Sustaining NANOOS, the Pacific Northwest component of the U.S. IOOS®:
NOAA Award: NA11NOS0120036 Reporting period: 6/01/2015 to 11/30/2015

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 (WECOA) Analytical Support [B. Hales, OSU].

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, WA glider) 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 recovery of the Cha'Ba surface and NEMO subsurface mooring components of this array. These moorings were recently recovered during a mooring operations/outreach-education cruise aboard the R/V Thomas G. Thompson from November 16-20, 2015, with ship time generously donated by the UW School of Oceanography due to active student participation. During the cruise a relatively simple winter "El Niño" subsurface mooring was also deployed, with the mooring designed to capture water mass variability on the shelf during a strong El Niño event. Additionally, numerous CTDs, water samples and net tows in support of OA and HAB monitoring and research were collected during the cruise. More than 20 students, volunteers and educators participated in this cruise along with the core APL team.

Mooring performance was again very good during this period, with the subsurface profiling mooring operating from deployment in late May continuously through late October when system batteries were depleted, recording more than 2000 near-full-depth profiles of a range of water properties. Cha Ba also performed well, with more than 90% of the instruments functioning continuously throughout the 6-month deployment. **Particularly noteworthy is that this deployment had the first successful "deep" (49 m) moored pH measurements on the Washington Shelf, with real-time observations from this new instrument presented at the Washington State Ocean Acidification Center Science Symposium in late June 2015.** These observations should significantly add to our understanding of the linkages between upwelling and pH changes on the NW Washington Shelf.

At the beginning of this period we received funding from NOAA OAP to begin the design and construction of a "winter" Cha Ba mooring, which will allow year-round observations on the Washington Shelf. The first deployment of this mooring is scheduled for Oct. 2016. Additionally, with IOOS OTT funding we have finished construction and testing of a real-time HAB detection mooring (equipped with an Environmental Sample Processor) that will be integrated with the NEMO-subsurface profiling mooring and deployed as early as May 2016.

With the continued influence of the "blob" in the North Pacific, the looming El Niño, and the West-Coast-wide HAB in the summer of 2015, there has been a heightened interest in observations from

these NANOOS moorings. In addition to Mickett presenting moored observations at the Washington Ocean Acidification Science Symposium in June, Mickett and Newton published a summary of the 2014 moored observations in the Puget Sound Marine Waters 2014 Overview Report, highlighting the evolution of the blob's influence as the shelf transitioned from an upwelling to a downwelling regime and discussing factors controlling the variability of dissolved oxygen on the shelf.

Outreach and collaboration efforts over this period were numerous. With assistance from A. Sprenger and R. Wold of APL/UW, we were able to recruit more than 20 students, educators and other volunteers for the 5-day mooring operations/outreach cruise in November, making this cruise another highly-successful outreach opportunity. **Volunteers were quickly immersed in the hands-on oceanography we carry out on these cruises including net tows, CTDs, mooring deployments, and seawater sample analysis. NOAA Operations Officer Justin Ellis of the Olympic Coast National Marine Sanctuary was able to participate in the cruise; he collected numerous surface water samples to investigate phytoplankton species distribution and for HAB/toxin analysis.** Aboard the *Thompson*, Mickett presented a well-attended overview of the NANOOS coastal and ORCA mooring programs and discussed recent oceanic anomalies. Finally, for the second time in a year, we were also able to support an Oregon elementary school science project by deploying a small, satellite-tracked sailboat.

Again the PIs collaborated with the NOAA Olympic Coast National Marine Sanctuary (OCNMS) to deploy 5 temperature sensors on 2 of their inshore moorings, with these data providing important spatial information on both internal wave patterns and mesoscale structure on the shelf. During this period we also continued collaboration with graduate student S. Bushinsky of UW Oceanography (advisor Dr. S. Emerson) through an NSF funded IGERT program to continue the deployment of a prototype self-calibrating DO measurement system on Cha'Ba.

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 pCO_2 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.** As of 21 December the glider has completed 657 dives (1314 profiles) with over 45% of battery life remaining and is projected for recovery in March 2016. End-of-life testing is underway on the failed battery pack from the previous mission, along with other similar packs that completed full missions, but the cause of the premature voltage drop has not yet been determined. Efforts are underway to improve the representation of the WA Shelf Seaglider on NVS and submit the data to the Glider DAC. 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 Nino, the "blob" and coastal upwelling.

Oregon Shelf Glider: 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. 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 the 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, the glider was on the TH line for 362 days during three deployments, sampled along nearly 5280 km of track line covering the transect about 10 times, and collected about 3120 vertical profiles of ocean properties. For the reporting period 6/1/2015 to 11/30/2015 the glider was on the TH line for 182 days during two deployments, sampled along nearly 2610 km of track line covering the transect about 5 times, and collected about 1490 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 were used to contribute to the "2014-2015 Pacific Anomalies Science and Technology Workshop" held on May 5-6, 2015, in La Jolla, CA, and were part of a talk presented at the PICES Annual Meeting in October 2015. **The glider data show that for the January to April 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.** Temperatures over the continental shelf varied from above normal to average, due to wind-driven coastal upwelling bringing cold, deeper water up to 50-m depth. Starting in mid-April 2015, the warm upper –ocean water was held offshore by coastal upwelling. From mid-June to October 2015, the glider captured the formation of a warmer than average California Undercurrent Eddy being shed offshore from the continental slope region.

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 fall turnaround cruises were conducted from R/V Oceanus, with the NH10 buoy recovered on September 28, 2015, and re-deployed on October 3, 2015. The 5-day gap is required because, when the system was redesigned to accommodate the new CO_2 systems, a new surface buoy was required, and only one could be afforded. **We see it as a high (but unfunded) priority to construct a second buoy to allow a gap-less time series and to provide more time for refurbishment between deployments.**
The recovery went well, but the mooring line parted below the 60m instrument, causing loss of the anchor and an SBE56 it contained. The recovered end of the line suggested it had been struck, since two of the three strands of line were clean cut and the third was quite ragged. Following recovery, instruments were removed from the line and attached to the CTD rosette frame, and a comparison calibration cast was performed.

The present deployment has more measurements reporting in real time, thanks to lessons learned from the previous setting. In addition to physical oceanographic and meteorological measurements under this program and biogeochemical measurements under Burke Hales program, the mooring is hosting a bio-optical package from Angelique White's lab at OSU. The mooring team designed and built an improved mounting collar for this package which is now in use.

The measurements from NH10 have contributed to several scientific analyses published in peer reviewed journals during this period, including the study by Mazzini et al (2015) of central Oregon's river-fed coastal buoyancy current; the work by Yamada, Peterson and Kosro (2015) on **the invasive green crab and the relationship of its year-class strength to physical and biological indices**; and a study of winter circulation off the Pacific Northwest by Durski et al (2015).

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. Near-bottom moorings were recovered in August of 2015, and returned data records for T, S, pCO_2, *p*H, and O_2. Preliminary data is shown in Figures 1-3. **While the data are preliminary and incomplete pending further processing, this is the first record of its kind linking the shelf-break source-waters to the mid-shelf near-bottom and surface time-series.**

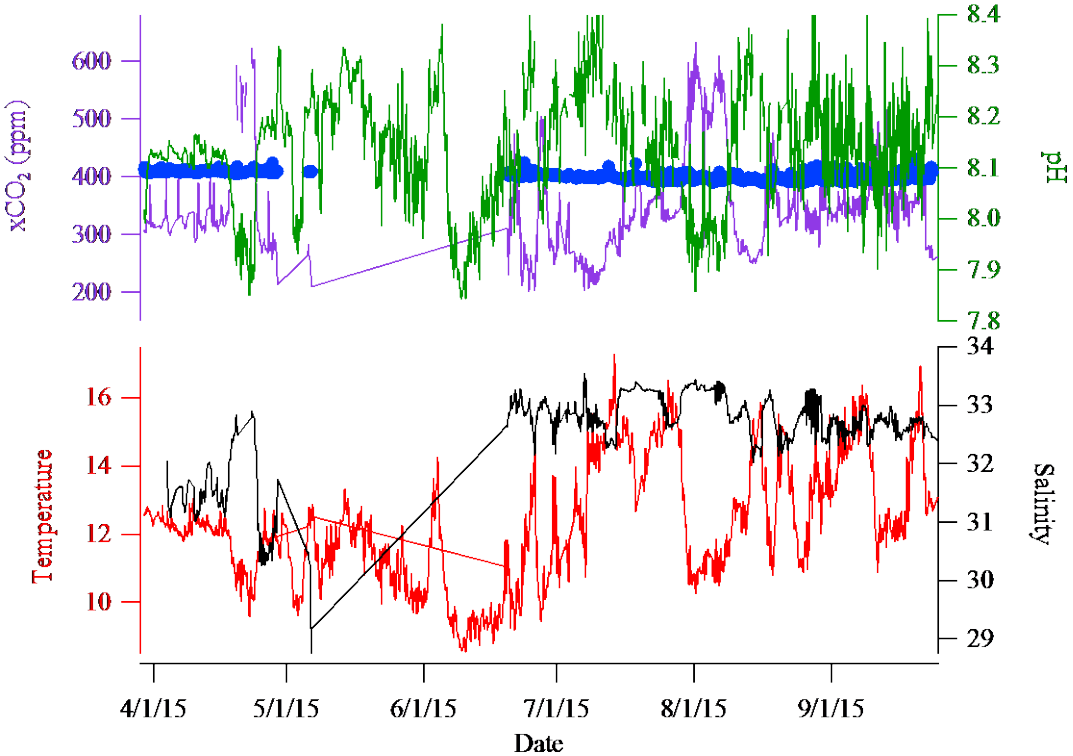


Figure 1. Surface measurements from NH10. Data gaps represent data transmission problems between the mooring and PMEL, but data are available and will be disseminated later (A. Sutton, pers. com.)

Surface measurements (Fig. 1) show the familiar pattern of the onset of spring upwelling and productivity, and associated variability in pH and pCO_2.

