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

NOAA Award: NA16NOS0120019 Reporting period: 12/01/2019 to 5/31/2020

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 FY19 period (= Y4 of this award; Y13 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 and expand 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 enhance 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.

During FY19, NANOOS has the following additional tasks (10-12) from the NOAA Ocean Acidification Program, coordinated via IOOS, and tasks 13-16 from IOOS:

10) Support (a) collection of OA measurements on our La Push [J. Newton, J. Mickett, UW] and (b) CB-06 [B. Hales, OSU] moorings, and (c) working with NOAA PMEL on mooring test beds.
11) Support collection of OA measurements at shellfish hatchery locations via technical expertise ((b) B. Hales, OSU and (c) 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 the GOA-ON data portal (J. Newton, UW; E. Mayorga, T. Tanner, UW)
13) Support evaluation of LiveOcean in IOOS cloud sandbox (P. MacCready, UW)
14) Support OceanHackWeek 2019 (E. Mayorga, UW)
15) Support biological data stewardship (E. Mayorga, UW)
16) Support a west-coast wide regional collaboration team project (J. Newton, 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 19; Y4 specific milestones are in bold.

Area	**Y4 Award = Y13 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 CB-06; 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 **-Re-establish Columbia glider; deliver data via NVS** **-Procure a glider for La Push operations** **-Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA** -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 -**Support evaluation of LiveOcean in IOOS cloud sandbox**
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** **-Support OceanHackWeek 2019**
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.

	-Coordinate a west-coast wide regional collaboration team workshop with NOAA West
Accountability	-Submit required IOOS progress reports and respond to other requests. -Comply with certification as a Regional Information Coordination Entity of US IOOS.

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

- ***Shelf***

***Washington Shelf Buoy Observations*:**

-Maintain La Push buoy; deliver NRT data streams via NANOOS Visualization System (NVS) [Curry, Mickett]
-Bring all data QA/QC to meet Certification standards [Curry, Mickett]

The Washington Coast buoy observation program, now led by B. Curry, Applied Physics Laboratory, University of Washington (APL-UW), continued to work towards maintaining and operating two real-time moorings 13 miles NNW of La Push, Washington. We have been working to have the Cha'ba buoy and NEMO-SS mooring ready to deploy this summer.

Due to the COVID-19 pandemic, the spring cruise that normally occurs in May, is scheduled for this summer during 27 Jun – 3 Jul 2020 on R/V Robertson and will require increased PPE, a field health and safety plan, and additional lodging. Both mooring designs were carefully reviewed and modified as needed after the shackle failure on winter Cha'ba in November 2019. Van Beest Green Pin® fixed nut shackles will now be used at the base of the Cha'ba mooring to provide triple safety (split pin, safety bolt and fixed nut). The COVID-19 pandemic has also delayed the return of sensors needed for the buoys due to the partial shutdown of Sea-Bird Scientific. Delivery of supplies needed for the cruise (cables, connectors, hardware, etc.) was also delayed due to disruptions in supplier chains.

We have also continued to work closely with both the Olympic Coast National Marine Sanctuary and the Quileute Tribe in maintaining and operating the two moorings, with the Quileute Marine Biologist, J. Hagen participating on deployment cruises. The summer cruise plan entails deploying summer Cha'ba and the NEMO-SS mooring, HAB sampling for the Quileute Tribe marine biologist J. Hagen, and a detailed CTD transect, including water sampling, from the buoy, up through the Strait of Juan de Fuca and down to Seattle. The winter cruise to recover summer Cha'ba and NEMO-SS and deploy winter Cha'ba is scheduled for 24 September – 2 October 2020 on the R/V Thompson.

B. Curry and J. Mickett finalized processing the 2019 data. In 2019, we observed cooling of the deep water on the coast, reversing a 5-year warming trend. A summary of the 2019 observations collected by these moorings was presented at the annual marine waters meeting and submitted for inclusion in the 2019 Puget Sound Marine Waters Report.

-Task 10a: Support collection of OA data from La Push buoys with NOAA OAP funding *[Curry, 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.
We continue to collaborate with Sea-Bird Scientific and will deploy two SeapHOx sensors on Cha'ba, near surface and at 85 m, this summer. We deploy the sensors and provide data and useful feedback to Sea-Bird Scientific and they provide calibrated sensors for our project.

- Task 10c: Support NOA-ON OA Mooring Test-beds *[Mickett, Newton]*
To fulfill the need for verification data for the NOAA PMEL prototype mooring (Prawler), this work involves using NEMO-Subsurface McLane profiler data to compliment concurrently-deployed Prawler data and to evaluate and publish an assessment of high-frequency, depth-dependent variability of pH/carbon variables on the shelf, with implications to shelf ecology. During this period Mickett completed processing of profiler data and published the data for public and PMEL access. Mickett also worked with PMEL researchers to access and use level 2 (partially processed) data to more closely compare Prawler and McLane crawler profilers.

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 g l i d e r . We use a 1000-m capable Seaglider equipped with the following sensors: CTD, dissolved oxygen (Aanderaa 4831 optode), light backscatter (700 nm), chlorophyll fluorescence and Colored Dissolved Organic Matter (CDOM) fluorescence (WET Labs Ecopuck). The gliders also measured depth-averaged velocity, which can be combined with geostrophic estimates of relative velocity to get absolute velocity and hence transport. The glider samples 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 (5/31/2020), the glider was on the TH line for 1704 days during nine deployments, sampled along approximately 31,366 km of track line covering the transect about 83 times, and collected about 13,702 vertical profiles of ocean properties. For the reporting period 12/1/2019 to 5/31/2020 the glider was on the TH line for 110 days during one deployment, sampled along nearly 2262 km of track line covering the transect about 3 times, and collected about 902 vertical profiles of ocean properties. Glider uptime was 60% due to inability to redeploy glider due to COVID-19 restrictions (see below). 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.

The TH glider line was suspended on March 19, 2020, because the local research vessel, the R/V Coral Sea, became unavailable due to COVID-19 restrictions. These restrictions remained in place through the

end of this report period (5/31/20). We were unable to locate an appropriate charter vessel for a deployment and Oregon State University travel restrictions prevented us from traveling to the research site. This resulted in an overall loss of 40% of TH line glider data during this reporting period.

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 (Figure 1). Water at depth was warm during mid-2019, like the subsurface warming associated with the 2015-2016 El Niño (Figure 1). The much-reported upper-ocean temperature anomaly from later summer 2019 was very shallow and has dissipated with the advent of winter storms. These calculations of these temperature anomaly data are being automated and anomaly data delivered to both NANOOS and CeNCOOS for plotting alongside other glider data.

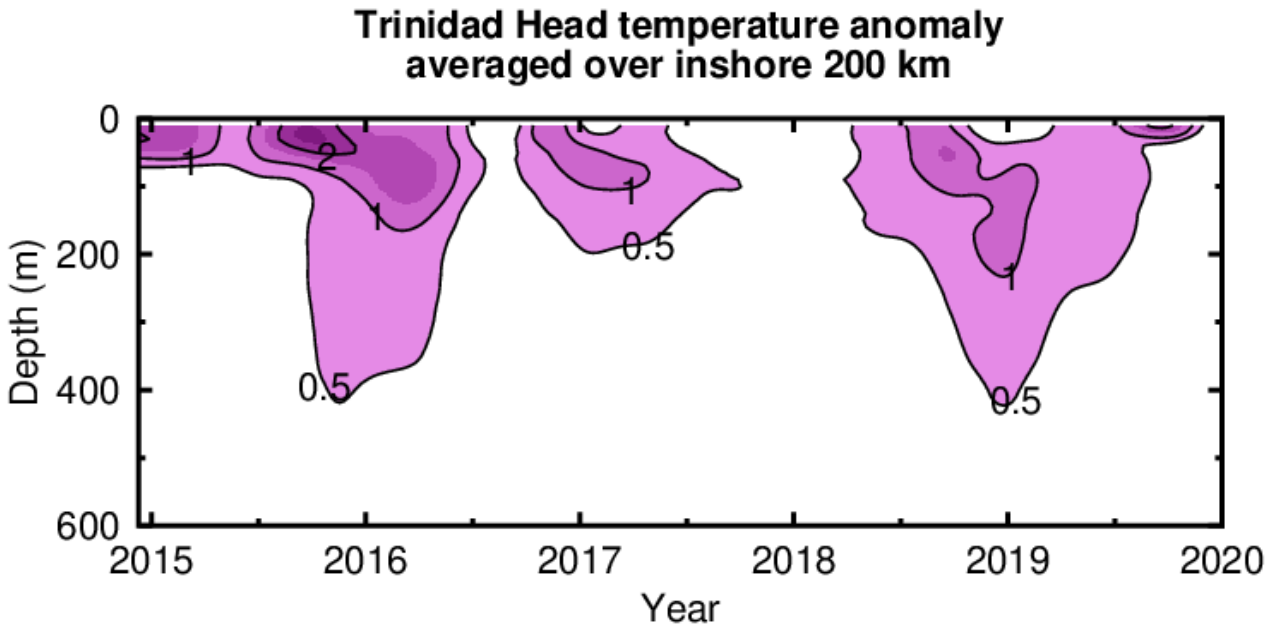

Figure 1: *Temperature anomaly from the Trinidad Head, CA (41° 3.5'N) glider line.*

