

Sustaining NANOOS, the Pacific Northwest component of the U.S. IOOS®:

NOAA Award: NA11NOS0120036

Reporting period: 12/01/2015 to 05/31/2016

1) Project Summary

Our overall project goal is to sustain the Northwest Association of Networked Ocean Observing Systems, NANOOS, as the Regional Coastal Ocean Observing System for the U.S. Pacific Northwest that serves regional stakeholders in alignment with the vision of U.S. Integrated Ocean Observing System (IOOS®). NANOOS, with its essential subcomponents (integrated in-water and land-based Observing Systems, Data Management and Communications, Modeling and Analysis, and Education and Outreach) that are closely integrated within the national IOOS® system, provides significant societal benefits across a wide spectrum of users including federal, tribal, state and local governments, marine industries, scientific researchers, Non-Governmental Organizations (NGOs), educators and the general public.

For this FY15 period (= Y5 of award; Y9 of NANOOS RCOOS operations) our specific objectives were to:

- 1) **Maintain NANOOS as the PNW IOOS Regional Association:** Sustain our proven role for regional coordination, administrative infrastructure, and stakeholder engagement.
- 2) **Maintain surface current and wave mapping capability.** Maintain existing HF-radar foundational capability providing a portion of critical national capacity, and continue investment in wave mapping at a critical port.
- 3) **Sustain existing buoys and gliders (with reduced glider deployment in WA) in the PNW coastal ocean, in coordination with national programs.** Maintain these essential assets providing regional observations, with focus on hypoxia, HABs, ocean acidification, climate change detection and modeling input.
- 4) **Maintain observation capabilities in PNW estuaries, in coordination with local and regional programs.** Maintain these to aid sustainable resource management, water quality assessment and sub-regional climate change evaluation, with high priority new feeds.
- 5) **Maintain core elements of beach and shoreline observing programs.** Contribute to hazard mitigation by providing essential observations and decision support tools for coastal managers, planners and engineers, as resources allow.
- 6) **Maintain NANOOS' Data Management and Communications (DMAC) system for routine operational distribution of data and information.** Sustain the DMAC system NANOOS has built, including the NANOOS Visualization System (NVS), for dynamic and distributed data access and visualization for IOOS.
- 7) **Contribute to a community of complementary numerical regional models.** Contribute to the operation of regional models, and the tools and products they support, covering the head of tide of estuaries to the outer edges of the EEZ in both OR and WA.
- 8) **Deliver existing user-defined products and services for PNW stakeholders.** Continue to provide meaningful and informative data products that will connect with user applications and serve society.
- 9) **Sustain NANOOS education and outreach efforts.** Foster ocean literacy and facilitate use of NANOOS products for IOOS objectives, the core task for which the entire NANOOS RCOOS is constructed, via existing approaches for engaging users.

Consistent with our FY15 de-scope letter from the IOOS Program Office, NANOOS has the following additional tasks during FY15:

- 10) Support collection of OA measurements on our La Push [J. Newton, J. Mickett, UW, see p. 4] and NH10 [B. Hales, OSU, see p. 6] moorings, working with NOAA PMEL and the NOAA OA Program Office through the IOOS Program Office.
- 11) Support West Coast Ocean Acidification Cruise (WECO) Analytical Support [B. Hales, OSU, see p. 7].

2) Progress and Accomplishments

During the project period, NANOOS accomplished its objectives outlined above. NANOOS maintained the RCOOS subsystems it has developed, implemented, and integrated with NOAA IOOS funding and substantial external leverage. NANOOS remained focused on delivering data-based products and services that are easy to use to diverse stakeholders to address high-priority issues and aid decision-making. NANOOS continued its proactive interactions and regional coordination with a wide range of PNW stakeholders, to prioritize and refine our observations, products, and outreach efforts as funding allowed.

NANOOS milestones for this award are provided in Table 1. Our assessment is that NANOOS has met these milestones for the reporting period. We report here progress for following: a) observing systems (shelf, estuaries, shorelines, and currents); b) modeling (estuaries and shelves); c) Data management and Communications (DMAC); d) User Products; e) Education and Outreach; and, f) Administrative.

Table 1. NANOOS Milestones for FY 15*:

Area	Y5 Award = Y9 NANOOS
Observations	
Shelf:	-Maintain La Push, Newport, and Columbia R. buoys and deliver NRT datastreams via the NANOOS Visualization System (NVS) (on-going) -Support collection of OA data from La Push buoy and NH-10 buoys (on-going) -Maintain WA and OR glider transects (except funds are insufficient for maintaining La Push and Grays to Quinault, WA gliders) and deliver these datastreams via the NVS (on-going)
Estuaries:	-Maintain Puget Sound, Columbia R., and South Slough assets and deliver these datastreams via the NVS (on-going)
Shorelines:	-Maintain shoreline observations in WA and OR and deliver these datastreams via the NVS (on-going)
Currents:	-Maintain OR HF radar sites and X-band radar site and deliver these datastreams via the NVS (on-going) -Maintain OR Priority-One HF surface current mapping radar sites to the national operations standard, deliver the data via NVS and the National HF Radar system (on-going)
Modeling	
OR/WA estuaries and coast models	-Maintain modeling & forecasting capabilities at OSU, OHSU, & UW and make model output available via the NANOOS web (on-going)
DMAC	
Web Site Improvement	-Sustain and refine (on-going)
Tailored Product Development	-With E&O committee, evaluate usefulness of web and product suite (on-going)
Education and Outreach	
Networking	-Maintain existing and build new relationships with NANOOS priority area users and the education community (on-going)
Product Development	-Work with DMAC, User Products Committee on Tailored Product Development, as per above schedule, and in Tri-Committee meetings (on-going)
User Engagement	-Execute evaluation of web site and product suite (on-going)

Administration	
Meetings	-Represent NANOOS at all NOAA IOOS, IOOS Association, and national meetings of significance (e.g., MTS/IEEE, Ocean Sciences) (on-going)
Project oversight	-Conduct regular PI meetings, annual Tri-Committee meeting, and assist with evaluations, as scheduled (on-going) -Assess whether focus on hypoxia, HABs, OA, biodiversity investments are providing enhanced and valuable information (on-going)
Coordination	-Conduct annual Governing Council (GC) meeting (met and on-going) -Conduct sub-regional, and user-group specific workshops as resources allow (on-going) -Coordinate with West Coast RAs and other RAs to optimize and leverage capabilities and assure consistencies, but with no travel and at reduced level (on-going)
Accountability	-Submit required IOOS progress reports, assessments, and performance metrics and seek certification as a member of US IOOS once certification standards and processes are determined (on-going)

a) **NANOOS Observing Sub-system:** Data from all assets reported here are served via NANOOS NVS.

- **Shelf**

Washington Shelf Buoy: Led by J. Mickett, Applied Physics Laboratory, University of Washington (APL-UW), over this period NANOOS funding was used primarily for field operations and costs related to the maintenance and re-deployment of the Cha’Ba surface and NEMO subsurface mooring components of this array as well as the recovery of the heavily-leveraged “El Niño” mooring deployed over the winter at the shelf mooring site. Additionally, during this period Mickett and his group worked with PIs of the ESP OTT project (Newton, Moore, Hickey and Trainer among them) to successfully deploy an ESP on the subsurface mooring. There were two cruises during this period. The first one was in March aboard the NOAA ship Bell M. Shimada to recover Cha Ba and the Seaglider (operated by C. Lee). The mooring was successfully recovered, however, the Seaglider was unfortunately not. The latter was apparently damaged under the ship during recovery operations and never re-surfaced. A second cruise aboard the *R/V Thomas G. Thompson*, with ship time generously donated by the UW School of Oceanography, took place at the end of May with objectives to deploy the ESP-subsurface mooring, recover the winter “El Niño” mooring, re-deploy a simple subsurface mooring, and to support HAB and OA sampling work off the Washington and Oregon coasts. This cruise was hugely successful with all science objectives met. Additionally, because of the available space on the Thompson, we were able take on more than two dozen volunteers—educators, students and the general public---so this was also a successful outreach opportunity. We were again able to support an Oregon elementary school science project by deploying a small, satellite-tracked sailboat. There was extensive media coverage of the ESP deployment following the cruise, and videographers that were aboard for the cruise produced several short informational videos on the ESP deployment and on the NANOOS Washington Coast moorings. Both of these videos can be found on the NANOOS website or at <https://vimeo.com/168020010>.

To date, the power of integrating the ESP on the subsurface mooring with Cha Ba only 400 m away has been clearly demonstrated. Measurements on Cha Ba and the other sensors on the subsurface mooring (an ADCP, CTD, and McLane profiler) are providing key contextual observations to better understand the ESP observations. These observations include near-surface chlorophyll, pH, DO, temperature, salinity and velocity. Using these data Mickett has developed several new data products---which have been enthusiastically welcomed by resource managers on the Washington Coast---to aid in the interpretation of ESP observations.

Following last year’s successful deployment of a SeaFET pH sensor at 50 m depth on Cha Ba, we have

encountered two obstacles with using the SeaFET. First, one instrument deployed at 60 m depth on the El Niño mooring flooded during the deployment—we are still hoping to recover data from this instrument. Second, the SeaFET deployed on Cha Ba in March at 50 m has been reporting incorrect pH values (in the 20s) since the deployment. In an attempt to get some reliable deep pH values at Cha Ba, we deployed a third mooring on the May Thompson cruise with a pH sensor and CTD with DO sensor at 50 m. Although these data aren't real-time, they will hopefully continue the summer timeseries of deep pH.

During this period, PIs Mickett and Newton and others presented a poster showing the influence and evolution of the “Blob” in coastal and Salish Sea waters at the Pacific Anomalies Workshop Newton led in January. Also, Mickett presented a poster showing similar results at the ASLO/AGU Ocean Sciences Conference in New Orleans in February. Additionally, Newton and Mickett submitted an article to the 2015 Puget Sound Marine Waters Overview Report detailing the 2015 observations from the Washington Coast moorings.

J. Newton (APL-UW) and J. Mickett have continued to work with NOAA PMEL scientists Drs. Adrienne Sutton, Simone Alin, and Richard Feely, to maintain pCO₂ and pH datastreams and provide calibration samples for NOAA OAP-IOOS Ocean Acidification Monitoring. Sensor data have been transmitted to the NOAA OA and PMEL Carbon Programs and to NANOOS. Using Cha'ba data, Washington Ocean Acidification Center (WOAC) postdoc Dr. Beth Curry has continued work with the PMEL Carbon Group to test pH proxies on the Washington Shelf.

Washington Shelf Glider: The Applied Physics Laboratory, University of Washington, Integrative Observational Platforms group led by C. Lee (APL-UW) launched Seaglider 187 on 16 June, 2015 off La Push near the Cha'Ba mooring. The glider makes repeat sections along a line that extends from 125W near the 500 m isobath (~45 km offshore) to 127W (~210 km offshore), repeating the section every 10 days. The glider makes vertical dives in a saw tooth pattern across the section from the surface to 1000-m and is equipped with the following sensors: conductivity, temperature, pressure and dissolved oxygen (SeaBird 43F optode). Estimates of depth-averaged velocity can be combined with geostrophic velocity estimates of relative velocity to compute absolute velocity across the section. The glider completed 876 dives over the course of a nine-month mission, but was struck and destroyed by the NOAA vessel Shimada during the approach for recovery on 15 March, 2016. Fortunately, all scientific data had previously been uploaded via Iridium satellite telemetry, and were thus preserved despite the loss of the vehicle. As Seaglider 187 was the only glider available for NANOOS operations, its destruction effectively ends data collection along the La Push line. Ongoing efforts will focus on data processing, the production of targeted data products, and scientific analysis. Should funds become available for the fabrication of replacement Seagliders and operations, the La Push line will be restarted. The WA Shelf Seaglider complements the mooring based monitoring along the coast by adding a spatial component to the point measurements to help in understanding ocean processes such as El Niño, the “blob” and coastal upwelling.

Northern California Shelf Glider: Due to the deployment of NSF OOI gliders, starting in early December, 2014, the Oregon State University glider research group led by J. Barth and K. Shearman (OSU) is obtaining vertical sections of ocean properties from off Trinidad Head, CA (41° 3.5'N) using an underwater glider, in collaboration with CeNCOOS. We use 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. We are collaborating with Dr. Eric Bjorkstedt (NOAA Southwest Fisheries Science Center, Humboldt State University) to facilitate field work off Trinidad Head. We are using two of our Seagliders in order to “hot swap” them on the line when their batteries run low. During this reporting period, this effort is jointly funded by NANOOS and CeNCOOS.