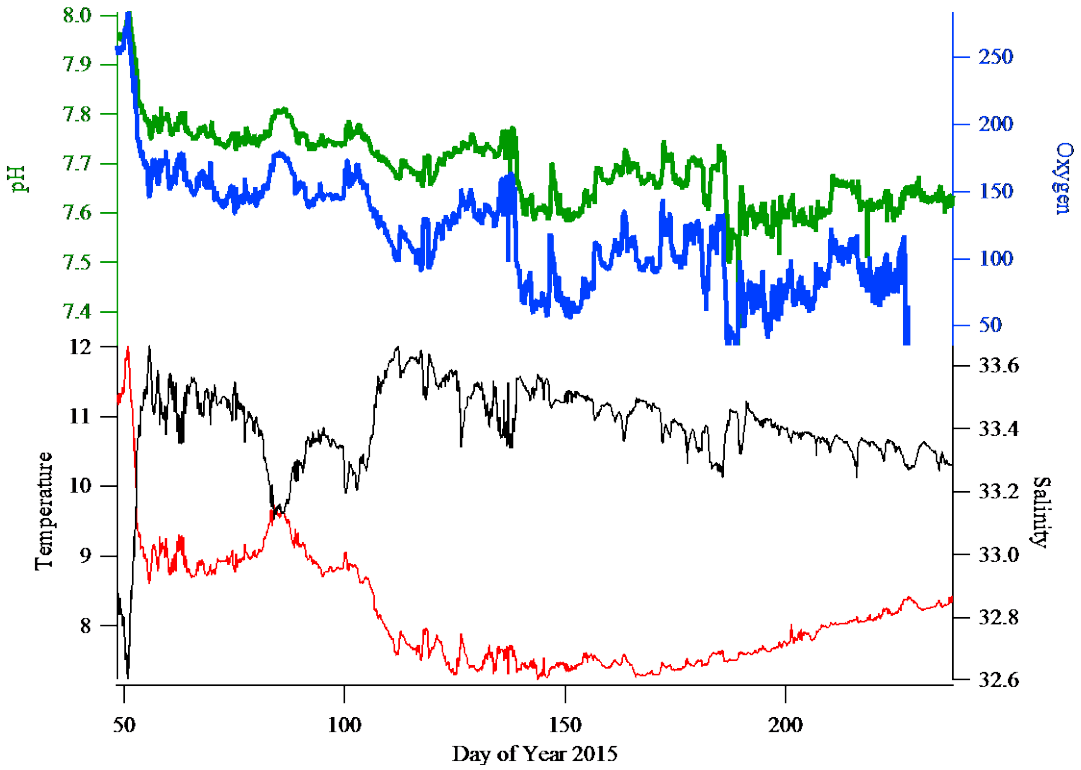


Figure 2. Near-bottom measurements from the deep mooring at NH10. SAMI pCO_2 instrument failed for this deployment.

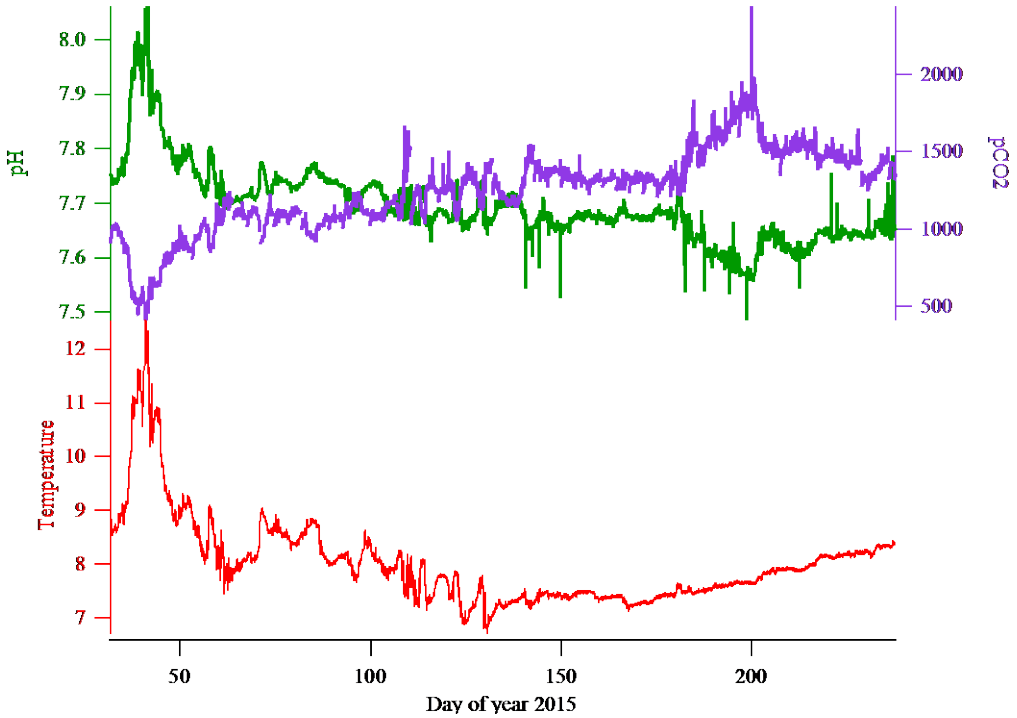


Figure 3. Near-bottom data from the shelf-break mooring at NH20. SBE16 data for T, S, O_2 appeared to be corrupted, but Hales is in consultation with SBE technical support to see if this can be resolved.

Near-bottom measurements (Fig. 2, 3) captured the brief period of deep mixing on the shelf in winter, followed by the return of colder, saltier upwelled source waters prior to the onset of local upwelling, and then the onset of local upwelling in late spring. **pH and O_2 (Fig.2) and pH and pCO_2 (Fig 3) show strong covariance, reflecting the respiration-control of these deep-water variables.**

The NH10 surface mooring was redeployed on 2 October, 2015. Initial performance was good, but a series of uninterrupted storms have caused the MAP equilibrator to become jammed in the mooring, making the surface-water xCO2 data unusable. Seastates have been so extreme that access to the mooring has been impossible. Likewise, re-deployment of the near-bottom moorings has been delayed, as the instrument-service took long enough that the extreme weather had set in and eliminated our ability to re-deploy.

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 (Baptista et al. 2015a), with partial support from NANOOS and the National Science Foundation. As discussed in previous reports, 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 deployed 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.** Moving forward, the station is expected to be seasonal. The first deployment measured in 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. A significant highlight of this reporting period was the success of the ORCA team in using both historic and real-time mooring observations to predict a significant fish kill at the southern end of Hood Canal that occurred in late August. Roughly several weeks in advance of the observed fish-kill event, Newton, Mickett, Devol and team drafted and disseminated a public notice to various stakeholders noting the building risk of such an event. **Despite a very early fall intrusion that entered Hood Canal in early August vs. the typical early-mid September, deep DO levels at the south end of the main stem of Hood Canal in late summer were among the lowest observed in a decade—at least partly due to a weak fall intrusion the previous fall (2014) associated with the warmer, less dense "blob" water. The issued public notice and regular updates warned that these conditions coupled with a sustained, strong southerly wind event could lead to upwelling of hypoxic water and a resultant fish-kill.** This sequence of events took place on August 28th. This predictive success highlights

the importance and utility of the ORCA program---specifically a long-term, high-frequency (> daily), real-time system that collects *profiles* of oceanic properties.

Non-routine work during this period included the continued successful testing of a prototype profiling mooring at the Dabob site, with the primary benefits of this system increased sampling frequency, lower maintenance costs and more reliable operation. Work also continued with the integration of a profiling pH sensor on the Carr Inlet mooring. Tests and modifications to this system continue, with the expectation of archivable data in January 2016. The shallow SeaFET at this mooring continues to provide scientific-quality data, though we have already had two instrument malfunctions. **This record, which comprises the first year-long, high-resolution pH measurement in Puget Sound, shows a rapid transition in the spring from lower winter pH values (~7.7) to higher values associated with primary production.** Summer values are highly variable, however (7.6—8.4), likely due to the patchiness and intermittency of phytoplankton blooms, which highlights the importance of continuous, high-frequency observations in detecting variability and trends. In the fall there is a rapid transition to lower (~7.7), more stable pH levels, which likely marks the end of the fall bloom.

We continued work to add meteorological stations to all six of the moorings (funding support from the non-profit Long Live the Kings, NANOOS and the Washington Ocean Acidification Center) with the ORCA team working with NANOOS DMAC to ensure archiving and availability of these data through NDBC.

During this period we also continued an 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 are in production with field deployment of the first units to take place during the winter of 2016. It is important to note that much of this work has been accomplished with significant contributions from non-NANOOS funding sources such as NOAA OAP and the Washington Ocean Acidification Center.

The project PIs and oceanographer W. Ruef, the ORCA operational lead, published a summary of 2014 ORCA observations in the Puget Sound Marine Waters 2014 Overview Report, highlighting the historically-large temperature, salinity and DO anomalies observed throughout the year and the significantly different reponse of Puget Sound basins. Additionally, Newton participated in a news media briefing in July, discussing the anomalous temperature and oxygen observations recorded by the ORCA mooring program. In November Mickett presented ORCA obsevations from Hood Canal at the CERF 2015 Conference in Portland, Oregon, focusing on deep water renewal processes.

We continued to collaborate with the NOAA PMEL Carbon Group (A. Sutton, S. Alin, R. Feely) to support the deployment of the pCO_2 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 with Wetlabs to test a bioluminescence sensor on an ORCA mooring.

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, BC. Data are uploaded daily to a cloud computing server at: http://107.170.217.21/VictoriaClipper30/level0/ and stored as daily files in a

NetCDF database, which will be a repository of the monitoring data. In addition, the database contains level 1 files (i.e., sensor data merged with position coordinates) and is expected to contain level 2 files soon (i.e., daily files combined into monthly files). Development of this database was leveraged with some EPA NEP funds, with help from APL-UW and with the aim to provide and serve these data via NANOOS. Further development of data products and QA/QC methods by Ecology staff will continue.

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 which is ready to be installed during the vessel's annual dry-dock maintenance in February 2016. This dry-dock period is also when the thermosalinograph will be re-installed after its factory calibration.

During the reporting period, Ecology published a Quality Assurance Monitoring Plan for the ferry sensor monitoring (Pool et al., 2015a). Ferry-based data were presented in two posters at the Coastal and Estuarine Research Federation 2015 Conference in Portland, Oregon. We examined surface indicators to temporally and spatially define potential thresholds for fish, shellfish, and phytoplankton (Bos et al., 2015). **We also examined relating ferry-based data to monthly discrete water samples and observations of *Noctiluca* blooms (Pool et al., 2015b).** During June to November 2015, waters at the entrance to Puget Sound reached 14 °C with the 13 °C isotherm warm anomaly extending across the Strait of Juan de Fuca (Fig. 4). Within Puget Sound, surface water temperatures warmed to ~15-20 °C during summer and cooled in Nov. (Figs. 4 and 5). Phytoplankton increased through summer with two periods of declines which coincided with *Nocitluca* blooms (Fig. 5). Ferry-based data products are included in Ecology's monthly "Eyes Over Puget Sound" reports.

