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

NOAA Award: NA16NOS0120019 Reporting period: 6/01/2017 to 11/30/2017

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 FY17 period (= Y2 of this award; Y10 of NANOOS RCOOS operations) our objectives were to:

1) **Maintain NANOOS as the U.S IOOS PNW Regional Association:** Sustain our proven role for regional coordination, administrative infrastructure, and stakeholder engagement, engaging federal and non-federal (tribal, academic, state, local, industry, NGO, etc.) partners.
2) **Maintain surface current and wave mapping capability.** Maintain existing HF-radar foundational capability providing critical national capacity; continue, to the extent possible, existing investment in wave mapping at critical ports.
3) **Sustain existing buoys and gliders in the PNW coastal ocean, in coordination with national programs.** Maintain these essential assets providing regional observations, with focus, to the extent possible, on hypoxia, HABs, ocean acidification (OA), climate change detection.
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. Sustain observing ability including to the extent possible, hypoxia and OA.
5) **Maintain core elements of beach and shoreline observing programs.** Contribute to hazard mitigation by providing, to the extent possible, essential observations and better decision support tools for coastal managers, planners and engineers.
6) **Provide sustained support to a community of complementary regional numerical models.** Contribute, to the extent possible, 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.
7) **Maintain NANOOS' Data Management and Communications.** Sustain, to the extent possible, the DMAC system NANOOS has built, including the NANOOS Visualization System (NVS), for dynamic and distributed data access and visualization for IOOS.
8) **Continue to deliver existing and, to the extent possible, create innovative and transformative user-defined products and services for PNW stakeholders**. Continue our NVS innovation to succeed in this vital translation: meaningful and informative data products that connect with user applications and serve society.
9) **Sustain NANOOS outreach, engagement and education.** Foster ocean literacy and facilitate use of NANOOS products for IOOS objectives, the core task for which NANOOS was constructed, via existing approaches for engaging users and increasing ocean awareness.

NANOOS has the following additional task during FY17 from the NOAA Ocean Acidification Program, coordinated via IOOS:

10) Support collection of OA measurements on our La Push, WA [J. Newton, J. Mickett, UW] and Newport, OR [B. Hales, OSU] 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 its objectives outlined above. NANOOS maintained the RCOOS subsystems it has developed, implemented, and integrated with NOAA IOOS funding and substantial external leverage. NANOOS remained focused on delivering data-based products and services that are easy to use to diverse stakeholders to address high-priority issues and aid decision making. NANOOS continued its proactive interactions and regional coordination with a wide range of PNW stakeholders, to prioritize and refine our observations, products, and outreach efforts as funding allowed.

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

Table 1. NANOOS Milestones for FY 17:

Area	**Y2 Award = Y11 NANOOS**
Observations	
Shelf:	-Maintain La Push buoy; deliver NRT data streams via NANOOS Visualization System (NVS) -Support collection of OA data from La Push buoys with NOAA OAP funding -Maintain Newport buoy; deliver NRT data streams via NVS -Support collection of OA data from NH-10 buoys with NOAA OAP funding *-Maintain Columbia R. buoy; deliver NRT data streams via NVS* -Maintain N CA shelf glider transect; deliver data via NVS -Bring all data QA/QC to meet Certification standards
Estuaries:	*-Maintain Puget Sound estuarine moorings; deliver data via NVS* -Maintain US-Canada ferry-box; deliver data via NVS -Maintain Columbia R. estuarine moorings; deliver data via NVS *-Maintain South Slough estuarine moorings; deliver data via NVS* -Bring all data QA/QC to meet Certification standards
Shorelines:	-Maintain shoreline observations in OR; deliver data via NVS -Maintain bathymetric observations in WA and OR; deliver data via NVS -Bring all data QA/QC to meet Certification standards
Currents:	-Maintain OR Priority-One HF radar sites to the national operations standard; deliver data via NVS and the National HF Radar system -Maintain X-band radar sites; deliver data via NVS -Bring all data QA/QC to meet Certification standards

Modeling	
OR/WA estuaries and coast models	*-Maintain modeling & forecasting capabilities at UW at reduced level; make model output available via NVS* *-Maintain modeling & forecasting capabilities at OHSU at reduced level; make model output available via NVS* *-Maintain modeling & forecasting capabilities at OSU at reduced level; make model output available via NVS* *-Model verification and validation*
DMAC	
Web Site Improvement	*-Sustain & enhance existing data streams, IOOS web services, GTS submission* *-Sustain, refresh and enhance hardware and software environment; appropriate staffing; and operations documentation* -Initial, limited implementation of NCEI data archiving, Glider DAC submission, QARTOD -Engage new local providers (not NANOOS funded), integrate their data into NVS and IOOS DMAC services, and assist with their data management & workflows -Strengthen DAC capabilities and resources through regional and thematic partnerships -Deploy ERDDAP to leverage web services, serve NANOOS applications and users -Sustain participation in IOOS DMAC community activities, including QARTOD development, semantic mapping, OGC WMS/WFS support, climatology data development, UGRID support, and shared code development and testing -Engage and leverage OOI and NSF EarthCube, international GOA-ON activities and Canadian collaborations -Engage West Coast and Pacific efforts, including WCGA and IPACOA -Improve ease of usability and user tracking capabilities *-Develop and implement user customization and notification capability on NVS* *-Depth vs. time plots and multivariate plotting*
Tailored Product Development	-Climatology and Tsunami resilience apps *-Tsunami mobile app re-build* -With E&O committee, evaluate usefulness of web and product suite
Education and Outreach	
Networking	-Maintain existing and build new relationships to stakeholder user groups and the education community enabling NANOOS to achieve affective outreach, engagement, and education *-Engage with regional formal education communities to use ocean observing and NANOOS products to support STEM education.*
Product Development	-Work with DMAC and User Products Committee on tailored product development to meet specific user needs, as per above, and through Tri-Committee meetings; for each new product engage users in product development. *-Evaluate website and product suite annually; interpret evaluation results with recommendations discussed at weekly Tri-Com tag-up calls*
User Engagement	-Gain feedback and conduct self-assessment after product release.

	-Conduct trainings to broader user groups and evaluate trainings to optimize NANOOS help functions -Engage with regional non-formal education communities to facilitate the use of NANOOS products to engage citizens to increase their ocean literacy. *-Maintain up-to-date success stories, employing effective use of social media* *-Be responsive to regional and local events (e.g., blooms, floods, etc.) to enhance relevancy to public and highlight regional stories with NANOOS members and partners.* -Support national communication through IOOS Program Office and IOOS Association collaborations.
Administration	
Meetings	*-Represent NANOOS at IOOS Program Office and IOOS Association meetings, and at national meetings of significance (e.g., Oceans 20xx, or bi-annual meetings of CERF and Ocean Sciences).* *-Engage at a regional level at meetings and workshops affecting PNW stakeholders and NANOOS.* *-Conduct annual GC meeting.*
Project oversight	-Provide NANOOS with oversight, coordination, and management of the full suite of activities that comprise NANOOS. *-Share project evaluation at the annual PI meeting.*
Coordination	*-Assure that NANOOS has transparent, effective, and representational governance via its Governing Council and the NANOOS Executive Committee composed of its elected Board and its functional committee chairs.* *-Assure these bodies are engaged in NANOOS prioritization of regional needs, work effort, and product development.* -Assure balance of stakeholders represented in NANOOS reflects the diversity found in PNW. *-Conduct annual all-PI meetings and Tri-Committee meetings, providing clear feedback and direction.* *-Coordinate with West Coast RAs and other RAs to optimize and leverage capabilities and assure consistencies.* -Engage in sub-regional and user-group specific workshops to aid coordination and optimization of effort.
Accountability	-Submit required IOOS progress reports and respond to other requests. *-Seek certification as a Regional Information Coordination Entity of US IOOS.*

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

• ***Shelf***

***Washington Shelf Buoy*:** The Washington Coast buoy observation program, led by J. Mickett, Applied Physics Laboratory, University of Washington (APL-UW), continued to maintain and operate two real-time moorings 13 miles NNW of La Push, Washington. During much of this reporting period the two moorings remained deployed and operating, with both moorings successfully recovered on October 16th. Data coverage over this period was near 95% for both moorings, with the only problems

involving a firmware bug in a new wind-direction compass on Cha'Ba and several data gaps in MP profiler data on the subsurface mooring due to a sheared motor pin. On Cha'Ba, compass issues were resolved with an on-site visit in July. For the second summer, with IOOS-OTT funding a real-time HAB detection system (Environmental Sample Processor) was integrated with the subsurface mooring for two of three sub-deployments (May 1- July 10 and Sept 5-October 16). Again, these deployments were highly-successful with real-time HAB information and associated environmental conditions available on the NANOOS website. Also as part of the latter OTT work, we organized and carried out several outreach events in the Native coastal communities, one involving roughly 50 Quileute elementary school students visiting the R/V *Robertson* and learning about the subsurface mooring on September 4.

