR	Central CA	37.50	-122.50	long	COCOMP	1	
Pescadero	CODAR/NPS	Central CA	37.25	-122.42	standard		1	
Big Creek Lumber	NPS/CODAR	Central CA	37.09	-122.27	long	CODAR	1	
Santa Cruz	NPS	Central CA	36.95	-122.07	standard			
Moss Landing	NPS	Central CA	36.80	-121.79	standard			
Point Pinos	NPS	Central CA	36.64	-121.94	standard	COCOMP		Not reporting in real time
Granite Canyon	NPS	Central CA	36.44	-121.92	standard		1	
Point Sur Long Range	NPS	Central CA	36.31	-121.90	long		1	Now on Pt Sur Rock, power problems at site.

Appendix B: CeNCOOS In-Situ Observing Assets																		
CeNCOOS Shore Station		Operator	Latitude	Longitude	Notes			Temp	Salinity	pH	Turbidity	Fluorescence	DO	Nitrate	Weather	Depth	P.A.R.	Radiation
Trinidad Pier	HSU	41.06	-124.15	since 2005				Y	Y	Y	Y	Y	Y			Y		
Humboldt Bay: Chevron Dock	HSU	40.78	-124.20	Since 12/12; replacing Dock B (2003-2012)				Y	Y	Y	Y	Y	Y			Y	Y	Y
Humboldt Bay: South Bay	HSU	40.43	-124.13	Since 2006, Does not report in real-time				Y	Y	Y	Y	Y	Y			Y		
Humboldt Bay: Indian Island	HSU/Wiyot	40.81	-124.15	Plans to make existing station real-time				Y	Y	Y	Y	Y	Y			Y		
Kibesillah Hill	SSU	39.60	-123.79	Does not report in real-time				Y				Y						
Bodega Head	SSU	38.32	-123.07	Does not report in real-time				Y				Y						
Horseshoe Cove, BML Seawater Intake	UC Davis	38.32	-123.07					Y	Y			Y				Y		
Carquinez	SFSU	38.07	-122.23					Y	Y	Y	Y	Y	Y					
Tiburon	SFSU	37.89	-122.45					Y	Y	Y	Y	Y	Y			Y		
Fort Point	UC Davis	37.81	-122.47	Turbidity not reported R/T				Y	Y		Y	Y						
Santa Cruz Wharf	UC Santa Cruz	36.96	-122.02					Y	Y	Y	Y	Y	Y			Y		
Moss Landing Seawater Intake	MLML	36.80	-121.79					Y	Y	Y	Y	Y	Y			Y		
Monterey: Municipal Wharf II	MLML	36.61	-121.89					Y	Y	Y	Y	Y	Y					
Morro Bay: T-Pier (BM1)	Cal Poly	35.37	-120.86					Y	Y		Y	Y	Y	Y	Y	Y		
San Luis Bay: Cal Poly Pier	Cal Poly	35.17	-120.74					Y	Y		Y	Y					Y	
CeNCOOS Gliders		Operator	Latitude	Longitude	Notes			Temp	Salinity	Fluorescence	Currents	Acoustic Backscatter	DO	Light Backscatter				
Monterey Bay Transect 66/67	MBARI/SIO	variable	variable	variable	1000-m Seaglider			Y	Y	Y	Y	Y						
Trinidad Head Transect (41-deg, 3.5-min N)	OSU							Y	Y	Y	Y		Y	Y				
CeNCOOS Buoys		Operator	Latitude	Longitude	Notes			Temp	Salinity	pH	Turbidity	Fluorescence	DO	Nitrate	Weather			
Tomales Bay	UC Davis	38.19	-122.93					Y	Y		Y	Y			Y			

Appendix C: CeNCOOS Platforms of Opportunity for Ocean Acidification

CeNCOOS Platforms of Opportunity for Ocean Acidification								
CO2	pH	T/S/DO	Lat	Lon	Name	Platform	Provider	Notes
N	Y	Y	41.06	-124.15	Trinidad Pier	Fixed Shore Platform	HSU	YSI pH
N	Y	Y	40.81	-124.15	Humboldt Bay/Indian Island	Fixed Shore Platform	Wiyot/HSU	real-time pending, YSI pH
N	Y	Y	40.78	-124.20	Humboldt Bay/Chevron Dock	Fixed Shore Platform	HSU	YSI pH
N	Y	Y	40.72	-124.22	Humobldt Bay/South Bay	Fixed Shore Platform	HSU	not real-time, YSI pH
N	Y	N	39.28	-123.80	Van Damme State Park	Rock	UC Davis	not real-time
Y	Y	Y			HIOC Burkolator/BML station	HIOC seawater intake	BML/OSU	Burkolator purchased with IOOS MSI funds
Y	Y	Y	38.32	-123.07	Bodega Head	Mooring	BML	
N	Y	N	38.32	-123.07	Bodega Marine Reserve	Rock	BML	not real-time
Y	Y	Y	na	na	Line off Bodega Bay	Ship	BML	
N	N	Y	38.16	-122.90	Tomales Bay	Seawater intake	BML	6-12 ft deep, not real-time; in oyster farm
N	Y	Y	38.07	-122.23	Carquinez Shore Station	Fixed Shore Platform	SFSU	
N	Y	Y	37.89	-122.45	Tiburon Shore Station	Fixed Shore Platform	SFSU	
N	Y	Y	36.96	-122.02	Santa Cruz Shore Station	Fixed Shore Platform	UCSC	included in CA SWRCB pilot project
N	Y	N	36.95	-122.06	Terrace Point	Rock	MBARI	plus discrete sampling monthly
Y	Y	Y	36.94	-122.08	OA2 (Terrace Point)	Mooring	MBARI	plus discrete sampling monthly
N	Y	Y	36.81	-121.77	L01 (Elkhorn Slough)	Mooring	MBARI	included in CA SWRCB pilot project
N	Y	Y	36.80	-121.79	Moss Landing Shore Station	Seawater intake	MLML	included in CA SWRCB pilot project
Y	Y	Y	36.75	-122.03	M1 (Monterey Bay)	Mooring	MBARI	0-300 m for T,S, currents
Y	Y	Y	36.75	-122.33	M2H/46044 (Monterey Bay)	Mooring	MBARI, NDBC	0-300 m for T,S, currents
N	Y	Y	36.62	-121.90	Monterey Bay Aquarium	Seawater intake	MBA	
N	Y	N	36.62	-121.91	Hopkins Marine Station	Rock	MBARI	plus discrete sampling monthly
Y	Y	Y	36.62	-121.90	OA1 (Hopkins Marine Station)	Mooring	MBARI	plus discrete sampling monthly
N	Y	Y	36.61	-121.89	Monterey Wharf	Fixed Shore Platform	MLML	
N	N	T/S	35.17	-120.74	San Luis Bay: Cal Poly Pier	Profiler	Cal Poly	Dry part time. Flow through system may work
N	N	Y	35.37	-120.86	BM1 (Morro Bay)	Fixed Shore Platform	Cal Poly	
N	N	Y	35.33	-120.85	BS1 (Morro Bay)	Fixed Shore Platform	Cal Poly	down for maintenance
Y	Y	Y	na	na	Monterey Bay	Surface wave glider	MBARI	deployed intermittently