CeNCOOS: Integrating Marine Operations for Decision Makers and the General Public

Leslie Rosenfeld
CeNCOOS Program Director
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039-9644
Phone: (831) 775-2126 FAX: (831) 775-1918 E-mail: role@mbari.org

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LONG-TERM GOALS

CeNCOOS is one of the eleven Regional Associations (RAs) comprising the national Integrated Ocean Observing System (IOOS). IOOS finds its legal basis in the Omnibus Public Land Management Act of 2009, which was signed into law by President Barack Obama on March 30, 2009. The task of the RAs is to "coordinate State, Federal, local, and private interests at a regional level with the responsibility of engaging the private and public sectors in designing, operating, and improving regional coastal and ocean observing systems in order to ensure the provision of data and information that meet the needs of user groups from the respective regions." A major emphasis is on producing products that meet the needs of end-users in four focus areas: Ecosystems and Climate, Water Quality, Marine Operations, and Coastal Hazards.

OBJECTIVES

CeNCOOS strives to maintain a sustained observational presence in the coastal ocean in order to: a) provide baseline information by which to quantify change; b) capture large, transient, unpredictable, and important events; and c) facilitate breakthroughs in knowledge not possible without these long-term observations. The primary objective of the CeNCOOS data management effort is to facilitate easy data access and use by researchers, modelers, product developers, managers, and the general public. Furthermore, CeNCOOS fosters solid working relationships between scientists and end-users in order to produce ocean information products of societal relevance in the four theme areas cited above.

APPROACH AND WORK PLAN

CeNCOOS is organized around institutions, rather than individuals, who can carry out a needed task and are committed to maintaining the continuity of the observing system over a period of many years. A listing of the institutions grouped by task follows.

1. All CeNCOOS activities are coordinated by the CeNCOOS program office located at MBARI. This office administers the CeNCOOS region including strategic planning, program governance, fiscal oversight, education and outreach, development and maintenance of the website, and product creation for end users. *Monterey Bay Aquarium Research Institute (MBARI)*

2. Maintain automated coastal shore stations for water quality, long term trends in temperature, salinity, sea level, chlorophyll fluorescence, and ocean acidification; Harmful Algal Bloom monitoring, forecasting, and mitigation. *Humboldt State University, UC Davis – Bodega Marine Lab, San Francisco State University – Romberg Tiburon Center, UC Santa Cruz, Moss Landing Marine Laboratories (MLML), California Polytechnic State University (CalPoly), Sonoma State University.*

3. Continuously operate across-shore glider transect to monitor temperature, salinity, chlorophyll fluorescence, currents, and eventually the carbon variables. Data from the glider are used to track ENSO events and climate change, and to feed data assimilating ocean circulation models. *MBARI*

4. Harden the HF radar surface current mapping network to reduce down time, improve accuracy, and produce products. The surface current data are used for search and rescue, marine operations, ecosystem forecasting, and are assimilated into ocean models. *UC Davis – Bodega Marine Lab, San Francisco State University– Romberg Tiburon Center, Naval Postgraduate School*

5. Run mesoscale atmospheric and data assimilating ocean circulation models to forecast currents, state variables, and ultimately ecosystem parameters. *Naval Research Laboratory – Monterey, CA, UC Los Angeles in conjunction with JPL, UC Santa Cruz*

6. Implement a data management and communications (DMAC) system to facilitate easy data access and use by researchers, modelers, product developers, managers, and the general public. An interoperable data system, both within the regional association and across RAs, is an integral and important part of the national IOOS process. *SAIC, MBARI*

WORK COMPLETED

Work completed during FY12 is reported here using the same organizational structure as in the Work Plan above.

1. A very well attended two-day CeNCOOS meeting was held in January 2012, and a Joint (with SCCOOS) Strategic Advisory Committee meeting was held in June. New CeNCOOS Program and Information Managers were hired. The CeNCOOS MOA was revised to ensure more diverse organizational representation on the Governing Council, and elections for five seats on the Council were held. Two additional organizations became CeNCOOS members.

CeNCOOS had a significant presence at the MBARI open house, a Monterey Bay climate change workshop, the Humboldt Bay Symposium, and the Cal Poly Center for Coastal Marine Sciences' Avila pier open house public outreach events. The first of three California ocean observing system training sessions for the State Water Resources Control Board (SWRCB) was held jointly with SCCOOS in September.

CeNCOOS worked with NANOOS, SCCOOS, and the West Coast Governors Alliance (WCGA) on Ocean Health to forge an MOU to collaborate on issues such as ocean acidification and data management. The final signature was collected just after the close of this reporting period.