During this period, we also carried out several operations to recover gear lost in 2016. In July PI Mickett and Quileute biologist and volunteer J. Hagen joined Olympic Coast National Marine Sanctuary (OCNMS) partners on the R/V *Nautilus* to recover more than $50k in lost instrumentation using R. Ballard's/URI's "Hercules" ROV. In early October Mickett and team traveled to Vancouver Island to successfully recover the hull, mooring controller and several instruments from the original Cha'Ba buoy, which broke free during the fall of 2016. A clean break in the mooring cable suggested a break from extreme tension—possibly due to a vessel or tow getting caught on the mooring.

Observational highlights include 1) the real-time detection of near-bottom hypoxia in late summer by the subsurface mooring, which augmented OCNMS sampling efforts, 2) detection of high levels of the toxin domoic acid (DA) with the ESP in both the spring and fall deployments, and 3) capturing the pH, DO, and temperature and salinity signatures of a strong Columbia River plume event in June. As these plume events diverge greatly from typical DO-pH relationships seen on the shelf, capturing this event will help us to better understand factors controlling carbon chemistry on the shelf.

Lastly, using supplemental funding in September we began the construction of a new "winter Cha'Ba" buoy to allow year-round mooring deployments. This mooring is due to be deployed in early January from the R/V Thompson.

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 data streams and provide calibration samples for NOAA OAP-IOOS Ocean Acidification Monitoring. Sensor data have been transmitted to the NOAA OA and PMEL Carbon Programs and to NANOOS. Using Cha'Ba data, Washington Ocean Acidification Center (WOAC) postdoc Dr. Beth Curry has continued work with the PMEL Carbon Group to test pH proxies on the Washington Shelf. Newton and Mickett have also continued to work closely with both the Olympic Coast National Marine Sanctuary and coast First Nations (Quileute) in maintaining and operating the two moorings, with the Quileute Marine Biologist, J. Hagen participating several deployment cruises and the R/V *Nautilus* gear recovery operation. The Sanctuary, in addition to providing ship time on the R/V *Nautilus*, provided generous support in helping to provide on-site assistance with communications on the NEMO ESP mooring.

A summary of the 2016 observations collected by these moorings were submitted for inclusion in the 2016 Puget Sound Marine Waters Report.

Oregon Shelf Glider Starting in early December 2014, the Oregon State University glider research group has been obtaining vertical sections of ocean properties from off Trinidad Head, CA (41° 3.5'N) using an underwater glider. We used a 1000-m capable Seaglider equipped with the following sensors: CTD, dissolved oxygen (Aanderaa 4831 optode), light backscatter (700 nm), chlorophyll fluorescence and Colored Dissolved Organic Matter (CDOM) fluorescence (WET Labs Ecopuck). The gliders also measured depth-averaged velocity which can be combined with geostrophic estimates of relative velocity to get absolute velocity and hence transport. The glider was flying from approximately the 100-m isobath (~10km offshore) to 130W (~500 km offshore), repeating the line every 30 days. We collaborated with Dr. Eric Bjorkstedt (NOAA Southwest Fisheries Science Center, Humboldt State University) to facilitate field work off Trinidad Head. We used two of our Seagliders in order to "hot swap" them on the line when their batteries run low. During this reporting period, this effort was jointly funded by NANOOS and CeNCOOS.

From its first occupation of the TH line on December 4, 2014, until the end of this reporting period (11/30/2017), the glider was on the TH line for 1191 days during seven deployments, sampled along approximately 22,000 km of track line covering the transect about 85 times, and collected about 10,000 vertical profiles of ocean properties. For the reporting period 6/1/2017 to 11/30/2017 the glider was on the TH line for 159 days during two deployments, sampled along nearly 3000 km of track line covering the transect about 9 times, and collected about 1310 vertical profiles of ocean properties. The glider "uptime" was 99%. Data are being sent in near real-time to the IOOS Glider Data Acquisition Center and, simultaneously, to the CeNCOOS and NANOOS data centers. When an individual glider deployment is complete, we submit the data to NODC.

Due to lack of full funding for year-round glider operations since 2015, we suspended glider operations on the Trinidad Head line on November 6, 2017. While NANOOS has been terrific in providing $75K/year in funds, CeNCOOS has steadily decreased their contribution to the present $45K. The OSU glider research group managed to stretch support to provide year-round coverage since December 2014, but can no longer do that. It is uncertain how long the suspension will last, but it will likely last until spring 2018 or even to the start of the next budget period starting June 1, 2018. We are disappointed to break the time series but without additional IOOS funds, we cannot continue operations.

Data from the Trinidad Head glider line are being used to monitor and understand the contributions of both the "Warm Blob" and the 2015-2016 El Niño to the warm anomalies observed in the northeast Pacific over the last several years. After a near-normal summer upwelling season in summer 2016 after the demise of the 2015-2016 El Niño, there remained a lingering warm anomaly, up to 1-degree C, from fall 2016 to summer 2017 off northern California (Figure 1). By October 2017, the water column temperature had returned to average.

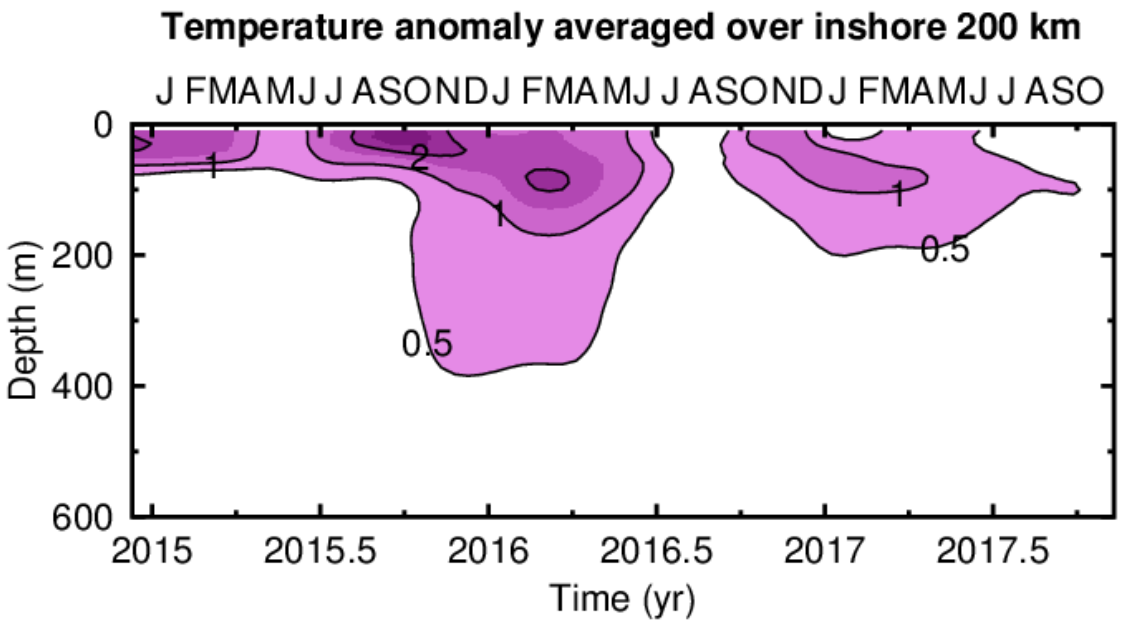

Figure 1. Temperature anomaly off Northern California, from fall 2016 to summer 2017.

Oregon Shelf Moorings: PI for physical oceanography is Mike Kosro (OSU); for pCO_2/biogeochemistry is Burke Hales. The NANOOS long-term Oregon shelf mooring, formerly at NH10, was relocated in June 2017 to a position near 43° 17.6N, 124° 32.2 W, somewhat south of Coos Bay, near the 100m depth contour, as described in the previous report. The mooring, designated CB-06, was deployed on June 10, 2017 at 3:52 UTC and recovered on November 1, 2017, at 15:45 UTC. The mooring configuration was the same as last used at NH10. It reports selected data in near-real-time data through the NANOOS Visualization System (NVS), and provides the same data to NDBC, using the WMO ID of 46128.

Data from the surface meteorological sensors (atmospheric pressure, wind, incoming solar radiation), ADCP current data at selected depths, near-surface water temperature and salinity, and buoy diagnostics (e.g. battery voltage, buoy heading, buoy GPS location) were buffered at 10-minute resolution and telemetered to shore in near real-time. This buoy also carried the MAPCO2 suite of biogeochemical sensors, provided by NOAA/PMEL and overseen by Burke Hales' group; these sensors also reported in near-real-time via Iridium satellite transmissions. In addition to these near-surface measurements, internally-recording sensors attached to the mooring line between the surface buoy and the anchor captured time series of temperature, conductivity/salinity, and, at 5 depths, pressure. These data were downloaded after the buoy was recovered and returned to OSU.

The mooring held despite significant wave heights exceeding 7m on Oct 19, and current speed exceeding 1 m/s. One instrument, the near-surface CTD, leaked a few drops of water in connection with this event, and will need to be repaired or replaced. Buoy reinstallation is planned for January 2018. In collaboration with Hales' group, we plan to construct a 2nd buoy which should expedite mooring turnaround next spring.

