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

NOAA Award: NA16NOS0120019 Reporting period: 12/01/2020 to 05/31/2021

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 the 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 FY20 period (= Y5 of this award; Y14 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), and 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.**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.
6) **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.
7) **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.
8) **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 FY20, NANOOS has the following additional tasks (10-12) from the NOAA Ocean Acidification Program, coordinated via IOOS, and tasks 13-18 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 by (a) [B. Hales, OSU] and (b) [B. Carter, UW], 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, T. Tanner, UW].
13) CRITFC observations, modeling, and DMAC transfer [C. Seaton, CRITFC].
14) Support OceanHackWeek [E. Mayorga, UW].
15) Support biological data stewardship [E. Mayorga, UW].
16) Conduct PNW Harmful Algal Bloom (HAB) observations, understanding, and prediction [R. McCabe, R. Osborne, P. MacCready, R. Callender/T. King, J. Newton, UW].
17) Conduct a HAB Environmental Sample Processor (ESP) deployment off Washington [J. Mickett, UW].
18) Support the Columbia River extension of the Salish Sea model [T. Khangaonkar, UW-Tacoma].

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 on progress for: a) Observations (shelf, estuaries, shorelines, and currents); b) Modeling (estuaries and shelves); c) Data Management and Communication (DMAC); d) User Products; e) Education and Outreach; and f) Administration.

Table 1. NANOOS Milestones for FY 20; Y5 specific milestones are in bold.

Area	**Y5 Award = Y14 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** **-Begin La Push glider 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
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**
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 effective 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 public relevance 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 (Y4)**

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) [Manalang, Curry, Mickett]

-Bring all data QA/QC to meet Certification standards [Manalang, Curry, Mickett]

The Washington Coast buoy observation program transitioned leadership of the operational team from B. Curry to D. Manalang, Applied Physics Laboratory, University of Washington (APL-UW), and continued to work towards maintaining and operating two real-time moorings 13 miles NNW of La Push, Washington.

The May 2021 spring cruise to recover winter Cha'ba and deploy summer Cha'ba and NEMO-SS aboard the R/V Robertson was cut short due to vessel engine problems, with only winter Cha'Ba buoy recovered. A follow-on cruise is planned for June 16-19 aboard the R/V Pacific Storm, operated by OSU's Marine Mammal Institute, to complete the deployment of summer Cha'Ba and NEMO-SS moorings, and recover the winter Cha'Ba moored instruments.

We continued to work closely with both the Olympic Coast National Marine Sanctuary and the Quileute Tribe in maintaining and operating the two moorings. Quileute Marine Biologist, Jenn Hagen, participated on deployment cruises in the past, but COVID-19 restrictions prevented her participation in 2020. She facilitated obtaining approval from the Quileute Tribal Council to enter the reservation to access the marina.

On March 22, 2021, we presented 2020 observations at the Puget Sound Marine Waters 2020 Workshop. Major observations were that the summer deep water on the shelf was the coolest since 2014 and that summer deep dissolved oxygen levels were above normal until the fall transition, then rapidly dropped to below-normal conditions. Of note is that 2020 was the first year with deep (85 m) pH measurements at this site, which was a result of a collaboration with SeaBird Scientific to test the Deep SeapHox instrument.

Task 10a: Support collection of OA data from La Push buoys with NOAA OAP funding
[Manalang, Curry, Mickett, Newton]

We continued to work with NOAA PMEL scientists Drs. Adrienne Sutton, Simone Alin, and Richard Feely, to maintain pCO_2 and pH data streams and provide calibration samples for NOAA OAP-IOOS Ocean Acidification Monitoring. Sensor data have been transmitted to the NOAA OA and PMEL Carbon Programs and to NANOOS. The system, mounted to the winter Cha'Ba buoy, was recovered on May 4, 2021, during the spring cruise on the R/V Robertson. The replacement system will be deployed during the follow-on cruise planned for June 16-19, 2021, when summer Cha'Ba is deployed.

We continued to collaborate with Sea-Bird Scientific and deployed a SeapHOx sensor at 85 m on summer Cha'ba and two SeapHOX sensors on winter Cha'ba, near-surface and at 85 m. Our team deploys the sensors and provides data and useful operational feedback to Sea-Bird Scientific, while 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 the McLane profiler data for 2019 and 2020 and made these data available to the PMEL partners.

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 off Trinidad Head, CA (41° 3.5'N) using an underwater glider. 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 12/1/2020 to 5/31/2021, the glider was on the TH line for 76 days on one deployment, sampled along nearly 1383 km of track line covering the transect about 3 times, and collected about 647 vertical profiles of ocean properties. Glider uptime was 42% due to loss of a Seaglider on February 6, 2021. Data are sent in near real-time to the IOOS Glider DAC and 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," the 2018-2019 El Niño, and the 2020-2021 La Niña (Figure 1). Note the return to cool conditions in late 2020 and early 2021.

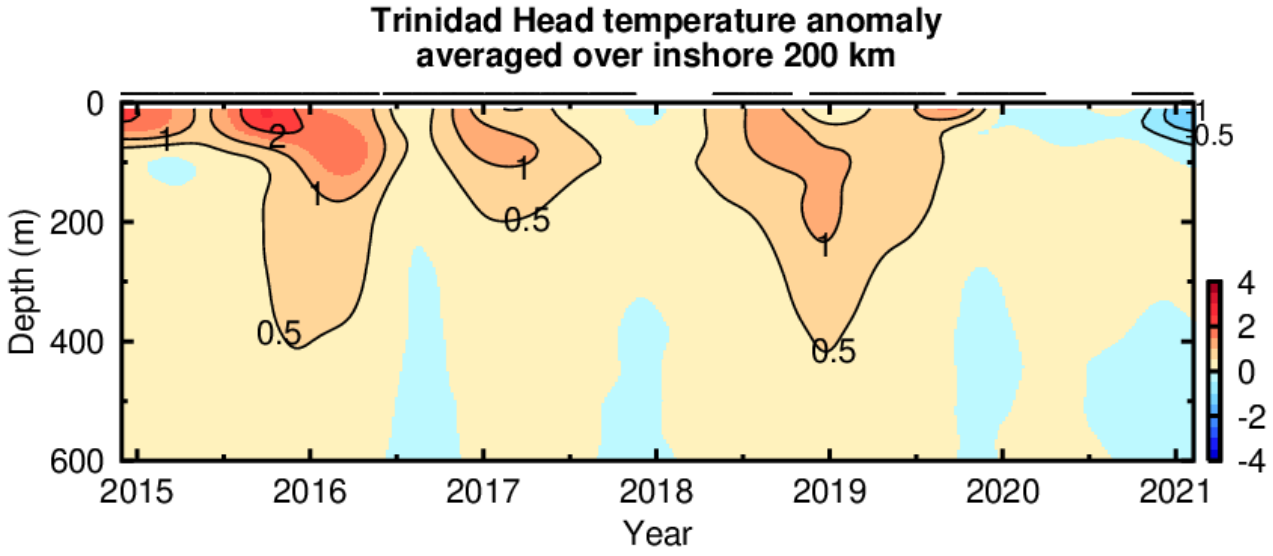

Figure 1. *Temperature anomaly from the Trinidad Head, CA (41° 3.5'N) glider line. Horizontal lines above the panel indicate when the TH-Line glider was in the water.*

Re-establish Columbia glider; deliver data via NVS *[Barth/Seaton]*
Through a collaboration with the Columbia River Inter-Tribal Fish Commission (CRITFC) the Oregon State University (OSU) glider research group (Barth) is operating the NANOOS Washington shelf glider program. Two CRITFC gliders are on loan to OSU. The program is designed to fly gliders off the central Washington coast, centered off Grays Harbor, WA, and south toward the Columbia River. The glider flies a mapping grid, from roughly the 30-m isobath, offshore to the shelf-break (~200 m). The mapping is done in consultation with the Quinault Indian Nation via Joe Schumacker, NANOOS Governing Council Representative and Executive Committee Representative for Tribes.

From April 13-21, 2021, OSU conducted a 9-day glider mapping deployment off Grays Harbor, WA. Glider data revealed the presence of near-bottom hypoxic water early in the upwelling season in response to the early and strong upwelling-favorable winds in 2021. Plans are in place to make additional glider maps in July and September 2021.

La Push glider *[Lee]*
Working through the continued challenges associated with the safe conduct of laboratory and field work during the COVID-19 pandemic, the APL-UW team has been able to maintain sampling along the La Push line, starting with the deployment of an SGX glider (next-generation Seaglider, SG236) on 27 September 2020. SG236 conducted 14 occupations of the La Push section before a faulty pressure sensor motivated its recovery. SG236 was among the first vehicles on the fleet to carry a RBR Legato CTD, selected to provide a low-power replacement for the original unpumped Seabird CTD, on an extended mission. Working within strict COVID safety protocols, Ben Jokinen and Mike Johnson employed M/V Swifty, hired from Westport Charters to venture offshore, successfully recovering SG236 and deploying SG249 on 26 April 2021. As of 15 June 2021, SG249 has conducted 4 occupations of the La Push Line, with projected mission endurance extending into mid-2022. Current work focuses on finalizing data processing for the new CTD and re-establishing data to the IOOS glider DAC.

Oregon Shelf Mooring Observations:
-Maintain Coos Bay buoy; deliver NRT data streams via NVS [Hales, Kosro]
-Bring all data QA/QC to meet Certification standards [Kosro, Hales]
Task 10b: Support collection of OA data from CB-06 buoy with NOAA OAP funding *[Hales]*
The CB06 mooring off Coos Bay, Oregon has been deployed since June 2017, most recently from March 2020 through April 7, 2021. The mooring measures water temperature at 11 depths, horizontal current at more than 40 depths (2 m separation), salinity near surface, and pressure at 2 depths, as well as surface meteorological data. In addition, the MAPCO2 system measures O_2 and pCO_2 and pH. A subset of the near surface data and ADCP currents are sampled and telemetered in near-real time back to shore. A replacement buoy was deployed on April 7, 2021.

Scheduling the mooring cruises proved challenging. Covid-19 imposed restrictions on travel to and from the port, and vessel-of-opportunity chances largely disappeared due to added restrictions. Moreover, the Miss Linda, our preferred local charter vessel, was not available due to the bad health of her captain. We contacted Pacific Tug, who were interested in the work, but had to delay our intended turnaround when their onboarding equipment needed upgrading. We finally did arrange a turnaround on April 7, which was successful at both mooring recovery and deployment, but some of the recovered sensors had exceeded their battery durations. The lack of ship days on a capable UNOLS or NOAA vessel could potentially interfere similarly in future CB06 turnarounds. The replacement buoy is collecting and transmitting data.

