**TITLE PAGE**

**Project Title:** CeNCOOS Partnership: Ocean Information for Decision Makers

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PROJECT SUMMARY

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Project Summary:
We propose to operate and further develop the Central and Northern California Ocean Observing System (CeNCOOS) established in 2004. The CeNCOOS collaborative consists of fifteen institutions and additional partners at local, state, territorial and Federal agencies as well as industry dedicated to serving the region's needs for ocean observing and providing data and information products that support marine operations, coastal hazards, climate variability and change, ecosystems, fisheries, and water quality. CeNCOOS and adjacent regional associations NANOOS and SCCOOS share some infrastructure and collaborate on data analysis, modeling, and product development. All three associations are guided by the West Coast Governors Alliance, and SCCOOS and CeNCOOS are additionally advised by the CA Joint Strategic Advisory Committee and the CA Ocean Protection Council. In the last five years, CeNCOOS developed harmful algal bloom nowcast and forecast capabilities, deployed ocean acidification sensors, and implemented a data management plan and infrastructure that meets IOOS requirements for catalog and data interoperability (also meeting regional catalog and

interoperability needs). In the next five years CeNCOOS will respond to the need for real-time assessments of the state of the coast, and in doing this contribute to the many mandated regional 'state-of' and 'conditions' reports, including the sanctuary conditions reports and the CA marine protected area monitoring program. To achieve this vision most of the proposed effort will be directed toward the observing system that presently supports 27 HFR sites, 13 shore stations, and two glider lines. All assets leverage additional support from 15 participating institutions and other NOAA science efforts. Funding at the $4M/yr level will enable CeNCOOS to respond to the user-requested needs for biological observations and permit the observing system to be maintained and augmented to measure biogeochemical variables of critical importance to the region: specifically carbonate chemistry and dissolved oxygen. CeNCOOS nowcast and forecast modeling capabilities, coordinated with the Coastal and Ocean Modeling Testbed and West Coast Ocean Forecast System, can accelerate progress towards the operational level with increased funding. Funding levels less than $4M/yr will prohibit new biology observations, but will allow the existing physical (and biological) observing system, modeling/forecasting, and data functionality to be maintained. The critical support for sustained observing provided by IOOS will continue to be augmented by the private, state, and Federal support received by CeNCOOS institutions and partners that extends the reach and impact of the CeNCOOS system. Multi-year warm spells and droughts, variability and trends in hypoxia and ocean acidification, and an increasing frequency of harmful algal blooms are among the current issues that affect the region's welfare and economies. The changes in temperature, sea level, pH, and aragonite saturation state forecast for the end of this century add urgency to the issues that CeNCOOS addresses. Ultimately the understanding and predictive capability supported by CeNCOOS can help realize the NOAA vision of healthy and resilient ocean ecosystems.

PROJECT DESCRIPTION

I. Background

1. The California Current, bays, and estuaries

The Coast of Central and Northern California is a remarkable environment. The beauty of the rugged Big Sur coast is mythic, salmon run in its northern rivers, its estuaries and sloughs support the Pacific Flyway. Upwelling within the California Current shapes California's weather and supports and influences multiple economic sectors. California's bays and estuaries contain several of America's largest ports surrounded by dense populations. Inhabited by Native Americans, discovered as a natural paradise, California's coast (and whale, otter, abalone, and sardine populations) has been driven to environmental catastrophe- and back again- several times. While California is known for setting the bar on environmental policy, the state struggles to balance the pressure between use and protection. Multiple regulatory entities and watchdog groups, including the California Coastal Commission, Ocean Protection Council, the state and Federal marine protected areas all seek the healthy and resilient systems envisioned by NOAA. The triple-threat of climate change, sea level rise, and ocean acidification forecast by the end of the century demands planning informed by forecasts; commitment warming and sea level rise are in the pipeline regardless of the future emission pathway. Recent concerns, including the drought, hypoxic events, the presence of anomalous warm water in 2014-15 (Bond et al. 2015), invasive species and biodiversity threats, the arrival of Fukushima debris and radiation (Smith et al. 2015), all underscore the need for observation, monitoring, and process based studies that will benefit stakeholders and enable informed decision-making.

2. Central and Northern California Ocean Observing System

The Central and Northern California Ocean Observing System (CeNCOOS), established in 2004, operates within this sensitive, diverse, and threatened 600 miles of coastline. The ocean health index for central (71/100) and northern California (67/100) assesses health against ten goals and reveals where the region is doing better (tourism, livelihoods), and worse (mariculture, lasting special places). Even in data-rich California the authors found that data gaps presented a challenge (Halpern, et al. 2014). The CeNCOOS mission is to enable the sustained and coordinated measurements, model nowcasts and forecasts, and integrated products needed to inform decisions and wise use. CeNCOOS benefits from infrastructure provided by its academic partners, by the State, and by its parent institution, the Monterey Bay Aquarium Research Institute. In 2005 the California State Coastal Conservancy and the State Water Resources Board invested $21M from voter-approved propositions to build the infrastructure to map ocean surface currents. In 2010 CeNCOOS and SCCOOS inherited the operation of the coastal ocean currents mapping program. The data are used continuously by data-assimilating regional ocean models and the surface current maps and forecasts are served to the U.S. Coast Guard for search and rescue and to OSPR and ERMA for environmental protection.

Through two previous awards and the current IOOS award to operate the observing system, CeNCOOS has continued to build a system that leverages support from academic scientists throughout the region. With the CeNCOOS contribution typically exceeded by academic partners, the CeNCOOS observing system has grown to its present state consisting of 27 high frequency current sensing radars, 13 shore stations, two glider lines, and a suite of physical and coupled models (Fig. 1). Typical of all regional associations, the observing system incorporates data from existing systems including the National Data Buoy Center buoys, the Coastal Data Information Program buoys, the National Estuarine Research Reserve buoys, and many others. CeNCOOS curates the data it produces, complying with the data lifecycle concept, and serves these additional observations integrated with satellite-derived imagery and model nowcasts and forecasts in a data portal tailored to meet the needs of scientists, resource managers and decision-makers, people with ocean businesses, livelihoods, and recreational interests, and students, educators, and interested citizens. Successes in the current cycle include the maintenance and growth of the observing system, establishment of two glider lines (one with NANOOS), creation of the data portal (and underlying systems and web services), revision of the web site, and the development and adoption of a strategic plan and framework for decision-making. From these leveraged beginnings and successes, CeNCOOS is positioned to increase the impact of the current system, achieve certification, contribute to evolving IOOS initiatives, and work towards the build-out of the observing system. Improvements to model nowcasts and forecasts, and the continued development of data-assimilating models will produce data and information products that meet regional needs. Data syntheses and real-time observations, with increasing emphasis on biology/ ecosystem/ biodiversity attributes, will contribute to assessment and state-of-the-coast monitoring in the region.

### 3. Partners

Recognizing the enormity of the coastal ocean observing challenge, the diversity of observations to be captured, and products to be developed, CeNCOOS recognizes its partners as critical to success. CeNCOOS partners with its members, its supported investigators, and with investigators on other supported CeNCOOS projects. CeNCOOS captures data from CDIP, NDBC, and NERRS buoys for example, and makes this partner data available via the CeNCOOS data portal. The observing system thus created is a 'system of systems'. Regionally CeNCOOS partners with NANOOS and SCCOOS, collaborating on proposals, observing systems, and communication. Nationally, CeNCOOS partners with IOOS data assembly centers, with IOOS initiatives and with the IOOS office. These partnerships expand the reach and impact of CeNCOOS and promote integration of the regional coastal ocean observing systems.

## II. Goals and Objectives

CeNCOOS vision is to be recognized and relied upon regionally and nationally as a trusted source of data, information, and expertise to inform wise use of the ocean, and thus help achieve the NOAA vision of the future: healthy ecosystems, communities, and economies that are resilient in the face of change. We work to achieve this vision in a dynamic coastal environment where multiple environmental and socio-economic stressors demand an extensive, coordinated effort to observe and monitor, understand, and ultimately develop a predictive capacity. We work with co-investigators and funded and unfunded partners who are dedicated to realizing the value that comes from observing, understanding, and predicting the coastal ocean environment. California shares issues with other regions including the need for data and information products that support marine operations; coastal hazards; climate variability and change; ecosystems, fisheries, and water quality. Within the past five years, the increasing frequency of harmful algal blooms, the occurrence of low pH (and low saturation-state) and hypoxic events affecting shelf habitats, and the need to monitor the conditions and biodiversity in marine protected areas have brought these additional issues into the spotlight.

