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

NOAA Award: NA16NOS0120019 Reporting period: 12/01/2017 to 5/31/2018

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 this reporting period the two moorings were serviced and then successfully re-deployed on the 22nd and 23rd of May. 2018. As of the end of the reporting period, all systems were working well with real-time observations being reported on

NANOOS NVS. As part of the deployment cruise we coordinated with both NOAA's Northwest Fisheries Science Center and Quileute Natural Resources to carry out an extensive HAB sampling survey from the mooring site 40 miles north to the entrance of the Strait of Juan de Fuca.

We had attempted to find a vessel of opportunity to deploy a newly-built winter surface mooring in the period from December to mid-April but were unsuccessful. We did have planned ship time on the R/V Thompson scheduled first for mid-December then early January, but this was canceled by the ship scheduler at the last minute due to unanticipated additional work for the ship. The NANOOS budget could not support both a winter cruise and a spring cruise, so we opted to forgo the winter deployment. Over this period we worked closely with Seabird Electronics to test and deploy two new versions of the SeaFET pH sensor. Presently two of these sensors are deployed on Cha'Ba.

In April, PI Mickett presented an overview of the 2017 observations from these moorings at the Puget Sound Marine Waters Workgroup meeting. One highlight was anomalously warm deep waters on the shelf during the summer of 2017 that we suspect could be the delayed signature of the Blob, slowly mixing downward in the water column. S. Alin of NOAA PMEL presented carbon chemistry observations from the Cha'Ba mooring at the same meeting. On May 12th UW School of Marine Affairs student Julie Ann Koehlinger presented her master's thesis which used observational data from both Sanctuary moorings and the UW/NANOOS moorings to investigate positive temperature anomalies on the Washington shelf. Lastly, Mickett co-authored a publication on non-linear internal waves of the Washington shelf heavily relying upon data from the UW/NANOOS moorings that was accepted to JGR-Oceans in March.

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 in the May deployment cruise and HAB survey.

Oregon Shelf Glider J. Barth 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 (5/31/2018), the glider was on the TH line for 1265 days during eight deployments, sampled along approximately 24,448 km of track line covering the transect about 85 times, and collected about 10,110 vertical profiles of ocean properties. For the reporting period 12/1/2017 to 5/31/2018 the glider was on the TH line for 49 days during one deployments, sampled along nearly 1000 km of track line covering the transect about 2 times, and collected about 400 vertical profiles of ocean properties. The glider "uptime" was 60% (see next paragraph for an explanation). 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. We can now report that the Trinidad Head glider line was restarted in April 2018. Barth is working with CeNCOOS, with NANOOS leadership support, to identify and secure the needed additional funds to ensure that the glider can run year-round.

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 late 2017, the water column temperature had returned to average.

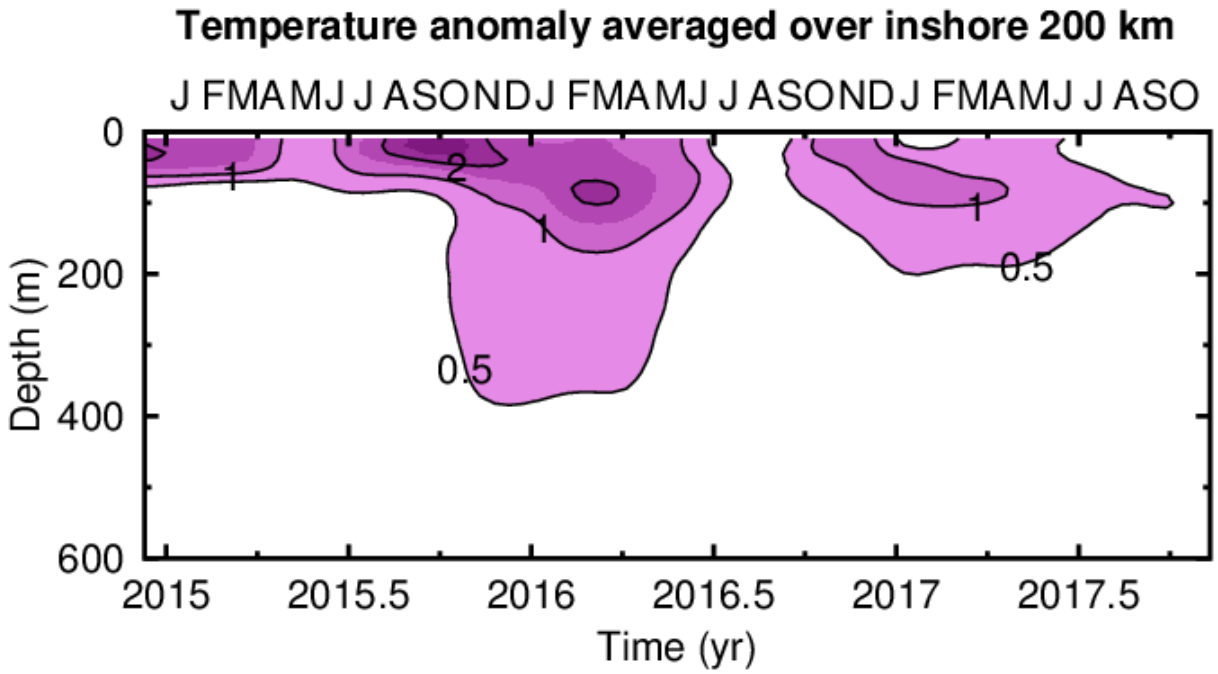

Figure 1. Temperature anomaly off Northern California, from fall 2016 to the end of 2017.

Oregon Shelf Moorings: PI for physical oceanography is Mike Kosro (OSU); for biogeochemistry is Burke Hales (OSU). The Oregon shelf mooring, CB-06, was re-deployed offshore of Coos Bay on April 26, 2018 at 43° 17.607' N, 124° 32.234' W, using *Miss Linda*, a charter boat out of Coos Bay. The mooring anchor was set at 10:55 PDT. Selected data are being transmitted by cell phone to shore, processed, and ingested into the NANOOS Visualization System (NVS) in near-real time, updating every hour. Diagnostic and buoy data are also collected and transmitted to shore (e.g. battery voltage, buoy heading, buoy GPS location). In addition, the full data suite includes vertical profiles of horizontal currents (u(z), v(z)) from a 300kHz ADCP, meteorological data (winds, solar insolation, barometric pressure), temperature at 18 depths, salinity at 4 depths, dissolved oxygen at 90m depth, and measured pressure at 4 depths; this full internally-recorded data set becomes available following instrument recovery. NOAA/PMEL provided a MAPCO2 suite of biogeochemical sensors for the mooring, which was overseen by Burke Hales' group; these sensors also report in real time via satellite phone. For this deployment, microcats 15473 and 15474 replaced damaged instruments at the surface and at 30m, and a new microcat/dissolved-oxygen instrument (16255/1724) was deployed on the mooring 10m above the bottom.

Since deployment, winds show moderate (to 20 kts) upwelling favorable peaks with near-surface ocean currents responding down-coast episodically at more than 0.5 m/s and with a strong vertical shear, with currents increasingly northward with depth, in the sense expected for upwelling flows.

Northern Oregon to Central Washington shelf: Led by A. Baptista, OHSU maintains observational assets in the Columbia River coastal margin. These assets are anchored on station SATURN-02, a seasonal inter-disciplinary buoy located off the mouth of the Columbia River at ~35m depth. 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 and for specialty buoy deployments.