From its first occupation of the TH line on December 4, 2014, until the end of this reporting period (5/30/2016), the glider was on the TH line for 561 days during five deployments, sampled along nearly 8444 km of track line covering the transect about 17 times, and collected about 4651 vertical profiles of ocean properties. For the reporting period 12/1/2015 to 5/30/2016 the glider was on the TH line for 176 days during two deployments, sampled along nearly 3164 km of track line covering the transect about 7 times, and collected about 1448 vertical profiles of ocean properties. The glider “uptime” was 99%. 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, we submit the data to NODC. Data from the Trinidad Head glider line are being used to monitor and understand the contributions of both the “Warm Blob” and El Niño to the warm anomalies observed in the northeast Pacific over the last several years. The glider data show that for the January to September 2015 period, the average 50-m temperature was 1-3 degrees C warmer than the historical average across the entire glider line out to 500 km offshore (Figure 1). Temperatures over the continental shelf during the 2015 summer upwelling season varied from above normal to average, due to wind-driven coastal upwelling bringing cold, deeper water up to 50-m depth. **Starting in September 2015, warm water associated with the 2015-2016 El Niño arrived at the TH line, with a positive 0.5-degree C anomaly extending to 500 m depth (Figure 1). The maximum temperature anomaly of over 2-degree C descended from the surface during the Warm Blob event to a depth of around 100 m.**

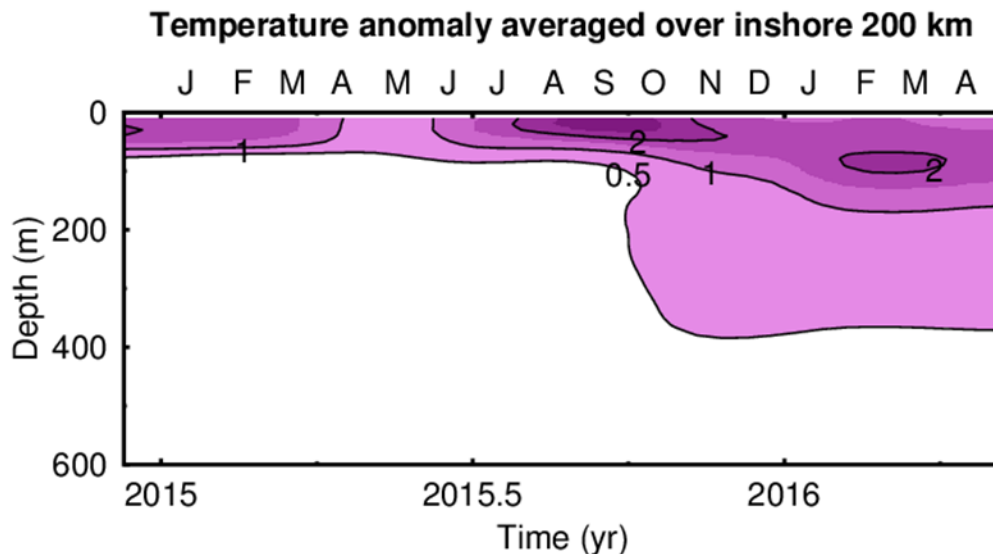


Figure 1: Temperature anomaly on the Trinidad Head, CA, (41° 3.5'N) glider line, averaged over the inshore 200 km of the 500-km long glider line. (Courtesy of J. Barth and S. Pierce, Oregon State University.)

Oregon Shelf Mooring: A mooring about 10 miles off Newport, Oregon, in 80 m of water (site NH-10) has been maintained since mid-2006, primarily through support by NANOOS (present PI is [Kosro](#)). Ship time to enable the mooring recoveries and deployments has been funded by the NSF CMOP Science & Technology Center. As CMOP is ending, this source of ship time will no longer be available, and new funding will need to be found for the ship time.

The most recent deployment of NH10 was on October 3, 2015, equipped with an Airmar weather station, two solar radiation meters, a WetLabs FLNTU fluorometry and turbidity sensor, a Seabird Microcat CTD, a Seabird 56 temperature sensor and a downlooking RDI 300kHz ADCP, all on the surface buoy. The buoy also contained Burke Hales' instrument suite for measuring pCO₂ and related fields. Below the buoy there were 7 SBE56's, 2 additional Microcat CTDs, and five SBE 39 temperature sensors, 2 of which also measured pressure. The anchor was built from three railroad wheels.

High waves associated with several past winter deployments have resulted in "hopping" or breaking of the mooring line (recently, jacketed wire rope). We have modified the design several times in the past 3 years with the intention of responding to these issues. The design used here fared very well in the first half of the deployment, surviving in wave heights exceeding 30 feet on Dec 10 and exceeding 25 feet on Dec 24 (earlier designs had trouble around 22 feet). However, on March 1, 2016, during waves of less than 18 feet, the upper part of the mooring became separated and began drifting north, coming to rest on a beach at Westport, WA, on March 10. The upper float containing the OA and weather gear, ADCP, FLNTU, 1 Microcat, and 4 upper ocean temperature sensors (3 56's, one 39) were recovered with data intact. However, the anchor and instruments below 20m, and a Microcat at 10m, were lost. A further modified design is being explored.

Data from the NH10 have contributed to analyses of the Pacific warm anomaly in presentations by Kosro (2016) at the Seattle workshop in January, and by Newton et al (2016) and Kurapov et al. (2016) in posters at the Ocean Sciences Meeting at New Orleans in February 2016.



B. Hales continues to maintain three mooring sites off the Oregon Coast, two bottom-mounted locations at the mid- and outer shelf (NH10 and NH20, respectively), and the surface expression at NH10. The Winter 15/16 deployment on 3 October went well and the mooring functioned well through the worst seastates we have experienced up until a particularly intense storm in late December knocked out communications. Despite the mooring breaking free early in March 2016, it eventually was recovered from the beach at Westport, Washington. Onboard instrumentation continued to log data in the intervening time, and the mooring was largely structurally intact. Work since March has consisted of mooring repairs and accumulation of sensors and hardware lost during the mooring break-free. The exceptionally stormy winter delayed redeployment of the near-bottom moorings until late spring/early summer, so rather than having an over-wintering data set to report on for this period, we have deployed moorings for a continuous observation of the spring transition.

The second subcomponent of Hales' work was the support of the nutrient and O₂ sample-collection and analyses during the recently completed WCOA cruise. Hales' team operated the onboard O₂ titration system during the cruise, and provided the data to the PMEL team for onboard O₂ electrode calibrations. Hales' team collected and analyzed about 1000 O₂ samples onboard the ship, and collected over 1700 samples for post-cruise nutrient analyses.

Northern Oregon to Central Washington shelf: Led by A. Baptista (OHSU), the Center for Coastal Margin Observation & Prediction (CMOP) maintains observational assets in the Columbia River coastal margin, with partial support from NANOOS and the National Science Foundation. These assets are anchored on SATURN-02 (a seasonal inter-disciplinary buoy at ~30m depth, off the mouth of the Columbia River; deployed during the reporting period) with additional data collected by glider operations ((as allowed by available funding; no deployment during the reporting period).

During the reporting period, a new station shelf station (SATURN-10) was maintained outside the mouth of the estuary, south of the South Jetty, at the request of the Corps of Engineers. SATURN-10 provides ocean conditions context and guidance on timing for crab monitoring. The station is seasonal, although its location might be adjusted annually. It measures real-time temperature, salinity, chlorophyll, DO and turbidity, in support of the adaptive management program for the Corps of Engineers Mouth of the Columbia River Regional Sediment Management Plan (RMCR 2011). A main goal of the RSMP is to increase the beneficial use of dredged sediment at the MCR to help protect shipping channel jetties, coastal beaches and nearshore habitats from erosion while avoiding and minimizing adverse environmental, resource and navigational safety effects. This process requires research and monitoring to ensure that disposal practices will not result in unacceptable adverse effects on the nearshore ocean ecosystem, especially commercial and recreational Dungeness crab populations, deemed among the most susceptible of local fisheries.

- **Estuaries**

Puget Sound, ORCA Buoy program: Led by J. Mickett, J. Newton, and A. Devol (UW), during this report period the ORCA (Oceanic Remote Chemical Analyzer) mooring system continued to undergo significant refurbishment and upgrade, while the field team carried out regular maintenance and repairs to keep this real-time system operational. Much of this work has been accomplished with significant contributions from non-NANOOS funding sources such as the Washington Ocean Acidification Center.

Non-routine work during this period included the continued testing of a prototype profiling mooring at the Dabob site, with the primary benefits of this system increased sampling frequency, lower maintenance costs and potentially more reliable operation. Malfunctioning satellite communications caused data gaps during the first half of 2016, but the system was successfully redeployed in May 2016 and is again reporting near real-time full water column profiles. Work also continued with the integration of a profiling pH sensor on the Carr Inlet mooring. A corroded connector on the CTD required a package swap, with the SeaFET returning back to the lab along with the broken CTD. Once redeployed, we will continue system evaluation to determine the feasibility of collecting accurate pH data while profiling, and expect to conclude testing in the second half of 2016. The surface SeaFET at this mooring continues to provide scientific-quality data, with no sensor malfunctions or down time during the reporting period. The high-frequency (> daily) record again shows a rapid transition in the spring from lower winter pH values (~7.8) to higher values associated with primary production (~8.4).

During this period, we made significant progress in our organized, formal effort to increase mooring reliability and to decrease maintenance costs. Prototype designs for a new, more robust winch control

module and communications system were deployed at Pt Wells for field testing. The prototype systems have operated successfully for over 4 weeks, and we are currently developing plans and budgets to build and deploy these systems on the other 5 moorings.

With regards to observations over this period, historically anomalous conditions continued at all moorings in the first half of 2016, with waters significantly less dense at depth than average. Oxygen concentrations at depth in southern Hood Canal started out the year below average, and at depth at the Hansville mooring (near Admiralty Inlet) oxygen concentrations were significantly less than two standard deviations below average, the lowest observed in spring at that location. We are closely watching these conditions as they continue to develop through the summer and hope to be able to again use the power of the long-term, high-frequency (>daily) real-time system to predict the risk of a southern Hood Canal fish kill.

The project PIs and oceanographer W. Ruef, the ORCA operational lead, shared a summary of 2015 ORCA observations both at the Puget Sound Marine Waters Workshop: “2015 in Review” meeting in April 2016 and submitted an article to the 2015 Puget Sound Marine Waters Overview Report. These summaries highlighted the persisting, historically-large temperature, salinity, and DO anomalies observed throughout 2015 and highlighted an unprecedentedly-early Hood Canal flushing event and its contribution to the mechanics of a fish kill observed in late summer, nearly 6 weeks earlier than previously observed events. Salinity during 2015 varied in three distinct periods: 1) in early 2015 the lingering influence of the “Blob”, which entered Puget Sound in late 2014, contributed to full-water column salinities that were fresher than long-term averages; 2) throughout summer more saline conditions developed as drought conditions persisted until early fall; 3) toward the end of 2015, rainfall associated with the wettest winter on record contributed to a fresher than average water column. During this period, PIs Mickett and Newton and others presented a poster showing the influence and evolution of the “Blob” in coastal and Salish Sea waters at the Pacific Anomalies Workshop Newton led in January. Also, Mickett presented a poster showing similar results at the ASLO/AGU Ocean Sciences Conference in New Orleans in February.

We continued to collaborate with the NOAA PMEL Carbon Group (Drs. Adrienne Sutton, Simone Alin, and Richard Feely) to support the deployment of the pCO₂ systems operated on the Twanoh and Dabob Bay moorings through system maintenance and collection of water samples to aid system calibration. Additional collaborations included work with King County to deploy a pH sensor on the Pt. Wells mooring, and assisting Seabird with field testing a next-generation prototype CTD system.

Washington State estuarine monitoring: Led by C. Maloy and C. Krembs (WA State Department of Ecology), Ecology’s Marine Waters Monitoring Program is using ferry vessels as a means of cost-effective and representative data collection. En route ferry-based monitoring is valuable because it can capture near-surface events such as blooms, river input, and tidal exchange over a large geographic area and at a fine-scale temporal resolution. Ecology has two sensors and a GPS on the *Victoria Clipper IV* passenger ferry vessel that runs twice daily between Seattle and Victoria, B.C.

Data are uploaded daily to a cloud computing server where they are stored as and processed into Level 0, Level 1, and Level 2 files as described:

1. Level 0 – A copy of uploaded daily files in ASCII format. <http://107.170.217.21/VictoriaClipper30/level0/>.
2. Level 1 – Daily files of sensor data stream merged with position coordinates. Files are in NetCDF format. <http://107.170.217.21/VictoriaClipper30/level1/>.

3. Level 2 – Daily files of gridded, geo-referenced sensor data stream. Grids follow the marine water quality assessment 303(d) listing of the Clean Water Act. Files are in NetCDF format.
<http://107.170.217.21/VictoriaClipper30/level2/>.