CeNCOOS relies on four strategies that align with regional and national priorities (Fig. 2). These strategies comprise five sub-systems, and the Governing Council has approved the following objectives for 2016-2021:

Objectives for the five sub-systems:

1. Project leadership and regional coordination (governance)
   - Govern the regional association and regional coastal ocean observing system, responsive to regional stakeholders and IOOS guidance
   - Oversee HFR network and shore station network and coordinate HFR, shore stations, data management, and modeling working groups
   - Coordinate with NANOOS and SCCOOS on observing systems, products, and funding
2. Observing system
   - Operate existing HFR network, with additional funds refresh equipment and improve data
   - Operate existing shore stations, with augmented funds a) refresh aging network; b) improve network reliability; c) augment observing stations with biology-focused sensors; d) enhance the spatial distribution of nearshore observing stations
   - Expand harmful algal bloom monitoring adding 2 sites north of SF, adding analyses at all sites
   - Capture and serve complementary data streams (e.g., satellite, CDIP, NDBC, NERRS buoys)
   - Support the Bodega line
3. Data Management
   - Maintain existing data access services and data browse and visualization capabilities
   - Become a certified regional information coordination entity (RICE)
   - Expand quality control and data analysis
   - Acquire legacy data prioritized according to societal benefit areas
4. Modeling and Analysis
   - Maintain existing nowcast and forecast capabilities with two ROMS and COAMPS
   - Advance ROMS towards operational status, increasing resolution, adding additional processes (river input), validation, hind-cast development and validation
   - Develop a hierarchy of modeling, working towards data assimilative coupled physical-biogeochemical models
5. Outreach and education
   - Maintain interactive web site and social media that complements data portal and web services; provide data products and information
   - Develop communications plan and implement
   - Emphasize products; further align CeNCOOS products and observing network with decision-maker needs

## III. Connection to Users/Stakeholders and Benefits

The users of CeNCOOS data and information products and the benefits and impact of the CeNCOOS collaborative are distributed throughout the region and reside in many economic sectors. The most tangible benefit of the CeNCOOS real-time observing stream has been the monitoring of conditions within the California Current and in California's bays, and estuaries, and monitoring and forecasting the conditions that influence plankton blooms (including HABs) and affect finfish and invertebrate fisheries. No less important is the real-time monitoring and forecasting of ocean currents required for search and rescue and oil spill/ pollution preparedness. The audience for coastal ocean forecasts is huge and CeNCOOS has been a leader in the development of data-assimilative regional ocean circulation models. CeNCOOS investigators are involved in the COMT and the WCOFS. The value of CeNCOOS data to conditions and 'state-of' reports is becoming recognized. This theme, contributing to assessments and conditions reports, is foundational to our proposal. Over the past five years CeNCOOS has provided increasingly extensive and sophisticated products to support each of the benefit areas identified by IOOS and we expect continued development to enhance these contributions.

Marine Operations and Coastal Hazards. CeNCOOS assets and forecasting supports marine operations along 600 miles of coastline, including five ports in San Francisco Bay. CeNCOOS systems can provide a wealth of information valuable to commercial and recreational uses in these regions. Real-time currents provided by 27 high frequency radars are re-distributed by a half-dozen applications, served to the GTS where they are assimilated by models, and provided to the U.S. Coast Guard for search and rescue (SAROPS), to the CA office of Spill Prevention and Response (OSPR), and to NOAA Office of Response and Restoration, and the GNOME data server and trajectory model. Measurements of surface currents were valuable in the COSCO Busan spill in San Francisco. CeNCOOS HFR measurements are scheduled for deployment in the Advanced Weather Interactive Processing System (AWIPS) at the Eureka National Weather Service Office. CeNCOOS supports HFR with a unique partnership between academic researchers, the Naval Postgraduate School, and industry leader CODAR Ocean Sensors.

Ecosystem assessment and climate. The CeNCOOS region includes three national marine sanctuaries and many state protected areas. These protections and priorities reflect the value of the services provided by coastal ecosystems, and acknowledge the dramatic exploitation, decline, and recovery of organisms and habitats that has occurred along the California coast. Monitoring, assessing, and ensuring the sustainable use of California's marine resources is a far-greater task than any one organization can handle. Guided by the West Coast Governors Alliance, the Joint Strategic Advisory Panel, by the Ocean Protection Council, and by the California Ocean Science Trust CeNCOOS is engaged in continuing coordinated efforts to maximize the benefits of its observing and forecasting capabilities. During the past five years, CeNCOOS augmented IOOS funding with support from NASA, NOAA, NSF, and OPC, working with partners on harmful algal blooms, ocean acidification, plankton monitoring, and biodiversity. At the higher funding tier CeNCOOS would respond to our region's priorities by emphasizing the broad area of ecosystem assessment, monitoring, and forecasting, and the related study of the physical environment that drives ecosystem change.

Water quality. Water quality has been recognized as one of the critical issues along the coast of California and in its bays and estuaries. CeNCOOS and SCCOOS partner with state and regional water boards, with the California Department of Public Health, with County environmental health programs, and citizen monitoring programs to meet regional water quality monitoring needs. CeNCOOS plays a small role in water-quality observing compared to partners but envisions increasing impact on water quality to come from nowcasts and forecasts using data assimilative models. These models can predict the near-time future impacts of pollution and threats to water quality. Several models, notably those for predicting ocean circulation and structure, and for predicting HABs, are nearing the operational level. Augmented funding in the next five years could accelerate improvements in estimates of current conditions and forecasting, by increasing resolution, adding ensemble forecasting, conducting validation and reanalysis, and incorporating important environmental drivers such as fresh-water run-off. CeNCOOS observing and forecasting systems both predicted and resolved the harmful algal bloom of May 2015 that resulted in shellfish warnings and closures in Central California.

Ocean acidification and hypoxia are aspects of water quality receiving significant attention from scientists, policy-makers, and the public. The West Coast Ocean Acidification and Hypoxia Science Panel, convened in 2013 at the request of the California Ocean Protection Council and involving 20 scientists representing California, Oregon, Washington, and British Columbia will issue an executive summary this Fall. With shelf-hypoxia events observed off Washington, and a multi-decade decline in oxygen within the oxygen minimum zone found in hydrographic data, and future climate-driven decreases in oxygen forecast within the OMZ, hypoxia is a pressing issue. Decreasing pH and the concomitant decrease in the saturation state may result from multiple influences including natural variability and anthropogenic carbon dioxide entering the ocean. CeNCOOS has worked with other regional associations to improve access to data and information via the IOOS Pacific Region Ocean Acidification Portal, and also works to install additional observing systems at sites relevant to shellfish growers and important to monitoring. To develop a predictive capability CeNCOOS works with scientists who are developing coupled models that track oxygen concentrations and the carbonate chemistry that affects pH and carbonate saturation states.

Broader Impacts: Broader impacts of CeNCOOS and its extensive support of academic collaborators include the coordination of applied marine science research throughout the region, the education and training of students and young scientists, production of data sets, journal articles, and new knowledge, the contribution that this technology-intensive science makes to STEM (science, technology, engineering, and math), and the legacy of a rich high-quality data archive that can be re-used for many purposes. CeNCOOS serves 3V big data: meaning data that is high velocity (many sensors deliver observations continuously, every few minutes), high volume (model outputs have four dimensions; resolution is increasing), and are highly various (especially true as biological data are emphasized). CeNCOOS' home institution, the Monterey Bay Aquarium Research Institute, has pioneered many of the innovations and sensors deployed across IOOS.

