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

NOAA Award: NA16NOS0120019 Reporting period: 12/01/2018 to 5/31/2019

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 FY18 period (= Y3 of this award; Y12 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 FY16 from the NOAA Ocean Acidification Program, coordinated via IOOS:

10) Support collection of OA measurements on our La Push [J. Newton, J. Mickett, UW] and NH10 and CB06 [B. Hales, OSU] moorings, working with NOAA PMEL and the NOAA OA Program Office through the IOOS Program Office.
11) Support collection of OA measurements at shellfish hatchery locations via technical expertise (B. Hales, OSU and B. Carter, UW JISAO), as part of Ocean Technology Transition in support of ocean acidification observing in support of Pacific coast shellfish growers.
12) Support Pacific Northwest Harmful Algal Bloom observing with an Environmental Sampling Processor (J. Mickett, UW).
13) Support HAB sampling with a Submaran Platform (J. Mickett, UW; N. Trenaman, OceanAero).
14) Support various GOA-ON activities (J. Newton, UW; E. Mayorga, UW).

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 18:

Area	**Y3 Award = Y12 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 Coos Bay buoy; deliver NRT data streams via NVS **-Support collection of OA data from CB-06 buoy with NOAA OAP funding** -Maintain Columbia R. buoy; deliver NRT data streams via NVS -Maintain N CA shelf glider transect; deliver data via NVS **-Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA** **-Support Environmental Sampling Platform for PNW HAB observing**

	-Test Submaran platform as an aid to sampling HABs in Juan de Fuca eddy -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 WA; deliver data via NVS -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 **- Fill gaps in HF Radar operations and maintenance by OSU to complete west coast coverage for health and safety** -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; deliver model output via NVS -Maintain modeling & forecasting capabilities at OHSU; deliver model output via NVS -Maintain modeling & forecasting capabilities at OSU; deliver model output via NVS -Model verification and validation **-Data denial tests at OSU**
DMAC	
Data Portal and 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 **-Enhance GOA-ON data portal an OA dashboard to the world** **-Enhance biological data stewardship within NANOOS**
Tailored Product Development	-Climatology, Tsunami resilience SeaCast, Surfer, and Beachview web app development -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. **-Engage in GOA-ON support activities (including North American Hub, Timeseries, and GOA-ON workshops)**
Accountability	-Submit required IOOS progress reports and respond to other requests. -Comply with 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 Observations*:**

-Maintain La Push buoy; deliver NRT data streams via NANOOS Visualization System (NVS) [Szuts]

-Bring all data QA/QC to meet Certification standards [Szuts]

The Washington Coast buoy observation program, now led by Z. Szuts, Applied Physics Laboratory, University of Washington (APL-UW), continued to maintain and operate two real-time moorings 13 miles NNW of La Push, Washington. The spring turn-around cruise 20-25 May 2019 on the APL-UW vessel R/V Jack Robertson was successful. Real-time measurements are reported on NANOOS NVS. We have established a protocol of annual calibrations for sensors deployed on the Washington shelf (for CTDs, dissolved oxygen, pH).

The winter mooring deployed in Oct 2018 was successfully recovered. It has a reduced number of sensors to minimize winter loss, with internally-recording moored CTDs, pH sensors (SeaFET v2), temperature sensors, and a real-time pCO2 and pH system from NOAA PMEL (Drs. Sutton, Alin and Feely). A number of instruments at the bottom of the mooring line were torn off due to suspected fishing activity.

Two summer moorings were deployed in May 2019, a surface mooring (Ċháʔba·) with realtime data transmission, and a subsurface mooring (NEMO Subsurface) with a profiling CTD and current profilers. These profilers are reporting data in real time on the NANOOS Visualization System (NVS). The surface buoy has a functioning AIS system for the first time, to avoid ship strikes and to transmit its location to nearby boaters. Two pH sensors are on the surface mooring at the surface and 45 m.

After the May cruise, a CTD transect and OA/HAB water sampling was collected through the Strait of Juan de Fuca, with a few profiles through Puget Sound to end at Seattle. HAB sampling was coordinated with the Quileute Tribe through biologist J. Hagen, who participated on this cruise.

-Support Environmental Sampling Platform for PNW HAB observing *[Mickett]*
This deployment was completed in October 2018, so there is nothing to report for this period. It is worth noting, however, that a NOAA MERHAB proposal with NANOOS as a partner (PIs Mickett, S. Moore, J. Newton and others) has been recommended for funding. This project would deploy this ESP mooring at the NANOOS mooring site for four consecutive HAB seasons (spring to fall) in years 2021-2024, providing valuable near real-time information on potential and extant HABs to stakeholders via the NANOOS Real-time HABs website.

-Support collection of OA data from La Push buoys with NOAA OAP funding *[Szuts, Mickett, Newton]*
We have continued to work with NOAA PMEL scientists Drs. Adrienne Sutton, Simone Alin, and Richard Feely, to maintain pCO2 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. Newton, Mickett, and Szuts 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 on several deployment cruises.

A summary of the 2018 observations collected by these moorings were submitted for inclusion in the 2018 Puget Sound Marine Waters Report.

-Test Submaran platform as an aid to sampling HABs in Juan de Fuca eddy *[Mickett]*
This work, which was initiated under the oversight of T. Vance of IOOS, involved carrying out several test missions using the Ocean Aero ASV (autonomous surface/underwater vehicle) Submaran to collect offshore HAB water samples and return these samples to shore for processing. It also included preliminary development work to design a system to collect up to a dozen samples. Partners included NANOOS, Ocean Aero, Olympic Region HAB partnership (ORHAB), NOAA NWFSC, the Makah, and the Applied Physics Laboratory, University of Washington (APL-UW). With the test deployment completed in September 2018, work during this period involved developing and drafting a white paper on a multi-sample prototype water collection system. As part of this effort, APL-UW mechanical engineer D. Martin traveled to San Diego to work directly with Ocean Aero for three days in early December 2018.

Ocean Aero and UW-APL engineers were able to successfully develop a low-cost prototype design that would allow up to 12 1-liter geo-referenced samples to be collected on a roughly 48-hour mission. The design evaluated and documented specific components (e.g. pumps, valves, tubing, sample storage) and plumbing configurations to build this system, with the team now positioned to assemble and test this system should additional funding become available for this work. A proposed budget for this continued work is included in the white paper. Again, with rough weather on the Washington and Oregon coasts often limiting collection of HAB samples via small boat, the Submaran collection system offers a potentially more reliable way to collect regular, spatially geo-referenced offshore HAB water samples. The Submaran system complements moored systems like the ESP mooring, which samples frequently at one location for a season, in that it can collect *spatial* information on HABs at less frequent (~weekly) intervals.

Oregon Shelf Glider Observations:

-Maintain N CA shelf glider transect; deliver data via NVS [Barth]

-Bring all data QA/QC to meet Certification standards [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 fieldwork 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 (5/31/2019), the glider was on the TH line for 1446 days during nine deployments, sampled along approximately 26,395 km of track line covering the transect about 73 times, and collected about 11,584 vertical profiles of ocean properties. For the reporting period 12/1/2018 to 5/31/2019 the glider was on the TH line for 182 days during two deployments, sampled along nearly 3400 km of track line covering the transect about 9 times, and collected about 1453 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.

Data from the Trinidad Head glider line are being used to monitor the demise of the 2014-2017 "Warm Blob" and the 2018-2019 El Niño. Water at depth is warm during Fall 2018, similar to the subsurface warming associated with the 2015-2016 El Niño (Figure 1). These temperature anomaly data are also being compared to similar information from farther south on the CalCOFI lines and farther north off Oregon and Washington from the Ocean Observatories Initiative gliders.

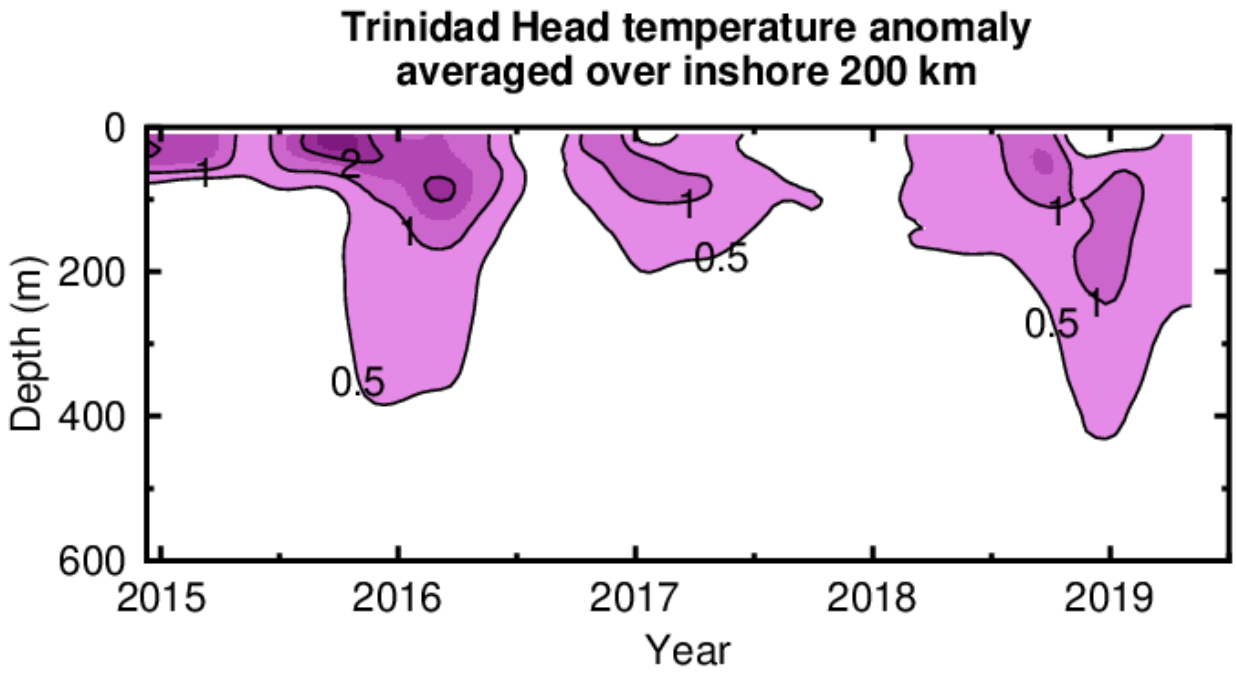

Figure 1: Temperature anomaly from the Trinidad Head, CA (41° 3.5'N) glider line.