All Level 1 files are listed in a THREDDS catalog where they can be downloaded or queried (via OPeNDAP or HTTPServer) as a data aggregate at:

http://107.170.217.21:8080/thredds/VC_WaterQuality_Catalog.html. Current plans are to add Level 2 files to the same catalog. Development of this data management system was leveraged with some EPA NEP and Ecology funds, with help from APL-UW and with the aim to provide and serve these data via NANOOS NVS. Further development of data products and QA/QC methods by Ecology staff will continue, but the program is at risk due to a lack of state funds to support the ferry monitoring technician after October 2016.

To ensure continuous quality of ferry-based measurements, we are working with Clipper Navigation, Inc. on installing a parallel fluorometer for QA/QC purposes and data comparisons. Ecology's shop has manufactured a stainless steel device to hold the parallel fluorometer. During the vessel dry dock period in late February to early March, a placeholder for the stainless steel device was installed. In addition, the thermosalinograph was re-installed and data from this sensor started streaming again.

From December 2015 to May 2016, water was generally cool in winter and warmed up in May (Figure 2). In early December, biofouling on an optical lens that measures chlorophyll fluorescence created noise in the data. After cleaning the lens on December 8, chlorophyll fluorescence was low through winter and started to increase in April and May, mainly in Puget Sound. Turbidity and CDOM were apparent in December and January and somewhat low in April and May.

Ecology gave oral presentations of ferry-based data during the Puget Sound Ecosystem Monitoring Program's (PSEMP) Marine Waters Workshop. Results were submitted for the annual PSEMP Marine Waters Report. Ferry-based data were also published in Ecology's monthly "Eyes Over Puget Sound" reports.

Columbia River estuarine monitoring: Under the direction of A. [Baptista](#), and with a mix of NSF, NANOOS, and regional-stakeholder funding, CMOP maintains a network of 15 endurance stations in the Columbia River estuary, which anchor CMOP's SATURN observation network. Also integral to SATURN, but not funded by NANOOS, are three freshwater stations: SATURN-06, maintained directly by the USGS, and SATURN-05 and SATURN-08, maintained by Dr. Joe Needoba with CMOP/NSF and regional stakeholder funding.

SATURN observations continue to be used extensively in support (directly or via data-informed modeling) of regional management and decision making associated with Endangered Species Act (ESA) biological opinions, salmon restoration, navigation improvements and hydropower operations. These observations are also integral to the four signature CMOP science initiatives, which address estuarine hypoxia and acidification, plankton blooms, and the biogeochemistry of lateral bays and estuarine turbidity maxima.

Recently, two significant "infrastructure" peer-reviewed papers were published. One, reported in the previous progress report, provides a comprehensive description of the infrastructure of the SATURN collaboratory, and is designed as an anchoring reference for publications relying on SATURN observations and simulations. The other describes adaptive sampling of microbial communities through the deployment of an Environmental Sampling Processor (ESP) at SATURN-03, with automated sampling

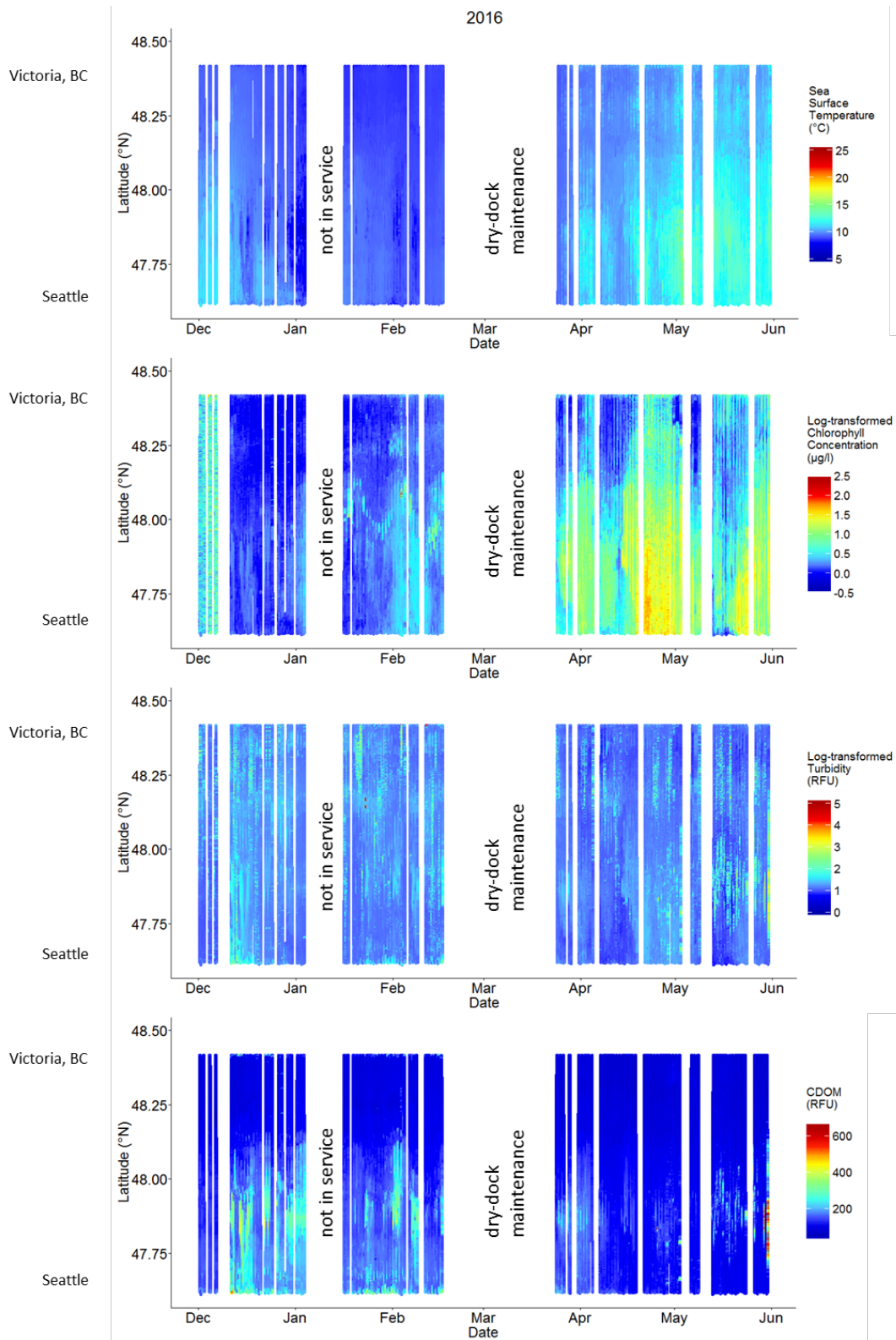


Figure 2: Spatio-temporal distribution of sea surface temperature, chlorophyll fluorescence, turbidity, and CDOM from Dec 2015 to May 2016. Data points represent 5-sec intervals of water measurements while the *Victoria Clipper IV* sailed between Seattle and Victoria, B.C.

targeted by select aspects of the function of the estuarine bioreactor (Herfort et al. 2016a,b: peer reviewed paper and presentation). This adaptive sampling offers a new window into the microbiology of the estuary.

SATURN stations continue to be used to support multi-disciplinary analysis (including, as a recent example, characterization of the effects on the Columbia River estuary of the PNW “blob:” Needoba et al. 2016 and Seaton et al. 2016) and peer-reviewed modeling efforts in the Columbia River (Kärnä and Baptista 2016; Kärnä and Baptista, submitted; Lopez and Baptista, submitted).

Oregon South Slough: Participation by the Oregon Department of State Lands (ODSL) in NANOOS is led by A. Helms (Estuarine Monitoring Coordinator) and A. DeMarzo (Estuarine Monitoring Assistant) at the South Slough National Estuarine Research Reserve (SSNERR).

South Slough NERR continued operating a network of moored water quality observing stations as part of the NERRS System-Wide Monitoring Program with additional support provided by NANOOS. Four real-time water quality monitoring stations located along the estuarine salinity gradient provided continuous water temperature, salinity, dissolved oxygen, pH, turbidity, and water level data over the period 12/01/15 – 05/31/16. Monthly, quarterly and annual quality assurance/quality control procedures were completed for water quality and weather data from all five stations. Data were submitted to the NERRS Centralized Data Management Office on 02/01/16 (quarterly water quality and weather), 04/15/16 (annual water quality), 05/02/16 (quarterly water quality and weather), and on 05/16/16 (annual weather).

Real-time data transmissions at the Elliot Creek station were down from the period 12/01/15-05/31/16 due to platform changes associated with the new EXO2 sonde equipment. In addition, this site needs all telemetry equipment replaced; a new enclosure and telemetry equipment will be installed in 2016. Currently, no instruments are deployed at the fifth water quality station (Boathouse) due to platform stability assessment and long term deployment concerns associated with the protective pipe that the datalogger is deployed inside; this site is subject to strong wave action that has broken the deployment housing. We relocated the weather station from the University of Oregon Institute of Marine Biology campus to Tom’s Creek Marsh at the south end of the reserve due to an OIMB wind turbine installed adjacent to the weather station. The wood platform was installed December 2015. The CR1000 datalogger and sensors were installed on the tower April-May 2016. Remaining tasks include digging a trench to secure the rain gauge cable and mounting the satellite antenna. The station will be operational and transmitting data by Summer 2016.

We maintain one water quality station in partnership with one of our local tribes, the Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians (CTCLUSI). This station, North Spit BLM, is located in lower Coos Bay (NESDID ID # 346F229A; sosnswq) and data are available via the NVS. E. Mayorga developed Python code and utilized common software libraries from IOOS DMAC to ingest water quality data from HADS (Hydrometeorological Automated Data System) to display through NVS; this effort will help with future stations that are maintained through partnerships or are outside of the scope of the NERRS CDMO.

The South Slough water quality stations provide real-time data access for shellfish growers in South Slough, including North Bend and Coos Bay Oyster Companies, Clausen Oysters, and Qualman Oyster Farms. The South Slough and CTCLUSI stations also provide environmental data for research, monitoring and education programs conducted at the reserve. During this reporting period, data from

the Winchester Creek SWMP/NANOOS station was compiled and analyzed for tidal marsh resilience to sea level rise synthesis. The synthesis results were developed into a manuscript and submitted to Global Change Biology on 04/01/16. Water level data from the Valino Island and Winchester Creek SWMP stations were used for tidal datum calculations for a Sentinel Site monitoring plan at the reserve. Examples of SSNERR education programs incorporating NANOOS data were a North Bend High School Coastal Ecology course on 12/09/15, SWMP/Sentinel Site Program Overview for education and outreach staff on 03/02/16, and an Oregon Coastal Master Naturalist Course on 05/26/2016. SWMP/NANOOS stations were also highlighted at an Oregon Ocean Acidification Monitoring Network meeting in Newport, OR on 02/18/16 and at the NERRS Annual Technician Training Workshop in Myrtle Beach, SC from 03/15/16-03/17/16.

South Slough expanded the network of water quality stations to include four stations (North Point, Isthmus Slough, Catching Slough, and Coos River) located in the upper Coos estuary through the NERRS Science Collaborative Partnership for Coastal Watersheds. One station, North Point, is located near commercial oyster cultivation areas and will be prioritized for adding real-time capability for growers and Bar Pilots to provide water level data along with incorporating this site into NVS once telemetry is installed.

Through NOAA Ocean Acidification program funding, South Slough added pCO₂/pH monitoring equipment at the Valino Island station in April 2015. In the future, we may explore ways to include these datasets through NVS, but currently are focusing on instrument maintenance, protocols, and data collection in the estuary for these ocean-built monitoring instruments.

- **Shorelines**

Washington Shorelines: NANOOS funds contribute to the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) led by G. [Kaminsky](#). In December 2015, CMAP conducted fall seasonal beach monitoring surveys in the Columbia River Littoral Cell (CRLC). Forty-six seasonal beach profiles and two surface maps were collected. Still without funding to repair or replace our ATV, CMAP has been able to continue collecting surface maps with a surplus quad from the Washington Conservation Corps. In March and April 2016, CMAP conducted winter seasonal beach monitoring surveys in the CRLC, collecting 49 beach profiles (1 less than normal which was collected by DOGAMI), 4 surface maps (no North Head surface map this season), and 63 sediment samples from multiple cross-shore locations along 13 of the profiles. One of CMAP's data controllers became damaged from saltwater corrosion, forcing its replacement and recollection of winter beach profiles and surface maps.

