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

NOAA Award: NA16NOS0120019 Reporting period: 06/01/2021 to 11/30/2021

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 in our award letter. Tasks 1-4 were "add to base" enhancements and are thus covered within the original NANOOS objectives reporting here; the remaining tasks are presented individually within this report. Tasks 5, 13, and 14 are from IOOS; tasks 7-11 are from the NOAA Ocean Acidification Program, tasks 6 and 12 originate from other NOAA offices coordinated via

IOOS.

5. $250,000 to further HABs understanding and prediction
6. $160,000 to fund the Columbia River extension (Salish Sea model)
7. $123,895 for NANOOS NOA-ON NH-10 observing (OSU)
8. $90,000 for GOA-ON data portal and support for GOA-ON Co-Chair (Newton, UW)
9. $80,000 for ocean acidification observing in support of Pacific coast shellfish growers, "Headlights Project"
10. $66,291 for NANOOS NOA-ON Cha'ba observing (UW)
11. $13,000 for NANOOS NOA-ON OA Mooring Test-beds (UW)
12. $108,000 transfer to CRITFC to continue the observations, modeling, and DMAC activities
13. $16,500 for biological data stewardship
14. $7,500 for OceanHackWeek

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 FY20; 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, Mickett]

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

The Washington Coast buoy observation program continued the work of maintaining and operating two real-time moorings 13 miles NNW of La Push, Washington.

After the May 2021 spring Coastal Buoy 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, a follow-on cruise occurred June 16-19 aboard the R/V Pacific Storm, operated by OSU's Marine Mammal Institute. The team deployed summer Cha'Ba and NEMO Subsurface (SS) moorings in 100m of water to collectively support instrumentation for measuring temperature, salinity, dissolved oxygen, water current, chlorophyll, and pH from near the seabed to the sea surface, in addition to surface water and air pCO2 and meteorological variables.

The fall 2021 Coastal Buoy cruise occurred from Sept 24-Oct 1 aboard the R/V Thompson (cruise # TN-395). The cruise combined coring work in Astoria Canyon (PI Andrea Ogston), mooring recoveries and deployments off the WA coast, attempted Quileute Lander recoveries, and CTD casts/water sampling at stations on the WA coast and in the Strait of Juan de Fuca. In addition to the Northwest Environmental Mooring team, undergraduate students from Newton and Ogston courses participated on the cruise, along with Ogston graduate students and Jennifer Hagen, Marine Policy Advisor for the Quileute Tribe.

Moorings recovered during the cruise include Summer Cha'Ba, NEMO-SS, and an Environmental Sampling Processor (ESP) mooring (funded by NOAA MERHAB), recovered from 100m depth. Winter Cha'Ba mooring was deployed in 100m water depth. The winter Cha'Ba mooring supports instrumentation for measuring temperature, salinity, dissolved oxygen, and pH at fixed depths along the mooring line in addition to surface water and air pCO2 and meteorological variables.

Recovery of the 2020 Winter Cha'Ba mooring line, which did not release from its seabed anchor during the May 2021 recovery cruise was attempted during both the June and September cruises, but was unsuccessful due to excessive loads.

We continued to work closely with both the Olympic Coast National Marine Sanctuary and the Quileute Tribe in maintaining and operating the two moorings. For the second year in a row, we installed a Deep SeapHOX instrument at 85m water depth in a continued collaboration with SeaBird Scientific.

Data coverage over the summer deployment period was excellent, with all but one instrument---the shallow ADCP on the subsurface mooring---performing as designed. The McLane profiler collected nearly 1000 profiles over approximately 3 months, showing for the first time regularly occurring patches of hypoxic water (<2 mg/L) well away from the bottom at depths centered around 50 meters.

Task 10: Support collection of OA data from La Push buoys with NOAA OAP funding *[Manalang, 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 measurement system, mounted to the summer Cha'Ba buoy, was deployed on June 17, 2021, during the spring cruise on the R/V Pacific Storm, then transferred to WinterCha'Ba and redeployed on Sept 30, 2021.

We continued to collaborate with Sea-Bird Scientific and deployed a SeapHOx sensor at 85 m on summer Cha'ba. Our team deploys the sensors and provides data and useful operational feedback to Sea-Bird Scientific, while they provide calibrated sensors for our project. The recovered SeapHOX instruments have been returned to Sea-Bird for data analysis.