On Aug 15, 2017, Gonzalo Saldías defended his PhD dissertation "Optics, structure and variability of the offshore Columbia River plume". Gonzalo's major professor was Kipp Shearman, Mike Kosro was a member of the committee, and Gonzalo used data from NH10 (and, extensively, data from the glider along the Newport hydrographic line) in his work.

Northern Oregon to Central Washington shelf: Led by A. Baptista (OHSU), the Center for Coastal Margin Observation & Prediction (CMOP) maintains observational assets in the Columbia River coastal margin, with partial support from NANOOS and the National Science Foundation. These assets are anchored on station SATURN-02, a seasonal inter-disciplinary buoy at ~35m depth off the mouth of the Columbia River. SATURN-02 data routinely contribute to model validation, capturing near-field Columbia River plume dynamics. Data also routinely offer local temporal context for NOAA fisheries cruises.

For the reporting period, SATURN-02 was deployed May 26 and recovered October 30. Parameters measured were (a) wind speed, direction and gust, air temperature and atmospheric pressure; (b) water velocity; and (c) the following scalar water parameters: temperature, salinity, dissolved oxygen/oxygen saturation, chlorophyll, turbidity, CDOM, phycoerythrin and (with a partial record) nitrate. Scalar water measurements were made with a new set-up, involving single at-surface sensors and a multi-level pumping system. Levels measured were 1, 6, 11, 16, 21 and 35m below the water surface. An unusually intense mixing event, including full-depth mixing on October 21, occurred between October 19 and 23.

During the reporting period, we also deployed North Head, a temporary 3-level buoy to support NOAA/USACE crab studies near dredged disposal mounds. North Head was deployed for approximately a month (September 14 – October 21), and captured the intense mixing event. Measurements included: (a) wind speed, direction and gust, air temperature and atmospheric pressure; and (b) the following scalar water parameters: temperature, salinity, dissolved oxygen/oxygen saturation, chlorophyll, and turbidity. Scalar water measurements were made with a set-up similar to SATURN-02, but only at three levels: 1, 6 and 14m below the water surface. The station was located at ~15m of water, north of the North jetty.

Additional data are collected by glider operations only as allowed by available funding. No deployment was conducted during the reporting period.

- **Estuaries**

Puget Sound, ORCA Buoy program: Led by J. Mickett, J. Newton, and A. Devol (UW), during this report period ORCA (Oceanic Remote Chemical Analyzer) mooring system continued to undergo significant refurbishment and upgrade, while the field team carried out regular maintenance and repairs to keep this real-time system operational.

During this period the ORCA team was very involved in collaborations with several other groups from UW. In June the team deployed a Scripps Zoocam for much of the summer on the profiling CTD package at Twanoh to investigate water property factors controlling zooplankton behavior and distribution. In September they deployed shellfish cages on the Pt. Wells, Dabob and Carr Inlet moorings as part of an

investigation of the influence of water properties on shellfish growth. Lastly, we collaborated with USGS scientists to test an iron-detection system on the Pt. Wells mooring.

System upgrades includes design and implementing a new power distribution on the buoy controller, increasing the robustness and reliability of power supply and control to the various instruments. We are also working toward bringing all moorings to a version-2 state, which includes an integrated router/cell modem and a new version of the winch control module.

Observations from this period, including water property anomalies, were presented regularly in the bi-monthly Washington Marine Waters update webinar conference calls. ORCA observations continue to be critical to helping us understand how Puget Sound recovers from the unprecedented warm anomalies of 2015 and 2016 and the freshwater anomaly resulting from record-rainfall last winter. At the end of this reporting period, in general most water properties had returned to "normal" levels.

We continued to collaborate with the NOAA PMEL Carbon Group (A. Sutton, S. Alin, R. Feely) to support the deployment of the pCO_2 systems operated on the Twanoh and Dabob Bay moorings through system maintenance and collection of water samples to aid system calibration. Additional collaborations included work with J. Keister and D. Grunbaum of UW Oceanography (Zooplankton Cam), J. Padilla-Gamino of UW Fishery Sciences (shellfish growth), and J. Crucius (UW/USGS).

Washington State estuarine monitoring: Led by C. Maloy and C. Krembs (WA State Department of Ecology), en route ferry-based monitoring is one part of Ecology's extensive long-term monitoring program covering Puget Sound and the coastal estuaries. Ferry monitoring complements Ecology's larger program by focusing on surface processes (e.g., temperature variations, frontal systems, tidal currents, blooms, river plumes etc.), and provides a means of continuously ground-truthing remote sensing techniques to greatly leverage and expand capabilities for Puget Sound environmental monitoring.

Ecology has two sensors (measuring temperature and chlorophyll fluorescence) and a GPS on the *Victoria Clipper IV* passenger ferry vessel that runs twice daily between Seattle and Victoria, BC. Data are uploaded daily to a cloud computing server at: http://138.68.225.121/VictoriaClipper30/level2/ and stored as daily files in a NetCDF database, the repository of the monitoring data. The IP address for data access changed in late June as part of a move to a different server. In addition, uploaded raw data files from 2010 to 2016 were archived whereas pre-2017 level 1 and level 2 files are on the new server. Both updates were necessary to accommodate the quickly increasing data volume.

During the reporting period, chlorophyll fluorescence data associated with algal blooms was finalized and submitted for the 2016 PSEMP Marine Waters Workgroup report. Trends of algal blooms and *Noctiluca* clearing those blooms were compared between 2011, 2012, 2015, and 2016 using fluorescence data and aerial photography (Figure 2). Regarding the monitoring equipment, the battery uninterruptible power supply UPS was replaced, and data loggers' clocks were updated in August to resume a brief break in the data stream.

Ferry observations are powerful tools to capture large scale surface temperature and chlorophyll patterns. Data from regular ferry routes are analyzed in combination with data from Ecology's

monthly water column stations and aerial photographs documenting the extraordinary impacts of global and regional climate variations of recent years.

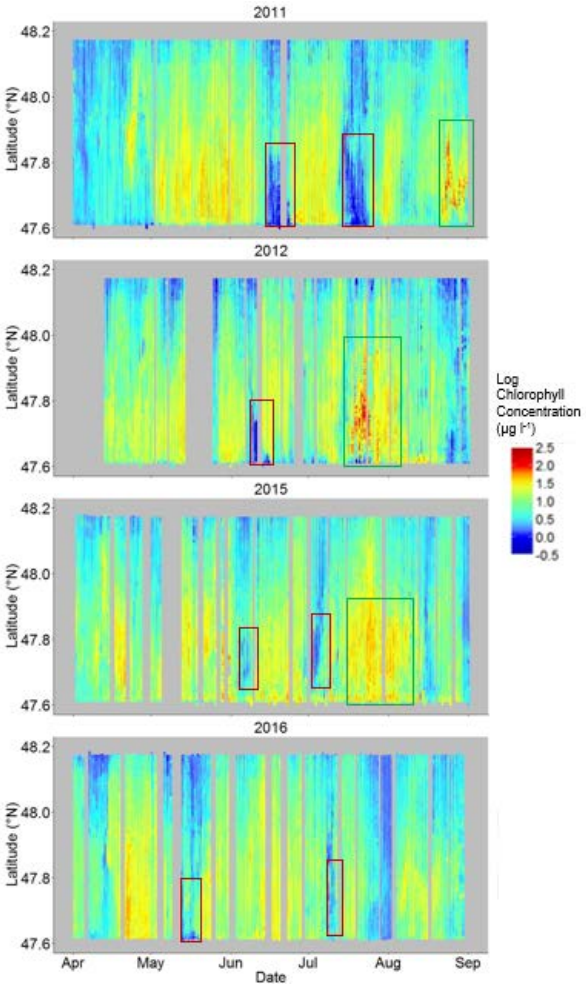

Figure 2. Scatter plots of near-surface chlorophyll measurements along the *Victoria Clipper IV* ferry route between Seattle and Admiralty Sill in 2011, 2012, 2015, and 2016. Red boxes show clearing of chlorophyll and green boxes show increase in chlorophyll. The plots were presented and published in the PSEMP Marine Waters 2016 report which was released in early December 2017.

Columbia River estuarine monitoring: Under the direction of A. Baptista, and with a mix of NSF (through June 30, 2017), NANOOS, and regional-stakeholder funding, CMOP has maintained 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. Joseph Needoba with regional stakeholder funding.

SATURN physical and biogeochemical observations have been extensively used in support (directly or via data-informed modeling) of interdisciplinary (Herfort et al. 2017) and regional science as well as science-informed management and decision making associated with Endangered Species Act biological opinions, salmon restoration, navigation improvements and hydropower operations. The strong symbiosis of

modeling and observations within SATURN was one of the examples used in the development of the recommendation of the IOOS Modeling Task Force (Wilkin et al. 2017).

It is the systemic use of observations in model calibration, validation and enhancement that enables confidence in the use of *in silico* oceanography to address complex estuarine processes such as estuarine regimes and water age (see previous NANOOS reports), estuarine turbidity maxima dynamics (Lopez 2017; also paper in preparation), and local wind-induced circulation (paper in preparation).