-Re-establish Columbia glider; deliver data via NVS [*Baptista*]
The OHSU glider program will—as a part of the full transition of CMOP assets—be transferred, starting June 1, to the Columbia River Inter-Tribal Fish Commission. That will become, to our knowledge, the first glider program run within IOOS by a tribal institution. The transition of CMOP assets has been planned for the past two years, in coordination with NANOOS and IOOS, and is designed to coincide with the retirement of Baptista. The driving vision is to enable CMOP assets to be sustainably maintained for time scales consistent with climate change science and management.

The program is designed to fly gliders off the Columbia River, in a mostly S/N transect in the Oregon/Washington continental shelf. After a multi-year interruption due to fund reductions, the program was restarted this fiscal year, as glider-specific funding was awarded to OHSU. The first mission was planned for Spring 2020 (specifically, May). That mission had to be postponed, due to COVID-19's restrictions on staff access to OHSU facilities, including CMOP's MERTS Field Station.

Oregon Shelf Mooring Observations:

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

-Task 10b: Support collection of OA data from CB-06 buoy with NOAA OAP funding *[Hales]*

The CB06 mooring weathered several significant winter storms and functioned well save for a SAMI-pH failure toward the end of the deployment. Using State-funded ship days for education, a team of undergraduate oceanography students and OSU technicians deployed the replacement buoy and recovered the previously deployed one in early March of 2020, shortly before COVID considerations shut down seagoing operations.

The system performed well over the last 6 months (Figure 2). We previously discussed the novel apparent 'ventilation' event in late October 2019, which was an unusual exposure of cold, salty, high CO2 and low pH water to the surface outside of the typical upwelling season. Since that event, fairly normal winter behavior was observed, with cool and gradually freshening surface waters accompanied mostly by near-atmospheric-equilibrium surface-water xCO2. Starting in mid-March following a strong freshening event, surface waters warm and maintain moderate salinity, increasing stratification. In response, there is an increase in Chl-a, and the beginnings of a rise in O2 and pH with a slight fall in pxCO2. Terminating this trend, however, is an apparent upwelling event, with cold, salty, low-pH and O2 and elevated pCO2 conditions. The decoupling of simple relations between pH and CO2 is evident in comparison of this event to the late October 2019 event. Although pH is as low (7.8) in this event as in the previous, xCO2 is only moderately elevated above atmospheric (~450 ppm) compared to the previous (700 ppm). This suggests different buffering relationships in early- and late-season upwelled waters, potentially related to on-shelf metabolic influences of summertime upwelling that had accumulated by fall of 2019.

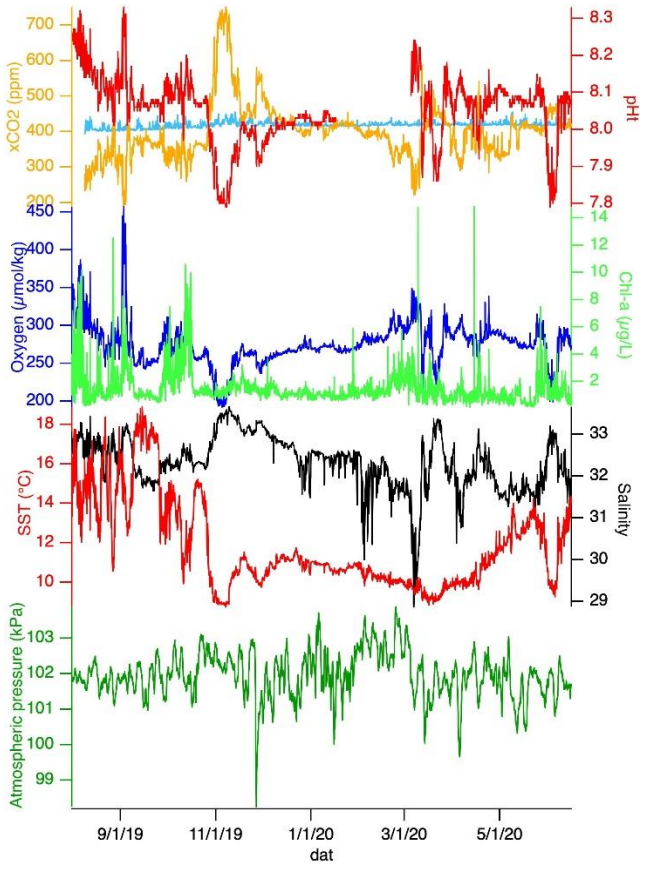

Figure 2: *CB06 mooring data over the past reporting period*

August 2019-June 2020 data from CB06. August mooring was recovered on 1 March, and replaced with a new mooring.

*-Bring all data QA/QC to meet Certification standards [**Kosro**, Hales]*
On Mar 4, 2020, the Oregon shelf mooring CB06 mooring was deployed with a fresh set of instruments and batteries, at the location offshore from Coos Bay at 43° 17.89 N, 124° 31.88 W, near the 100m isobath, and the previous setting of the mooring (from Aug 3, 2019) was then recovered. Real time data from the refreshed mooring are transmitted to shore via cell modem for several of the physical and meteorological systems, and via Iridium satellite by Burke Hales group for the biogeochemical data. These data are then passed to the NANOOS Visualization System (NVS) and to a local server (http://bragg/CB06_Telemetry/Plots/) where they are plotted and provided to the public. The data are also forwarded to the National Data Buoy Center (NDBC), which displays them online as buoy 46128.

The loss of the CB06 mooring in 2019 (due, we strongly suspect, to a ship strike) meant the loss of a full suite of scientific instruments. To replace them, we will need to transfer funds from another of our research projects. We will be in touch with UW and the program office for authorization.

-Task 11a: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA
[Hales] Hales continues to work with Whiskey Creek Shellfish Hatchery to provide technical assistance to maintain the Burke-o-Lator there. WCSH recently suffered a fire, and has only recently come back online. Hales continues to offer significant assistance to the new installation at Hog Island's Humboldt Bay hatchery, trouble-shooting and training multiple on-site personnel. Hales continues to provide assistance to the operation of the BoL at the Kodiak Fisheries lab and in the training and advice of new personnel there. Hales has refurbished the system from the Taylor Shellfish Hatchery at Quilcene to bring the fluidic systems up to state of the art, and is awaiting their receipt of their TSG from service at SBE before making a site-visit there to train personnel in the operation of that new system.

-Task 11b: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA
[Carter] Mr. Herndon continued to provide ongoing technical assistance for the Burke-o-lator seawater chemistry analytical system at Taylor Shellfish Hatchery. Earlier this year, he delivered the Burke-o-lator system to Oregon State University, where it is undergoing needed repairs. In addition, he provided technical support for deploying and maintaining an ACDC CO2 sensor at a Puget Sound shellfish-growing location by developing a thorough plan for siting and securing the system. The deployment of the ACDC has unfortunately continued to be delayed by personnel turnover with project partners, who have not yet been able to supply the repaired sensors in support of the final stages of this technology transfer project as well as now the pandemic lockdown.