Task 11: Support NOA-ON OA Mooring Test-beds *[Mickett, Newton]*
This project was completed in the last reporting period. See Chu et al. 2020 for results.

Shelf Glider Observations:
-Maintain N CA shelf glider transect; deliver data via NVS [Barth]
-Bring all data QA/QC to meet Certification standards [Barth]
The objectives for these observations were completed during the original award period. No NCE funds were spent on continuing work. See next progress report on the new 5-year award for a summary of recent activities.

Re-establish Columbia glider; deliver data via NVS *[Barth/Seaton]*
The objectives for these observations were completed during the original award period. No NCE funds were spent on continuing work. See next progress report on the new 5-year award for a summary of recent activities.
La Push glider *[Lee]*
Operations in 2021 continued despite the challenges associated with the ongoing COVID-19 pandemic. SG236 was recovered on 26 April 2021 after a seven-month mission, during which it collected nearly 1,300 profiles along the La Push line. SG249 was deployed on the same trip, and as of late December 2021, is eight months into its mission, with recovery projected for March 2022. SG249 suffered a science controller

failure mid-way through its mission. Although the glider shifted to an alternative path for controlling its primary sensors, this event ended sampling with bio-optics and oxygen probes. Reprocessing of NANOOS glider data continues, aiming to bring data holdings up to the most recent version of corrections, and to establish a permanent path for submission of 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 7: 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. 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, 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 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.

Challenges with vessel availability persist, with complications associated with the pandemic, as well as with an exceptionally sudden transition to fall downwelling conditions in 2021. As an example, an opportunistic turnaround on the last voyage of the *RV Oceanus* was not feasible given quarantine restrictions, and that cruise went on to suffer an on-board covid outbreak. We have recently had competent support from the tug *Pacific Eagle*; however, operating conditions have limited that access as the late-September fall-transition was abrupt and extreme, trapping the vessel in Yaquina Bay for several weeks before it could return to its home port in Coos Bay. A narrow window of opportunity in late November was the first since late September, and we chose to recover the CB06 buoy then, without a more lengthy associated redeployment. The buoy is effectively ready to redeploy, but unworkable conditions prevail and we are unsure of when that opportunity will present itself.

Task 9a: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA [Hales]

Hales has made several contributions to supporting shellfish growers, including a visit to the Alutiiq Pride Marine Institute in July to advise on optimal remedial culture buffering, and to assist with upgrading system operating software and to troubleshoot several operational issues. Hales is hosting the technical team from the Sitka Tribes of Alaska Environmental Regulatory Laboratory, which turned over without adequate training from the departing team, in his lab at OSU, guiding them in sample analysis techniques, standard preparation and data QC and synthesis. Hales continues to support and to advise operators at Hog Island's Humboldt hatchery, NOAA's Kodiak facility and the Whiskey Creek Shellfish Hatchery. Hales has been working with colleague Wiley Evans to finalize the processed data products for IPACOA, and anticipates delivery in March of 2022.

Task 9b: 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, due to a lengthy run of pandemic closure and personnel turnover challenges.

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 deployed on Jul 30, 2021. 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, and phycoerythrin. Scalar water measurements were made through single at-surface sensors and a multi-level pumping system. Levels measured were 1, 6, 21 and 35m depth.

Real time data from SATURN coastal stations are displayed on NVS while the station is deployed. 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. CMOP stations are expected to be the next batch of NANOOS stations integrated into the NANOOS centralized ERDDAP server for delivery to NDBC.

Task 5: 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 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 have been 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. At this point in the contract offshore sampling activities and equipment needs for each tribe have been identified and purchased or are being finalized. Some tribes have already initiated offshore sampling operations this year that are drawing on their allocations, others are still working on identifying equipment and staffing needed to bring them up to full capacity. The extension and second round of this funding has been critical in helping get each tribe's program up and running according to their individual needs.

[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 used a small amount of salary and equipment support to continue these forecasts.

[King]: Daily coordination and communication for partners continues as our partners take samples during the COVID 19 pandemic. We fielded 525 emails or calls from participants regarding data recording, phytoplankton identification and other program questions and provided an additional 36 alerts to the Washington Department of Health regarding harmful levels of *Alexandrium*, *Dinophysis* and/or *Pseudo-nitzschia* species. A presentation was made to the Puget Sound Partnership Marine Water Quality Working Group on July 21, 2021.