The transition of the CeNCOOS wind product from JPL to MBARI was completed.

2. Operations of 12-14 shore stations and one nearshore mooring continued. A new shore station, operated by MLML with assistance from Monterey Abalone Co. was installed on the Monterey Wharf. The Tiburon station was redeployed on a newly built pier and the Humboldt station was upgraded and moved to a new location.

Three CeNCOOS shore stations (Humboldt Bay Chevron Pier, Santa Cruz Wharf, and MLML seawater intake) are part of the California SWRCB ocean acidification pilot project which began in late summer 2012 and is scheduled to last a year. Durafet pH sensors have been deployed and weekly water samples are being sent for carbon variable analyses at Scripps. These data will used in conjunction with data from other co-located sensors to evaluate the methodology to measure pH in a variety of coastal settings.

CeNCOOS continues to support the creation of a statewide HAB monitoring and alert program, and CeNCOOS supported HAB monitoring at Monterey and Santa Cruz wharfs is critical to the development and testing of predictive HAB models.

3. MBARI has been operating a profiling glider along CalCOFI line 67 off Monterey Bay since 2007, and with CeNCOOS support has done so almost continuously since 2009. These data are available through the CeNCOOS THREDDS server (http://www.cencoos.org/thredds/catalog/glider/catalog.html) and are also distributed with other Scripps glider data. Seasonally averaged data for this transect are now being produced (http://www.mbari.org/bog/waveglider/glider_seasonal.html). In addition, as part of its collaborative efforts with other regional oceanographic projects, CeNCOOS assisted with glider operations for the Controlled, Agile, and Novel Observing Network (CANON) experiment which took place in Monterey Bay in May 2012. Profiling gliders from MBARI, UCSC, and NPS were included, as were MBARI AUVs. The experiment captured the highest levels of pCO_2 ever observed at the M1 mooring, and included the first full deployment of a Liquid Robotics wave glider equipped with MBARI ocean acidification equipment. It is hoped that the latter will become part a routine part of the CeNCOOS observing network in the future.

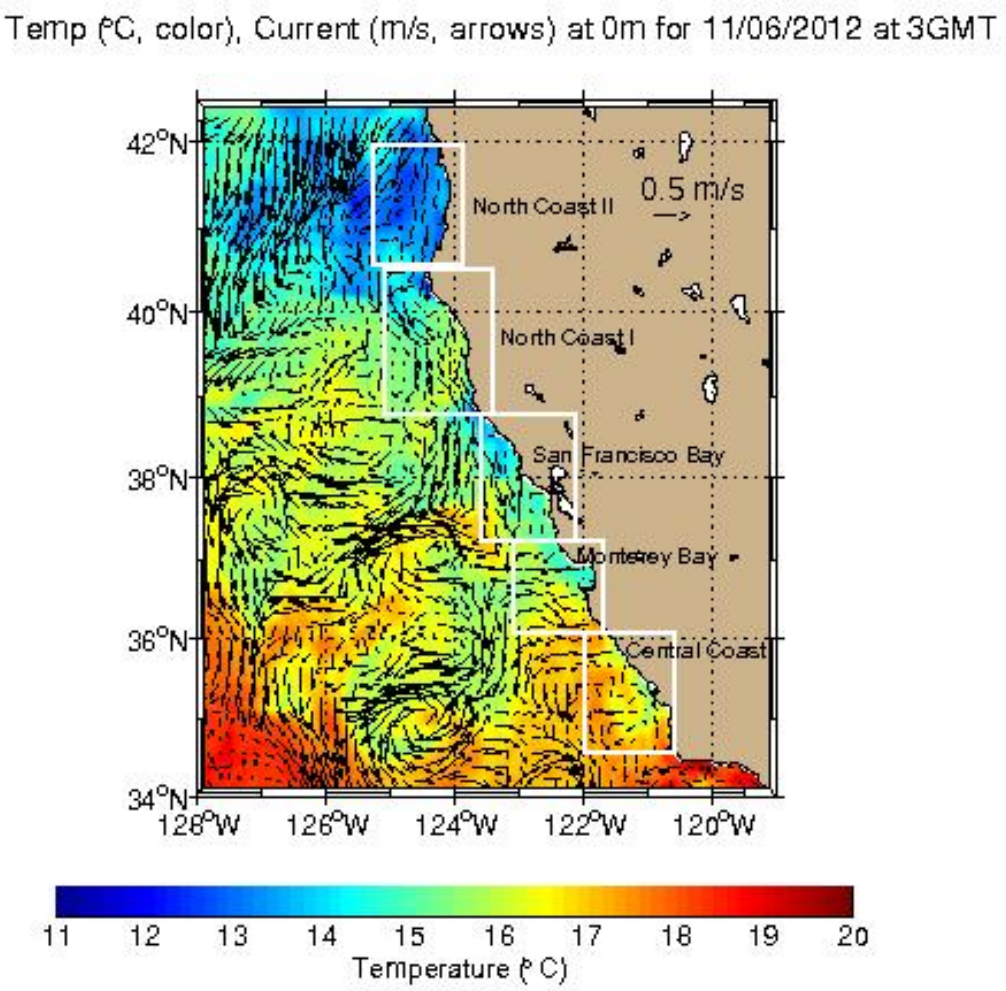
4. CeNCOOS maintains 28 HF radar stations, some of them with quite old equipment. Most of the HF radar effort during this reporting period has been directed at the challenge of maintaining continuous operations and data capture. Most, but not all, stations have remained in service through FY12. With the departure of Mark Moline from Cal Poly, SCCOOS has taken over responsibility for the HF radars at the southern end of the CeNCOOS region.