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]
The CMOP ocean buoy (SATURN-02) will—as a part of the full transition of CMOP assets—be transferred, starting June 1, to the Columbia River Inter-Tribal Fish Commission. That will become, to our knowledge, the first such ocean buoy run within IOOS by a tribal institution. The transition of CMOP assets has been planned for the past two years, in coordination with NANOOS and IOOS, and is designed to coincide with

the retirement of Baptista from OHSU. The driving vision is to enable CMOP assets to be sustainably maintained for time scales consistent with climate change science and management.

SATURN-02 is 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 last recovered November 8, 2019. Parameters measured were (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.

The Spring deployment of SATURN-02 had to be postponed, due to COVID-19's restrictions on staff access to OHSU facilities, including CMOP's MERTS Field Station.

Real time data from SATURN coastal stations are already being displayed on NVS. CMOP 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. Preparing for the transition from OHSU to CRITFC introduced some operational delays on QA/QC. However, Seaton participated in planning the integration of QARTOD flagging into the NANOOS centralized ERDDAP server, consistent with IOOS and NDBC policy recommendations. He also continued to monitor the maturation of the IOOS QARTOD library being developed by Axiom.

- **Estuaries**

Puget Sound Buoy Observations:

-Maintain Puget Sound estuarine moorings; deliver data via NVS [Curry]
-Bring all data QA/QC to meet Certification standards [Curry]

Led by B. Curry, and J. Mickett during this report period, the ORCA (Oceanic Remote Chemical Analyzer) mooring system and Bellingham Bay Se'lhaem buoy continued to be operational. Upgrades to the ORCA system and lab protocols are ongoing and buoy endurance continues to improve. More powerful solar panels have been added to all but one of the buoys. The buoys are fully implemented with real-time pH measurements; the data is being sent and plotted in real-time. We continue to work with A. Sutton, S. Alin, and R. Feely (NOAA PMEL Carbon Group) deploying pCO_2 systems on Twanoh and Dabob Bay and collecting water sample for system calibration. Data continue to be made available through NANOOS NVS and through the NWEM ORCA server.

Due to the COVID-19 pandemic, the field team has had wear additional PPE and practice social distancing guidelines but thankfully have been able to carry our regular maintenance and repairs to keep this real-time system operational. The new boat (a 24' Almar Sounder) has been a wonderful addition to the project.

The ORCA buoys tracked the development and evolution of a large salinity anomaly in Puget Sound that spanned most of the year in 2019. The salinity anomaly has persisted in 2020 except for a fresher than

average period February-March. A summary of the 2019 observations collected by the ORCA and Bellingham Bay Se'lhaem buoys were presented at the annual marine waters meeting and submitted for inclusion in the 2019 Puget Sound Marine Waters Report.

We continue to work towards quality control (QARTOD) and data archiving for all the ORCA data. The pH nectcdf files will soon be ready to submit for data archiving.

Washington State Estuarine Observations:

-Maintain US-Canada ferry-box; deliver data via NVS [Krembs]

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

Led by C. Krembs (WA State Department of Ecology), en-route ferry-based monitoring and moorings are two parts of Ecology's extensive long-term monitoring program that covers Puget Sound and the Washington coastal estuaries. The ongoing ferry monitoring complements Ecology's extensive marine monitoring program station network by focusing on surface processes (e.g., temperature variations, frontal systems, tidal currents, blooms, river plumes, etc.) integrating between stations on a large scale. Thereby providing a means of continuously ground-truthing for remote sensing techniques to greatly leverage and expand capabilities for Puget Sound environmental monitoring. Moorings were previously deployed to provide continuous information on estuarine water conditions and to complement Ecology's monthly marine water sampling. The value of this NANOOS supported effort becomes increasingly apparent. Though the fixed moorings program ended due to funding shortfalls, we focus efforts on data quality control and data analysis to make the dataset publicly available.

The COVID-19 pandemic and subsequent rapid and lasting lockdown for Washington State profoundly affected state agencies and ferry operations (Victoria Clipper V suspended until Aug 7) operating along its 80 nautical mile transect between Seattle and Victoria, BC. While this critically slowed the progress of deploying our sensor packages to collect data on the Victoria Clipper V ferry vessel, we used the time to continue to more actively showcase NANOOS strength, achievements, and benefits to the agency. In February, Suzan Pool presented an hour-long, well perceived agency seminar at WA State Department of Ecology that summarized the agency's continuous marine water monitoring that NANOOS supported. Time spent on this included assembling the presentation with strategies, methods, data volumes, and charts of all continuous data collected since 1997. Suzan showed four types of continuous data platforms (Figure 3). She also presented plots to show examples of data richness and analysis methods that were implemented over the years. One example shows temporal trends for three data platforms near Bay Center in Willapa Bay (Figure 4) supported by NANOOS. The seminar presentation was well received by colleagues and highlighted the importance to be integrated with NANOOS to leverage information gained at a larger scale.

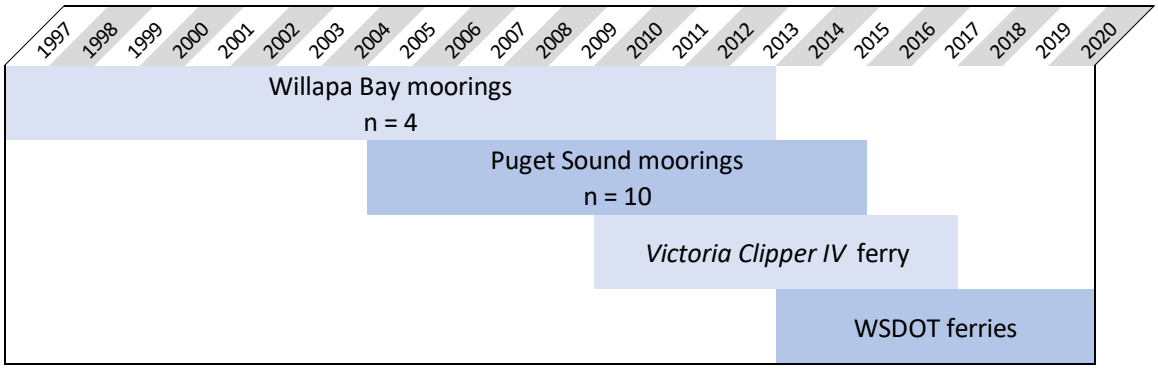

Figure 3. *Four types of continuous data platforms used by WA State Department of Ecology*

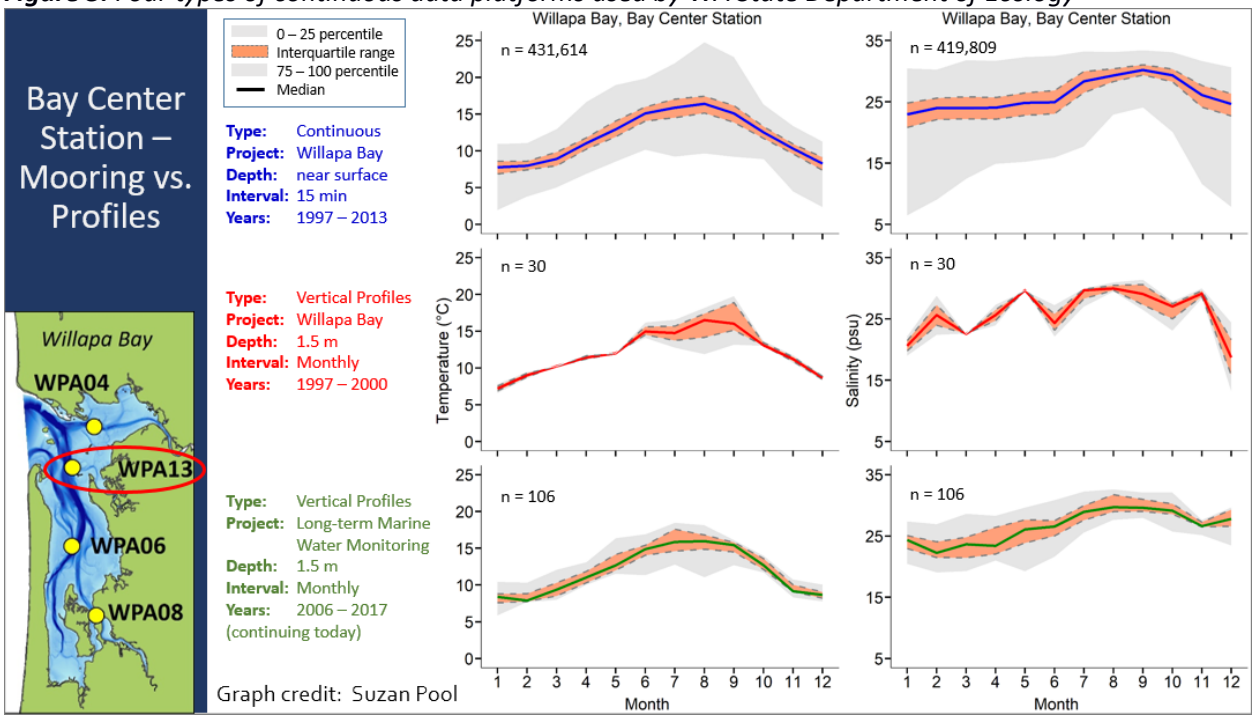

Figure 4. *Temporal trends for three data platforms near Bay Center in Willapa Bay*