SATURN-02 was last recovered October 30, 2017 and will be re-deployed June 2018. Parameters measured were (a) wind speed, direction and gust, air temperature and atmospheric pressure; (b) water velocity; and (c) scalar water parameters: temperature, salinity, dissolved oxygen/oxygen saturation, chlorophyll, turbidity, CDOM, phycoerythrin and nitrate. Scalar water measurements were made in the last deployment, and moving forward, 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.

We are also preparing for deployment (scheduled for August-October 2018) of two temporary 3-level buoys to support NOAA/USACE studies of the impact of dredged disposal on crabs. One station will be deployed north and the other south of the Colombia River mouth. Each station has, with variations, been deployed in the past, but this will be the first time that both will be deployed simultaneously for a north-south contrast. target measurements include: (a) wind speed, direction and gust, air temperature and atmospheric pressure; and (b) 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: near surface, mid-water column and near bottom. Additional data are collected by glider operations, but only as allowed by funding. No glider 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.

Throughout this period the ORCA team was very involved in collaborations with several other groups. Over much of the spring the team prepared the Scripps Zoocam for a planned June deployment on the Hoodsport ORCA mooring. This system, which was deployed at the Twanoh mooring last year, will be used to investigate water property factors controlling zooplankton behavior and distribution. In December-April they serviced and re-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, over the winter we collaborated with Seabird Scientific to test a new prototype pH sensor on the Carr Inlet mooring.

The group continued to work toward completing a number of system upgrades, including designing and assembling new winch-control modules (3 of 5 winched moorings now have these), integrating a router/cell modem into the pressure case (2 of 5 winched moorings have these), and upgrading the solar panels on the moorings to ones that are twice as efficient.

In April Mickett presented at the Salish Sea Ecosystem Conference, using ORCA data to investigate long-term water property trends in Puget Sound. One highlight of this research included the finding that in landward basins with significant river input such as Carr Inlet and Hood Canal, most of the seasonal and inter-annual variability of salinity is a consequence of changes in river flow. Additionally, this work found that both changes in inflowing water associated with the "Blob" and increased local solar heating led to record-high water temperatures in Carr Inlet in the summer of 2015.

Additionally, ORCA team member W. Reuf presented a summary of the 2017 ORCA observations at the April Puget Sound Marine Waters meeting. One highlight from 2017 observations was the large freshwater anomaly that persisted throughout the late winter and spring of 2017. This anomaly was clearly a consequence of 2017 having one of the wettest winters on record in the Puget Sound region.

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.

During the reporting period, logistical issues such as I-5 freeway closure caused by an Amtrak train crash in DuPont and the subsequent annual vessel maintenance, prevented us from restoring a data stream lost in Nov 2017. Around March, we learned that the Victoria Clipper IV was going up for sale. Therefore, we removed most monitoring equipment from the vessel. The thermosalinograph was also disconnected from the monitoring system but remains on board until engineers remove it from a water line in the port engine room. The optical fluorometer and its related accessories and standards were loaned to Integral Consulting for research being conducted by a student at the University of Washington. The student research focuses on using optical instruments to measure water properties of a few small embayments in Puget Sound.

With eight years of data on hand, we performed an initial data processing of the entire data set from the optical fluorometer. The process included filtering out data from when the ferry vessel was in port or shipyard and when it was sailing in Elliott Bay or Victoria Harbour. The post-processing data were plotted annual heatmaps for examination of spatial and temporal isothermal patterns along the ferry route. An idea that isothermal patterns could potentially be used to identify when survival of temperature sensitive species could occur was presented in a posted (Pool et al. 2018) at the Salish Sea Ecosystem Conference in May. The poster is available on Ecology's publications website at: https://fortress.wa.gov/ecy/publications/SummaryPages/1803017.html

Columbia River estuarine monitoring: Led by A. Baptista, OHSU maintains multiple endurance stations in the Columbia River estuary, anchoring the CMOP/SATURN 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. J. Needoba (OHSU) with regional stakeholder funding.

SATURN physical and biogeochemical observations have been extensively used in support (directly or via data-informed modeling) of interdisciplinary 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.

It is the systemic use of observations in model calibration, validation and enhancement that enables confidence in the use of *in silico* oceanography (Baptista et al. 2018a) to address complex estuarine processes such as estuarine regimes and water age (see previous NANOOS reports), estuarine turbidity maxima dynamics (see previous NANOOS reports), and local wind-induced circulation (paper in preparation) and salmon lifecycle (Gosselin et al. 2017, Morrice et al. 2018a, b).

Also of interest in the period is early reporting on the implementation of a standardized real-time data quality assurance system for the SATURN stations (Seaton et al, 2018).

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 Reserve continued operation of a water quality observing network as part of the NERRS System-Wide Monitoring Program with additional support provided by NANOOS. Over the period 12/01/17–05/31/18, four real-time water quality monitoring stations located in the South Slough estuary provided near real-time water temperature, salinity, dissolved oxygen, pH, turbidity, and water level measurements. Water quality sondes were deployed and exchanged monthly, and routine station maintenance and data management were completed for the weather and water quality stations. The Charleston Bridge water quality station is located on a deteriorating dock owned by North Bend Oyster Company and will be moved to a nearby pier, where the oyster company has recently moved some of their grow out operations. The SWMP nutrient diel sampling (ISCO auto sampler) was relocated to the same pier beginning January 2018. Currently, no instruments are deployed at the Boathouse water quality station due to platform evaluation and assessment.

We maintain one water quality station in partnership with the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians (CTCLUSI) located in lower Coos Bay (NESDID ID # 346F229A; sosnswq) and data are available via the NVS. In March 2018, the North Spit station experienced a short circuit that was compromising conductivity/temperature sensors. We replaced the sonde communication cable and the signal output adaptor for sonde to telemetry compatibility, and real-time data transmissions resumed without damage to conductivity/temperature sensors.

The South Slough water quality stations provide real-time data access for shellfish growers in South Slough, including Coos Bay and North Bend Oyster Companies, Clausen Oysters, and Qualman Oyster Farms. The South Slough Reserve and CTCLUSI stations provide environmental data for research, monitoring and education programs conducted at the reserve and at the CTCLUSI Department of Natural Resources and Culture. Data from SWMP/NANOOS stations were presented for a Reserve outreach program delivered to students and instructors from Stonehill College, MA in May 2018. Water quality data from all stations were utilized for a Fish Assemblage research project at the Reserve funded by the Pacific Marine and Estuarine Fish Habitat Partnership. Reserve staff DeMarzo invited Jonathan Allen to a Port of Coos Bay Harbor Safety Committee meeting 5/15/2018 where he presented an Overview of NANOOS and NVS applications and products for the group, which is comprised of industry stakeholders, local, state, and federal agencies and waterway users including US Coast Guard, US Army Corp of Engineers, Coos Bay shipping pilots, and commercial fishermen.

South Slough expanded the network of water quality stations, which currently include three active stations (Isthmus Slough, Catching Slough, and Coos River) located in the Coos estuary. A fourth station, North Point (currently inactive due to infrastructure issues) is located near commercial oyster cultivation areas and will be prioritized for future real-time capability. South Slough continued *p*CO2/ pH monitoring equipment at the Valino Island station and the Charleston Bridge stations in collaboration with Oregon State University.