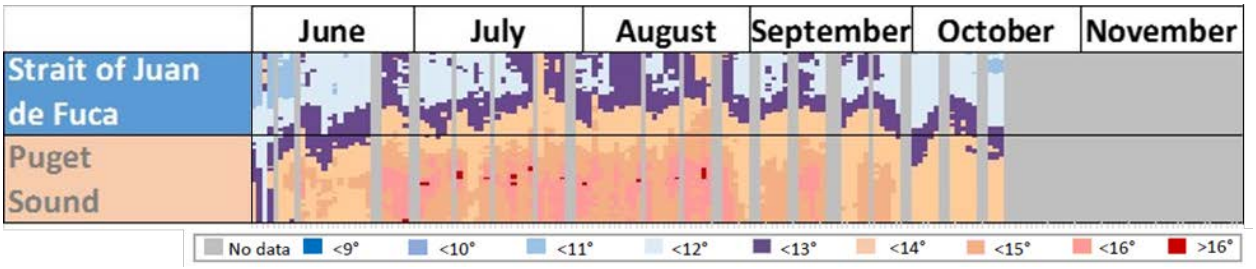
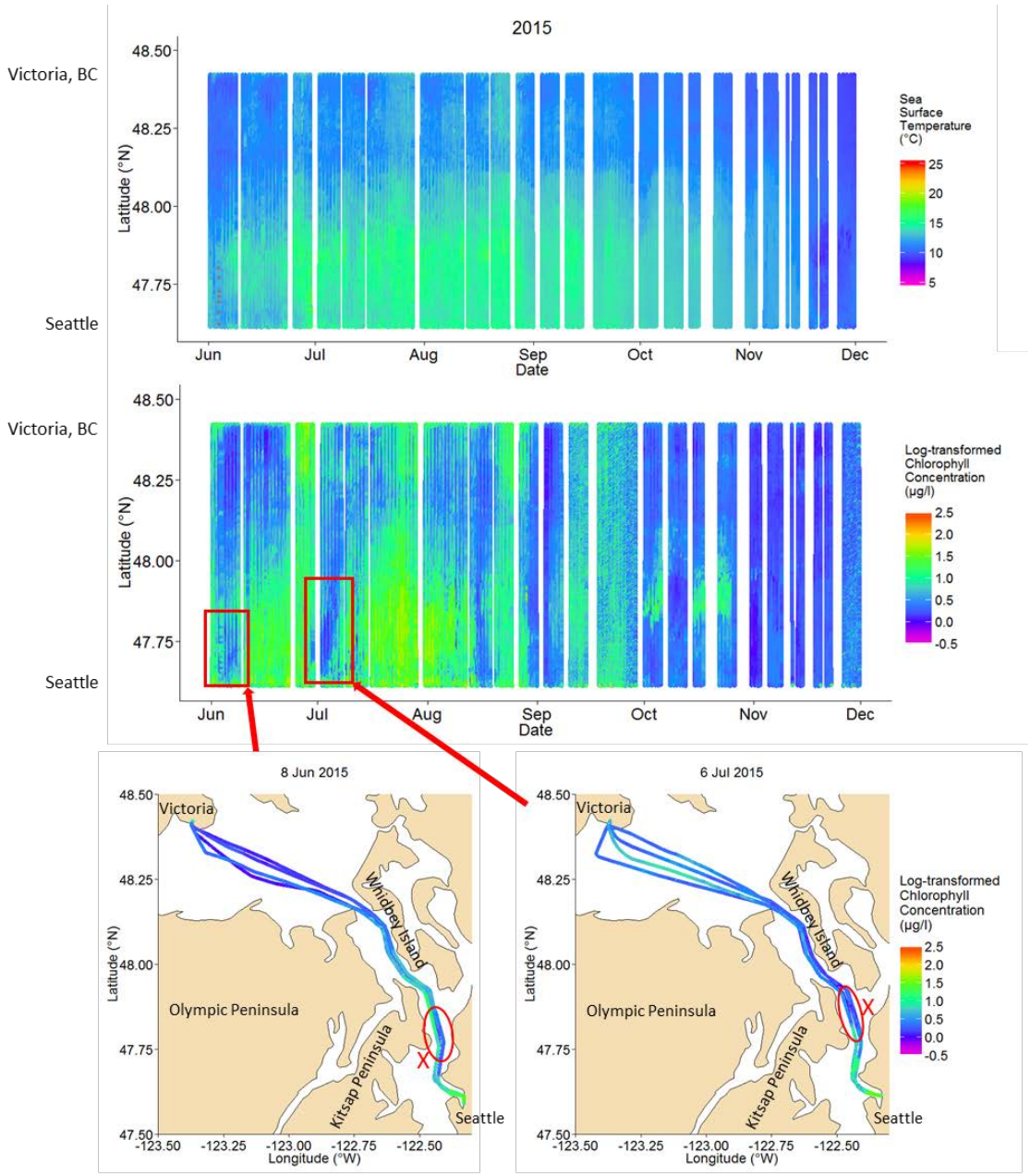


Figure 4. Isotherms along the north-to-south ferry transect for Jun – mid-Oct 2015. Data from November are pending. The 13 °C isotherm is in the Strait of Juan de Fuca during most of summer.

Ecology's remaining nearshore mooring station in Mukilteo was removed in late October due to lack of funding. In August, EPA divers assisted with freeing the moorings from entangled crab pots. **This summer, the near-bottom and near-surface instruments recorded the warmest water temperature since station installation (Fig. 6).** The near-surface instrument also recorded the most saline water. The records are in response to a massive exchange of warm water from "the Blob" and low river flows during the summer drought. We continued the moorings program's contribution to the monthly "Eyes Over Puget Sound" reports until the current budget situation required us to remove the moorings in late October. Due to a tight budget, Ecology continues to have only one Field Technician (S. Pool), partially supported by NANOOS funds.



Noctiluca bloom surfacing on 8 Jun 15 near Seattle, WA

Photo not shown; remnants of *Noctiluca* blooms were observed near Mukilteo and East Passage.

Figure 5. Temporal-spatial distribution of sea surface temperature (top) and chlorophyll fluorescence (bottom) in Jun to Nov 2015. Temperature was ~15-20 °C in Puget Sound during summer and cooled in Nov. Phytoplankton bloomed in Jun and late Jul following *Noctiluca* blooms and in Oct near Whidbey Island (~47.8 – 48.0 °N).

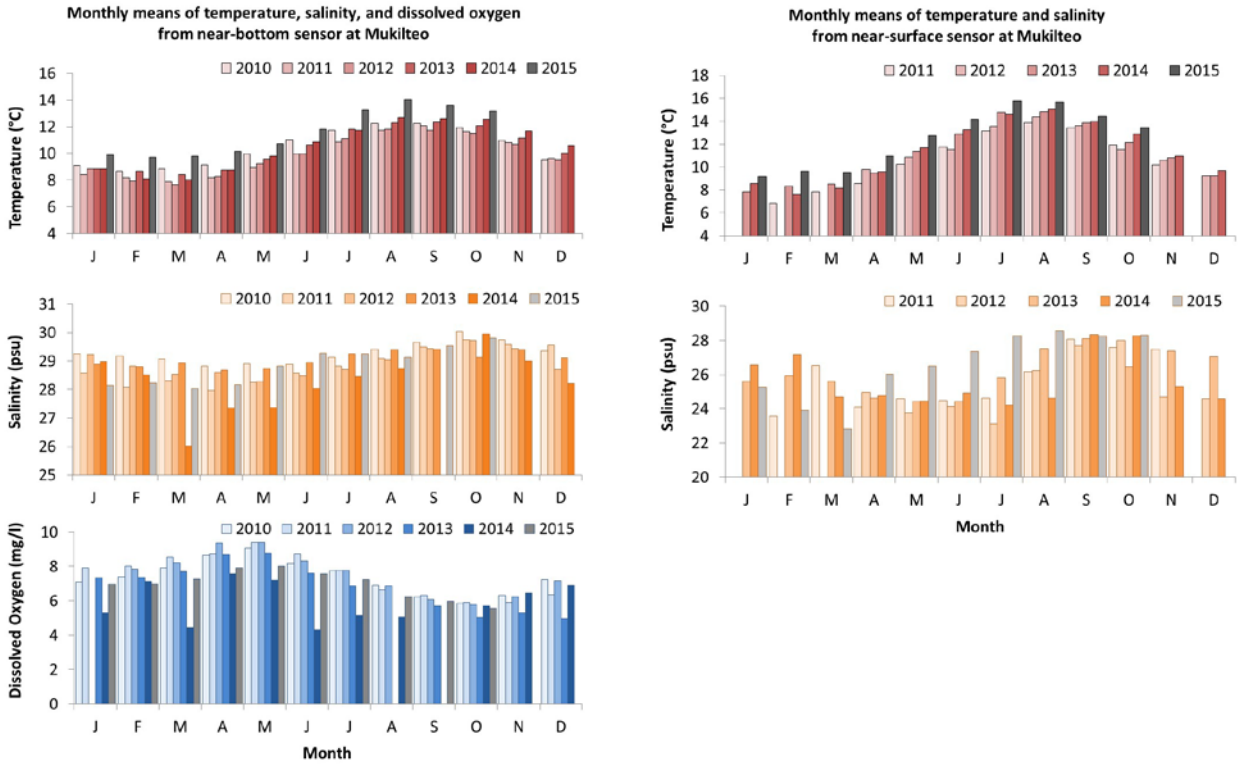


Figure 6. Monthly means of temperature, salinity, and dissolved oxygen from moorings at the Mukilteo station (data are provisional).

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.

During the reporting period, two significant "infrastructure" peer-reviewed papers were published. One provides a comprehensive description of the infrastructure of the SATURN collaboratory (Baptista et al. 2015a), and is designed as an anchoring reference for publications relying on SATURN observations and simulations. The other paper reports on adaptive sampling of microbial communities through the deployment of an Environmental Sampling Processor (ESP) at SATURN-03, with automated sampling targeted by select aspects of the function of the estuarine bioreactor (Herfort et al. 2015a). **This adaptive sampling offers a new window into the microbiology of the estuary (Herfort et al. 2015b).**

Of particular interest during the period, SATURN stations have enabled the characterization of the effects on the Columbia River estuary of the PNW "blob," a phenomenon of warm surface waters that that persisted in the North Pacific since the winter of 2013-2014. Early reports on the "blob" as viewed from the Columbia River include (Needoba et al. 2015) and (Baptista et al. 2015b).

Also, SATURN stations continue to be used to support multi-disciplinary modeling efforts in the Columbia River (Baptista et al. 2015c; Kärnä and Baptista 2015a,b; Cervantes et al. 2015a,b; Kärnä et al. 2015; Llebott et al. 2015a,b; Lopez et al. 2015; Rostaminia et al. 2015a,b; Seaton et al. 2015a,b). As reported by (Besse et al. 2015), undergraduate course work on statistical analysis has also been developed utilizing SATURN observational data and modeling results.