## IV. Work Plan

Work proposed for the 2016-2021 operation and development of CeNCOOS is presented below, prioritized for 3 funding levels (base capacity ($1.5M/yr), level-funded ($2.5M/yr), and augmented ($4M/yr). Base capacity would curtail most observing systems (including potential elimination of observations in one or more regions) and reduce all subsystems (except HFR and data management) relative to the existing system. At $2.5M/yr observing, forecasting, and data management would continue at slightly above the current level ($2.3M/yr) although what can be achieved will slowly erode as costs rise. Augmented funding ($4M/yr) would allow new biological observing systems to be deployed and fund the replacement of equipment and augmentation of existing systems. The outreach, engagement, and education subsystem would also be expanded. Costs and details associated with equipment, supplies, travel, personnel, contractual commitments, fringe benefits, and partner responsibilities are provided in the detailed budget narrative (appendix).

### 1. Governance Subsystem

The CeNCOOS governance subsystem plans, operates, continuously monitors, develops, and improves the CeNCOOS observing system. Governance tasks are accomplished by a small team (3.4 FTE) at host institution MBARI, advised by a multi-tiered system of working groups and advisory panels that donate time and expertise. CeNCOOS supports an executive director and program manager who manage the day-to-day governance and operation of the CeNCOOS system, oversee its response to users and stakeholders, participation and coordination with other IOOS initiatives, and the activities of the fifteen sub-award institutions support by CeNCOOS. The director and program manager are assisted by the MBARI grants office which ensures efficient financial operations and compliance. The director and program manager are also assisted by the CeNCOOS information manager and product developer, who coordinate with three working groups to provide ongoing systems support and oversight (data management committee, shore station working group, HFR working group). These activities are described in the annual IOOS proposal (containing milestones and sub-award statements of work) and are reported semi-annually to the GC and IOOS. Guided by the CeNCOOS strategic plan and the relevant IOOS documents this core team and the working groups implement the day-to-day decision making and operation of the observing system.

The CeNCOOS Governing Council guides the goals and objectives of CeNCOOS including the preparation of this and other proposals. The Governing Council consists of 15 voting members, 3 at-large and two each representing research, industry/for-profit, Federal, state/regional/local, education, and non-profit organizations. The membership consists of party members who have signed the memorandum of agreement and affiliate members. The host institution staff, governing council, and members are guided by the framework for decision-making, the strategic plan, and the memorandum of agreement and bylaws. The development of these documents began in 2012 and the framework was approved in July 2013, achieving a significant milestone in the current grant that strengthens CeNCOOS ability to perform as a RA and RCOOS. The final decision-making authority within CeNCOOS lies with the Governing Council.

CeNCOOS receives guidance and steering from multiple sources. The West Coast Governors Alliance guides NANOOS, SCCOOS, and CeNCOOS; WCGA priorities are included in the strategic plan. The California Joint Strategic Advisory Committee guides SCCOOS and CeNCOOS; its priorities also informed the strategic plan. The state-wide JSAC consists of members appointed by the SCCOOS and CeNCOOS leadership. The JSAC meets annually and guides the RA's on how best to meet state needs. Ocean-focused organizations are another key driver of CeNCOOS regional priorities. The Ocean Protection Council is the state-authorized, state-supported entity that exists to promote ocean protection, sustainability, and the wise use of the state's ocean resources. The California Office of Spill Prevention and Response (OSPR) is the body charged with spill prevention and response. The non-governmental non-profit California Ocean Science Trust is a boundary organization that links to the state, and helps make science (and CeNCOOS observations) useful in decision-making.

In the next five years with base funding ($1.5M/yr) CeNCOOS will operate the governance subsystem outlined above, fully meeting its responsibilities as an IOOS RA and RCOOS and satisfying its current responsibilities and partnerships. With level funding CeNCOOS will not increase governance subsystem spending. With funding above the current level, the Governing Council recommended the largest possible increase to the observing and modeling/ analysis subsystems, and recommended that governance subsystem support be increased only to the extent necessary. CeNCOOS will continue to seek additional funding opportunities to maintain and develop the system.

2. Observing subsystem

a. Shore stations and moorings. Our vision for the CeNCOOS nearshore network is to provide data that will allow us to understand nearshore variability in ocean conditions for the region while also resolving variation at finer spatial scales. Both scales are important to meet the needs of regional stakeholders including scientists studying nearshore biota and conservation areas to understand their productivity, biodiversity and resilience in the face of climate change; coastal communities including members of Native American tribes dependent on local biota for commercial, recreational and subsistence fishing and gathering; mariculture and aquaculture businesses; natural resource managers dealing with cumulative needs for and impacts on marine life and trying to sustainably balance it all under changing ocean conditions. All will be impacted by changes in nearshore ocean conditions or water quality, and need to know what is happening now and what is likely to happen in the future.

Ideally nearshore observing stations (both shore-stations and moorings), would be located strategically to capture the major influences on regional variability in ocean conditions such as major river plumes and upwelling centers and shadows. This core network would be supported by ancillary observing stations in areas where localized transformation of water properties or conditions is likely to have direct effect on an MPA or ASBS or an aquaculture facility or another area of concern. Our goal is to build out the existing CeNCOOS network to achieve this vision. For this proposal period we identify four primary objectives for improving the network (listed in increasing order of expense and effort): 1) refresh aging network instrumentation to sustain observations; 2) improve network reliability by acquiring a pool of back-up instruments and sensors for rapid recovery in the event of failures; 3) augment observing stations with sensors to measure carbonate chemistry and dissolved oxygen; and 4) enhance the spatial distribution of nearshore observing stations to realize the advantages of a networked configuration.

The first two priorities are strictly operational objectives. The latter two address fundamental science needs if we expect to be able to provide coastal communities, agencies and decision makers with the information they need to make informed decisions about sustainably managing ocean resources in the face of a changing climate. Ocean acidification and hypoxia are regional threats to marine life that are likely to increase over the next decade. Nearshore ecosystems are especially diverse and the waters that bathe them are far more variable than previously appreciated. Some of the sources of variation are well understood, but many are not. Regional ocean conditions set the stage, but the conditions that nearshore organisms experience are a product of local modification due to the physical complexity of the nearshore margin and seafloor, that alters transport and currents, but also due to the influence of the biota itself as it interacts with the water. Our current network of nearshore observing stations is not inadequate for answering these important questions. Most of the observing stations also need to enhance their capabilities for characterizing carbonate chemistry and dissolved oxygen concentration. While dissolved oxygen and pH are measured by most observing stations, pH alone is not sufficient to characterize seawater carbonate chemistry (or aragonite saturations state). Achieving 'weather-quality' accuracy and precision in estimating aragonite saturation state through carbonate chemistry measurements is a high priority for the CeNCOOS network and its stakeholders, but cannot be achieved without further investment or sacrificing existing observing capacity.

CeNCOOS supports six university partners who operate shore stations along the California coast and in bays, and estuaries. The network is expanded by non-CeNCOOS supported monitoring by CDIP, NDBC, NERRS, SFEI, and other groups who provide data to the portal. The locations and sensors deployed reflect many influences, including legacy (existing) deployments, the interests and abilities of the partners, the equipment partners supplied, the interests of stakeholders (e.g., mariculturists, scientists, managers), and financial and logistical constraints. With base capacity (1.5M/yr) this observing system cannot be supported. Stations that already receive sufficient outside support may continue, and those that do not will be suspended. Under level funding ($2.5M/yr) all existing shore stations will continue with annual calibration and data management. Changes to real-time data management will be needed to meet certification requirements and will be pursued. . However, many network instruments and sensors have surpassed or are approaching the end of their useful lives. Many stations currently experience outages when sensors fail or equipment needs to be serviced or repaired. Loss of existing network capacity is likely due to aging equipment under level funding. With expanded funding, refurbishment and refresh of existing equipment can be accomplished over five years. Three new sites will be added in SF Bay (see biology initiative below) and equipped with YSI EXO2 sondes, and in year 3 two SF Bay sondes will be replaced with EXO2 sondes. The budget for outside services and materials and supplies include $20,000-$30,000 each year for the repair and replacement of individual sensors and purchase of sensors described under biology below.

