Sustaining NANOOS, the Pacific Northwest component of the U.S. IOOS®:
NOAA Award: NA11NOS0120036 Reporting period: 06/01/2014 to 11/30/2014

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 FY14 period (= Y4 of award; Y8 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 FY14 de-scope letter from the IOOS Program Office, NANOOS has the following additional tasks during FY14:
10) Enhance our level of HF radar operation and maintenance for existing stations in Oregon, consistent with the IOOS Program Office and HF Radar Plan directives [M. Kosro, OSU, see p. 17-18];
11) 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.

2) Progress and Accomplishments

During the project period, NANOOS accomplished or made substantial progress on all 15 of the 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 allows.

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 14*:

Area	**Y4 Award = Y8 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) -Transition Newport, OR glider to Crescent City, CA, if the NSF-funded OOI Newport glider is on-line. (In process, *see p. 5 for update*)
Estuaries:	-Maintain Puget Sound, Columbia R., Willapa and South Slough moorings 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/WAestuaries and coast models	-Maintain modeling & forecasting capabilities at OSU, OHSU, & UW at reduced level and make model output available via the NANOOS web (on-going) -Transition Salish Sea model to operations (In process, *see p. 19 for update)*
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, NFRA, and national meetings of significance (e.g., MTS/IEEE, Ocean Sciences) (met for FY14 and on-going) -Support post IOOS Summit activities (done) -Support Marine Sensor Innovation (done)
Project oversight	-Conduct regular PI meetings, annual Tri-Committee meeting, and assist with evaluations, as scheduled (met for FY14 and on-going) -Assess whether focus on hypoxia, HABs, OA, biodiversity investments are providing enhanced and valuable information (met for FY14 and on-going)
Coordination	-Conduct annual Governing Council (GC) meeting (met and on-going) -Conduct sub-regional, and user-group specific workshops (e.g., for CMSP; ocean acidification, etc) 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 (met for FY14 and on-going)

a) NANOOS Observing Sub-system: Data from all assets reported here are served via NANOOS NVS. We note the National Science Foundation's (NSF's) Ocean Observing Initiative (OOI) plans for gliders and buoys within the NANOOS region. In this report, we mention these additions and how NANOOS's observing effort is adapting to design an optimal and integrated observing system for the region.

- ***Shelf***

Washington Shelf Buoy:

Now led by J. Mickett, Applied Physics Laboratory, University of Washington (APL-UW), due to co-PI M. Alford's move to Scripps Institute of Oceanography, over this period NANOOS funding was used primarily for field operations and costs related to the deployment and recovery of the Cha'Ba surface and NEMO subsurface mooring components of this array. Both moorings and the NANOOS Seaglider were successfully deployed in late June from APL's R/V *Robertson*. The moorings were recovered from the University of Washington's R/V *T. G. Thompson* on October 24th, through State of Washington funded student ship time on a cruise involving undergraduate and graduate students. The Seaglider remains deployed with an expected recovery time of late-March/early-April, when we expect to re-deploy the moorings. This summer's mooring deployments were the most successful to date in terms of both the availability of near real-time data and the amount of data collected. In particular, the subsurface mooring performed exceptionally well, providing near full-depth profiles of water properties every three hours from deployment until late September, when the batteries on the telemetry system were depleted. These NRT data, which were available on NVS, were invaluable for monitoring changes in dissolved oxygen on the shelf over the summer. In total, nearly 2000 profiles were collected over the deployment (Figure 1). Leveraging support from an ONR project to study internal waves on the Washington Shelf (Alford, Mickett) for this deployment Cha'ba was instrumented with 42 additional temperature sensors, with vertical spacing of 1-4 meters. In addition to capturing many internal wave events, this unprecedented time series captured a rapid warming of the water column in late September and again in late October, that was associated with the relaxation of upwelling winds and the onshore movement of the so-called Pacific "blob" of anomalously warm sea temperatures.

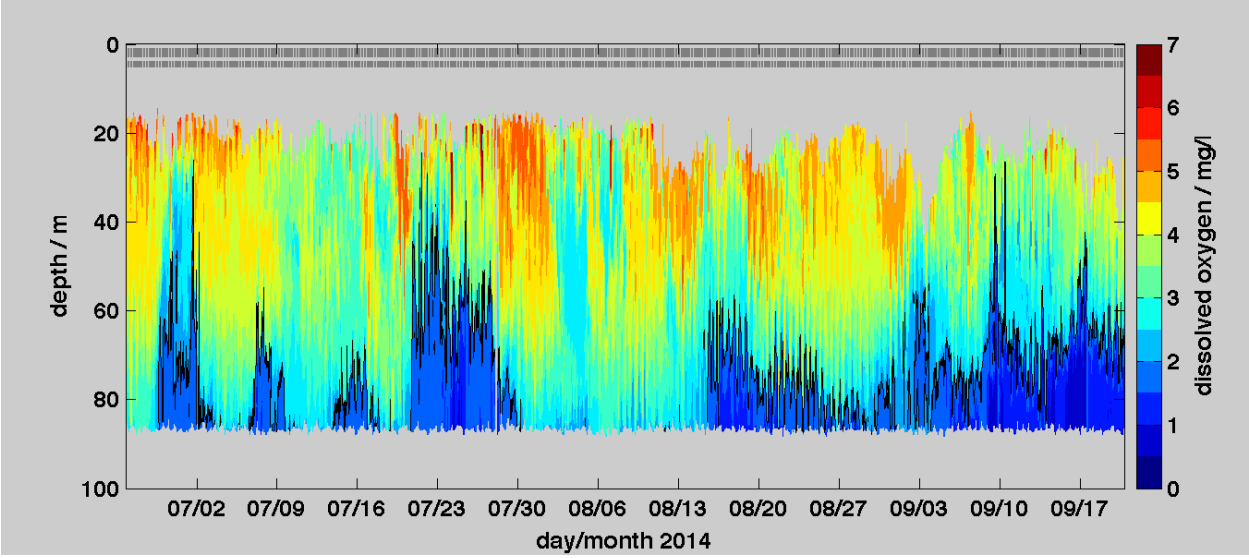

Figure 1: Contour plot of a subset of the ~2000 dissolved oxygen profiles provided to NANOOS NVS in near-real time by the NEMO-subsurface mooring off La Push, WA, during the summer 2014 deployment.

The fall recovery cruise on the R/V *Thompson* was possible because of the generous donation of state-funded ship days by the UW School of Oceanography. As part of this combined educational and mooring cruise, PIs Newton and Mickett along with Chief Scientist Dr. Jody Deming provided instruction to a dozen Astrobiology graduate students on oceanographic data collection methods and observations and involved students from two undergraduate courses.

Again the PIs collaborated with the NOAA Olympic Coast National Marine Sanctuary (OCNMS) to deploy 9 temperature sensors on 5 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. As extended offshore tests were critical to development of this system, Cha'Ba provided a perfect platform for this work.

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 initiated work with the PMEL Carbon Group to test pH proxies on the Washington Shelf.

Also using primarily Cha'ba data, graduate student Shuang Zhang and co-authors Alford and Mickett submitted a paper to JGR entitled ``Characteristics of Nonlinear Internal Waves on the Washington Continental Shelf." S. Zhang, who has primarily used Cha'ba data for her thesis on non-linear internal waves on the Washington Shelf, has a PhD defense date scheduled for December 11, 2014.

Washington Shelf Glider: The Applied Physics Laboratory, University of Washington, Integrative Observational Platforms group led by C. Lee (APL-UW) launched Seaglider 187 on 25 June, 2014. At the

time of this report, SG187 has collected over 1440 profiles (720 dives) and continues sampling on a mission that has a projected end date of late April, 2015 (for approximately ten months of continuous operations).

Oregon Shelf Glider: During June through November 2014, the Oregon State University glider group led by J. Barth and K. Shearman conducted sampling using underwater gliders off Newport, Oregon. The Newport Hydrographic (NH) Line was sampled using a 1000-m Seaglider on the offshore part of the line and a 200-m Slocum glider on the inshore part of the line. We collected a total of 211 glider-days of measurements along 4232 km of track. This included 10,910 vertical profiles and 39 cross-margin vertical sections. The central Oregon glider data are being shared with NANOOS modeler Dr. Alexander Kurapov to 1) investigate the influence of the Columbia River plume on upwelling off central Oregon (Kurapov et al., 2013) and 2) incorporate glider data into the data-assimilative modeling forecast system for the NANOOS region. The glider data will be useful in assessing the influence of unusually warm waters off the Pacific Northwest during summer-fall 2014.

The transition of glider operations on the Newport Line to being operated by NSF's Ocean Observatories Initiative (OOI) started in October 2014. Data from the OOI gliders will soon be made publicly available after an initial verification period.

PI Barth is collaborating with Dr. Eric Bjorkstedt (NOAA Southwest Fisheries Science Center, Humboldt State University) to obtain glider observations off Trinidad Head, CA (41° 3.5'N). In late November, 2014, a 1000-m Seaglider was deployed off Coos Bay, OR, for transit to the Trinidad Head, CA, line where sampling will begin in December 2014. This effort is jointly funded by NANOOS, CeNCOOS, and SWFSC for FY14.

Oregon Shelf Mooring: Led by M. Kosro (OSU), 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. Ship time to enable the mooring recoveries and deployments has been funded by the NSF CMOP Science & Technology Center.

The successful fall 2014 recovery of the NH-10 and pCO_2 moorings was accelerated by two weeks, and our redeployment postponed slightly, easing logistics for the Oceans Observatory Initiative (OOI), which is starting operations along the Newport Hydrographic Line. The redeployment was the culmination of months of design and construction work to build a combined physical oceanography and CO_2 mooring, and reduce the mooring's vulnerability to movement in wintertime high waves. NANOOS PI Burke Hales did a great job of leading the re-engineering effort, with a team of OSU techs (Russell, Simpkins, Langner, Hubbard, Arnesen). A shortage of time for long-term testing was felt in some intermittent or non-working real-time components, and a strong buoy tilt, but these are seen as teething pains. The buoy is reporting wind speed, incoming solar radiation, pCO_2, surface T and S, ADCP velocity profiles, etc. in near-real time. Spring recovery/turnaround is scheduled for March 2015 on the R/V *Oceanus*.

For the fall 2014 deployment, 3 T-sensors with pressure were purchased to allow depth monitoring along the looser tether which resulted from adding scope to the mooring in pursuit of weather hardening. We also contracted with Andrew Hamilton, expert in the buoy-dynamics program WHOI Cable, to run simulations for our buoy re-design.

Ship time for the fall 2014 early recovery was provided by OOI, and for the re-deployment by CMOP, which has provided ship time for all other NANOOS NH-10 mooring work. With the planned wind-down

of the CMOP program after fall 2015, continued Oregon mooring work in NANOOS will require new funds for shiptime, use of a NOAA ship, or other option.

Kosro is examining the raw data from the preceding NANOOS deployments, with a goal of producing a quality-controlled data set. Subsets of the real-time data are available via the NANOOS Visualization System (http://www.nanoos.org) and as buoy 46094 at the National Data Buoy Center (http://www.ndbc.noaa.gov/station_page.php?station=46094).

B. Hales leads the pCO_2 measurements from the NH-10 buoy for NOAA OAP-IOOS Ocean Acidification Monitoring in Cascadian Coastal Waters. Work on this component centered on development of the new winter-worthy MAPCO2-capable 'NewH10' mooring (Figure 2). This mooring (Figure 2) was engineered and fabricated at the CEOAS machine shop, and deployed in October, 2014. The mooring employs a syntactic foam flotation element, reverse-catenary tether with shock-absorbing snubber design, heavy anchor (anchor weight = 3x buoy flotation), and a tapered subsurface profile to dissipate wave energy. It incorporates the historical hydrographic and meteorological capabilities of previous NH-10 moorings, specifically, thermistor array on the tether, CTD and ADCP on the mooring bridle, meteorological sensor array and cellular modem on the surface tower. Previous iterations of NH-10 winter moorings were susceptible to mooring dislocation during heavy storm conditions, sometimes as far as the Washington coast, tether failure, or low-visibility spar designs that were lost, presumably due to vessel collision. This design was intended to address these prior failure modes, and in its >2 months in the water, has seen several instances of extreme seastate and wind conditions. The deployment itself was during conditions of swells approaching 20', and shortly after deployment, a significant wind event occurred. Since that time, there have been several instances of gale-force winds, and one instance recently of hurricane-force winds with >30' waves. The mooring has persisted, although it did move slightly to the north during the most extreme event, and is currently reporting data to the NANOOS data portal. Figure 3 shows the history of MAPCO2 data at NH-10, including a few validation samples (more recent samples were collected but have not yet been analyzed). The persistently stormy, downwelling conditions have led to a surface-ocean that is near, although slightly below, atmospheric CO_2 equilibrium.