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 06/01/15 – 11/30/15. The telemetry transmissions at the Winchester Creek station were interrupted temporarily during this period from 6/1/15-6/10/15 due to platform changes associated with the EXO instrument deployments. On 6/10/15, a new fiberglass enclosure and telemetry equipment, to accommodate the EXO2 sonde, were installed and data transmission resumed on 6/10/15 18:30 PST. Real-time data transmissions at the Elliot Creek station were down from the period 6/1/15-11/30/15 due to platform changes associated with the new EXO2 sonde equipment. This site is being prepared for a new enclosure and telemetry equipment to be installed at the beginning of 2016. Currently, no instruments are deployed at the fifth water quality station (Boathouse) due to platform evaluation and assessment. We are relocating 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 datalogger and sensors were removed and sent to Campbell Scientific and RM Young for calibrations completed October/November 2015, and construction for the new wood platform began November 2015.

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. Real-time data transmissions were temporarily interrupted beginning 08/28/15-9/17/15 due to the sonde connector/field cable and sensor malfunctions. Telemetry transmissions were interrupted 9/29/15-10/26/15 due to station maintenance associated with new equipment upgrades, including EXO2 sonde deployments and associated hardware changes. 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 SWMP/NANOOS stations were summarized and analyzed for an Olympia oyster restoration and conservation guide, including analyses of environmental conditions and site assessments influencing restoration potential.** Two examples of SSNERR education programs incorporating NANOOS data were an Oregon State University Estuary Ecology course on 10/10/15 and a North Bend High School Coastal Ecology course on 12/9/15. Programs incorporated field based activities along with using NVS to compare field collected and real-time data to answer hypothesis driven questions.

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 plan to explore ways to include these datasets through NVS, but currently are focusing on instrument maintenance, data collection and protocols 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 June 2015, CMAP conducted spring seasonal beach monitoring surveys in the Columbia River Littoral .Cell (CRLC). Forty-six seasonal beach profiles and two surface maps were collected. Additional beach profiles and backshore features were walked in June and again in September to collect data at Washaway Beach to help Oregon State University (OSU) in modeling future shoreline change for the rapidly eroding area. From July to September, summer seasonal CRLC surveys were performed. CMAP collected 50 seasonal beach profiles and 14 surface maps, as well as 64 sediment samples from multiple cross-shore locations along 13 of the profiles. In addition, 206 beach profiles were collected to coincide with single-beam sonar bathymetric transects collected by USGS and OSU.

At the end of the CRLC survey season, and after spending nearly $9,000 on repairs over the past year with another $3,000 in additional repairs needed, the All-Terrain Vehicle (ATV) used by Ecology was determined to be at the end of its life, and OSU's ATV was used to finish out the seasonal surface maps. **Given the persistent lack of funding, it remains unclear how or if Ecology will be able to continue the tine series of beach surface maps as we have over the past 19 years, and it comes at a time when we should be augmenting our beach monitoring to document the regional response to this year's strong El Niño. There is no known source of funding to repair or replace the ATV.**

In July 2015, CMAP worked with the USGS to collect beach and nearshore profiles at the Elwha River mouth, documenting additional accumulation of sediment in the nearshore as well as changes to the drainage channels. The survey area was expanded to the west to Freshwater Bay and the east to Ediz Hook in order to capture change throughout the drift cell. In June and October 2015, as part of data collected for the USACE, CMAP performed two additional monitoring surveys of part of the Elwha drift cell, collecting multibeam, boat-based lidar, and beach topography data from Angeles Point to the tip of Ediz Hook. The data will aid the USACE in developing a sediment transport model for the area.

CMAP had a very busy survey season collecting boat-based lidar around the Puget Sound for baseline mapping of feeder bluffs and associated drift cells. Sites include portions of shoreline of Whidbey Island,

Guemes Island, Camano Island, Dabob Bay, Point Whitehorn/Cherry Point, Point Roberts, Dungeness, and Maury Island. In addition, a third survey to monitor the USACE Shoalwater protective berm near Tokeland was performed in August 2015.

G. Kaminsky presented Ocean Shores and Westport beach profile and surface map data and an overview of coastal erosion issues at a Science Forum on Changing Coastlines presented by the Grays Harbor Marine Resources Committee on November 17, 2015. **The talk highlighted the beach monitoring program and the coastal management challenges associated coastal erosion and illustrated how trends and fluctuations shown by the time series can be used for better decision-making.**

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, with surveys of beach observation sites having been undertaken in August/September 2015 (Rockaway cell (25 sites), along the Clatsop Plains (6 sites), and in the Neskowin cell (15 sites)). During this period, DOGAMI staff also worked with PI Ruggiero and students to collect bathymetric surveys along the Rockaway littoral cell.

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.

Due to the current phase of mild weather conditions and a lack of significant storms in the past four years, many of the Oregon beach study sites exhibited a general trend toward accretion. Erosion issues that had plagued a number of sites in the past, for now remain stable. **However, the fully developed 2015/16 El Niño is now materializing and the OBSMAP network is in a good position to document its effects on selected beach sites along the Oregon coast; strong El Niño's typically produce elevated water levels and above normal waves that are conducive to increased beach erosion.** Ocean water levels along the PNW coast are currently well above (>25 cm) typical seasonal levels for this time of year and recent storms (post Nov 30th reporting period) suggest the potential for significant erosion. Results from the Fall monitoring period (now underway) will be provided in the next reporting period.

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. However, as stated in previous reports, problems with aging infrastructure remain an ongoing area of concern.

Nearshore Bathymetry: During summer 2015, P. Ruggiero's group at Oregon State University collected nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC). Over 220 individual cross-shore profiles were collected 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 PI Kaminsky's group at Ecology developing complete maps of the nearshore planform. **These nearshore bathymetric data continue to provide a critical source of information for improving coastal hazard mitigation along the coastlines of the CRLC.**

Also, in summer 2015 Ruggiero's group also collected 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.**

The PWC-based nearshore surveying system used by Ruggiero's group is now over 8 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 using our newly approved FCC frequency in the 12-13MHz range to provide better spectrum separation for our YHS, WLD and WSH systems. We greatly improved performance of our Yaquina Head long-range site (YHL). The performance had degraded over time, with decreased range and increasing reflected power. The problem was finally solved (after much diagnostic work) by replacing the transmit cable. Range has now increased dramatically and reflected power is reduced. As previously reported, our site at Winchester Bay was rendered inoperative by a severe winter storm, which eroded the access road and tore up the utility company's buried power line. In August, line repairs were completed under direction (and funding) of the US Coast Guard, and we have been able to restart WIN during this operating period. A break-in at Loomis Lake, WA (LOO) was interrupted by our alarm system, but not before substantial damage had been done to the shelter. A new, sturdier wooden shelter was designed, constructed, and installed by HF tech Erik Arnesen, and this site was returned to operation. However, on Oct 29 LOO's equipment was loaned to WIN and YHL while the equipment from those sites was sent to CODAR for repair.

We continue scientific collaborations with several groups. We published an updated paper testing the skill of physical and biological indices of the year-class strength of green crabs, an invasive species to Oregon waters (Yamada, Peterson, and Kosro, 2015). Our HF data continue to be used to guide a regional data-assimilating predictive model by Alex Kurapov's group. **We contributed to a recent paper in Nature Scientific Reports (Mazzini, et al, 2015) which used HF, NH10, and other data to describe the buoyancy current fed by rivers along the Oregon coast.** Scott Durski led a manuscript published in Ocean Dynamics (Durski et al, 2015) on modeling and remote sensing of the winter circulation off Oregon, and the influence of the 2009-10 El Niño; HF data served as ground truth for the model, which in this case did NOT assimilate data, to keep the model forcings physical and well understood.

In outreach, Kosro gave an invited presentation at the State of the Coast conference on Oct 24 in Coos Bay, on the anomalous conditions in the Pacific Northwest waters, including “the Blob” and El Niño.

Port X-band Radar: Led by M. Haller (OSU), wave imaging radar operations continue at both the Yaquina Bay Inlet (Newport South Jetty) station and the temporary station at the Columbia River mouth (Cape Disappointment station), with some hardware-related interruptions and degradations.

We would like to highlight some exciting news in regards to the Newport radar station. As a follow-up to the two-day technical training course we delivered at the NOAA Office of Coast Survey (May, 2015), **the Coast Survey is now supporting the transfer of our radar at the South Jetty to the top of the US Coast Guard observing tower** on the north side of the inlet to the Yaquina (see picture below). Lieutenant Commander Samuel Greenaway is the new Chief of the Hydrographic Systems and Technology Branch and we met with him and Chief Warrant Officer Ryan O’Meara (USCG, Yaquina Station) on December 14, 2015 to scope out the engineering work required to move the station and setup communications (see picture below). We are very excited by this opportunity; the new location on top of the USCG tower will provide a significant increase in elevation, which will substantially increase the footprint and quality of the radar observations. **We have also committed to working with the Coast Survey on an existing SBIR project they have that is developing radar-based, real-time bathymetric products for navigational inlets.** This new collaboration is expected to begin soon after the first of the year.

Picture caption: (left) M. Haller with DCC Matthew Piper (USCG) and LCDR Sam Greenaway (NOAA) atop the USCG Yaquina Bay observation tower. (right) USCG observation tower from ground level.

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. Routines for pre- and post-assimilation quality control have been established, along with new online tools (http:// http://ingria.coas.oregonstate.edu/rtdavow/, L. Erofeeva, OSU).

During the report period, we continued to support the data assimilative version of the 3-km resolution OR model (41-47N), with results posted online. **At the same time we continued testing new model configuration (OR-WA model, with data assimilation) that has the domain extended to 41-50N (including both OR and WA shelves), improved resolution (2-km), river discharges included (Columbia, Fraser, Puget Sound sources), and tides.** We recently submitted the outputs from this new model to NANOOS NVS (in collaboration with C. Risien). The old OR model will be decommissioned, replaced by the OR-WA system.

As a companion effort, OSU PhD student I. Pasmans has continued tests of a hybrid ensemble-variational data assimilation method, applied to the OR-WA model. In this method, the initial condition error covariance is computed using an ensemble of model forecasts. This project has been transitioned to the XCEDE supercomputer, to speed up analyses and computations. Steps have been made toward assimilating glider T and S data.

Methods for accurate model set-ups and data assimilation are being transferred to NOAA NOS, where we contribute to development of the West Coast Ocean Forecast System (WCOFS).