b. Gliders and transects CeNCOOS currently provides partial support for two glider lines, the Monterey and the Trinidad Head line. SCCOOS gliders operate off Point Conception and off Southern California. These four glider lines are the backbone of continuous California Current monitoring (Fig. 1, 3). The data support multiple scientific studies and are assimilated into regional models. With base capacity ($1.5M/yr) CeNCOOS cannot support gliders. With level funding the two CeNCOOS glider lines can be partly supported, with partners supplying the needed additional funding. The Trinidad line will be supported jointly with NANOOS, and the Monterey line jointly supported with the Glider DAC group (D. Rudnick), which is supported by OAR. The Monterey and Trinidad Head line benefit from existing ship-based sampling. With expanded funding ($4M/yr) a glider would be purchased to initiate the Bodega glider line (prioritized in the 2011-2016 proposal as the next glider to add). Operational support remains to be identified. High priority science/management goals for the Bodega line include transiting/monitoring the edge of the newly-expanded Cordell Bank National Marine Sanctuary, and monitoring conditions affecting the Russian River (NOAA Habitat Focus Area), and affecting Sacramento River Salmon exiting San Francisco Bay. The establishment of the Bodega line, standing south of Trinidad Head and North of Monterey, fills a critical spatial gap and provides continuous monitoring supplemented by biology-focused ship transits at three CC locations (Trinidad, Monterey, Bodega). With expanded funding, episodic flights in the Monterey region will also be supported using two existing gliders (UCSC) typically deployed as part of shorter, process-study efforts including targeted harmful algal bloom prediction and monitoring efforts supported by NOAA.

c. New Biology-Focused Observing With increased funding ($4M), CeNCOOS will add sensors needed to monitor aspect of the biology and ecology throughout the region and will expand its coordinated monitoring activity in San Francisco Bay working in partnership with SFEI, NERRS, the California Ocean Science Trust, and others. The CeNCOOS build-out plan includes the following:

i. Capital expenditures as described in the build out plan, needed to observe biological/ ecosystem/ biogeochemical sensors at the shore station and selected mooring sites. The priority for sensor purchases will be oxygen, fluorescence, pH, and nutrients, taking advantage of the new X-prize developed technologies for pH and coordinating with ACT on nutrient sensors. Priority measurements recommended by the California Current Acidification Network (C-CAN) (McLaughlin at al. 2014), will be adopted by CeNCOOS, building on existing nearshore observing infrastructure and allowing for direct calculation of aragonite saturation state ($\Omega_{arag}$) and a full characterization of the seawater CO2 system. The priority measurements recommended by C-CAN needed for nearshore observing networks to estimate $\Omega_{arag}$ include: temperature, salinity, dissolved oxygen (DO) and at least two of these four carbonate system parameters: pH, $p(CO_2)$, $C_T$ (total carbon) and $A_T$ (total alkalinity). CeNCOOS shore stations and nearshore moorings already measure temperature and salinity; many measure dissolved oxygen also. pH is measured at several as well, but not to the standards required to estimate $\Omega_{arag}$ for OA related research. Thus we will upgrade a strategic set of shore and mooring stations to include autonomous, commercially available optical DO sensors, Durafet style pH sensors and pCO2 sensors, in addition to temperature and salinity. Three UV nitrate sensors will be added to the SF Bay in years 1-3, and later added to Humboldt Bay (yr 2) and Morro Bay (yr 3). Burkolator OA units will be installed with partners at Humboldt Bay, Bodega Bay, and Morro Bay in years 4-5. We will work with C-CAN network on appropriate QA/QC methods, including cross-laboratory analyses. We will add chlorophyll *a* (CHL-a) fluorescence sensors to shore stations that do not currently have these sensors, for continuous monitoring of chl-a fluorescence. These will be accompanied by weekly discrete samples of chl-a biomass. The chl-a biomass samples will also serve as check samples to scale the fluorescence data across the network.

ii. Expand the HABMAP network by adding sites in northern California. The California HABMAP network recommended collecting standardized observations of phytoplankton abundance (focusing on harmful algal organisms, in particular Pseudo-nitzschia,Alexandrium, and Dinophysis) and corresponding environmental data, including nutrients and toxin concentrations, at all SCCOOS and CeNCOOS pier stations. Due to funding constraints CeNCOOS has historically only included the Santa Cruz Municipal Wharf and Monterey Commercial Wharf, and limited observations from San Francisco Bay (Romberg Tiburon Center). CeNCOOS will expand HAB observations to include Fort Point (San Francisco), Bodega Bay, and Humboldt Bay, with additional samples from Trinidad Bay. At each site Solid Phase Adsorption Toxin Tracking (SPATT) samplers will be deployed ~weekly, and phytoplankton enumeration samples will be collected. The existing monitoring data from the shore stations will be used to interpret the HAB data. Toxins will be analyzed at UC Santa Cruz; phytoplankton enumeration will be conducted either locally at each site (if the capacity exists) or will be analyzed at UC Santa Cruz. All data will be posted to the existing HABMAP server, which is integrated with the CeNCOOS and SCCOOS data portals. During bloom events additional samples will be archived for other purposes, including expanded toxin detection and molecular analysis. SPATT are routinely analyzed for domoic acid and microcystins, but archived SPATT can also be analyzed for saxitoxins, okadaic acid, and pectenotoxins, with additional analysis triggered by observation of target HAB organisms or wildlife mortality events. These data will be particularly valuable for calibration/validation of the existing CeNCOOS/NOAA/NASA predictive model for domoic acid events.

iii. Contribute to the Bodega line (Quarterly or better ship sampling). CeNCOOS support will be leveraged with existing support and make this a regular and sustainable line, adding to the existing historical Bodega line data set to create a time series.

iv. Deploy animal tags. Researchers within the Tagging of Pacific Predators program have been at the forefront in the development and application of animals as ocean sensors of the ocean environment. We propose to continue the development of using animals as oceanographers by deploying CTD tags on California sea lions, northern elephant seals and mako sharks. Our objective is to create operational data from animals that utilize the central coast of California. We propose to expand our ability to collect oceanographic data using animals by deploying tags on sea lions that will provide real time CTD profiles of the California Current and on elephant seals as they traverse the eastern Pacific. Tags deployed on elephant seals will include two of the new fluorometry tags. Data acquired from all tags will be uploaded daily via the portal newly created by TOPP partners called the Animal Telemetry Network DAC (http://oceanview.pfeg.noaa.gov/ATN/). CeNCOOS will support TOPP by purchasing tags. Elephant seal tags are deployed in March and May June, and sea lion tags are deployed in October-November after the annual molt. Like much of the CeNCOOS observing system this activity is augmented by extensive additional support.

d. Ocean Currents from high frequency radar (HFR) CeNCOOS supports three partners who operate 27 HFR sites (20 national priority sites (appendix)), providing hourly maps of surface currents for the region. Long-range data are available throughout the region that link with long-range HFR data from SCCOOS and NANOOS to provide continuous west-coast coverage. Higher resolution standard-range data are available for high-priority waters off San Francisco Bay, extending from Monterey Bay to Bodega Bay, and highest resolution sites provide surface currents in outer San Francisco Bay. Data stream to regional and national databases and are served through CORDC, NDBC and other sites. Data are available in near-real-time for operational needs (shipping, oil spill mitigations, search and rescue, sailing/boating) and aggregated data are used retrospectively to address environmental issues, to produce ecosystem assessments and to improve knowledge of circulation in coastal and bay waters.

Full support for CeNCOOS ($4M/yr) will allow for improved readiness, less downtime, improved data quality, new data/decision-support products, and enhanced understanding of coastal ocean circulation to support ecosystem/environmental assessment. Each partner operating HFR systems would benefit from additional personnel time, pre-emptive hardware repair, and enhanced QA/QC efforts – plus at the system level, CeNCOOS will be able to build in more refined operational checks and contingency to respond more rapidly to unanticipated major events, such as oil spill or search-and-rescue. Equally important is that full funding level will allow an ongoing effort to respond to decision-maker needs by developing new products, from simple graphical products to new indices and tools that are built on sophisticated analyses. A top priority for analysis and product generation is to assemble and QC all raw data collected to date, re-process the radial measurements using best-available metadata, and produce a retrospective data set of surface currents (up to 15 years off Monterey and Bodega Bays) that is expected to be far superior to the real-time data generated now (this retrospective data set will be updated continuously with a lag of 3-6 months). This effort will greatly improve the radar data archive and enable multiple new products, including a data set that will be used in ROMS reanalysis. An analyst/product developer would be supported to work with HFR operators as well as modelers and other partners in CeNCOOS to provide useful information products.