5. The Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS®) forecasts for the CeNCOOS region (http://www.cencoos.org/sections/models/ROMS.shtml) were upgraded from a developmental status queue to the operational suite. This upgrade is important because the CeNCOOS forecasts should be more reliable and robust as part of the Navy operational suite. Additional, a new capability to provide the model output in a community standard format (grib) has been adopted.

The UCSC Ocean Modeling Group operates a near-real-time 4D-Variational assimilation system for the California Current System; every day producing an estimate of the ocean state one day before the present for the U.S. west coast at 0.1º resolution. Figures of model output are generated daily (http://www.cencoos.org/sections/models/UCSC_ROMS.shtml) and model output is posted to a THREDDS server (http://oceanmodeling.pmc.ucsc.edu:8080/thredds/catalog.html). The archive of CCS model output extends from January 1, 2011 through the present. During this reporting period,

procedures were implemented such that these files now meet all IOOS protocols for interactive web access (see section 6 below). Additionally, code for diagnostic studies of model output was developed to enable analysis of area-averaged kinetic energy and enstrophy, comparison of modeled temperature and salinity structure with climatological values, and documentation of the fraction of rejected observations as well as the locations of maximum deviation between model fields and measured values. These diagnostics, which leverage funding external to this project, will be added to the web page in the future.

The UCLA/JPL 3-km resolution California statewide ROMs nowcast/forecast system, developed over the past four years, is now running routinely and results are posted on the JPL website (http://ourocean.jpl.nasa.gov/CA/) which is linked from the CeNCOOS site. CA ROMS uses COAMPS atmospheric forcing, and assimilates both in situ and remotely sensed data, including satellite and land-based HF radar data, with a multi-scale 3DVAR data assimilation scheme. Six hourly nowcasts and daily 72-hour forecasts are produced.



Surface temperature and velocity nowcast for the CeNCOOS region from the UCLA/JPL California ROMS.

6. CeNCOOS underwent an external review of its DMAC activities during May 2012. As a result, in addition to making CeNCOOS datasets available via THREDDS servers as described above, the CeNCOOS Program Office has added an ERDDAP server, and is undertaking other changes.

UCSC upgraded its THREDDS data server to enable aggregation of sequential West Coast ROMS output files into a "Best Time-Series" served as a single OPeNDAP url (http://oceanmodeling.pmc.ucsc.edu:8080/thredds/catalog/ccsnrt/fmrc/catalog.html?dataset=ccsnrt/fmrc/CCSNRT_Aggregation_best.ncd) and enable ncISO and WCS metadata services which offer data discovery and web mapping services to be run directly from the THREDDS server.

Two additional variables, air temperature and barometric pressure, and a number of new stations were added to the CeNCOOS data portal, which was also upgraded to improve ease of use and data accessibility. The iPhone app was also improved.

Starting with HF radar surface currents, COAMPS winds, and satellite sea surface temperature and ocean color, CeNCOOS is exploring ways make model and remotely sensed data more readily accessible for use in geographic information systems.

RESULTS

The essence of this project is not scientific research nor development of new technology, but rather the continuous application of appropriate technology to observe and forecast ocean conditions in order to advance scientific understanding, and to create informational products based on scientifically sound data and knowledge and to make these data and products accessible to inform those making decisions about the ocean, whether for purposes of public safety, resource utilization, resource management, or recreation. The evidence of our success in meeting that goal is that CeNCOOS data, products and expertise is sought by state and federal agencies, public utilities, industry, and the general public to help plan and execute their ocean activities.

IMPACT AND APPLICATIONS

National Security

HF radars have the potential to be used for tracking unidentified vessels. This is not a current CeNCOOS capability, but could potentially be developed in the future.