Columbia River Estuarine Observations:

-Maintain Columbia R. estuarine moorings; deliver data via NVS [Baptista]

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

The CMOP estuarine observation network will—as a part of the full transition of CMOP assets—be transferred, starting June 1, to the Columbia River Inter-Tribal Fish Commission. That will become, to our knowledge, the first such estuarine/coastal observational network run within IOOS by a tribal institution. The transition of CMOP assets has been planned for the past two years, in coordination with NANOOS and IOOS, and is designed to coincide with the retirement of Baptista from OHSU. The driving vision is to enable CMOP assets to be sustainably maintained for time scales consistent with climate change science and management.

Multiple endurance stations for the lower Columbia River estuary have anchored the CMOP/SATURN network, and will now be under the responsibility of CRITFC. Originally a part of SATURN, but not funded by NANOOS, are two freshwater stations: SATURN-05 and SATURN-08 (maintained by J. Needoba (OHSU) with regional stakeholder funding; those stations do not transfer to CRITFC.

The NANOOS supported estuarine stations that are maintained on a permanent or seasonal basis are SATURN-01 (occasional), 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). Each of the stations is designed to capture specific features of the estuary.

Real time data from SATURN coastal stations are already being displayed on NVS. CMOP 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. Preparing for the transition from OHSU to CRITFC introduced some operational delays on QA/QC. However, Seaton participated in planning the integration of QARTOD flagging into the NANOOS centralized ERDDAP server, consistent with IOOS and NDBC policy recommendations. He also continued to monitor the maturation of the IOOS QARTOD library being developed by Axiom.

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 (Research Technician) at the South Slough National Estuarine Research Reserve (SSNERR). SSNERR 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 monitoring stations located along the salinity gradient of the South Slough estuary provided continuous water temperature, salinity, dissolved oxygen, pH, turbidity, and water level data over the period 12/01/19 – 5/31/20. Telemetry transmissions were continuous for the Valino Island, Winchester Creek, and Elliot Creek stations. The Charleston Bridge station instrument collected data, but real-time transmissions weren't completed for the reporting period because the station is being prepared for installation of a new data collection platform and telemetry equipment (Yellow Springs Instruments Turnkey Storm3 system). Tom's Creek weather station stopped transmitting December 2019 and resumed with replacement of the transmitter on 12/31/2019. The weather station solar radiation and rain sensor cables were damaged March-April 2020 and replacement sensors and cables were ordered May 2020. Monthly instrument deployments and retrievals, station maintenance, and data download, QA/QC, and management were completed for the weather and water quality stations during the reporting period following NOAA NERRS Centralized Data Management Office protocols, including 2019 Annual water quality and weather data submissions in April and May 2020.

SSNERR maintains one Coos Bay water quality station in partnership with the Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians (CTCLUSI). This station, North Spit BLM, is located in the lower Coos estuary with data available through NVS (NESDID ID # 346F229A; sosnswq).

South Slough expanded the network of water quality stations into the Coos estuary, which currently includes three stations located at Isthmus Slough, Catching Slough, and Coos River. The Reserve added pCO2/pH monitoring equipment at the Valino Island and Charleston Bridge water quality stations and data collection was completed August 2019 with current efforts this reporting period focused on time-series and grab data analysis in collaboration with Oregon State University (Chan, Magel, and Hales).

The SSNERR water quality stations provide real-time data access for shellfish growers in the Coos estuary, 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 projects at the Reserve funded through the Office of Coastal Management 2019 Margaret A. Davidson Graduate Fellowship including environmental modeling analyses (water and air temperature, turbidity, salinity, DO, solar radiation)

from four stations (Charleston Bridge, Valino Island, Winchester Creek, and Tom's Creek) to characterize potential drivers of eelgrass decline and another project on habitat characteristics of an endangered salt marsh plant in South Slough estuary. Two presentations from these projects were delivered at the Ocean Sciences meeting (2/17/20): Connectivity in Coos Bay, OR: do changes in physical dynamics lead to changes in eelgrass habitat (Marin Jarrin, Sutherland, and Dye) and Distribution and habitat characteristics of *Chloropyron maritimum palustre* (bird's beak) in the South Slough estuary (Suesue and Helms), and included estuarine water temperature and salinity data from three SWMP/NANOOS stations. A 2020 NOAA Ernest F. Hollings undergraduate scholar project is utilizing turbidity and tidal range data to assess salt marsh resilience to sea-level rise. NANOOS Visualization System tools were integrated into boating safety plans for the Reserve developed in Spring 2020, and water quality data were used for a poster presentation on eelgrass wasting disease for the Oregon Marine Scientist and Educator Alliance (ORSEA) Capstone Outreach program (Geierman, Hampel, and Mueller; 5/15/20).

COVID-19 impacts affected routine SWMP field and laboratory work typically completed with assistance from quarterly (Spring) SWMP internships and due to social distancing restrictions for fieldwork and lab space, the Reserve was unable to host interns or volunteers March – May 2020.

- **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 2019, 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.

In March 2020, CMAP began conducting winter seasonal beach monitoring surveys in the CRLC, but were interrupted by the Coronavirus pandemic. We were able to complete roughly half of our normal survey work, collecting 27 out of 50 seasonal beach profiles, 3 out of 5 surface maps, and 35 out of 63 sediment samples from multiple cross-shore locations along 7 of the 13 routinely sampled profiles. Seasonal monitoring surveys were not conducted in the North Beach or Grayland Plains subcells, including the supplemental work that has been done at the Westport by the Sea Condos and near the jetty in Ocean Shores, where intensive monitoring has been conducted since fall 2015.

With other project funds, CMAP continued more intensive beach monitoring of the constructed dynamic revetment at North Cove. CMAP collected 13 beach profiles before and after a storm in mid-January 2020 as well as a full survey with 47 beach profiles and a surface map in February. Surveys in March were canceled due to COVID-19. The dynamic revetment continues to demonstrate positive results in preventing significant loss of the uplands during the winter. Sediment has deposited and accumulated on the upper beach, showing good recovery of the sediment-starved shoreline.

To continue comparing the performance of the dynamic revetment constructed of quarry spalls to a natural cobble berm, CMAP collected 14 seasonal beach profiles near Kalaloch at South Beach in early January and March. At both North Cove and Kalaloch, CMAP is tracking tagged cobbles as well as collecting sediment grain size data with digital photographs. CMAP also took on winter storm monitoring of a new dynamic revetment constructed on the north end of the Shoalwater Bay berm as an emergency response to high tides and large storm waves at the end of December 2019. CMAP collected 30 cross-shore beach profiles at the end of December and again mid-January to begin monitoring the effectiveness of the revetment.

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 surveys – were collected in the Neskowin (15 sites) littoral cell in January 2020. Winter surveys were collected in the Neskowin (15 sites) and Rockaway littoral cells (25 sites), as well as along Clatsop Spit (6 sites) in March 2020, just prior to statewide lockdowns in response to the COVID19 outbreak. In addition to measurements of 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 2020, our monitoring data indicated that the suite of beach observation sites were within the typical winter range determined from 22 years of beach monitoring.