Oregon Shelf Mooring Observations:

-Maintain Coos Bay buoy; deliver NRT data streams via NVS [Kosro, Hales]

-Bring all data QA/QC to meet Certification standards [Kosro, Hales]

Following several months of un-workable sea states, the Oregon shelf mooring, CB-06, was re-deployed on March 9, 2019, using its newly constructed 2nd buoy, near Coos Bay, at 43° 17.497' N, 124° 32.297' W, in about 100m of water. The work was done from the charter vessel Miss Linda out of Charleston, OR. Acquisition and telemetry of data from meteorological and oceanographic (physical and chemical) sensors on the buoy were successful. Data were plotted in near-real time for the NANOOS Visualization System (NVS) and on a local server (http://bragg/CB06_Telemetry/Plots/). They were also forwarded to NDBC, which displayed them as buoy ID 46128. Strong inertial currents were evident in the near-surface ADCP currents, and initial salinities (below 32) were clearly influenced by river flow.

A moderately strong storm hit during April 6-7, 2019. The buoy has 3 separate and independent reporting systems to measure and telemeter its position to shore. During that evening, all 3 streams of location data stopped, and we never received an updated position for the buoy. The US Coast Guard conducted some helicopter checks in the vicinity, but no buoy was sighted. We alerted sheriffs' deputies and park rangers along the Oregon and Washington coasts; one sighting was reported, but it failed to be confirmed on follow-up. We conclude that the buoy and its contents were lost at sea. We obtained vessel-tracking data (AIS) for April 6 and 7 to investigate whether the buoy had been struck by a known vessel. While the track of no vessel appeared to get closer than 2 or 3 miles, the nearest vessel, a container ship bound for Mexico, executed some very odd maneuvers (turns, decelerations, accelerations) in the latitude of CB06, and passed the buoy location at about the right time. A container

vessel is equipped with substantial lifting capacity, and could have separated itself from an entangled buoy with relative ease.

As we have developed full hot-swappable capability, the second buoy is ready to deploy as soon as we identify ship time and receive the MApCO2 from PMEL. We have an identified cruise of opportunity on the RV Oceanus from 29 July to 4 August, but will pursue other for-hire opportunities sooner than that. We intend to rebuild the lost buoy with new funds and deploy at the same location once we can purchase/build/assemble the needed pieces and instruments.

-Support collection of OA data from CB-06 buoy with NOAA OAP funding *[Hales]*
As the most recent deployment lasted only a month March-April 2019, the data is only minimally interpretable. For the interval sampled, the data exhibited the now-familiar pattern of moderately undersaturated winter-time pCO_2 conditions, and relatively stable pH ranging from 8.1 – 8.2. A handful of check samples collected in late March confirm the MApCO2 observations.

-Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA *[Hales]*
Hales' team continues to work with Whiskey Creek Shellfish Hatchery to provide technical assistance to maintain the Burke-o-Lator and field-test the ACDC sensor. Hales' student, W. Fairchild, is processing historical WCSH data, and has a continuous compiled record of pCO_2 and TCO_2 going back to 2014 showing the clear transitions between upwelling and downwelling conditions, and interannual variability in the intensity and timing of upwelling signals. In addition, Hales and team are working extensively with several other local-expert site operators to maintain, troubleshoot, and repair BoL instrumentation. Hales has extensively assisted J. Tyburczy and J. Abell with the operation of the BoL at Hog Island's Eureka hatchery facility, the newest addition to the shellfish-industry supporting instrumentation. This instrument appears to be performing well. Hales has extensively assisted with the troubleshooting of the Hog Island Marshall grow out facility, an instrument that has been plagued with damage and technical shortcomings. The instrument was removed and delivered to OSU for more thorough repair in early June. Our technical personnel are currently involved in other seagoing operations, and we will assess the system and advise on its repair later this summer. Redeployment options for this instrument are under consideration. Technical personnel limitations for supporting this instrument are significant and must be addressed before the decision is made to return the instrument there. Hales' team has had extensive interactions with PSI personnel in recent months, and has embarked upon upgrading the Willapa Bay SuperCO2 instrument to full BoL capabilities. Hales has updated the operational software, and tested it extensively at the Hakai Institute and at WCSH, and will distribute this update to other users in coming months.

-Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA *[Carter]*
Technical assistance to maintain the Burke-o-Lator and field test the ACDC sensor was provided by Julian Herndon (UW JISAO) at the Taylor Shellfish Hatchery. During this period, Herndon created and provided liquid standards for the Taylor Burke-o-Lator, and helped to troubleshoot and ordered parts to refresh that system. This is one of the oldest systems in the West Coast Burke-o-Lator network.

Northern Oregon to Central Washington Shelf Observations:
-Maintain Columbia R. buoy; deliver NRT data streams via NVS [Baptista]
-Bring all data QA/QC to meet Certification standards [Baptista]

Led by PI A. Baptista, OHSU maintains observational assets in the Columbia River coastal margin. These assets are anchored on SATURN-02, a seasonal inter-disciplinary buoy, with real-time telemetry, located off the mouth of the Columbia River at ~35m depth. SATURN-02 data routinely contributes to model validation, capturing near-field Columbia River plume dynamics. Data also routinely offer local temporal context and for specialty buoy deployments and for cruises.

SATURN-02 was re-deployed on May 17, 2019. Parameters measured are (a) wind speed, direction and gust, air temperature and atmospheric pressure; (b) water velocity; and (c) the scalar water parameters: temperature, salinity, dissolved oxygen/oxygen saturation, chlorophyll, turbidity, CDOM, phycoerythrin and nitrate. Scalar water measurements were made through single at-surface sensors and a multi-level pumping system. Levels measured are 1, 6, 11, 16, 21 and 35m depth.

Figure 2 shows that, shortly after the deployment of SATURN-02, there was an onset of hypoxia in the coast. While the moderating effect of the high-oxygen plume is clearly visible at the surface, the depth extent of the low oxygen increases substantially over time.

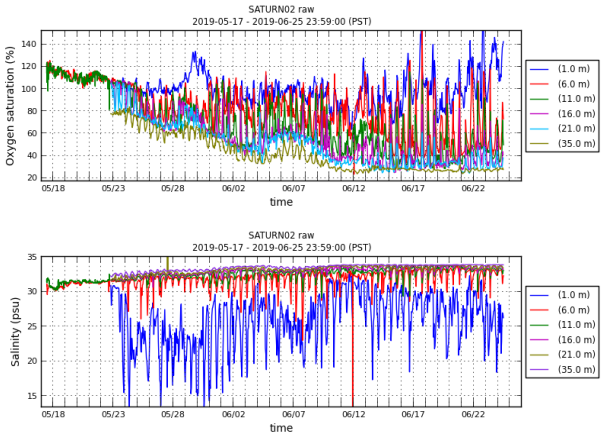

Figure 2: Oxygen saturation (top) and salinity (bottom) at SATURN-02, after deployment on May 17, 2019. Levels are relative to the water surface. Data show the onset of coastal hypoxia, periodically moderated on a local basis by the highly oxygenated freshwater plume.

OHSU also deployed North Head, a temporary real-time buoy to support NOAA/USACE studies of the impact of dredged disposal on crabs. The station was deployed north of the Columbia River mouth on June 12, 2019. 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: 1, 6 and 14m below sea level.

Real time data from SATURN coastal stations are already being displayed on NVS. OHSU also provides access to SATURN long-term datasets via THREDDS, inclusive of a catalog summary—both essential building blocks to support the NVS display of long term datasets.

QARTOD flagging for real-time data remains an objective, with substantive implementation tentatively targeted for the October 2019 IOOS Hackathon.

- **Estuaries**

Puget Sound Buoy Observations:

-Maintain Puget Sound estuarine moorings; deliver data via NVS [Szuts]

-Bring all data QA/QC to meet Certification standards [Szuts]

Led by Z. Szuts, 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.

The ORCA moorings continue to be upgraded with newer designs to improve their performance and minimize maintenance effort. With more spare parts in the lab, the team is able to build duplicates prior to going in the field to swap out more complete systems and avoid diagnosing problems in the field. A few key parts are still needed to complete this effort. They have continued regular dive inspection of the buoys, to catch potential failures quickly. The Bellingham Bay Buoy Se'lhaem, part of this network, provided near full data up-time and minimal field servicing.

Collaborations continued with multiple ongoing projects that required lots of fieldwork. For NOAA Ocean Acidification, we have been maintaining and deploying pH sensors, now mostly upgraded to version 2. For work with A. Sutton, S. Alin, and R. Feely (NOAA PMEL Carbon Group), we supported deploying pCO_2 systems on Twanoh and Dabob Bay, including water samples for system calibration. For a Bivalve study by J. Padilla-Gamino (UW Fishery Sciences), we have attached and serviced cages for bivalve to grow in. Support has continued for a study by investigators at the Smithsonian Museum of Natural History to investigate biofouling by placing plates on 3 moorings.