A paper in press for the Bill Peterson commemorative volume on Climate, Zooplankton and Salmon in

Progress in Oceanography (Yamada, Fisher and Kosro, "Relationship between ocean ecosystem indicators and year class strength of the invasive European green crab (*Carcinus maenas*) in Oregon estuaries") uses moored data we collected for NANOOS at NH10. A change in the relationship between physical forcing and local recruitment indicates the possible role of additional larval sources from the north or from local estuaries for this invasive species.

The CB06 mooring has now been in place for 4 years, with a few operational gaps. A clear pattern is being established with more quiescent dynamics in wintertime, with O_2 and pCO_2 values near atmospheric equilibrium, and pH_t staying broadly within a range of 8.0 - 8.1. In contrast, summer conditions show large dynamic ranges in all conditions, with O_2 ranging from far below saturation (<175 µmol/kg) to far above (> 450 µmol/kg), pCO_2 from <250 - >1000 µatm, and pH <7.7 - >8.3. The most recent data, following an operational gap Jan-Mar 2021 confirm this pattern (Figure 2).

This project has suffered several operational challenges described in the previous progress report, which only corrected a couple of months ago. COVID-19 operational restrictions made it challenging to travel to and from the port, and to find availability for cruise-of-opportunity chances to collect validation samples, service the mooring, or even perform the ~6-month turnaround. Negotiations with the Pacific Tug Company in Coos Bay began in December of 2020, and after several failed attempts due to weather and equipment limitations, the mooring was recovered, and a replacement re-deployed in early April 2021. This deployment was well over a year, and far longer than our nominal 6-month turnaround schedule. Most systems had reached end-of-battery-life by late December or early January, and there is thus a several-month data gap as a result. In addition, there will be more extensive repairs needed for the recovered system before it is re-deployed in late September or Early October. Service of the recovered mooring is underway.

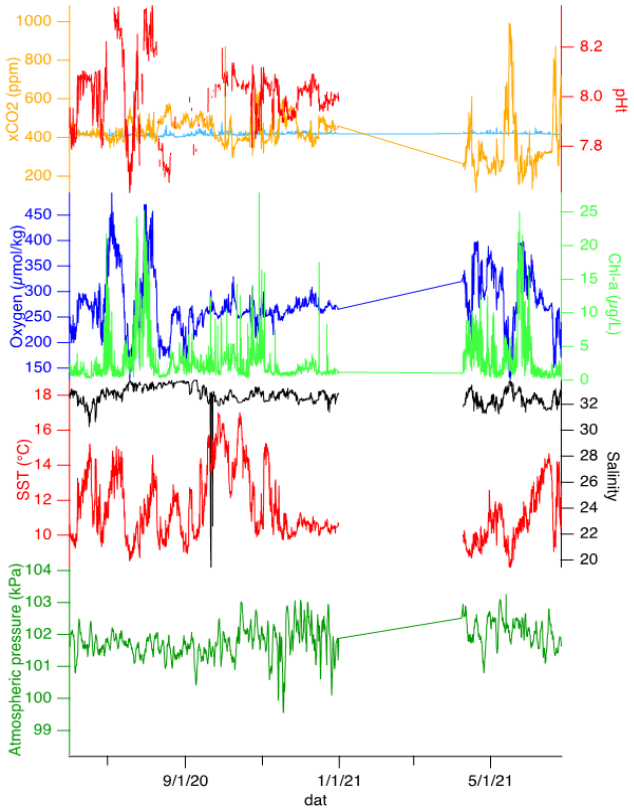

Figure 2. *CB06 data for June 2020 – June 2021.*

Task 11a: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA
[Hales]
Hales continues to assist shellfish aquaculturists on the west coast with water chemistry measurement and interpretation, and mitigation steps. Hales has engaged in weekly consultations with operators at Alutiiq Pride Marine Institute (APMI) and the Kodiak NOAA fisheries lab to improve operational and data processing activities. Whiskey Creek Shellfish Hatchery is now fully operational and the Burke-o-Lator system there has been in place and fully functional for the last few months. The Quilcene system is being refurbished and waiting on delivery of a few components before it is completed. Discussions with T. Martz regarding the data from the system formerly installed at the Carlsbad AquaFarms have yielded promise, with the data being part of a near-complete doctoral thesis. The data is challenging to interpret because of a large and previously unrecognized thermal artifact in the seawater intake, and because of a leak of atmospheric air into the equilibrator headspace. In collaboration with W. Evans, data from the APMI and Kodiak systems will be available in the coming months.

Task 11b: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA
[Carter]
Via UW technician, Mr. Julian Herndon, we continued to provide ongoing technical assistance for the Burke-o-lator (BOL) seawater chemistry analytical system at Taylor Shellfish Hatchery (TSH). The BOL system sent to Oregon State University for repairs has been repaired and should be re-installed in the near future, after a long delay necessitated by OSU campus closure due to COVID. TSH has been operating another BOL system from the Washington State network (from Willapa Bay). Mr. Herndon continues to make liquid standards for TSH to use during BOL operation. However, current COVID work access requirements are making it difficult for Mr. Herndon to obtain access to the NOAA facility where he prepares the standards and to receive travel approval to visit the TSH site. Thus, this year is likely to have unavoidable data gaps. The deployment of the ACDC has unfortunately continued to be delayed due to project partners not having supplied the repaired sensors to support the final stages of this technology transfer project (likely due to pandemic lockdown at this time rather than personnel turnover as previously).

Northern Oregon to Central Washington Shelf Observations:
-Maintain Columbia R. buoy; deliver NRT data streams via NVS [Seaton]
-Bring all data QA/QC to meet Certification standards [Seaton]
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 were 1, 6, 11, 16, 21 and 35m depth.

The May 2021 deployment of SATURN-02 was delayed into June 2021. Several COVID-19 incidents at the MERTS campus led to 20 days during which the MERTS workspace was unavailable. The SATURN-02 buoy deployment is currently planned for late June 2021.

Real time data from SATURN coastal stations are normally 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. 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.

Task 16: HAB observations, understanding, and prediction *[McCabe, Osborne, MacCready, Callender/King, Newton]*

[Osborne]: UW Olympic Natural Resources Center, in collaboration with the ORHAB (Olympic Region Harmful Algae Bloom Partnership) Steering Committee, which includes representation of the four Coastal Treaty Tribes (Hoh, Quileute, and Makah Tribes and the Quinault Indian Nation), oversaw the continued processing and budgetary allocation of $40,000 ($10,000 a piece for each of the four tribes) into the operating budget for ORHAB. These funds are now being used to enhance the capacity of each tribe to undertake offshore sampling, over-and-above the weekly shore-side sampling they do as part of ORHAB's longitudinal monitoring program. Beyond administrative processing, at this point in the contract potential offshore sampling activities and equipment needs for each tribe have been identified or are being finalized. Some tribes have already initiated offshore sampling operations this fall that are drawing on their allocations, others are looking more towards equipment needed to bring them up to capacity. After the 1st of the year, a bulk equipment and supply order is biennially undertaken with all ORHAB partners that will finalize the equipment purchases drawing upon these funds.

[MacCready]: The LiveOcean 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. During this period MacCready published a paper (MacCready et al., 2021) documenting the LiveOcean modeling system that is used as part of the PNW HAB Bulletin. He continues work with Dr. Banas and Dr. Hally Stone (currently a Knauss Fellow in Washington DC), evaluating the model forecasts in relation to observed HAB events on OR and WA beaches.

[King]: PI King and Research Analyst Nguyen managed SoundToxins, a diverse partnership of agencies, colleges, tribes, shellfish and finfish producers, environmental learning centers, environmental groups, and residents trained to provide monitoring and research of phytoplankton species in Puget Sound. During the COVID-19 shutdown, SoundToxins' operations were deemed essential under the Washington governor's "Stay Home, Stay Healthy" order to provide critical information to the Washington State Department of Health on the level of harmful algae species at our sentinel monitoring locations.

With the funding received we were able to provide daily coordination and communication for partners including supply distribution to 23 of our sites for their weekly/biweekly sampling. We held an annual re-training event for 26 members to refresh and enhance their knowledge and skills in sampling techniques and phytoplankton identification. We fielded 126 emails or calls from participants regarding data recording, phytoplankton identification and provided an additional 42 alerts to the Washington Department of Health regarding harmful levels of *Alexandrium*, *Dinophysis* and/or *Pseudo-nitzschia* species.

[McCabe]: PI McCabe has continued to collaborate with Barbara Hickey (UW School of Oceanography) and Vera Trainer (NOAA NWFSC) to produce the Pacific Northwest Harmful Algal Blooms Bulletin (PNW HAB Bulletin) for coastal shellfish managers. A total of eight PNW HAB Bulletins are typically produced each calendar year, with nominally four Bulletins during spring razor clam digs and another four during fall razor clam digs.

McCabe, Hickey, and Trainer produced four PNW HAB Bulletins to support coastal shellfish managers during the reporting period of the spring 2021 razor clam season. These include Bulletins on 11-Apr-2021, 21-Apr-2021, 9-May-2021, and 20-May-2021. An additional fifth Bulletin is anticipated during June 2021. All Bulletins continue to incorporate the NANOOS logo on the upper right of the first page. The PNW HAB Bulletins are made publicly available on both the ORHAB (http://depts.washington.edu/orhab/pnw-hab-bulletin/) and NANOOS (http://www.nanoos.org/products/habs/forecasts/bulletins.php) websites.

Task 17: HAB ESP deploy *[Mickett, UW]*
Due to the inability of PIs S. Moore and N. Adams to access their lab at the NOAA NWFSC, the deployment originally planned for the spring of 2021 was delayed until the following spring. In the meantime, the group is working to refine the telemetry and pump control systems for the ESP mooring with MERHAB funds, in support of both the NANOOS spring 2021 deployment and future MERHAB deployments.

ESTUARIES

Puget Sound Buoy Observations:

-Maintain Puget Sound estuarine moorings; deliver data via NVS [Manalang, Curry]
-Bring all data QA/QC to meet Certification standards [Manalang, Curry]
The Northwest Environmental Moorings program leadership was transitioned from B. Curry to D. Manalang (APL-UW) during this project period. The ORCA (Oceanic Remote Chemical Analyzer) mooring system and Bellingham Bay Se'lhaem buoy continued to be operational during the COVID-19 pandemic. Upgrades to the ORCA system and lab protocols are ongoing and buoy endurance continues to improve. The buoys are fully implemented with real-time pH measurements; the data is being sent and plotted in real-time on the NWEM website. 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 samples for system calibration. Data continue to be made available through NANOOS NVS and through the NWEM ORCA server. New summary plots for all the sensors (temperature, salinity, oxygen, and fluorescence) have been added to the NWEM website key products.