As an observational aspect of interest during the reporting period, SATURN estuarine stations appear to respond to the intense October mixing event in the shelf via a reduction of salinity, increase of dissolved oxygen and increase of mixing. This synchronicity is being examined as a possible opportunity for a cross-scale model benchmark.

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

South Slough NERR continued operating a network of moored water quality observing stations as part of the NERRS System-Wide Monitoring Program with additional support provided by NANOOS. Four real-time water quality monitoring stations located along the estuarine salinity gradient provided continuous water temperature, salinity, dissolved oxygen, pH, turbidity, and water level data over the period 06/01/17 –11/30/17 and telemetry transmissions were continuous. Monthly station maintenance, instrument deployments and retrievals, and data management were completed for the weather and water quality stations during the reporting period. The Charleston Bridge station, located on a dock owned by North Bend Oyster Company has been deteriorating over the years and reserve staff identified a suitable pier for relocation, also owned by the North Bend Oyster Company. Currently, no instruments are deployed at the fifth water quality station (Boathouse) due to platform evaluation and assessment.

We maintain one water quality station in partnership with one of our local tribes, the Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians (CTCLUSI). This station, North Spit BLM, is located in lower Coos Bay (NESDID ID # 346F229A; sosnswq) and data are available via the NVS. Real-time data transmissions were continuous for the reporting period.

The South Slough water quality stations provide real-time data access for shellfish growers in South Slough, including North Bend and Coos Bay Oyster Companies, Clausen Oysters, and Qualman Oyster Farms. The South Slough Reserve and CTCLUSI stations also provide environmental data for research, monitoring and education programs conducted at the reserve. During this reporting period, data from SWMP/NANOOS stations were incorporated into the Oregon Ocean Acidification and Hypoxia Monitoring Inventory, an effort led by many collaborators, including Oregon Department of Fish and Wildlife, Tillamook Estuaries Partnership, Oregon State University, Environmental Protection Agency, Oregon Department of State Lands, and Oregon Department of Environmental Quality. South Slough also participated on an Oregon Watershed Enhancement Board proposal related to expanding ocean acidification and hypoxia monitoring in Tillamook Bay, which included water quality monitoring protocols from the NERRS/NANOOS stations. In addition, water quality data from all stations were

utilized for a South Slough Fish Assemblage research project funded by the Pacific Marine and Estuarine Fish Habitat Partnership.

South Slough expanded the network of water quality stations to include four stations (North Point, Isthmus Slough, Catching Slough, and Coos River) located in the Coos estuary. One station, North Point, is located near commercial oyster cultivation areas and will be prioritized for adding real-time capability for growers to provide water quality data along with incorporating this site into NVS. South Slough added *p*CO2/ pH monitoring equipment at the Valino Island station as well as the Charleston Bridge station (OSU collaboration) and continued data collection and monthly instrument maintenance.

• **Shorelines**

Washington Shorelines: NANOOS funds contribute to the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) led by G. Kaminsky. In June 2017, CMAP completed spring seasonal beach monitoring surveys in the Columbia River Littoral Cell (CRLC). Forty-six beach profiles and two surface maps were collected. In addition, CMAP collected six supplemental profiles in Westport and 13 in Ocean Shores, in two locations of the CRLC where erosion is threatening property. Significant erosion is also occurring at Benson Beach just north of the Columbia River where the southernmost profiles in the sub-cell are at their most eroded state since monitoring ensued. Seasonal beach profile data and contour change plots are made available through the NANOOS Visualization System.

In August-September 2017, CMAP conducted summer seasonal beach monitoring surveys in the CRLC, collecting 50 beach profiles (plus a total of 37 supplemental profiles), 14 surface maps, and 61 sediment samples from multiple cross-shore locations along 13 of the profiles. In addition, over 200 beach profiles were collected to extend the nearshore bathymetry profiles collected by the USGS and OSU using personal watercraft. While most beaches show recovery by the end of summer, the beach in front of the Westport-by-the-Sea condos has remained sediment starved.

In the middle of the summer CRLC survey season at the end of August 2017, Ecology's base station was severely vandalized and most of the equipment was either heavily damaged or rendered unusable. After using old equipment and spare parts to get through the remainder of the survey season, most items were replaced or sent in for recalibration and testing, setting our program back by about $6,500. The total cost to replace the damaged equipment is expected to be between $17,500 and $20,500 and a funding source to do this remains unknown.

On October 4, 2017, CMAP collected additional data at Ocean Shores in response to an early storm that caused erosion of the dune after it had started to recover during the spring and summer with the construction of sand fences in front of the dune toe north of the shoreline armoring.

On November 30, 2017, CMAP began conducting fall seasonal beach monitoring surveys (to be completed in December) in the Grayland Plains subcell. In addition to the eight seasonal beach profiles collected throughout the sub-cell and six supplemental profiles collected near Westport, nine additional supplemental beach profiles were collected in front of the Westport-by-the-Sea condos for

a consultant working on an assessment of coastal protection options for mitigating future erosion hazard impacts.

During the past six months, CMAP has done some other monitoring work around Washington. In June 2017, CMAP conducted a boat-based lidar survey of 5 km of shoreline near Edgewater Beach in south Puget Sound to document shoreline change after the removal of a 240 m-long bulkhead. In July 2017, CMAP worked with surveyors from the USGS to collect beach profiles at the Elwha river delta. The Elwha monitoring surveys have cut back to once per year as changes to the river mouth slow and funding declines.

Oregon Shorelines: Leveraging NANOOS, the Oregon Beach and Shoreline Mapping Analysis Program (OBSMAP) efforts are led by J. Allan of the Oregon Department of Geology and Mineral Industries (DOGAMI). Beach profile data were collected in the Neskowin (15 sites) – summer and winter surveys – and in the Rockaway (25 sites), Clatsop cells (6 sites), and Neskowin (15 sites) littoral cells this past summer (August 2017) and fall (November 2017). Fall surveys of the Neskowin beaches have been delayed until early January 2018 due to mechanical problems with our ATV. Datum-based shorelines were also collected during the same beach monitoring campaigns. Beach profile data have been processed, QA/QC'd, and archived both locally and remotely. The reduced profile plots, change plots and trends have been posted to the NANOOS beach and shoreline portal (http://nvs.nanoos.org/BeachMapping).

***Nearshore Bathymetry*:** P. Ruggiero's group at Oregon State University completed processing nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC). Over 220 individual cross-shore profiles were collected during summer 2017 extending from the lower inter-tidal to ~12 m of water depth (~2000 m from the shoreline). Approximately 400 kilometers of nearshore mapping took place within 10 days of field data collection. These data have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. In all cases these nearshore bathymetry measurements have been combined with topographic measurement collected by Ecology developing complete maps of the nearshore planform.

Ruggiero's group also completed the processing of nearshore bathymetric data collected within the Rockaway littoral cell in Oregon. Several individual cross-shore beach profiles were processed from the lower intertidal to approximately 25m 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.

These data continue to provide a critical source of information for improving coastal hazard mitigation along the coastlines of the CRLC and Rockaway and for understanding the morphodynamics of high energy beaches. In particular, this NANOOS funded nearshore bathymetric data is being incorporated in a coastal hazards decision support tool supported by NOAA's Climate Program Office in both Tillamook County, OR and Grays Harbor County, WA.

Unfortunately, the PWC-based nearshore surveying system used by Ruggiero's group experienced significant technical issues during this field campaign and the Rockaway 2017 data set is not complete. This is partially due to the fact that the equipment is now almost 10 years old and is starting to show

some wear and tear. In particular, the PWCs themselves have been driven for hundreds of hours in very demanding conditions and may only have one to two years left of being able to safely collect this data before needing to be replaced or extensively serviced.

• **Currents**

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

During this period, field repairs/improvements continued. Erik replaced batteries in the Uninterruptible Power Supplies (UPS) which provide backup power at our sites at YHS2 and YHL1. In June, he did a field repair of communication systems and the remote power switch at LOO1. Erik has continued to install Raspberry Pi computers at our sites, using his own program to monitor for power outages, and to alert him when power goes out, and when power returns. A field repair of antenna cables was required at YHS2 in July, and the air conditioner was repaired at LOO in July. The cell modem at YHL1 was replaced in August, and at YHS in October. In November, Anne reported that the door at the equipment hut at STV2 was out of true and would no longer close; Erik travelled to the site and repaired the hut.

In late July and early August, Charter Communications reported experiencing interference from our system at a location near our Seaside installation. We worked exhaustively with Charter and Codar to eliminate any possible sources of interference, installing ferrite chokes on all cables and external wires. We also swapped receiver and transmitter at the site with that from another site. We also brought a spare transmit antenna which was swapped in. Progress was made difficult because we were not able to clearly sense the interference with our own equipment, and had to rely on Charter. Codar offered to send their chief of engineering to the site, and he did participate by phone. In the end, it turned out that Charter had made a mistake in reading their sensors, and subsequently reported there was no interference after all.