• **Shorelines**

Washington Shorelines: NANOOS funds contribute to the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) led by G. Kaminsky. In December 2017, CMAP completed fall 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. Seasonal beach profile data and contour change plots are made available through the NANOOS Visualization System.

Over the entire CRLC in Washington, fall storms had the greatest impact on Benson Beach just north of the Columbia River North Jetty. The beach access road along the jetty was closed due to over-washed driftwood and some of the camp sites were closed due to dune erosion. Black sand (magnetite) was prevalent along the northern half of the beach toward North Head. Compared to last fall, changes in profiles Canby and Hans RM are similar: profile rotation with erosion of the dune and increase in beach elevation. At Canby, the beach profile aggraded by nearly 1 m while the dune retreated by 25 m. At Hans RM, the dune retreated by ~10 m with ~0.4 m of beach aggradation. Changes in profiles at Aschwa and Philo were similar to one another but, in contrast, the beach lowered, by 0.7-0.7 m at Aschwa and by 0.4 m at Philo, with 4 m of dune retreat.

In March 2018, CMAP conducted winter seasonal beach monitoring surveys in the CRLC, collecting 50 beach profiles (plus a total of 19 supplemental profiles), 5 surface maps, and 62 sediment samples from multiple cross-shore locations along 13 of the profiles. Compared to last winter, all profiles at Benson Beach show dune retreat. The most significant retreat and beach lowering occurred at the northernmost profile, Aschwa, with dune retreat on the order of 20 m and lowering of the upper beach by ~0.5 m. Canby showed minimal change since last winter, with a slight rotation of the profile such that the lower beach is lower and upper beach is higher than last year. However, there is ~7 m of dune retreat. Philo experienced 15 m of dune retreat with a decrease in the elevation of the entire profile of ~0.5 m. The dune scarp at Hans RM retreated by ~2 m. The dune toe lowered by ~30 cm while the lower beach increased in elevation by ~40 cm.

George Kaminsky gave a presentation for the Mouth of Columbia River Science-Policy Workshop in Ilwaco, WA in May 2018. For comparison purposes, the beach profile changes along the length of Benson Beach were contrasted against changes along two stretches of shoreline north of North Head that are the same length as Benson Beach (3.0 km). Volume change trends were derived for the duration of the time series from winter 1998 to winter 2018 and for the past three years, winter 2018 to winter 2018. All profiles except the two closest to the north of North Head (BMAC and PC004) either accreted less or eroded more in the short term than in the long term. At Benson Beach, where beach and dune erosion has been the long-term trend at the four profiles, the short-term erosion rates increased from 2.9 to 9.1 times the long-term rates, averaging 4.5 times greater (eroding an average of 292,300 cubic yards per year over the short term compared to 65,000 cubic yards per year over the long term). Over then 3.0-km reach north of North Head, the beach and dunes accreted 23,200 cubic yards per year over the short term compared to 30,100 cubic yards per year over the long term, a 23% decrease), whereas over the next 3.0-km reach northward, the beach and dunes only accreted 20,900 cubic yards per year over the short term compared to 72,700 cubic yards per year over the long term, a 71% decrease. Total volume changes including the nearshore bathymetry data collected at Benson Beach and North Head over the past four summers (2014-2017) at Benson Beach

increased from 1.3 to 2.3 million cubic yards of erosion, while the North Head reach experienced a cumulative increase in sediment deposition from 0.2 to 0.6 million cubic yards. In comparison, the nearshore south of the Columbia River South Jetty experienced a cumulative increase in sediment deposition from 0.8 to 1.9 million cubic yards. These monitoring results stress the urgency in improving sediment management at the mouth of the Columbia River, including proceeding with establishing the North Head nearshore placement site, eliminating deep water disposal of dredged material, and directly nourishing Benson Beach.

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) – fall and winter surveys – and in the Rockaway (25 sites), Clatsop cells (6 sites), and Neskowin (15 sites) littoral cells this past fall (December 2017/January 2018) and winter (March 2018). Updated beach measurements were also undertaken down in the Gold Beach (12 sites), Rogue Shore (9 sites), and Nesika Beach cells (14 sites). These latter sites were last observed in August 2013, and the most recent measurements reflect an important update to the monitoring network, given the length of time between observations. Updated beach measurements (25 sites) were also undertaken in the Netarts Cell in late winter/early spring. At all sites, datum-based shorelines were also measured 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 the processing of 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.

These data continue to provide a critical source of information for improving coastal hazard mitigation along the coastlines of the CRLC and portions of the Oregon coast and for understanding the morphodynamics of high energy beaches. In collaboration with the US Geological Survey and the Washington Department of Ecology the nearshore bathymetry and topographic data being collected via NANOOS at the mouth of the Columbia River (Figure 2) is being used to inform regional sediment management practices.

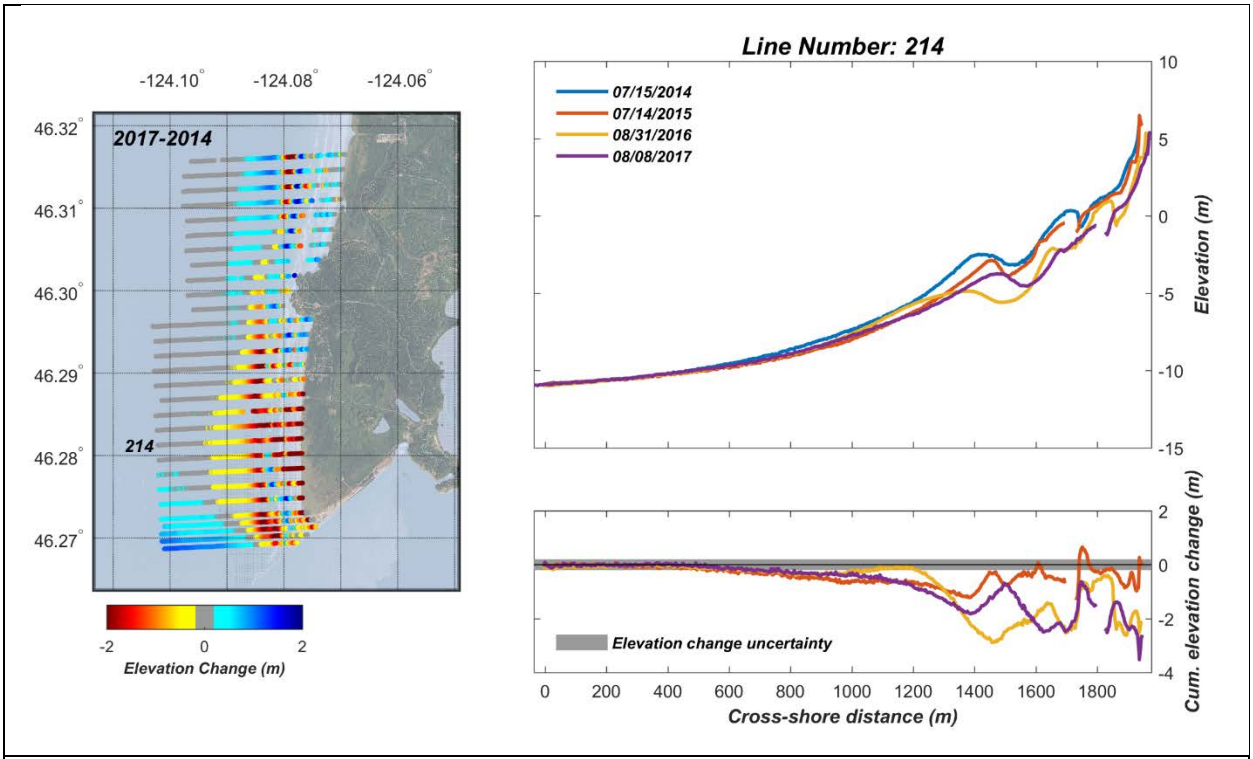

Figure 2. Left: Map showing typical data coverage at Benson Beach along with erosion/accretion patterns from 2014-2017. Right/top: Example profile 214; Right/bottom: cumulative change.