As a result of the COVID19 outbreak and statewide lockdowns, plans to update beach survey measurements in the Netarts (northern Oregon coast) and Gold Beach (southern Oregon coast) littoral cells had to be put on hold. It is unclear at this stage whether we will be able to make these up with a late summer (~August-September timeframe) survey of the sites. The latter will be dependent on successful measurements of our core monitoring sites in Neskowin, Rockaway and along the Clatsop plains scheduled for September 2020.

Technical information on developing coastal hazards in the Rockaway littoral cell have been shared with Oregon State Parks and Department of Land Conservation and Development to address an emerging erosion hazard issue developing in the vicinity of Twin Rocks, the product of ongoing erosion of the foredune.

***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 collected in summer 2019 along the four sub-cells of the Columbia River littoral cell (CRLC). Over 220 individual cross-shore profiles were collected during summer 2019 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 bringing the data to certification standards. 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 5). The data are used in many 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.

Our summer 2020 field data collection will most likely be significantly impacted. Due to Oregon State University travel restrictions we have not been able to train new field personnel this year so most likely will have a smaller crew. Further, if research activities are resumed over the summer we will have to drive individual cars and stay in single occupancy hotel rooms. Further, due to social distancing guidelines we most likely will only be able to launch boats from marinas as opposed to beaches. Due to these restrictions and impacts on our budget we hope to be able to collect ~50% of our normal data set during summer of 2020.

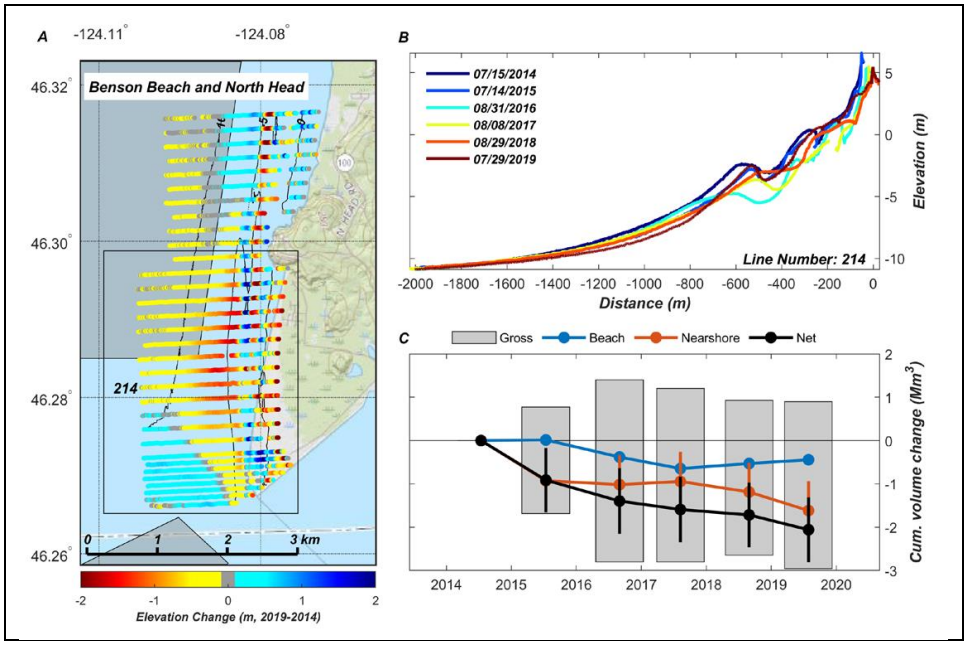

Figure 5. *A, Map showing cumulative elevation changes between 2014 and 2019 for Benson Beach and North Head regions within Long Beach subcell; depth contours (5-m interval between –10 and 0 m) based on 2014 survey. Black line outlines profiles used to calculate net volume changes in Benson Beach region. Gray-filled boxes show North Head study area (northwest corner) and Columbia River Shallow Water Site (southwest corner) dredge-placement areas. B, Example profile showing changes in beach and nearshore morphology along survey line 214 (location shown in A). C, Time-series plot of volume changes calculated for Benson Beach region; net volume changes are provided for beach and nearshore depth zones, as well as net volume changes integrated over entire region.*

- **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.

During this period, NANOOS scored an HFR Net Performance metric for the 2 main reporting quarters (Q2 and Q3 of 2020) of 91% and 76% respectively (https://hfrnet.ucsd.edu/diagnostics), or 83% for the past year. This exceeds the target figure of 80%.

In-house repairs were performed on several systems, including at STV2 for the loss of signal; Erik thoroughly cleaned the circuit boards back at OSU and returned it to working condition. New Mac minis were installed at sites including YHS2 and WLD2 to allow newer data acquisition software. Radial web server software required re-installation at YHS2 and at WLD2. A new UPS was installed at CBL1, and required troubleshooting to get it to register updated metadata. Work continued on MAN1 for the lightning damage, and a purchase order for replacement equipment was placed, funded by OSU's self-insurance (delivery is stalled by COVID-19 closure at Codar). SEA1 lost power in Feb 2020, and when we got on site, GFCI was tripped and moisture had condensed in the Rx and Tx; solved by running the heater overnight with 2 fans. At WLD2, cable to the monopole receive channel broke; took 3 days to travel, locate the break in the dense undergrowth, and repair. After repair, had to reset the phases. At CBL1, Erik found the anchor screws for the Rx antenna had rotted, allowing some azimuthal offset in the antenna. He re-engineered and replaced the anchor screws, reset the angle, and tightened the guy lines to prevent motion.

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

Permitting to install the next site to the north, at Westport, WA, has been a complex and time-consuming process, but thanks to the persistence of UW's Paul Rudell, and with the help of the Program Office's Environmental Compliance Officer Mequela Thomas, both UW and Washington State Parks have agreed to the installation (signed papers promised soon). We are working with the National Parks service on a proposal to install at the next site farther northward on the coast, near Kalaloch. Renewal of FCC licenses to operate the radio equipment is made challenging by the mandated changes in license type, frequencies, and operating conditions that must be met because of the new requirements which take effect in 2021. Operators will need to rely on the recently contracted IOOS frequency coordination consultants for their expertise in this arena.

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 and operate the radar station at the Yaquina Bay inlet in Newport, OR. Imagery, videos, and spectrum plots are posted to our webpage (http://research.engr.oregonstate.edu/haller/Newport) and imagery and spectral plots are available on NANOOS NVS Explorer. Occasional maintenance of the radar system includes replacing backup hard drives

and remedying wear and tear issues such as replacing motor brushes.

In January 2020 we were contacted by researchers (X. Chen & W. Huang) from Memorial University (Canada) seeking to test a rain detection algorithm using marine radar data. We were pleased to be able to present five days of hourly radar images from our Newport archives which we were able to correlate with some rainfall using local gauges. Their paper, "Rain-contaminated Region Segmentation of X-band Marine Radar Images with an Ensemble of SegNets" is currently under review for *IEEE Transactions on Geoscience and Remote Sensing.* During May 2020 we supplied a more expansive dataset of 1000 images over a one-year time period with a climatology of rain conditions for a comprehensive follow-on study. This data set also included wind data from the local NOAA weather station (NDBC NWPO3) and wave conditions from the OOI Coastal Endurance Oregon Shelf Surface Mooring.

We are in the process of upgrading our radar to a new Furuno model that we expect to be much more reliable. In concert with this, we will be replacing the older data acquisition hardware and software with a new radar DAQ card from Cambridge Pixel that will allow us greater flexibility in data collection. The Coast Guard (Station Yaquina Bay) has asked for a live display of the radar imagery as well, which we intend to provide with the new radar.

b) NANOOS Modeling Subsystem:

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, ACSPO Global SST from VIIRS, 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, e.g., as the Tuna Forecast and SeaCast applications. 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.

During the report period, we continued our real-time operation. At the same time we have been working to complete publication of data assimilation tests and analyses aimed at further system improvement [Pasmans and Kurapov, 2019; Pasmans et al., 2020]. This work was leveraged by the Quantitative Observing System Assessment Program (QOSAP) funds, provided earlier through NANOOS. We have also continued transition of details of the data assimilation technology to the NOAA US West Coast Operational Forecast System (WCOFS), which is currently at the testing phase at NOAA NOS. In particular, building upon our success with the NANOOS OSU system, transition has been made to include assimilation of alongtrack altimetry in WCOFS. In preparation to acquiring a new OSU cluster to enable further continuous forecast system operation, we have run tests of such a system at the Dell site.