Due to the COVID-19 pandemic, the field team has had to wear additional PPE and practice social distancing guidelines but thankfully have been able to carry out regular maintenance and repairs to keep this real-time system operational, due in part to our dedicated boat, a 24' Almar Sounder.
The ORCA buoys continued to track conditions that were, on average, warmer and saltier than climatalogical averages from 2005-2017. A summary of the 2020 Puget Sound mooring data was submitted for inclusion in the Puget Sound Marine Waters Report, to be released later this year. ORCA mooring data will be integrated into a set of Puget Sound Metrics, developed by UW researchers, and will be hosted on the NANOOS website.

We continue to work towards quality control (QARTOD) and data archiving for all the ORCA data.

Washington State Estuarine Observations:

-Maintain US-Canada ferry-box; deliver data via NVS [Krembs]
-Bring all data QA/QC to meet Certification standards [Krembs]
Cross Border Ferry Monitoring, Environmental monitoring
Ecology's cross-border ferry monitoring program leverages infrared satellite and flight observations with surface data from ferry data. The benefit of high-resolution surface data is that inferences can be drawn on the dynamic of water exchange processes across Admiralty Reach, mid channel and nearshore temperature observations.

The ferry system is still in the process of the installation onto the Victoria Clipper ferry as ship engineers become available during COVID downsized operations. The new Victoria Clipper vessel is of European origin requiring adjustment to power supply and plumbing of water lines. Upgraded system from the old Victoria Clipper to data streams and plumbing allows for more opportunities to add additional collaborative sensors. The addition of a collaborative pCO2 sensor provides important CO_2 surface gradient measurements in the water and the near water boundary layer along its 80-mile transect between Seattle WA and Victoria BC.

- **Electronic systems:** The VC ferry electronic system consists of 4 sensors (GPS, thermosalinograph thermistor and pCO2 sensor), 4 computers, 3 different Voltage systems 230V AC, 120V AC, 12V DC with respective cables, 2 power backers and 3 relays to elicit power cycles to pumps.
- **Data systems:** The VC ferry data architecture consists of 1 master Raspberry Pi (Linux) computer synchronizing location and clocks from a GPS unit and eliciting duty cycles by switching relays to pumps. The master also collects and bundles data from the three remaining Raspberry Pis connected each to a unique sensor (thermosalinograph, thermistor and pCO_2 sensor). The master Raspberry Pi controller and computer (Alpha010, Figure 3) is the only instrument that is remotely accessible with a password=protected router.
- **Pluming:** Seawater is pumped against a hydraulic gradient and a length of about 15 m to reach from the sea-cheat into the forward wet room of the starboard hull of the Victoria Clipper. A self-priming large pump runs at a steady flow rate. The air is removed actively by the pump and a bubble bypass leaving the section where sensors are installed ideally bubble free. Sensors are either directly plumed in-line or can subsample and re-inject their water into the mainstream upstream to the pump allowing for additional sensors being installed on the ship.
- **Database:** Data of time, location, temperature, and salinity and pCO2 are transferred and stored in a cloud server and relational database accessible via a cloud server. Here data are subjected to QC range tests and are repackaged so it can serve NANOOS and its NVS interface.
- **Data Display:** All temperature and salinity data are made available for daily download through a stand-alone simple web-based app (shiny IO) which displays data graphically. Data display will show daily georeferenced transect plots of temperature and salinity against cumulative acquired historical data in the background. Planned data visualizations have not started and will be developed as data become available.

The installation of the Victoria Clipper ferry was broken down into several construction blocks that we currently pursued and tested independently.

- **Electrics:** Stable power supply, wiring and interconversion between shore and ship power 380V (AC) and 230V (AC), water-pump and compressor power 120V (AC), electronics power supply 12V (DC), power backed controllers (Raspberry Pi), GPS, router, sensors, and data cable runs. Controller (Alpha01) elicits relays, duty cycles, and initiates geographic data collection and shut off for all sensors.
- **Data:** A raspberry Pi Alpha 1 collects GPS, time and sensor data bundling and transferring them to a cloud-based database. Geo-referencing and time synchronization is initiated by a Raspberry Pi Beta01. Peripheral raspberry PIs (Gamma 01-03) operate and collect data from individual sensors and can be programmed specific to a sensor.
- **Sensors and accessories:** Thermosalinograph (installed in-line), thermistor (mounted onto aluminum hull below waterline), collaborative pCO2 sensor (air and water) and SeaBird pump subsampling from the main line.
- **Plumbing and water flow:** Water supply lines, pumps, priming and flushing of the water supply system, setting of constant flow rates and removal of air bubbles via a bypass.

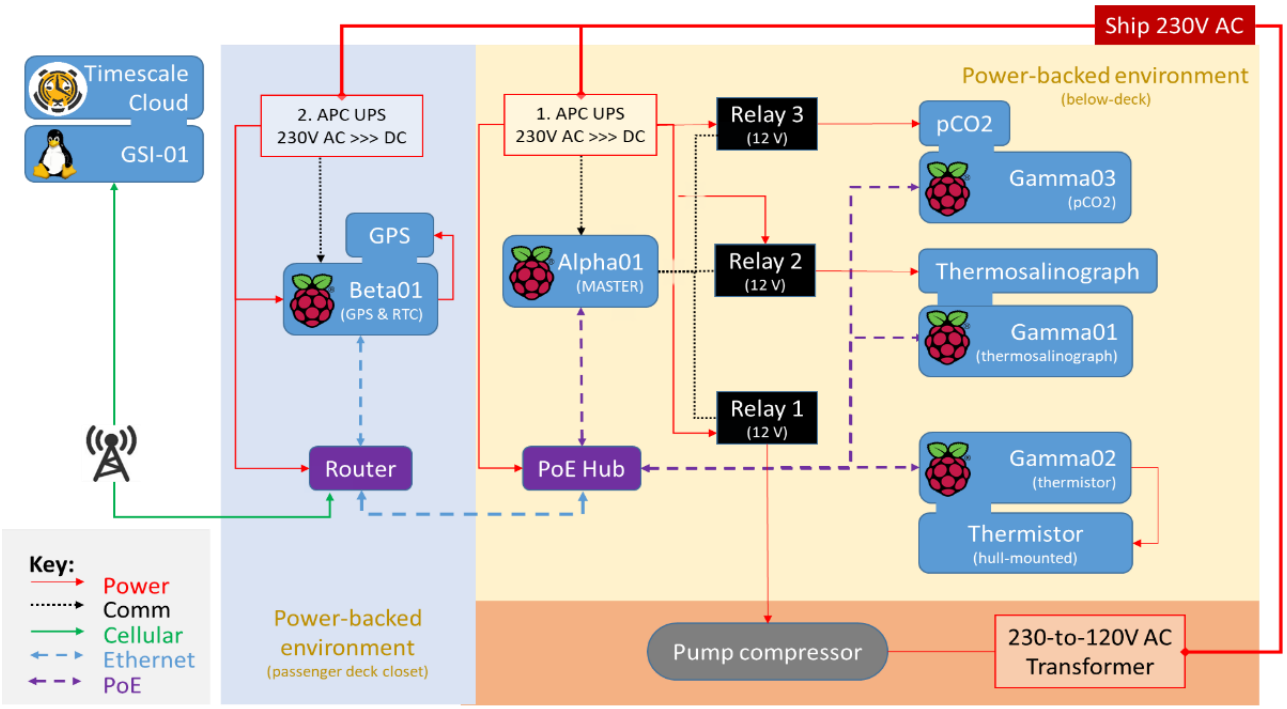

Figure 3. Wire diagram of the ferry system depicting different power supply voltages, electrical and digital components (raspberry Pi controllers, relays, and sensors), data communication, geo-referencing, time synchronization and the cloud-based data transfer and storage in a relational database.

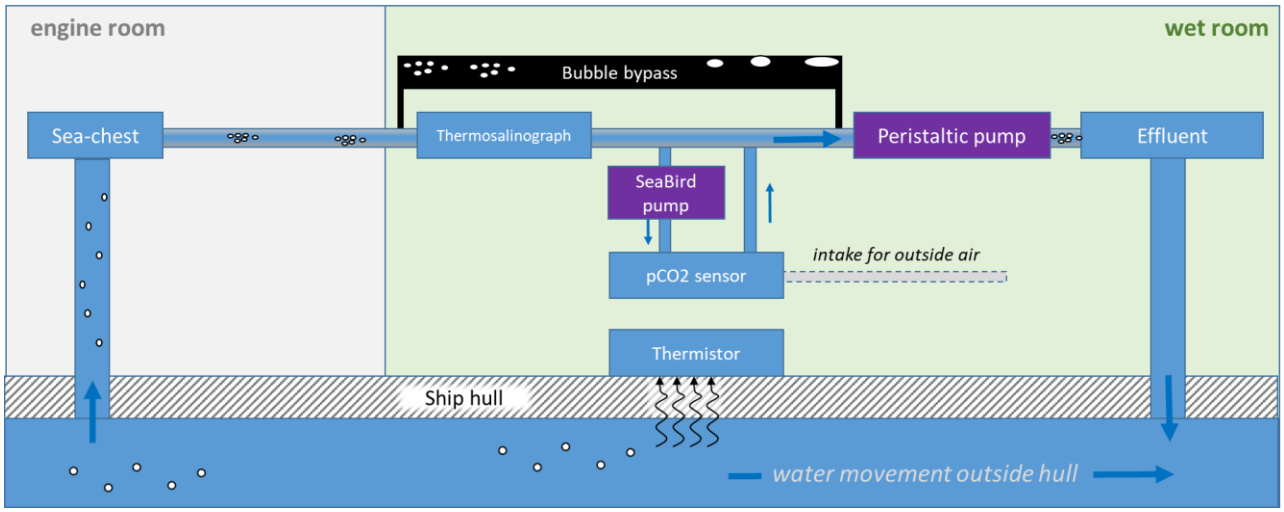

Figure 4. Plumbing on board the Victoria Clipper. The water is pumped against a hydraulic gradient from the sea chest to the sensors with a peristaltic high-volume, self-priming pump. As water travels along the pipes over about 15 m water is purged from air bubbles before reaching the sensors. This is achieved by a bubble-bypass. Intake and effluent of water are on different sides of the hull. To compensate for temperature differences between intake water and water reaching the sensors a hull mounted thermistor (aluminum hull is a good conductor) allows for a temperature correction. A collaborative pCO2 sensor is subsampling the main water line using a seabird pump via a closed system configuration. The pCO2 sensor also water and air pCO2 concentrations via an additional ocean-air intake.