As part of finishing FY13 IOOS-NOAA OAP work on Ocean Acidification Monitoring at Aquaculture Facilities, B. Hales and colleagues have been developing real-time full-suite carbonate measurement systems for deployment at facilities with flowing streams of seawater. While funding for this component ended in August, 2014, updates on several developments can be reported. To date, these systems have been built and deployed at OSU, OSU-HMSC, Whiskey Creek Shellfish Hatchery (WCSH; Netarts, OR), Taylor Shellfish Hatchery (Quilcene, WA), UC-Santa Barbara, USC Wrigley Marine Science Center. The IOOS funding targeted new deployments of these systems at three additional locations: Carlsbad Aquafarms (Carlsbad, CA); Hog Island Oyster Company (HIOC; Marshall, CA); and Alutiiq Pride Shellfish (Seward, AK). As of the previous progress report, the two systems at Carlsbad Aquafarms and Alutiiq Pride had been delivered, but not implemented and brought online. Since then, both systems have been brought online, and personnel at both locations trained.

The Carlsbad system has suffered several setbacks in the form of changes in management at the hatchery, and, while functioning, is not networked sufficiently for data to be shared in real time. The Alutiiq system (Figure 4) is up and running, providing daily e-mails of the real-time processed data to NANOOS for display.

Figure 2: The NewH10 MAPCO2 mooring, developed and built at OSU-CEOAS. Left, populated mooring ready for deployment on deck of OSU's *RV Oceanus*; middle, crossing the bar in 20' seastates; right, deployed mooring at NH10.

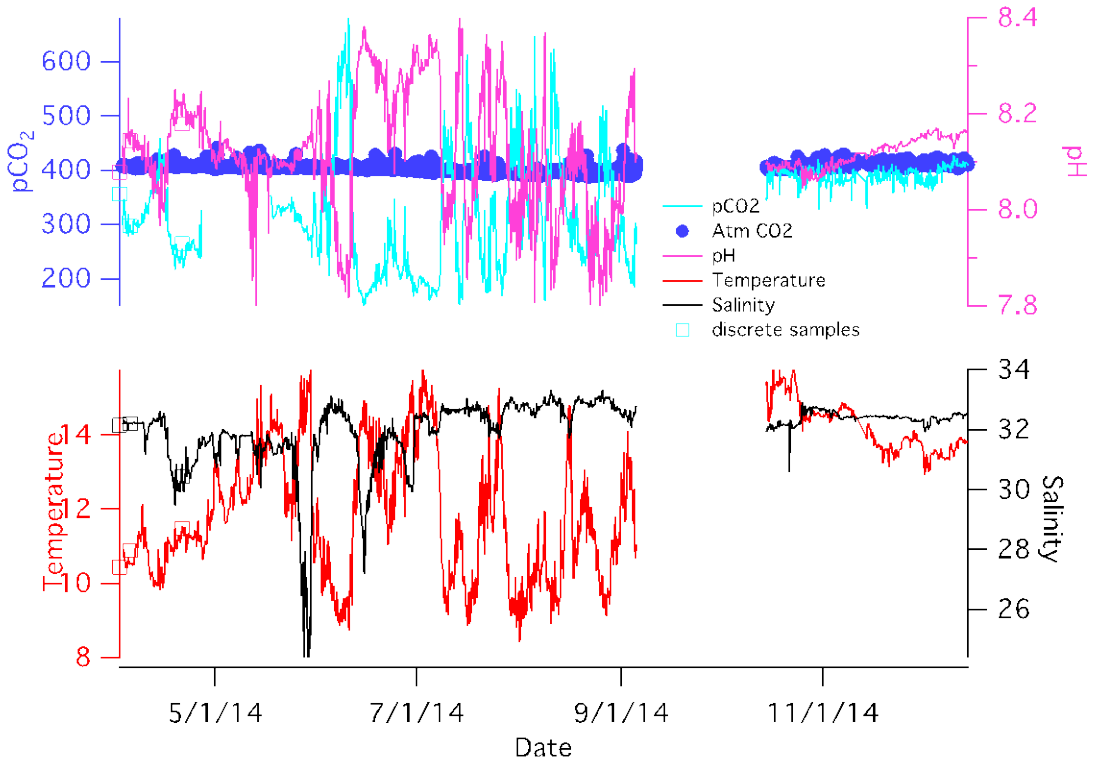

Figure 3: Time-series of NRT data from NH-10 MAPCO2 mooring provided to NANOOS NVS showing surface water and atmospheric pCO_2 (light blue line and solid blue circles, respectively), pH (magenta line), Temperature (red) and salinity (black). Open squares are opportunistic validation samples (color matches line of in-water parameter) collected during close-pass-by ship opportunities, analyzed in Hales' lab at OSU. The interval from 9/10 through 10/12 corresponds to an interval when the mooring had to be recovered to make for the OOI cable-laying ship. Data after 10/12 are collected with sensors mounted aboard the NewH10 buoy.

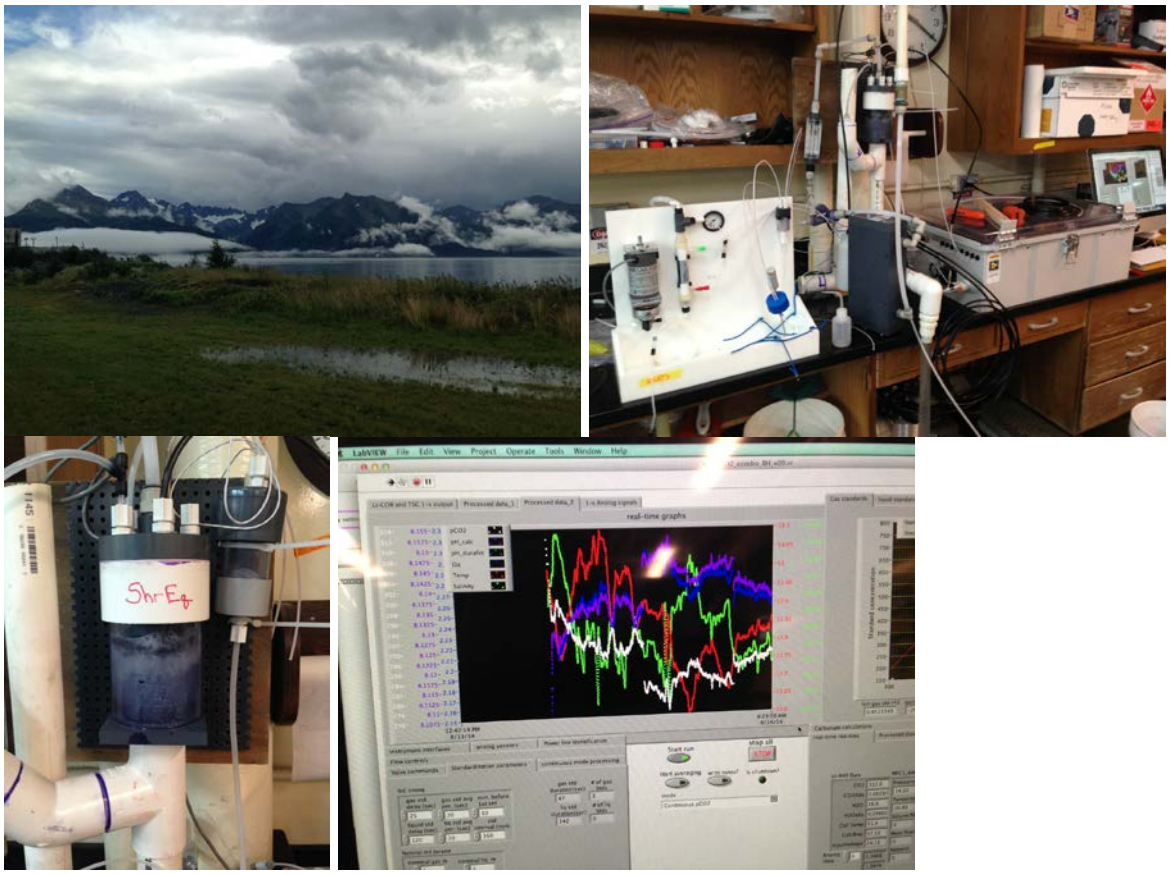

Figure 4. The IOOS-funded Alutiiq Pride combined pCO_2 T_{CO2} analyzer installation at Alutiiq Pride shellfish hatchery in Seward, AK. Upper left, Resurrection Bay from the facility. Upper right, the system, in place. Lower left, the new fast-response bubble/showerhead equilibrator. Lower right, first real-time measurements, including live determination of Ω, at Alutiiq Pride. These data are served via the new IOOS IPACOA portal.

Hales has also continued to work with local experts and NANOOS personnel to bring the data quality up to state of the art, and to provide that data in near real-time. Hales has worked with shellfish aquaculture personnel (B. Eudeline, Taylor Shellfish; A. Suhrbier, Pacific Shellfish) to bring the data from their respective sites online via daily data e-mails to NANOOS, and with NANOOS DMAC personnel (E. Mayorga) to provide access to the Hog Island data. Work with NOAA personnel (G. Lebon) and with Eudeline and Suhrbier has provided better operating stability of the instruments in Dabob and Willapa Bays, and has also brought state of the art liquid standard preparation capabilities to Dabob Bay.

Northern Oregon to Central Washington shelf: Led by A. Baptista (OHSU), the Center for Coastal Margin Observation & Prediction (CMOP) maintains glider operations and two offshore buoys (SATURN-02 and OGI-01), with partial support from NANOOS. The operation and maintenance of the glider and SATURN-02 is also partially funded by the National Science Foundation.

SATURN-02 is a station with seasonally changing configuration. The more robust, interdisciplinary and real time configuration is typically in May/Jun through Sep/Oct. For this reporting period, SATURN-02 was deployed in an interdisciplinary configuration from July through September. OGI-01 is deployed year-round in “winter configuration” (surface CT, no telemetry), as the deployment of an

interdisciplinary suite of sensors–although highly desirable for modeling support–remains unfunded. Deployment of the buoy in minimal configuration satisfies USCG regulations.

Glider operations have historically been seasonal (April-September), driven in part by collaboration with the Quinault Indian Nation, and focused on characterizing shelf hypoxia for fisheries management. The glider operations are also important for model calibration. Since May 2009, we have had 425 days of glider operations. No glider missions were conducted this year, a direct consequence of the creation of a new station (SATURN-09, reported below) in the estuary – in a flat funding situation. We anticipate returning to glider operations in 2015, but the extent of the operations will be limited by available funding.

Archival data from these platforms, and those from the Columbia River estuary, below, are publicly available. NANOOS NVS functions as the PNW-integration portal, displaying real-time data and allowing downloads of recent data; it also contains links to the CMOP SATURN website, which offers access to both the near real-time data and since-inception archival data, besides allowing interactive analysis of data within and across stations through the SATURN Data Explorer[1].

- **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, with two additional moorings (Carr Inlet and Hoodsport) completely serviced during this period. This brings the total number of moorings fully serviced in 2014 to five—with only the North Buoy remaining. A new Surlyn foam hull, which allows the integration of multiple sensors including the MAP-CO_2 system, replaced the existing fiberglass hull on the Carr Inlet mooring.