Estuaries

Puget Sound:

NANOOS PI P. MacCready (UW School of Oceanography), working with Drs. Banas, Siedlecki, and McCabe (UW Joint Institute for the Study of Atmosphere and Ocean), have created a pre-operational forecast model, called *LiveOcean*, of ocean circulation in Puget Sound and adjacent waters. In the past six months the team used NANOOS support to integrate the forecast model output into the NANOOS NVS data portal, including automated comparisons with in situ observations. **The team also worked to improve the model predictions of carbon chemistry required for calculating pH and aragonite saturation State.** 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), greatly accelerating the work and leveraging the impact of NANOOS funds. During this past 6 months in addition to the model development MacCready and Siedlecki gave a total of 7 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 (Baptista et al. 2015a). Two recent peer-reviewed papers (Karna et al. 2015; Karna and

Baptista 2015) report on rigorous benchmarking of the circulation model, and offer insights into current capabilities, limitations and opportunities for further progress, as discussed in (Baptista et al. 2015c). An inter-comparison with a NANOOS ROMS circulation modeling in the shelf, with added synergies between the two efforts, is being conducted (Morrice et al. 2015a,b). Modeling of water age (Karna and Baptista 2015b), sediment (Lopez et al. 2015) and biogeochemical (Llebott et al. 2015a,b; Cervantes et al. 2015a,b) dynamics in the estuary have also progressed considerably.

As described in an earlier NANOOS progress report, recent 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 (Seaton et al. 2015b), are being exported internationally, via the Our Global estuary initiative (Baptista et al. 2015b; Seaton et al. 2015a).

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) monthly NANOOS DMAC technical calls; 3) GOA-ON Data Portal Meeting (Jun 1-2, Monaco); 4) annual NANOOS Governing Council & P.I. meetings (Aug 20-21); 5) QA/QC workshop at CERF (Nov 8, Portland); 6) NANOOS DMAC mini-hackathon meeting (Nov 13); and 7) MEOPAR Ocean Data Management Forum (Nov 18-19, Montreal).

*The **NANOOS Visualization System (NVS)*** was upgraded to versions 4.0 (Jul) and 4.1 (Nov), adding an overhauled timeline control and a dynamic plotter integrated with the timeline; **these enhancements remove important barriers for the display of long time series and enable more consistent control of site-based (including site forecasts) and overlay time series.** NVS enhancements also encompass asset additions and continuous updates: 1) new or newly incorporated near-real-time in-situ monitoring assets (a new, seasonal network of water temperature and salinity and air temperature sensors at 15 sites in Puget Sound, from the WA Dept. of Health; a new site on a shellfish growing area at Quilcene Bay, WA; and PMEL pH and salinity data on the NDBC Cape Elizabeth buoy); 2) the UW "LiveOcean" ROMS model forecast for WA and surrounding waters, with overlays at many depths; 3) updated and in some cases expanded the spatial extent of monthly anomalies for all climatology/anomaly overlay assets; and 4) many redeployments and smaller upgrades, including restored or expanded sensors. In addition, the data harvesters for King County and a new ORCA profiling system were overhauled.

NANOOS and IOOS DMAC system implementation. 1) **NANOOS made great strides in handling glider data for submission to the Glider DAC and internal use in user products.** CMOP-OHSU (C. Seaton, R. Senior) submitted a five-year (2009-2013) glider archive to the Glider DAC and is now ready to submit trajectories in near-real-time once their Slocum glider is redeployed. APL-UW has been processing Seaglider data (La Push transect) and developing the code to submit previous and ongoing trajectories to the Glider DAC. 2) CMOP-OHSU, OSU and APL-UW have worked together to develop the necessary components for handling long time series of station data for user-product incorporation, web-service

delivery, and archiving with NCEI. We have been designing and testing implementations of the NODC netcdf templates to support these goals, and are engaging NCEI's Matt Biddle to design a NANOOS workflow for NCEI archiving starting with CMOP-OHSU data. 3) APL-UW enhanced and expanded its data submission to NDBC. 4) E. Mayorga supported QARTOD efforts, serving as co-editor for the Dissolved Nutrients manual released this Fall, presenting on QARTOD activities at a CERF workshop in Nov. (Mayorga & Bushnell, 2015), and serving on the IOOS DMAC QARTOD Working Group. 5) NANOOS contributed to IOOS DMAC community implementation and engagement activities, including an active role in multiple issues discussed in the ioos-tech list and IOOS Github repositories; NERRS-handling code improvements submitted to the pyoos repository; contribution to an IOOS DMAC MTS'15 paper (Snowden et al. 2015); contribution to ERDDAP documentation on password-protected web service access; and participation in the MEOPAR Data Management forum as an invited speaker (Mayorga 2015).

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. He also supported WA marine spatial planning data efforts via a monitoring asset inventory and advisory assistance.

Ocean Acidification (OA) Data. NANOOS continued its support for multiple efforts involving OA data. In the Pacific NW, it expanded the coverage of OA-relevant assets (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. **IPACOA data ingest was significantly expanded by the inclusion of 15 OA-relevant NERRS water quality sites using the pyoos NERRS collector as enhanced by NANOOS; by the extension of all PMEL data streams to the start of each time series; and the inclusion of a remote-sensing based SST climatology/anomaly overlay from NANOOS.** Globally, E. Mayorga attended the GOA-ON (Global OA Observation Network) Data Portal meeting (June 1-2, Monaco) and supported ongoing discussions regarding a GOA-ON data portal; contributed to the publication of a community paper on OA data management strategies (Garcia et al. 2015); and initiated a collaboration (see https://github.com/ioos/conda-recipes/pull/563) to support and enhance the use of the “mocsy” carbonate-system library via the IOOS conda recipes Python repository.

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 Boeing, 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) Updated analyses of wave buoy and tide data in situ assets that has

allowed for the inclusion of National Ocean Service (NOS) tide gauge data and Coastal Data Information Program (CDIP) wave buoy data in 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 July 22nd, **NANOOS released NVS v4**. This updated version of NVS reflected the implementation of an entirely new NVS timeline capability (Figure 7). Developed by NANOOS web designer Troy Tanner and Robert Carr, the new timeline uses the HTML canvas element to display both the timeline and the plots. This new approach allows the timeline to greatly expand its' maximum range, from ~90 days to over 40 years. Users can interactively pan and zoom the timeline to view desired ranges. By default, when a variable is selected in the info window, the timeline automatically resizes to fit the entire data range in the viewable area. Users can also move the mouse over the plot to see readouts of time and values (Figure 7. Included in this release are new UI controls for depicting measurements at multiple depths.

NVS v 4.1 was released on November 5th and continued the enhancements to the timeline capability. This release included UI controls for users accessing the forecast and comparator tools within NVS. Previous versions relied on static plots, which have now been superseded by a fully interactive plotting environment.

Updates to the NVS Climatology web app continued throughout this period with the addition of over a dozen new assets and updates to the overlays. During this period, Allan (UPC Chair) and Risien (OSU) implemented the following:

- Climatologies derived for National Ocean Service (NOS) tide gauge stations (9 sites) established along the Oregon/Washington open coast, and within the Puget Sound Region were added;
- Climatologies derived for Coastal Data Information Program (CDIP) wave buoys (7 sites) located offshore the NANOOS region were added; and,
- Updated ocean and atmospheric overlays that included AVISO, MODIS and NARR datasets.

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).

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 have continued to focus on building and sustaining connections with Pacific Northwest educators and partnering with local and regional science and marine science education efforts.

Figure 7: showing the recently released NVS v4.1 that now includes an upgraded timeline, enabling users to visualize longer time series as well as the actual measured values in the timeline.

- 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. The program, in its 2nd 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. The school was recently awarded grant funds to support to bring every 7th grader on a day-long educational/research cruise out on Puget Sound and Sprenger will be helping coordinate the science activities for that 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 fourth year this past summer, Sprenger partnered 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 are incorporating their data into the year-long investigation. In addition, a summer camp run by staff from a local marine science education nonprofit, Salish Sea Expeditions, was able to work with prenger to 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.
- A few science programs in the Northwest that have independently begun similar student-led buoy/sensor platforms research projects and Sprenger has begun working with them to collect information on their programs and experiences to share with the broader education community.

Sprenger and Rick Baker, partner from Whidbey Watershed Stewards, were recently accepted to present this at the upcoming Ocean Sciences meeting in New Orleans in Feb. 2016.

- **Sprenger co-chaired with WA Sea Grant Education Specialist Maile Sullivan, the summer 2015 NW Aquatic and Marine Educators Summer conference, which was held at UW in Seattle July 20-24 2015 with attendance of 125 informal and formal educators. NANOOS was prominently featured during the conference, with Newton as keynote speaker and Sprenger and Wold presenting posters during poster session.**
- Sprenger and Wold coordinated more than 20 students, educators and other volunteers for the 5-day mooring recovery cruise for the La Push (Chaba and NEMO) buoys in November, making this cruise a highly-successful educational opportunity. Volunteers were quickly immersed in the hands-on oceanography we carry out on these cruises including CTDs, mooring deployments, glider deployments, and seawater sample analysis. Field technicians representing the Quileute Nation 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 *Thompson*, Mickett gave a well-attended overview presentation of the formation and evolution of the "blob", showing moored observations, and also presented a general overview of the mooring system. Finally, we were also able to support an Oregon middle school science project by deploying a small, satellite-tracked sailboat.
- **One of the educators that joined the May 2015 cruise, Ben Ewing from Toledo, OR, incorporated his experiences with the buoy and glider deployment into a very successful classroom STEM project with his middle school students this fall.** Students built their own gliders (using the SeaGlide curriculum), with data provided by the OSU glider group students used an educational GIS program to plot the track of a glider off the Oregon coast and used excel to plot and analyze profile data. As culmination, students presented their work to the local town council.

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.

- **On 29 July, Newton gave a radio interview on KOMO regarding the warm Pacific Ocean temperature anomaly, the blob.** The interview is at our website on the Tracking the Blob slide. The following day was "Puget Sound Awareness Day" with several contributions to the media from Newton and other NANOOS partners (Ecology, WA DOH, NOAA PMEL, NOAA NWFSC). Newton and NANOOS were featured in several TV, newspaper, and radio pieces.
- On 13 September, NANOOS was invited to participate in Pop-Up Science's Street Smarts Ocean Acidification event on the Seattle-Bainbridge Island ferry. NANOOS and other organizations used games, NVS demos and visual displays to describe ocean acidification and monitoring efforts in local waters.
- Newton participated in a documentary filming about OA with others from NOAA PMEL and UW on 29 September. National Geographic is the sponsor.
- On 16 October, Newton was invited to present "NANOOS: Delivering Observations and Information in the Pacific Northwest" to the 2015 Coastal Marine Resource Committee Summit in La Push, WA.
- **NANOOS provided the "Great Build a Buoy Challenge" activity at the Seattle Aquarium's annual Discover Science Weekend in November. The buoy challenge was again incredibly popular among attendees with non-stop buoying by kids of all ages throughout the weekend.**
- In November, staff from AOOS, SCCOOS, and NANOOS jointly held an exhibit booth at the CERF conference in Portland OR: "West Coast Regional Associations of IOOS", providing information on IOOS and the regional associations to national audience of estuarine and coastal scientists.