Due to the strong El Niño conditions along the Washington coast this winter, most of the beaches in the CRLC experienced erosion due to waves and elevated water levels. The most significant erosion occurred in Westport and Ocean Shores, where there was massive dune retreat and beach lowering. An emergency rock revetment was placed on the beach in Ocean Shores following repair of the existing geotubes in an effort to save the dune from additional erosion where there are several houses and condos built. In Westport, the entire foredune has eroded in front of the Westport by the Sea condos, leaving the buildings vulnerable to flooding due to wave overtopping. In response to these erosion events, CMAP established additional transects in both Westport and Ocean Shores to allow for more detailed monitoring of these sensitive areas. With additional funding provided by the state legislature to address coastal hazards in Grays Harbor County, CMAP will continue to do more intensive surveys in both locations throughout the next year(s).

In mid-February 2016, CMAP worked with the USGS to collect beach and nearshore profiles at the Elwha

River mouth. CMAP completed its fourth multibeam and boat-based lidar survey to monitor the USACE Shoalwater protective berm near Tokeland in April 2016. The data we collected is being used by the WDOT to take a closer look at changes to the channel and potential impacts to the road near the SR-105 groin.

Four members of CMAP presented research at the Salish Sea conference in Vancouver, Canada this April, reporting on various projects and surveys we have conducted around the Puget Sound with great response to our growing capacity in collecting multibeam and boat-based lidar data. G. Kaminsky also gave a presentation on coastal erosion and hazards to the Quinault Indian Nation on January 22 and the Ocean Shores Planning Commission on January 26.

Oregon Shorelines: Leveraging NANOOS, the Oregon Beach and Shoreline mapping Analysis Program (OBSMAP) efforts are led by J. Allan of the Oregon Department of Geology and Mineral Industries (DOGAMI). As part of DOGAMI's commitment to NANOOS, the OBSMAP network continues to be sustained. DOGAMI had a very busy field season in 2015/16 in preparation for the effects of the 2015/16 El Niño that affected the US West Coast over the winter. In the majority of cases, we were able to complete pre- and post- El Niño measurements at multiple sites (~105 sites) on the Oregon coast over the Fall/Winter season.

The following accomplishments were achieved during this reporting period:

- (1) Fall surveys were completed for Rockaway and Nehalem Spit (18 sites) and in the Neskowin cell (15 sites) in December 2015. Due to a series of intense storms in late December, surveys along the remainder of the Rockaway cell (Bayocean Spit (7 sites)) and on the Clatsop Plains (6 sites) had to be deferred until mid-January 2016;
- (2) Late winter (March 2016) surveys were completed for the entire Rockaway and Neskowin cells and on the Clatsop Plains (46 sites total);
- (3) Profile sites in the Newport cell were updated in April 2016 for the first time since winter 2013. These data required a complete re-evaluation of the original survey control, which was updated to the NAD83 (2011) datum;
- (4) completed late winter (March 2016) surveys (59 sites) in the Cannon Beach littoral cell on the northern Oregon coast in Clatsop County;
- (5) worked with colleagues in the USGS, OSU, and WDoE to develop a journal paper (in review) summarizing the impacts of the 2015/16 El Niño on US West Coast beaches. Our collective analyses demonstrated that the 2015/16 El Niño produced the largest shoreline retreat as measured at Mean High Water since measurements began in 1997. Although the shoreline retreat was the largest observed, the amount of beach erosion in the NANOOS region was largely moderated due to several years of accretion that effectively allowed the beaches to gain sand, effectively creating a safety buffer to the bluffs and dunes at the back of the beach. Had the beaches not accreted so much over the past few years, the impact to dunes and bluffs could have been significant; and,
- (6) participated in a USGS topo/bathy workshop to assess the availability of coastal nearshore and land-based topographic/bathymetric data for the purpose of developing a high resolution DEM for the PNW region.

PI Allan continues to upgrade analysis procedures through code improvements. Data archiving is also being updated to reflect more refined approaches. Data for the OBSMAP monitoring sites are made available through the NANOOS Visualization System.

Data from the OBSMAP beach monitoring continues to be used by agencies such as the Oregon Parks and Recreation Department to help guide permitting for engineering structures, by local community

groups and geotechnical consultants in Neskowin and Rockaway to help guide their understanding of changes taking place along their beach, by residents in the Cannon beach area, who are concerned about plans to lower dunes in their area, and by the USACE interested in beach morphological changes taking place adjacent to the mouth of the Columbia River.

No significant issues were experienced with equipment during this period.

Nearshore Bathymetry: P. Ruggiero’s group at Oregon State University completed processing nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC). Over 220 individual cross-shore profiles were collected during summer 2015 extending from the lower inter-tidal to ~12 m of water depth (~2000 m from the shoreline). Approximately 400 kilometers of nearshore mapping took place within 10 days of field data collection. These data have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. In all cases these nearshore bathymetry measurements have been combined with topographic measurement collected by Ecology developing complete maps of the nearshore planform. **These data continue to provide a critical source of information for improving coastal hazard mitigation along the coastlines of the CRLC and for understanding the morphodynamics of prograding beaches (Ruggiero et al., 2016).**

Ruggiero’s group also completed the processing of nearshore bathymetric data within the Rockaway littoral cell in Oregon. Over 80 individual cross-shore beach profiles were processed from the lower intertidal to approximately 25 m of water depth (~1500 m from the shoreline). These data have been combined with topographic data collected synoptically by DOGAMI, and have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. **This NANOOS funded nearshore bathymetric data is being incorporated in a coastal hazards decision support tool supported by NOAA’s Climate Program Office Coastal and Ocean Climate Applications (COCA) program.**

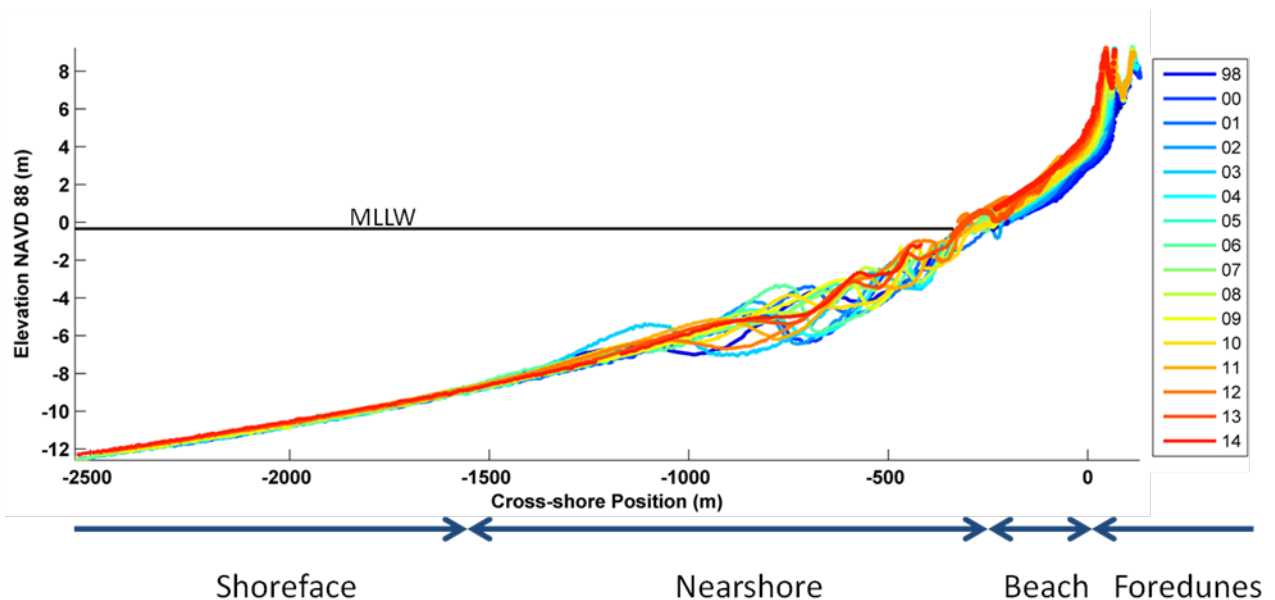


Figure 3. Example evolution of beach profile from the Long Beach Peninsula. Origin is the approximate shoreline position (~3.0 m contour) from the 1998 survey (from Ruggiero et al., 2016).

The PWC-based nearshore surveying system used by Ruggiero's group is now almost 9 years old and the equipment is starting to show some wear and tear. In particular, the PWCs themselves have been driven for hundreds of hours in very demanding conditions and may only have one to two years left of being able to safely collect this data before needing to be replaced or extensively serviced.

- **Currents**

Coastal Currents: Surface current maps determined from an 11-site Seasonde array along the Pacific Northwest coast continue to be obtained hourly, and provided to the public through NANOOS NVS, and via the national network to NDBC, the USCG, and other agencies, led by M. Kosro, OSU.

We have begun analyses to harden the transmit sides of our systems. Transmit antennas have been in the field 24-hr/day, in all weather conditions, in some cases for as long as 16 years. Their cables run up to 800 ft in length and have been in service for similar lengths of time. When cables or antennas get damaged, power to the antenna can be reflected back toward the receiver. We recently completed a survey of our transmit antennas to prioritize replacements among them (typical cost, \$12,000 each, plus cables and installation).

We have ordered (and, during the no-cost extension period, received) back-up electronics which can be swapped into sites when the receiver, transmitter, or a (long-range) transmit antenna fails and must be sent to Codar for repair. This should improve our up-time. Prior to this, we have moved equipment from the northern end of the array (Loomis Lake, WA) to maintain the longest continuous mapping array possible. The majority of costs were provided by IOOS, but were substantially supplemented by more than \$40,000 from a competitive grant from the Oregon State University Research Equipment Reserve Fund.

Scientifically, we contributed to the 2nd Pacific Anomalies Workshop in Seattle during 20-21 Jan 2016. Kosro discussed open ocean-coastal ocean interactions around the anomalous period, drawing in part on material aggregated and presented in the NVS climatology app. A paper led by collaborator Sung Yong Kim (Kim, Kurapov and Kosro, 2015) was published in December examining the distribution and strength of near-inertial currents and the effect of upper ocean stratification, including the Columbia River plume. Our HF data continue to contribute to numerical modeling efforts through their use for data assimilation. They are distributed to the national HF data center and, from there, to the National Data Buoy Center and the National Center for Environmental Information. Data are also provided to NOAA Office of Response and Restoration, and most recently to the US National Weather Service.

Port X-band Radar: Led by M. Haller (OSU), wave imaging radar operations have continued at the temporary station at the Columbia River mouth (Cape Disappointment station), with intermittent hardware-related interruptions. During the first half of 2016 at Yaquina Bay Inlet (Newport South Jetty) station we have worked with our collaborators at the NOAA Office of Coast Survey (LC Samuel Greenaway) and Arete Associates (Ken Vierra) to complete the engineering design necessary to transfer our radar observing station from the South Jetty to the roof of the USCG observation tower at the Yaquina Bay Lighthouse. The radar is scheduled to be installed on the tower on June 8-9, 2016. This new installation site is expected to provide excellent imaging conditions over a footprint of ~6 km radius, including the nearshore zone all the way north to Yaquina Head. We are particularly excited about producing new and improved and frequent bathymetric information for the area and real-time observations of waves in and around the inlet. We are working with USCG Yaquina Bay Station on further development of real-time data products.

b) NANOOS Modeling Subsystem:

Shelf: Computer circulation modeling and forecasting of PNW coastal ocean shelf conditions has been conducted by A. Kurapov's group at OSU. The system utilizes the Regional Ocean Modeling System (ROMS) as the forecast model. Along-track altimetry observations from Jason-2, CryoSat, and Altika, hourly GOES SST, and surface currents from land-based high-frequency (HF) radars have been assimilated to improve initial conditions for the forecasts, using the assimilation system developed at OSU. Results are provided to fishermen and public via the NANOOS Visualization System. Via the OpenDAP server, forecast currents are also provided to the NOAA Office of Response and Restoration Lab in Seattle, where they can be used with the tools for oil spill mitigation. The OpenDAP link also provides access to the real-time fields by the Cyberinfrastructure group of the IOOS-sponsored Coastal Ocean Modeling Testbed (COMT) project.

To fulfill our educational role, we are making the fields accessible to a group of OSU students participating of the SeaCast.Org project. In the scope of this project (supported by Oregon Sea Grant and NSF Research Traineeship program) a group of students with different backgrounds work together to develop a mobile application displaying ocean SST, current, and wave forecasts and obtain feedback from the fishermen community toward future product improvement.

During the report period, we completed tests of the new OR-WA model configuration (featuring an extended domain from 41-50N, 2-km horizontal resolution, river discharges, and tides). The new model has been put online and the old OR-only model has been decommissioned. As part of the continuing skill assessment efforts, we have demonstrated that the OR-WA model is an accurate predictor of the total coastal sea level. Modifications in data assimilation included improved treatment of altimetry data. Tests have shown that the present configuration “feels” altimetry data without the need for detiding the analysis solution.