Level funding ($2.5M/yr) will be sufficient to maintain the existing network, including annual antenna patterns and other maintenance, as well as limited/reactive equipment repair and replacement of parts. With each year, the system becomes more vulnerable to aging (some HFR sites are 15-20 years old and all are at least 9 years old). A level-funded budget does not allow development of products, which short sells the value of HFR data as it is not readily accessible to users without reduction for use-specific needs. With reduced funding ($1.5M), the HFR network will continue to be operated with reduced QC procedures (e.g., antenna pattern measurements), slower response times (longer data gaps), reduction in network coverage with loss of aging antennas, and reduced capacity to respond to events. This would be a system in decline and readiness will decrease at a rate that depends on how long systems endure with minimal maintenance.

3. Data Management and Communications

Data is at the core of CeNCOOS and data management is an essential component that supports and connects all CeNCOOS efforts including Observing Modeling and Analysis and Outreach, Stakeholder Engagement, and Education. CeNCOOS operates data management systems for curation and dissemination of data. At the base capacity CeNCOOS will continue to maintain these systems. With level to increased funding, CeNCOOS, including Axiom as an integral part, will pursue opportunities to expand their DMAC capabilities and services to a broader group of data providers and users by facilitating the integration of additional data into regional or national data assembly centers and their accessibility via IOOS standards-compliant data access services. With data quality as a priority, the CeNCOOS data management team is actively engaged and contributes to QARTOD efforts by participating in the IOOS DMAC QARTOD Working Group, QARTOD workshops, the development of manuals and implementation efforts.

The CeNCOOS Data System is based on a service oriented architecture that employs interoperable systems to enable data discoverability via web services and catalogs. Full details of this system are described in the CeNCOOS data management plan. In summary: Data will be stored and served in approved common data formats and will be distributed and replicated across multiple servers to provide reliable data services. A geographically distributed fully functioning mirror site will enable failover of CeNCOOS data systems. Data will be archived at appropriate NOAA archive centers. Data will conform to IOOS metadata standards and access to metadata will be enabled by a web catalog service. CeNCOOS web service endpoints and metadata will be made available to the IOOS catalog on demand. Web based data browsing and display tools will be maintained including the CeNCOOS integrated portal catalog, ERDDAP, Web Map Server (WMS) based on GeoServer, and the THREDDS data server. To facilitate interoperability, CeNCOOS datasets will be openly disseminated with direct data access provided through multiple services including OPeNDAP, WCS, WFS, WMS, SOS.

CeNCOOS will partner with Axiom Data Science to provide a standards based lifecycle data management framework that maximizes the discoverability, accessibility, and usability of data and information products and ensures their sustained use. CeNCOOS leverages Axiom's data systems which also support AOOS and SECOORA to use common infrastructure enabling the dedication of more funds to system advancements and innovation than would otherwise be possible. The relationship between CeNCOOS and Axiom is a collaborative partnership designed not only to serve the needs of CeNCOOS but also to allow for greater contributions to the larger IOOS community. CeNCOOS works closely with Axiom to develop data management plans, statements of work, facilitate the flow of data and ensure a coordinated end to end system. The standards and protocols, and annual work plans of the CeNCOOS DMAC subsystem are revised annually and reviewed by the six-person DMAC committee.

4. Modeling and Analysis

CeNCOOS supports two data assimilative and nowcast/forecast systems based on the Regional Ocean Modeling System (ROMS). CeNCOOS supports an atmospheric model (COAMPS) at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) to provide nowcast/ forecasts of the atmospheric circulation and boundary conditions used by the ROMS.

The larger ROMS domain covers the entire US west coast (USWC) from Baja California to Vancouver Island with a spatial resolution of 1/10 degree (~10 km) in the horizontal and 42 terrain-following layers in the vertical direction. The USWC ROMS is forced at the surface by atmospheric fields produced by the 4-km Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) which is run in near-real-time at FNMOC. Lateral boundary conditions are obtained from the HYCOM global ocean state estimate. The current configuration does not include tidal forcing. Both the satellite and in situ observational data are assimilated into ROMS through the 4-dimensional variational (4DVAR) method (Moore et al., 2011a) to produce real-time nowcast and forecast (Moore et al., 2011b, 2013). The 4DVAR assimilation procedure runs over 4-day assimilation cycles. A coupled NPZD ecosystem model assimilates satellite-derived chlorophyll and produces a biogeochemical state estimate.

The second ROMS domain covers the entire California (CA) coast with a spatial resolution of 3 km and 40 vertical layers. The CA ROMS is forced at the surface by atmospheric fields produced by the 5-km Weather and Research Forecast (WRF) model which is run in near-real-time by the National Center for Environmental Prediction (NCEP). The global 1/12$^{o}$ HYCOM model run at Naval Oceanographic Office (NAVO) provides open boundary conditions. Tidal forcing derived from satellite altimetry is included at the open boundaries. The data assimilation is based on a multi-scale 3DVAR (Li et al., 2008, 2009). The 3DVAR assimilation is carried out every 6 hours at 03, 09, 15, 21 GMT. Every day at 03 GMT, a 3-day non-data assimilative run is made as the forecast. A more detailed description and real-time images can be found at http://west.rssoffice.com/ca_roms. The CA ROMS is supported by CeNCOOS and SCCOOS. Products are available from SCCOOS and CeNCOOS. Advice and interaction from both regions guides CA ROMS development.

One of the proposed tasks is to carry out a collaborative model validation effort involving both modelers and data providers. The output from both the USWC and CA ROMS models can be accessed from CeNCOOS: http://www.cencoos.org/data/access. It is therefore expected the model performance and nowcast/forecast skill will be evaluated and assessed by a broader community. Both the UCSC and UCLA modeling teams are expected to report the results from these performance evaluation and assessments in peer-reviewed journals. Another proposed task is to add freshwater forcing by rivers and waste water treatment plants to these two ROMS models.

In the event of increased funding, we have several advances of the present system that we will pursue. First, we will develop and implement a higher resolution model. This implementation will either consist of an increase (e.g., tripling) of the model resolution over the entire USWC or CA domains or within a subdomain (e.g., Monterey Bay) of the existing system. This increase of our model resolution will be coordinated with the West Coast Ocean Forecast System (WCOFS) that is currently being developed jointly by NOAA and Oregon State University (PI: A. Kurapov). The second advance would be to add biogeochemical models to our real-time nowcast/forecast systems. The USWC ROMS model has been working with the NEMURO ecosystem model and the CA ROMS model with the CoSiNE ecosystem mode. Both NEMURO and CoSiNE models include multiple phytoplankton and zooplankton functional types and are better suited to the different biogeographic zones of the California Current System than the traditional NPZD model previously being used. Oxygen and carbonate chemistry can also be added into these ecosystem models to allow estimates of hypoxia and pH. Finally, these proposed activities will be carried out in close collaboration with the IOOS Coastal Ocean Modeling Testbed (COMT) team (U.S. IOOS, 2012) and guided by the ecological forecasting roadmap (NOS, 2012). One notable example of the potential benefit to COMT is the biogeochemical data assimilation. Such a capability does not exist presently in other real-time coastal ocean systems, but clearly would provide great benefit to NOAA in its effort to provide comprehensive ocean state estimates for the coastal ocean. Another example is to compare the various data assimilation schemes such as 3DVAR, 4DVAR and EnKF so as to optimize the assimilation solution with the computational resources available. Working closely with the NOAA partners within the COMT project will ensure a smooth transition of these research models and results into real-time operations.