Progress on the installation:

- GSI contracted for this project successfully completed the architecture of data and power supply, including programming of duty cycles and dataflow. A mock setup in the lab demonstrated that microcontrollers (Raspberry Pi) performed time synchronization between sensors using GPS-time and geographical referencing and transmits data to the cloud-based database (Figure 3).
- Cable runs from the wet room to the engine room and GPS and modem located in the communication room on the passenger deck have been installed.
- Major plumbing lines of seawater from the engine room to the wet room have been installed on the vessel (Figure 4).
- A strong self-priming, industrial-scale seawater pump (Graco 10-40E) has been received and is waiting to be installed by ship engineers in Seattle.
- Power backers (230V) to support computers on the network are on hand.
- Ecology has supported the architecture of the water flow against a negative hydraulic gradient. A mockup plumbing in the lab will establish how effective the bubble bypass is operating prior to installation on the ship (Figure 4).
- The pCO_2 sensor is on hand and Ecology IT has approved the proprietary software (Oceanus) for its operation.
- The SeaBird pump is on hand and will be tested for in-line subsampling for the pCO2 sensor.
- The cloud-based server (server GSI-01) and relational database is set up and receives data (Figure 3).
- Web app for data display is under development and will be deployed on the Shiny IO web-based app.

Columbia River Estuarine Observations:

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

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

The NANOOS supported estuarine stations that are maintained on a permanent or seasonal basis are SATURN-01 (when possible), SATURN-03, SATURN-04, SATURN-07, SATURN-09, CBNC3, Elliot Point and Woody Island. All except CBNC3 have real-time telemetry. All but CBNC3, Elliot Point and Woody Island (which currently only measure salinity and temperature, or only temperature in the case of Woody Island) are interdisciplinary (physics and biogeochemistry). Each of the stations is designed to capture specific features of the estuary. SATURN-09 was redeployed in December 2020. It was serviced on-station for maintenance and instrument replacement in May 2021 in preparation for the summer season. SATURN-07 was rebuilt in winter 2021 and redeployed in Apr 2021. Incorporation of improved microcircuit technology allowed better power management and monitoring than in previous generations of the buoy.

Observations at SATURN-03, located at Pt. Adams within the region of the Columbia River estuary with daily high salinity, showed unusually early hypoxia (Figure 5). The decade-scale oxygen concentration observations at SATURN-03 showed that the hypoxia event was the earliest in the decade of observations. The hypoxia occurred in high salinity water, driven by the sustained early upwelling conditions that also produced hypoxia on the shelf observed by the Washington coast glider mission.

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. Data is subject to QA/QC, which is included in data submitted to NCEI via NANOOS. Improvements were made to QA/QC methods for chlorophyll through a benchtop fluorometer purchased with non-NANOOS funds. Additionally, 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.

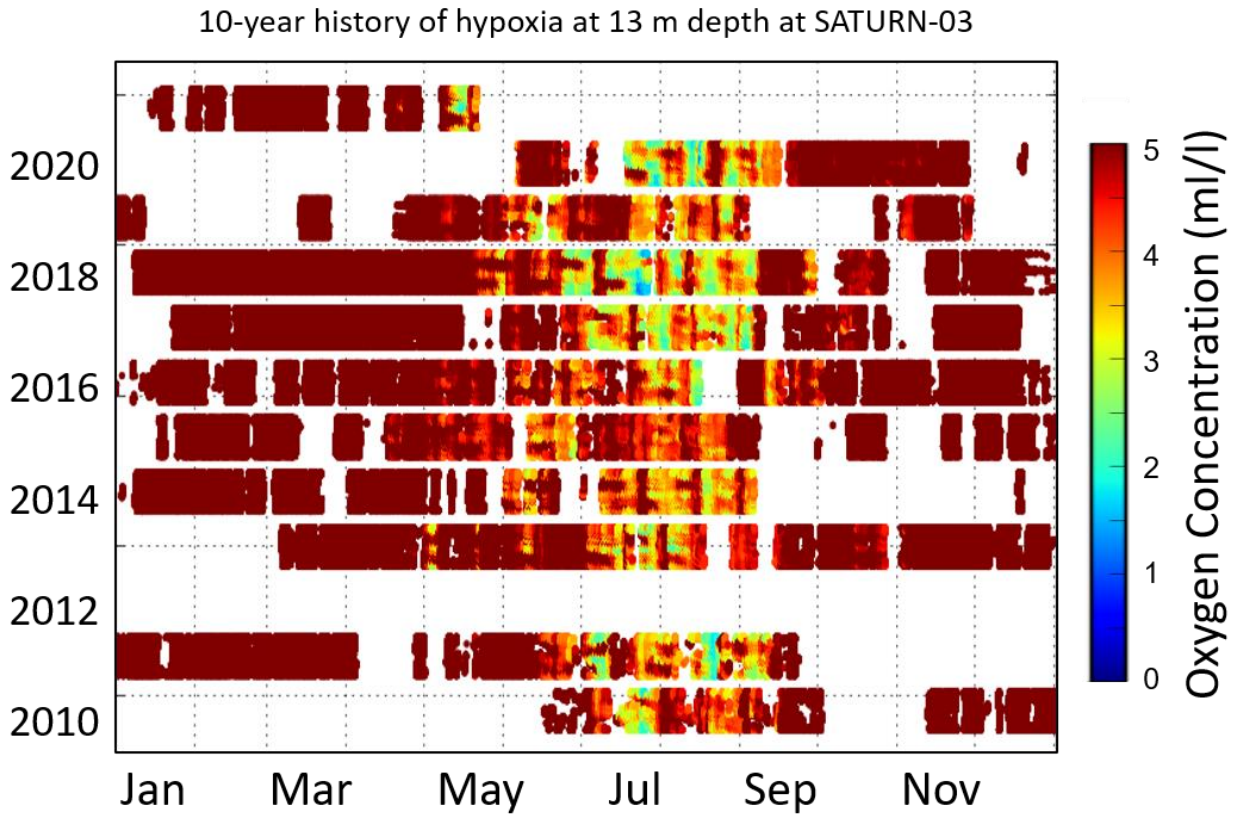

Figure 5. Time series of oxygen concentrations from SATURN-03 showing early-onset hypoxia in 2020.

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) in Coos Bay, OR. South Slough Reserve continued operation of a network of moored estuarine water quality observing stations as part of the NERRS System-Wide Monitoring Program with additional support provided by NANOOS. There are four real-time water quality monitoring stations located along the salinity gradient of the South Slough estuary that provided continuous data of water temperature, salinity, dissolved oxygen, pH, turbidity, and water level measurements every 15 minutes over the period 12/01/20 – 05/31/21. Telemetry transmissions were continuous for two of the stations, including Winchester Arm (soswiwq), and Elliot Creek (sosecwq) platforms. The Valino Island and the Charleston Bridge stations continued to collect continuous data, but the stations were offline in preparation for installation of new data collection platforms and replacing aging telemetry equipment with the Yellow Springs Instruments Turnkey Storm3 system. In collaboration with the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians (CTCLUSI), SSNERR maintains the North Spit BLM water quality station, located in the lower Coos estuary and data are available through NVS (NESDID ID # 346F229A; sosnswq). Tom's Creek weather station provided continuous measurements of air temperature, relative humidity, barometric

pressure, and wind speed/direction. Monthly instrument deployments and retrievals, station maintenance, and data download, QA/QC, and management were completed for the water quality and weather stations during the reporting period following NOAA NERRS Centralized Data Management Office protocols, including 2020 Annual water quality and weather data submissions in April – June 2021.

In addition to the lower Coos Bay CTCLUSI station, South Slough expanded the network of water quality stations into the upper Coos estuary, which includes three stations located at Isthmus Slough, Catching Slough, and Coos River. The Reserve added pCO_2/pH monitoring equipment at the Valino Island water quality station and data collection was completed 2019 with current analyses of time-series data from instruments, and grab data analyses in collaboration with Oregon State University (Chan and Hales) and University of Washington, Puget Sound Institute (Magel).

The SSNERR water quality and weather stations provide real-time data for shellfish growers in the Coos estuary, including North Bend and Coos Bay Oyster Companies, Qualman Oyster Farms, and Clausen Oysters. The South Slough 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 Margaret A. Davidson Graduate Fellowship including environmental modeling analyses from water quality stations to characterize drivers of eelgrass (*Zostera marina*) declines. The analyses utilized water quality and meteorological data from SWMP/NANOOS stations, including water and air temperature, pH, turbidity, salinity, dissolved oxygen, and solar radiation. The Reserve's 2020 Margaret Davidson Fellow is utilizing water quality data for her research on phytoplankton communities and prediction of HABs. NANOOS Visualization System tools were integrated into boating safety plans for the Reserve implemented in 2021. The Reserve education program developed teacher training workshops that incorporated products developed from water quality and tidal marsh metrics for evaluating wetland resilience to sea level rise.

COVID-19 impacts affected routine SWMP field and laboratory work during the Winter and Spring 2021 due to social distancing restrictions for fieldwork, boat use, lab space, and housing accommodations, and therefore the Reserve was unable to host in-person interns December 2020 – beginning of May 2021.

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. Continuing to follow COVID-safety precautions, CMAP completed fall seasonal beach monitoring surveys in the Columbia River Littoral Cell (CRLC) in December 2020. Forty-six beach profiles and two surface maps were collected. In March 2021, CMAP conducted winter seasonal CRLC beach monitoring surveys, collecting 50 beach profiles, 5 surface maps, and 52 sediment samples along 11 of the cross-shore profiles (note that we discontinued sediment collection at two profiles at the south end of Long Beach due to data redundancy). Seasonal beach profile data and contour change plots are made available through the NVS.

In addition to the regular CRLC beach monitoring work, CMAP continues to conduct more detailed surveys in Westport and Ocean Shores, two locations that experienced significant erosion during the winter of

2015-2016, threatening adjacent coastal properties. In both December 2020 and March 2021, CMAP collected 7 supplemental profiles in Westport to monitor the dune nourishment area fronting the Westport by the Sea Condominiums and 13 supplemental profiles at the south end of Ocean Shores. The constructed dune in front of the condos experienced continued erosion over the winter and is narrow and undercut along most of the area.

CMAP continued to monitor the performance of the dynamic revetment at North Cove with funding from the Pacific County Conservation District. Beach topography surveys were conducted in December 2020 and February 2021, where 48 profiles and a surface map collected during each survey will be used to create a digital elevation model of the survey area and compared for change over time. An additional storm response survey was conducted after a large wave event in January 2021 where 15 profiles and a surface map were collected. During each full, seasonal survey, individual rocks that were tagged in early 2019 with PIT tags were located to track their position through time. In February, nearly 50% of the 544 tagged rocks on site were found. In addition to tracking the rocks, CMAP also recovered 65 rocks that were re-weighed and measured to compare to their original dimensions. Over their two years of deployment, most of the rocks have decreased in weight (mean weight loss = 0.79 kg) and have become more rounded in shape.