Methods for model skill assessment and data assimilation have been shared with NOAA NOS, where we contribute to development of the West Coast Ocean Forecast System (WCOFS). Some of those efforts are presented in (Kurapov et al., 2016).

Estuaries

Puget Sound: NANOOS PI P. MacCready (UW School of Oceanography), working with Drs. Siedlecki, and McCabe (UW Joint Institute for the Study of Atmosphere and Ocean) continued work on a pre-operational forecast model, called *LiveOcean*, of ocean circulation and biogeochemistry in Puget Sound and adjacent waters. In the past six months the team used NANOOS support to run multi-year hindcasts of the system including the carbon fields from which pH and aragonite saturation state are calculated. The model predictions are being validated against NOAA ship-based observations and moorings (in collaboration with J. Barth and F. Chan at OSU). NANOOS also supported salary for Dr. MacCready's system administrator, David Darr, who oversees computer operations and assists with the gathering and archiving of model atmospheric fields from Dr. Cliff Mass (UW). The forecast work is also supported by a grant of state funds made through the Washington Ocean Acidification Center (WOAC), and by a grant of cloud compute/storage resources from Microsoft, greatly accelerating the work and leveraging the impact of NANOOS funds. The model system will also be used for a recently-funded NOAA project to predict Harmful Algal Blooms. During this past 6 months in addition to the model development MacCready gave a total of 4 scientific or outreach talks on the project (see Presentations).

MacCready is a member of the NOAA West Coast Ocean Forecast System Technical Working Group, and this model is a candidate for nesting inside of the NOAA operational models of the California Current that are being developed.

Columbia River: With a mix of NSF funding, regional stakeholder funding, and modest NANOOS funding, CMOP maintains an extensive modeling system for the Columbia River coastal margin, denoted *Virtual Columbia River* (VCR). The VCR is operated under the direction of A. Baptista, but it is a multi-institutional collaboration involving modelers and non-modelers, in academia and across regional, federal and tribal agencies.

The modeling capabilities of the VCR continue to assist the region in the study of salmon life cycle, habitat and status under the Endangered Species Act and in relation to hydropower management and climate change, as described in previous progress reports. A recent peer-reviewed paper (Karna and Baptista 2016) systematically characterizes the estuarine skill of a decade-plus simulation database of circulation in the river-to-shelf continuum. Papers describing advances in the modeling of estuarine water age (Kärna and Baptista, submitted) and sediment dynamics (Lopez and Baptista, submitted) were recently submitted for peer review, and other papers will soon be submitted in the areas of biogeochemical modeling and modeling of salmon habitat. Two of the papers on salmon habitat address the sensitivity of the Columbia River to sea level rise and to the Cascadia Subduction Zone, respectively—as previewed in a conference paper on the topic (Baptista et al. 2016a). Also of note are new studies of the effect of local (in-estuary) atmospheric forcing on the circulation in the Columbia River (Scrocarro 2016a,b)

As described in earlier NANOOS progress reports, applications of the Virtual Columbia River include (a) the Columbia River Treaty Review, a collaboration with the USGS, Army Corps of Engineers, Bonneville Power Administration, Columbia River Inter-Tribal Fish Commission and others; and (b) the post-construction assessment of the ecological impact of the Columbia River Channel Improvement Project, a collaboration with the Army Corps of Engineers, NOAA, and a large number of state and federal agencies.

Lessons learned in the SATURN collaboratory, across observations and modeling (including operational modeling, are being exported internationally, via the Our Global estuary initiative (Baptista et al. 2016b), which has recently been adopted by the Partnership for the Observation of the Global Ocean (POGO).

c) Data Management and Communications (DMAC) Subsystem:

Chaired by E. Mayorga (APL-UW), this committee is composed of members from CMOP-OHSU, DOGAMI, OSU and UW. The DMAC and User Products (UPC) teams work in an integrated fashion on the prioritization, development and evaluation of data services and user products. NANOOS is also an active collaborator in national IOOS DMAC efforts. Meeting highlights for this period include: 1) weekly NANOOS DMAC-UPC calls; 2) annual NANOOS DMAC & UPC meeting (Mar 21-22, Seattle); 3) Ocean Sciences Meeting (Feb 22-26, New Orleans); 4) 3rd GOA-ON Science Workshop (May 9-11, Australia); and 5) IOOS DMAC QARTOD Working Group calls.

The **NANOOS Visualization System (NVS)** was upgraded in May to versions 4.5 and 4.6, with DMAC-supported additions including: a greatly improved Glider visualization App based on more extensive handling of glider data files; grouping of variables by general categories (e.g., atmospheric); and explicit flagging and separation of “retired” assets. NVS enhancements also encompass asset additions and continuous updates: 1) new or newly incorporated near-real-time in-situ monitoring assets (a new mooring with meteorological and water sensors at two depths in Bellingham Bay, WA; a new “Burkolator” sensor at Quadra Island, BC, Canada; an existing CDIP buoy in N. CA not previously ingested by NVS; a ferry-based ADCP sensor in Puget Sound; and a new “Environmental Sample Processor (ESP)” deployment with data ingest, off La Push, WA); 2) updated monthly anomalies for many climatology/anomaly overlay assets, in some cases with expanded spatial extent and variables;

and 3) many redeployments and smaller upgrades, including restored or expanded sensors. In addition, a new data harvester for IOOS SOS compliant data services was nearly completed, leveraging the IOOS pyoos package and initially supporting IPACOA needs.

NANOOS and IOOS DMAC system implementation. 1) All NANOOS web services were improved to enhance discoverability, standards compliance and service robustness through better use of appropriate keywords and standard attributes, web-service software updates, and server hardware and system updates; in addition, a ugrid-compliant WMS service based on ncWMS2 was added to the CMOP-OHSU THREDDS while other WMS services (THREDDS / OSU & GeoServer/ APL-UW) were updated. 2) NANOOS DMAC substantially expanded the use of its github presence (<http://github.com/nanoos-pnw>) for team communications, issue tracking, and code sharing. 3) We made great strides in handling glider data for submission to the Glider DAC and internal use in user products. The code and procedures for submitting Seaglider data from the La Push (WA) transect are nearly ready; files for the last two deployments will be submitted shortly. 4) We advanced the preparation of CMOP-OHSU data files and workflow for archiving with NCEI in coordination with NCEI's Matt Biddle. 5) NANOOS continued to support QARTOD via feedback on the Glider DAC QC Manual for Temperature and Salinity Data and active participation in the IOOS DMAC QARTOD Working Group. 6) NANOOS contributed to IOOS DMAC community implementation and engagement activities, particularly in three areas: a. *IOOS SOS*: assessment of SOS implementations, leading to documentation improvements and the identification of issues with the IOOS 52North SOS (bounding box filters; height encodings) that are being addressed; b. *pyoos*: engagement with developers and previous code contributions in support of a major new release, version 0.7.0; c. *OOI (Ocean Observatories Initiative)*: engagement with OOI staff and use and contribution to OOI code to develop near-real-time harvesting of Coastal Endurance (Pacific NW) mooring data to be integrated into NVS soon. In addition, E. Mayorga continued to present IOOS and NANOOS DMAC perspectives within NSF-supported Cyberinfrastructure initiatives, including EarthCube and the recently developed *Observations Data Model 2* ("ODM2", Horsburgh et al. 2016).

West-Coast Coastal and Marine Geospatial Data. NANOOS continued its support of the West Coast Ocean Data Portal (WCODP) efforts through E. Mayorga's participation in IT working group conference calls and follow-up discussions. These discussions included a refocusing to serve the emerging data needs of the newly formed West Coast Regional Planning Body (RPB), including the identification of priority marine geospatial data catalogs for improving metadata and harvesting into the WCODP catalog to address priority data gaps. NANOOS will be actively engaged in supporting these efforts, and recently upgraded its GeoServer instance and staff capabilities in order to support these needs.

Ocean Acidification (OA) Data. NANOOS substantially expanded its engagement in OA data efforts (Mayorga et al. 2016). Through close interactions with the Hakai Institute, a new Canadian NANOOS member, the data harvesting workflow for an existing AOOS "Burkolator" asset was made much more robust, and this workflow was then leveraged to a new Burkolator asset at Quadra Island in British Columbia (Salish Sea). A newly deployed OA-relevant NANOOS mooring in Bellingham Bay (Salish Sea) was also integrated into NANOOS systems (see NVS section above). In the cross-regional scope of IPACOA (IOOS Pacific Region Ocean Acidification), we continued to support Burkolator data stream ingest by the IPACOA application and other RA DMAC teams. In addition, due to strong interest from CariCOOS, we integrated CariCOOS OA assets into the IPACOA application. Development of a pyoos-based data harvester for IOOS SOS data services is nearly completed, initially using CeNCOOS OA assets to focus the development effort. Globally, a new project was initiated to develop an OA data portal for GOA-ON (Global OA Observation Network); development is well under way, in collaboration with NOAA PMEL and international partners. Status and plans were presented recently at a GOA-ON meeting (Mayorga 2016).

d) User Products Committee (UPC):

The UPC operates in concert with and is informed by both the DMAC and Education & Outreach subsystems. The objective of the NANOOS UPC is to guide the conceptual development of the data/analysis products (i.e. observations, time series, models, applications, etc.) identified by NANOOS stakeholders, and guide the development of appropriate graphical formats and lines of communications for product dissemination. Critical to this process has been the recognition that the UPC works closely with other NANOOS committees, most importantly the DMAC and Education/Outreach teams to ensure product concepts are effectively developed and tested prior to their release.

Chaired by J. Allan (DOGAMI) this committee is composed of members from OHSU, UW, OSU, NANOOS E&O, OR Sea Grant, and NOAA. NANOOS UPC chair Allan participates in weekly “tag-up” calls with a smaller sub-group comprised of members from DMAC, UPC, E&O, and Web development in order to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this 2015 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; 2) participated in and ran the annual Tri-committee meeting in Seattle, WA, which was held on March 21-22, 2016. The purpose of this meeting was to evaluate our achievements over the past 6 months, visualize and discuss pending updates to NVS, and plan for future enhancements. As a result of this meeting, we agreed to organize at least one public outreach meeting in 2017 on the Oregon coast with the goal of reaching out to stakeholders to solicit feedback on our various public products; 3) Continued to refine and update the climatology web app, including analyses of wave buoy and tide data in situ assets which make up the NVS climatology web app.

NVS: The backbone of the NANOOS RCOOS is the NANOOS Visualization System (NVS) that currently distributes data from a myriad of regional and federal assets.

On May 23rd 2016, NANOOS released NVS v4.6. This version of NVS reflected a minor update to the NVS platform, centered mainly on improvements to the overall look and feel of the NVS environment. Changes to NVS included improvements to the platforms variable groupings in the info panels, with the variables now grouped by type, such as atmospheric, hydrographic, or biological (Figure 4). In addition, v4.6 includes the addition of the new APL-UW biological data profiler, as well as minor enhancements to the NVS Boaters app, which now includes the NDBC/CDIP wave buoys used by boaters.

NANOOS software engineer Troy Tanner has also been working behind the scenes to operationalize the new NVS situational awareness capability (Figure 4), expected to be released in late summer 2016. This exciting new development will provide users with the ability to view synoptically the conditions around the NANOOS region.

Updates to the NVS Climatology web app continued throughout this period and included the following:

- Improvements to the downloading and processing of near real-time data were implemented during this period using refined codes that access THREDDS data provided by the NDBC. Note there remains one major problem with this approach in that NDBC currently does not include wave direction and average wave period as part of these data. We have approached NDBC about making these data available via THREDDS with the other regular data but with no success to date;
- Enhancements to the seasonal to interannual Climatologies were updated and new variables added for National Ocean Service (NOS) tide gauge stations (9 sites); and,
- Climatologies of WaveWatch III model data have been developed for the period 1982 to the present. These data are not yet available on NVS live and will be made available in late summer.

These types of plots now enable users to visualize conditions at multiple stations in the NANOOS region, and importantly assess conditions at various stations that may be perceived to be unusual in our region against longer time series.

Website: Efforts during this period were largely directed at further improvements in the overall NANOOS web experience (<http://www.nanoos.org/products/products.php>).