We have advanced the planning for the addition of radars (made available by IOOS from the "closing the gaps" campaign) farther north along the Washington coast. Mike Kosro and Jan Newton have discussed possible sites in consultation with Jack Harlan and with Ocean Networks Canada. We have requested meetings with the tribes for the week of 18 December.

HFRnet diagnostics (https://hfrnet.ucsd.edu/diagnostics/) indicate uptime during the period using the NOAA metric was 92% in Q1/FY18, and 81%/80% in Q3-Q4 of FY17. These are all at or above the target level of 80%.

Kosro participated in the NANOOS Community Workshop in Newport, July 13 2017, leading two breakout discussion groups.

Port X-band Radar: Led by M. Haller (OSU), during this period we have been developing an application for our real-time radar images from Yaquina Bay Lighthouse radar station. A beta version of the application is shown in the figure below. The image shown is a 2-minute averaged radar image that conveys information about wave breaking and tidal currents in the inlet. Fishing vessels etc. are

also identifiable. The radar image is embedded in Google Earth and has layering capability through the slider at the lower right. Presently, we are working on adding a capability to slide through a time history of images, on the time scale of an hour for example.

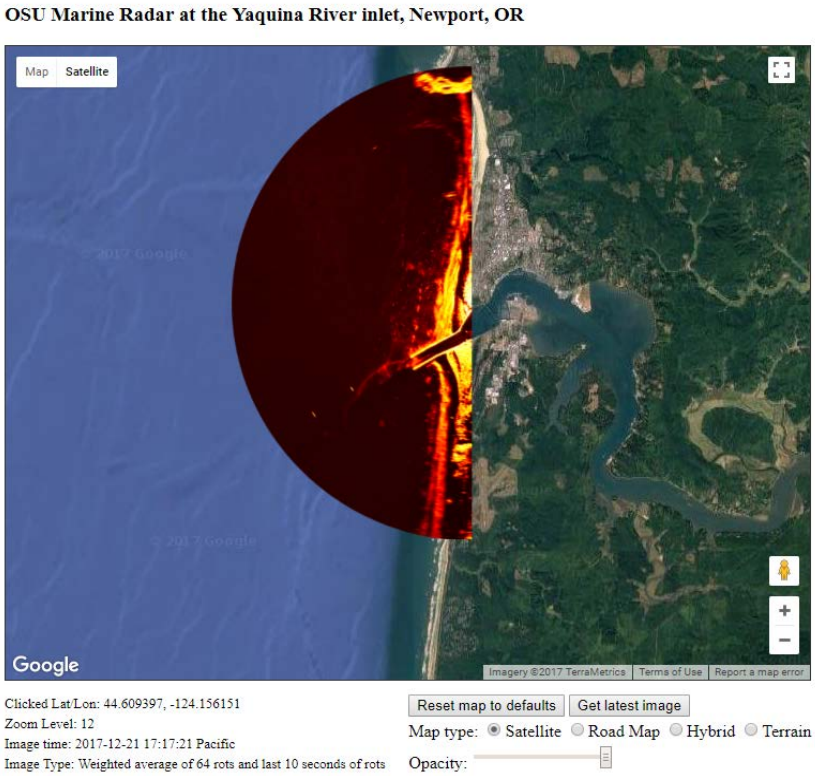

Figure 3. A 2-minute averaged radar image from the Yaquina Bay Lighthouse radar station: http://research.engr.oregonstate.edu/haller/Newport/radar_map.php

b) <u>NANOOS Modeling Subsystem:</u>

Shelf: Computer circulation modeling and forecasting of PNW coastal ocean shelf conditions has been conducted by A. <u>Kurapov</u>'s group at OSU. The system utilizes the Regional Ocean Modeling System (ROMS) as the forecast model. Along-track altimetry observations from Jason-2, CryoSat, and Altika, hourly GOES SST, and surface currents from land-based high-frequency (HF) radars have been assimilated to improve initial conditions for the forecasts, using the assimilation system developed at OSU. Results are provided to fishermen and public via the NANOOS Visualization System. Via the OpenDAP server, forecast currents are also provided to the NOAA Office of Response and Restoration Lab in Seattle, where they can be used with the tools for oil spill mitigation. The OpenDAP link provides access to the real-time fields by the Cyberinfrastructure group of the IOOS-sponsored Coastal Ocean Modeling Testbed (COMT) project. Routines for pre- and post-assimilation quality control have been established, along with new online tools (http:// http://ingria.coas.oregonstate.edu /rtdavow/, L. Erofeeva, OSU). We also continue to provide the forecast fields to the SeaCast.Org student project aimed at development of an interactive online ocean forecast tool using recommendations from local fishermen.

During the report period we continued our real-time operation. In response to the feedback from the local fishermen, new tools were developed and added to NANOOS NVS, namely maps of the thermocline depth. Since the current satellite SST product assimilated into the system, based on GOES, will be soon retired, we made steps to find replacement. Currently, we are evaluating utility of the NPSS VIIRS L3U SST product developed by A. Ignatov and his group at NOAA/NESDIS/STAR.

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

Estuaries

Puget Sound:

NANOOS PI P. MacCready (UW School of Oceanography), working with Drs. Siedlecki (Univ. Of Connecticut), McCabe (UW Joint Institute for the Study of Atmosphere and Ocean), and Banas (U. Of Strathclyde) run a pre-operational forecast model, called *LiveOcean*, of ocean circulation in Puget Sound and adjacent coastal waters. In the past six months the team used NANOOS support to improve the model carbon chemistry based on an error found in the code using comparisons with using 2016 NOAA cruise data. A new version of the model, also incorporating improved treatment of open boundary conditions, has been run from 2013 to the present and now forms the current forecast on NANOOS NVS. The model fields are also made available through the NOAA IOOS EDS system, and are used as open boundary conditions by Dr. Susan Allen at UBC and Co-PI Baptista for their forecast systems. Moving toward the next step of a high resolution (~300 m) Salish Sea grid, a number of experiments were done to tune the tidal response in the inland waters. 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 gave an outreach talk at the Pacific Coast Shellfish Growers Conference, and another more technical talk for the WA State Department of Ecology. 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. The model system is being used in the NOAA-funded MERHAB PNW project to make short-term forecasts of when *Pseudo-nitzschia* HABs may reach WA beaches.

Columbia River: With a mix of NSF funding (through June 30, 2017), regional stakeholder funding, and modest NANOOS funding, CMOP maintains an extensive modeling system for the Columbia River coastal margin, denoted Virtual Columbia River (VCR). The VCR is operated under the direction of A. Baptista, but it is a multi-institutional collaboration involving modelers and non-modelers, in academia and across regional, federal and tribal agencies.

The modeling capabilities of the VCR has assisted the region in the study of salmon life cycle (Gosselin et al. 2017), habitat (Rostaminia 2017) and status under the Endangered Species Act and in relation to hydropower management and climate change. Recent applications of the Virtual Columbia River include the Columbia River Treaty Review and the post-construction assessment of the ecological

impact of the Columbia River Channel Improvement Project, multi-institutional collaborations reported on previous NANOOS reports.

Recent peer-reviewed publications report on rigorous benchmarking of the circulation and sediment models (see previous NANOOS reports) and offer insights into important estuarine processes, including water age (see previous NANOOS report), estuarine turbidity maxima (Lopez et al. 2017; also paper in preparation), climate change impacts in the estuary (paper in review) and local wind-induced circulation (paper in preparation).

Recognizing the challenges that the highly energetic and strongly stratified Columbia River estuary and plume system poses to numerical models, we have recently experimented with a different class (Discontinuous Galerkin [DG]) of unstructured-grid finite element models, both using an existing code SLIM (paper conditionally accepted) and a newly developed code Thetis (paper in review). Results are promising, in the sense that DG codes (and in particular Thetis) offer for the plume substantially improved skill over the continuous Galerkin codes (SELFE, SCHISM) that we have used in the VCR, and other similarly-skilled finite volume codes (such as FVCOM). In addition, Thetis' skill appears in several controlled (synthetic) test cases to be comparable or superior to that of the finite different code ROMS. Future efforts on Thetis will include more extensive testing in the Columbia river estuary-plume system and improvements of computational efficiency, which are still required for this code to be a practical alternative.

An invited presentation to the Gordon Research Conference on Coastal Ocean Dynamics summarized the status of *in silico* oceanography using the Columbia River as an example. Participation in the multi-institutional IOOS Modeling Task Force led to recommendations for moving the ocean modeling field forward, as described in (Wilkin et al. 2017).

c) Data Management and Communications (DMAC) Subsystem:

Chaired by E. Mayorga (APL-UW), this committee is composed of members from CMOP-OHSU, DOGAMI, OSU and UW. The DMAC and User Products (UPC) teams work in an integrated fashion on the prioritization, development and evaluation of data services and user products. NANOOS is also an active collaborator in national IOOS DMAC efforts.