[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 five PNW HAB Bulletins to support coastal shellfish managers during the reporting period. These included one additional spring 2021 Bulletin on 7-Jun-2021 in support of a razor clam harvest by members of the Quinault Indian Nation, as well as four other Bulletins during the fall 2021 razor clam harvest season (20-Aug-2021, 12-Sep-2021, 27-Sep-2021, and 11-Oct-2021). A "PNW HAB Bulletin Conditions Update" email was also issued on 22-Oct-2021 citing increased risk related to northward advection of marine toxins in southern Oregon and northern California. On 12-Nov, the Oregon Department of Agriculture reported that a razor clam sample collected from the Coos Bay North Jetty area contained 6.9 ppm of domoic acid. A razor clam sample collected from Gold Beach on 24-Nov contained 60 ppm of domoic acid, well over the 20 ppm regulatory limit. Both of these recent southern Oregon samples indicate that the 22-Oct-2021 assessment of elevated risk was timely and well founded. All Bulletins continue to incorporate the NANOOS logo on the upper right of the first page. The PNW HAB Bulletins are made publically 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.

FY19 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 spring of 2022. In the meantime, the group is working to refine the telemetry and pump control systems for the ESP mooring with MERHAB funds carrying out one of the team's most successful deployments this past fall. Preparations have begun in earnest for the NANOOS-funded spring 2022 deployment, which will be coordinated with the UW/APL mooring group spring deployments (Manalang and team).

ESTUARIES

Puget Sound Buoy Observations:

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

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

The Northwest Environmental Moorings (NWEM) program continues to maintain six Oceanic Remote Chemical Analyzer (ORCA) moorings and a Bellingham Bay Se'lhaem buoy. Aging winch systems have contributed to downtime of water column profiling equipment on ORCA buoys during this period, but the NWEM team continues to adapt and repair failed systems, and has implemented qualitative tracking

systems to better evaluate ORCA uptime, data availability, and maintenance activities.

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 buoys and collecting water samples for system calibration. Data continue to be made available through NANOOS NVS and through the NWEM ORCA server.

The ORCA buoys continued to track conditions that were, on average, warmer and saltier than climatological averages from 2005-2017, though this became less evident (more average) in the latter part of the period. ORCA mooring data has been integrated into a set of Puget Sound Metrics, developed by UW researchers, and will be hosted on the NANOOS website.

The team is working with NVS to update our Data Management Plan, including movement towards quality control (QARTOD) and data archiving and improved access for all of 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
Victoria Clipper:
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 drawback of ferry systems is that COVID has affected ferry operations between the US and Canada.

After a short period, late summer 2021 to fall period in which the Victoria Clipper resumed operations with a newly (re)hired crew and engineers, Clipper Navigations suspended all runs between Canada and the US due to low profitability until march 2022.

Due to these unforeseen larger circumstances, the ferry system is still in the process of getting equipment installed onto the Victoria Clipper ferry itself. Since June, smaller updates have been accomplished. However little progress has been made on the installation of the electronic data and plumbing systems on the ship.

Progress on the installation:

1. The 230V compressor and pump assembly have been delivered and moved into the forward lab space for final installation – likely to happen over the next few months as the ship's personnel can devote time to it. Once installed the plumbing and flow-through tests can be performed (likely will not happen until early 2022).
2. The data logging components are assembled and ready for an extended bench-test in the next few weeks.
3. Some cableling needed replacement and GIS has been working with PumpTech to purchase interface cable we need to programmatically control the pump.
4. Code for geo-fencing is being finished so that sampling routines can be defined by geographic polygons around areas where when equipment is turned on/off (e.g., leverage the GPS data feed to ensure that we turn the pump off when the vessel comes into dock at Seattle or Victoria – or ends up being pulled out of the water at the shipyard for maintenance – or needs to re-fuel (I think

they do this over near Harbor Island)).
There likely will not be a lot of new info to report until early next year when we get closer to the vessel starting to run again.