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.

Extensive model validation and movies of the daily forecast focused on different stakeholders are presented at: 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 six months MacCready and Darr have maintained the LiveOcean forecasts (no missed days), focusing especially on reliability of the HYCOM forcing fields. MacCready and McCabe have continued with validation against multiple observational sources. MacCready participated in a NOAA OCNMS Workshop in January 2020 and gave a talk about the model at the Ocean Sciences meeting in February 2020. 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.

The work of MacCready's group is largely unaffected by COVID-19. We use a number of remote computers and are able to perform all research tasks from home offices.

-Task 13: Support evaluation of LiveOcean in IOOS cloud sandbox [MacCready]

Recently MacCready and Darr worked with Tiffany Vance (NOAA) and Patrick Tripp (RPS, a consulting company contracted by NOAA) to port the LiveOcean system to a cloud computing platform. The goal is to evaluate whether or not cloud computing is a cheaper, more reliable, more flexible alternative to PI-based forecast computing. During the past six months Tripp has maintained a pre-operational version of LiveOcean working in AWS. MacCready gave a presentation on this at a Cloud Sandbox Workshop in May 2020.

Columbia River Modeling:

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

-Model verification and validation [Baptista]

The CMOP modeling system will—as a part of the full transition of CMOP assets—be transferred, starting June 1, to the Columbia River Inter-Tribal Fish Commission. That will become, to our knowledge, the first such modeling system run within IOOS by a tribal institution. The transition of CMOP assets has been

planned for the past two years, in coordination with NANOOS and IOOS, and is designed to coincide with the retirement of Baptista from OHSU. The driving vision is to enable CMOP assets to be sustainably maintained for time scales consistent with climate change science and management.

OHSU has maintained 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. During this reporting period, we conducted simulations in support of FEMA storm surge mapping for Clatsop County.

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.

Leveraging the modeling system, we also developed an Individual Based Model (with hydraulic transport, swimming and growth modules) to understand the use of the estuary by juvenile salmon. This effort was collaborative with the NOAA Northwest Fisheries Science Center, and led to a PhD thesis (Morrice 2020) and a peer reviewed publication (Morrice et al. 2020), with a second peer-reviewed submission in preparation. The PhD student responsible for the IBM, Katherine Morrice, is now a Knauss Fellow, at the Department of Energy.

c) Data Management and Communications (DMAC) Subsystem:

See Table 1 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 28, online); and 3) monthly IOOS DMAC webinars.

*The **NANOOS Visualization System (NVS)*** enhancements encompass asset additions and continuous updates: 1) new data streams from the new CDIP Angeles Point wave buoy, intended to help monitor sediment transport around the Elwha River plume and Port Angeles, and from newly integrated or reestablished data integrations at NWS wind stations north and south of the Columbia River mouth, a USGS river gage in Vancouver, WA, and the Friday Harbor Laboratory weather station; and 2) a new Glider App for an OOI glider transect off Newport – the first glider data available NVS, to be followed by other transects in the near future; and 3) redeployments and smaller upgrades, including new pH sensors at ORCA buoys at Dabob Bay, Hansville and Point Wells, and an update to the latest version of the SalishSeaCast model output from UBC.

NANOOS and IOOS DMAC system implementation.

- Data Archiving. Monthly NCEI archiving of fixed-location time series data from OHSU CMOP stations

continued operationally. Efforts to archive Oregon shoreline change surveys carried out by DOGAMI for the last twenty years, and pH sensor data from Washington Shelf and Puget Sound moorings maintained by the UW NorthWest Environmental Moorings (NWEM) group, are ongoing.

- ERDDAP Implementation. A NANOOS ERDDAP server (http://data.nanoos.org/erddap/index.html) has been released, providing data access and distribution to 111 datasets that include NANOOS gliders, NANOOS-processed time series and climatologies from NDBC, NOS and CDIP, and NANOOS-originated remote sensing products. Ongoing development is focused on enabling access to the same near-real-time station data streams currently available on NVS; an initial release is planned for this Summer.
- Other advancements. NANOOS is a co-organizer in the 2020 OceanHackWeek (https://oceanhackweek.github.io) collaborative educational event taking place online in August 2020, 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, NSF, the UW eScience Institute and other sources.

Ocean Acidification (OA) Data. NANOOS continued its ongoing support for OA data efforts. pH sensors are now present on ORCA buoys at Dabob Bay, Hansville and Point Wells, and the data streams have been integrated into NVS. pCO2 sensors on the ONC Baynes Sound Mooring (Strait of Georgia, BC) were restored to service, and a new pH sensor was deployed and integrated into NVS. Globally, international collaborations on the GOA-ON (Global OA Observation Network) data portal were strengthened: (1) The GOA-ON Data Portal now includes metadata, track visualizations, and data links from 71 Biogeochemical Argo Floats (BGC Argo). These BGC Argo Floats all measure pH throughout the water column, along with other hydrographic parameters. (2) A new-real-time data stream from an OA monitoring mooring in Chile was integrated into the data portal, featuring pH and pCO2 sensors. (3) Procedures and best practices for GOA-ON asset inventory curation were improved and better documented, leading to more consistent and robust records. (4) In addition, we initiated discussions with NOAA PMEL, NCEI and others about future GOA-ON asset inventory workflow overhauls and enhancement to capabilities.

Biological data stewardship. NANOOS is actively working to advance the integration of biological data into its products and the delivery of regional biological data to national IOOS networks, including the Marine Biodiversity Observation Network (MBON) and the international Ocean Biogeographic Information System (OBIS). This is being done through engagement with regional partners to identify and prioritize a set of important biological survey and measurements datasets that can be reprocessed and standardized for delivery and integration into these systems; and development of internal capacity for handling biological data. We have identified and taken initial steps to process a Hood Canal (Salish Sea) zooplankton densities dataset from Prof. Julie Keister, University of Washington School of Oceanography. This initial work is expected to lead to the processing of the broader and longer-term Salish Sea Marine Survival Project Zooplankton Dataset. In addition, DMAC staff participate in the regular Biological Data Standards working group calls and in new and emerging biological data projects in the region.

-Task 12: Enhance GOA-ON data portal an OA dashboard to the world [Mayorga, Tanner, Newton]
The GOA-ON Data Portal now includes metadata, track visualizations, and data links from 71 Biogeochemical Argo Floats (BGC Argo). These BGC Argo Floats all measure pH throughout the water column, along with other hydrographic parameters. The BGC Argo Floats included on the GOA-ON Data Portal are managed by the Southern Ocean Carbon and Climate Observations and Modeling project, the Norwegian Institute of Marine Research, the Federal Maritime and Hydrographic Agency of Germany, the Second Institute of Oceanography China Argo Project and the Observatoire Oceanologique de Villefranche.

Float tracks were generated from the Argo Ifremer ERDDAP server. (2) A new-real-time data stream from an OA monitoring mooring managed by the Universidad de Chile was integrated into the data portal. Located in central Chile near Concepcion, this station has pH and pCO2 sensors. As with other Chilean stations with integrated data harvesting, data access was facilitated by the CEAZA Met regional system. This addition also entailed an enhancement to the CEAZA Met data access mechanism. (3) Procedures and best practices for GOA-ON asset inventory curation were improved and better documented, leading to more consistent and robust records. (4) In addition, we initiated discussions with NOAA PMEL, NCEI and others about future GOA-ON asset inventory workflow overhauls and enhancement to capabilities.

-Task 14: Support OceanHackWeek 2019 [Mayorga] This task was completed and reported on in the last reporting period. This project was completed last reporting period.

-Task 15: Enhance biological data stewardship within NANOOS [Mayorga]
NANOOS is actively working to advance the integration of biological data into its products and the delivery of regional biological data to national IOOS networks, including the Marine Biodiversity Observation Network (MBON) and the international Ocean Biogeographic Information System (OBIS). This is being done through engagement with regional partners to identify and prioritize a set of important biological survey and measurements datasets that can be reprocessed and standardized for delivery and integration into these systems; and development of internal capacity for handling biological data. We have identified and taken initial steps to process and map to Darwin Core a Hood Canal (Salish Sea) zooplankton densities dataset from a University of Washington scientist. This dataset is published in BCO-DMO (https://www.bco-dmo.org/dataset/682074), but not in OBIS. In addition, DMAC staff participate in the regular Biological Data Standards working group calls and in new and emerging biological data projects in the region.