At the time of the Hoodsport mooring servicing cruise in mid-September, all six ORCA moorings were operational, but we have since had a number of set-backs including a gill net tangling in the Hoodsport hydrowire/CTD package and damaging the winch and hydrowire and an extreme weather event in late November which damaged the solar panels and other components on the Pt. Wells mooring. Despite these setbacks, we have made substantial progress over the last six months to increase the robustness of this network, including the development and successful deployment of the next generation of buoy controllers and carrying out an upgrade to aging cellular telemetry components. This work has primarily been accomplished with NANOOS funds in addition to federal (NOAA OAP) and Washington state (WOAC) funding supporting OA observations. 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.

During this period, with primary funding from the non-profit "Long Live the Kings" which focuses on salmon survival, we also began the integration of a new meteorological package including a PAR sensor on four of the moorings. Additionally, we have plans to deploy SeaFET pH sensors purchased by WOAC on several of the moorings in December 2014 and January 2015, with work to develop a driver to integrate this instrument with the existing buoy controller largely carried out in November.

In early October the primary laboratory space supporting this program moved from UW Oceanography to APL-UW, merging with the existing NANOOS-supported NEMO lab which maintains the Cha'ba and

[1] http://www.stccmop.org/datamart/observation_network/dataexplorer

NEMO-subsurface moorings. This move has already benefitted the ORCA program in a number of ways, including the easy access to APL resources including vessels (e.g. the *R/V Robertson*), a full-service machine shop, and the availability of senior engineers for advice and assistance.

Observations from the ORCA mooring network in addition to data collected as part of the Washington State Department of Ecology Marine Waters Monitoring Program captured two unprecedented deep-water renewal events that took place in Hood Canal in December 2013 and February 2014, resulting in some of the highest deep dissolved oxygen levels and coldest temperatures observed to date in Hood Canal (Figure 5). These observations, which are among the first that suggest local surface cooling in fjords can drive deep water renewal events, were presented by PI Mickett at the Eastern Pacific Ocean Conference (EPOC) in mid-September, with plans to submit a paper on these data in early 2015.

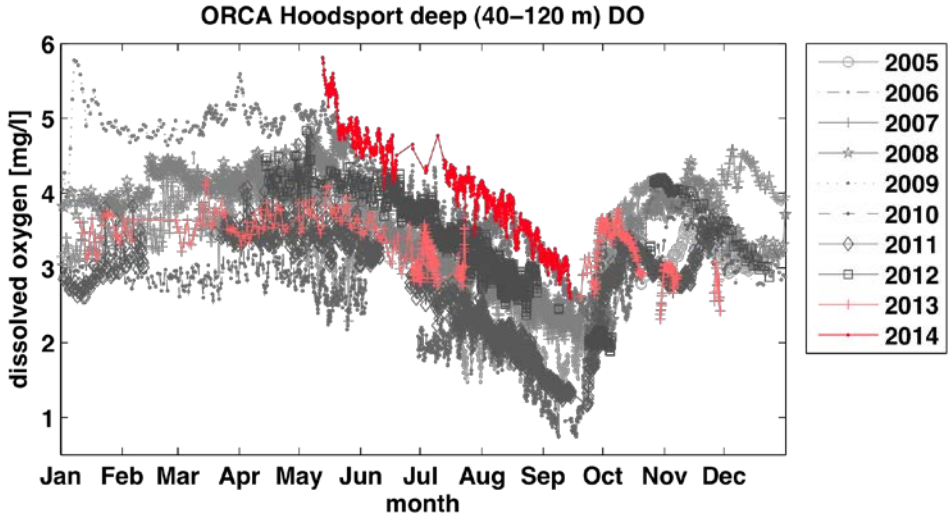

Figure 5: Depth-averaged (40-120 m) dissolved oxygen at the NANOOS Hoodsport ORCA mooring showing the anomalously high dissolved oxygen in 2014 (red). While NRT data are served by NANOOS NVS, this historical perspective is important and will be addressed in future by climatology product development.

Washington State estuarine monitoring: Participation by the WA State Department of Ecology's (Ecology) Marine Waters Monitoring Program is directed by C. Maloy (Marine Monitoring Unit Supervisor) and led by C. Krembs (Senior Oceanographer). Due to budget cuts, Ecology continues to have only one mooring staff, a dedicated Field Technician (S. Pool), partially supported by NANOOS funds.

Ecology is using ferry vessels as a cost-effective means of data collection. En route ferry monitoring is valuable because it can capture near-surface events such as blooms, river input, and tidal exchange on a daily basis and over a large geographic area. Ecology has two sensors and a GPS on the *Victoria Clipper IV* passenger ferry vessel that runs twice daily between Seattle and Victoria, BC. The 80-mi ferry transect has enabled observation of algal and *Noctiluca* blooms, tidal excursions, dynamic and structure of isotherms and freshwater, and event-driven water exchange between Central Sound and Strait of Juan de Fuca. It is also an important asset to acquire daily high-resolution ground-truthing information to calibrate satellite images. In July, 2014, we successfully upgraded the data collection system. Data are uploaded daily to a cloud computing server at: http://107.170.217.21/VictoriaClipper30/level0/. We are now leveraging some EPA NEP funds towards developing a NetCDF database, which will be a

repository of ferry monitoring data, with help from APL-UW, with the aim to provide these data via NANOOS. Ecology staff started development of data products and QA/QC methods. Ferry data products, in addition to mooring data, are included in the monthly Eyes Over Puget Sound report. One sample data product is a temporal-spatial distribution of parameters as shown in Figure 6.

Ecology maintained its sole nearshore mooring station in Mukilteo (with daily telemetry of real-time data to Ecology's website and NANOOS NVS) in collaboration with Everett Community College and Port of Everett. This station monitors the dynamic water exchange between Central Basin and Whidbey Basin and collects information on water quality attributes at depth. Temperature and salinity were increasing and dissolved oxygen was variable then increasing through fall (Figure 7). The Admiralty Reach station remains suspended with plans to resume in 2015. Budget cuts have meant continued suspension of the Manchester, Shannon Point, and Willapa Bay stations. We have restored the moorings program's contribution to the monthly "Eyes Over Puget Sound" reports.

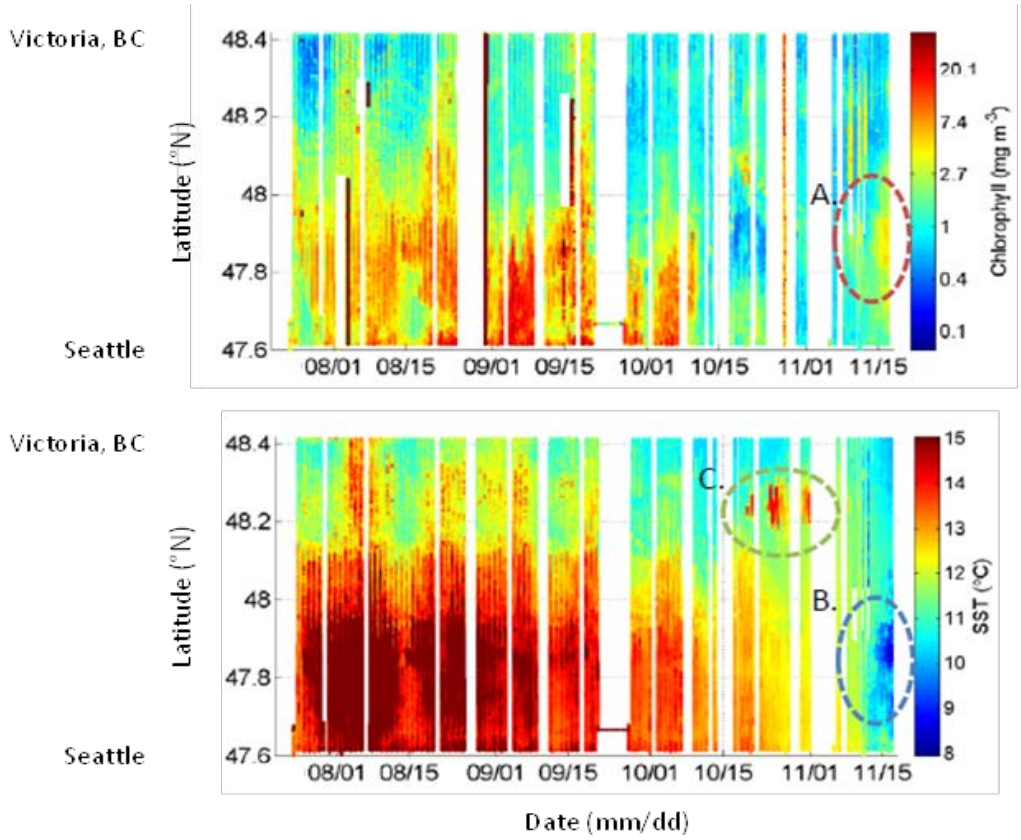

Figure 6: Temporal-spatial distribution of chlorophyll fluorescence (top) and sea surface temperature (SST; bottom) in 2014 observed via Victoria Clipper ferry monitoring. A-B) Colder water with moderate levels of chlorophyll fluorescence from Whidbey Basin enters the Main Basin near Triple Junction (Edmonds = B); Cool SSTs are observed throughout Puget Sound during November, falling below 11 °C. C) Warm temperature anomaly detected in the Strait of Juan de Fuca during the last half of October.

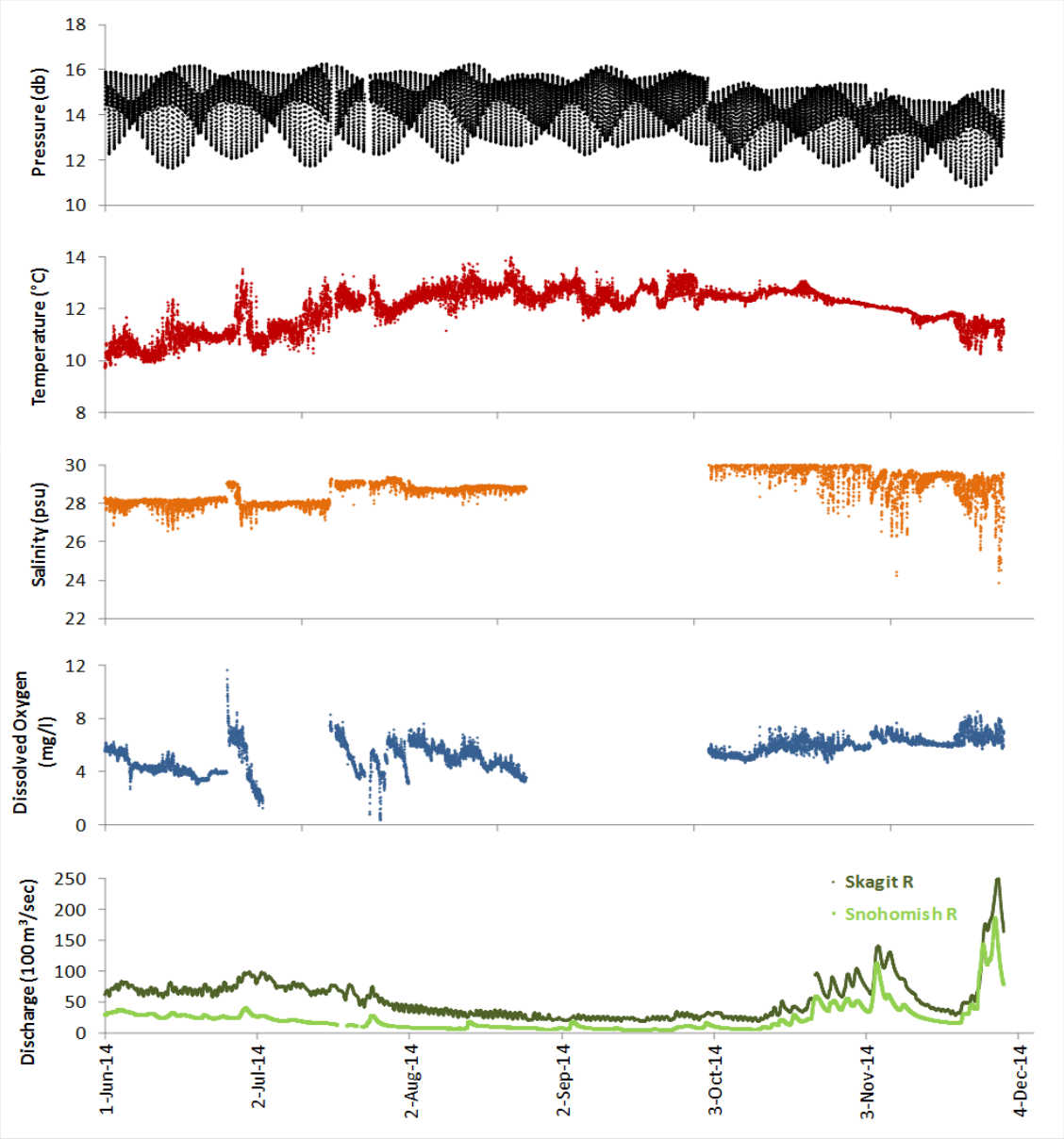

Figure 7: Time series of pressure, temperature, salinity, and dissolved oxygen from near-bottom mooring at the Mukilteo station (data are provisional); The NRT data were served via NANOOS NVS. River discharge data are from USGS.