Though not complete, the UCSC set of diagnostic fields for ROMS should improve assessment of the overall data assimilative system and may provide useful information to other users, including the US Navy.

Economic Development

The potential impacts of the CeNCOOS on economic development are numerous and include: improving safety and efficiency of shipping; enhancement of tourism through information provided to beach goers and marine recreational users; increased sustainability of fisheries; improved aquaculture operations, and assessment of wave energy as a renewable energy source.

Quality of Life

CeNCOOS is working with the State of California in assessing the efficacy of marine protected areas, is heavily involved in detecting (and in the future hopefully forecasting) harmful algal blooms, and is a primary resource for long-term ocean time series used to assess ocean conditions in the context of climate change. We expect that in the future, CeNCOOS ecosystem models will aid in ocean resource management.

Science Education and Communication

CeNCOOS strives to educate a diverse audience for the purpose of promoting informed use of ocean observations, models, and derived products in decision-making about the ocean. This is accomplished through a variety of approaches, including the website, in-person training sessions, hand-outs, seminars, and participation in public ocean education events. CeNCOOS contributes to the development of the ocean observing system workforce through student internships, graduate student involvement, and post-doctoral fellows. The majority of CeNCOOS principal investigators are academics who incorporate CeNCOOS data and results into their curricula to benefit both undergraduate and graduate students.

CeNCOOS is collaborating with the San Francisco Exploratorium in setting up several assets at their new facility at Piers 15 and 17. In late 2012, a new high-resolution high frequency radar site will be activated at the pier, and a new shore-based water quality station will follow in 2013. A "Color of Water" exhibit is also being developed for their facility.

TRANSITIONS

National Security

The COAMPS weather forecasts for the CeNCOOS region are used by the National Weather Service. The CeNCOOS glider data is assimilated into Navy models. The CeNCOOS HF radar surface current data available continuously for search and rescue and oil spill response.

Economic Development

A chlorophyll based productivity index for Humboldt Bay has been developed. Oyster growers want to know on a real time basis how much phytoplankton, which is consumed by their oysters, is coming into the Bay so that they can understand what is affecting the growth rates of the animals, to help them decide whether or not they should outplant more animals or harvest them for sale.

Decisions regarding time of transit, whether to hold a cargo ship offshore due to dangerous wave conditions, how heavily to load a ship, and the actual route of a vessel, all greatly impact the cost of maritime operations. Maritime operators, especially those in the busy ports of SF Bay, use CeNCOOS generated products to inform decisions such as these.

Commercial fishermen use the CeNCOOS Data Portal iPhone app to access ocean and weather conditions.

Quality of Life

The CeNCOOS wind page, and the CeNCOOS Data Portal and San Francisco Bay Currents iPhone apps are used by surfers, sailors and other recreational users to plan their activities.

Local city and county planners are using CeNCOOS-generated data and long-term trends for rapid response and future planning regarding inundation and flooding at the Pajaro River mouth and the Carmel River mouth – two areas that are very susceptible to flooding and erosion in big wave and precipitation events.

Science Education and Communication

CeNCOOS collaborated with the SCCOOS to educate the State Water Resources Control Board about the use of ocean observing system data and products to help address water quality issues in California.

RELATED PROJECTS

This CeNCOOS project is closely related to literally dozens of other federally, state, and privately funded projects – too many to be listed individually here. Every one of our PIs has closely related projects. These include a NASA-funded study entitled Utilizing Ecosystem Information to Improve the Decision Support System for Central California Salmon, and HABs projects funded by NOAA and the California Ocean Protection Council.

PUBLICATIONS

Frolov, S., J.D. Paduan, M.S. Cook, and J. Bellingham, 2012: Improved statistical prediction of surface currents based on historic HF-radar observations. *Ocean Dynamics*, DOI 10.1007/s10236-012-0553-5.

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Rogers-Bennett, L., R. Kudela, K. J. Nielsen, A. Paquin*, C. O'Kelly, G. Langlois, D. Crane & J. Moore. 2012. Dinoflagellate bloom coincides with marine invertebrate mortalities in northern California. *Harmful Algae News*, submitted.

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OUTREACH MATERIALS

Our greatest outreach tools include the website: www.cencoos.org , the CeNCOOS Data Portal: http://204.115.180.244/CeNCOOS/DataPortal.html and the wide array of Data Products available on the website: http://www.cencoos.org/sections/products/index.html. Outreach materials developed during this reporting period include our most recent newsletter (http://www.cencoos.org/sections/news/newsletter_2012_summer.php), informational handouts for our Congressional delegation and posters for scientific and public meetings.