- 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.
- 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.

f) NANOOS Administration:

D. Martin (NANOOS Board Chair) and J. Newton (NANOOS Executive Director) 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 during the period. Newton participated in weekly Tri-Comm calls. Key events for this period included:

- Newton and Martin led the annual NANOOS PI meeting and the annual NANOOS Governing Council meeting over August 20-21, 2015. Newton led the PI meeting discussions and Martin served as Chair of the NANOOS Board during the GC meeting.
- Martin and Newton participated in IOOS Association and IOOS Fall meetings on September 14-16, 2015, in Tampa/St. Petersburg, FL that covered a wide range of national and regional IOOS-related issues. Martin was invited to attend the SECORA annual meeting on September 17th and participated in the tribute to Worth Nowlin, an IOOS pioneer.
- On June 2nd, Newton was invited by NWFSC Western Regional Coordinator Timi Vann to meet with National Weather Service Western Region Director Grant Cooper at NOAA PMEL Sand Point. This lead to discussion of synergies between NANOOS and NWS.
- Over June 29-30, Newton accompanied U.S. IOOS Director Zdenka Willis to Victoria, B.C. to visit with Scott McLean, ONC President Kate Moran, and other members of Ocean Networks Canada (ONC). There they discussed joint interests including HF radar installations along the Strait of Juan de Fuca. Following the visit, Newton hosted Zdenka in Seattle on July 1-2, visiting with several NANOOS PIs and partners, including at UW, NOAA PMEL and NOAA NWFSC.
- Newton and Martin used input from the NANOOS Executive Committee to formulate the proposal response to the FFO for 5-y IOOS Regional awards. They held several calls to identify priorities and ratify the budget.
- On 13 August, Newton hosted staffers from the offices of Senator Cantwell, Congressmen McDermott, Heck, and Kilmer onboard the R/V Barnes, visiting a NANOOS buoy and explaining how IOOS is making a difference.
- Newton and Martin met with the Director of the National Centers for Coastal Ocean Science, Mary Erickson, on November 17th, 2015. Newton discussed synergies with HAB modeling, NANOOS capabilities and operations. Martin provided updates on the Applied Physics Laboratory's involvement with IOOS and other scientific/technical efforts.

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. Martin participated in the Annual Site Visit for this effort on June 9th, 2015. 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 student cruises on 13 July and 23 October. A major new initiative within CMOP, directed by Newton, involves the construction and deployment of a sophisticated ocean sensing buoy to be placed in Bellingham Bay, Washington, to provide data via NVS and to be operated by NWIC as a legacy outcome from CMOP. Progress was made on this project, building buoy components, obtaining permits, and involving NWIC students in this work.

Additional coordination included:

- Newton met with Rohinee Paranjpye, NOAA NWFSC, on June 8th to discuss follow-up from the pathogen workshop that NANOOS participated in.
- Newton was invited by the Western Association of Marine Labs (WAML) to attend their annual meeting in Redondo Beach, CA, on 27-28 July and present talks on GOA-ON and IOOS data management.
- Newton coordinated with other West Coast RAs, following the intent of our mutual MOU, as well as several other RAs to optimize and leverage capabilities and assure consistencies. This included: coordination with AOOS, CeNCOOS, SCCOOS and PacIOOS on the IPACOA data portal; participation advising the COMT effort; lead for the Pacific Anomalies Workshop 2 to be held in Seattle on 20-21 January 2016. The workshop is coordinated with and supported by U.S. IOOS, NOAA Climate, WA and CA Sea Grants, and NOAA NWFSC.
- Newton gave a NOAA OAP Data Synthesis Products webinar "IOOS Pacific Region Ocean Acidification Data Portal" on 9 September. The video of the talk is available from the IPACOA slide on the NANOOS website.
- Newton attended and presented at the Eastern Pacific Ocean Confernce in Fallen Leaf Lake, CA, 20-23 September. Her talk, "How the Blob affected Puget Sound" was one of many IOOS contributions, as noted by her and CeNCOOS Director Dave Anderson in a contribution to the IOOS Z-gram.
- Newton was invited by NERRS Program Director Marie Bundy to provide a webinar presentation to NERRS Research Coordinators on OA and IOOS "OA and West Coast Monitoring" on 23 June 2015.
- NANOOS PI Barth and Newton continued to support the West Coast Ocean Acidification and Hypoxia Science Panel (http://calost.org/science-advising/?page=ocean-acidification-and-hypoxia-panel), working on scientific manuscripts and public interest documents regarding west coast US and Canadian OA issues and effects. PI Barth is one of several scientists featured in the recent "Ocean Acidification" video: http://www.oregonocean.info/index.php/ocean-acidification-and-hypoxia.

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

- On June 8th, Martin welcomed the international participants in the annual meeting for the International Arctic Buoy Program (IABP) and briefed them on Applied Physics Laboratory arctic initiatives and the close relationship we have with the Alaskan Regional Association (AOOS).
- From June 23-25, Martin participated in the semi-annual meeting of the Ocean Networks Canada (ONC) International Science Advisory Board (ISAB) that provides guidance and counsel to the Canadian effort to field, evolve and improve two research-focused ocean observatories (VENUS and NEPTUNE Canada) that simultaneously serve emergent operational societal needs. In this context, Martin provides both scientific expertise and as well as serves to communicate the U.S. experience with IOOS and operational ocean observing efforts that are part of the unique hybrid nature of ONC.

- Newton represented IOOS on the Global Ocean Acidification Observing Network Executive Committee calls and activities. This included: invited participation in an OAiRUG meeting 6-7 July 2015 in Paris; giving a GOA-ON-IOOS-NOAA OAP poster "Ocean Acidification: Global Issue, Local Effects: The Global Ocean Acidification Observing Network" at the UNESCO "Our Common Future Under Climate Change" on 9 July; and participation in the GOA-ON Executive Committee meeting in Monaco, 19-20 November.
- Newton, a member of MEOPAR's International Science Advisory Committee, provided input and review support throughout the period. She provided an interview on MEOPAR's OA strategy which was published: http://www.nce-rce.gc.ca/Research-Recherche/Stories-Articles/2015/OceanAcidification-AcidificationOceans_eng.asp

Additional NANOOS coordination:
Newton led two OTT coordination calls for the OA project with AOOS, CeNCOOS, and SCCOOS.
Newton helped coordinate the C-CAN webinar series on OA
Newton participated in three "OA Round Tables" organized by PMEL and NWFSC
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 July and September 2015.

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 one change in key personnel for this period. The Boeing Company, which had been an integral partner in the development of NANOOS' DMAC is no longer involved as of FY15. The fruitful partnership led to many innovations that are now implemented. We appreciate the partnership and Boeing continues to be a NANOOS member and part of our Governing Council.

6) Budget Analysis
With an award start date of 1 June 2011 and end date of 31 May 2016, as of 30 November 2015 we are 90% of the way through the project and 50% through FY15. The full project award amount to date is $13,479,098 and the total amount spent as of 30 November 2015 is $11,013,037 with another $79,117 encumbered. That means that at 90% the project time, 82% of the awarded funds have been spent or encumbered. However, we note that an additional amount has been encumbered since 30 November (first two weeks of December 2015) resulting in 95% of the awarded funds that spent or encumbered. These percentages match well, indicating that spending is commensurate with our plan. We anticipate that NANOOS will maintain its budget accordingly. 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 spend rate for this award are solid and appropriate for this point in the reporting period.** The expenditures to date are suitable for maintaining robust execution of NANOOS plans to meet our objectives.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

Baptista, A.M., 2015. Estuary and plume conditions. The Columbia River Eulachon (smelt): State of the Science and Science to Policy Forum, Portland, OR.

Baptista, A.M., E. Buskey, M. Davis, M. Leinen, V. Subramanian, Y. Spitz, 2015b. Our Global Estuary. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Baptista, A.M., T. Kärnä, J. Lopez, Y.H. Spitz, 2015c. Pushing an estuarine circulation model to the brink: Lessons learned and next steps. Society for Industrial and Applied Mathematics (SIAM) Conference on Mathematical and Computational Issues, Stanford, CA.

Besse, I., V. Green, M. Ward, N. Watts, A.M. Baptista, 2015. The biomathematics workshop: A new model for inter-institutional collaboration and interdisciplinary undergraduate research. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Bos, J., S. Albertson, C. Krembs, S. Pool, C. Falkenhayn Maloy, and B. Sackmann, 2015. Ecosystem Thresholds in Surface Waters of the Salish Sea using Continuous Measurements from Ferry Sensors. Poster presented at Coastal Estuarine and Research Federation 2015 Conference, Portland, OR. Ecology Publication No. 15-03-041. https://fortress.wa.gov/ecy/publications/documents/1503041.pdf

Cervantes, B., Y. Spitz, A.M. Baptista, 2015a. Modeling the formation, retention and ecological impact of *Mesodinium* blooms in the Columbia River estuary. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Cervantes, B., C. LLebot, Y. Spitz, A.M. Baptista, 2015b. Modeling study of the formation and retention of a Mesodinium bloom in the Columbia River estuary. 14th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM). Portland, OR

Herfort, L., B. Crump, C. Fortunato, L.A. McCue, V. Campbell, H. Simon, L. Fine, A.M. Baptista, P. Zuber, 2015. Factors shaping the composition and metabolic activity of Columbia River estuarine turbidity maxima bacterial communities. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Kaminsky G., 2015. Understanding our Dynamic Coastline: How the Past Informs the Present and Future, Changing Shorelines: A Science Forum—Coastal Erosion, Flooding and Sea Level Rise, Grays Harbor Community College, November 17, 2015.

Kärnä, T. and A.M. Baptista, 2015b. Water renewal time scales in the Columbia River estuary. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Kosro, M. Presentation on Pacific Warm Anomalies. State of the Coast conference, Hales Events Center, Southwestern Oregon Community College, Coos Bay, OR, October 24, 2015

Kosro, P.M., C. Risien, J.A. Barth, A. Kurapov, R.K. Shearman, and P.T. Strub, 2015. Arrival of 2014-2015 Warm Anomaly waters off Oregon. PICES Annual Science Meeting, Qingdao, China, October, 2015.

Llebott, C, Y. Spitz and A.M. Baptista, 2015a. Monitoring and modeling the net ecosystem metabolism of the Columbia River estuary. Coastal and Estuarine Research Federation Biennial Conference (CERF 2015), Portland, OR.