CMAP also continues to collect seasonal beach profiles near Kalaloch at South Beach on the Olympic Peninsula along a natural composite beach as a comparison to the constructed cobble revetment at North Cove. In January and April 2021, 14 profiles were collected. CMAP performed rock tracking at Kalaloch in January 2021, where 45 out of 150 rocks were found (30%).

CMAP resumed survey vessel work this spring, collecting boat-based lidar data of various bluffs and beaches around the Puget Sound and Strait of Juan de Fuca. This work is a second round of surveys funded by the Estuary and Salmon Restoration Program (ESRP) as a follow up to surveys we conducted back in 2015 and will allow us to map high-resolution shoreline changes and quantify bluff sediment supply to beaches. To date, we have collected topographic lidar data at 13 sites spanning 114 km of shoreline. Data collection for this project will continue through the end of June 2021.

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 and winter surveys – were collected in the Neskowin (15 sites, January and March 2021) littoral cell, Rockaway littoral cell (25 sites, December 2020 and March 2021), and along the Clatsop Plains (6 sites, January and March 2021). Additional post-winter surveys had been planned for the Netarts and the Gold Beach area. However, due to equipment failures associated with our TSC2 field computer and rover GPS, this was not possible. To address the latter, the State of Oregon invested ~$29K in new field equipment to replace aging equipment, which will be used in our next round of fieldwork scheduled for late summer 2021. In addition to measurements of the transects, datum-based shorelines were also collected at the majority of the sites during the same beach monitoring campaigns; unfortunately, we were unable to collect post-winter shoreline change information in the Neskowin cell due to equipment related failures.

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 2021, our monitoring data indicated that the

suite of beach observation sites in the Neskowin cell had experienced erosion responses not seen since ~2008, while with a few exceptions, changes in the Rockaway and Clatsop cells were generally in the typical winter range. Erosion responses in the Neskowin cell was surprising since winter storm waves were generally at the lower end of the winter spectrum (Significant wave heights ~7-8 m), although they did tend to coincide with extreme ocean water levels, which allowed the wave runup to reach much higher elevations. Thus, differences in responses between Neskowin and other field sites probably relate to the overall volume of beach sand present, with Neskowin having generally narrower beach widths and lower beach volumes relative to the other sites.

During this period PI Allan continued to work with the NANOOS DMAC team (Risien and Mayorga (former NANOOS DMAC chair) and NOAA IOOS (Biddle) to develop a process for archiving NANOOS beach change data at NOAA NCEI. At the time of writing, the overall components of the data archiving have been resolved and tested, with profile data successfully pushed to http://data.nanoos.org/ncei/dogami/, where NOAA NCEI will eventually be able to access the data. NOAA NCEI is presently reviewing the archival process via their Archive Appraisal Committee; at the time of writing, the archival committee had approved the overall framework for archiving profile data.

Nearshore Bathymetry Observations *[Ruggiero]*
-Maintain bathymetric observations in WA and OR; deliver data via NVS
-Bring all data QA/QC to meet Certification standards
P. Ruggiero's group at Oregon State University completed the processing of nearshore bathymetry data collected in summer 2020 along the four sub-cells of the Columbia River littoral cell (CRLC). Over 220 individual cross-shore profiles were collected during summer 2020 extending from the lower intertidal 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. Our summer 2020 field data collection was significantly impacted due to the pandemic and therefore we were unable to collect additional data along the Oregon coast during summer 2020.

These nearshore bathymetric data continue to provide a critical source of information for improving coastal hazard mitigation along the coastlines of the CRLC and portions of the Oregon coast and for understanding the morphodynamics of high energy beaches. In collaboration with the US Geological Survey and the Washington Department of Ecology the nearshore bathymetry and topographic data being collected via NANOOS at the mouth of the Columbia River is being used to inform regional sediment management practices. The US Army Corps of Engineers is performing a pilot experiment in which they placed approximately 283,000 CY of sediment to form a disposal feature offshore of North Head, WA (Figure 6). The profiles shown in Figure 6 allow us the opportunity to observe if the increased supply related to the nourishment placed in over 40 ft water depth makes it into the nearshore. Our monitoring has shown that the offshore ends of our survey lines have been very stable (example below is line 209) over the past few years in this area.

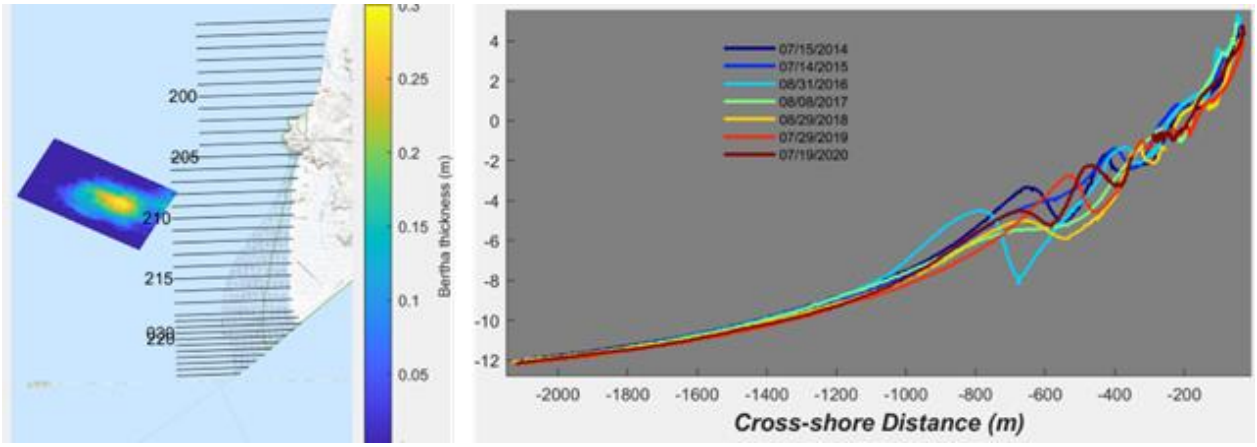

Figure 6. Left) Map showing location of USACE dredge disposal feature ('Bertha') at North Head region. Right) Example profile showing changes in beach and nearshore morphology along survey line 209.

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 2021) of 74% and 83% respectively (https://hfrnet.ucsd.edu/diagnostics), ranking 3rd and 2nd respectively among the nine measured regions. Sites at PSG1 (Crescent City, CA) and STV2 (Ft. Stevens, OR, Columbia River and Priority 2) were primarily responsible for outages.

We replaced field computers at two sites, and uninterruptible power supplies (UPS) at three. We recovered from numerous power interruptions (PSG1, WSH1, LOO1, CBL1, PSG1, SEA1, YHL1, WIN1) – power at many of these coastal sites is dirty and less reliable. To minimize data loss, we monitor the number of returned files, have real-time diagnostic displays, and are able to cycle power at our sites via the internet or, at some locations, by landline phone. The PSG1 site (Crescent City) has lost signal in the monopole antenna; our helper there has spliced the cable, but it appears to need more work. These site visits should get easier as Covid restrictions on travel ease.

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

In early June, OSU HFR technicians travelled to WSP1 (near Westport, Washington), to finish the installation work and to obtain measured ("walking") antenna patterns. The site now only requires a license to operate on the ITU frequencies (requires an FCC certification of Codar's equipment for these bands). We anticipate further discussions with Olympic National Park on a new site farther north (near Kalaloch) in June and will consider their specific suggestions for locations, in advance of another on-site visit.

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.

We have successfully upgraded our radar to a new Furuno model, which should provide better mechanical durability. We have also installed a new OSU-designed-and-built open-source data acquisition and recording software based on the next-generation Cambridge Pixel HPx-model radar data acquisition card. This new system offers greatly increased configuration flexibility and improved radiometric resolution.

b) NANOOS Modeling Subsystem:

Shelf Modeling:

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

-Model verification and validation [Kurapov, Zaron]

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 the 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. We have also continued comparative assessments of the OSU system and the NOAA US West Coast Operational Forecast System (WCOFS), which was transitioned to operations in March 2021. In particular, we have utilized the COMT EDS visualization system to compare both systems to the available buoy data. We started work transitioning the OSU assimilation codes to a NOAA supercomputer, to compare directly the time efficiency of these codes, to inform the future WCOFS development. This work will be continued. To provide a synopsis of the last decade of events along the US West Coast, including the 2014-16 heat wave, we continued analysis of the multiyear outputs of the 2-km version of the West Coast model, including comparisons against the NANOOS and OOI in-situ assets. In terms of visualization, we have proposed to utilize the WCOFS Viewer as a paradigm for the interactive model displays and quality control (https://coastaloceanmodels.noaa.gov/WCOFS/Viewer/).

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 CICOES), 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 Seaton 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. MacCready is a member of the NOAA West Coast Ocean Forecast System Technical Working Group. A daily extraction of selected LiveOcean fields are available through the THREDDS server set up by Craig Risien nanoos.ceoas.oregonstate.edu/thredds/catalog/NANOOS/LiveOcean_Files/catalog.html.

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. During this period MacCready published a paper (MacCready et al., 2021) documenting the LiveOcean modeling system that is used as part of the PNW HAB Bulletin. He continues work with Dr. Banas and Dr. Hally Stone (currently a Knauss Fellow in Washington DC), evaluating the model forecasts in relation to observed HAB events on OR and 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.

Columbia River Modeling:
-Maintain modeling & forecasting capabilities at CRITFC; deliver model output via NVS [Seaton]
-Model verification and validation [Seaton]
CRITFC 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.

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. During this reporting period we have been evaluating the results of experimentation with the next generation SCHISM model.

Task 13: CRITFC observations, modeling, and DMAC transfer *[Seaton]*
Leveraging the existing modeling system and prior work on implementing SCHISM modeling of the estuary, CMOP worked in collaboration with NOAA/NOS/OCS/Coast Survey Development Lab-Coastal Marine Modeling Branch (with joint funding from OCS, IOOS, NGS and CO-OPS transferred through IOOS/NANOOS, for Task 13) on the development of a new SCHISM model for the northern and tropical Pacific Ocean. After initial work on development of a 2D tide model, the focus of development shifted to 3D model development with the potential for trans-Pacific port-to-port modeling of surface currents in support of navigation. Work during this period included training new staff at CRITFC and GIS and mesh development

work, producing an initial good quality 3D model for the Pacific basin, and progressively improved resolution for Guam, Fiji, and Timor Leste. A simplified Columbia River mesh has been incorporated into the basin scale model as well.