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 has been the recognition that the UPC works closely with other NANOOS committees, most importantly the DMAC and Education/Outreach teams to ensure product concepts are effectively developed and tested prior to their release.

Chaired by J. Allan (DOGAMI) this committee is composed of members from OHSU, UW, OSU, NANOOS E&O, and NOAA. NANOOS UPC chair Allan participates in weekly "tag-up" calls with a smaller sub-group comprised of members from DMAC, UPC, E&O, and Web development to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this 2020 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; 2) Participation in the annual tri-committee meeting held on May 28th, 2020; 3) performed additional modifications to matlab code for processing and plotting NDBC and CDIP time-series data for inclusion in the climatology app.

NVS: The backbone of the NANOOS RCOOS is the NANOOS Visualization System (NVS) that currently distributes data from a myriad of regional and federal assets. During this reporting period, NANOOS did

not release any major update to NVS; the last update was V6.3, which was released in June 2019.

During this period work commenced to build an “overview” application in order to track the status of every asset, model and satellite overlay, and markers (web cams, marinas and boat launching ramps, and tsunami critical facility markers) via a web-based application (Figure 6). The objective of this tool is to allow core NANOOS staff (Web, DMAC, E&O, User Products, and Admin) to visualize the status of any data stream that is disseminated via NVS in order to identify potential problems or outright failures. This tool was identified as a need due to changes to DMAC leadership, with the resignation of DMAC lead, Emilio Mayorga. The completed application is now operational.

NVS Mobile App: NANOOS released a major update (v2.2.) to the TsunamiEvac mobile phone app. Version 2.2 includes the addition of push notifications from the National Tsunami Warning Center that may include information statements on distant earthquakes, tsunami watches, advisories, or warnings (Figure 7). With notifications enabled the messages are pushed directly to your phone (iOS and Android), even if the phone is in sleep mode. These improvements are important for local residents and visitors to the Pacific Northwest coast concerning potential distant tsunami threats. For local tsunami threats, long-duration (3-5 minutes) earthquake shaking will be your only warning.

Figure 6. *NVS Overview web app showing asset status, measurement variables (when they were last measured), and not shown the NVS apps that include the asset.*

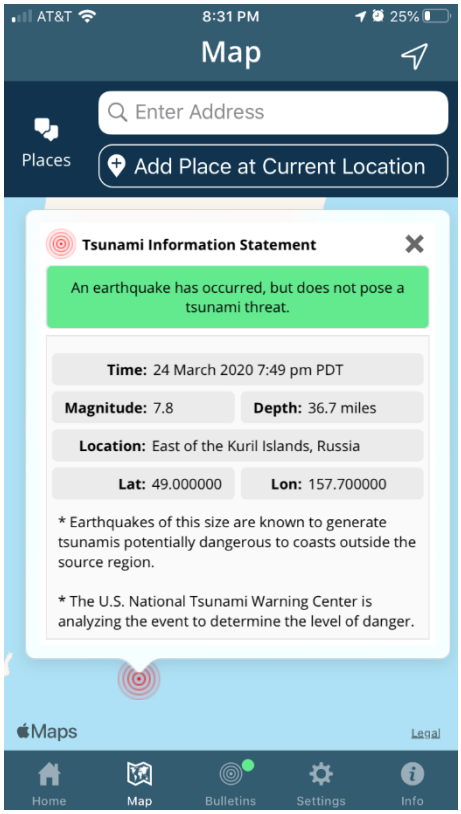

Figure 7. *NVS TsunamiEvac smartphone application for iOS which now includes push notifications from the US Tsunami Warning Center.*

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, and Rudell, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton, Wold, and Rudell were active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. Rudell and Wold continued participation with IOOS E&O calls as they occur.

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

- NANOOS has been partnering with a small local non-profit, Whidbey Watershed Stewards, to work with the 7th & 8th graders at South Whidbey Middle School ocean science and technology program. In previous years students design, build, and deploy buoys at the Langley Marina then retrieve and analyze their data. This project is on hold due to COVID-19.

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 and Rudell engaged with the recreational boating community, presenting at various meetings to display the NVS Boaters App while gaining their direct feedback. Wold and Rudell gave seminars and live demonstrations at two regional boaters' events: The Portland Boat Show (January) and the Seattle Boat Show (January and February).
- Wold gave a virtual seminar demonstrating the NVS Boaters App to the Seattle Sailing Club on 28 April.
- Wold staffed a table at the 'Sound Waters – A one-day university for all' on Whidbey Island, WA 1 February, where she engaged with interested citizens. This annual event, hosted by Sound Water Stewards, was attended by over 500 individuals.
- Wold 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 again invited to participate in the annual Curiosity Expo: Climate Change at the Pacific Science Center on 28-29 February. Wold demonstrated using the NVS Climatology App to track oceanographic conditions and compare with data from previous years
- 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."
- Newton was invited by NOAA's Office of National Marine Sanctuaries to present "Understanding the Marine Heat Wave in the Pacific Northwest" in their Webinar Series on 24 April. The webinar was part of a speaker series in partnership with Olympic Coast National Marine Sanctuary, Feiro Marine Life Center, and the Peninsula College STEM Club. Jan gave a view into the mechanisms and effects of marine heatwaves and used data and screenshots from NANOOS NVS Climatology App to show these events and differences in how marine heatwaves are manifest in different coastal areas. Over 700 people registered and 475 attended this webinar, showing strong interest in ocean and climate literacy.

f) NANOOS Administration:

See table for milestones [Newton]

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

- Newton and Martin attended the Spring IOOS and IOOS Association meetings in Washington D.C. during 3-5 March and did Hill visits on 5-6 March.

Additional coordination and representation included:

- Newton represented NANOOS at the NOAA OAP PI meeting in Miami FL on 7-9 January and gave a talk on the regional vulnerability assessment she leads, involving social science and four coastal treaty tribes. She also was on a panel to discuss co-design and how IOOS facilitates stakeholder connections.
- Newton contributed NANOOS updates on oceanographic conditions in the Pacific Northwest for the NOAA WestWatch webinar series on 7 January and 21 April, along with the other two west

coast Ras CeNCOOS and SCCOOS, and a similar but local-scale Salish Sea Marine Conditions webinars on 22 January, 23 March, and 27 May 2020.

- Newton attended the "Roundtable on Putting Oceans Data to Use," hosted by the Center for Open Data Enterprise (CODE) in Washington, D.C. on 10 February 2020. CODE hosted the invitation-only roundtable in partnership with NOAA, Ocean Conservancy, Esri, Amazon, and Microsoft to discuss the potential of oceans data, identify new opportunities, and develop data-driven strategies to improve ocean health and promote the Blue Economy.
- Newton represented NANOOS and IOOS at the Ocean Sciences Meeting in San Diego, CA, on 16-21 February, with a talk on how NANOOS NVS meets stakeholder needs. She co-chaired a breakout session at the Research Coordination Network meeting on 16 February on ocean observing systems.
- Newton served on the Salish Sea Ecosystem Conference steering committee, attending a program planning meeting in Bellingham, WA, on December 10-11. 2019.
- Newton was invited to give a presentation "Oceans and Climate: Mitigating Impacts on our Aquatic Food Systems" in the Winter Seminar series for the Nutritional Sciences Programs and CHanGE (Center for Health and the Global Environment): Food Systems in the Age of Climate Change at the University of Washington on 14 January. Students taking the seminar wrote questions and learned why observations and modeling affect food security.
- Newton attended the Long Live the Kings Marine Salmon Survival Workgroup Meeting, in Victoria, BC, on 3-4 February 2020. There she connected with Canadian collaborators who post data and model results on NANOOS NVS.
- Newton is a new member of the NOAA Science Advisory Board's Ecosystem Sciences and Management Working Group, which met virtually on 5-6 May. The work group is charged with providing scientific advice and broad direction for research, monitoring, and ecosystem management, including underlying observations and data management issues.
- Newton was invited by NOAA's Office of National Marine Sanctuaries to present "Understanding the Marine Heat Wave in the Pacific Northwest" in their Webinar Series on 24 April. The webinar was part of a speaker series in partnership with Olympic Coast National Marine Sanctuary, Feiro Marine Life Center, and the Peninsula College STEM Club. Jan gave a view into the mechanisms and effects of marine heatwaves and used data and screenshots from NANOOS NVS Climatology App to show these events and differences in how marine heatwaves are manifest in different coastal areas. Over 700 people registered and 475 attended this webinar, showing strong interest in ocean and climate literacy.
- Newton was invited to contribute to an expert working group, "*Scoping marine biodiversity protection in US waters*", sponsored by the Lenfest Ocean Program and the National Marine Sanctuary Foundation. The goal of the project is to identify key information needed to develop a framework for marine habitat and biodiversity conservation in waters of the U.S. and associated territories. She attended the first virtual meeting 28 May.