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.

During the reporting period, we continued to advance the characterization of ocean-induced estuarine hypoxia and acidification, and the role of local production in mitigating these deleterious ocean effects.

Of particular note, we installed a new interdisciplinary station (SATURN-09) at the mouth of Youngs Bay, to help characterize the role of this lateral bay in the estuary. This station has a surface-floating package of sensors, measuring temperature, salinity, chlorophyll, phycoerythrin, DO, turbidity and CDOM.

Early data (Figure 8) suggest that Youngs Bay has a distinctive behavior relative to the main estuary, the more marine Baker Bay, and the freshwater Cathlamet Bay. With brackish salinity and a compressed temperature variation over the tidal cycle, the station is very responsive to river discharge (which is decreasing in the period shown in Figure 8). Turbidity increases with flow, with strong modulation by the spring-neap cycle. Oxygen saturation tends to be low, except during periods of *Mesodinium* bloom (when supersaturation occurs). Local respiration appears dominant for most of the period, and stronger than in other parts of the estuary. Effects of ocean-driven hypoxia are not obvious at SATURN-09 when (in September) they are clear at SATURN-03 (in the South Channel) and SATURN-07 (in Baker Bay).

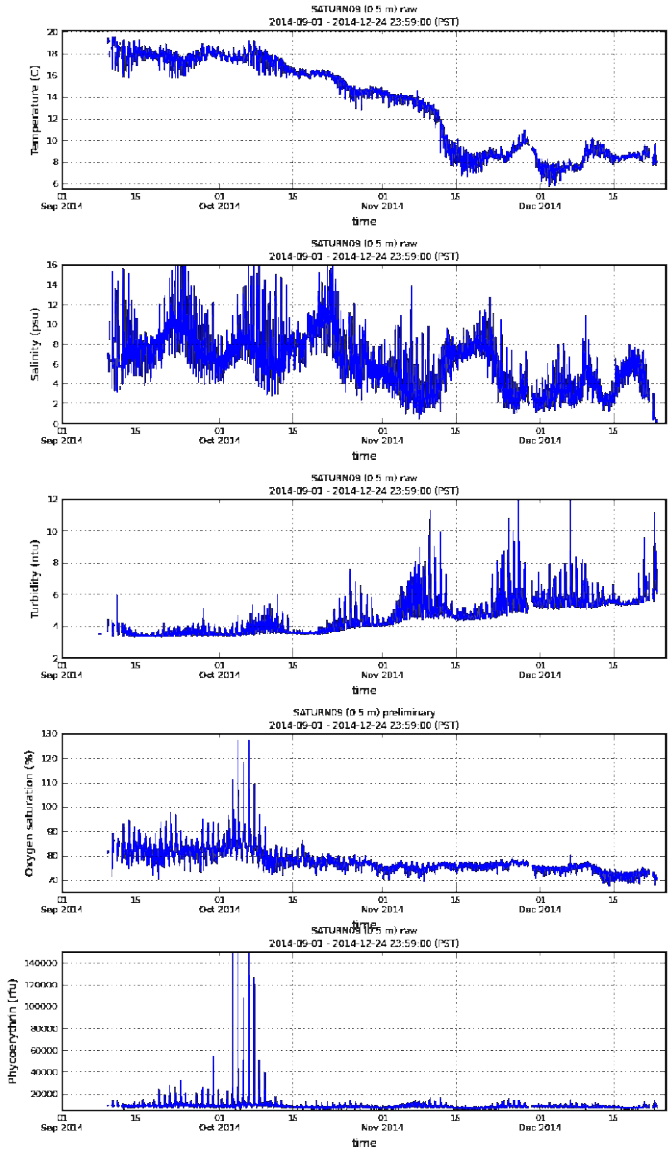

Figure 8: Raw data from SATURN-09, since deployment (select sensors). Results are shown as produced on the web via Data explorer and also available via NANOOS NVS.

Also of relevance during the reporting period is the submission of a first paper on adaptive sampling experiments of microbial communities. The experiments involved the deployment of an Environmental Sampling Processor (for several days-to-week scale periods) at SATURN-03, with automated sampling targeted by select aspects of the function of the estuarine bioreactor.

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.

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 observing stations and a real-time weather station as part of the NERRS System-Wide Monitoring Program with additional support provided by NANOOS. The five water quality monitoring stations located along the estuarine salinity gradient provided continuous data over the period June 2014 – November 30, 2014. Four of the water stations and the weather station are equipped with telemetry systems. The Elliot Creek water station telemetry components were down beginning 11/19/14 and 11/22/14, and we are troubleshooting equipment parts; all sensors are working and data collection has been uninterrupted. We are also exploring relocation options for the weather station due to the recent installation of a nearby wind turbine (10kW, 140 ft) on the Oregon Institute of Marine Biology Campus to power a new facility, the Charleston Marine Life Center. The wind turbine was installed on 12/5/2014 and is located approximately 80 feet from the weather station.

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 is located in Lower Coos Bay; the North Spit BLM (NESDID ID # 346F229A; sosnswq). This partner station was made available through the NVS this summer on 8/6/14. NANOOS DMAC lead E. Mayorga developed Python code and utilized common software libraries from IOOS DMAC to ingest water quality data from HADS (Hydrometerological Automated Data System) in order to display the data through NVS; this was an important breakthrough for an innovative mechanism to access the data outside of the NERRS Centralized Data Management Office (CDMO) and will help with future water quality stations that are maintained through partnerships or are outside of the scope of the NERRS CDMO.

The South Slough and the CTCLUSI North Spit 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 to monitor environmental conditions. The stations also provide important environmental data for research and monitoring projects conducted at the reserve, by visiting investigators, and by researchers at the nearby University of Oregon Institute of Marine Biology. These projects include eelgrass, fecal coliform monitoring, saltmarsh and native oyster restoration projects. The weather station provides real-time data to assess the short-term effects of local weather on water quality within the estuary.

We expanded the network of water quality stations to include four stations (North Point, Isthmus Slough, Catching Slough, and Coos River) in Upper Coos Bay through the NERRS Science Collaborative Partnership for Coastal Watersheds project. These stations, installed in Fall/Winter 2013, are important additions to understanding water quality dynamics in the larger Coos estuary. One station, North Point, is located near commercial oyster cultivation areas (Clausen Silver Point Oysters, Coos Bay Oyster Company, North Bend Oyster Company). South Slough will prioritize adding real-time capability to the North Point station for the oyster growers and for Coos Bay Bar Pilots to provide real-time water level data.

- **Shorelines**

Washington Shorelines: NANOOS funds contribute to the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) led by G. Kaminsky. In June 2014, CMAP conducted spring seasonal beach monitoring surveys in the Columbia River Littoral Cell (CRLC). In total, 46 profiles

and two surface maps were collected. 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. In Ocean Shores, the wave bumpers are still exposed due to lack of upper beach recovery this summer. Minimal dune recovery and vegetation regrowth was also observed in the Grayland Plains at profile Spice and in Westport, a large scarp is still present at profile Worm.

In nearly every surface map survey, CMAP experienced mechanical failures of its All-Terrain Vehicle and constant repairs of its aging equipment. Much of the source of failures stem from corrosion problems despite a high level of care and maintenance of the equipment. Costly repairs and downtime have been incurred because there are insufficient funds to replace equipment.

CMAP has been engaged throughout this reporting period with Pacific County Department of Community Development with scoping a coastal erosion assessment to provide the County with more accurate estimates of how soon and where future erosion will occur so they can better justify a building moratorium to minimize future loss of homes and the problem of solid waste going into the ocean as the land erodes away. CMAP also provided beach profile data to coastal engineering consultants who are reviewing recently completed FEMA flood hazard maps in Grays Harbor County, particularly along Westport and Grayland Plains.

In the beginning of September, CMAP worked with the USGS to collect beach and nearshore profiles at the Elwha River mouth. This was the first survey where topographic data was collected all the way to Ediz Hook as it has been necessary to expand the survey area eastward as new sediment is transported throughout the drift cell. Also in September, CMAP conducted the first of several surveys to monitor the Shoalwater protective berm constructed by the USACE near Tokeland where beach profiles and surface map data was collected on land while boat-base lidar and multibeam bathymetry data was collected via the R/V *George Davidson*.

Oregon Shorelines: Leveraging NANOOS, the Oregon Beach and Shoreline mapping Analysis Program (OBSMAP) efforts are led by J. Allan and V. McConnell 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 September 2014 (Rockaway cell (25 sites) and along the Clatsop Plains (6 sites)) and October 2014 (Neskowin cell (15 sites)). Our September surveys of the Rockaway cell was undertaken in conjunction with OSU (PI Ruggiero) in order to complete bathymetric surveys of transects within that particular cell.

Data for the OBSMAP monitoring sites are 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 beach study sites exhibit a general trend toward accretion. Erosion issues that had plagued a number of sites in the past are for now considered to be stable. 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 in Neskowin and Rockaway to help guide their understanding of changes taking place along their beach, and more recently by residents in the Cannon beach area, who are concerned about plans to lower dunes in their area.

In November, PI Allan presented to about 200 people at the South Coast Community College in Coos Bay on the topic of the effects of future climate change on Oregon coastal hazards. The material presented

included information relating current patterns and trends of coastal change (served up via the NVS Beaches and Shoreline changes web app) as well the new Climatology web app. The latter was used to showcase the effects of a recent storm that impacted the Port Orford area on October 26th, 2014. In addition, Allan participated in several meetings involving staff from multiple agencies, counties, cities, and NGOs concerned about coastal resilience to climate change issues on the northern Oregon coast (specifically in Tillamook and Clatsop counties). NANOOS data derived from the NVS Data Explorer, the Beach and Shoreline and Climatology web apps, along with information pertaining to ocean acidification all featured during the meeting. Finally, PI Allan attended an all-PI meeting on August 11th in Vancouver, Washington.

During this period, problems with aging infrastructure continued to be an issue, with our ATV (now 10 years old) continuing to experience reliability issues. We are also beginning to experience problems with our GPS radio transmitters, which have failed on a few occasions.

Nearshore Bathymetry: During summer 2014, 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 (e.g., Figure 9).

Also during summer 2014, Ruggiero's group collected nearshore bathymetric data along much of Lane County Oregon. Over 50 individual cross-shore beach profiles were processed from the lower intertidal to ~25 m of water depth (~1500 m from the shoreline). These data have been combined with topographic data collected synoptically by PI Allan's group at DOGAMI, and have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. The combined beach/nearshore observation dataset now available for Lane County is being used to assess 1% (100-year) coastal flood and erosion risk along the county shorelines for the purposes of developing updated FEMA flood insurance rate maps.

Finally, in summer 2014 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.