• 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. Anne Dorkins and Erik Arnesen of OSU are the primary engineers/technicians.

During this period, brief power outages were experienced at the Cape Blanco site CBL; our system of Raspberry Pi computers provided text alerts when the sites went down and came back up. In Feb 2018, our site at Point St. George (PSG, Crescent City, CA) began overheating, threatening the electronics. A trip to the site showed that the air handling system had been modified – it was returned to working condition, posted with an advisory, and training was replacement computer was configured, installed, and solved the problem. Data acquisition computer was replaced at STV in Feb 2018. YHL became unreachable in March 2018, problems on the USB bus. In May, YHL computer again not performing; had to do a firmware update and re-enter parameters. Construction at the private home used for our Seaside site (SEA) resulted in several power outages, which stopped data collection; once the problem was found, we came to accommodation. In late Feb 2018, a truck took down a main electricity feeder pole in the Winchester Bay area, causing power loss to our WIN site and apparently destroying our enhanced UPS system there, with collateral damage to our computer and/or settings. A replacement UPS was installed and the site returned to operation. The site at WSH1 is down, waiting for an upgrade to long-range.

HFRnet diagnostics (https://hfrnet.ucsd.edu/diagnostics/) indicate uptime during the report period using the NOAA metric was 94% in Q1 (Oct-Dec), 90% in Q2 (Jan-Mar) and 87% in Q3 (Apr-present). These are all at or above the target level of 80%.

Two scouting trips to identify potential HF sites on the Washington coast were undertaken, in Dec 2017 and in Apr 2018. During the first we met with tribal representatives of the Makah, the Quileute, and the Quinault Nations, and viewed candidate sites, though travel was limited by snow which fell on the first night. On our second trip, we were accompanied by Jack Harlan, IOOS HF Program Head, and Chad Whelan, Chief Technology Officer of Codar. Considerable progress was made.

Kosro co-authored two peer-reviewed papers during the reporting period. Ivo Pasmans, an OSU graduate student, presented a paper at Ocean Sciences showing that model assimilation of glider data introduced large deviations, but these were quenched when HF data was co-assimilated with the glider data.

Port X-band Radar: Led by M. Haller (OSU), during this period we have continued operation of the marine radar station at Yaquina Bay Lighthouse radar station. The USCG station has supported our radar atop their watchtower since 2016. During this reporting period, we worked with U.S. Coast Guard Station Yaquina Bay to share observations in support of situational awareness of the inlet and nearshore region. In February, we met with USCG staff at the station in Newport to present example products and discuss how our observations could support their work. Following the meeting, we put together a slide presentation for their station reservists explaining the radar image products with examples including nearshore bathymetry, the Yaquina river plume, and large rip currents related to the rock reef.

Our Newport real-time web portal (http://research.engr.oregonstate.edu/haller/Newport/index.html) continues to develop. For example, during this period we have added the following products:

- Recent radar image history (last three hours) clickable
- Directional wavenumber spectra plots
- Radar-derived bathymetry overlay with depth contours, adjustable transparency
- Responsive layout for desktop and mobile browsing.
- Separate page with a history of two-day long radar movies (link at the top of the main portal).

In the coming months we plan to perform more bathymetry calculations with the cBathy algorithm and analyze seasonal changes and assess changes near the Yaquina bar and the results of dredging. The web portal will continue to undergo adjustments and improvements for performance and usability.

b) NANOOS Modeling Subsystem:

Shelf:

Computer circulation modeling and forecasting of PNW coastal ocean shelf conditions has been conducted by A. Kurapov's group at OSU. The system utilizes the Regional Ocean Modeling System (ROMS) as the forecast model. Along-track altimetry observations from Jason-2, CryoSat, and Altika, satellite 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 web tool (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 SeaCast.org was added to the NANOOS NVS collection of applications.

During the report period we continued our real-time operation. For many years we had utilized SST data from the geostationary GEOS satellite. Its operation at the west coast was discontinued in March 2018. In anticipation of this loss, we evaluated utility of the NPSS VIIRS L3U SST product developed by A. Ignatov and his group at NOAA/NESDIS/STAR. Without loss to our operations we switched to assimilating this new data stream as a replacement to GOES.

Using leverage by the IOOS COMT project, OSU student Ivo Pasmans performed a series of tests assimilating glider data into our OR-WA forecast system and provided recommendations to their use in combination with the surface data (Pasmans et al. 2018). 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. NANOOS 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). In the past six months the team used NANOOS support to develop the next generation model grid and forcing fields to enable accurate daily forecasts in Puget Sound and the Salish Sea. We maintained reliable forecasts on the NANOOS NVS and NOAA IOOS EDS systems. LiveOcean model fields are used as open boundary conditions by Dr. Susan Allen at UBC and Co-PI Baptista for their forecast systems. The model system is actively used, and funded by, the NOAA MERHAB PNW project to make short-term forecasts of when *Pseudo-nitzschia* HABs may reach WA beaches. The forecast work is also supported by the Office of Naval Research, and by a grant of state funds made through the Washington Ocean Acidification Center (WOAC), leveraging the impact of NANOOS funds. During this past 6 months in addition to the model development MacCready gave three presentations on LiveOcean, including a C-CAN webinar. MacCready is a member of the NANOOS Executive Council and the NOAA West Coast Ocean Forecast System Technical Working Group. This model is a candidate for nesting inside of the NOAA operational models of the California Current that are being developed.

Columbia River: Led by A. Baptista, OHSU maintains an extensive modeling system for the Columbia River coastal margin, integral to CMOP/Saturn and denoted Virtual Columbia River (VCR). The VCR has

evolved from multi-institutional collaborations 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, estuarine pathways (Morrice et al. 2018a, b) and status under the Endangered Species Act and in relation to hydropower management and climate change. Particularly notable 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. An on-going application focus on the impacts of the global sea level rise on the estuary (Baptista et al. 2018b,c).

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 (Vallaeys et al. 2018) and a newly developed code Thetis (paper in review). Results are promising, as are newly developed simulations with a high-order (TVD-based) version of the SELFE-derived code SCHISM. Results for the SCHISM application (Baptista et al. 2018a) have led to the development (in progress) of a simulation database that offers (over an equivalent SELFE database) improvements in the representation of: estuarine classification, salinity intrusion, inflow numbers, vertical stratification, salt retention in ebbs, and residuals.