The **NANOOS Visualization System (NVS)** was upgraded in July (version 5.4) with new climatology and upwelling indices and updated WA tsunami evacuation zones. NVS enhancements also encompass asset additions and continuous updates: 1) new or newly incorporated near-real-time in-situ monitoring assets (new NANOOS OSU CB-06 mooring off Coos Bay OR [relocated former NH-10 mooring] and CMOP Elliott Bay mooring in the Columbia estuary; and integration of CeNCOOS Humboldt and Trinidad Pier platforms in N. California); 2) upgraded and expanded coverage of La Push glider section plots, to cover all deployments and new monthly plot products; 3) updated monthly anomalies for climatology/anomaly overlay assets, and expansion to near-global geographical domains for HYCOM and WaveWatch III models; and 4) many redeployments and smaller upgrades, including chlorophyll depth-profile plots for ORCA moorings, and La Push ESP HAB redeployment with enhanced data presentation.

Open Data Sharing: With few exceptions, all IOOS-funded observations and model output are already available for public access via the NANOOS Visualization System (NVS), which in addition to data

browsing and visualization incorporates custom, machine-readable data services. Current exceptions include more technically challenging data types such as ADCP, which we are starting to address.

These data streams are also made available freely and via machine-readable, IOOS-registered, IOOS-recommended services, as described in other sections below. In limited cases these efforts lag data distribution via NVS due to technical challenges and prioritization of limited resources. Incorporation of these data streams is an ongoing effort.

NANOOS also invests substantial efforts to engage (serving as "clearinghouse") other, non IOOS-supported regional and non-traditional data providers, including Canadian ones, to integrate and redistribute their data streams, particularly via NVS. These data streams are also made available via machine-readable, IOOS-registered, IOOS-recommended services, except where restrictions from providers exist or have not been clarified. Partnership agreements and documentation in the future will help clarify or resolve these situations. For example, OOI data streams currently integrated into NVS are not being distributed via the NANOOS SOS service, until appropriate discussions between NANOOS, IOOS and OOI can be had about who is the proper entity to register and advertise such data via the IOOS registry and catalog (although these OOI data streams can be downloaded from NVS).

Data management planning and coordination: As documented in other sections, NANOOS: enables open data sharing, offers data in approved common data formats, provides data feeds to GTS, implements a service oriented architecture, implements ontologies, controlled vocabularies and identifiers, implements metadata standards and metadata management and query capabilities, provides this information to the IOOS Catalog, and ensures local storage and offsite, permanent archiving of data at approved facilities. NANOOS has continually improved its data management and coordination capabilities. Important discussion of problems, new capabilities, and standard operations both among the distributed NANOOS DMAC team and between the team and IOOS and related staff now take place largely on the NANOOS presence on GitHub, http://github.com/nanoos-pnw. Procedure automation and ongoing improvements include asset inventory extraction and distribution via GeoServer, server monitoring tools, server hardware and software refreshments, and more robust server backups. We engaged the IOOS Modeling and Analysis Subsystem via discussions and testing with the EDS Model Viewer team regarding improved access to the OSU ROMS model, operationalized access to the UW LiveOcean model, and made substantial progress with integrating the OHSU-CMOP SELFE into the EDS Model Viewer. NANOOS has also strongly coordinated efforts with IOOS staff and the IOOS and wider community. This coordination has included exchanges regarding IOOS-supported or IOOS- relevant software, discussions on standards and metadata conventions (such as for the asset inventory), etc. We continued to engage with QARTOD via active participation in the IOOS DMAC QARTOD Working Group. As specified in the NANOOS RICE Certification application (revision to be submitted soon), NANOOS has initiated a pilot QARTOD implementation phase which will include the implementation of min-max range testing by March 2018, and full QARTOD flagging and implementation by January 2019.

NANOOS attends and actively participates in the annual IOOS DMAC coordination meeting. NANOOS DMAC also has actively engaged overlapping communities, including the Ocean Acidification monitoring community (from cross-regional to national and global), the West Coast Ocean Partnership, and NSF-supported Cyberinfrastructure initiatives, including EarthCube, CUAHSI, the Observations Data Model 2 ("ODM2") initiative, NEON, and particularly OOI. The partnership with OOI has led to ongoing improvements in the integration into NVS of OOI near- real-time data streams from the core moorings (6) and sensors in the Pacific NW Endurance Array, including the related cabled Benthic Platforms and support for the creation of conda packages for the OOI "cgsn-

parsers" raw-data access code. including contributions (via github) to the OOI raw-data access code. Emilio Mayorga (DMAC Lead) was recently invited to be a member of the Ocean Networks Canada International Science Advisory Board.

Provision of data to the Global Telecommunication System (GTS): NANOOS makes all its IOOS-supported, near-real-time observing data streams available to the GTS via NDBC (for fixed in situ assets) and the Glider DAC.

Data access services: NANOOS hosts IOOS recommended services to serve observing and modeled data. These include two THREDDS server and one Hyrax server for model output, which in CY 2017 were leveraged to support historical observing data and data synthesis products; and an IOOS 52North SOS for fixed-location observing data. These services are registered with the IOOS Registry. Improvements in CY 2017 included updates to the THREDDS servers, addition of ERDDAP services (still in experimental mode for internal consumption and testing, but soon to be released for public use), and additions to the data and metadata content of the NANOOS 52N SOS.

Glider and HFR data are distributed via IOOS supported thematic DACs. In addition, NANOOS hosts standard-compliant services OGC WMS and WFS services via GeoServer.

Catalog registration: Three NANOOS WAFs (Web Accessible Folders) at http://data.nanoos.org/metadata/ continue to host metadata records registered at https://registry.ioos.us, currently providing 76 metadata records. The NANOOS present on the new IOOS Catalog can be seen at https://data.ioos.us/organization/nanoos. The extent, comprehensiveness and currency of these records will continue to be refined and expanded to match IOOS catalog capabilities. In addition to these IOOS Catalog records provided directly by NANOOS, 15 additional metadata records affiliated with NANOOS are also available in the Catalog, at https://data.ioos.us/dataset?q=NANOOS

Common data formats: All data served by NANOOS via IOOS recommended services (see #4) are also provided via IOOS recommended data formats, including IOOS SOS SWE and NetCDF-CF. Similarly, such formats are also used in data submitted via thematic DACs, particularly the Glider DAC and HFR DAC.

Metadata standards: All metadata served by NANOOS via IOOS recommended services (see #4) are also provided via IOOS recommended metadata formats, including IOOS SOS SensorML (Network and Station), NetCDF-CF ACDD, and ISO 19115-2. The quality and extent of the metadata content are under regular revision, as areas of improvement are identified, particularly via engagement with IOOS.

Storage and archiving: NANOOS started archiving data with NCEI in Spring 2017 (an NCEI Submission Agreement is available). In this initial stage, the SATURN network data from OHSU-CMOP was used as a pilot to develop metadata conventions, file segmentation and archival procedures that can be readily adapted to fixed-location in-situ data streams from other NANOOS sources. Nearly all historical data have been submitted, and all current data is being submitted monthly starting on July 15 (a search on NANOOS and "Buoy / Station" at https://www.nodc.noaa.gov/ioos/ yields 31 results as of 2017-12-07). Archival files are in the NCEI NetCDF Templates v2.0 format and follow ACDD and CF conventions. The NANOOS DAC automatically stages monthly incremental archive updates on the 10 th of the month at http://data.nanoos.org/ncei/ohsucmop/, and these are automatically downloaded (pulled) by NCEI by the 15th of the month.

In late 2017 NANOOS DMAC started working with other providers to lay out initial plans for NCEI archival following the conventions and procedures developed for the NANOOS SATURN network data set. We plan to have formally initiated the process with NCEI for all NANOOS Fixed-location Sensor Platforms by February 2019; the date for completion of the process may vary depending on issues that arise in discussions with NCEI.

In addition, all CY 2017 IOOS supported glider data from NANOOS also were archived with NCEI via submission to the Glider DAC. All delayed-mode data from the UW-APL La Push Glider was submitted in early 2017. Data from the operational OSU Trinidad Head Glider are submitted to the DAC by CeNCOOS, as part of the NANOOS-CeNCOOS collaboration that supports and co- funds this glider. Final archiving of NANOOS glider data into NCEI is either already taking place or being figured out.

Ontologies, vocabularies, common identifiers: NANOOS makes comprehensive use of IOOS recommended ontologies and vocabularies in all its hosted, IOOS recommended services and metadata. IOOS recommended identifiers (urn's, as well as WMO/NWS ID's when available) are used in the NANOOS SOS service.

d) User Products Committee (UPC):

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

Chaired by J. Allan (DOGAMI) this committee is composed of members from OHSU, UW, OSU, NANOOS E&O, OR Sea Grant, and NOAA. NANOOS UPC chair Allan participates in weekly "tag-up" calls with a smaller sub-group comprised of members from DMAC, UPC, E&O, and Web development in order to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this 2017 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; 2) helping to organize and participating in a stakeholder outreach workshop in Newport Oregon on July 13th; 3) Attendance at the annual NANOOS governing council and all PI meeting on August 10-11, 2013; 4) Met with an Oregon Surfrider representative to explore 'surfer' needs for a new recreational user web app targeting surfers and kayakers that NANOOS is proposing to build.