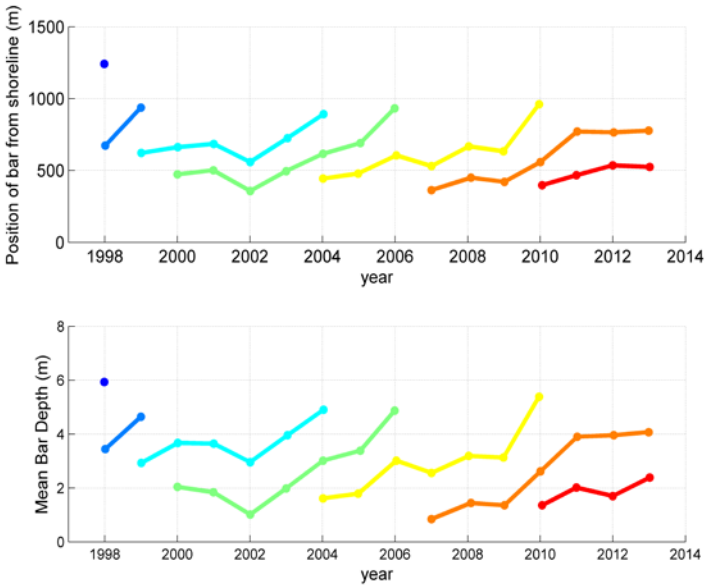

Figure 9: Average sandbar distance from shore and mean sandbar water depth from 1998 to 2013 in the North Beach, WA sub-cell of the Columbia River littoral cell illustrating net offshore sandbar migration. Colors represent individual sandbars.

- **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.

Our scientific collaborations continue on several fronts: a second published paper with Sung Yong Kim in our examination of inertial currents looks at data (HF currents, local winds); a regional numerical ocean model (ROMS, Kurapov); and idealized models to estimate the local response and its decay timescale (Kim, Kosro and Kurapov, 2014). The paper by Osborne et al. (2014) examining locally "hot spots" of diurnal tidal signals in the ROMS model and in the HF data has been published. And we continue work with A. Kurapov, Scott Durski and others on the winter circulation and effects of the 2009-10 El Niño (presentation Kurapov et al., 2014).

We have addressed numerous infrastructure issues. At Cape Blanco, the land and buildings have been transferred from the USCG to the FAA; FAA is planning to replace our current shelter with a new building, which will include space for our needs. A break-in at our shelter at LOO (Loomis Lake, WA) occurred on Sept 24; the alarm scared away the intruder, but the building was damaged, and we are gearing up to build a replacement. At YHL (Yaquina Head, OR), we experimented with moving our receive antenna to address a long-standing signal-to-noise problem; the test was successful, and the antenna has been moved permanently. A new shelter is being considered at WLD (Waldport, OR, our first site, established in 1996) to reduce the frequency and difficulty of buried cable replacements; aside from construction, electrical contracting costs would run to more than $5000 to get power to the new location. We have built and installed a replacement antenna enclosure at MAN (Manhattan Beach, OR), and installed an exterior cell antenna at STV (Ft. Stevens, OR) to improve communications. Reprocessing of cross-spectra to radials is underway for SEA (Seaside, OR); taking advantage of a new pattern from jet-ski operations and a systematic check of sites for proper phases in ideal-pattern, solutions has been completed.

Kosro attended the meeting of the HF Technical Steering Committee in Boulder, 24-25 July, and provided NANOOS representation and HF background for the IOOS Directors Retreat there 26-27 August. With Jan Newton, he briefed Senator Maria Cantwell on the HF mapping role in USCG search and rescue. He also provided information on NANOOS observations for the Marine Technology Showcase in Newport, Oregon, October 20-22.

Port X-band Radar: Led by M. Haller (OSU), the wave imaging radar at Newport South Jetty continues regular operations providing wave spectral information to the NANOOS Visualization System on an hourly basis. After a brief down period, the system returned to operation late July. It was determined that the previously-reported vibration issue was caused by a worn motor gear; the issue was resolved by replacing the motor's gear box. Radar and data collection operations continued smoothly until mid-November when the radar motor failed. The motor was replaced and the radar was returned to operation mid-December.

Our temporary installation at the Mouth of the Columbia River (using leveraged funds) continues to generate significant stakeholder interest. M. Haller was interviewed in *Civil Engineering Magazine* ("Ocean-Monitoring Radar Could Be Lifesaver for Shipping Vessels", November, 2014) and was also featured in the university publication OSU College of Engineering *Momentum!* ("Keeping ships safe at sea by tracking hazardous waves", December 2014). In addition, M. Haller was an invited guest speaker at the monthly *Industry Breakfast* at the U.S. Coast Guard Marine Safety Unit Portland (Nov. 20, 2014). There we presented our efforts at monitoring the complex wave and current dynamics at the MCR and discussed their impact on navigation with members of the Coast Guard and the Columbia River Bar and River Pilots (among others). Recently, we have been contacted by David B. Enabnit, Technical Director Office of Coast Survey, NOAA in regards to using our radar systems and processing algorithms for bathymetric monitoring at navigational inlets. We are initiating a collaboration and providing technical advisement for a system test on the east coast this spring.

b) NANOOS Modeling Subsystem:

Shelf: Computer circulation modeling 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. The system produces daily updates of 3-day forecasts of ocean conditions, including currents, temperature and salinity through the water column (at 3-km horizontal resolution). 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. Routines for pre- and post-assimilation quality control have been established, along with new online tools (http://ingria.coas.oregonstate.edu/rtdav/, L. Erofeeva, OSU).

During the report period, we improved the model by providing boundary conditions from the 1/12th degree resolution Navy ROMS (which replaced the boundary conditions based on climatology). Additional steps have also been made to put online the new model that is extended to 41-50N (including both OR and WA shelves) and includes the Columbia River fresh water plume. In particular, we started to operate this new model in the near-real time regime (but still without assimilation).

Initial assimilation tests using this new configuration have been done, and the impact of the river plume on assimilation is being studied. Efforts have been made to improve the initial condition error

covariance based on an ensemble of model runs with localization (ongoing study by I. Pasmans, OSU PhD student).

- **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), are creating 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 begin making live daily forecasts (Figure 10). 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 had meetings with scientists from Washington State Department of Ecology and Department of Natural Resources to discuss uses of model output. MacCready also presented results on this work in a talk for a non-specialist audience. 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.

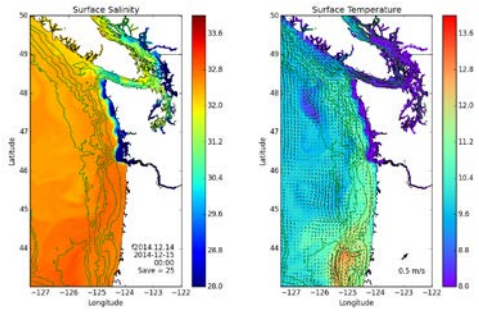

Figure 10. Surface salinity (left) and Temperature (right, °C), with instantaneous velocity vectors overlain. This is from a recent daily forecast made by the UW *LiveOcean* system. The model is forced with realistic winds (UW WRF), ocean (HYCOM), rivers (USGS and NOAA Northwest River Forecast Center), and tides. The model will be used to make forecasts of Ocean Acidification for shellfish growers.

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 circulation modeling capabilities of the VCR 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. Modeling of sediment and biogeochemical dynamics in the estuary has progressed considerably, with papers in preparation on both topics (for submission next reporting period).

Of particular note in the period, was the conclusion of reports of circulation model-based studies for (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.

Also of note is the conditional acceptance (and submission of the revisions) of a paper describing a rigorous model benchmark for the Columbia River estuarine circulation (Kärnä et al, revised Dec 2014). Two related papers of significance are currently in preparation, for submission next reporting period. One describes the skill of simulation database DB31 (1999-2013), and the other characterizes physical regimes in the estuary based on that simulation database.

Several presentations at regional and international forums were made on the Virtual Columbia River and its societal applications (list below).

c) Data Management And Communications (DMAC) Subsystem:
Chaired by E. Mayorga (APL-UW), this committee is composed of members from Boeing, 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) annual NANOOS Governing Council & P.I. meetings (Aug 11-12); 2) weekly NANOOS DMAC-UPC teleconferences; 3) newly instituted monthly NANOOS DMAC technical teleconferences; and 4) IOOS DMAC monthly webinars.

NANOOS Visualization System (NVS) enhancements encompass asset additions and continuous updates: a) new or newly incorporated near-real-time in-situ monitoring assets (3 CMOP-OHSU Columbia estuary sites; a collaborative tribal-NERR site in Coos Bay, OR; UW sensors newly added to the Penn Cove Shellfish platform; CO_2 and pH sensors at the OSU NH-10 buoy; and "Burkolator" OA sensor packages at 3 existing shellfish growers' sites); b) creation and incorporation into NVS of site climatologies and anomalies for NDBC buoy and C-MAN stations, merging near-real-time and QA/QC'c data; c) new OSU climatology and monthly anomaly AVISO remote sensing mean-sea-level and NCEP NARR model reanalysis winds; d) expanded MODIS-Aqua SST & Chl-a monthly anomalies, and first inclusion of anomaly overlays into NVS; and e) many redeployments and smaller upgrades. These additions were facilitated by an overhaul of the NVS harvester for CMOP data to ingest from a THREDDS server instead of an older, custom data stream (including the development of a THREDDS-derived JSON catalog file); the incorporation of readers from the IOOS-supported PyOOS package into the NVS harvesting suite; and the Oct. deployment of NVS 3.8, featuring the new Climatology App and greatly enhanced handling of cyclical climatologies and long-range time-series overlays.

NANOOS and IOOS DMAC system implementation. A new, central metadata web-accessible folder (WAF) was created (http://data.nanoos.org/metadata) to support registration of NANOOS datasets and services with IOOS. This WAF was used to register the OSU MODIS-Aqua climatology and anomaly services hosted at NOAA-SWFSC ERDDAP. This registration was part of a concerted push for NANOOS service registration, through which we worked with IOOS to repair and finalize the registration of the OSU ROMS THREDDS-based services and the NANOOS 52North SOS service. A CMOP-OHSU THREDDS server was upgraded, and the SELFE irregular-grid model forecasts it hosts are being prepared for registration with IOOS by January. NANOOS also continued its contributions to IOOS DMAC community implementation activities, including an active role in the IOOS Github repositories, and collaborative development and dissemination of Python tools for convenient IOOS data access. PyOOS use was accompanied by code contributions (Github pull request). We also contributed to discussions and trouble-shooting for IOOS Catalog ingestion of 52North SOS end points, the use of MMI resources to enable controlled-vocabulary-based discovery of IOOS Catalog assets, and many other topics.

West-Coast Coastal and Marine Geospatial Data. NANOOS collaborations with the West Coast Governors Alliance Ocean Data Network (WCODN) strongly supported the enhancement of ISO 19115-1 and ocean-observing ISO 19115-2 metadata best practices and handling in the West Coast Ocean Data Portal (WCODP) Catalog (http://portal.westcoastoceans.org), and the use of OGC WMS (including temporal WMS, "WMS-T") by both service providers and the newly released WCODP Marine Viewer client (http://maps.westcoastoceans.org). NANOOS registered several of its metadata records with the WCODP Catalog and used its GeoServer instance to serve WCODN partner datasets via OGC web services (WMS, WFS, etc). C. Risien (OSU) participated in the 3rd WCODN network meeting, Nov 3-4 in Costa Mesa, CA (Mayorga & Risien, 2014). E. Mayorga served as the technical mentor for the WCODN SeaGrant fellow (L. Lilly) hosted by SCCOOS; this fellowship ended in Nov. With NANOOS assistance, the fellow successfully created several west-coast data products (surface currents, temperature and wave climatologies, ocean acidification asset inventory, etc) derived from RA datasets and services, and registered these products with the WCODP catalog. Her work, described broadly at http://westcoastoceans.wordpress.com/2014/10/28/coming-full-circle-with-the-west-coast-ocean-observing-systems/ and in detail at http://cdip.ucsd.edu/share/IOOS_WCODP_products/IOOS_WCODP_products/, has been very well received by the WCODN and partner communities, and will help WC RA's to better serve our regional users.