Llebot, C., Y. Spitz and A.M. Baptista, 2015b. Unstructured-grid modeling of the biogeochemistry of a complex estuary. 14th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM), Portland, OR.

Lopez, J. and A.M. Baptista, 2015. Sediment model derived estimates of light attenuation in estuarine environments. 14th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM), Portland, OR.

MacCready, P., S. Siedlecki, R. McCabe, N. Banas, 2015. LiveOcean: a daily forecast model of ocean acidification properties for Washington coastal waters. Washington Ocean Acidification Center Symposium, University of Washington, June 26, 2015.

MacCready, P., 2015. The Biggest River in Puget Sound. Pacific Science Center Science Café, Tacoma, WA, July 14, 2015.

MacCready, P., S. Siedlecki, R. McCabe, N. Banas, 2015. The LiveOcean Daily Forecast Model: Thoughts on developing and maintaining complex software systems. Eastern Pacific Ocean Conference, Lake Tahoe, September 23, 2015.

MacCready, P., S. Siedlecki, R. McCabe, N. Banas, 2015. The LiveOcean Daily Forecast Model: Near-term predictions of ocean acidification in Washington waters. Washington Marine Resources Advisory Council Meeting, Pt. Townsend, WA, October 13, 2015.

MacCready, P., 2015. Estuarine Inflow. Coastal and Estuarine Research Federation Conference, Portland, OR, November 10, 2015.

MacCready, P., S. Siedlecki, R. McCabe, N. Banas, 2015. Recent Advances in Modeling Puget Sound & Coastal Waters. University of Washington Water Seminar, 12/1/2015.

Mayorga, E., 2015. US IOOS Regional Data Management: The NANOOS NW Perspective. *MEOPAR Ocean Data Management Expert Forum*, Montreal, Nov 18-19

Mayorga, E. and M. Bushnell, 2015. Quality Assurance/Quality Control of Real-Time Oceanographic Data (QARTOD). *CERF Quality Control and Management of Continuous, High-Frequency, Biogeochemical Sensors Workshop*, Portland, Nov 8

Mickett, J., A. Sutton, W. Ruef, J. Newton, D. Feely, A. Devol, S. Alin, 2015. "Moored Observations of pH and **p**CO_2: An overview and a bit of what have we learned so far." Washington Ocean Acidification Center Science Symposium, June 26, 2015, Seattle, WA.

Mickett, J., J. Newton, A. Devol, C. Krembs and W. Ruef, 2015. "Investigating an extreme high dissolved oxygen and cold water anomaly in a Washington fjord." CERF 2015, Portland, OR, November 2015.

Mickett, J., "An overview of the NANOOS Washington Coast and ORCA mooring systems and highlights of recent observations." R/V *Thomas G. Thompson*, Nov 18, 2015.

Morrice, K., A.M. Baptista, T. Kärnä, J. Lopez, Y. Spitz, P. MacCready, 2015a. Sensitivity of shelf and estuary circulation simulations to atmospheric forcing and ocean boundary conditions. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Morrice, K., A.M. Baptista, T. Kärnä, J. Lopez, Y. Spitz, P. MacCready, 2015b. Sensitivity of shelf and estuary circulation simulations to atmospheric forcing and ocean boundary conditions. 14th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM), Portland, OR.

Needoba, J., C. Seaton and A.M. Baptista, 2015. Time series observations of nearshore water conditions in the Columbia River estuary during the 2014-2015 NE Pacific temperature anomaly. 2015 Pacific Anomalies Science and Technology Workshop, La Jolla, CA.

Newton, J., 2015. OA and West Coast Monitoring. NERRS webinar, 23 June 2015

Newton, J., 2015. Observing ocean acidification in the Pacific Northwest. NAME Conference, Seattle, WA, 23 July 2015

Newton, J., 2015. NANOOS: Delivering observations and information in the Pacific Northwest. 2015 Coastal Marine Resource Committee Summit, La Push, WA, 16 October 2015

Newton, J, J Mickett, A Devol, W Ruef, 2015. How the Blob affected Puget Sound. Eastern Pacific Ocean Conference, 21 September 2015.

Newton, J. 2015. NANOOS and the blob. Puget Sound Partnership Science Panel meeting, Everett, WA, 28 October 2015.

Newton, J, J Mickett, A Devol, W Ruef, 2015. Update from NANOOS and UW-ORCA, Washington Department of Ecology Info-calls, 24 September and 15 October 2015.

Newton, J., L. Jewett, P. Williamson, Z. Willis, R. Feely, and N. Bednarsek. 2015. Ocean Acidification: Global Issue, Local Effects: The Global Ocean Acidification Observing Network. UNESCO Our Common Future Under Climate Change, Paris, France, 9 July 2015

Newton, J. and T. Klinger. 2015. Addressing ocean acidification in Washington State. CERF 2016, Portland, OR, 10 November 2015.

Rostaminia, M., A.M. Baptista, P.J. Turner, J. Lopez, G.R. Priest, D. Bottom, C. Roegner, 2015a. Salmon habitat response to the sea level rise and a large-magnitude subduction earthquake. 14th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM). Portland, OR.

Rostaminia, M., A.M. Baptista, J. Lopez, P.J. Turner, G.C. Roegner, D. Teel, 2015b. Salmon habitat response to sea level rise and seismic subsidence in the Columbia River estuary. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Ruggiero, P. "Envisioning Coastal Futures: Exploring alternative scenarios for Oregon's coastline," Coastal and Estuarine Research Federation 2015, Portland, OR, November 10, 2015.

Ruggiero, P. "The Role of Vegetation in Determining Foredune Morphology, Exposure to Sea Level Rise, and Storm-Induced Coastal Hazards: A US Pacific Northwest Perspective," ASBPA meeting on Dune management challenges on developed coasts, Kitty Hawk, NC, October 27, 2015.

Ruggiero, P. "Envisioning Grays Harbor County Coastal Futures," Coastal Erosion, Flooding, and Sea Level Rise Science Forum, Aberdeen, WA, November 17, 2015.

Seaton, C., P. J. Turner, A.M. Baptista, T. Kärnä, 2015a. The Virtual Columbia River: operational infrastructure for daily forecasting, retrospective analysis, and predictions of change in a complex estuary. 14th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM). Portland, OR.

Seaton, C., P.J. Turner, J. Gonçalo, A. Fortunato, A. Oliveira, A.M. Baptista, 2015b. Operational estuarine modeling: lessons learned from selected US and Portuguese estuaries. Coastal and Estuarine Research Federation Biennial Conference (CERF) 2015, Portland, OR.

Siedlecki, S. Modeling ocean acidification and hypoxia in the coastal ocean. Washington Ocean Acidification Center Symposium, University of Washington, June 26, 2015.

Publications:

Allan, J.C., P. Ruggiero, N. Cohn, G. Garcia, F. O'Brien, K.A. Serafin, L. Stimely, and J.T. Roberts, 2015. Coastal Flood Hazard Study, Lincoln County, OregonRep. Open file report O-15-06, 361 pp, Oregon Department of Geology and Mineral Industries, Portland, Oregon.

Allan, J.C., P. Ruggiero, G. Garcia, F. O'Brien, L. Stimely, and J.T. Roberts, 2015. Coastal Flood Hazard Study, Tillamook County, OregonRep. Special Paper 47, 283 pp, Oregon Department of Geology and Mineral Industries, Portland, Oregon.

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Allan, J.C., P. Ruggiero, G. Garcia, E.L. Harris, J.T. Roberts, and L. Stimely, 2015. Coastal Flood Hazard Study, Clatsop County, OregonRep. Open file report O-15-05, 210 pp, Oregon Department of Geology and Mineral Industries, Portland, Oregon.

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, 2015. Coastal vulnerability across the Pacific dominated by El Niño/Southern Oscillation: *Nature Geoscience*.

Baptista A.M., C. Seaton, M. Wilkin, S. Riseman, J.A. Needoba, D. Maier, P.J. Turner, T. Karna, J.E. Lopez, L. Herfort, V.M. Megler, C. McNeil, B.C. Crump, T.D. Peterson, Y. Spitz, and H.M. Simon, 2015a.

Infrastructure for collaborative science and societal applications in the Columbia River estuary. *Frontiers of Earth Science*. 9(4):659-682.

Barnard, P. et al. (including P. Ruggiero and J. Allan), 2015. Coastal vulnerability across the Pacific dominated by El Niño/Southern Oscillation, *Nature Geosciences*, 10.1038/ngeo2539.

Cornu, C., J. Souder, J. Schmitt, E. Larsen, C. Burch Johnson, C. Duncan, E. Wright, A. Helms, B. Yednock, D. Ivy, H. McDonald, M. Beeken, R. Rimler, J. Bragg, A. Andazola-Ramsey, B. Tanner, D. Swieca, C. Piazzola, C. Duncan, 2015. Communites, Lands, and Waterways Data Source. Partnership for Coastal Watersheds, South Slough National Estuarine Research Reserve, and Coos Watershed Association. Coos Bay, OR. 667 pp.

Durski, S.M., A.L. Kurapov, J.S. Allen, P.M. Kosro, G.D. Egbert, R.K. Shearman, 2015. Coastal ocean variability in the U.S. Pacific Northwest region: seasonal patterns, winter circulation and the influence of the 2009-2010 El Niño. *Ocean Dynamics*, 65: 643-663, doi:10.1007/s10236-015-0891-1.

Garcia, H.E., C. Cosca, A. Kozyr, E. Mayorga, C. Chandler, R.W. Thomas, K. O'Brien, W. Appeltans, S. Hankin, J.A. Newton, A. Gutierrez, J.P. Gattuso, L. Hansson, M. Zweng, and B. Pfeil, 2015. Data management strategy to improve global use of ocean acidification data and information. *Oceanography* 28(2):226–228, doi:oceanog.2015.45.

Herfort, L., C. Seaton, M. Wilkin, B. Roman, C.M. Preston, R. Marin, K. Seitz, M.W. Smith, V. Haynes, C.A. Scholin, A.M. Baptista, and H.M. Simon, 2015. Use of continuous, real-time observations and model simulations to achieve autonomous, adaptive sampling of microbial processes with a robotic sampler. *Limnology* and *Oceanography*: *Methods*. doi:10.1002/lom3.10069.

Kärnä, T., A.M. Baptista, J.E. Lopez, P.J. Turner, C. McNeil, T.B Sanford, 2015. Numerical modeling of circulation in high-energy estuaries: A Columbia River estuary benchmark. Ocean Modelling. 88:54-71.

Kärnä T. and A.M. Baptista, 2015a. Conditionally accepted. Evaluation of a long-term hindcast simulation for the Columbia River estuary. *Ocean Modelling*.