ORCA observations continue to be critical to helping us understand how Puget Sound recovers from the unprecedented warm anomalies of 2015 and 2016 and from hydrological anomalies. Data continue to be made available through NANOOS NVS and through the NWEM ORCA server. We have established a protocol of annual calibrations for CTDs and other sensors (dissolved oxygen, pH).

Washington State Estuarine Observations:
-Maintain US-Canada ferry-box; deliver data via NVS [Maloy]
-Bring all data QA/QC to meet Certification standards [Maloy]
Led by C. Maloy and C. Krembs (WA State Department of Ecology), Ecology's extensive long-term monitoring program covers Puget Sound and the Washington coastal estuaries. This long-term program consists of monthly marine water sampling to monitor marine water quality and to examine water processes as they relate to temperature variations, currents, river flows, nutrients, algal blooms, etc. Moorings were previously deployed to provide continuous information on estuarine water conditions and to complement Ecology's monthly marine water sampling. Since the moorings program ended, we focused our efforts on performing data quality control and conducting data analysis.

The long-term program, with assistance from our information technology staff, has been working to make Ecology's marine water column data publicly available by putting them into the agency's Environmental Information Management (EIM) database system. During the past several months, about 97% of the water column profiles were transferred from our internal marine water column database to EIM. As part of this process, two comparisons were made as part of quality control and assurance. The first was to compare record counts between the internal database and EIM. The second was to compare values of each measurement between the two databases. At this time, we have CTD vertical profiles from Jan 1999 to Dec 2017 in EIM.

For the moorings, we are continuing to examine the value of including pressure data in our analysis, particularly because the instruments did not have a pressure sensor from 1997 to 2007. After this

step is completed, we will transfer the Bay Center mooring's temperature and salinity data into Ecology's EIM database. Having mooring data in EIM will allow researchers, scientists, and interested citizens to freely search for and obtain the mooring data.

Columbia River Estuarine Observations:

-Maintain Columbia R. estuarine moorings; deliver data via NVS [Baptista]
-Bring all data QA/QC to meet Certification standards [Baptista]

Led by PI A. Baptista, OHSU maintains multiple endurance stations for the lower Columbia River estuary that anchor the CMOP/SATURN network. Also associate to SATURN, but not funded by NANOOS, are two freshwater stations: SATURN-05 and SATURN-08, maintained by J. Needoba (OHSU) with regional stakeholder funding.

The NANOOS supported estuarine stations that are maintained on a permanent or seasonal basis are SATURN-01, SATURN-03, SATURN-04, SATURN-07, SATURN-09, CBNC3 and Elliot Point. All except CBNC3 have real-time telemetry. All but CBNC3 and Elliot Point (which currently only measure salinity and temperature) are inter-disciplinary (physics and biogeochemistry). Except for SATURN-01 and SATURN-07, all these stations are currently deployed.

Multiple other estuarine stations have collected historically important data, and we re-deploy some of these stations on occasion, as resources allow and scientific or regional needs recommend; none of these stations has been deployed so far in 2019, although Grays Point is under consideration to help better understand salt propagation in the northern flats of the estuary.

Data from all real-time estuarine stations are already displayed on NVS. Data from stations without telemetry are not currently displayed on NVS, but are retroactively stored in national oceanographic archives. OHSU also provides access to SATURN long-term datasets via THREDDS, inclusive of a catalog summary—both essential building blocks to support the NVS display of long term datasets.

QARTOD flagging for real-time data remains an objective, with substantive implementation tentatively targeted for the October 2019 IOOS Hackathon.

South Slough Estuarine Observations:

-Maintain South Slough estuarine moorings; deliver data via NVS [Helms]
-Bring all data QA/QC to meet Certification standards [Helms]

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 operation of 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 stations provided measurements of water temperature, salinity, dissolved oxygen, pH, turbidity, and water level data over the period 12/01/18 –05/31/19. Telemetry transmissions were continuous from December through 4/6/2019. All four water quality stations and the weather station were affected by a GPS rollover event. All stations were fixed by 5/7/2019 with firmware updates for Sutron Satlinks and replacement of the transmitter (TX312) to the newer model

TX321 at the weather station. Instrument deployments, routine station maintenance, and data management were completed for the weather and water quality stations during the reporting period following NOAA NERRS Centralized Data Management Office protocols.

We maintain one Coos Bay 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 (NESDID ID # 346F229A; sosnswq), is located in the lower Coos estuary with data available via the NVS.

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 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 research and education programs at the Reserve including a project funded by the NERRS Science Collaborative Capacity Building grants – *Building capacity to respond to an eelgrass (*Zostera *sp.) decline in the South Slough estuary, OR* with participation from over fifty eelgrass scientists and stakeholders and NOAA NERRS Teachers on the Estuary Workshops February (Ocean Acidification theme) and June 2019 (Seal Level Rise theme) with 20 Oregon and Washington K-16 teachers participating.

South Slough expanded the network of water quality stations into the Coos estuary to include four stations (North Point, Isthmus Slough, Catching Slough, and Coos River). The North Point station is located near commercial oyster cultivation areas and will be prioritized for adding telemetry and hosting data via NVS. South Slough added pCO2/ pH monitoring equipment at the Valino Island station as well as the Charleston Bridge station through OSU collaboration and continued data collection and maintenance, including annual SeapHOx and SAMI-CO2 refurbishment supported through NANOOS.

- **Shorelines**

Washington Shoreline Observations:

-Maintain shoreline observations in WA; deliver data via NVS [Kaminsky]
-Bring all data QA/QC to meet Certification standards [Kaminsky]

NANOOS funds contribute to the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) led by G. Kaminsky. In December 2018, 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 7 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.

Benson Beach continued to manifest as the coastal erosion hotspot for the CRLC. Compared to last fall, all profiles at Benson Beach show dune retreat. The most significant retreat and beach lowering occurred at the northernmost profile, Aschwa, with dune retreat of approximately 18 m and lowering of the beach by 1-1.5 m. The dune at Canby retreated by 6 m and the profile also shows beach lowering of approximately 40 cm or less. The southern two profiles show an increase in beach

elevation as the dune retreated, as the shoreline rotated into equilibrium. The dune at Philo retreated by 11 m and the beach accreted across the profile below 4 m NAVD88 by 0.8-1 m. The dune at Hans RM only retreated by 1.5 m and the beach accreted below 4 m NAVD88 by 0.6 m.

The largest storm event for the winter occurred in December and significant storm events occurred in early January, but other than Benson Beach, most beaches of the CRLC did not experience significant erosion impacts. At Westport, approximately 500 cy of sand and new coir mat was added to the dune fronting Westport by the Sea Condominiums at the end of January. New revetment rock was placed at Ocean Shores at profile X1 South to protect the house from the end scour of the revetment to the north.

In March 2019, CMAP conducted winter seasonal beach monitoring surveys in the CRLC, collecting 50 seasonal beach profiles (plus a total of 19 supplemental profiles as in the fall), 5 surface maps, and 62 sediment samples from multiple cross-shore locations along 13 of the profiles. Benson beach experienced significant retreat and overwash due to loss of the dunes north of the Aschwa profile.

With other project funds, CMAP continued more intensive beach monitoring at North Cove following the construction of a dynamic revetment spanning approximately 2 km. CMAP collected 36 beach profiles and a surface map in December, 40 beach profiles and a surface map in January, and 47 beach profiles and a surface map in both February and March. The dynamic revetment appears to have prevented significant loss of the uplands during the winter. Topographic surveys show the revetment was remarkably resilient to storm waves and high water levels, with little to no landward retreat. To begin to compare the performance of the dynamic revetment constructed of quarry spalls to a natural cobble berm, CMAP began collecting 12 seasonal beach profiles near Kalaloch at South Beach in late February and May.

Oregon Shoreline Observations:

-Maintain shoreline observations in OR; deliver data via NVS [Allan]

-Bring all data QA/QC to meet Certification standards [Allan]

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 – fall (December 2018) and winter surveys (February/March 2019) – were collected in the Neskowin (15 sites) and Rockaway littoral cells (25 sites), as well as along Clatsop Spit (6 sites). PI Allan also updated beach monitoring networks established in the Netarts littoral cell (24 sites) and at Gold Beach (21 sites)/Nesika Beach (14 sites) on the southern Oregon coast. Surveys for these three areas were undertaken in April 2019. In addition to the transects, 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). As of late winter 2019, our monitoring data indicated that the state of Oregon's beaches had fallen within the typical post-winter range defined from 22 years of beach monitoring. However, localized erosion was identified at a number of sites at the north end of Gold Beach, along Netarts Spit, and along the south-central portion of Rockaway Beach. Entering the 2018/2019 winter season, we had originally expected erosion might dominate the observed changes due to the development of an El Niño that occurred late summer 2018, and persisted over the 2018/19 winter. Under El Niño conditions, we typically experience

above average wave and water level conditions that tends to promote beach and shoreline erosion. However, the El Niño weakened substantially, such that wave and water level conditions remained well below normal.

In response to ongoing erosion problems along Siletz Spit, NANOOS beach change data collected along Siletz Spit in spring 2019 and from past years, was able to be shared with geological consultants seeking to understand recent changes taking place along the spit. These data are being used to design engineering structures used to mitigate the erosion, provide up-to-date change data that describes recent changes taking place on the spit, as well as by Oregon State Parks when making decisions about whether to grant permits for any existing or new engineering.

PI Allan also worked with a volunteer from the Oregon Shores Conservation Coalition to evaluate a simple beach profiling technique to document changes at a few test profile sites on the Clatsop Plains. The long-term goal is to see whether it might be feasible to utilize citizen scientists to undertake measurements of beach change at predefined sites. To date, the success of this effort remains uncertain as the technique being trialed does not appear to be robust enough to enable confidence in the measured data. We are currently exploring other low-cost techniques that could be adopted Coast watcher volunteers.