The stakeholder meeting undertaken in July was very successful with ~60 people in attendance, representing state and federal agencies, tribes, local government, scientists, fishermen, and the public-at-large. Overall, the impression given was that NANOOS/NVS is meeting its primary goal of delivering effective products to NANOOS stakeholders. However, we did gain insights into how the various apps are being used (fishing (recreational and commercial), trip planning, education), existing limitations (primarily access to NVS while out on the ocean beyond 20-25 miles, which is limited by access to cell phone coverage), and areas in need of improvement (the ability to overlay multiple overlays (ideally 2); improving model output temporal scales; latitude/longitude graticules etc.). A

number of these issues have since been addressed. We also received input on potential new products that could be implemented by NANOOS. Perhaps the most significant of these is the ability for a user to “build their own web app”, an idea that the UPC have been discussing for some time.

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. During this period, NANOOS released two minor updates. v5.4 released in July , included updates to the Climatology web app overlays, along with the addition of several Climate indices (MEI, Nino 3.4, PDO, and NGPO) as well as an upwelling index (Bakun Upwelling). In addition to improvements to the Climatology app, v5.4 included updates to the tsunami web app that reflected updates to the evacuation zones for the Washington coast, along with updated to links to the ‘official’ evacuation brochures.

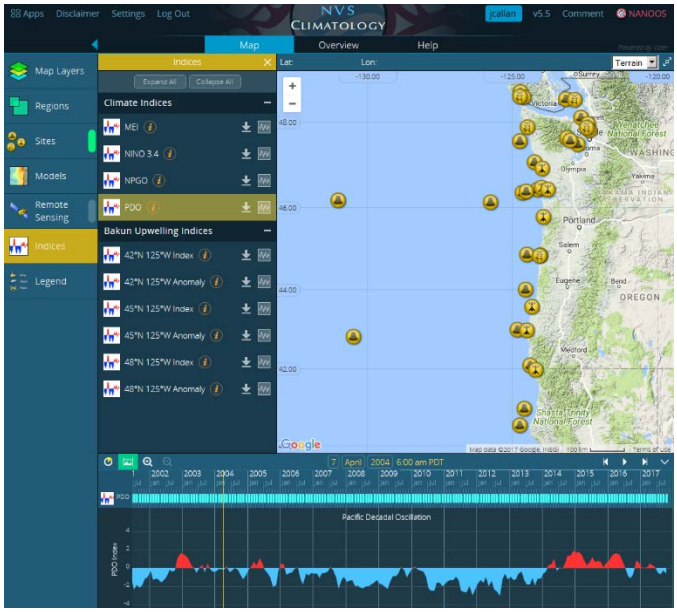

Figure 4. A minor update was released on December 4 that reflected the inclusion of latitude/longitude map graticules (shown in the Climatology app figure) in NVS.

NVS Mobile App: NANOOS released v4.1 of its NVS mobile phone app for both Android and iOS version. Currently we are working on a complete rebuild of the TsunamiEvac smartphone app, which is currently broken in both the latest Android and iOS operating systems. Completion of this rebuild will also provide the necessary code to enable a google map view of the NANOOS region and sensor platforms within the NVS smartphone app.

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, Lebrec, and Wold, with support from DMAC and UPC subsystems and many NANOOS member collaborators.

Newton, Sprenger Lebrec, and Wold are all active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. Sprenger and Wold continue participation with IOOS E&O calls as they occur.

Summary of Education Accomplishments: NANOOS education efforts have continued to focus on building and sustaining connections with Pacific Northwest educators and partnering with local and regional science and marine science education efforts.

- Sprenger was invited to present on ocean observing and real-time data tools at the Salish Sea Student Science Symposium (grades 5-12) on 12 June.
- For the seventh year, Sprenger partnered with WA Sea Grant to co-instruct the NOAA Science Camp's Junior Leadership Program's research project. Sprenger also worked with a new 3-day ROV camp run by the NOAA Science Camp program, leading activities on ocean observing
- A summer camp run by a local marine science education nonprofit and a NANOOS member, Salish Sea Expeditions, worked with Sprenger to use NANOOS materials to implement their own version of the student research project
- Sprenger exhibited at the summer 2017 Northwest Aquatic and Marine Educators (NAME) conference in Homer, Alaska, and presented - "Eyes on the Ocean—Get to Know Your Regional Coastal Ocean Observing System"
- Newton spoke on ocean acidification and NANOOS data use to a teacher workshop by the Institute for Systems Biology on 18-19 July. ISB links to our NANOOS OA info page and portal.

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.

- Wold engaged with the recreational boating community, presenting at various meetings to showcase the NVS Boaters App while gaining their direct feedback. Wold gave seminars at four regional boaters' events: The Puget Sound Yacht Club (June), 'Coho Ho Ho' sailing rally (August), Corinthian Yacht Club (September), Puget Sound Cruising Club (November).
- NANOOS had an exhibit table during the Pacific Coast Shellfish Growers Annual Conference in Welches OR Sept. 18-22; Sprenger demonstrated and gathered feedback on NVS, IPACOA, and GOA-ON web portals from the shellfish growing community.
- Sprenger, Wold and Lebrec represented NANOOS at the Pacific Marine Expo in Seattle, the largest of its kind on the west coast, sharing NOAA's exhibit space.
- Sprenger, Lebrec, and Wold continue to update content on the NANOOS portal, as well as improve the site's usability by updating the search tool on the products page and streamlining the documents archive.
- Over 60 people attended the NANOOS community workshop in Newport, Oregon on July 13. After presentations from NANOOS staff highlighting NANOOS and the NANOOS Visualization System (NVS), workshop attendees discussed current and foreseeable needs for ocean observing in the Pacific Northwest. Small group discussions on various topics included recreational boating, maritime operations, fisheries (particularly for tuna), ocean conditions, coastal hazards, and shellfish growing.

- Newton, Sprenger, Lebrec, and Wold are all active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments.
- Lebrec and Sprenger represented NANOOS at the NOAA Open House on June 9. Lebrec and Sprenger attended the annual Seattle Aquarium Discover Science Weekend, November 10-11, with over a thousand visitors each day. The exhibit by NANOOS, which included a "Great Build a Buoy Challenge" and NVS demonstrations, was very popular.
- NANOOS maintains Facebook and Twitter accounts, each with growing audiences. NANOOS also has a growing audience for its monthly newsletter, the "NANOOS Observer."
- Sprenger and Wold continue participation with IOOS E&O calls as they occur.

f) NANOOS Administration:

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

- Newton and Martin led the annual NANOOS PI meeting and the annual NANOOS Governing Council meeting over August 10-11, 2017 at the Washington State University – Vancouver campus. Newton led the PI meeting discussions and Martin served as Chair of the NANOOS Board during the GC meeting.
- New members of the NANOOS Governing Council include Aquatic Innovations Research and Long Live the Kings.

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 Coastal Margin Observation and Prediction, which NANOOS leveraged 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.

Additional coordination and representation included:

- Newton attended the Director's Meeting, and Strategic Meeting with the IOOS PO Leadership, on 14-15 June in Washington DC.
- Newton hosted and attended the annual fall IOOS Program meeting on 25-27 September, which was held at the University of Washington in Seattle, held there due to the Caribbean hurricanes.
- Newton served on the IOOS Association Executive Committee and attended IOOS Program and IOOS Association calls as available during the period.
- Newton represented NANOOS and IOOS at the 3rd Blue Planet Symposium held in College Park, Maryland, USA on 31 May-2 June 2017. She co-chaired a session on "Threats from Pollution, Warming and Acidification" and spoke on societal impacts from warming and acidification, based on IOOS-OAP work. The symposium was co-hosted by NOAA and the University of Maryland.
- NANOOS contributed updates on oceanographic conditions in the Northwest for the NOAA West-Watch webinar series on June 6, August 22, and October 24, along with the other west coast RAs.
- Referred by the Makah Tribe, Newton was invited to participate in the Marine Resource Education Program (MREP) West Coast Workshop in Santa Cruz, CA on August 29-31, giving a lecture on

oceanography, observing data, and climate change/variation.

- Newton was invited as a resource expert at the Western Indian Ocean Marine Science Association (WIOMSA) sponsored "Ocean Acidification workshop – developing regional capacity for ocean observations in support of SDG target 14.3" in Dar es Salaam, Tanzania, on October 26-27. She gave talks on OA and GOA-ON, and facilitated discussions of observing needs in the Western Indian Ocean.
- Newton was invited by Plymouth Marine Lab, UK, and the International Alliance to Combat Ocean Acidification to attend the UN COP 23 from November 8 – 12 in Bonn, Germany, where she participated in five different speaking panels. Most highlighted the need for observations to support Sustainable Development Goals (SDGs) and how GOA-ON/IOOS is building capacity for observations to serve society.
- NANOOS PI Barth and Newton acted as liaison to the West Coast Ocean Acidification and Hypoxia Science Panel working to construct an inventory of OA and biological observations from the NANOOS region.