An invited presentation to the Gordon Research Conference on Coastal Ocean Dynamics (see previous NANOOS reports), and more recent follow-up presentations (Baptista 2018, Baptista et al. 2018a) summarize 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 previous NANOOS reports.

c) Data Management and Communications (DMAC) Subsystem:

Chaired by E. Mayorga (APL-UW), this committee is composed of members from CMOP-OHSU, DOGAMI, OSU and UW. The DMAC and User Products (UPC) teams work in an integrated fashion on the prioritization, development and evaluation of data services and user products. NANOOS is also an active collaborator in national IOOS DMAC efforts. Meeting highlights for this period include: 1) weekly NANOOS "tag-up" calls; 2) monthly NANOOS DMAC technical calls; 3) annual NANOOS Tri-Committee meeting (April 19-20, Portland); 4) annual IOOS DMAC meeting (May 21-23, Silver Spring); 5) IOOS Biodata training workshop (Feb 8-9, Seattle); and 6) Salish Sea Ecosystem Conference data center panel (April 4, Seattle; Mayorga et al., 2018).

NANOOS Visualization System (NVS). NVS was upgraded in December (version 5.5) and May (6.0), with DMAC-supported additions involving new or expanded data layers (NOAA tide gage table presentation, Xtide station expansion into Canada, web cams, and Surfrider water quality citizen

science data) in two new Apps, the Seacast and Beach View Apps. NVS enhancements also encompass asset additions and continuous updates: 1) new or newly incorporated near-real-time in-situ monitoring assets (two OOI benthic platform data streams) and a new, Canadian nowcast model from the University of British Columbia ("SalishSeaCast"); 2) new overlay products from the OSU ROMS model (thermocline and pycnocline depths, and bottom temperature and salinity); and 3) many redeployments and smaller upgrades, including several NANOOS redeployments from UW, CMOP-OHSU and OSU, restored OOI moorings, and WA Department of Health seasonal network redeployment.

NANOOS and IOOS DMAC system implementation. During this period NANOOS was approved as a **Certified Regional Information Coordination Entity (RICE)**, after submittal of the revised application package in February. This milestone was the culmination of a major NANOOS effort that started in late 2016 and fully launched in 2017, when the application was first submitted. Preparation of the DMAC components of the application, particularly the NANOOS Data Management Plan (DMP) together with individual DMP's by NANOOS observing-asset PI's, led to important advancements in the maturity of the NANOOS DMAC effort and concrete system enhancements, including expanded documentation of operations, enhanced system monitoring, and more robust backup procedures. The NANOOS DMP, available on the NANOOS portal, is a new resource that brings more information and transparency about NANOOS data management and distribution processes for observational data (models are outside the scope of the current Certification process).

Other highlights in these areas included:

1. Progress was made in a pilot implementation of automated QC testing and flagging of monitoring data streams based on QARTOD tests and code. These initial steps will be greatly expanded in the next 6 months, with planned engagement from NANOOS PI's and other providers of near-real-time observational data streams in the region. CMOP-OHSU is embarking on a parallel QARTOD implementation that will be carried out in coordination with the NANOOS DMAC pilot (Seaton et al., 2018).
2. At the annual IOOS DMAC meeting, NANOOS contributed to the organization of a session led by RA's and focusing on common DMAC challenges and approaches implemented by the regions.

Marine Biological Data. In early 2017 the IOOS Program Office engaged with NANOOS DMAC (Mayorga) to co-organize and host a training workshop on marine biological data, focusing on recommended best practices, standards, and tools for sharing such data with national interoperable systems. The workshop took place February 8-9 in Seattle and was a success, bringing together participants from across the US, Canada, and Europe. It also created momentum and an opportunity within NANOOS to focus on one existing biological dataset, apply these best practices and eventually submit the dataset to the MBON and OBIS biological data systems. This pilot exercise is providing valuable experience that will benefit other regional datasets in the future.

Ocean Acidification (OA) Data. NANOOS continued its ongoing support for OA data efforts. In the cross-regional IPACOA (IOOS Pacific Region Ocean Acidification) program, initial but significant steps were taken to expand the geographical scope from the Pacific / West Coast region to the national scale. In addition, we worked with CeNCOOS to adapt existing data harvesters to ingest Burke-o-Lator data streams from an ERDDAP server; this capability will be operational very soon and will be applied to other regions as appropriate. Work was also initiated to integrate data from a new MapCO2 OA mooring from Hakai

Institute, in British Columbia. Globally, the GOA-ON (Global OA Observation Network) data portal was enhanced to present the asset inventory information in a more integrated fashion, directly on the asset pop-up window. This enhancement was accompanied by new team documentation describing the GOA-ON asset inventory metadata entry template and automated processes that ingest that information into the data portal. Finally, the usability enhancements from the NVS 6.0 release were applied to both the IPACOA and GOA-ON data portal, which are built on this framework.

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, 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 to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this 2017/2018 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; 2) Participation in the annual tri-committee meeting in Portland, Oregon on April 19-20; 3) Participation in a NANOOS/Or Sea Grant meeting to explore integration of the Seacast app into NVS; 4) Presentation to the Coos Bay maritime harbor safety group on NANOOS maritime/boater apps on May 15, 2018.

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 one minor update on 4 December 2017 and a major update on 1 May 2018. v5.5 released in December reflected the addition of map graticules that can be turned on/off by the user.

NVS v6 is a major update that included significant changes to the user interface, driven by the need to create a cleaner/simpler look (Figure 3). The original 10 buttons down the left side of the screen (i.e. regions, filters, routes, current conditions, fixed/mobile and retired platforms, remote sensing, models, and legend) have been consolidated to 5 buttons (*See figure below*): Platforms, Routes, Filters, Legend and Layers. The latter is now the central repository for all overlays that are include in NVS and is more consistent with approaches used elsewhere in the GIS world. In addition to the more cosmetic changes, v6 included an expansion to Xtides that now includes Canadian tide forecasts. This addition was in response to a specific request from recreational boaters operating in the Salish Sea.

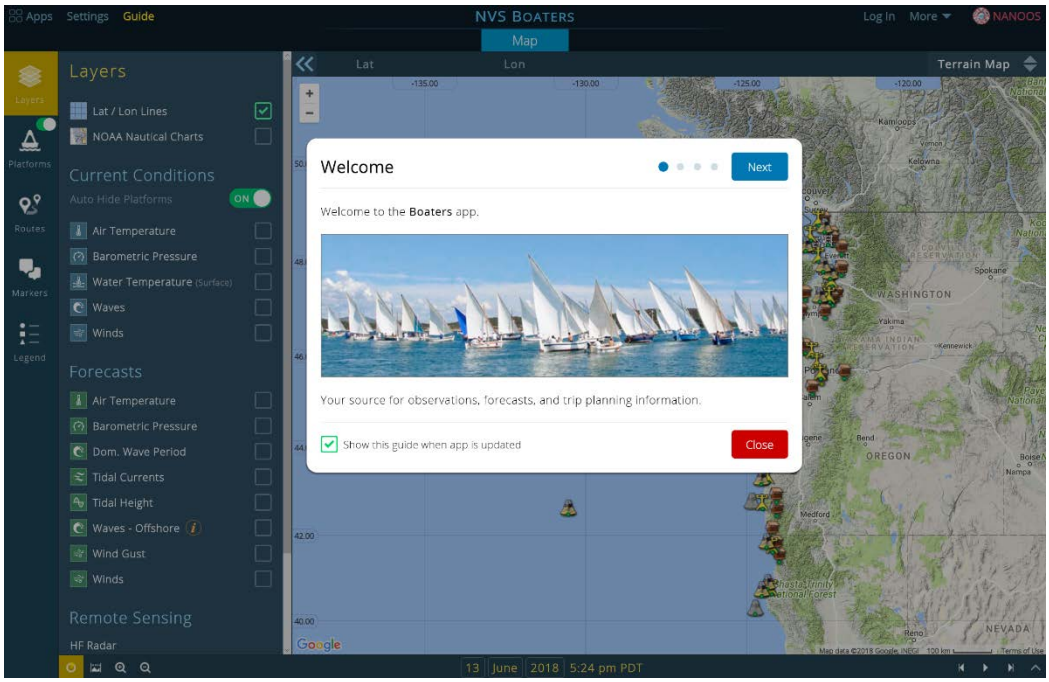

Figure 3. The revised NVS user interface, sporting a new simpler/cleaner look. This version also included a new introductory "Welcome" screen that walks the user through screens that describe how to use a specific app.