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

- Barth participated on January 8, 2020 in a strategic planning 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 represented IOOS on the Global Ocean Acidification Network Executive Committee calls and activities. She is a co-Chair of GOA-ON, along with Bronte Tilbrook, CSIRO. With Dr. Adrienne Sutton, NOAA PMEL, she coordinated the "Ocean Acidification Time-Series Analysis Workshop" held on 25-26 February 2020, Seattle, USA, with international participation.
- Newton participated in the GOA-On North American Hub Meeting at the Universidad Del Mar, Huatulco Campus, Oaxaca, Mexico, December 16-18, 2019 and led discussions on the data portal, engaging with NCEI and others on streamlining data needs, which is leading to a NOAA OAP-NCEI proposal. She also gave an invited seminar on ocean acidification to students and faculty at the Puerto Ángel Campus.
- Newton is a member of the GOA-ON Biology Working Group and attended a writing workshop for a paper on recommendations for biological observations relative to ocean acidification held in Kristeneberg, Sweden, 20-24 January 2020.
- Newton served as a member of the International Science Advisory Committee for the Canadian Marine Environmental Observation Prediction and Response (MEOPAR) program.
- Newton is a member of the Science Advisory Team for the Joint European Research Infrastructure in the Coastal Ocean (JERICO).

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 a research seat as a member of the Olympic Coast National Marine Sanctuary Advisory Council, participating in advisory committee meetings on 13 March, virtual, and on 29 May, virtual.
- 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. Oregon is preparing for review of their network of marine reserves due in 2023. On March 3-4, 2020, Barth participated in an "Oregon Marine Reserves Size and Spacing Workshop 2.0" to consider recent information related to the design of Oregon's marine reserves network.
- Barth serves as the Co-Chair of the new Oregon Ocean Acidification and Hypoxia Coordinating Council, enacted as a state law in fall 2017. Oregon issued its Ocean Acidification and Hypoxia Plan in June 2019 (https://www.oregonocean.info/index.php/oah-action-plan). On February 7, 2020, Barth testified to the Oregon Senate Committee on Environment and Natural Resources in support of additional ocean acidification and hypoxia monitoring efforts.

- Task 16: Coordinate a west-coast wide regional collaboration team workshop with NOAA West and west coast IOOS RAs *[Newton]* Newton had discussions with NOAA West lead Timi Vann and NOAA RVA Co-PI Melissa Poe and CeNCOOS and SCCOOS Directors Henry Ruhl and Clarissa Anderson but plans for a workshop in person are not relevant due to COVID-19, thus this project is being re-scoped and developed.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

Haller, M.C. Remote sensing at coastal inlets, *Coastal Engineering Research Board Executive Session*, Corvallis, OR, March 4, 2020.

Helms, A. Eelgrass Declines in the South Slough estuary, OR. NERRS Annual meeting, Charleston, SC, November 19, 2019.

Kaminsky, G., A. Stevens, G. Gelfenbaum, E. Elias, and P. Ruggiero. Observations of Coastal Change and Numerical Modeling of Sediment Transport Pathways at the Mouth of the Columbia River. Lower Columbia Solutions Group (LCSG) Meeting, Astoria, OR, January 14, 2020.

Kaminsky, G., H. Weiner, D. McCandless, A. Hacking, and G. Alampay. Winter 2019-2020 Monitoring of the North Cove and Shoalwater Dynamic Revetments. Willapa Erosion Control Alliance Now (WECAN) Meeting, Tokeland, WA, February 26, 2020.

MacCready, P., Participant: Olympic Coast National Marine Sanctuary, Condition Report Status & Trends Workshop, Ocean Shores, WA 1/2020.

MacCready, P. and R. McCabe, Presentation: "Estuarine Circulation of the Salish Sea", Ocean Sciences Meeting, San Diego 2/2020, talk.

MacCready, P., Participant and Speaker: NOAA/ NOS Sandbox Modeling Workshop, Seattle, WA, 5/2020.

Newton, J., T. Klinger, R. Feely, S. Alin, N. Bednarsek, S. Siedlecki, M. Poe. Ocean Acidification: a global issue with local effects. Invited Lecture. Puerto Ángel Campus, GOA-ON North American Hub Meeting. Mexico, 18 December 2019.

Newton, J., M. Poe, S. Alin, R. Feely, S. Siedlecki, M. Watkinson, J. Schumacker, K. Wrubel, J. Green, J. Hagen, J. Waddell, S. Fradkin, M. Chadsey, A. Sutton. The Olympic Coast as a Sentinel: An Integrated Social-Ecological Regional Vulnerability Assessment to Ocean Acidification. NOAA Ocean Acidification Program Community Meeting, Miami, FL, 8 January 2020.

Newton, J. Oceans and Climate: Mitigating Impacts on our Aquatic Food Systems. Winter Seminar (Nutritional Sciences Programs and CHanGE (Center for Health and the Global Environment): Food Systems in the Age of Climate Change. University of Washington, Guggenheim Hall, Seattle, WA, 14 January 2020.

Newton, J. NANOOS observations to serve stakeholders. Whats up doc? Seminar series. University of Washington, APL Commons, Seattle, WA, January 15, 2020.

Newton, J. C. Risien, T. Tanner, J. Allan, E. Mayorga, M. Kosro, C. Seaton, R. Wold. Meeting Stakeholder Needs in the Pacific Northwest US via the NANOOS Visualization System (NVS). Ocean Sciences meeting, San Diego, CA, 21 February 2020.

Newton, J. Understanding the Marine Heat Wave in the Pacific Northwest. NOAA Office of National Marine Sanctuaries Webinar Series. 24 April 2020

Suesue, S. and A. Helms. Distribution and habitat characteristic of *Chloropyron maritimum palustre* (bird's beak) in the South Slough estuary. Ocean Sciences meeting, San Diego, CA, February 17, 2020.

Publications:

Chen, X., W. Huang, M.C. Haller, and R. Pittman. 2020. Rain-contaminated region segmentation of X-band marine radar images with an ensemble of SegNets, submitted to IEEE Trans. Geosci. Remote Sens., Feb. 2020.

Haller, M.C., D.A. Honegger, R. Pittman, A. O'Dea, and A. Simpson. 2019. Real-Time Marine Radar Observations of Nearshore Waves and Flow Structures from Shore-based Towers. 2019 IEEE/OES Twelfth Current, Waves and Turbulence Measurement (CWTM), San Diego, CA, 2019. doi:10.1109/CWTM43797.2019.8955152

Honegger, D.A., M.C. Haller, and R.A. Holman. 2020. High-resolution bathymetry estimates via X-band marine radar: 2. Effects of currents at tidal inlets, Coastal Engineering, 156, 2020. https://doi.org/10.1016/j.coastaleng.2019.103626

Morrice K. 2020. An individual-based model to evaluate juvenile chinook salmon migration in the Columbia River estuary. PhD dissertation. OHSU. May 2020.

Morrice K., A.M. Baptista, and B. Burke. 2020. Environmental and behavioral controls on juvenile Chinook salmon migration pathways in the Columbia River estuary. Ecological Modeling. https://doi.org/10.1016/j.ecolmodel.2020.109003

Stevens, A.W., Elias, E., Pearson, S., Kaminsky, G.M., Ruggiero, P.R., Weiner, H.M., and Gelfenbaum, G.R. 2020. Observations of coastal change and numerical modeling of sediment-transport pathways at the mouth of the Columbia River and its adjacent littoral cell: U.S. Geological Survey Open-File Report 2020–1045, 82 p., https://doi.org//10.3133/ofr20201045.