***Nearshore Bathymetry Observations*:**
-Maintain bathymetric observations in WA and OR; deliver data via NVS [Ruggiero]
-Bring all data QA/QC to meet Certification standards [Ruggiero]
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 2018 (Figure 3) 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 (Figure 4). The data continues to be used in a large number of scientific studies – see list of publications. 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 is being used to inform regional sediment management practices. Leveraging this collaboration, NANOOS PIs have collaborated with the USGS to release some of the data via USGS data release publications (Stevens et al., 2019).

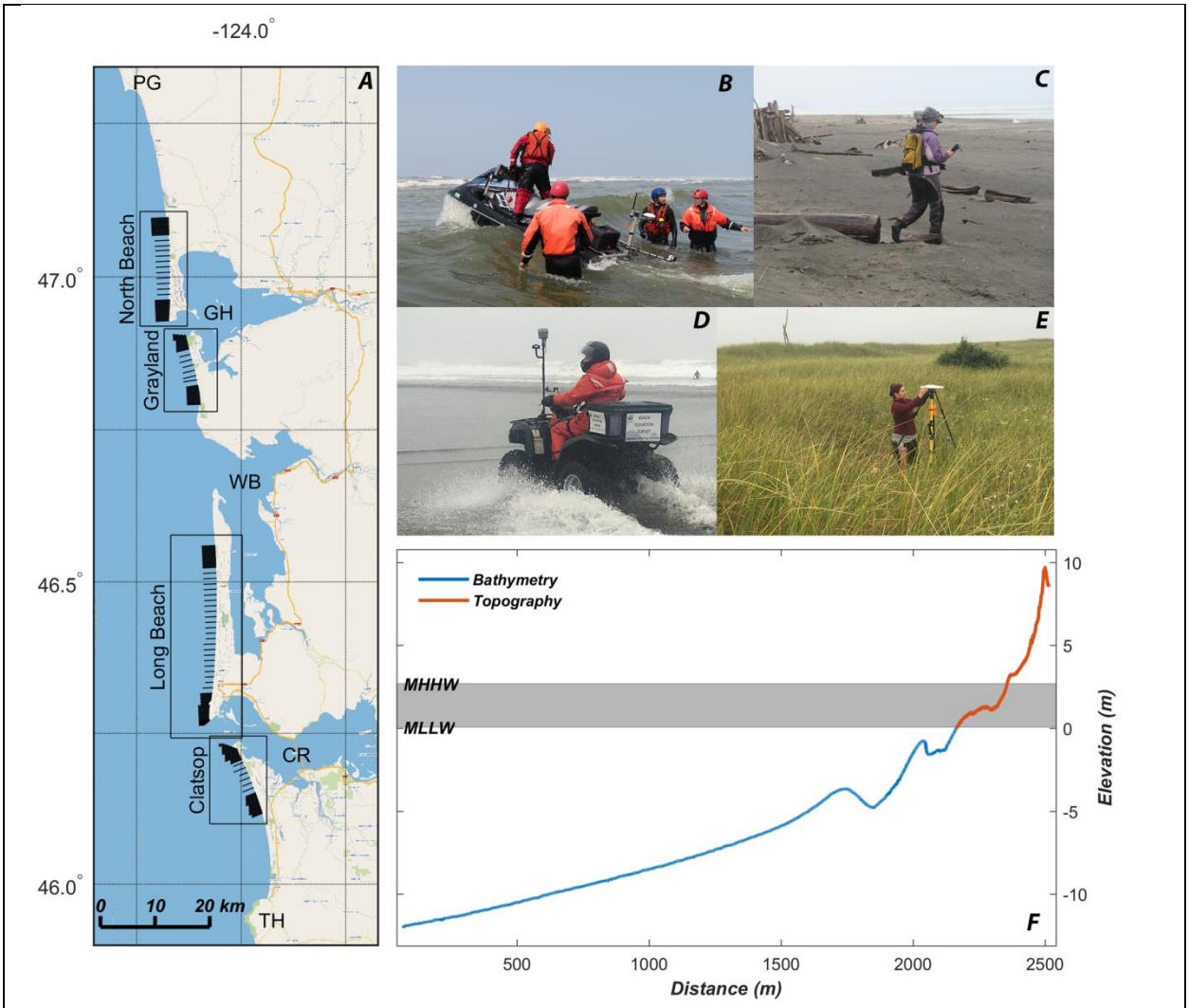

Figure 3. *A*, Map of the Columbia River littoral cell showing the locations of survey lines, sub-cells (North Beach, Grayland, Long Beach, Clatsop), and major estuary entrances of Grays Harbor (GH), Willapa Bay (WB), and the Columbia River (CR). *B-E*, Photographs showing instrumentation used during the bathymetric and topographic surveys. F, Example profile showing overlap between bathymetry and topography data. The gray bar indicates the intertidal portion of the profile between mean lower low water (MLLW) and mean higher high water (MHHW).

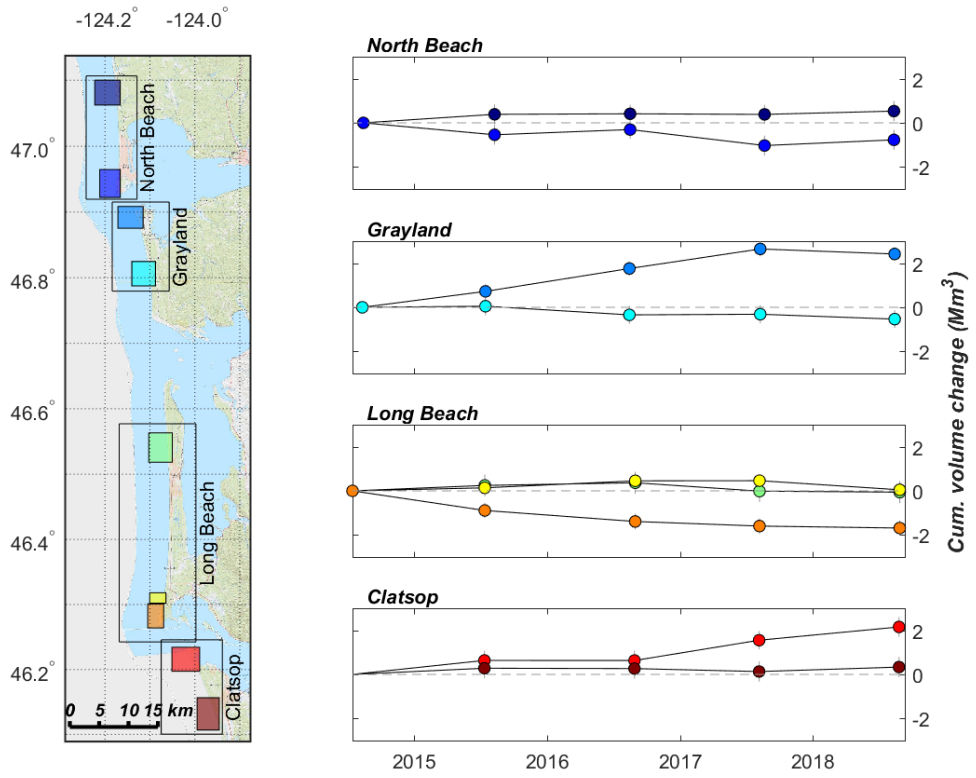

Figure 4. Integrated cumulative net volume changes for each detailed "surface map" area. The location of the surface map areas and associated sub-cell is provided on the map at left. The colored boxes correspond to the colors of the markers on the time-series plots on the

• **Currents**

Coastal Current Observations:

-Maintain OR Priority-One HF radar sites to the national operations standard; deliver data via NVS and the National HF Radar system [Kosro]

-Bring all data QA/QC to meet Certification standards [Kosro]

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.

Operationally, Anne Dorkins, our excellent long-serving research assistant, will retire later in 2019. She is training our present field tech, Erik Arnesen, on the operational details which he will take over. We anticipate a part-time hire to pick up part of Erik's field load, and especially for his mooring prep work on CB-06.

In mid-January 2019, we were alerted by Century Link that there had been a lightning strike near our equipment at Manhattan Beach (MAN1). An in-person inspection showed obvious lightening damage to the transmit antenna, and to the rest of the system from the EM pulse. All equipment from the computer rack was returned to OSU, as were the receive (Rx) and transmit (Tx) antennas. A replacement Tx antenna was purchased from Codar, and the rest of the equipment was returned for a

replace/repair evaluation. We are still awaiting the results of that evaluation. The replacement antenna has arrived, and Erik is working with a team to re-lay the cables. The local wiring system was repaired by an electrician. We hope to get the site back up with spare equipment once the Tx antenna is installed.

At Seaside (SEA1), the GFC outlet was tripping repeatedly; Erik traced the problem to a faulty Tx switching power supply, which was replaced. The cell modem was upgraded there, and at several other sites as well.

At Point St. George, CA (PSG1), a sharp change in Rx characteristics was detected on antenna loop #1 on 1/6. A test with the Time-Delay-Reflectometer found a break in the cable about halfway to the antenna. A spare cable, installed with the original 3, was swapped in. As Washburne (WSH1), we changed operating frequency from 12.147 MHz to 12.017 MHz to avoid broadcast interference in that band.

Data quality is being tracked by heads-up displays of incoming data statistics, by emailed and texted alerts of missing hourly files, by daily counts and data-quality plots, etc. We are working toward the QARTOD suite.