5. Outreach, Stakeholder Engagement, and Education

The goal of CeNCOOS outreach, stakeholder engagement, and education is to increase science literacy and the impact of coastal ocean observing on decision-making and wise use of the ocean. Our educational component is aimed at science literacy and science, technology, engineering and math (STEM) education at universities. By supporting educators at ten post-graduate teaching and research institutions in the region, CeNCOOS expands its reach geographically and beyond the sciences. CeNCOOS investigators teach undergraduate courses for science and non-science majors, teach graduate courses, and provide internships, work study, and volunteer experiences. CeNCOOS data is used to support these activities and provide real world data sets accessible to students. For university marine science students, CeNCOOS provides work experience in basic research and applied science. The CeNCOOS annual progress report and the underlying reports from sub-awardees describe some of the students engaged, topics studied, and research supported.

The CeNCOOS web and social media provide our broadest outreach, serving data and information products to a region-wide audience. We can be topical and timely, addressing issues as they arise and crises as they occur, allowing us to contribute the data component/ data informed perspective on issues important to people. For example, CeNCOOS and SCCOOS posted information on surface currents and oil spill trajectories within hours of the Refugio spill in June 2015. Both the web and social media provide two-way communication. Users can comment on the information and data products, provide feedback and suggestions, and thus shape the flow of information so that it meets their needs. Our help-desk ticket system tracks and organizes our response to feedback. Additional stakeholder feedback is received from the many advisory bodies in the region, for example the California Current Acidification Network and the Blue Ribbon Panel on OA and hypoxia. The three formal advisory bodies identify and guide the issues the RA should be involved in, help prioritize activities, and set goals for CeNCOOS.

For the last 8 years CeNCOOS has participated in the IOOS Outreach Committee. This volunteer committee provides a forum for discussing effective strategies and techniques, sharing products, and coordinating efforts among the 11 RAs and the IOOS Program Office. By sharing our knowledge, we leverage resources both financially and programmatically. The Outreach Committee will continue to hold monthly calls, develop effective communication strategies, and share successes and lessons learned. In addition to existing joint efforts (eg., producing summary documents that represent all associations, common branding and look and feel, monthly coordination meetings), the cross-RA outreach committee identified the following areas for collaboration: communicating our impact, maintaining databases and resources for shared use, sharing approaches on emerging issues and opportunities such as citizen science, sharing efforts and resources at major trade and academic meeting venues (e.g., MTS, SPIE), providing data to educators in support of ocean literacy, and developing common outreach materials. Enhanced funding will enable RA education and outreach staff to meet and work together.

At base capacity ($1.5M/yr) CeNCOOS will continue the existing product development, existing outreach, and internet-based education and outreach. Support for educational activities at universities would be curtailed. At level funding ($2.5M/yr), CeNCOOS would continue existing product development and communications activities, internet based education and outreach, and continue the support for investigators at universities and their associated outreach activities. We will produce and implement a communications plan that identifies education and outreach materials to be produced. At the enhanced tier ($4M/yr) CeNCOOS would support the above activities, the Center for Ocean Solutions partnership discussed below, and augment the staff time (product developer, information manager) needed to implement the COS-CeNCOOS partnership. With additional funding we will support a West Coast Governors Alliance (WCGA) intern jointly with SCCOOS and NANOOS. In 2013/14 the three RAs jointly supported an intern that, in addition to the value of the data products they created, increased the coordination between the west coast regional associations and the WCGA. Support for coordinated San Francisco Bay observing will provide opportunities for education and outreach in the most densely populated and impacted bay in the CeNCOOS region. By creating a collaborative network of several institutions within the larger CeNCOOS network, we will create a more efficient model for operations and communication with a public venue, the Exploratorium, serving as the education and outreach node for the network. Tools for CeNCOOS data exploration and visualization can be tested with public and K-12 audiences and successful prototypes shared with the broader community.

The difficulty in using scientific information in decision-making is well known. Enhanced funding will enable CeNCOOS to partner with the Center for Ocean Solutions, an interdisciplinary center focused on science in decision-making, on outreach and engagement specifically targeting regional decision-makers. The partnership with COS has three phases: one to identify stakeholders and CeNCOOS-relevant products, a second phase to identify stakeholder needs and best practices, and a third phase to develop approaches and strategies that increase the impact CeNCOOS has on regional decision-making. We expect this effort to analyze and improve CeNCOOS engagement will inform our product development and observing systems as we tune them to meet decision-maker needs. We believe that this effort could serve as a model for how other Regional Associations better meet the needs of their regional decision-makers.

Milestone Schedule (x milestone, ---- continuous activity, gray denotes active sub-award) Lvl indicates the funding level required to support the task ($M/yr).

| lvl | Task year | 1 | | | | 2 | | | | 3 | | | | 4 | | | | 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | quarter | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| | **Governance** | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Coordinate observing systems | | x | | x | | x | | x | | x | | x | | x | | x | | x | | x |
| 1.5 | Coordination (IOOS, IOOSA, MTS, AGU, Hill, CA govt) | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Manage projects, receive, disburse, oversee funds | | | | x | | | | x | | | | x | | | | x | | | | x |
| 1.5 | Facilitate partnerships incl grant writing | | | | x | | | | x | | | | x | | | | x | | | | x |
| | **Observing** | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Operate 27 HF radar | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2.5 | Operate 13+ shore stations | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2.5 | Operate 2 glider lines | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | Expand monitoring SF Bay | | | | | | | | | | | | | | | | | | | | |
| 4 | Add 2 HAB sites, analyses | | | | | | | | | | | | | | | | | | | | |
| 4 | Add sensors to existing network (OA, hypoxia, nutrients) | | | | | | | | | | | | | | | | | | | | |
| 4 | Refresh HFR at 10%/yr | | | | | | | | | | | | | | | | | | | | |
| 4 | Refresh/replace shore sta. | | | | | | | | | | | | | | | | | | | | |
| 4 | Bodega line | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | Animal tagging | | x | | x | | x | | x | | x | | x | | x | | x | | x | | x |
| | **Data** | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Acquire real time obs (HFR, shore, glider, model) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.5 | Perform QC incl QARTOD | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Maintain & export catalog | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Web services incl. ERDDAP, THREDDS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 1.5 | Archive data at repositories | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2.5 | RICE certification | | | | x | | | | | | | | | | | | | | | | |
| 2.5 | Maintain portal, continue integrating data | | | | | | | | | | | | | | | | | | | | |
| 4 | Add prioritized legacy data | | | | | | | | | | | | | | | | | | | | |
| 4 | Additional QC, post-process | | | | | | | | | | | | | | | | | | | | |
| | **Modeling & analysis** | | | | | | | | | | | | | | | | | | | | |
| 2.5 | Provide boundary conditions | | | | | | | | | | | | | | | | | | | | |
| 2.5 | Operate 2 ROMS | | | | | | | | | | | | | | | | | | | | |
| 4 | Increase resolution, verification, add rivers, tides | | | | | | | | | | | | | | | | | | | | |
| 4 | Improve HFR assimilation, historical HFR products | | | | | | | | | | | | | | | | | | | | |
| 4 | Copepods as indicators | | | | | | | | | | | | | | | | | | | | |
| 4 | Novel upwelling indices | | | | | | | | | | | | | | | | | | | | |
| | **Outreach and education** | | | | | | | | | | | | | | | | | | | | |
| 1.5 | Maintain web, social media | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | Engage w/ WCGA | | | | | | | | | | | | | | | | | | | | |
| 4 | Engage Center Ocean Sol. | | | | | | | | | | | | | | | | | | | | |

List of appendix pages (50 total)
1 references
1 figures
1 NEPA
3 support letters
18 abbreviated CV for sub award lead investigators (D. Anderson J. Barth, R. Bochenek, Y. Chao, F. Chavez, T. Connolly, J. Dorman, J. Doyle, C. Edwards, M. Elliot, T. Hallenbeck, R. Kudela, J. Largier, S. Monismith K. Nielsen , J. Paduan, D. Wendt, C. Whelan)
6 MBARI budget narrative for sub-awards and MBARI
17 Sub-award work plans (Axiom, CalPoly, CODAR, Farallons Institute, HSU, NPS, NRL, OSU, Point Blue, SFSU, SJSU, Stanford, UCD, UCLA UCSC (2p), WCGA)

APPENDICES- REFERENCES


Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua (2015), Causes and impacts of the 2014 warm anomaly in the NE Pacific, Geophys. Res. Lett., 42, 3414–3420, doi:10.1002/2015GL063306

Feely, R. A., Alin, S. R., Newton, J., Sabine, C. L., Warner, M., Devol, A., & Maloy, C. (2010). The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. Estuarine, Coastal and Shelf Science, 88(4), 442-449.