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

- From June 21-22, David Martin and Jack Barth participated in the semi-annual meeting of the Ocean Networks Canada (ONC) International Science Advisory Board (ISAB) that provides guidance and counsel to the Canadian effort to field, evolve and improve two research-focused ocean observatories (VENUS and NEPTUNE Canada) that simultaneously serve emergent operational societal needs. In this context, Martin and Barth provide both scientific expertise as they communicate the U.S. experience with IOOS and operational ocean observing efforts that are part of the unique hybrid nature of ONC.
- Newton represented IOOS on the Global Ocean Acidification Observing Network Executive Committee calls and activities. Newton was involved in the GOA-ON Executive Committee and Biology Working Group.
- Newton represented IOOS on the Joint European Research Infrastructure for Coastal Observatories (JERICO) SAC, fostering international collaboration.
- Newton, a member of the Canadian Marine Environmental Observation Prediction and Response (MEOPAR) International Science Advisory Committee, provided input and review support during the period. She participated in the MEOPAR Annual Meeting on June 20-22 in Montreal, Canada.

Additional NANOOS coordination:

- Newton participated in "OA Round Tables" organized by NOAA PMEL and NWFSC.
- Newton participated in NOAA FATE meetings for J-SCOPE, the ecological forecasting model for seasonal coastal ocean prediction on NANOOS' portal: http://www.nanoos.org/products/j-scope/.
- Newton continued to represent NANOOS in regional efforts, e.g., C-CAN, PSEMP, Pacific Salmon Marine Survival, and West Coast Ocean Data Portal.
- Newton continued to fill the Research seat as a member of the Olympic Coast National Marine Sanctuary Advisory Council.
- Barth serves on the Oregon Ocean Policy Advisory Council's (OPAC) Scientific and Technical Advisory Committee (STAC) responsible for providing expertise on ocean issues including the implementation and monitoring of Oregon's marine reserves and ocean acidification monitoring efforts. He attended a STAC meeting on October 26, 2017, in Newport, Oregon.

- Barth serves as the Co-Chair of the new Oregon Ocean Acidification and Hypoxia Coordinating Council, enacted as a state law in fall 2017. He briefed OPAC on the Council's formation activities during a November 1, 2017, meeting in Astoria, OR.
- Barth hosted national Sea Grant Deputy Director Nikola Garber for a 3-month internship at Oregon State University. During her time at OSU she was introduced to a variety of state and federal agencies and stakeholders working on or concerned with ocean acidification issues. This included trips to Newport, OR, the Whiskey Creek Shellfish Hatchery, OR, and several labs and agencies in the Seattle, WA, area.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

Allan, J., R. Wold, C. Risien, T. Tanner, J. Newton, M. Kosro. Break-out session presentations at NANOOS Community Workshop. Newport, Oregon, July 13 2017.

Baptista, A.M. In Silico Estuarine Oceanography: Are We There Yet? Gordon Research Conference in Multi-Scale Coastal Ocean Dynamics and Exchange Processes. University of New England, Biddeford, Maine, June 11-16, 2017.

Haller, M.C. Keynote Address: Sensing the Ocean with Marine Radars, Hydraulic Measurements & Experimental Methods (HMEM) Conference. Durham, New Hampshire, July 10, 2017.

MacCready, P. What Causes Predictable and Unpredictable Variation of the Tide & How Will It Change in The Future? Pacific Coast Shellfish Growers Association Annual Conference. Welches, Oregon, September 19, 2017.

Mayorga, E., T. Tanner, J. Newton. Supporting diverse Pacific NW marine data access needs via the NANOOS Visualization System. 2017 Marine Technology Summit. University of Washington, Seattle, Washington, November 6, 2017.

Newton, J. Turning the Headlights on High: Improving an Ocean Acidification Observation System to Support Shellfish Growers. Pacific Coast Shellfish Growers Association Annual Conference. Welches, Oregon, September 19, 2017.

Newton, J. Oceanography Basics: Understanding the oceans, effects from climate and humans, and how we observe. Marine Resource Education Program, West Coast, Santa Cruz, California, August 31, 2017.

Newton, J. Ocean Acidification: a global issue with local effects. Washington Association of District Employees Annual Meeting, Leavenworth, Washington, June 13, 2017.

Newton, J. NANOOS: The Northwest Association of Networked Ocean Observing Systems, Puget Sound Harbor Safety Committee Meeting, August 2, 2017.

Newton, J. State of the Ocean: Understanding Effects from Climate and Humans. San Juan Islands Conservation District, Friday Harbor, Washington, August 3, 2017.

Newton, J. "What is ocean acidification? Introduction to the threat of ocean acidification for ocean health and ocean resources" 26 October, and "The Global Ocean Acidification Observing Network" 27 October, Western Indian Ocean Marine Science Association (WIOMSA) "Ocean Acidification workshop – developing regional capacity for ocean observations in support of SDG target 14.3," Dar es Salaam, Tanzania, 26-28 October 2017.

Newton, J. UNFCCC Conference of the Parties (COP) 23, Bonn, Germany, 9-13 November 2017, spoke on five panels:

Oceans and Climate Initiatives Alliance (OCIA), 9 November, *"The Global Ocean Acidification Observing Network"*;

European Union Oceans Day "Oceans, Climate, and the role of Science: from challenges to solutions," 10 November, *"The Global Ocean Acidification Observing Network: a first step in managing responses to ocean acidification";*

International Council for Science, World Climate Research Program (ICSU/WCRP) Event "Where and when habitability limits of the Earth will be reached due to climate change?," 10 November, *"Observing Ocean Acidification - Working together globally to make a difference locally"* https://www.wcrp-climate.org/news/wcrp-news/1245-cop23-learn-about-wcrp-contributions-2;

UN Climate Change Conference - World Wildlife Fund Event "Oceans and Climate: the evidence unwrapped," 12 November, *"Observing ocean acidification: a global issue with local effects"*;

International Alliance to Combat Ocean Acidification Event, 13 November, *"Science Perspectives"* https://www.oaalliance.org/2017/11/13/international-alliance-to-combat-ocean-acidification-announces-new-members-including-fiji-and-new-plans-for-action-at-climate-talks-in-bonn/.

Publications:

Allan, J. C., Gabel, L., and O'Brien, F. In press. Beach and shoreline dynamics in the Cannon Beach littoral cell; Implications for dune management: Oregon Department of Geology and Mineral Industries. Special Paper

Gosselin, J.L., R.W. Zabel, J.J. Anderson, J.R. Faulkner, A.M. Baptista and B.P. Sandford. 2017. Conservation planning for freshwater-marine carryover effects on Chinook salmon survival. Ecology and Evolution. 10.1002/ece3.3663

Herfort L., B. C. Crump, C. S. Fortunato, L. A. McCue, V. Campbell, H. M. Simon, A. M. Baptista, P. Zuber. 2017. Factors affecting the bacterial community composition and heterotrophic production of Columbia River estuarine turbidity maxima. Microbiology Open. 10.1002/mbo3.522

Jorge Diez, N. Cohn**,** G. Kaminsky, R. Medina, and P. Ruggiero. In press. Spatial and temporal variability of dissipative dry beach profiles in the Pacific Northwest, U.S.A., Journal of Coastal Research. DOI: 10.2112/JCOASTRES-D-17-00149.1

Lopez J.E. 2017. Sediment dynamics in an energetic estuary. Division of Environmental & Biomolecular Systems. Doctor of Philosophy (Advisor: A.M. Baptista)

Pool, S., C. Krembs, J. Bos, and B. Sackmann. 2017. Victoria Clipper observations and *Noctiluca* blooms. *In*: S. K. Moore, R. Wold, K. Stark, J. Bos, P. Williams, N. Hamel, C. Krembs, and J. Newton (eds), Puget Sound marine waters: 2016 overview. NOAA Northwest Fisheries Science Center for the Puget Sound Ecosystem Monitoring Program's Marine Waters Workgroup. 56 pp.

Rostaminia M. 2017. Change in variability in the Columbia River estuary: a habitat perspective. Division of Environmental & Biomolecular Systems. Doctor of Philosophy (Advisor: A.M. Baptista)

Ruggiero, P., S. Hacker, E. Seabloom, and P. Zarnetske. 2017. The role of vegetation in determining dune morphology, exposure to sea level rise, and storm-induced coastal hazards: A U.S. Pacific Northwest perspective, in Barrier dynamics and the impact of climate change on barrier evolution, Moore and Murray Eds, Springer.

Washington State Department of Ecology. 2017. Eyes Over Puget Sound, Surface Conditions Report, October 31, 2017. Ecology Publication No. 17-03-073. http://www.ecy.wa.gov/programs/eap/mar_wat/eops/EOPS_2017_10_31.pdf.

Wilkin J., L. Rosenfeld, A. Allen, R. Baltes, A.M. Baptista, R. He, P. Hogan, A. Kurapov, A. Mehra, J. Quintrell, D. Schwab, R. Signell and J. Smith. 2017. Advancing coastal ocean modeling, analysis, and prediction for the U.S. Integrated Ocean Observing System. Journal of Operational Oceanography, 1-12. 10.1080/1755876X.2017.1322026