In an analysis of the effects of ocean conditions on green crab recruitment (Yamada, Fisher, and Kosro, 2019, submitted), we used surface HF data to fill gaps in the record from in-situ current meters, adjusting by regressions for changes in measurement depth.

Ivo Pasmans published the first paper from his PhD thesis, which showed the importance of including surface measurements, including HF currents, when assimilating subsurface glider data into circulation models, to avoid creation of unphysical eddies in the vicinity of the glider track (Pasmans et al., 2019).

Monthly-averaged surface current maps from the first and last month of the reporting period are shown below (Figure 5). Note that multiple equatorward jets separate from the coastal region in the May_2019-averaged map (left), with generally equatorward flow prevailing. For the December_2018-averaged map, the flow is generally poleward; this is especially true for the waters leaving the waters leaving the Columbia River mouth.

- Fill gaps in HF Radar operations and maintenance by OSU to complete west coast coverage for health and safety [Kosro]

Work is proceeding on siting new radars in Washington State. For the southern of these, in-person visits highlighted the large width of Washington beaches, which would result in excessive signal loss before reaching the ocean. An additional search for narrow beaches using Google Earth turned up Westport Light State Park, and a site visit with Park officials went very well. We are seeking permission from WA State Parks, and will interface with the IOOS Environmental Compliance Coordinator. Additional work is going forward on the next site farther north, tentatively at Kalaloch, which will require extensive consultation with the US National Parks Service. A third potential site, farther north yet, is on Tatoosh Island, under the jurisdiction of the Makah. We plan a site visit in early June 2019.

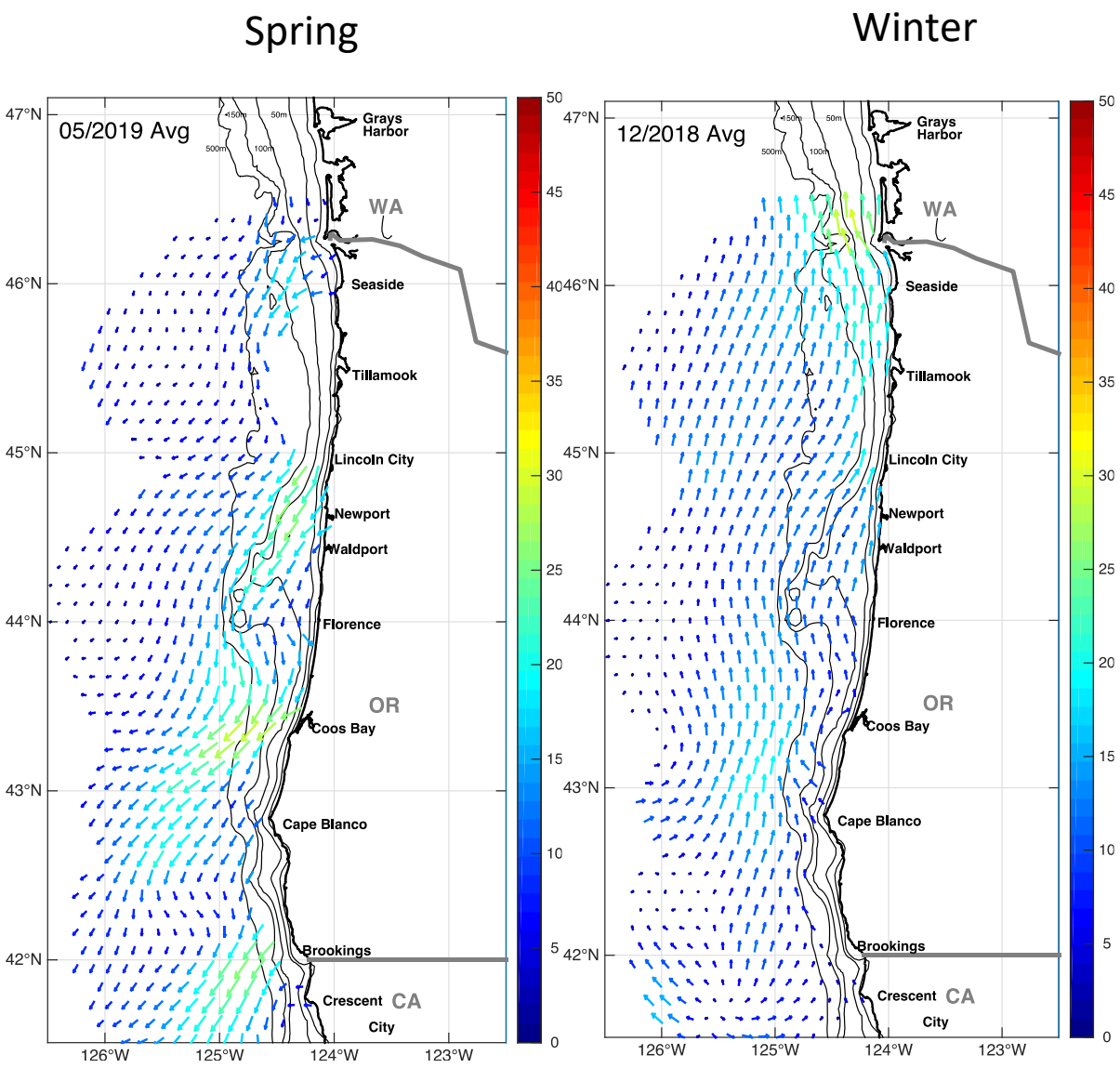

Figure 5. Monthly average maps of surface currents from start (12/2018) and end (05/2019) of the report period. The contrasting maps show the general reversal of currents from northward in the winter to southward in the spring. In the spring, notice the presence of at least 3 separating equatorward coastal jets. In winter, notice the northward flow of waters from the Columbia River mouth over the shelf and upper slope. Spring gap in currents around Tillamook are from an HF site disabled by lightning strike.

Port X-band Radar Observations:

-Maintain X-band radar sites; deliver data via NVS [Haller]

-Bring all data QA/QC to meet Certification standards [Haller]

We continue to maintain the X-band marine radar station at USCG Station Yaquina Bay in Newport, OR with occasional short periods of downtime for maintenance or repairs. This includes meeting QA/QC standards for the data and we continue to develop our database standards with the goal of making the database public and searchable. We have recently updated our presence on NVS (working with Jonathan Allan) such that there is once again a map marker visible for the station, and we now include "zoomed-in" radar images of the bar in addition to spectral plots and full-scale images.

On the outreach side of things, we were recently involved in the official USCG investigation into the accident of the *Mary B II* fishing vessel. On January 9th, 2019, the fishing vessel *Mary B II* capsized attempting to cross the Yaquina Bay Bar, which resulted in the deaths of three commercial fishermen. Data from the OSU radar station was post-processed for vessel tracking information, which documented the time-space positioning of the fishing vessel (Figure 6) as well as two USCG support vessels. Our group supplied these tracking data as well as wave information from the time of the event in the form of plots as well movies of radar image sequences and vessel tracks. These materials all became exhibits at the investigative hearing and M. Haller testified in person on May 16th 2019 in Newport. Video of Dr. Haller's testimony, including video and imagery provided by the research group, is available at https://livestream.com/accounts/17374493/events/8625145/videos/191338858.

Presently, we are working on operationalizing the radar-derived bathymetry estimates. These estimates are computationally intensive and QA/QC still requires significant manual effort, so operationalization is non-trivial. Eventually, we hope to integrate the data into NVS in a similar fashion as to what is currently available on our web-page: (http://research.engr.oregonstate.edu/haller/Newport/, (see Bathymetry Map Opacity slider and Bathymetry Contours option). Example comparison between our radar-derived bathymetry and the available DEM are shown in Figure 7. For the yearly NANOOS meeting this summer we plan to compare these data with that collected by P. Ruggiero's group during Sept. 2018.

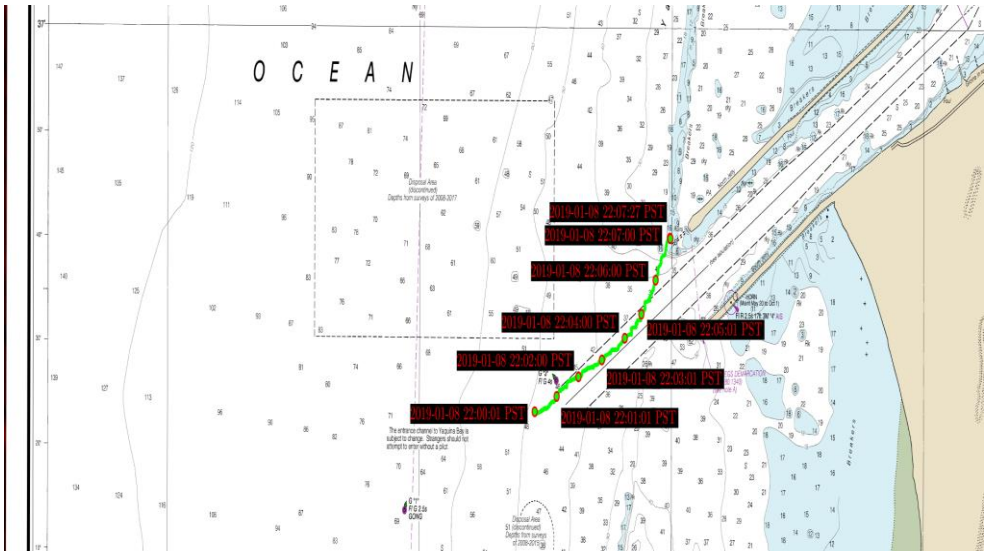

Figure 6. Vessel track of the Mary B II with time stamps overlayed on nautical chart as exhibited at USCG investigative hearing.