Halpern BS, Longo C, Scarborough C, Hardy D, Best BD, et al. (2014). Assessing the Health of the U.S. West Coast with a Regional-Scale Application of the Ocean Health Index. PLoS ONE 9(6): e98995. doi:10.1371/journal.pone.0098995

Li, Z., Y. Chao, J. C. McWilliams, and K. Ide (2008) A three-dimensional variational data assimilation scheme for the Regional Ocean Modeling System: Implementation and basic experiments. *Journal of Geophysical Research (Oceans)*, 113, C05002, doi:10.1029/2006JC004042.

Li, Z., Y. Chao, J.C. McWilliams, and K. Ide (2009). A Three-Dimensional Variational Data Assimilation Scheme for the Regional Ocean Modeling System. *Journal of Atmospheric and Oceanic Technology*, 25, 2074-2090.

McLaughlin, K., S.B. Weisberg, A. Dickson, G. Hofmann, J. Newton. 2013. Core Principles for Development of a West Coast Network for Monitoring Marine Acidification and Its Linkage to Biological Effects in the Nearshore Environment. California Current Acidification Network (C-CAN).

McLaughlin, K., S.B. Weisberg, S. Alin, A. Barton, T. Capson, A. Dickson, B. Eudeline, D. Gledhill, B. Hales, T. Martz, J. Salisbury. 2014. Guidance Manual for Establishing a Land-Based Station for Measurement of Ocean Acidification Parameters. California Current Acidification Network (C-CAN).

Moore, A.M., Arango, H.G., Broquet, G., Powell, B.S., Zavala-Garay, J., Weaver, A.T. (2011). The regional ocean modeling system (ROMS) 4-dimensional variational data assimilation systems. I: System overview and formulation. *Progress in Oceanography*, 91, 34-49.

Moore, A. M., H. G. Arango, G. Broquet, C. A. Edwards, M. Veneziani, B. S. Powell, D. Foley, J. D. Doyle, D. Costa, P. Robinson, (2011), The regional ocean modeling system (ROMS) 4-dimensional variational data assimilation systems. II: Performance and application to the California current system. *Prog. Oceanogr*. doi:10.1016/j.pocean.2011.05.003.

Moore, A.M., C. A. Edwards, J. Fiechter, P. Drake, H.G. Arango, E. Neveu,S. Gurol and A.T. Weaver, 2013: A 4D-Var Analysis System for the California Current: A Prototype for an Operational Regional Ocean Data Assimilation System. In ``Data Assimilation for Atmospheric, Oceanic and Hydrological Applications, Vol. II," Liang Xu and Seon Park, Eds. Springer, Chapter 14, 345-366.

Smith, J. N., Brown, R. M., Williams, W. J., Robert, M., Nelson, R., and Moran, S. B., 2015. Arrival of the Fukushima radioactivity plume in North American continental waters. PNAS, 112(5):1310-1315.

U.S. Integrated Ocean Observing System, 2012. Coastal Ocean Modeling Testbed Terms of Reference. http://www.testbeds.noaa.gov/pdf/comt-TOR-091412.pdf Accessed August 7, 2015.

U.S. Integrated Ocean Observing System, 2015. RICE Certification Requirements Guidance. Accessed Aug. 7, 2015.

U.S. IOOS, 2013. A Plan to Meet the Nation's Needs for Surface Current Mapping, http://www.ioos.noaa.gov/library/national_surface_current_plan.pdf, accessed Aug. 9, 2015.

U.S. IOOS, Toward a U.S. IOOS® Underwater Glider Network Plan Part of a comprehensive subsurface observing system, (http://www.ioos.noaa.gov/glider/strategy/glider_network_whitepaper_final.pdf, accessed Aug. 9, 2015.

APPENDICES. Figures

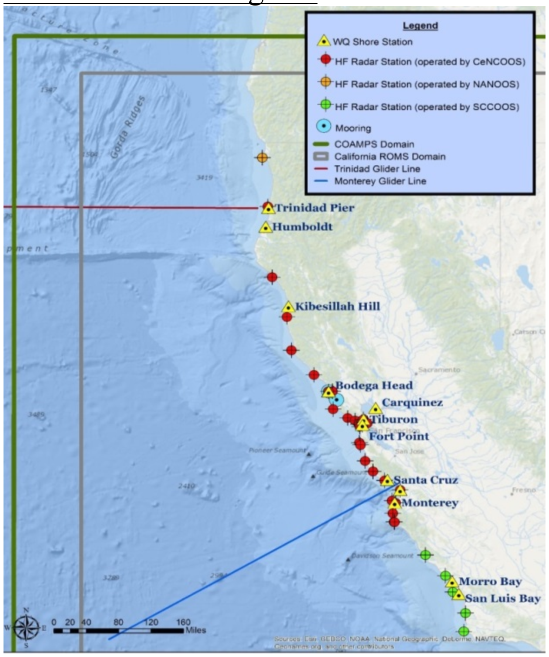


Figure 1. CeNCOOS-supported Observing Network consists of 27 HF radars, 13 shore stations, 2 glider lines, 2 ROMS models (grid), COAMPS atmospheric model (May 2015). The CeNCOOS web site and data portal integrates information from many other sensors including CDIP, NERRS, NDBC, and satellite observations.

| | Federal, Regional or State Priority | Strategy 1: *Long-term measurements* | Strategy 2: *CeNCOOS data portal* | Strategy 3: *Data-assimilating ecosystem models* | Strategy 4: *Products to inform policy & decision makers* |
|---|---|---|---|---|---|
| IOOS Themes | Marine Operations | ◆ | ◆ | ◆ | ◆ |
| | Coastal Hazards | ◆ | ◆ | | ◆ |
| | Climate Variability and Change | ◆ | ◆ | ◆ | ◆ |
| | Ecosystems, Fisheries, & WQ | ◆ | ◆ | ◆ | ◆ |
| WCGA Priorities | Marine Debris | ◆ | ◆ | ◆ | ◆ |
| | Adaptation to Climate Change | ◆ | ◆ | ◆ | ◆ |
| | West Coast Ocean Data Portal | | ◆ | | ◆ |
| | Ocean Acidification | ◆ | ◆ | ◆ | ◆ |
| CA OPC Focus Areas | Science-based Decision-making | ◆ | ◆ | ◆ | ◆ |
| | Climate Change | ◆ | ◆ | ◆ | ◆ |
| | Sustainable Fisheries & Ecosystems | ◆ | ◆ | ◆ | ◆ |
| | Impacts from Land-based Sources | ◆ | ◆ | | ◆ |
| | Existing & Emerging Ocean Uses | ◆ | ◆ | ◆ | ◆ |

Figure 2. Priority Matrix (CeNCOOS Strategic Plan) shows how the four strategies contribute to themes and priorities identified by IOOS, the West Coast Governors Alliance, and the CA Ocean Protection Council.

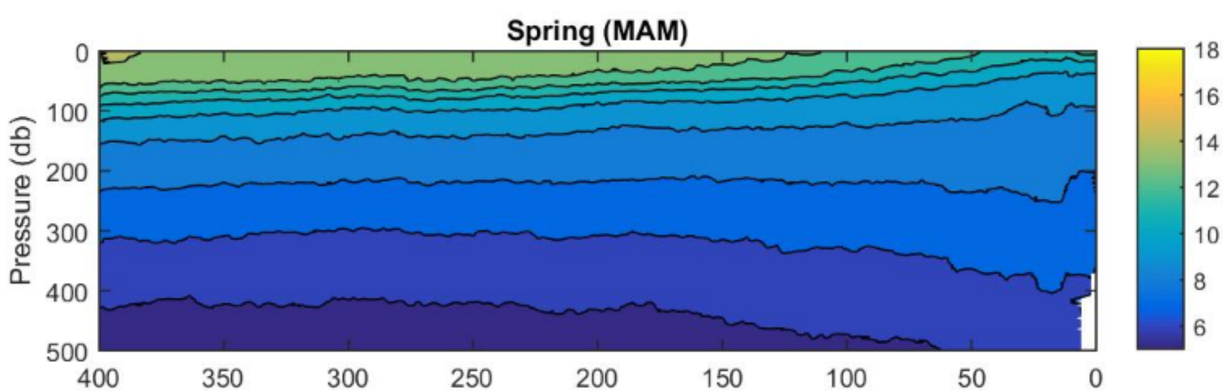


Figure 3. Spring ocean temperature profile from glider observations along the Monterey line (blue line above) vs distance offshore (km) depicts the ocean thermocline, the California Current with upwelling along the coast (right side), and the warmer water and deeper mixed layer of the North Pacific gyre (left side).