v6 also included the release of a new web app called Seacast (http://nvs.nanoos.org/Seacast; Figure 4). This app reflects a collaboration between Oregon Sea Grant and NANOOS to integrate the Seacast app maintained at http://seacast.org/ into NVS. The app was originally developed for fishermen and delivers an easy-to-use interface for Oregon coastal fishermen that shows forecasted sea conditions for a three-day period. The app was originally developed by Oregon Sea Grant with input from fishermen. Seacast displays forecasts for currents, sea surface and bottom temperature, wave height, wave direction, wave period, winds, sea bottom temperature, surface and bottom salinity, and sea surface height. However, with the end of the project, Oregon Sea Grant had no means to maintain it. Following discussion with various members of the NANOOS team the decision was made for NANOOS to develop an entirely new Seacast app within NVS.

NVS Mobile App: NANOOS software engineers are continuing to work on a rebuild of the TsunamiEvac smartphone app, which is currently broken in both the latest Android and iOS operating systems. A draft version of the new tsunami smartphone app was presented and demonstrated at the Tri-Com meeting in April. 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, Mitchell-Morton and Wold, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton, Sprenger Lebrec, Mitchell-Morton 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.

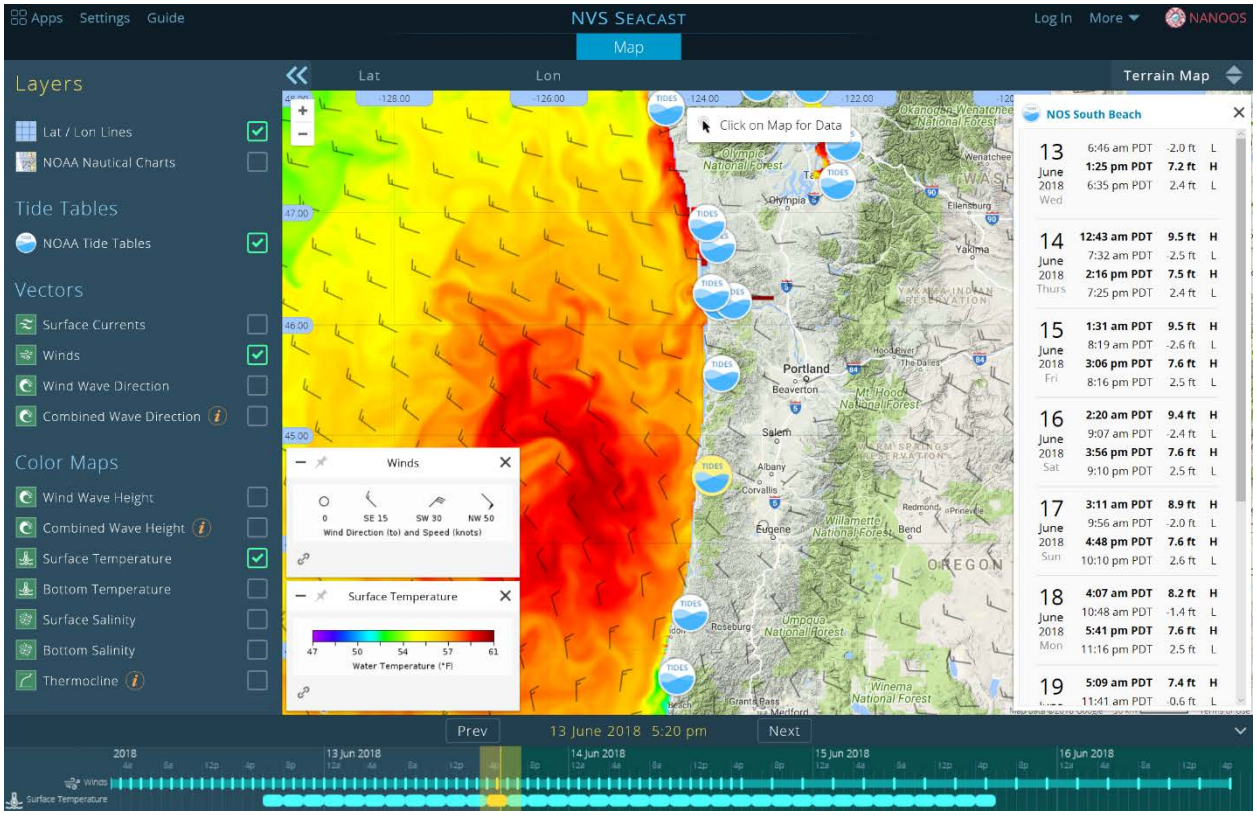

Figure 4. The new Seacast Web App integrated into NVS (http://nvs.nanoos.org/Seacast). The original version of the app was designed with input from local fishermen in Newport, Oregon, and subsequently enhanced by NANOOS.

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 on the planning committee and exhibited at the annual one-day environmental educator event in north Puget Sound, "Storming the Sound" on 25 January, reaching over 120 educators.
- Sprenger has been partnering with a small local non-profit, Whidbey Watershed Stewards, to work with the 8th graders at South Whidbey Middle School ocean science and technology program. Students have designed, built, and deployed 13 buoys at the Langley Marina and will be retrieving and analyzing their data in early June.
- For the eighth year, Sprenger is partnering with WA Sea Grant and NOAA staff in Seattle to co-instruct the NOAA Science Camp's Junior Leadership Program's research project this coming July.
- Sprenger is serving on the planning team for the upcoming Northwest Aquatic and Marine Educators annual summer conference to be held in Portland OR in July 2018.
- Sprenger is updating lesson plans on the NVS portal to reflect new version of NVS 6.0

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 display the NVS Boaters App while gaining their direct feedback. Wold gave seminars and live demonstrations at five regional boaters' events: The Portland Boat Show (January), Seattle Boat Show (January), Sauvie Island Yacht Club (March), US Power Squadron District 32 Spring Conference (March), 'Coho Ho Ho' sailing rally (May).
- Lebrec and Wold staffed a table at the 'Sound Waters – A one-day university for all' on Whidbey Island, WA 3 January, where they engaged with interested citizens. The event was attended by over 500 individuals.
- NANOOS hosted an IOOS-wide exhibit booth at Ocean Sciences Meeting 13-15 February in Portland, OR, and invited all IOOS Regional Associations to participate by sending materials, personnel, etc. NANOOS outreach staff also compiled and distributed a list of all IOOS/RA related events at the meeting.
- At the Salish Sea Ecosystem Conference in Seattle, WA on 4-6 April, Sprenger and Wold presented a poster and staffed an exhibit table to provide information on what NANOOS has to offer and demonstrate NVS.
- Lebrec represented NANOOS with an exhibit table and a presentation at the Saltwater Sportsmen's Show in Salem, OR, on 24-25 February to promote the NVS Tuna Fishers App and engage with the Oregon fishing community.
- Newton gave outreach talks involving NANOOS at the Seattle Boat Show (31 January), Port of Seattle (1 February), Willapa Hills Audubon Society Meeting (26 February), Puget Sound Partnership Science Panel (28 February), and the Salish Sea Ecosystem Conference (5 April).
- Sprenger, Lebrec, Mitchell-Morton 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.
- Newton, Sprenger, Lebrec, Mitchell-Morton 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.
- NANOOS continues efforts on social media, regularly posting on Facebook and Twitter accounts with news, photos, and interesting data. NANOOS also has a growing audience for its monthly newsletter, the "NANOOS Observer."