Task 18: Columbia River extension of Salish Sea model *[Khangaonkar]*
Progress Report Prepared by the Salish Sea Modeling Center, UW Tacoma (SSMC)
Subaward Title: Addition of Columbia River to SSM-OFS - Refinement and Robust Testing
Scope of Work Summary: The overall objective of this project is to incorporate the Columbia River domain from Astoria, OR river mile (RM) 0 at the mouth, to Bonneville Dam at RM 146 into the Salish Sea Model. The Salish Sea Model Operational Forecast System (SSOFS) is currently under refinement, testing, and transition to NOS through a separate IOOS funded project. This subaward to the Salish Sea Modeling Center (SSMC), UW Tacoma, through NANOOS supplements that effort with scope of work focused on Columbia River specific data acquisition and synthesis, iterative model refinement, skill assessment, and reporting. The subaward consists of 4 tasks. They are listed below along with a summary of associated progress and results.

Review and Processing of (2020/21) Data: Columbia River ADCP/CTD Survey: The original scope of work proposed by the Salish Sea Modeling Center (SSMC) UW Tacoma, was based on acquisition, synthesis, and use of a comprehensive currents and stratification data set from a survey of the Columbia River NOAA CO-OPS, planned for the period 2020-2021. However due to COVID19 related impacts to NOAA field efforts, the survey was postponed to a future date beyond the project schedule. In consultation with IOOS the approach was modified to substitute the survey data set with monitoring data previously collected on the Columbia River by various organizations. The focus of this skill assessment would be (a) Water Surface Elevation, (b) Temperature, and (c) Salinity at this time to be conducted with an alternate data set. The skill assessment for currents would be revisited later (2023) when acoustic doppler current profiler (ADCP) data may become available.

The existing data include buoys and monitoring stations maintained by NOAA PORTS (physical oceanographic real time systems), USGS, and the Center for Coastal Margin Observation & Prediction (CMOP). Some of these data have been assembled already through Northwest Association of Networked Ocean Observation System (NANOOS). The target years for skill assessment have been changed from 2020-2021 to historical years 2015-2017.

SSMC has already downloaded the 2015-2017 water quality data provided by CMOP. Figure 7 below shows the 14 CMOP stations (in red). These data were first processed by CMOP (QC'd text files), and further processed at SSMC to a suitable format for visualization and comparison with model results for skill assessment.

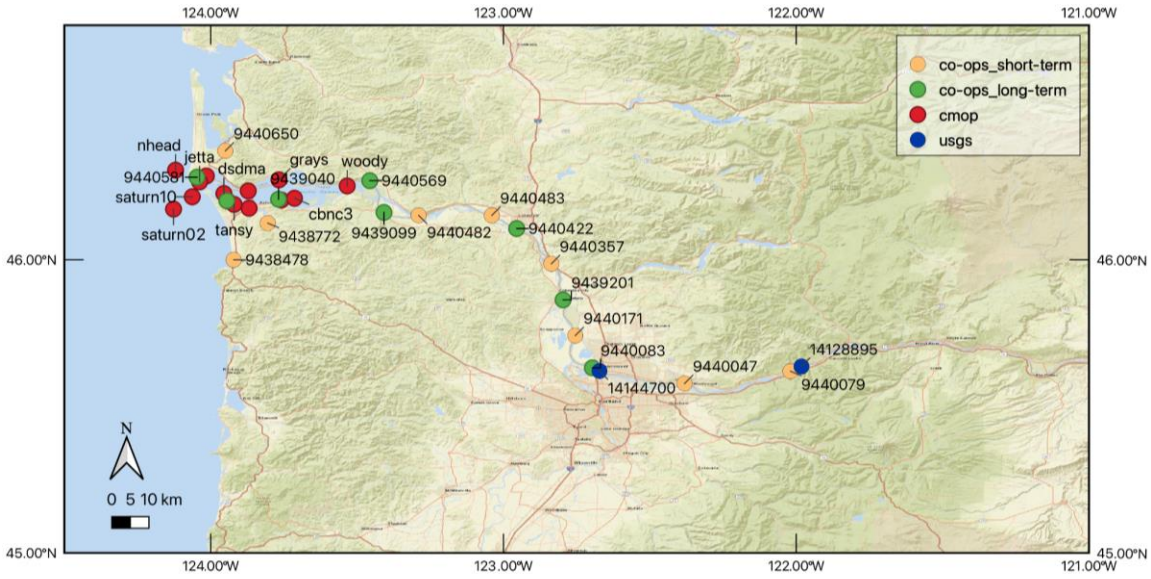

Figure 7: NOAA CO-OPS, CMOP, and USGS stations that were available with data suitable for SSM-OFS skill assessment effort

Station locations and names for the CMOP data set are listed in Table 2 below.

Table 2: CMOP station used in this study with their locations and names

Station ID	Station Name	Latitude	Longitude	Station ID	Station Name	Latitude	Longitude
saturn01	Saturn01	46.235	-123.872	jetta	Jetty A	46.266	-124.038
saturn02	Saturn02	46.173	-124.127	grays	Grays	46.273	-123.767
saturn03	Saturn03	46.200	-123.941	dsdma	Desdemona Sands Light	46.226	-123.955
saturn04	Saturn04	46.204	-123.759	cbnc3	Cathlamet Bay North Channel	46.210	-123.714
saturn07	Saturn07	46.286	-124.015	tansy	Tansy Point	46.189	-123.920
saturn09	Saturn09	46.176	-123.869	woody	Woody	46.252	-123.534
saturn10	Saturn10	46.215	-124.063	nhead	North Head	46.306	-124.120

The CMOP data set provides good coverage of the Columbia River estuary region that extends 37 RM and provides the necessary stratification data from the complex salt-wedge type estuary. However, the skill assessment effort must cover the remaining 109 miles of the domain.

We will primarily rely on data from 9 NOAA-COOPs stations and 2 mainstem Columbia River USGS stations shown in Figure 7 that provide monitoring data. However, we also have additional stations on the Columbia River where NOAA predictions are available based on tidal constituents. Tables 3 and 4 provide a listing of USGS and NOAA stations available to us.

Table 3: NOAA CO-OPS stations on the Columbia River (left column: stations with tidal predictions, right column: stations with continuous monitoring data)

Station ID	Station Name	Latitude	Longitude	Station ID	Station Name	Latitude	Longitude
9440079	Beacon Rock State Park	45.62	-122.02	9440083	Vancouver, WA	45.63	-122.70
9440047	Washougal, Columbia River, WA	45.58	-122.38	9439201	Saint Helens, OR	45.86	-122.80
9440171	KNAPP (Thornes) LNDG, Willow Bar, WA	45.74	-122.76	9440422	Longview, WA	46.11	-122.96
9440357	TEMCO Kalama Terminal	45.99	-122.84	9439099	Wauna, OR	46.16	-123.41
9440483	Barlow Point	46.15	-123.04	9440569	Skamokawa, WA	46.27	-123.46
9440482	Cape Horn Columbia River, WA	46.15	-123.29	9439040	Astoria, OR	46.21	-123.77
9438772	Cathcart Landing, OR	46.13	-123.81	9439011	Hammond, OR	46.20	-123.95
9438478	Seaside	46.00	-123.92	9440581	Cape Disappointment, WA	46.28	-124.05
9440650	Greenhead Slough	46.37	-123.95				

Table 4: USGS stations on the Columbia River

Station ID	Station Name	Latitude	Longitude	Station ID	Station Name	Latitude	Longitude

14144700	Columbia River at Vancouver, WA	45.62	-122.67	14128895	Hamilton Creek Near Mouth, at N Bonneville, WA	45.64	-121.98

As part of this task, a script has already been developed to compare CMOP data with SSM solution by finding the nearest SSM nodes and depth and converting predicted unit to match the CMOP data unit. CMOP data include vertical profile of water quality constituents: Chlorophyll, Dissolved oxygen, Turbidity, Nitrate, pH, Salinity, and Temperature. They are measured from various depths that range from 3m to 35 and vary by station and time. Table 5 below provides a list of water quality constituents available from CMOP stations.

Table 5: The water quality constituents, unit, station, and measure type that are collected by SSMC. The measure type is different according to the distinct station and year.

Water Quality Constituents	Unit	Station	Measure Type
Chlorophyll	µg/L	saturn01, saturn02, saturn03, saturn04, saturn07, saturn09, saturn10, nhead	FLNTU, Multi-exciter, AlgaeWatch, Fluorometer
Dissolved oxygen	mL/L	saturn01, saturn02, saturn03, saturn04, saturn07, saturn09, saturn10, nhead	Oxygen, CTO
Turbidity	ntu	saturn01, saturn02, saturn03, saturn04, saturn07, saturn09, saturn10, nhead	FLNTU, Multi-exciter, Turbidity
Nitrate	µM	saturn01, saturn02, saturn03, saturn04	ISUS, SUNA
pH	pH	Saturn03, saturn04	pH
Salinity	psu	saturn02, saturn07, saturn10, nhead, dsdma, jetta, grays, cbnc3, tansy	CTO, CT, CTD
Temperature	℃	saturn02, saturn03, saturn07, saturn10, nhead, dsdma, jetta, grays, cbnc3, tansy, woody	CTO, CT, CTD, Thermistor, Temperature

Figure 8 below provides an example of time series data from one of CMOP stations.

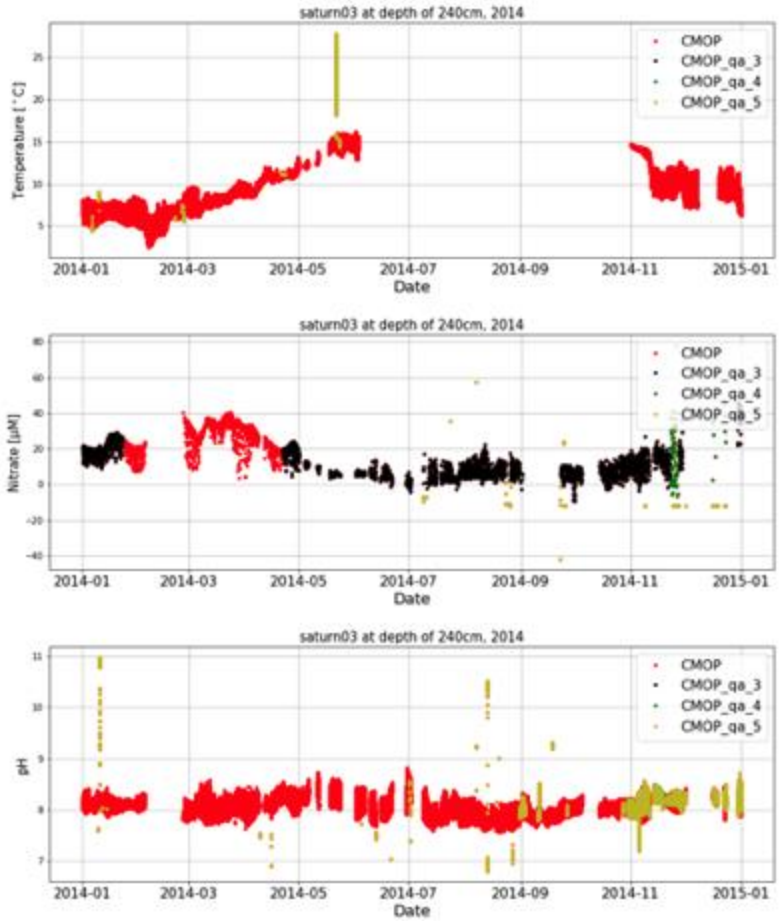

Figure 8. Temperature, Nitrate, and pH data time series using CMOP data collected from saturn03 at depth of 240cm in 2014. Data are indicated with different Quality Assurance (QA) level 3 (black), 4 (green), and 5 (yellow). QA level 1, and 2 which are regarded as good or good enough are included in CMOP data (red).