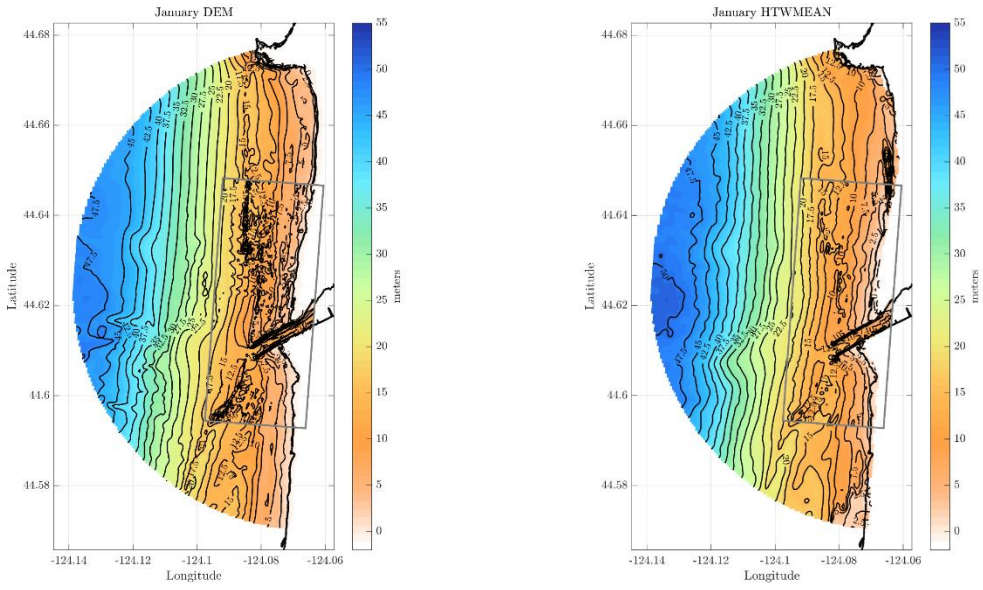

Figure 7. (left) Newport area DEM (right) bathymetry estimated from Yaquina X-band station using January 2018 observations

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

Shelf Modeling:

-Maintain modeling & forecasting capabilities at OSU; deliver model output via NVS [Kurapov]

-Model verification and validation [Kurapov]

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

During the report period, we continued our real-time operation. Our work included communications with the users, namely fishermen questioning velocity evolution during a spring transition event. 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). Additional tests using the OSU system and the more advanced, ensemble-variational formulation for data assimilation have been completed.

-Data denial tests at OSU [Kurapov]

Using leveraging by the Qualitative Observing System Assessment Program (QOSAP), the OSU student Ivo Pasmans ran comparative data-denial tests assimilating the glider data alone and in combination with the surface data, with application to the OSU OR-WA coastal ocean forecast system. A paper on this topic has been published (Pasmans et al., 2019a). One more QOSAP manuscript has been submitted (Pasmans et al., 2019b).

Shelf and Salish Sea Modeling:

-Maintain modeling & forecasting capabilities at UW; deliver model output via NVS [MacCready]

-Model development, verification and validation [MacCready]

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. The model has 500 m horizontal grid size in the Salish Sea and coastal estuaries, and 45 rivers. The model resolves biogeochemical fields, including carbon variables, across the whole domain, from estuaries to beyond the shelf break. In the past six months development and testing of an expanded grid has been done. The new domain extends around Vancouver Island, allowing a much more realistic treatment of the flow though Johnstone Strait at the northern end of the Strait of Georgia. Getting tidal and other transport properties right there was found to be essential for accurate simulation of tides in Puget Sound. In addition, improvements were made to the tide, atmosphere, and

river forcing. In the new grid atmospheric forcing down to 1.4 km is included, a significant improvement over the earlier 12.5 km WRF fields.

Validation results and movies of the daily forecast focused on different stakeholders are presented on the LiveOcean website: http://faculty.washington.edu/pmacc/LO/LiveOcean.html. Model fields are available through 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. 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 8 talks (6 invited) at scientific and stakeholder meetings. 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. It was also used for a project tracking the larvae of invasive Green Crabs from the cost to the Salish Sea.

Columbia River Modeling:

-Maintain modeling & forecasting capabilities at OHSU; deliver model output via NVS [Baptista]

-Model verification and validation [Baptista]

Led by PI A. Baptista, OHSU maintains an extensive modeling system for the Columbia River coastal margin, 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, habitat, estuarine pathways, and status under the Endangered Species Act and in relation to hydropower management and climate change (see previous NANOOS reports). They are currently assisting FEMA in creating storm surge flooding maps for Clatsop County, in the lower estuary.

Anchoring the system are simulations of circulation, conducted in four distinct forms: (1) daily forecasts, (2) multi-year simulation databases, currently 1999-2018, (3) scenario simulations, and (4) process simulations. Of these, daily forecasts are displayed on NVS.

To meet the challenges that the highly energetic and strongly stratified Columbia River estuary and plume pose to numerical models, we have experimented with—and contrasted among—multiple codes (Thetis, SLIM, SELFE and SCHISM) representing different classes of unstructured-grid finite element methods. Although Discontinuous Galerkin methods (as coded in Thetis) offer the best numerical skill, our default code (SCHISM, a variant of SELFE) uses a Galerkin finite element/finite volume method. SCHISM was chosen for its robustness, breadth of practical application across river-to-ocean scales, and (at present) relative cost-efficiency.

We are currently conducting an extensive calibration of SCHISM for the Columbia River, refining our earlier such efforts. The focus on the representation of salinity intrusion, vertical stratification, and

residual circulation. Model skill assessment relies heavily on the SATURN observation stations, and ancillary other in-estuary observations. Progress was reported to the developer's workshop of the SCHISM model (Seaton et al. 2019).

In addition to circulation modeling, the OHSU efforts have included: (1) transferring an existing, interactive, particle tracking infrastructure for broader use throughout NANOOS; and (2) developing an Individual Based Model (with hydraulic transport swimming and growth modules) to help regional stakeholders understand the use of the estuary by juvenile salmon. The latter is at the core of an ongoing PhD thesis research at OHSU (K. Morrice).

c) Data Management and Communications (DMAC) Subsystem:

See table for milestones [Mayorga]

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) annual NANOOS Tri-Committee meeting (May 16-17, Seattle); 3) monthly IOOS DMAC webinars; and 4) annual IOOS DMAC meeting (April 30 - May 2, Silver Spring).

*The **NANOOS Visualization System (NVS)*** was upgraded in April (version 6.2), with enhancements to the custom Apps to better support user needs. NVS enhancements also encompass asset additions and continuous updates: 1) many redeployments and smaller upgrades, including several NANOOS redeployments from UW, CMOP-OHSU and OSU, serviced and redeployed OOI moorings, WA Department of Health seasonal network redeployment, new sensors on some existing platforms, and new or reprocessed glider section plots; and 2) in Canada, telemetry stabilization on the new Hakai MAP CO2 buoy and a new variable – nitrate concentration – added to the University of British Columbia "SalishSeaCast" nowcast model. Ongoing enhancements include the refinement and documentation of a particle-tracking service from CMOP-OHSU being integrated into NVS.

NANOOS and IOOS DMAC system implementation.

- Data Archiving. In addition to the operational monthly NCEI archiving of fixed-location time series data from OHSU CMOP stations, NANOOS initiated work with NCEI to archive the Oregon shoreline change surveys carried out by DOGAMI for the last twenty years; discussions and tests are continuing between NCEI and NANOOS staff. We also initiated efforts leading to establishing an NCEI data archiving workflow for Washington Shelf and Puget Sound moorings maintained by the UW NorthWest Environmental Moorings (NWEM) group.
- QARTOD QA/QC testing. Pilot implementations of automated IOOS QARTOD near-real-time QC testing and flagging continued to make progress. An initial live implementation is planned for Summer 2019, in coordination with CMOP-OHSU.
- ERDDAP Implementation. Prototyping of the ERDDAP online data access and distribution application was advanced, with tests for integration of datasets including NANOOS and OOI gliders, NANOOS-processed long time series at fixed stations, NANOOS-originated remote sensing products, and the fixed-location time series data available on NVS. An initial, live release is planned for July 2019.
- Other advancements. 1) As a result of technical discussions and prototyping, considerable progress was made towards enabling a more comprehensive integration of data streams from the OOI Endurance Array; these are expected to be completed and become available on NVS in the next 6

months; 2) NANOOS is a co-organizer in the 2019 OceanHackWeek advanced educational event taking place at the UW in August 2019, bringing together grad students and young professionals from the US and internationally to advance capabilities in data science focused on oceanographic applications. This event is being supported by IOOS and NSF.

Ocean Acidification (OA) Data. NANOOS continued its ongoing support for OA data efforts. In the newly expanded and rebranded IPACOA (now IOOS Partners Across Coasts Ocean Acidification) data portal, initial steps were taken to augment the representation of OA monitoring assets across the US and Canada. Globally, international collaborations on the GOA-ON (Global OA Observation Network) data portal were strengthened, with closer coordination on the management and processing of the GOA-ON asset inventory, and on the development of a new data portal App focused on Sustainable Development Goal (SDG) 14.3.1, expected to be released publicly in the near future. Finally, the usability enhancements from the NVS 6.2 release involving filters were applied to both the IPACOA and GOA-ON data portal, which are built on this framework.

d) User Products Committee (UPC):

See table for milestones [Allan]

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 is 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 2018/19 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; and 2) Attendance at the annual Tri-Com meeting of the three standing committees, which took place at the University of Washington on 16-17 May 2019. The purpose behind this meeting is to evaluate product development activities over the previous year, and importantly identify the priorities for existing product enhancement as well as development plans for new concepts in the next fiscal year.
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 major update. V6.2 released in April that included major improvements to the NVS filtering capability, as well as enhancements to the Surfers and Tsunami apps.