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Sustaining NANOOS, the Pacific Northwest component of the U.S. IOOS®:
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- **Products and Services:**

"The number and brief description of contributions to new or improved regional products or services, and national products or services:"
During 2015, NANOOS offered four new or improved regional products/services.

1. NANOOS Visualization System (http://nvs.nanoos.org/Apps): NANOOS released two updates to the NVS platform, v4.0 and 4.1. In v4.0, the NVS Timeline has been completely overhauled. Developed by NANOOS web designer Troy Tanner and Robert Carr, the new timeline uses the HTML canvas element to display both the timeline and the plots. This new approach allows the timeline to greatly expand its' maximum range, from ~90 days to over 40 years. Users can interactively pan and zoom the timeline to view desired ranges. By default, when a variable is selected in the info window, the timeline automatically resizes to fit the entire data range in the viewable area. Users can also move the mouse over the plot to see readouts of time and values. Included in this release are new UI controls for depicting measurements at multiple depths. In v4.1, the timeline plotting functionality has been expanded to enable users to interact with the forecast and comparator tools within NVS. See our Progress Reports for more information on NVS and its associated apps.
2. Climatology (http://nvs.nanoos.org/Climatology): Since the inception of NVS, NANOOS users have expressed a strong interest in having access to long-term climatology products that characterize the ocean and climate throughout the region. The recently built NVS Climatology web app addresses this need. This new product provides access to conditions of our region's ocean environment measured on any one particular day relative to conditions measured in the recent past, as well as with respect to their seasonal to interannual variability, and in terms of their extremes.

In 2015, the Climatology web app has been expanded to include National Ocean Service (NOS) tide gauges located along the PNW coasts of Oregon and Washington, as well as gages in Puget Sound. A total of nine gages were analyzed and climatologies developed. In addition to the tide gages, analyses and climatologies were also completed for seven Coastal Data Information Program (CDIP) wave buoys.

3. In 2015, continued efforts were directed at improving the overall NANOOS web experience (http://www.nanoos.org/products/products.php). The products page was restructured and a more refined search tool for those looking for coastal and ocean data was introduced.
4. A new NVS help video has been completed, which provides a general overview of the NVS platform and its associated web applications. Additional more focused training videos are currently under development.

- **Data Management:**

"A) Progress towards a standards-based foundation for DMAC capabilities; B) Demonstrated progress towards: a) open data sharing; b) provision of data to WMO GTS; c) implementation of a service-oriented architecture; d) use of common vocabularies and identifiers; e) improved use of metadata conventions; and f) data storage and archiving; C) On-going program-level participation in data management planning and coordination."

During 2015, NANOOS made steady progress towards a standards-based foundation for its DMAC capabilities. Its DMAC compliant web services were enhanced, specifically: registration and subsequent enhancement of the THREDDS service for CMOP-OHSU irregular-grid SELFE model output (C. Seaton), and incremental enhancements to the IOOS 52North SOS server. NANOOS made great strides in

handling glider data for submission to the Glider DAC and internal use in user products. CMOP-OHSU (C. Seaton, R. Senior) submitted a five-year (2009-2013) glider archive to the Glider DAC and is now ready to submit trajectories in near-real-time once their Slocum glider is redeployed. APL-UW has been processing Seaglider data (La Push transect) and developing the code to submit previous and ongoing trajectories to the Glider DAC (current and recent trajectories are submitted to NDBC). We are working with the NANOOS OSU glider operator to inventory, re-process and submit previous deployments. NANOOS also enhanced the submission of data from many of its IOOS-supported observing assets to NDBC, for redistribution to the WMO GTS.

CMOP-OHSU, OSU and APL-UW worked together to develop the necessary components for handling long time series of station data for user-product incorporation, web-service delivery, and archiving with NCEI. We have been designing and testing implementations of the NODC netcdf templates to support these goals, and are engaging NCEI's Matt Biddle to design a NANOOS workflow for NCEI archiving starting with CMOP-OHSU data. NVS now has the capability to display long time series of in situ data through a user-friendly, dynamic plotter.

In addition to improved data and metadata availability via services and service and dataset registration with the IOOS Catalog, NANOOS continued to contribute to the distributed metadata cataloging efforts of the West Coast Governors Alliance on Ocean Health's (WCGA) Ocean Data Network (WCODN) initiative. Through that initiative, in early 2015 NANOOS provided a key fix for a long-standing bug that prevented proper handling of ISO 19115-2 metadata records in the WCODP Catalog, opening the door for metadata registration for ocean data from West Coast RA's. He also supported discussions between the West Coast Ocean Data Portal catalog (WCODP, http://portal.westcoastoceans.org) team and CeNCOOS and SCCOOS to establish best practices and facilitate the registration of their metadata.

NANOOS continued its strong commitment to open data sharing and making regional community observing assets more widely discoverable and accessible both to online users (via user products, specially NVS) and via programmatic, standards-based access. We continually engage the Pacific NW community to leverage NANOOS capabilities and community interest to integrate locally based monitoring assets (from state, local and tribal agencies; private industry; academia; and multi-stakeholder partnerships) into the NANOOS DMAC system, after which these previously inaccessible data streams become discoverable and available nationally. These efforts are reflected in the ongoing expansion of community observing assets served by NANOOS.

NANOOS also supported IOOS data management planning, coordination, and capabilities. E. Mayorga supported QARTOD efforts, serving as co-editor for the Dissolved Nutrients manual released this Fall, presenting on QARTOD activities at a CERF workshop in Nov., and serving on the IOOS DMAC QARTOD Working Group. Other NANOOS DMAC team members also participated in QARTOD implementation conference calls early in the year.

We also continued our contributions to IOOS DMAC community implementation activities, including an active role in the IOOS Github repositories and ioos-tech mailing list, and collaborative development and dissemination of Python solutions and tools for convenient IOOS data access. These contributions included discussions on the assessment of duplicate datasets and handling of WMO ID's in the IOOS Catalog; the use and documentation of controlled vocabularies and semantic searching; NERRS-handling code improvements submitted to the pyoos repository; contribution to an IOOS DMAC MTS'15 paper led by D. Snowden (IOOS P.O.); and contribution to ERDDAP documentation on password-protected web service access. Finally, NANOOS engaged the broader community: E. Mayorga presented IOOS DMAC architecture and practices at an RDA-DataONE Semantic Metadata workshop (Feb) and an NSF EarthCube technical meeting (Apr), while C. Risien continued to serve as an interface with the OOI Endurance Array team via his dual funding support from NANOOS and OOI. In November, E. Mayorga also participated in the MEOPAR Ocean Data Management Expert Forum as an invited speaker, together with D. Snowden.

- **Observing Assets:**

"Current inventory of all regional observing assets:"

A live, dynamic, up-to-date inventory of NANOOS-integrated observing assets, both those funded by NANOOS and those funded by other parties but served through our system, is part of NVS. It is accessed from the "Asset List" section in the NVS Data Explorer at, http://nvs.nanoos.org/Explorer?section=Asset%20List. This list is pulled live from the NVS database. It currently shows a subset of all the metadata information found on the NVS database, but the downloadable csv file ("Download Asset List" button) includes attributes not shown online, such as latitude & longitude. Note the sorting and filtering functionality, and the "History" column on the right which displays complete asset status history via the "Show" link. Asset offline status is indicated by a grayed-out asset icon on the left. The same inventory is also available for download as a simple link under *About NANOOS > Documents > Key Documents* (http://www.nanoos.org/about_nanoos/documents.php), as "NANOOS Asset List" (direct link: http://nvs.nanoos.org/services/download_asset_list.php). A complete history of asset updates is available via the NVS Asset History Web App at http://nvs.nanoos.org/AssetHistory, as well as via the History tab on an individual asset's pop-up window on NVS.

These inventories include *in situ,* remote sensing and model assets.

Fixed-location *in-situ* observing assets from this inventory are also available programmatically via the NANOOS/NVS 52North SOS service accessible from the IOOS Catalog at http://catalog.ioos.us/services/filter/NANOOS/SOS.

Finally, custom, lightweight JSON web services available from NVS also provide asset inventory and history information; these web services will be fully documented in the near future via the NANOOS Portal.

"A list of 'platforms of opportunity' that are being used to support monitoring of ocean acidification:"

NANOOS has compiled and continuously updates an inventory of Pacific NW telemetry-enabled assets directly relevant for ocean acidification monitoring. Near-real-time (NRT) data streams from most of these are already ingested into NVS, and most are available also on the new NVS Shellfish Growers Web App (http://nvs.nanoos.org/ShellfishGrowers).

The set of directly OA-relevant assets is accessible from the NVS Data Explorer (http://nvs.nanoos.org/Explorer) by clicking on Filters, then scrolling down and selecting pH/pCO_2 under "Variables". Current operational status is indicated via status colored icons, asset marker gray-out, and the asset status information. Additional information on OA monitoring in the Pacific NW is available from the NANOOS Ocean Acidification Theme Page, at http://www.nanoos.org/education/learning_tools/oa/ocean_acidification.php

During the past year for the supplemental report, new or significantly enhanced OA assets include:

4. Quilcene — New shellfish-growers monitoring site (September)
5. ORCA Carr Inlet — New near-surface pH sensor (April)
6. Cha'ba — New mid-water-column pH sensor (June)
7. Whiskey Creek — Reactivated NRT ingest via new email delivery (April)
8. NDBC Cape Elizabeth — ingestion of PMEL pH data (August)
9. LiveOcean model — New UW ROMS model for WA waters (July). Developed with support for OA biogeochemistry, OA variables will be available in 2016.
10. WA Dept. of Health — New seasonal network of 15 air and water temperature and salinity sites in shellfish harvesting areas in Puget Sound (July). While these sites do not include OA sensors per se,

they directly support the regulatory and resource management needs of the shellfish growing and harvesting community that is also concerned with OA monitoring.

NANOOS supports the IOOS Pacific Region Ocean Acidification (IPACOA) data portal which serves OA data streams throughout the Pacific Ocean Basin (http://www.ipacoa.org). This portal serves OA relevant data from regional IOOS observing systems in Alaska (AOOS), Washington and Oregon (NANOOS), Central and Northern California (CeNCOOS), Southern California (SCCOOS), and the Pacific Islands (PacIOOS) as well as NOAA's Ocean Acidification Program (OAP) via the Pacific Marine Environmental Laboratory (PMEL) and the NOAA National Estuarine Research Reserve System (NERRS) network (water quality sites with pH sensors).

In addition to ongoing support for Burkolator data streams from shellfish grower sites, in Nov. 2015 NANOOS integrated NERRS sites and extended OAP/PMEL data streams to the beginning of each multi-year time series. We will begin to integrate additional OA-relevant data streams from each RA in early 2016 and expand coverage throughout the year.