Task 2: Iterative Refinement of Columbia River Grid and Testing with SSM-OFS:
We have recently received a Columbia River gridded data set from NOAA. The work of refining the Columbia River portion of the Salish Sea Model has been initiated.

Task 3: Robust Skill Assessment of Hydrodynamics – Columbia River Focus:
Not yet initiated.

Task 4: Documentation and Report/Publication:
Not yet initiated.

Task 5: Project Management:
Ongoing

c) NANOOS Data Management and Communications (DMAC) Subsystem:
See Table 1 for milestones [Risien]
Chaired by C. Risien (OSU), this committee is composed of members from CRITFC (formally CMOP-OHSU), DOGAMI, OSU and UW. The DMAC and User Products (UPC) teams work in an integrated fashion on the prioritization, development and evaluation of data services and user products. NANOOS is also an active collaborator in national IOOS DMAC efforts.

The ***NANOOS Visualization System (NVS)*** enhancements encompass asset additions and continuous updates. During this reporting period, new/renewed data streams were integrated from the CMOP Saturn-07 mooring and Woody Island fixed station, as well as from the redeployments of Cha'Ba, NDBC 46015, and NDBC 46002.

NANOOS and IOOS DMAC system implementation. *[Risien, Tanner]*

- Data Archiving. Monthly NCEI archiving of fixed-location time series data from OHSU CMOP stations continued operationally, see https://www.ncei.noaa.gov/thredds-ocean/catalog/ioos/nanoos/ohsucmop/catalog.html. NANOOS/DOGAMI completed and submitted an Advanced Tracking and Resource tool for Archive Collections (ATRAC) document to NCEI for the archiving of Oregon shoreline change surveys carried out by DOGAMI for the last twenty years. The archive request was submitted for review to the NCEI Archive Appraisal Committee (AAC). Upon approval, NANOOS will work with NCEI to complete the archiving of these data. A subset of CB-06 mooring observations have been archived with NCEI, see https://www.ncei.noaa.gov/data/oceans/ncei/ocads/metadata/0190840.html. NANOOS worked closely with NDBC to test data archiving via an ERDDAP pull method rather than the traditional XML FTP push method. This testing process included NANOOS developing an initial set of QARTOD tests. Test results are stored in the NetCDF files harvested by NDBC. The first dataset that will be transitioned to this new NDBC archiving process is the CB-06 (WMO # 46128) mooring.
- ERDDAP Implementation. A NANOOS ERDDAP server (https://data.nanoos.org/erddap/index.html) has been released, providing data access and distribution to 38 datasets, including NANOOS gliders and NANOOS-originated remote sensing products. The NANOOS-processed time series and climatologies from NDBC, NOS and CDIP are available via ERDDAP at OSU (https://nanoos.ceoas.oregonstate.edu/erddap/index.html). Ongoing development is focused on developing QARTOD tests and providing data streams to NDBC.

Task 12: Enhance GOA-ON data portal an OA dashboard to the world *[Tanner, Newton]*

The GOA-ON Portal content is constantly updated, often with 2-3 new slideshow items, information pages, or resource links per week. A new webinar section was created to display and highlight upcoming webinars in one location for easy access. Past and archived webinars are also listed to allow users to revisit past talks.

Task 14: Support OceanHackWeek *[Mayorga]*

Planning for OceanHackWeek 2021 (https://oceanhackweek.github.io) is underway, and applications opened on June 1st. Building on the 2020 virtual event, OceanHackWeek 2021 will be held on August 3-6 as a hybrid in-person and virtual event. The in-person event will take place at the Bigelow Laboratory for Ocean Sciences, Maine, as an all-day workshop. For the virtual event (led by the UW), formal daily activities will take place over a period of up to 3 hours per day, tentatively in at least two time zones, PDT and Australian EST (UTC+10). As in previous years, OceanHackWeek brings together oceanographers across disciplines and career stages, from the US and internationally, to advance capabilities in data science focused on oceanographic applications and cultivate an open-science and sharing culture. It is being supported by IOOS, NSF, the UW eScience Institute, Bigelow Laboratory for Ocean Sciences, the Ocean Carbon and Biogeochemistry (OCB) program and private foundations.

Task 15: Enhance biological data stewardship within NANOOS *[Mayorga]*

Transitions in NANOOS DMAC personnel have continued to hinder progress on the integration of biological data into NANOOS products and the delivery of regional biological data to national IOOS networks,

including OBIS. However, DMAC staff continued to engage with the Biological Data Standards working group and the new ESIP Biological Data Standards Cluster. We anticipate re-starting previously initiated work on processing the Hood Canal (Salish Sea) zooplankton densities dataset from Prof. Julie Keister, UW School of Oceanography, by September 2021.

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 2020/21 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences, and 2) Participation in a tri-committee meeting of DMAC, Web/Products, and Outreach on April 30th to evaluate ongoing plans for product development in 2021/22.

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.

Due to changes in DMAC roles and leadership, work continues to focus on modernizing the NVS data harvesters. This is needed since the existing platform design is not sufficiently robust enough to sustain future growth needs and was reinforced in late December 2020 when the existing harvester database failed. Considerable time has therefore centered on rebuilding the harvesters to a new format. The work is ongoing and is expected to take several months and will preclude any new app development or enhancement until the harvesters have been updated. In parallel with rebuilding the harvesters, the web team also spent a considerable amount of time building a new harvester that provides data to the NOAA NDBC via ERDDAP.

Work was completed on a new tsunami evacuation road routing tool that was released via the NANOOS tsunami portal on 11 March 2021 to commemorate the 2011 Tohoku Japan great earthquake and tsunami. This effort reflected a collaboration between DOGAMI, University of Oregon (UO) Infographics experts and NANOOS. During this period, the UO team completed building the evacuation road routing capability and developed a web service that is called by NANOOS. To visualize the service, development was completed to operationalize the tsunami evacuation routing capability (Figure 9). The completed product allows a user to enter an address, and a route to the nearest safe exit point out of the tsunami inundation zone is automatically generated. Information displayed in a pop-up depicts the route information, including a recommended evacuation speed needed to reach high ground in time to outrun the impending tsunami wave. The user can then either save/or print a pdf of the map.

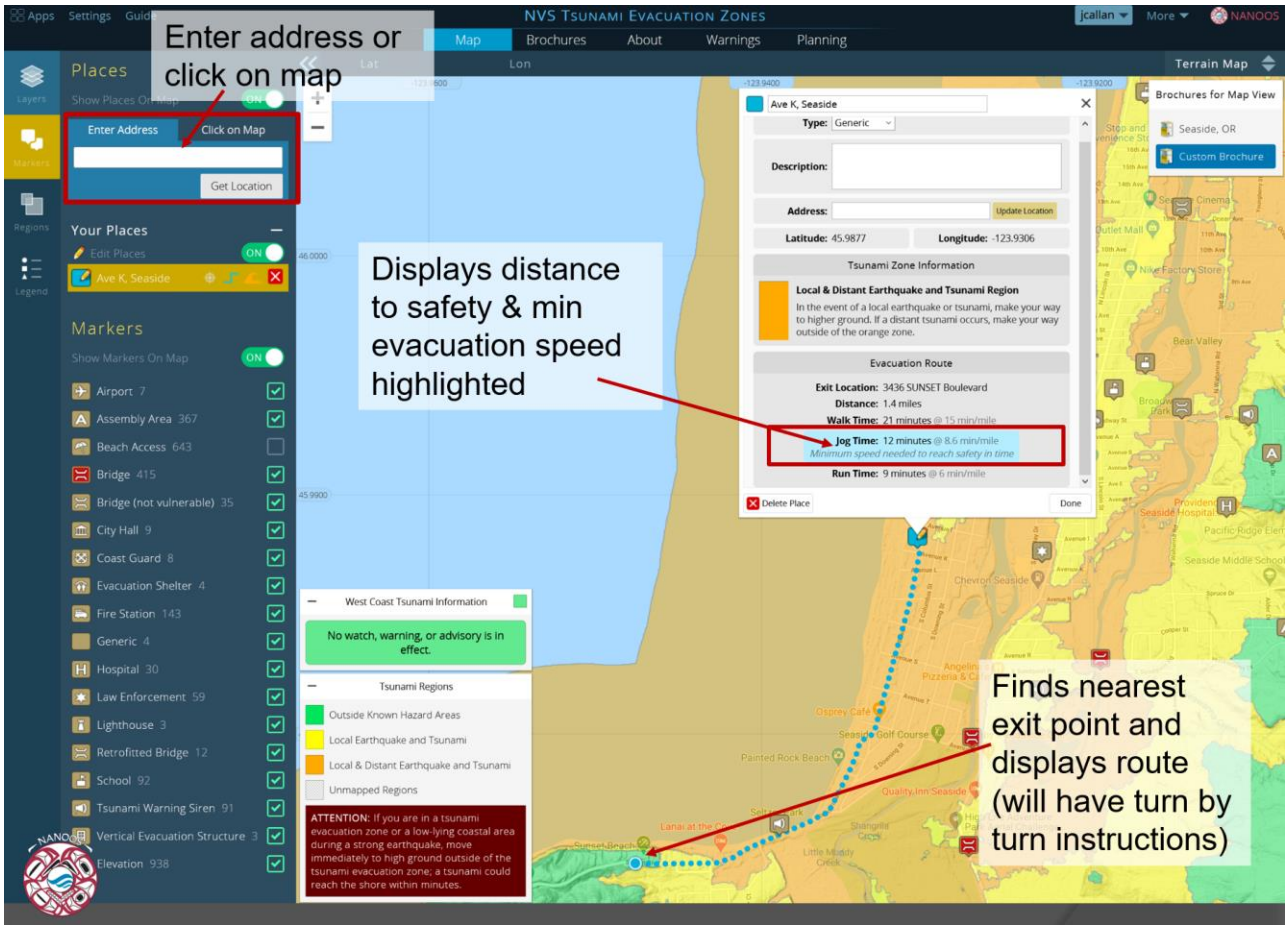

Figure 9. Screenshot of the web-based Tsunami Evacuation App, highlighting new functionality.