Ocean Acidification (OA) Data. As mentioned above under "NVS" and elsewhere, NANOOS integrated into NVS several new or greatly upgraded OA-relevant data streams in the PNW. "Burkolator" sensors went online and started being ingested in near-real-time at shellfish growers' sites at Whiskey Creek (OR), Dabob Bay (WA) and Willapa Bay (WA). These sites now feature new OA variables such as alkalinity, TCO2 and aragonite saturation state, made available to the IOOS Catalog via the NANOOS SOS. NANOOS is now also ingesting CO_2 and pH sensor data at the OSU NH-10 buoy, additional pH sensors from the Penn Cove Shellfish platform, and a new OA-relevant site at Coos Bay (OR) that is a collaboration between the South Slough NERR and a regional tribe confederation (CTCLUSI).

As part of FY13 MSI activity, NANOOS released in November the new "IOOS Pacific Region Ocean Acidification" data visualization application (IPACOA, http://www.ipacoa.org). Adapted from a generalization of the NVS framework, IPACOA currently ingests all live Burkolator sites, PMEL pCO_2 sensors, and data from other OA-relevant sensors. NANOOS also assisted IPACOA RA's (specifically AOOS, CeNCOOS and SCCOOS) to ingest into their systems Burkolator data streams within their regions.

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 2014 period included: 1) multiple weekly NANOOS

DMAC and UPC teleconferences; 2) Attendance at the annual NANOOS Governing Council meeting on August 11-12th, 2014; and 3) the release of the NVS 'Climatology' web app developed for the Pacific Northwest (PNW), and its subsequent enhancements. Allan also attended and presented at the Northwest Marine Technology summit held in Newport on October 20th to 22nd, presenting on the new 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 1st, NANOOS released NVS v3.7, which reflected a minor update to the overall look and feel of the NVS platform.

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. After a considerable amount of time involved in developing both the data and overlays that could be used in such a product, NANOOS finally released a new 'Climatology' web app on October 23rd (Figure 11, http://nvs.nanoos.org/Climatology). 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. The web app consists of two components:

- Climatologies derived for selected NDBC (9) and C-MAN (5) stations based around the following core parameters: air and water temperature, wind speed, barometric pressure, significant wave height and peak spectral wave period. The plots depict simple statistics such as daily means and standard deviations (±1σ and +2σ). These data are updated on a daily basis blending data that has already been subject to stringent QC checks, with more recent data (last 45 days) that have been subject to more limited QC; and,
- Ocean overlays depicting:
  - Monthly averages of chlorophyll and sea surface temperatures derived from MODIS satellite data, NCEP North American Regional Reanalysis (NARR) 10m winds and mean sea levels derived from AVISO satellite altimetry data, averaged over the length of the data to depict seasonal changes; and,
  - Monthly changes (expressed as anomalies) in chlorophyll and sea surface temperatures derived from MODIS satellite data (2002-present), NCEP North American Regional Reanalysis (NARR) 10m winds (1993-present), and AVISO sea level heights (1993-present, Figure 11). These latter data show monthly deviations in the observed parameter relative to the long-term mean.

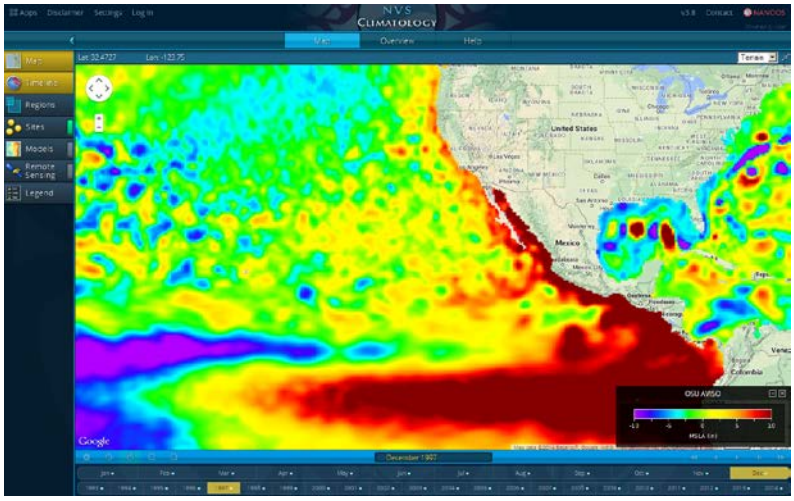

Figure 11. The new NANOOS Climatology web app showing mean sea level anomalies for December 1997 at the peak of the major El Niño. Access to data from specified months and years is accomplished through the NVS timeline.

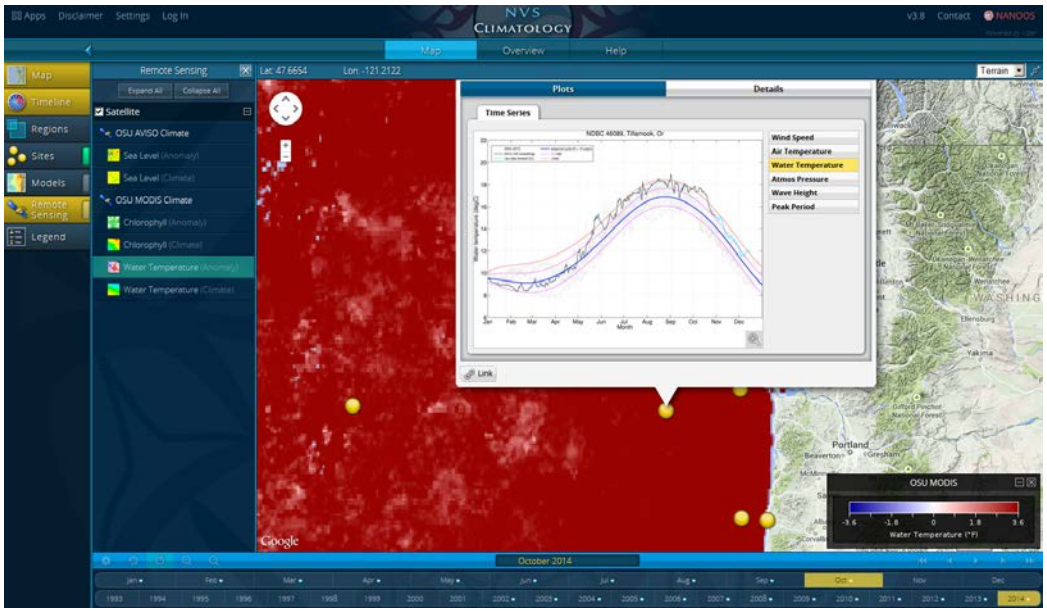

Figure 12. Climatologies have been derived for NDBC (9) and C-MAN (5) stations for the following core parameters: air and water temperature, wind speed, barometric pressure, significant wave height and peak spectral wave period. The plots depict the current conditions as a solid black (QCd data) and cyan (limited QC) line; measurements from other years are included as gray lines. Simple statistics such as daily means (solid blue line) and standard deviations (±1σ (magenta) and +2σ (red)) are also displayed.

Figure 12 provides an example of water temperature measurements at buoy 46089 for 2014; the buoy is located ~140km offshore from Seaside, Oregon. Sea surface temperatures derived from MODIS satellite data are shown for the month of October as an overlay. The time series plot provides an example of unusually warm ocean temperatures (termed the 'blob') that have persisted in the northeast Pacific in 2014. Measurements derived from multiple NDBC water temperature sensors in the region highlight the fact that temperatures are typically exceeding 1-2σ above normal. These types of plots highlight our ability to now showcase conditions that may be perceived to be unusual in our region against longer time series.

Mobile Applications*[2]*: The NANOOS UPC/DMAC sub-working group is responsible for the release and maintenance of mobile applications that can access and display data from NANOOS data sources. Currently there are two such applications, ***NVS*** and ***Tsunami Warning NW*** that are available to the general public on both Android and iOS platforms. During this period, Boeing (lead on mobile application development) undertook a survey of the mobile application code base to identify any changes needed for consistency with the latest mobile operating systems and devices. Several key areas were identified that need upgrading including support for additional screen sizes, memory management, map based features and map overlays for gridded data. Included in this assessment, Boeing completed an inventory of existing datasets maintained in NVS to insure the mobile apps are up-to-date. Boeing also commenced code reorganization in order to enhance application maintainability and future enhancements.

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

[2] http://www.nanoos.org/mobile_apps/index.php

The NOAA FATE funded "J-SCOPE" web page on NANOOS (http://www.nanoos.org/products/j-scope/) was updated with a "Year in Review" section describing how the ecological forecasts performed for 2013. In general, the temperature predictions did better than oxygen or chlorophyll, but the forecasts appear to have 2-4 months of predictive skill. The 2014 forecasts, including sardine habitat, was also added. Project leads Isaac Kaplan (NOAA NWFSC) and Samantha Siedlecki (UW JISAO) look forward to posting a January 2015 forecast in the winter of 2015.

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 Vander Geissen, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton, Sprenger and Vander Giessen are all active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. Sprenger continues 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.

- In June 2014 Newton, with support from Sprenger, presented a NOAA OAP SOARCE webinar: "Ocean Acidification Data Visualizations: How to access and use IOOS data" see http://oceanacidification.noaa.gov/AreasofFocus/EducationOutreach/SOARCEWebinarSeries/Archive6-24-14.aspx. The webinar was attended by nearly 200 people.
- 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 third year this past summer, Sprenger partnered with WA Sea Grant to co-instruct the NOAA Science Camp's Junior Leadership Program's research project. Sprenger advised high school students in designing, building and deploying buoys near the NOAA campus on Lake Washington to answer student derived research questions. This winter Sprenger and WA Sea Grant staff have been working to improve and expand the program to more educational settings.
- Sprenger spearheaded a partnership with staff from NANOOS member Ocean Inquiry Project, WA Sea Grant, NOAA PMEL and NOAA NWFSC to hold a two-day educator workshop in Seattle, "Tuning into Pteropods, Finding a Story in Data" in August of 2014. 20 informal and formal educators from OR and WA attended the 2 day workshop. The workshop included presentations from Drs. Jan Newton, Meg Chadesy (WA Sea Grant OA Specialist), Nina Bednarsek (PMEL). It also included a cruise on Puget Sound collecting oceanographic data and sampling for pteropods, a visit to the NOAA NWFSC Mukilteo Lab, and a session at UW computer lab looking at RTD via NANOOS. Evaluations from the workshop were very positive and Sprenger continues to work with some of the educators that attended the workshop to support them in bringing OA and RTD into their education programs. NANOOS hopes to support similar workshops in both Oregon and Washington in 2015.
- In September Sprenger traveled to Santa Cruz CA to meet with SCCOOS, CeNCOOS and West Coast National Marine Sanctuary education staff to share ideas for future collaboration.
- Sprenger is updating NANOOS education pages content with more resources and updated lesson plans based on educator workshops held in Nov. '13 and Aug '14.
- Sprenger is co-chairing, with WA Sea Grant Education Specialist Maile Sullivan, the upcoming summer 2015 NW Aquatic and Marine Educators Summer conference, which will be held at UW in Seattle July 20-24 2015

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

- NANOOS sponsored and was an exhibitor at the annual PCSGA conference in the fall of 2014, providing information and demonstrations of the NVS Shellfish App to conference attendees. Newton also presented on the status of OA and OA monitoring efforts of interest to shellfish growers.
- In October, J. Allan presented on NANOOS and the new NVS Climatology App "Developing regional climatology products for the NANOOS region" at the NW Marine Technology Summit held in Newport OR.
- NANOOS provided the "Great Build a Buoy Challenge" activity at Seattle Aquarium's Discover Science Weekend. The buoy challenge was again wildly popular among attendees with non-stop buoying throughout the day. Over 2,700 adults and kids visited the Aquarium on the day of the Great Build a Buoy.
- Newton provided OA talks to numerous interested regional groups including marine managers, shellfish growers, and at an EcoBuilding conference (see presentations).
- NANOOS continues efforts on social media, regularly posting on Facebook with news, pictures, and interesting data. Vander Giessen continues to update the NANOOS blog (http://www.nanoos.org/education/blog/blog.php) posting on field maintenance work and research cruises and is working to gather blog post contributions from NANOOS collaborators.
- Sprenger and Vander Giessen continue to update content on the NANOOS portal.
- M. Haller was interviewed in *Civil Engineering Magazine* ("Ocean-Monitoring Radar Could Be Lifesaver for Shipping Vessels", November, 2014) and was also featured in the university publication OSU College of Engineering *Momentum!* ("Keeping ships safe at sea by tracking hazardous waves," December 2014).