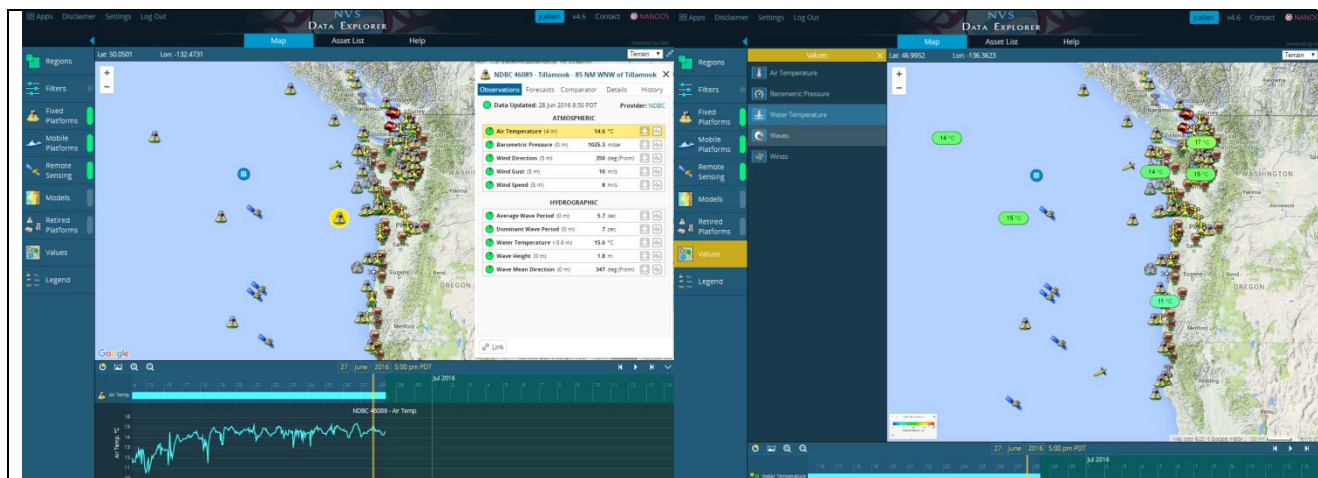


Figure 4: (left) Enhancements to NVS v4.6 includes new variable grouping in the info pop-ups that allow for easier interpretation of the data, and (right) the new NVS situational awareness capability showing water temperature at a number of stations, will allow users to better understand the overall synoptic conditions occurring in the NANOOS region.

e) NANOOS Education and Outreach Subsystem:

NANOOS Education and Outreach efforts are focused on growing NANOOS’ audience of engaged citizens, promoting and facilitating the use of ocean observing data and increasing ocean literacy in our region. These efforts are largely completed by NANOOS staff Newton, Sprenger and Wold, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton, Sprenger and Wold are all active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. Sprenger and Wold continue participation with IOOS E&O calls as they occur.

Summary of Education Accomplishments: NANOOS education efforts continue to focus on building and sustaining connections with Pacific Northwest educators and partnering with local and regional science and marine science education efforts in both OR and WA.

- Sprenger has been collaboratively partnering with South Slough Estuary Research Reserve and OR Sea Grant to support their current BWET grant implementing the OR Coast Education Program (OCEP) workshops for OR teachers. She will be presenting at two 4-day workshops this summer – one in Coos Bay for MS/HS teachers and one in Newport for ES/MS teachers.
- Sprenger continues to work with Langley Middle School’s 7th grade science program and the local non-profit organization Whidbey Watershed Stewards to support a year-long investigation into the water quality of Langley Harbor - SWOOS – the South Whidbey Ocean Observing Station. The program, in its 3rd year, has been expanded from a semester to a year-long focus. In October Sprenger visited each 7th grade science class, presenting on NANOOS and working with students to

use data coming from NVS. In April every 7th grader participates on a half day educational/research cruise out on Puget Sound, for a total of 4 half day cruises over two days. Sprenger worked with NANOOS member Ocean Inquiry Project to coordinate the science activities for each day.

- Sprenger continues to facilitate and promote education using student-built buoys as a research project for K-12 students both in and out of school. For the upcoming fifth summer, Sprenger will be partnering with WA Sea Grant to co-instruct the NOAA Science Camp's Junior Leadership Program's research project. She also worked with a sub-set of students in a "FLEX" (elective) class at Langley Middle School to design, build and deploy buoys to measure temperature and light in Langley Harbor. The students successfully deployed and recovered these in November over a long weekend and some students chose to improve their designs and do a 2nd deployment in April. The students incorporated their data into the year-long investigation, and presented their work to the community. In addition, a summer camp run by staff from a local marine science education nonprofit, Salish Sea Expeditions, will, for the 2nd year, use NANOOS equipment and supplies to implement their own version of the student built buoy research project during sessions of their week-long summer marine science camp.
- Newton was invited by Bellevue College to give the Earth Day Science Café on 22 April. Her talk "The Blob is dead – or is it?" included an extended Q&A session with students from an Oceanography class taught at Bellevue College.
- Three educators from the Oregon Coast and four NWIC students joined the 3-day ESP deployment cruise for the La Push (Cha'ba and NEMO) buoys in May with NANOOS PIs Mickett and Newton, and Sprenger, making this cruise a highly-successful educational opportunity. Students and educators learned how to do CTD casts, seawater sample analysis and net tows. Newton mentored the NWIC students re chlorophyll filtration. One student was so overjoyed that her chemistry class "made sense now!" Staff from the Quileute Nation and NOAA NWFSC were also able to participate in the cruise, collecting numerous surface water samples to investigate phytoplankton species distribution and for HAB/toxin analysis. Aboard the *R/V Thompson*, Mickett and Moore gave a well-attended overview presentation of the ESP. We were also able to support an Astoria Oregon high school science project by deploying a small, satellite- tracked sailboat.

Summary of Outreach Accomplishments: NANOOS outreach efforts have been focused on engaging with target user groups, including shellfish growers, boaters and scientists, improving and updating the content on the NANOOS web portal, and energizing social media outreach efforts.

- NANOOS Education and Outreach staff created an overview video demonstration that guides users through various NVS features and applications. This video went live in December and is accessible on the NANOOS web portal.
- NANOOS hosted a successful Pacific Anomalies Workshop 2 at the University of Washington on January 20-21, 2016. Over 150 scientists attended the 2-day workshop which focused on atmospheric, oceanic, and ecosystem dynamics associated with the warm water anomaly known as the 'Blob,' as well as the interactions of the Blob and 2015-16 El Niño.
- NANOOS is contributing data streams from the Cha'ba La Push mooring to two new Olympic Coast National Marine Sanctuary visitor kiosks located at Forks Visitor Center and Kalaloch Lodge.
- In February, Wold represented NANOOS at the annual Saltwater Sportmen's Show in Salem, OR, demonstrating NVS, particularly the NVS Tuna Fishers App, and providing information to hundreds of recreational fishers and charter guides.
- At the Salish Sea Ecosystem Conference in Vancouver, BC on 13-15 April, Wold presented a poster and staffed an exhibit booth to provide information on what NANOOS has to offer and demonstrate NVS. Wold spoke with more than 200 people during the conference about NANOOS.
- Newton gave public outreach talks on NANOOS, including a NOAA Northwest Fisheries Sciences

Center Monster JAM Seminar on 4 February "NANOOS: Delivering Coastal Ocean Observations and a Whole Lot More" and a Marine Science and Technology (MaST) seminar on 6 February "Understanding the Blob and El Niño and their effects on Puget Sound" in Des Moines, WA.

- NANOOS provided the "Great Build a Buoy Challenge" activity at University of Washington's annual "Paws on Science Weekend" at the Pacific Science Center in May. The buoy challenge was again incredibly popular among attendees with non-stop buoying by kids of all ages throughout the weekend.
- **The IOOS OTT funded harmful algal bloom ESP sensor deployment in May aboard *R/V Thompson* was documented on video by Transect Films (<https://vimeo.com/168020010>) and gained media attention:**
 - **Le, P. "Scientists launch 'ocean robot' to test Washington waters for shellfish toxins." The Seattle Times, Seattle, WA, May 30, 2016. <http://www.seattletimes.com/seattle-news/ocean-robot-deployed-off-our-coast-to-look-for-toxic-algae/>**
 - **Hickey, H. "UW, NOAA deploy ocean robot to monitor harmful algal blooms off Washington coast." UW Today, Seattle, WA, May 25 2016. <http://www.washington.edu/news/2016/05/25/uw-noaa-deploy-ocean-robot-to-monitor-harmful-algal-blooms-off-washington-coast/>**
- NANOOS continues efforts on social media, regularly posting on Facebook with news, pictures, and interesting data. Sprenger and Wold continue to update the NANOOS blog (<http://www.nanoos.org/education/blog/blog.php>) posting on educational opportunities and research cruises and also work to gather blog post contributions from NANOOS collaborators.
- The NANOOS Observer has been reinitiated. This newsletter is being distributed to a wide audience, nearly 1000 and growing.
- Sprenger and Wold continue to update content on the NANOOS portal, as well as continue to improve the site's usability by updating the search tool on the products page and streamlining the documents archive.
- PI Barth is one of several scientists in the recent "Ocean Acidification" video: <http://www.oregonocean.info/index.php/ocean-acidification-and-hypoxia/563-ocean-acidification-video>.

f) NANOOS Administration:

J. Newton (NANOOS Executive Director) and D. Martin (NANOOS Board Chair) continued to provide leadership to NANOOS operations and connection to the US IOOS enterprise. They and M. Kosro (NANOOS Board Vice Chair) participate in IOOS Program Office and IOOS Association calls. Newton is a member of the IOOS Association Executive Committee and participated in their teleconferences throughout the period. Newton also participated in weekly Tri-Comm calls. Key events for this period included:

- Newton participated in the annual NANOOS TriComm meeting March 21-22, 2016 in Seattle to review existing and prioritize work for the remainder of the year.
- Martin and Newton participated in IOOS Association and IOOS Spring Meetings on March 1-4, 2016, in Washington D.C. that covered a wide range of national and regional IOOS-related issues. In addition to discussions on IOOS with IOOS Program Office and other RA leaders, Hill visits and meetings with OMB constituted important parts of this week's activities. They participated in Hill Visits along with Andrew Barnard, WETLabs, to brief the WA and OR delegations on progress and difference that NANOOS is making to regional stakeholders.
- On March 24th Newton was invited by NOAA NWFSC Director John Stein and NOAA Western Regional Coordinator Timi Vann to brief Admiral Brown at their Montlake lab. This lead to

discussion of the importance of observations to NOAA and the great synergies NANOOS has with NWFSC. Adm Brown requested Newton's slide on RA's engaging stakeholders and assuring national consistency.

- For the Pacific Anomalies Workshop 2 (PAW2) that NANOOS hosted at UW January 20-21, 2016, Newton worked with sister RAs SCCOOS, CeNCOOS, and AOOS, as well as sponsors IOOS PO, NOAA OAR Ocean Climate Observation Program, NOAA Western Regional Team, CA Sea Grant, WA Sea Grant, the University of Washington and a diverse Steering Committee to define the scope, agenda, outputs and speakers. Two videos capture the highlights and are on-line at NANOOS (<http://www.nanoos.org>) and a short workshop summary and recommendations list is in prep.
- Newton hosted the first meeting of the IOOS Honorary Directors on 26 January, 2016, at UW-APL, with members of the IOOS Association Board. She and Josie Quintrell, IOOS Association Director attended the JOCI meeting at UW Center for Urban Horticulture the next day, 27 January, and gave input regarding the value of decision-critical information.
- On April 21, 2016, Martin led portions of the Applied Physics Laboratory's annual meeting of the Laboratory's External Advisory Board meeting and discussed future research and operational aspects of ocean observing. NANOOS PI Mickett gave a presentation on Cha'ba and Puget Sound moorings.
- Newton was asked to participate in the workshop at NDBC Stennis, MS, to write a "National Strategy for a Sustained Infrastructure of Coastal Moorings" on April 5-7, 2016 with representatives from NDBC, IOOS PO, AOOS, SCCOOS, GLOS, and NERACOOS. She has contributed to writing parts of the Strategy, the draft of which will be released in July 2016.

Assuring coordination within NANOOS, throughout the reporting period, Martin and Newton remained deeply involved with a complimentary research ocean observing effort in the Pacific Northwest, the NSF-funded Science and Technology Center (STC) for Coastal Margin Observation and Prediction, which NANOOS leverages heavily in the areas of DMAC and Education and Outreach. Martin serves as Co-Director for the Center and Newton directs the UW Education efforts for this multi-institution project.

Newton continued to develop education opportunities for at-sea training with Northwest Indian College (NWIC) students through CMOP, including deploying a buoy in Bellingham Bay 11 February 2016. A new initiative within CMOP directed by Newton, the construction and deployment of the ocean sensing buoy in Bellingham Bay, Washington, is now providing data via NVS that students use in the classroom and are involved in its operation. This buoy is a legacy outcome from CMOP involving NWIC students in the work and the first buoy in northern Puget Sound.