NVS Mobile App: No updates during this period to report.

<u>e) NANOOS Education and Outreach Subsystem:</u>

See table for milestones [Wold, 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, Carini, and Rome, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton and Wold were active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. 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's ocean science and technology program. In previous years students design, build, and deploy buoys at the Langley Marina then retrieve and analyze their data. The field portion of this project is on hold due to COVID-19. However, Wold participated in a virtual workshop on 24 February for South Whidbey Middle

School science teachers, demonstrating using NVS data in the classroom.

- Members of the NANOOS Enabling Change work group have been developing ocean science curricula with the Technology Access Foundation, a Seattle-based non-profit that works with public schools and teachers to bring STEM opportunities to students from traditionally underserved and underrepresented communities. In early May, Newton, Carini, Wold, and Rome led three classes through a primer on Marine Heatwaves followed by a demonstration of the NVS Tuna Fishers and Climatology apps and student-led inquiry of NVS data to identify and discuss Marine Heatwaves in the region. This curriculum is now available on the NANOOS Education webpage.
- A new Maritime High School will welcome its inaugural freshmen class in Fall 2021. NANOOS is in conversation with school staff to discuss how NANOOS can support student experiences in marine science, such as internships and time at-sea assisting with field research.
- During Spring quarter, NANOOS staff hosted and mentored an undergraduate student through the UW Louis Stokes Alliance for Minority Participation (LSAMP) internship program. Our goal is to pilot these types of STEM activities in Seattle, and then reach out to NANOOS PIs throughout the region to expand our reach and provide students with hands-on NANOOS data experience applied in their own backyards.

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 virtually at group meetings to demonstrate the NVS Boaters App while gaining direct feedback.
- Wold maintained communication with members of various recreational, educational and stewardship organizations while their regular meetings and events were on hold due to COVID.
- The annual Sound Waters University, an educational event for the public hosted by the Whidbey Watershed Stewards, was held virtually in 2021. NANOOS participated with an exhibitor webpage that included videos, links, and instructional documents.
- Wold, Carini, and Rome continued to update content on the NANOOS portal.
- NANOOS maintained a growing Facebook audience. NANOOS also has a growing audience for its bimonthly newsletter, the “NANOOS Observer.”

f) NANOOS Administration:

See table for milestones [Newton]

J. Newton (NANOOS Executive Director), D. Martin (NANOOS Board Chair through March 2021), Andrew Barnard (current NANOOS Board Chair), M. Kosro (NANOOS Board Vice Chair), and N. Rome (NANOOS Program Manager) continued to provide leadership to NANOOS operations and connection to the US IOOS enterprise. R. Carini, NANOOS Research Associate, took on more responsibilities supporting NANOOS Administration, Outreach, and DMAC. Newton, Rome, and Carini 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, Rome, Carini, and Kosro participated in weekly Tri-Com calls. Key events for this period included:

- Newton, Rome, Carini, and Barnard attended the virtual Spring IOOS and IOOS Association meetings on 2, 5, and 9 March 2021.
- Newton and Barnard led virtual Hill visits with the Washington and Oregon congressional delegations throughout March-April 2021.
- NANOOS held a Tri-Com meeting on 30 April to scope priorities for product development.
- Joe Schumacker, Quinault Indian Nation, participated in a Congressional briefing on 11 May

regarding the importance of observing data and model forecasts discussing NANOOS' role in providing decision-ready information.

Additional coordination and representation included:

- NANOOS Executive Director Newton and NANOOS Program Manager Rome submitted to IOOS the 5-year NANOOS proposal, in coordination with the GC, PIs, stakeholder input, and the EOIs from new and current PIs. It is available here: http://www.nanoos.org/documents/key/NANOOS-Proposal-FY21-25.pdf
- Newton continued to support the **NANOOS Enabling Change Working Group**, with meetings every month throughout the period.
- Newton and AOOS Director Molly McCammon are members of the Ecosystem Sciences and Management Working Group and participated in meetings on 19 and 25 January, 10 March, and 17 May. Both are serving as co-chairs of the WG.
- Newton participated in a working group to develop the National HAB Observation Network and on the Coastal Climate Signal. She also represented NANOOS on the California Current Acidification Network (C-CAN).
- Newton was invited to serve on an Expert Panel on Coordinated Monitoring for OAH and attended meetings December 2020 through May 2021 by the California Ocean Science Trust and the Ocean Protection Council.
- Newton participated in the West Coast Coastal Solutions Workshop Committee and its Workshop on 31 March-1 April.
- Newton serves on the Plenary Committee for the CERF 2021 Conference. She is also working with other IOOS RA directors to submit a contributed session on the Coastal Climate Signal.
- Newton led several NANOOS sub-contracts on proposals: Two for the OAP-National Sea Grant call on ocean acidification, two for IOOS Community Ocean Model Testbed (COMT), and three for the NSF Convergence Accelerator.

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

- Barth participated on January 5, 2021, in strategic planning meetings 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.
- Throughout the period, Newton continued to participate in OceanObs19 discussions, and, along with CeNCOOS director Clarissa Anderson, developed an OceanShots poster, which was presented on 3 February.
- Newton represented IOOS on the Global Ocean Acidification Network Executive Committee calls and activities. She is a co-Chair of GOA-ON, along with Steve Widecombe, Plymouth Marine Labs. Newton is a member of the GOA-ON Biology Working Group and continued efforts on a paper about recommendations for biological observations. She worked with GOA-ON to submit Ocean Acidification Research for Sustainability "OARS", which was endorsed as an official programme by the U.N. Decade of Ocean Sustainability. She participated in a UN led workshop 12-13 April on SDG 14.3.1 Indicator, discussing the role of the GOA-ON data portal that NANOOS provides.
- Newton stayed involved in Canadian observing activities including for MEOPAR and CIOOS-Pacific. Newton is a member of the Canadian IOOS (CIOOS) Pacific General Oversight Committee, attending meetings on 1 February and 9 April. Newton participated in a meeting of the Marine

Environmental Observation, Prediction, and Response Network, a Canadian Center of Excellence (MEOPAR) Annual Scientific Meeting on 28 January.
- Newton is a member of the Science Advisory Team for the Joint European Research Infrastructure in the Coastal Ocean (JERICO). She provided reviews for the JERICO Trans-National Access (TNA) selection panel.

Additional NANOOS coordination:
- Newton was renewed as the Research Seat for the Olympic Coast National Marine Sanctuary (OCNMS) Advisory Council; she participated in meetings on 22 January, 26 March, and 21 May. Newton was selected as OCNMS' Volunteer of the Year (2021). She participated in the Sanctuaries' Climate Virtual Workshop 26-28 January.
- Newton participated in the Olympic Region Harmful Algal Bloom (ORHAB) Steering Committee calls throughout the period.
- Newton was invited to participate in the Olympic Region OA Centennial site (OASeS) Steering Committee throughout the period.
- 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 contributed NANOOS updates on oceanographic conditions in the Pacific Northwest for the NOAA WestWatch webinar series on 26 January and 20 April, along with the other two west coast RAs, and a similar but local-scale Salish Sea Marine Conditions webinar on 17 February and 19 May.
- Barth participated in a 2-day Pacific Fisheries Management Council workshop on "Climate and Fisheries" on February 2-3, 2021.
- Barth participated in a 2-week virtual international workshop "Ocean Glider Best Practices" sponsored by Oceangliders of the international Global Ocean Observing Systems (https://www.oceangliders.org/) on May 11-25, 2021.
- 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.
- 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). The OAH Council submitted their second biennial report in September 2020.

Coordinate a west-coast wide regional collaboration team workshop with NOAA West and west coast IOOS RAs *[Newton]* As reported last time, plans for a workshop in person are not relevant due to COVID-19, thus this project is being re-scoped and developed. We have made progress on a vision for this that will include a paper on best practices and a shorter virtual west coast workshop.

Presentations and Publications acknowledging NANOOS support:
underline indicates NANOOS PI

Presentations:
Allan, J. 'Beach and Shoreline Responses in the Newport Littoral Cell', Surfrider Oregon Chapter, January 14, 2021.

Allan, J. 'Oregon's Tsunami Program', National Tsunami Hazard Mitigation Program, January 26, 2021.

Allan, J. 'Evacuation Modeling… Beat the Wave', A Presentation to the Oregon Coastal Management Program of the Department of Land Conservation and Development, April 26, 2021.

Fawcett, G. K. (USCG Marine Casualty Investigator; New Orleans, LA), "Weather Considerations at Pacific Northwest Hazardous Breaking Bars and the Coast Guard's Commercial Fishing Vessel Accident Investigations", *101st American Meteorological Society Meeting*, Jan 2021.

McCabe, R. M. 'Physical processes and accumulated understanding in marine ecosystems', Pacific Marine Environmental Laboratory, Seattle, WA, March 24, 2021.

Newton, J.A. 'An overview of conditions in Puget Sound during 2020', Puget Sound Environmental Monitoring Program Marine Waters Working Group Annual Workshop, Seattle, WA, March 22, 2021.

Newton, J.A. 'Ocean Acidification: A global issue with local effects.' UW Marine Biology Seminar Series, Seattle, WA, 30 March 2021.

Newton, J.A. 'Assessing Regional Vulnerability to Ocean Acidification in the Olympic Region.' OA Alliance Webinar "Accounting for OA across vulnerability and Risk Assessments", Seattle, WA, 30 March 2021.

Ruggiero, P. and others. 'Optimizing the ecosystem services of US Pacific Northwest coastal beaches and dunes', Oregon King Tides invited seminar, January 2021.

Seaton, C. 'Coastal Margin Observation and Prediction at CRITFC', Pacific Northwest Aquatic Monitoring Partnership steering committee meeting, May 6, 2021.

Seaton, C. 'Surface Currents for Navigation and the Environment', NOAA HSRP Virtual Spring meeting, March 3-4, 2021.

Seaton, C. 'Development of a Pacific Basin model', NOAA SCHISM Boot camp and workshop, February 18, 2021.

Publications:
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