As a result of the success of the Seacast app, which includes the ability to query oceanographic and climate data defined from overlays, NANOOS began the process of changing and updating its overlay structure during this reporting period, such that more overlays could be independently queried by users of NVS. As noted above, this capability was first implemented with the Seacast app in May 2018 for a few discrete overlays. In 2019, interactive overlays were recently updated and released for the Surfers app, providing surfers with the ability to query and have returned, results for multiple

variables (e.g. primary and secondary waves and periods, wave direction, wind and ocean related data), for any given location. This is a powerful capability that allows users to gain a better understanding of site specific oceanographic or climate conditions, which may be used to make informed decisions about where the best surf conditions are likely to be.

Minor updates were implemented in the Climatology web app that included enhancements to all model overlays and climate indices. Updates were also implemented to the buoy climatologies due to changes in NDBC data sampling and reporting that broke our codes. In addition, during this period NANOOS software engineers began working on a prototype particle tracking capability that could be queried by interested parties. A prototype has been developed based on model data provided by NANOOS partner, CMOP. We anticipate having a functioning particle tracking tool completed in the next reporting period, with tracking capabilities being expanded to include several other operational models used in the NANOOS region.

NANOOS continues to provide significant improvements to the Tsunami web app. During this period, we implemented refinements to the overlay inundation zones for both Washington and Oregon, effectively standardizing the look of the overlays for both states. Additional enhancements included improvements to the legend to accommodate the use of an additional evacuation zone choice requested for the community of Gearhart Oregon, as well as refinements to the elevation and critical facility markers. Work was also initiated to address broken tsunami warning messaging that would normally appear in the app should an information statement, watch, or warning be issued by the National Tsunami Warning Center (TWC). The problem stems from changes to the TWC messaging protocol that were implemented without our knowledge. We anticipate having the broken links corrected in the ensuing weeks.

NVS Mobile App: In January 2019, NANOOS finally released version 2 of its TsunamiEvac mobile phone app for both Android and iOS version (Figure 8). Development of this smartphone app dominated our software engineers time over much of 2018 as the original version of the TsunamiEvac app had to be rebuilt and redesigned completely from the ground up. The end result is an outstanding application that is now widely used by coastal residents and visitors, who live and recreate along the Oregon and Washington coast. We anticipate the next major refinement to the app will include the ability to push tsunami information statements, watch or warning messages directly to the phone should an event take place anywhere in the Pacific Basin.

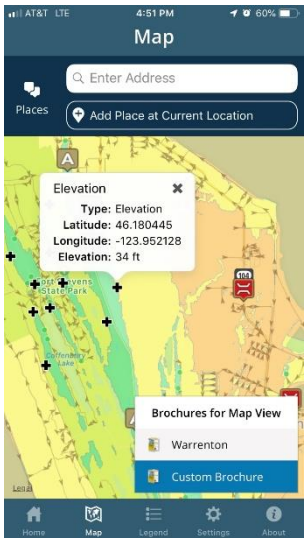

Figure 8. Screenshot of v2 of the TsunamiEvac smartphone app for iOS. Functionality built into the app are broadly the same as the web portal, with the added benefit of being able to locate oneself in the tsunami zone.

e) NANOOS Education and Outreach Subsystem:

See table for milestones [Wold, Rudell, Newton]

NANOOS Education and Outreach efforts 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 were largely completed by NANOOS staff Newton, Wold, Mitchell-Morton and Rudell, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton, Wold, Mitchell-Morton, and Rudell were active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. Mitchell-Morton, Rudell and Wold continued participation with IOOS E&O calls as they occur. As of 1 April, Mitchell-Morton moved on from 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.

- NANOOS 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 buoys at the Langley Marina then retrieved and analyzed their data.

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 two regional boaters' events: The Portland Boat Show (January) and the Seattle Boat Show (January).

- Wold staffed a table at the 'Sound Waters – A one-day university for all' on Whidbey Island, WA 2 February, where she engaged with interested citizens. Newton was invited to give a talk on ocean acidification, which included NANOOS work and data. This annual event, hosted by Sound Water Stewards, was attended by over 500 individuals. Wold was then invited to present various aspects of NVS to the Camano Island Chapter of Sound Water Stewards on April 24.
- Mitchell-Morton 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.
- NANOOS was invited to participate in the first annual Curiosity Days: Climate Change at the Pacific Science Center on 2-3 March. Mitchell-Morton and Wold demonstrated using the NVS Climatology App to track oceanographic conditions and compare with data from previous years.
- Wold demonstrated the new NVS Surfers app to the Surfrider Foundation Seattle (March 19) and Portland (April 9) Chapters to showcase features and gain direct feedback.
- NANOOS was invited to participate in the Blue Forum (May 17) hosted by Washington Maritime Blue and attended by over 100 guests. Newton provided a presentation and Rudell staffed an exhibit table. Newton and Rudell engaged with members of the maritime and communications tech sectors and highlighted NVS and the Maritime Operations Application.
- Mitchell-Morton, Rudell and Wold continued to update content on the NANOOS portal.
- NANOOS maintained Facebook and Twitter accounts, each with growing audiences. NANOOS also has a growing audience for its bimonthly newsletter, the "NANOOS Observer."

f) <u>NANOOS Administration:</u>

See table for milestones [Newton]

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 participated in the annual Tri-Comm meeting in Seattle, WA, on 16-17 May.
- New members of the NANOOS Governing Council include Northwest Indian College and Pacific Shellfish Institute. The NANOOS Executive Council has no current vacancies.

Additional coordination and representation included:

- Newton attended the annual spring IOOS Program meeting on 19-21 March, in Washington, D.C. She also visited Washington and Oregon Congressional delegations while there. Additionally, Newton served on the IOOS Association Executive Committee and attended IOOS Program and IOOS Association calls as available.
- Newton represented NANOOS and IOOS at the AGU meeting in Washington, D.C. on 11 December 2018, and at ASLO in San Juan Puerto Rico on 1 March 2019, meeting with CARICOOS staff and director afterwards. She was invited to speak at the Ocean Visions meeting in Atlanta, Georgia, on 1-4 April 2019.
- Newton contributed NANOOS updates on oceanographic conditions in the Pacific Northwest

for the NOAA WestWatch webinar series on 22 January, along with the other two west coast RAs, and now a similar but local-scale Salish Sea Marine Conditions webinar on 25 April. She and other NANOOS PIs contributed to the annual Marine Waters Overview on 1 May.

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

- Jack Barth participated on February 21, 2019, 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, Barth provides 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 continued as a member of the International Science Advisory Committee for the Canadian Marine Environmental Observation Prediction and Response (MEOPAR) program, though no activities were scheduled during the period. She was invited to their General Assembly to be held in June 2019 and to speak at an OA workshop there.
- Newton, a member of the Science Advisory Team for the Joint European Research Infrastructure in the Coastal Ocean (JERICO), reviewed proposals fostering international collaboration. She organized a site visit of NANOOS for three JERICO leaders who wanted to learn more about the structure and function of NANOOS as they prepare their next JERICO proposal. Patrick Farcy (IFREMER), Dominique Durand (COVARTEC), and Antoine Gremare (U Bordeaux) visited 11-12 February in Seattle, which included a virtual session with Carl Gouldman, IOOS Director.
- Newton is on the Program Committee for the OceanObs'19 meeting to be held in Honolulu in September 2019. She participated in several teleconference calls, planning meetings in Washington D.C. (8 December) and Paris (29-30 March) and a site visit in September 2019, with follow-on meetings with PacIOOS for coordination and with Western Pacific Fisheries Council to develop indigenous participation in the conference.
- Newton was invited to two meetings on ocean acidification in Dunedin, New Zealand
- Newton represented IOOS on the Global Ocean Acidification Observing Network Executive Committee calls and activities. Newton was involved in the Biology Working Group and brought NANOOS capabilities for GOA-ON's web and data portal. She co-chaired the 4th International GOA-ON workshop and attended:
    - GOA-ON Executive Committee meetings on April 13 and 18, before and after the China workshop, where the Implementation Strategy she lead was released.
    - GOA-ON 4th International Science Workshop on April 14-17 in in Hangzhou, China, where she helped plan the agenda and introduced GOA-ON and its data portal. This workshop brought together ~250 scientists from 60 nations.

Additional NANOOS coordination:

- Newton participated in NOAA 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, the West Coast Ocean Data Portal, and "OA Round Tables" organized

by NOAA PMEL and NWFSC.

- 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.
- 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.
- Barth serves as the Co-Chair of the Oregon Ocean Acidification and Hypoxia Coordinating Council, enacted as a state law in fall 2017. The OAH Council submitted their first biennial report to the Oregon legislature in September 2018 that included recommendations for action on dealing with ocean acidifcation and hypoxia. An Oregon OAH Action Plan, a requirement of Oregon's membership in the international OA Alliance, will be published in summer 2019.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

Haller, M. C. "Real-Time Marine Radar Observations of Nearshore Waves and Flow Structures from Shore-based Towers", *IEEE/OES Currents, Waves, Turbulence Measurement and Applications*, San Diego, CA, March 12, 2019.

Helms, A., S. Schooler, S., K. Wirfs, and E.Eidam. "Eelgrass Declines in the South Slough estuary, Coos Bay, OR." Pacific Estuarine Research Society Meeting. Anacortes, WA. April 25-27, 2019.

MacCready, P., "Modeling the Salish Sea & Pacific Northwest Coastal Waters: LiveOcean" Presentation for JERICO Visiting Delegation, UW 2/2019.