Additional coordination included:

- Newton was invited by AOOS to attend their Alaska OA Workshop in Anchorage on 29-30 January to provide perspective from NANNOS, C-CAN, and GOA-ON as well as the IOOS OTT "Headlights" project with shellfish growers.
- Newton was invited by EPA to attend their HAB meetings in Seattle, WA, on 29-31 March and present a round table poster on NANOOS activities relevant to HABs and a talk to the tribal caucus on "Understanding the Blob and El Nino with Implications for HABs". Discussion centered on understanding current conditions and use of NANOOS to do that.
- NANOOS coordinated with other West Coast RAs, to present monthly contributions to the NOAA Regional Team's Western Regional Environmental Conditions and Impacts Coordination (WRECIC) Webinars on 25 Jan, Feb 20 (by Jonathan Allan), 21 March, 25 April, 25 May by Newton. This monthly effort was well attended in the NANOOS region and hopes are for it to continue bimonthly. Timi Vann and Dan McEvoy hosted this successful event.

- Newton is on the Advisory Committee for the West Coast Ocean Forecast System (WCOFS) and participated in a call on 27 May with the other west coast IOOS regional associations and the project team.
- Newton attended and presented at the Ocean Sciences Meeting in New Orleans, LA, 22-26 February. Her poster: "Synthesis of Observations and Real-Time Views of Pacific Anomalies from the NANOOS Region" was one of many NANOOS contributions, as noted in this report.
- Newton participated in a teleconference call with NERRS re OA coordination on 17 March 2016 led by NERRS Program Director Marie Bundy and remains involved with the group.
- NANOOS PI Barth and Newton participated in the West Coast Ocean Acidification and Hypoxia Science Panel (<http://westcoastoah.org>) that released its final recommendations regarding west coast US and Canadian ocean acidification and hypoxia issues on April 2016 (Chan et al., 2016). PI Barth is one of several scientists in the recent "Ocean Acidification" video: <http://www.oregonocean.info/index.php/ocean-acidification-and-hypoxia/563-ocean-acidification-video>. Newton was the lead author for the Monitoring Framework technical document: <http://westcoastoah.org/wp-content/uploads/2016/02/OAH-Panel-Monitoring-Network-4.1.16-FINAL.pdf>
- PI Barth briefed Oregon's Ocean Science Trust on January 22, 2016, about challenges facing Oregon's coastal ocean and priorities for ocean research.
- Newton is on the Olympic Coast Sanctuary's ocean acidification and sentinel site committee (OASes), helping them to scope a fall workshop. She participated in a planning call March 21.

Keeping the goals and capabilities of NANOOS and IOOS represented internationally, NANOOS Administration and PIs made several important contributions:

- On February 11, 2016, Martin participated in a teleconference as part of his duties as a member of the Ocean Networks Canada (ONC) International Science Advisory Board (ISAB). ONC contains functional components analogous to both the operational aspects of the U.S. IOOS and the basic research foci of the U.S. OOI. Martin addresses both of these two complimentary aspects of ocean observing as a member of the ONC ISAB.
- Newton represented IOOS on the Global Ocean Acidification Observing Network Executive Committee calls and activities. This included: invited participation in the "Workshop on OA Research in China" at State Key Lab, Shanghai, China on 28-29 April 2016 giving a NANOOS-IOOS-NOAA OAP-GOA-ON talk "Helping the Shellfish Industry through Observations: Lessons from the Pacific Northwest, US;" attending the Oceans in a High CO2 World Conference in Hobart on 3-6 May, presenting "Assessment of OA Biological Response in Washington state Coastal and Estuarine Waters;" and co-chaired the GOA-ON 3rd Workshop in Hobart, Tasmania, Australia, 8-10 May.
- Newton, a member of MEOPAR's International Science Advisory Committee, provided input and review support throughout the period, with a Red Team Advisory call 29 January and attending the ISAC meeting in Toronto April 19-20.
- NANOOS PI Barth serves as Co-Chair of the PICES (North Pacific Marine Science Organization) Advisory Panel on "North Pacific Coastal Ocean Observing Systems."

Additional NANOOS coordination:

Newton participated in NOAA FATE meetings for J-SCOPE, the ecological forecasting model for seasonal coastal ocean prediction on NANOOS' portal: <http://www.nanoos.org/products/j-scope/>.

Newton continued to represent NANOOS in regional efforts, e.g., C-CAN, PSEMP, Pacific Salmon Marine Survival, and West Coast Ocean Data Portal.

Newton continued to fill the Research seat as a member of the Olympic Coast National Marine Sanctuary Advisory Council, and attended their meetings in January and March 2016.

3) Scope of Work

There were neither current nor anticipated changes in scope of work, aside from downtime for various observing assets detailed above, due to weather, aging infrastructure, lack of sufficient funding support or other matters beyond our control.

4) Personnel and Organizational Structure

There was no changes in key personnel for this period.

6) Budget Analysis

With an award start date of 1 June 2011 and end date of 31 May 2016, as of 31 May 2016 we are 100% of the way through the project and 100% through FY15. We have requested and been awarded a No Cost Extension for this project for 9 months, through 28 Feb 2017, meaning we are 88% through the project (including the extension period).

As of 29 June 2016 we have spent \$12,445,338.88 of the \$13,478,098 provided so \$1,032,759.12 is unspent. Of that amount \$889,714.91 is encumbered so the actual balance remaining that is available for use is \$143,044.21. Thus, we have spent or committed 98.9% of the funding provided. This matches well with our expectations for this time.

Encumbrances are funds dedicated to specific planned expenditures in the UW Financial Systems where they are treated as funds already spent though they are not invoiced until actually spent. All of the sub-awards are encumbered and thus not available to be spent for any other purpose. Indirect costs are also encumbered. **In summary, we assess that the remaining amount for this award is commensurate with what is needed for the remaining tasks under the NCE for this point in the reporting period.** We will be closing out this project as soon as the tasks are complete.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

- Anderson, D., J.A. Antolinez, F.J. Mendez, P. Ruggiero. On the importance of wave simulation techniques for forecasting shoreline change. Ocean Sciences Conference, New Orleans, LA, February 2016.
- Baptista, A. M., M. Davis, M. Leinen. Estuarine observing in the era of Our Global Estuary, 2016b. 17th Meeting of the Partnership for the Observation of the Global Ocean (POGO-17), Yokohama, Japan.
- Baptista, A. M., M. Rostaminia, P. J. Turner, T. Kärnä and J. Lopez, 2016a. Salinity in the Willamette River? Seriously?!? Estuarine tales of rising seas, seismic subsidence and uncertainty. 2016 Columbia River Estuary Conference: Recent Anomalous Environmental Conditions – Drivers and Consequences, Astoria, OR.
- Barnard, P.L., A.D. Short, M.D. Harley, K.D. Splinter, S. Vitousek, I.L. Turner, J. Allan, M. Banno, K.R. Bryan, A. Doria, J.E. Hansen, S. Kato, Y. Kuriyama, E. Randall-Goodwin, P. Ruggiero, I.J. Walker and D.K. Heathfield. Recent Pacific Ocean basin coastal response to inter-annual climate variability with implications for future climate change impacts, Ocean Sciences Conference, New Orleans, LA, February 2016.
- Cohn, N., B. Hoonhout, P. Ruggiero, L. Moore, S. de Vries, D. Roelvink, O.Duran, and E. Goldstein. Exploring nearshore-beach-dune interaction using a coupled modeling framework. Ocean Sciences Conference, New Orleans, LA, February 2016.
- Haller, M.C. Invited Seminar: What I have learned about the Nearshore through the use of radar remote sensing, Engineering School of Sustainable Infrastructure and Environment, University of Florida, February 12, 2016.
- Haller, M.C. On the imaging of rip currents in X-band radar, POA Seminar Series, CEOAS, Oregon State University, March 1, 2016.
- Kosro, P.M. Ocean ocean-coastal interactions. Pacific Anomalies Workshop, University of Washington, Seattle, WA, January 20-21, 2016.
- Kurapov, A., P.M. Kosro, J.A. Barth, E. Myers, E. Bayer. Analysis of anomalous oceanic conditions along the US West Coast in 2014 using a high resolution regional ocean model (Poster). Pacific Anomalies Workshop, University of Washington, January 20-21, 2016.
- Kurapov, A.L., J.A. Barth, P.M. Kosro, E.P. Myers, E.J. Bayler. Anomalous ocean conditions along the US Pacific coast in 2014: analyses using the West Coast Operation Forecast System (WCOFS). PO43B-08, Ocean Sciences Meeting, New Orleans, LA, February 25, 2016.
- MacCready, P., S. Siedlecki, R. McCabe, N. Banas. Recent Advances in Modeling Puget Sound & Coastal Waters. University of Washington Water Seminar, Seattle, WA, December 1, 2015.
- MacCready, P., S. Siedlecki, R. McCabe, N. Banas, 2016. "The LiveOcean Daily Forecast Model: Near-term predictions of ocean acidification in Washington waters." Physical Oceanography Lunch Seminar, University of Washington, Seattle, WA, January 2016.
- MacCready, P., S. Siedlecki, R. McCabe, 2016. Effect of the 'Blob' on shelf water properties in the NE Pacific (Poster). Pacific Anomalies Workshop, University of Washington, Seattle, WA, January 20-21, 2016.
- MacCready, P. Ocean Dynamics and the Salish Sea. Sound Waters Talk, Whidbey Island, WA, February 2016.
- Mayorga, E. GOA-ON Data Portal: Goals, status and plans. 3rd GOA-ON Science Workshop, Hobart, Australia, May 9-11 2016.
- Mayorga, E., J. Newton and T. Tanner. Ocean Acidification monitoring data collaborations, integration and dissemination: The US Pacific NW regional IOOS experience with local to global efforts (Poster). *Ocean Sciences Meeting*, New Orleans, LA, February 22-26, 2016.

Mickett, J. B., J. Newton, A. Devol, W. Ruef. The Response of Puget Sound to the 2014–2015 North Pacific Warm Anomaly. Pacific Anomalies Workshop, Seattle, WA, 20-21, 2016.

Mickett, J. B., J. Newton, A. Devol, W. Ruef, The Response of a Branch of Puget Sound to the 2014–2015 North Pacific Warm Anomaly, AGU/ASLO Ocean Sciences, New Orleans, LA, February 21-26, 2016.

Mickett, J. B., S. Moore and ESP team, The Northwest IOOS ESP Coastal Mooring, Monterey Bay Aquarium Research Institute, May 5, 2016.

Mickett, J. B., S. Moore and J. Newton, The Northwest IOOS ESP Coastal Mooring, R/V *Thomas G. Thompson*, May 24, 2016.

Needoba, J.A., T.D. Peterson, C. Seaton, S.F. Riseman, and A.M. Baptista. Anomalous hydrologic and biogeochemical conditions in the Columbia River estuary during 2014-2015. 2016 Columbia River Estuary Conference: Recent Anomalous Environmental Conditions – Drivers and Consequences, Astoria, OR.

Newton, J., J. Mickett, A. Devol, P.M. Kosro, Joseph A. Needoba, C.M. Risien, J.C. Allan. Synthesis of Observations and Real Time Views of Pacific Anomalies from the NANOOS Region. ME44E-0895, Ocean Sciences Meeting, New Orleans, Feb 25, 2016.

Newton, J. NANOOS: Delivering Coastal Ocean Observations and a Whole Lot More. NOAA NWFSC Monster Jam, Seattle, WA, February 4, 2016.

Newton, J. Understanding the Blob and El Nino and their effects on Puget Sound. MaST Seminar, Highline College, Des Moines, WA, February 6, 2016.

Newton, J. Northwest Association of Networked Ocean Observing Systems (NANOOS): Ocean Observing in the Pacific Northwest (Poster). EPA HABs meeting, Seattle, WA, March 29-31, 2016

Newton, J. Understanding the Blob and El Nino with Implications for HABs. EPA HABs meeting: Tribal Caucus, Seattle, WA, March 31, 2016.

Newton, J. Assessment of OA Biological Response in WA State Coastal and Estuarine Waters. 4th International Symposium on the Ocean in a High-CO2 World, Hobart, Australia, May 4, 2016.

Newton, J, J. Mickett, A. Devol, W. Ruef. Update from NANOOS and UW-ORCA, Washington Department of Ecology Info-calls, January 7, March 31 and May 26, 2016.

Newton J., J. Mickett, A. Devol, Marine Waters Year in Review: Cha'ba data, Puget Sound Marine Waters Workshop: "2015 in Review", April 1, 2016, Seattle, WA.

Newton J., S. Weisberg, T. Klinger. Coalescing Science for Policy: Perspectives from the West Coast Ocean Acidification and Hypoxia Science Panel. Salish Sea Ecosystem Conference, Vancouver, B.C., April 13-15, 2016.