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. As available, Newton participated in weekly Tri-Comm calls.

Key events for this period included:

- Newton and Martin represented NANOOS at the IOOS spring meeting on 6-8 March in Washington, D.C. and conducted WA and OR delegation Hill briefings along with NANOOS member Andrew Barnard, from Seabird Scientific.
- Newton led the annual NANOOS Tri-Comm meeting over 19–20 April 2018 at the Oregon Health Science University campus.
- Newton attended a meeting with Rear Admiral Tim Gallaudet–Assistant Secretary of Commerce for Oceans and Atmosphere–along with UW and NOAA personnel on 26 January in Seattle, WA, as well as at a breakfast meeting organized by NANOOS member OSU COAS Dean Roberta Marinelli at the Ocean Sciences meeting in Portland, OR, on 15 February.

Additional NANOOS coordination and representation included:

- Newton represented NANOOS at the launch of WA Governor Jay Inslee's Washington Maritime Blue 2050 initiative to bolster maritime sector innovation on 12 December 2017.
- Newton was invited to give talks on ocean acidification at the Seattle Boat Show and Port of Seattle on 31 January and 1 February 2018, respectively.
- NANOOS hosted IOOS Biological Training Workshop in Seattle, Washington, on 8–9 February, co-chaired by Emilio Mayorga with participation by Newton and four NANOOS region biologists.
- NANOOS helped lead the National Coastal Mooring workshop, hosted by the Alliance for Coastal Technologies (ACT) and sponsored by IOOS, on March 20–22 in Seattle, WA, involving many NANOOS PIs and regional participants.
- Newton co-chaired a session on ocean acidification and gave a talk 'An overview of the Global Ocean Acidification Observing Network, GOA-ON: serving science and policy' at Ocean Sciences Meeting 2018 on 12 February in Portland, OR. She also gave an outreach talk on the IOOS OTT project on OA observing technology: 'Scientists and Shellfish Growers working together for increased knowledge' on 12 February.
- Newton represented NANOOS at the signing of WA Governor Inslee's Executive Order 18-02 on Orca Whale preservation on 14 March in Seattle, WA.
- Newton represented NANOOS at the launch of the pH sensor-equipped yacht "Visit Seattle" taking part in monitoring during the Clipper "Round the World" yacht race on 27 April in Seattle.
- Newton was invited to represent NANOOS in a presentation to the NSF OOI Facilities Board on 7 May in Seattle, WA.
- Newton represented NANOOS in the ACT Hyperspectral Workshop to develop a report on the current state of hyperspectral imagine and advise on IOOS information needs for this technology on 15–16 May in Honolulu, HI.
- Newton presented along with CeNCOOS and SCCOOS on coastal conditions in the NOAA Western Regional Center's West Watch webinar series on 23 January and 22 May 2018.
- Newton served as the Research Seat for the Olympic Coast National Marine Sanctuary Advisory Council, attending meetings in coastal WA on 8 December, 2 February, 23 March, and 18 May.

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

- Newton serves on the Ocean Obs'19 Program Committee and participated in a working meeting 27-29 March in Washington DC and participated in calls and other planning activities.

- NANOOS PIs Barth and Mayorga sit on 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.
- Newton was invited to participate in the Sustainable Development Goals 14.3.1 indicator methodology Expert Workshop on 16–18 January 2018 in Paris, France, with respect to the GOA-ON data portal and stakeholder observations.
- Newton was invited to participate in the Canadian Nearshore Productivity Workshop, 22-23 February 2018, in Vancouver, British Columbia, hosted by the Dept. of Fisheries and Ocean Canada, to give a talk on assessing nearshore dynamics from NANOOS.
- Newton moderated a session "Salish Sea Marine Ecosystem Data Collation and Management" at the Salish Sea Ecosystem Conference, which included speakers from Ocean Network Canada, Hakai Institute, NANOOS, Pacific Salmon Foundation, and the Northwest Indian Fisheries Commission on 4 April in Seattle, WA.
- Newton is a member of the Global Ocean Acidification Observing Network Executive Committee calls and activities and attended their Annual Meeting in Sopot, Poland, on 28-31 May.
- Newton is a member of the International Technical Advisory Council for the Joint European Research Infrastructure for Coastal Observatories (JERICO), fostering international collaboration with IOOS and shared practices. During the period, she reviewed proposals that will be evaluated at their General Assembly in June 2018 and is asked to discuss JERICO's Ocean Obs'19 CWP.
- 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 as they began developing the Canadian Integrated Ocean Observing System (CIOOS).

Ongoing NANOOS coordination:

- Barth continued to serve 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.
- Newton participated in "OA Round Tables" organized by NOAA PMEL and NWFSC.
- Newton continued to represent NANOOS in regional efforts, e.g., C-CAN, PSEMP, Pacific Salmon Marine Survival, and the West Coast Ocean Data Portal.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

Allan, J.C. Between a Rock and the Ocean: Implications of Future Sea Levels on Pacific Northwest Beaches and Estuaries. Oregon Surfrider, Charleston, Oregon. 28 November 2017.

Allan, J.C. Clatsop Spit: Recent Coastal Changes, 2015-2018. MCR Beneficial Use Technical Workshop. 10 May 2018.

Baptista, A.M., Seaton, C.M. and Turne, P.J. Lessons from a humbling benchmark. *In silico* estuarine oceanography: Are we there yet? NSF Workshop on the future of coastal and estuarine modeling. Raleigh, NC, 18-21 June, 2018a.

Baptista, A.M. Observations and Simulations to Characterize a Changing Estuary: The Good, the Bad, and the Uncertain, 2018 Columbia River Estuary Conference. Astoria, OR, 10-12 April 2018.

Baptista, A.M., Rostaminia, M., Seaton, C.M. and Turner, P.J. Revised Estimates of Impacts of Sea Level Rise in the Columbia River Estuary, 2018 Columbia River Estuary Conference. Astoria, OR, 10-12 April 2018.

Baptista, A.M., Rostaminia, M., Turner, P. J. and Seaton, C. M. Using Multi-Year Simulations to Disentangle Variability and Change in Estuaries, Abstract OC13A-10, presented at 2018 Ocean Sciences Meeting. Portland, OR, 12-16 February, 2018c.