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 participates in their teleconferences. During 4-7 November, Martin and Newton participated in IOOS Association and IOOS Fall meetings in National Harbor, MD, which covered a wide range of national and regional IOOS-related issues. Newton and Martin held annual NANOOS meetings for all PIs and the Governing Council in Vancouver, WA on 11-12 August 2014. Martin served as Chair of the NANOOS Board during the GC Meeting.

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 (CMOP), 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 5th and 6th and in the CMOP All-Hands meeting 6-7 October, 2014. Newton continued to develop education opportunities for at-sea training with the Northwest Indian College (NWIC) through CMOP. 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.

For coordination within IOOS, over the period, 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 includes: the Sea Grant post-doc, Laura Lilly's work on ocean acidification and marine debris; coordination with AOOS, CeNCOOS, SCCOOS and PacIOOS on the IPACOA data portal; and participation advising the COMT effort. Newton also presented at the RAE/TCS giving an IOOS lightning talk for Coastal Resilience, Stormy Weather on 4 Nov in National Harbor, MD.

Newton participated in November with the IOOS PO and SCCOOS on a call and drafting a product highlighting the importance of NDBC buoy 46089 to several PNW user groups including maritime operators, such as the Columbia River Bar Pilots, fishers, coastal zone managers, and others.

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

Martin participated in the semi-annual meeting of the Ocean Networks Canada (ONC) International Science Advisory Board (ISAB) on 24-26 June. ISAB 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.

NANOOS PI Barth helped propose a new PICES (North Pacific Marine Science Organization) Advisory Panel on "North Pacific Coastal Ocean Observing Systems" which was approved in October 2014. He will serve as a U.S. member of the Advisory Panel. Also at PICES, Barth presented a "10-y NANOOS Retrospective" for J. Newton, providing an overview of NANOOS achievements and products.

NANOOS PI Barth served on the International Scientific Committee, moderated a panel on "The dawn of the robotic exploration of our planet ocean," and co-chaired a scientific session on "Transforming our understanding of ocean processes through new technologies" at the 2nd International Ocean Research Conference held in Barcelona, Spain, November 16-21, 2014.

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 re west coast US and Canadian OA issues and effects.

Newton represented IOOS and NANOOS in several high-level ocean acidification events, promoting OA observing systems of NANOOS, IOOS, and GOA-ON (Global OA Observing Network http://www.goa-on.org/), stressing the need for integration of local through global observing systems and the work underway at each of these levels. These events included: attending Secretary of State John Kerry's "Our Ocean" Conference - June 17-18th, Washington DC; presenting at US Dept of State OA Roundtable - 21 August, Washington DC on "Ocean Acid: Understanding Problems and Policy Responses, Responding to Challenges: Non-USG Role and Actors"; presenting at UN SIDS Conference OA Workshop: State of the Science Considerations for SIDS - August 28-29, Apia, Samoa; presenting at UNESCO IOC side event - "Coping and Adapting to Ocean Threats for Resilient SIDS" and giving a GOA-ON intervention at UN SIDS Conference: Ocean, Seas and Biodiversity Partnership Dialogue, Sept 1-3, Apia, Samoa. She also spoke regionally at shellfish growers events including a Marine Managers and Shellfish Growers Workshop (Sept 10) and the PCSGA meeting (Sept 23-4) and nationally at the RAE National Summit on OA Observing Systems, Local to Global (Nov 3).

Mickett presented NANOOS data at the NW Power and Conservation Council Ocean Forum on Nov 18.

Newton was invited to attend press events with Senator Cantwell, at the USCG base in Port Angeles on 8 August (with NANOOS PI Kosro) and at NOAA PMEL Sand Point on 10 August. She was asked to speak

on IOOS and OA efforts at the 10 August event, with media reports on TV, radio, and newspapers. She also was requested to brief Kilmer, Heck and Cantwell staff over the reporting period.

Additional NANOOS coordination on various scales:

Newton was requested to participate in the Coastal States Organization conference on 1-2 October, providing brief comments on IOOS before dinner.

Newton participated in NWFSC HAB Stakeholders meeting held in Seattle, on 26 June 2014.

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/. Also during the reporting period Newton continued to represent NANOOS in regional efforts, e.g., C-CAN, 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 November 2014. She participated in a NOAA NWFSC webinar on coastal indicators for OCNMS.

Newton completed the GOA-ON Plan: http://www.goa-on.org/.

Newton serves on the MEOPAR International Science Advisory Committee to provide advice and find synergies between IOOS and MEOPAR.

Newton, a member of the Scientific Advisory Committee of the Joint European Research Infrastructure Network for Coastal Observatories (JERICO), reviewed Trans National Access (TNA) proposals.

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. NANOOS succeeded in meeting our milestones for this period.

4) Personnel and Organizational Structure

In July 2014, NANOOS PI Matthew Alford left his position at APL-UW to take a permanent position at Scripps Institution of Oceanography. The task he co-led with NANOOS PI John Mickett, the WA coastal buoy operations, is now being solely implemented by Mickett. We will miss Matthew's input but there are no implications for operations from this move. We appreciate Mickett's increased leadership on this task. NANOOS gained Western Washington University (WWU) as a new member. There were no other changes in key scientific or management personnel for this period.

6) Budget Analysis

With an award start date of 1 June 2011 and end date of 31 May 2016, as of 30 November 2014 we are 70% of the way through the project. The full project award amount to date is $10,601,208 and the total amount spent as of 30 November 2014 is $8,407,263. This means at 70% of the project time, 79% of the awarded funds have been spent. These percentages (70% and 79%) match reasonably well, indicating that spending is commensurate with our plan. We anticipate that NANOOS will maintain its budget accordingly. Of the remaining $2,193,945 balance, $1,525,193 is committed as encumbrances ($1,510,355 is committed to subcontracts to major collaborators). 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:

Adam, K. and J.A. Barth. What's driving intraseasonal cross-shelf variability of near-bottom hypoxia: shelf or slope processes? Eastern Pacific Ocean Conference, Sept. 17-20, 2014. Mt Hood, OR

Allan, J., C., Risien, and T. Tanner. Developing regional climatology products for the NANOOS region. Northwest Marine Technology Meeting, Oct 20-22, 2014. Newport, OR

Baptista, A. You need the results when? Place-based estuarine science with global societal implications. 2nd International Ocean Research Conference, November 17, 2014. Barcelona, Spain

Baptista, A. The Columbia River Basin. JPAC Public Forum: "North America's Coasts in a Changing Climate," November 6, 2014. Arlington, VA

Baptista, A. The Columbia River as a river-dominated bioreactor: A data informed *in silico* exploration. 61st Annual Eastern Pacific Ocean Conference, September 18, 2014. Timberline Lodge, Mt. Hood, OR

Baptista, A.M., T., Karna, J.E. Lopez. Lessons learned from pushing a circulation model to the brink. 13th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM), Keynote, August 26, 2014. Lisbon, Portugal

Barth, J.A. What goes on beneath the waves and when we're not watching. PICES Annual Meeting, Oct.16-26, 2014. Yeosu, Korea

Barth, J.A. Using autonomous underwater gliders to observe continental margins and oceanic boundary currents. PICES Annual Meeting, Oct. 16-26, 2014. Yeosu, Korea

Barth, J.A., F. Chan and S.D. Pierce. Understanding and predicting hypoxia over the continental margin in the northern California Current. 2nd International Ocean Research Conference, Nov. 16-21, 2014. Barcelona, Spain

Haller, M. was an invited guest speaker at the monthly Industry Breakfast, U.S. Coast Guard Marine Safety Unit, Nov. 20, 2014. Portland, OR

Kärnä, T., A.M. Baptista. Wanted: Modern unstructured-grid regional circulation model. 13th International workshop on Multiscale (Un)-structured mesh numerical Modeling for coastal, shelf, and global ocean dynamics (IMUM). August 25, 2014. Lisbon, Portugal

Kim, S.Y., P. M. Kosro and A.L. Kurapov. Evaluation of directly wind-coherent near-inertial surface currents off Oregon using a statistical parameterization and analytical models. 61st annual Eastern Pacific Ocean Conference (EPOC) 2014, Sept. 17-20, 2014. Timberline, OR

Kurapov , A.L., S. Durski , J.S. Allen, G.D. Egbert, P.M. Kosro, R.K. Shearman, J.A. Barth. Coastal ocean variability in the US Pacific Northwest region influenced by the 2009-2010 El Niño. 61st annual Eastern Pacific Ocean Conference (EPOC) 2014, Sept. 17-20, 2014. Timberline, OR

MacCready, P., R. Fatland, W. Ye, N. Oscar. Ocean Modeling: Using the Cloud to Connect Science & the Public. Microsoft Research Faculty Summit, July 15, 2014. Redmond WA

Mayorga, E. and C. Risien. West Coast IOOS Regional Associations Updates: NANOOS. West Coast Ocean Data Network Meeting, Nov. 3-4, 2014. Costa Mesa, CA

Mickett, J. (for J. Newton). OA Updates from WOAC and NANOOS. Ocean and Plume Science Management Forum, Nov. 18, 2014. Portland, OR

Newton, J., J. A. Barth, D. L. Martin, P. M. Kosro, J. Allan, E. Mayorga and many NANOOS Colleagues. Ten-year retrospective of the Northwest Association of Networked Ocean Observing Systems (NANOOS). PICES Annual Meeting, Oct. 16-26, 2014. Yeosu, Korea

Newton, J. Ocean Acidification in Pacific Northwest Waters, Puget Sound Science Panel, Western Washington University, June 3, 2014. Bellingham, WA; also for San Juan Institute, June 25, 2014. Friday Harbor, WA; and for EcoBuilding Conference, October 10, 2014. Seattle, WA

Newton, J. Ocean Acidification 101, OA in PNW waters, and how to access and use IOOS OA data, Educator workshop, August 15, 2014. Seattle, WA

Newton, J. Responding to the Challenge: local through global perspectives, Ocean Acid: Understanding Problems and Policy Responses, Responding to Challenges: Non-USG Role and Actors, August 21, 2014. Washington, DC

Newton, J. The Global Ocean Acidification Observing Network, UN SIDS Conference OA Workshop: State of the Science Considerations for SIDS, August 28, 2014. Apia, Samoa

Newton, J. The Global Ocean Acidification Observing Network, UN SIDS Conference UNESCO IOC side event: Coping and Adapting to Ocean Threats for Resilient SIDS, Sept 1, 2014. Apia, Samoa

Newton, J. UN SIDS Conference UN SIDS Conference: Ocean, Seas and Biodiversity Partnership Dialogue, Sept 3, 2014. Apia, Samoa

Newton, J. Ocean Acidification: Washington's Response, Marine Managers and Shellfish Growers Workshop, Sept 10, 2014. Friday Harbor, WA

Newton, J. Turning the Headlights on High: Improving Ocean Acidification Observing Systems in Support of Pacific Coast Shellfish Growers, Pacific Coast Shellfish Growers Association (PCSGA) meeting Sept 23, 2014. Vancouver, WA

Newton, J. Carbon chemistry observations in the Salish Sea: evidence for upwelling influence and implications of sills for OA effects, 61st annual Eastern Pacific Ocean Conference (EPOC) 2014, Sept. 18, 2014. Timberline, OR

Newton, J. Ocean Acidification Observing Systems, Local to Global, Restore America's Estuaries/The Coastal Society National Summit, November 4, 2014. National Harbor, MD

Newton, J. NANOOS - Stormy Weather: Using Observations to Lower Risks in the Pacific Northwest, Restore America's Estuaries/The Coastal Society National Summit, November 5, 2014. National Harbor, MD

Pittman, R.W., G.M. Díaz Méndez, D.A. Honegger, M.C. Haller. Wave imaging marine radar for Maritime Operations. NW Marine Technology Summit, Oct. 20-22, 2014. Newport, OR

Publications:

Adams, K.A., J.A. Barth and F. Chan, 2013. Temporal variability of near-bottom dissolved oxygen during upwelling off central Oregon. Journal of Geophysical Research, 118, doi:10.1002/jgrc.20361.