# MBARI/CENCOOS Detail Budget

Updated: 8/31/2015

| | | Year1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SALARY/WAGES** | Months | **Y1** | **MONTHS** | **Y2** | **MONTHS** | **Y3** | **MONTHS** | **Y4** | **MONTHS** | **Y5** | **Total** |
| **Total Salary & Wages** | | **446,897** | | **459,284** | | **472,045** | | **485,186** | | **498,724** | **2,362,136** |
| **FRINGE BENEFITS** | | | | | | | | | | | |
| **Total Fringe Benefits** | | **245,362** | | **252,152** | | **259,147** | | **266,350** | | **273,770** | **1,296,781** |
| **Total Salary & Benefits** | | **692,259** | | **711,436** | | **731,192** | | **751,536** | | **772,494** | **3,658,917** |
| **CAPITAL EQUIPMENT (items >$5K)** | | | | | | | | | | | |
| Animal Tags (9 per year) | | 63,234 | | 63,234 | | 63,234 | | 63,234 | | 63,234 | 316,170 |
| YSI EXO2 Sondes, sensors for SF Bay | | 68,220 | | | | | | | | | 68,220 |
| SF Bay network (nitrate analyzer) | | 27,665 | | 55,330 | | | | | | | 82,995 |
| Real time transmission | | 11,740 | | | | 11,740 | | | | | 23,480 |
| Nitrate Analyzer (HSU) | | | | 27,665 | | | | | | | 27,665 |
| YSI EXO2 Sondes | | | | | | 45,480 | | | | | 45,480 |
| Nitrate Analyzer (Morro Bay) | | | | | | 27,665 | | | | | 27,665 |
| Burkolators (2 Y4 - HSU, BML, 1 Y5 - CalPoly) | | | | | | | | 120,000 | | 60,000 | 180,000 |
| | | **170,859** | | **146,229** | | **148,119** | | **183,234** | | **123,234** | **771,675** |
| **TRAVEL** | | | | | | | | | | | |
| MBARI travel | | 26,139 | | 26,139 | | 26,139 | | 26,139 | | 26,139 | **130,695** |
| **Total Travel** | | **26,139** | | **26,139** | | **26,139** | | **26,139** | | **26,139** | **130,695** |
| **PARTICIPANT SUPPORT** | | | | | | | | | | | |
| **MATERIALS & SUPPLIES** | | | | | | | | | | | |
| education and outreach consumable materials | | 1,500 | | 1,500 | | 1,500 | | 1,500 | | 1,500 | 7,500 |
| Non-cap Equipment (parts to repair/replace sensors) | | **23,363** | | **26,624** | | **30,359** | | 26,639 | | 31,639 | 138,624 |
| **Total Materials & Supplies** | | **24,863** | | **28,124** | | **31,859** | | **28,139** | | **33,139** | **146,124** |
| **PUBLICATIONS/DOCUMENTATION** | | | | | | | | | | | |
| Journal publication fees incl. open source fees | | 2,000 | | 2,000 | | 2,000 | | 2,000 | | 2,000 | 10,000 |
| Graphics for education and outreach publications | | 3,000 | | 3,000 | | 3,000 | | 3,000 | | 3,000 | 15,000 |
| **Total Publications** | | **5,000** | | **5,000** | | **5,000** | | **5,000** | | **5,000** | **25,000** |
| **OUTSIDE SERVICES** | | | | | | | | | | | |
| annual calibration | | 16,000 | | 16,000 | | 22,000 | | 22,000 | | 22,000 | 98,000 |
| shore station repair/replacement | | 20,639 | | 34,639 | | 20,639 | | 21,077 | | **17,012** | 114,005 |
| operate Burkolator | | | | | | | | **10,000** | | **30,000** | 40,000 |
| engagement meeting support/facilitation | | 4,000 | | 4,000 | | | | | | | 8,000 |
| IOOS Association dues | | 9,500 | | 9,500 | | 9,500 | | **9,500** | | **9,500** | 47,500 |
| **Total Outside Services** | | **50,139** | | **64,139** | | **52,139** | | **62,577** | | **78,512** | **307,505** |
| **SUBAWARDS** | | | | | | | | | | | |
| Axiom | | 237,250 | | 250,000 | | 250,000 | | 250,000 | | 250,000 | 1,237,250 |
| CalPoly | | 116,250 | | 129,000 | | 129,000 | | 129,000 | | 129,000 | 632,250 |
| CODAR | | 282,382 | | 295,132 | | 295,132 | | 295,132 | | 295,132 | 1,462,910 |
| Farallones Institute | | 53,250 | | 66,000 | | 66,000 | | 66,000 | | 66,000 | 317,250 |
| HSU | | 104,550 | | 117,300 | | 117,300 | | 117,300 | | 117,300 | 573,750 |
| MLML | | 58,330 | | 65,248 | | 61,862 | | 68,905 | | 65,648 | 319,993 |
| OSU | | 62,250 | | 75,000 | | 75,000 | | 75,000 | | 75,000 | 362,250 |
| Point Blue | | 19,948 | | 19,948 | | 0 | | 0 | | 0 | 39,896 |
| SFSU | | 147,908 | | 160,658 | | 160,658 | | 160,658 | | 160,658 | 790,540 |
| Stanford (COS) | | 72,915 | | 71,254 | | 83,022 | | 0 | | 0 | 227,191 |
| UCD | | 509,450 | | 522,200 | | 522,200 | | 522,200 | | 522,200 | 2,598,250 |
| UCLA | | 137,250 | | 150,000 | | 150,000 | | 150,000 | | 150,000 | 737,250 |
| UCSC | | 392,250 | | 405,000 | | 405,000 | | 405,000 | | 405,000 | 2,012,250 |
| CSSF | | 15,000 | | 15,000 | | 15,000 | | 15,000 | | 15,000 | 75,000 |
| Sub options "one yr projects" | | 60,000 | | 60,000 | | 60,000 | | 60,000 | | 60,000 | 300,000 |
| **Total Subawards** | | **2,268,983** | | **2,401,740** | | **2,390,174** | | **2,314,195** | | **2,310,938** | **11,686,030** |
| **Subawards subject to OH** | | **359,948** | | **40,052** | | **25,000** | | **25,000** | | **25,000** | |
| **OH on Subawards** | | **183,573** | | **20,427** | | **12,750** | | **12,750** | | **12,750** | **242,250** |
| **TOTAL DIRECT COSTS** | | **3,238,242** | | **3,382,806** | | **3,384,622** | | **3,370,820** | | **3,349,455** | **16,725,946** |
| **MODIFIED TOTAL DIRECT COST BASE** | | **1,158,348** | | **874,889** | | **871,329** | | **898,391** | | **940,283** | **4,743,241** |
| **TOTAL INDIRECT COSTS** | **51%** | **590,758** | | **446,194** | | **444,378** | | **458,180** | | **479,544** | **2,419,054** |
| **TOTAL DIRECT & INDIRECT COSTS** | | **3,829,000** | | **3,829,000** | | **3,829,000** | | **3,829,000** | | **3,828,999** | **19,145,000** |
| **NPS** | | **91,000** | | **91,000** | | **91,000** | | **91,000** | | **91,000** | **455,000** |
| **NRL** | | **80,000** | | **80,000** | | **80,000** | | **80,000** | | **80,000** | **400,000** |
| **Total Costs** | | **4,000,000** | | **4,000,000** | | **4,000,000** | | **4,000,000** | | **4,000,000** | **20,000,000** |