Cohn, N., Hoonhout, B., Ruggiero, P., de Vries, S., Moore, L., Goldstein, E., Duran, O., and Roelvink, D. Synchronization of sediment exchanges between the nearshore, beach, and dune: Insights from field observations and a coupled numerical model. Ocean Sciences. Portland, OR. February 2018.

Helms, A., Schmitt, J., and Belanger, J. Overview of National Estuarine Research Reserves Network, System-Wide Monitoring Program, NANOOS Data Visualization System, and Land Use. South Slough Reserve Formal Education Program for Stonehill College, MA. 18 May 2018.

MacCready, P., S. Siedlecki, R. McCabe, and N. Banas. LiveOcean: A Daily Forecast Model of Biogeochemistry in Washington Marine Waters. C-CAN Webinar. January 2018.

MacCready, P., S. Siedlecki, R. McCabe, and N. Banas. LiveOcean: A Daily Forecast Model of Biogeochemistry in Washington Marine Waters." Talk for visiting delegation from Indonesia, UW-APL. February 2018.

MacCready, P., Siedlecki, S., McCabe, R., & Banas, N. LiveOcean: A Daily Forecast Model of Biogeochemistry in Washington Marine Waters. Salish Sea Ecosystem Conference, Seattle, WA. May 2018.

Mayorga, E., T. Tanner, J. Allan, J. Newton, and R. Wold. Supporting diverse Pacific NW marine data access needs via the NANOOS Visualization System (NVS) and data services. Salish Sea Ecosystem Conference / Salish Sea Marine Ecosystem Data Collation and Management panel, Seattle, WA, 4 Apr 2018.

Morrice, K.J., Baptista, A.M. and B. J. Burke. Estuarine Pathways of Juvenile Chinook Salmon in the Columbia River, 2018 Columbia River Estuary Conference. Astoria, OR, 10-12 April, 2018a.

Morrice, K., Baptista, A.M. and Burke, B. J. Estuarine Pathways of Juvenile Salmon in the Columbia River, Abstract EP44A-0877, 2018 Ocean Sciences Meeting. Portland, OR, 12-16 February, 2018b.

Newton, J. and Feely, R. Ocean Acidification: What are its impacts now and in the future? Seattle Boat Show, Seattle, WA. 31 January; Port of Seattle, Seattle, WA. 1 February 2018.

Newton, J., Tilbrook, B., Jewett, E. An overview of the Global Ocean Acidification Observing Network, GOA-ON: serving science and policy. Ocean Sciences Meeting 2018, Portland, OR. 12 February 2018.

Newton, J., Hales, B., Evans, W., Jewett, E., Rhoades, J. Scientists and Shellfish Growers working together for increased knowledge. Ocean Sciences Meeting 2018, Portland, OR. 12 February 2018.

Newton, J. Assessing nearshore dynamics from NANOOS. Nearshore Productivity Workshop, Vancouver, British Columbia, Canada. 22-23 February 2018.

Newton, J. Ocean Acidification: A Global Issue with Local Effects. Willapa Hills Audubon Society. Longview, WA, 26 February 2018.

Newton, J. Data and Decision Tools from NANOOS. Puget Sound Partnership Science Panel. Seattle, WA, February 28, 2018.

Newton, J., Alin, S., Curry, B., Sutton, A., Mickett, J., Feely R., Lebrec, M., Greeley, D., Ruef, W., Fassbender, A., and Klinger, T. Patterns and variability in ocean acidification conditions in Puget Sound and the Strait of Juan de Fuca. Salish Sea Ecosystem Conference. Seattle, WA. 5 April 2018.

Newton, J., Mickett, J., Curry, B., and Tyler, B. Central Salish Sea observations. Puget Sound Ecosystem Monitoring Program, Marine Waters Overview workshop, Seattle, WA. 17 April 2018.

Pasmans, I., Kurapov, A., Barth, J.A., Kosro, M., and Shearman, K. Why gliders appreciate good company: glider assimilation in a 4DVAR system with and without surface observations. Paper OM13A-03, Ocean Sciences Meeting, Portland, OR, 12 February 2018.

Pool, S., Krembs, C., Bos, J., and Albertson, S. Using ferry monitoring data to explore the importance of isotherms on the winter survival of Northern anchovy in Puget Sound. Ecology Publication No. 18-03-017. Presented at Salish Sea Ecosystem Conference, 4 April 2018.

Seaton, C.M., Wilkin, M. and Baptista, A. M. OD24C-2735: Implementation of a Standardized Real-time Data Quality Assurance System for the Columbia River Estuary, Abstract OD24C-2735 2018 Ocean Sciences Meeting. Portland, OR, 12-16 February, 2018.

Publications:

Allan, J.C., Gabel, L., and O'Brien, F. 2018. Beach and shoreline dynamics in the Cannon Beach littoral cell: Implications for dune management. Oregon Department of Geology and Mineral Industries, Special Paper 49, 123 p.

Cohn, N., Ruggiero, P., de Vries, Sierd, and Kaminsky, G. 2018. Sediment exchanges between the nearshore, beach, and dune: Insights from field observations at time scales of days to decades. Geophysical Research Letters, https://doi.org/10.1029/2018GL077836.

Diez, J. Cohn, N., Kaminsky, G., Medina, R., and Ruggiero, P., 2018. Spatial and temporal variability of dissipative dry beach profiles in the Pacific Northwest, U.S.A., Journal of Coastal Research. 34(3), 510–523, https://doi.org/10.2112/jcoastres-d-17-00149.1

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. https://doi.org/10.1002/ece3.3663

Fassbender, A. J., Alin, S. R., Feely, R. A., Sutton, A. J., Newton, J. A., Krembs, C., Bos, J., Keyzers, M., Devol, A., Ruef, W., and Pelletier, G. 2018. Seasonal Carbonate Chemistry Variability in Marine Surface Waters of the Pacific Northwest. Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-138.

Hamann, M., Alford, M. H., & Mickett, J. B. 2018. Generation and propagation of nonlinear internal waves in sheared currents over the Washington continental shelf. Journal of Geophysical Research: Oceans, 123, 2381-2400. https://doi.org/10.1002/2017JC013388.

Pasmans, I., A. L. Kurapov, J. A. Barth, P. M. Kosro, and R. K. Shearman. 2018. Why gliders appreciate good company: Glider assimilation in a 4DVAR system with and without surface observations. JGR Oceans, submitted.

Soh, H.S., S.Y. Kim, Kosro, P.M. and Kurapov, A.L. 2018: Do Nonorthogonally and Irregularly Sampled Scalar Velocities Contain Sufficient Information to Reconstruct an Orthogonal Vector Current Field? J. Atmos. Oceanic Technol., 35(4), 763–795, https://doi.org/10.1175/JTECH-D-17-0062.1

Vallaeys V., Kärnä, T., Delandmeter, Lambrechts, P., Baptista, A.M., Deleersnijder, E. and Hanerte, E. 2018. Modeling the coupled estuary-plume dynamics in the Columbia River. Ocean Modelling. https://doi.org/10.1016/j.ocemod.2018.02.004

Yoo, J. G., Kim, S. Y., Bruce, D., Cornuelle, P., Kosro, M., & Kurapov, A. 2017. A Noninterpolated Estimate of Horizontal Spatial Covariance from Nonorthogonally and Irregularly Sampled Scalar Velocities. J. Atmos. Oceanic Technol, 34(11), 2407–2430. http://doi.org/10.1175/JTECH-D-17-0100.1