Baron, H.M., P. Ruggiero, N.J. Wood, E.L. Harris, J. Allan, P.D. Komar, and P. Corcoran, 2014. Incorporating climate change and morphological uncertainty into coastal change hazard assessments. Natural Hazards, doi: 10.1007/s11069-014-1417-8.

Kärnä, T., A.M. Baptista, J.E. Lopez, P.J. Turner, C. McNeil, T.B. Sanford. (revised Dec 2014). Numerical modeling of circulation in high-energy estuaries: A Columbia River estuary benchmark. Ocean Modelling, in review.

Kim, S.Y, P.M Kosro, and A.L. Kurapov, 2014. Evaluation of directly wind-coherent near-inertial currents off Oregon using a statistical parameterization and analytical and numerical models. Journal of Geophysical Research, 119(10): 6631-6654, doi: 10.1002/2014JC010115.

Mazzini, P.L.F., J.A. Barth, R.K. Shearman and A. Erofeev, 2014. Buoyancy-driven coastal currents off the Oregon coast during fall and winter. Journal of Physical Oceanography, 44, 2854-2876.

Mull, J. and P. Ruggiero, 2014. Estimating storm-induced dune erosion and overtopping along U.S. West Coast beaches. Journal of Coastal Research, 30(6), 1173-1187, DOI: 10.2112/JCOASTRES-D-13-00178.1.

Newton, J.A, J. Allan, and T. Tanner, 2014. Recent NANOOS contributions to maritime operations and boater traffic. Sidelights, Council of American Master Mariners, Vol. 44, No 3, http://www.mastermariner.org/sidelights/Sidelights_June-Aug2014.pdf

Newton, J.A., R.A. Feely, E.B. Jewett, P. Williamson, and J. Mathis (2014): Global Ocean Acidification Observing Network: Requirements and Governance Plan, First Edition, IAEA, http://www.goa-on.org/docs/GOA-ON_Plan_final_Sept_2014.pdf

Osborne, J.J., A.L. Kurapov, G.D. Egbert, and P.M. Kosro, 2014: Intensified Diurnal Tides Along the Oregon Coast. Journal of Physical Oceanography, 44(7): 1689-1703, doi:10.1175/JPO-D-13-0247.1.

Washington State Department of Ecology. 2014a. Eyes Over Puget Sound, Surface Conditions Report, June 23, 2014. Ecology Publication No. 14-03-074. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2014_06_23.pdf

Washington State Department of Ecology. 2014b. Eyes Over Puget Sound, Surface Conditions Report, July 28, 2014. Ecology Publication No. 14-03-075. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2014_07_28.pdf

Washington State Department of Ecology. 2014c. Eyes Over Puget Sound, Surface Conditions Report, August 18, 2014. Ecology Publication No. 14-03-076. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2014_08_18.pdf

Washington State Department of Ecology. 2014d. Eyes Over Puget Sound, Surface Conditions Report, September 16, 2014. Ecology Publication No. 14-03-077. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2014_09_16.pdf

Washington State Department of Ecology. 2014e. Eyes Over Puget Sound, Surface Conditions Report, October 29, 2014. Ecology Publication No. 14-03-078. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2014_10_29.pdf

Washington State Department of Ecology. 2014f. Eyes Over Puget Sound, Surface Conditions Report, November 17, 2014. Ecology Publication No. 14-03-079. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2014_11_17.pdf

Zhang, S., M.H. Alford and J.B. Mickett, 2014. Characteristics of Nonlinear Internal Waves on the Washington Continental Shelf. Journal of Geophysical Research, submitted.

Sustaining NANOOS, the Pacific Northwest component of the U.S. IOOS®:
NOAA Award: NA11NOS0120036
December 2014 Progress Report Annual Supplemental
(The information request from IOOS Program office is underlined and in quotes)

- **Products and Services**

"The number and brief description of contributions to new or improved regional products or services, and national products or services:"

During 2014, NANOOS offered four new or improved regional products/services.

1. NANOOS Visualization System (http://nvs.nanoos.org/Apps): NANOOS released five updates to the NVS platform. These included v3.2, which added additional content to the NVS help content along with improvements to the Timeline feature; v3.3 added a new 'Boaters' app (introduced below); v3.5 resulted in minor updates to the NVS coding; v3.7 provided enhancements to the NVS layout; and v3.8 introduced a new 'Climatology' web app (introduced below). See our Progress Reports for more information on NVS and its associated apps.
2. PNW Boaters (http://nvs.nanoos.org/Boaters): This web app, accessed through NVS, was designed expressly for recreational boaters. The app provides easy access to a number of sensors (including measured tides) located at various tide gauges as well as a variety of climate overlays; a number of the overlays depict model results, which are displayed for locations throughout the Pacific Northwest region. The user is also able to turn on/off NOAA's nautical charts and identify marina locations throughout the NANOOS region. Finally, a major addition is the inclusion of a new Tides 'situational awareness' feature that depicts the current tide elevation imbedded in a rising or falling icon. The Tides overlay is also linked directly to the timeline enabling the user to access future tide forecasts, the values of which are updated in the NVS Google maps for all stations where forecasts are available.
3. 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. The web app consists of two components:

- Climatologies derived for selected NDBC (9) and C-MAN (5) stations based around the following core parameters: air and water temperature, wind speed, barometric pressure, significant wave height and peak spectral wave period. The plots depict simple statistics such as daily means and standard deviations ($\pm 1\sigma$ and $+2\sigma$); and,
- Ocean overlays depicting:
    - Monthly averages of chlorophyll and sea surface temperatures derived from MODIS satellite data, NCEP North American Regional Reanalysis (NARR) 10m winds and mean sea levels derived from AVISO satellite altimetry data, averaged over the length of the data to depict seasonal changes; and,
    - Monthly changes (expressed as anomalies) in chlorophyll and sea surface temperatures derived from MODIS satellite data (2002-present), NCEP North American Regional Reanalysis (NARR) 10m winds (1993-present), and AVISO sea level heights (1993-present). These latter data show monthly deviations in the observed parameter relative to the long-term mean.

4. IPACOA: The IOOS Pacific Region Ocean Acidification Data Portal (http://www.ipacoa.org/) is a new regional portal enabling access to sensors measuring changes in seawater chemistry (parameters measured include: CO_2 measured in both the air and in water, pH, Salinity, and water temperature) within the Pacific Basin. This portal was funded by U.S. IOOS, with data streams contributed by 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 through NOAA's Ocean Acidification Program (OAP) and Pacific Marine Environmental Laboratory (PMEL).

4. **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 2014 NANOOS made steady progress towards a standards-based foundation for its DMAC capabilities. Its DMAC compliant service-oriented architecture was upgraded and expanded. THREDDS servers at OSU and CMOP-OHSU were upgraded; ROMS model output from OSU (C. Risien) were registered with the IOOS Catalog, and irregular-grid SELFE model output were enhanced and will be registered in early 2015 (C. Seaton). An IOOS 52North SOS was deployed initially in Spring, holding observing assets, and upgraded later in the year. Ongoing enhancements are being made to this SOS service to expand its coverage and DMAC compliance. NANOOS also worked with NGDC and IOOS to help advance IOOS capabilities to handle OGC WMS cataloging at the NGDC GeoPortal and IOOS Catalog, based on refinements of our GeoServer instance. While NANOOS operates a distributed service architecture, its more centralized services (hosted by UW) were reorganized this year to be served from a new, stable domain name at http://data.nanoos.org; these include http://data.nanoos.org/52nsos/sos/, http://data.nanoos.org/geoserver/, the root metadata Web-Accessible Folder (WAF) http://data.nanoos.org/metadata/, and the technology-demonstration ERDDAP implementation of Animal Acoustic Telemetry standards at http://data.nanoos.org/deverddap/.

Observing and model output service offerings by NANOOS were progressively upgraded to use the full suite of IOOS controlled vocabularies, including CF standard names, IOOS Parameter Vocabulary, Ocean Acidification vocabulary, and asset metadata vocabularies adopted by IOOS. NANOOS DMAC Chair E. Mayorga continued to make contributions towards the advancement of these vocabularies within IOOS by refining vocabulary documentation, contributing to discussions, and providing Python code examples that demonstrate the use of vocabulary services hosted by the Marine Metadata Interoperability (MMI) project.

In addition to improved metadata availability via services and datasets registered with the IOOS Catalog, NANOOS has been one of the main technical contributors 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 NANOOS has helped advance the development and adoption of community best practices for use of ISO 19115-1 and 19115-2 metadata for ingestion by the West Coast Ocean Data Portal catalog (WCODP, http://portal.westcoastoceans.org) and re-serving via the WCODP OGC CSW catalog endpoint, particularly with regards to ocean observing data for use by the geospatial and marine spatial planning communities. Our support to the WCODN helped enhanced the use of OGC WMS (including temporal WMS, "WMS-T") by both service providers and the newly released WCODP Marine Viewer client (http://maps.westcoastoceans.org).

NANOOS also provides access to NDBC to many of its IOOS-supported observing assets, for redistribution to the WMO GTS.

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. S. Uczekaj (Boeing) served on the IOOS DMAC Steering Committee in the first half of the year, until the Committee was restructured. E. Mayorga was a co-presenter on the Feb and May IOOS DMAC monthly webinars – on Python tools for ocean data access (with Rich Signell, USGS), and CUAHSI HIS and the Water Data Center (with Rick Hooper, CUAHSI Director), respectively. We also continued our contributions to IOOS DMAC community implementation activities, including an active role in the IOOS Github repositories, and collaborative development and dissemination of Python tools for convenient IOOS data access. Early in the year E. Mayorga worked with SECOORA to test, document, enhance and disseminate good practices for the IOOS-supported PyOOS package; he later provided code contributions to PyOOS. Mayorga also collaborated with Rich Signell (USGS) to develop best practices and accessible code examples using online IPython notebooks, and configurations for replicating IOOS-friendly Python environments; this work helped set the stage for the subsequent IOOS System Integration Test activity. Finally, NANOOS also contributed to discussions and trouble-shooting on other topics, including IOOS Catalog ingestion of 52North SOS end points.

- **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 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 listing of recent (3 months) asset updates history 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 both observing (*in situ* and 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. Some variable-depth and depth-profiling sensor data have not been integrated into this service as of Dec. 2014 due to technical challenges, but will be available January 2015.

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, OA assets with modifications include:

1. Seattle Aquarium — started ingesting CO_2 data in April 2014
2. Penn Cove Shellfish — enhanced monitoring with new sensors in August 2014
3. Taylor Shellfish Dabob — new pCO_2 and TCO_2 sensors; aragonite saturation offered online as of Nov 2014
4. PSI Bay Center — new pCO_2 sensor and aragonite saturation online as of November 2014
5. Cha'ba — CO_2 in air and water and pH back online July 2014 after recovery/re-deployment
6. NH10 — CO_2 in air and water and pH online once integrated into the summertime mooring in July 2014 and the wintertime mooring in October 2014
7. South Slough NERRS at CTCLUSI — pH ingested into NVS in August 2014

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).

The data streams can be lumped into three groupings:

1. Burkolator data from shellfish grower sites
2. NOAA OAP/PMEL data
3. Other regional OA data the IOOS RAs are serving.

This portal was created with funding from a FY13 MSI award to NANOOS and was originally intended to serve group 1 data only. However, at the time of implementation, the Pacific IOOS RA Directors elected to include the other two groups, with concurrence from NOAA PMEL. At the time of this report, Pacific Region data from groups 1 and 2 are currently being served by IPACOA. The third grouping will take additional time before it is complete, but can be a national resource for the OA platforms of opportunity or intentional OA assets in the Pacific and could be ported to other regions.