MacCready, P., "Forecasts of Ocean Acidification in the Salish Sea & Pacific Northwest Coastal Waters LiveOcean Update" Presentation for MRAC (WA Marine Resources Advisory Council) Meeting 2/2019.

MacCready, P., "The Estuarine Circulation of the Salish Sea" UW PO Seminar, 2/2019.

MacCready, P., "The Salish Sea Estuarine Circulation: Causes and Consequences" Sound Waters Conference, Whidbey Island, WA, 2/2019.

MacCready, P., "LiveOcean: Computer Modeling of Pacific Northwest Coastal Estuaries and the Salish Sea: A New Resource for Shellfish Growers" 26th Conference for Shellfish Growers, Union, WA, 3/2019.

MacCready, P., "The Estuarine Circulation of the Salish Sea" Univ. of Connecticut Seminar, 3/2019.

MacCready, P., "LiveOcean: Realistic Ocean Modeling for Applied Science Problems in the Pacific Northwest" Plenary Talk for Long Island Sound Research Conference, Long Island, NY, 3/2019.

MacCready, P., et al., "LiveOcean: Short-term Forecasts of Ocean Acidification for the Washington Coast & Salish Sea" talk for Washington Ocean Acidification Center Science Meeting, Seattle, WA, 5/2019.

Newton, J., M. Poe, S. Alin, R. Feely, S. Siedlecki. "The Olympic Coast as a Sentinel: An Integrated Social-Ecological Vulnerability Assessment to Ocean Acidification." AGU Fall Meeting, Washington, D.C., December 11, 2018.

Newton, J. "Big Oceans, Small Sensors, Large Knowledge." Future of the Oceans Lecture Series, Port Townsend, WA, January 13, 2019.

Newton, J. "Reporting Regional Environmental Conditions & Impacts in the West: NANOOS." NOAA West Watch, January 22, 2019.

Newton, J. "Ocean acidification in the Pacific Northwest." Sound Waters Conference, Whidbey Island, WA, February 2, 2019.

Newton, J. "NANOOS: Structure and Function" Presentation for JERICO Visiting Delegation, UW February 11-12, 2019.

Newton, J. "Lessons learned from Washington State." Commonwealth Ocean Acidification Action Group Workshop, Dunedin, New Zealand. 17-19 February 2019.

Newton, J. "Scientists and shellfish growers working in partnership to measure ocean acidification variables and deliver data to support shellfish aquaculture." New Zealand Ocean Acidification Annual Science Meeting. Dunedin, New Zealand. 20-21 February 2019.

Newton, J. L. Jewett, B. Tilbrook, K. Isensee, and R. Feely. "The Global Ocean Acidification Observing Network, GOA-ON: Observing on local scales globally." ASLO 2019 Aquatic Sciences Meeting, San Juan, Puerto Rico, March 1, 2019.

Newton, J. "What is NANOOS?" Port Angeles Climate Action Researchers Group, webinar, March 6, 2019

Newton, J. "Ocean Observations from local to global scales, with applications from science to society." OceanVisions2019 Climate Summit, Atlanta, GA, April 2, 2019.

Newton, J. "The Global Ocean Acidification Observing System: Introduction, Goals, Data Portal, and Community". International Scientific Committee at the 4th Global Ocean Acidification Observing Network (GOA-ON) International Workshop, Hangzhou, China, April 14-17, 2019.

Newton, J. "Marine Conditions: Salish Sea Updates from NANOOS", webinar, April 25, 2019.

Newton, J. "How do we observe ocean status? The view from NANOOS." Washington Maritime Blue, Blue Forum Meeting, Seattle, WA, May 14, 2019.

Poe, M., J. Donatuto, J. Newton. "Whatever Happens to Clams and Salmon Happens to Us: How place-based assessments of social and cultural risks of ocean acidification can improve integrated social-ecological applied research." International Scientific Committee at the 4th Global Ocean Acidification Observing Network (GOA-ON) International Workshop, Hangzhou, China, April 17, 2019.

Seaton C., P. Turner and A. Baptista. "Updates from a humbling benchmark: Modeling highly stratified regimes in the Columbia River estuary." Presented to the SCHISM Developer's Workshop, CA, April 2019.

Publications:

Anderson CR, Berdalet E, Kudela RM, Cusack CK, Silke J, O'Rourke E, Dugan D, McCammon M, Newton JA, Moore SK, Paige K, Ruberg S, Morrison JR, Kirkpatrick B, Hubbard K and Morell J (2019). Scaling Up From Regional Case Studies to a Global Harmful Algal Bloom Observing System. Front. Mar. Sci. 6:250. https://doi.org/10.3389/fmars.2019.00250.

Antolinez, J.A.A., Mendez, F., Anderson, D., Ruggiero, P., and G. Kaminsky, 2019. Predicting climate driven coastlines with an efficient simple multi-scale model, Submitted to: Journal of Geophysical Research: Earth Surface Processes, https://doi.org/10.1029/2018JF004790.

Bailey K, Steinberg C, Davies C, Galibert G, Hidas M, McManus MA, Murphy T, Newton J, Roughan M and Schaeffer A (2019). Coastal Mooring Observing Networks and Their Data Products: Recommendations for the Next Decade. Front. Mar. Sci. 6:180. https://doi.org/10.3389/fmars.2019.00180.

Barth, J. A., S. E. Allen, E. P. Dever, R. K. Dewey, W. Evans, R. A. Feely, J. Fisher, J. P. Fram, B. Hales, D. Ianson, J. Jackson, K. Juniper, O. Kawka, D. Kelly, J. M. Klymak, J. Konovsky, P. M. Kosro, A. Kurapov, E. Mayorga, P. McCready, J. Newton, R. I. Perry, C. M. Risien, M. Robert, T. Ross, R. K. Shearman, J. Schumacker, S. Siedlecki, V. L. Trainer, S. Waterman, and C. E. Wingard, 2019. Better regional ocean observing through cross-nation cooperation: A case study from the Northeast Pacific. Frontiers in Marine Science, 6:93, https://doi.org/10.3389/fmars.2019.00093.

Cohn, N., Hoonhout, B. Goldstein, E., de Vries, S. Moore, L., Duran, O.V., and Ruggiero, P., 2019. Exploring marine and aeolian controls on coastal foredune growth using a coupled numerical model, Journal of Marine Science and Engineering, *J. Mar. Sci. Eng.7*(1), 13; https://doi.org/10.3390/jmse7010013.

Cohn, N., Ruggiero, P., Garcia-Medina, G., Anderson, D., Serafin, K., and Biel, R., 2019. Environmental and Morphologic Controls on Wave Induced Dune Response, Geomorphology, 329, 108-128, https://doi.org/10.1016/j.geomorph.2018.12.023.

Haller, M.C., D.A. Honegger, R. Pittman, A. O'Dea, and A. Simpson, "Real-Time Marine Radar Observations of Nearshore Waves and Flow Structures from Shore-based Towers", *Proceedings of IEEE/OES Currents, Waves, Turbulence Measurement and Applications*, San Diego, CA, 2019.

Honegger, D.A., M.C. Haller, and R.A. Holman, High-resolution bathymetry estimates via X-band marine radar: 1. Beaches, Coastal Engineering, 149, 39-48, 2019.

Honegger, D.A., M.C. Haller, and R.A. Holman, High-resolution bathymetry estimates via X-band marine radar: 2. Tidal inlets and river mouths, revision requested *Coastal Engineering*, March 2019.

Iwamoto MM, Dorton J, Newton J, Yerta M, Gibeaut J, Shyka T, Kirkpatrick B and Currier R (2019). Meeting Regional, Coastal and Ocean User Needs With Tailored Data Products: A Stakeholder-Driven Process. Front. Mar. Sci. 6:290. https://doi.org/10.3389/fmars.2019.00290.

Pasmans, I., A. L. Kurapov, J. A. Barth, A. Ignatov, P. M. Kosro, and R. K. Shearman, 2019a: Why Gliders Appreciate Good Company: Glider assimilation in the Oregon-Washington coastal ocean 4DVAR system with and without surface observations, J. Geophys. Res., https://doi.org/10.1029/2018JC014230.

Pasmans, I. and A. L. Kurapov, 2019b: Ensemble 4DVAR (En4DVar) Data Assimilation in a Coastal Ocean Circulation Model. Part I: formulation and ensemble statistics, submitted to Oce Mod.

Serafin, K., Ruggiero, P., Barnard, P., and Stockdon, H., 2019. Linking large-scale changes of the future wave climate to local coastal hazards: The influence of shelf bathymetry and beach topography on extreme total water levels, Coastal Engineering, 150, https://doi.org/10.1016/j.coastaleng.2019.03.012.

Stevens, A.W., Weiner, H.M., Ruggiero, P.R., Kaminsky, G.M., and Gelfenbaum G.R., 2019, Beach topography and nearshore bathymetry of the Columbia River littoral cell, Washington and Oregon: U.S. Geological Survey data release, https://doi.org/10.5066/P9W15JX8.

Tilbrook B, Jewett EB, DeGrandpre MD, Hernandez-Ayon JM, Feely RA, Gledhill DK, Hansson L, Isensee K, Kurz ML, Newton JA, Siedlecki SA, Chai F, Dupont S, Graco M, Calvo E, Greeley D, Kapsenberg L, Lebrec M, Pelejero C, Schoo KL and Telszewski M (2019). An Enhanced Ocean Acidification Observing Network: From People to Technology to Data Synthesis and Information Exchange. Front. Mar. Sci. 6:337. https://doi.org/10.3389/fmars.2019.00337.

Yamada, S. B., J. Fisher, and P. M. Kosro, 2019. Ocean ecosystem indicators forecast year class strength of the invasive European green crab (*Carcinus maenas*) in Oregon Estuaries. Submitted to Progress in Oceanography.