Pierce, S.D., J.A. Barth, R.K. Shearman, and A. Erofeev, 2016. Underwater Glider Observations of the 2014-15 Northeast Pacific Warm Anomaly. Ocean Sciences Meeting, Abstract ME44E-0897, New Orleans, LA, February, 2016.

Ruef, W., J. Newton, J. Mickett, A. Devol, Marine Waters Year in Review: the 2015 ORCA Time Series, Puget Sound Marine Waters Workshop: "2015 in Review", April 1, 2016, Seattle, WA.

Scroccaro, I., A.M. Baptista, P.J. Turner, 2016a. Local atmospheric effects in the Columbia River estuary: can we simulate them, and do they matter? 2016 Columbia River Estuary Conference: Recent Anomalous Environmental Conditions – Drivers and Consequences, Astoria, OR.

Scroccaro, I., A.M. Baptista, P.J. Turner, T. Kärnä, J. Lopez, C. Seaton, 2016b. Modeling study of the Columbia River estuary (USA) with different meteorological models. ECSA 56 Coastal systems in transition: From a 'natural' to an 'anthropogenically-modified' state, Bremen, Germany.

Seaton, C., S. Riseman, M.P. Wilkin, J. Goodman, P.J. Turner, J.A. Needoba, A.M. Baptista, 2016. Columbia River endurance stations: eyes on the Warm Blob, and beyond. 2016 Columbia River Estuary Conference: Recent Anomalous Environmental Conditions – Drivers and Consequences, Astoria, OR.

- Wold, R, J. Newton, E. Mayorga, J. Allan, C. Risien, T. Tanner. Use of climatology data products to understand variation in the Salish Sea: The NANOOS Climatology App delivers. Salish Sea Ecosystem Conference, Vancouver, B.C., April 14, 2016.
- Wold, R, A. Sprenger, J. Allan, E. Mayorga, J. Newton, T. Tanner. Data collection, mapping, visualization and information management techniques and their role in ecosystem recovery (Poster). Salish Sea Ecosystem Conference, Vancouver, B.C., April 13-15, 2016.

Publications:

- Chan, F., Boehm, A.B., Barth, J.A., Chornesky, E.A., Dickson, A.G., Feely, R.A., Hales, B., Hill, T.M., Hofmann, G., Ianson, D., Klinger, T., Largier, J., Newton, J., Pedersen, T.F., Somero, G.N., Sutula, M., Wakefield, W.W., Waldbusser, G.G., Weisberg, S.B., and Whiteman, E.A. The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions. California Ocean Science Trust, Oakland, California, USA. April 2016.
<http://westcoastoah.org/wp-content/uploads/2016/04/OAH-Panel-Key-Findings-Recommendations-and-Actions-4.4.16-FINAL.pdf>
- Cohn, N. and P. Ruggiero, 2016. The influence of seasonal to interannual nearshore profile variability on extreme water levels: Modeling wave runup on dissipative beaches. *Coastal Engineering*, <http://dx.doi.org/10.1016/j.coastaleng.2016.01.006>.
- Honegger, D. and M.C. Haller, Intratidal to interseasonal variability of oblique, internal hydraulic jumps at a stratified estuary mouth, *AGU Ocean Sciences Meeting*, New Orleans, LA, 2016.
- Horsburgh, J.S., A.K. Aufdenkampe, E. Mayorga, K.A. Lehnert, L. Hsu, L. Song, A.S. Jones, S.G. Damiano, D.G. Tarboton, D. Valentine, I. Zaslavsky & T. Whitenack, Observations Data Model 2: A community information model for spatially discrete Earth observations. *Environmental Modelling & Software* 79: 55-74, doi:10.1016/j.envsoft.2016.01.010
- Kärnä T. and A.M. Baptista, 2016. Evaluation of a long-term hindcast simulation for the Columbia River estuary. *Ocean Modelling*. 99:1-14.
- Kärnä T. and A.M. Baptista, submitted. Water age in the Columbia River estuary. *Estuarine, Coastal and Shelf Science*.
- Kim, Sung Yong, A.L. Kurapov, and P.M. Kosro, 2015. Influence of varying upper ocean stratification on coastal near-inertial currents. *Journal of Geophysical Research*, 120(12): 8504-8527, 2015JC011153.
- Kurapov, A. L., S. Erofeeva, and E. Myers, 2016: Coastal sea level variability in the US West Coast Ocean Forecast System (WCOFS), *Oc. Dyn.*, submitted.
- Lopez J. and A.M. Baptista, submitted. Benchmarking an unstructured-grid sediment model in an energetic estuary. *Ocean Modelling*.
- Moore, L., O. Duran, P. Ruggiero, 2016. Vegetation control allows autocyclic formation of multiple dunes on prograding coasts. *Geology*, DOI:10.1130/G37778.1.
- Newton, J., Hill, T.M., Feely, R.A., Barth, J.A., Boehm, A.B., Chan, F., Chornesky, E.A., Dickson, A.G., Hales, B., Hofmann, G., Ianson, D., Klinger, T., Largier, J., Pedersen, T.F., Somero, G.N., Sutula, M., Wakefield, W.W., Waldbusser, G.G., Weisberg, S.B., and Whiteman, E.A. Ocean Acidification and Hypoxia Monitoring Network: Tracking the Impacts of Changing Ocean Chemistry to Inform Decisions. California Ocean Science Trust, Oakland, California, USA. April 2016. <http://westcoastoah.org/wp-content/uploads/2016/02/OAH-Panel-Monitoring-Network-4.1.16-FINAL.pdf>
- Raposa, K., K. Wasson, E. Smith, J. Crooks, P. Delgado, S. Fernald, M. Ferner, A. Helms, L. Hice, J. Mora, B. Puckett, D. Sanger, S. Shull, L. Spurrier, R. Stevens, S. Lerberg. April 2016, *submitted*. Assessing tidal marsh resilience to sea-level rise at broad geographic scales with multi-metric indices. *Global Change Biology*.

- Ruggiero, P., G. Kaminsky, G. Gelfenbaum, N. Cohn, 2016. Morphodynamics of prograding beaches: A synthesis of seasonal- to century-scale observations of the Columbia River littoral cell. *Marine Geology*, 376, 51-68, 10.1016/j.margeo.2016.03.012.
- Washington State Department of Ecology. 2015. Eyes Over Puget Sound, Surface Conditions Report, December 14, 2015. Ecology Publication No. 15-03-079.
<https://fortress.wa.gov/ecy/publications/documents/1503079.pdf>
- Washington State Department of Ecology. 2016a. Eyes Over Puget Sound, Surface Conditions Report, February 8, 2016. Ecology Publication No. 16-03-070.
<https://fortress.wa.gov/ecy/publications/documents/1603070.pdf>
- Washington State Department of Ecology. 2016b. Eyes Over Puget Sound, Surface Conditions Report, March 16, 2016. Ecology Publication No. 16-03-071.
<https://fortress.wa.gov/ecy/publications/documents/1603071.pdf>
- Washington State Department of Ecology. 2016c. Eyes Over Puget Sound, Surface Conditions Report, April 6, 2016. Ecology Publication No. 16-03-072.
<https://fortress.wa.gov/ecy/publications/documents/1603071.pdf>
- Washington State Department of Ecology. 2016d. Eyes Over Puget Sound, Surface Conditions Report, May 2, 2016. Ecology Publication No. 16-03-073.
http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2016_05_02.pdf

**Sustaining NANOOS, the Pacific Northwest component of the U.S. IOOS®:
NOAA Award: NA11NOS0120036**

June 2016 Progress Report Annual Supplemental

The reporting period for this annual supplemental is 6/1/2015-5/31/2016.

- **Regional Ocean Governance Organization activities**

1. **NANOOS Collaboration with the West Coast Governors Alliance on Ocean Health (WCGA):**

NANOOS continued its close collaboration with the WCGA in partnership with the two other West Coast IOOS Regional Associations, SCCOOS and CeNCOOS. This collaboration focused particularly – but not exclusively – on the WCGGA Ocean Data Network (WCODN, <http://network.westcoastoceans.org>).

NANOOS Director Jan Newton is a member of the WCODN Action Coordination Team (ACT). As core members of the WCODN IT working group, NANOOS DMAC Lead E. Mayorga continued to provide technical support and guidance to the West Coast Ocean Data Portal (WCODP, <http://portal.westcoastoceans.org>) and related efforts through his participation in conference calls and follow-up discussions. These discussions included a refocusing to serve the emerging data needs of the newly formed West Coast Regional Planning Body (RPB), including the identification of priority marine geospatial data catalogs for harvesting into the WCODP catalog to address priority data gaps. NANOOS will be actively engaged in supporting these efforts, and recently upgraded its GeoServer instance (<http://data.nanoos.org/geoserver/>) and staff capabilities to better support these needs.

Geospatial catalogs in Washington and Oregon are among the priority catalogs identified by the WCODN to support RPB needs. NANOOS has continued to support these regional efforts, including continued provision of OGC WMS web service access to the ERMA Pacific Northwest application (<https://erma.noaa.gov/northwest/erma.html>), supporting WA marine spatial planning data efforts (<http://www.msp.wa.gov>) by providing a monitoring asset inventory and advisory assistance, and technical interactions with the Northwest Straits Commission “SoundIQ” (<http://www.nwstraits.org/our-work/soundiq/>) application team to provide WMS access to NANOOS data products.

Finally, NANOOS actively worked with the California Current Acidification Network (C-CAN) and their alignment with WCGA efforts. Newton is a member of the West Coast Ocean Acidification and Hypoxia Science Panel.

- **Efforts to leverage IOOS funding**

NANOOS continues to be substantially leveraged in every aspect of its effort. None of NANOOS’ assets or teams is supported 100% by IOOS funds. Maintaining the sources of the current leverage, in times of budget cuts and shrinking funding levels affecting all sectors of NANOOS, represents a major commitment of time. NANOOS leadership, Newton and Martin, as well as all of the NANOOS PIs, actively engage to leverage and build capacity for our existing systems. We can honestly say leveraging activities permeate daily practice throughout NANOOS. These include CMOP’s NSF funding, UW’s and OSU’s NOAA OAP funding, federal investments in NERRS, and state of Oregon and state of Washington funding.

Additional examples include:

A new buoy, Se'lhaem, was deployed in Bellingham Bay on February 11th. NANOOS member, CMOP (the Center for Coastal Margin Observation and Prediction), through its education partner University of Washington, deployed the buoy in partnership with the Northwest Indian College (NWIC) and Western Washington University (WWU).

The National Science Foundation Ocean Observing Initiative (OOI) project has a large footprint in the NANOOS region, as mentioned in the Progress Report, with gliders and buoys now deployed. NANOOS has adapted its observing plan to take advantage of these additions and worked to gain seamless data delivery of OOI assets into the NANOOS data Visualization System (NVS). This latter effort is not yet visible, but has received active attention and is functioning in the test stage of NVS.

The HAB focused OTT IOOS project includes work with the NWFSC, tribes, and NANOOS' La Push mooring. The OA focused OTT IOOS project was written in collaboration with three other RAs, AOOs, CeNCOOS, and SCCOOS, and involves leveraged shellfish grower and hatchery operations utilizing state directed OA monitoring funds in AK, WA, and OR.

NANOOS Puget Sound moorings are partially supported by the State of Washington's Washington Ocean Acidification Center.

NOAA Fisheries and the Ecosystem (FATE) program renewed funding for the JISAO-Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE) project, in which NANOOS is a partner, along with NOAA Northwest Fisheries Science Center and the UW-NOAA Joint Institute for the Study of Atmosphere and Oceans (JISAO).

- **Update to NANOOS membership and Board of Directors**

NANOOS gained NOAA Pacific Marine Environmental Laboratory, Washington Department of Health, Hakai Institute, Salish Sea Expeditions, Raincoast GeoResearch and Say Yes! To Life Swims as new members, each with Governing Council representation. We also secured a new Governing Council representative for the Vancouver Island University, Dr. Helen Gurney-Smith.

Following the August GC/PI meeting, NANOOS held elections for the following board assignments, which had been filled by acting members: Jonathan Allan, DOGAMI, for OR State Agencies; Andy Lanier, for OR Federal Offices; Casey Moore, SeaBird Scientific, and Andrew Barnard, WetLabs, for Industry; and Paul Dye, The Nature Conservancy, for Non-Government Organizations. The vacant Member-at-Large position was filled by Margaret Barrette of the Pacific Coast Shellfish Growers Association. All other Board members have not changed during this period and they have stayed engaged.

- **Governance activities and accomplishments**

Newton and Martin held annual NANOOS meetings for all PIs and the Governing Council in Vancouver, WA on 20-21 August 2015. Newton coordinated with J. Allan, User Products Committee Chair, to organize the Tri-Comm meeting, held 21-22 March 2015 in Seattle, WA, hosted by APL-UW.