Washington State ferries ADCP monitoring between Port Townsend and Whidbey Island:
The Washington state ferry has a bottom mounted ADCP to collect data perpendicular to Admiralty Reach to address fluctuations in water exchange between the Strait of Juan de Fuca and Puget Sound. During COVID the system has been maintained by Dr. Thompson APL. Activities included maintenance and security updates of data communication systems and wireless data transfers, regular maintenance of technical components, direct data recovery from instruments and systems on the ships.

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 recovered for servicing in November 2021 and is expected to be redeployed in January. SATURN-07 is on-station and expected to be recovered for servicing early in 2022. 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 repeated hypoxic events over the summer (Figure 1). While estuarine hypoxia does not reach the extreme hypoxia levels seen offshore, hypoxia levels observed in the estuary are known to have behavioral effects on salmon, and the lowest levels seen in the estuary are potentially lethal to salmon.

Real time data from SATURN coastal stations are 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.

In-vivo and extracted chlorophyll measurements from weekly samples have been used to develop robust calibrations for the sensors at SATURN-03 and SATURN-04. However, the calibration and inter-comparison of data from chlorophyll sensors deployed across the SATURN observatory has been a long-standing challenge. Beyond the well characterized shore-based stations, we have been limited in our ability to apply similar types of calibrations to fluorometers deployed on our buoy stations due to their remote locations. In the past we have relied upon manufacturer calibrations for these stations, however, we deploy sensors from multiple manufacturers and factory calibrations, typically made against fluorescent standards, often differ significantly from sample-based calibrations.

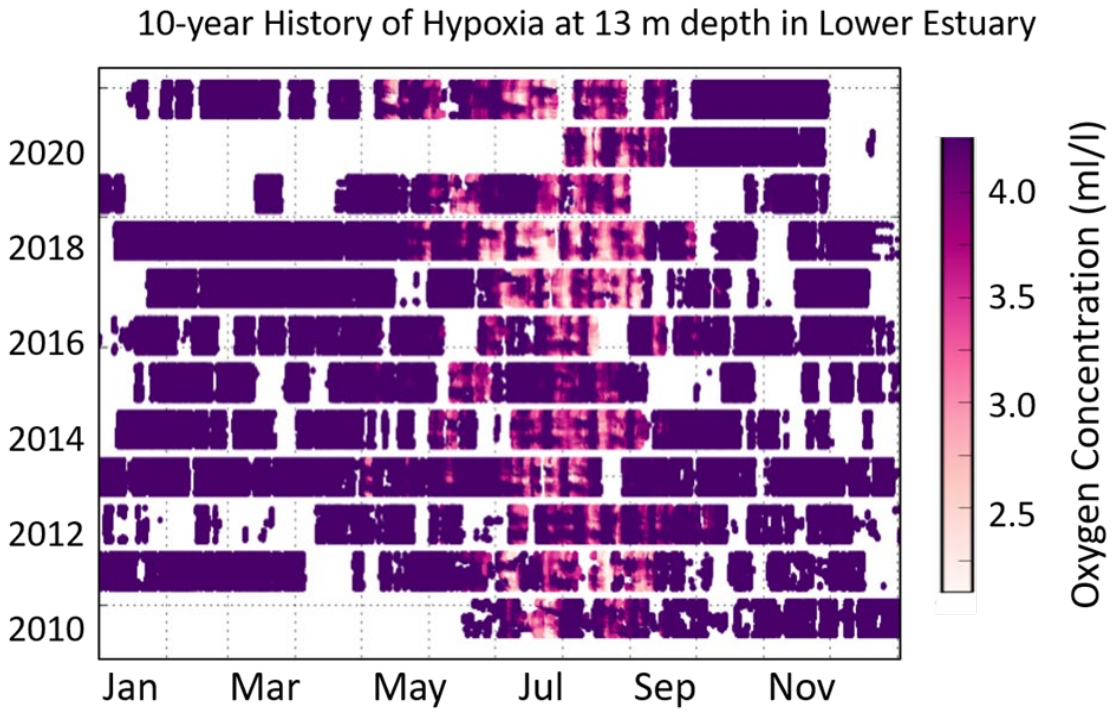

Figure 1. *Time series of oxygen concentrations from SATURN-03 showing hypoxia in 2021.*

Recent analysis of data from new protocols implemented in January 2021 to address these challenges have yielded promising results. We have begun co-deploying several of the buoy sensors, including the chlorophyll fluorometers, at SATURN-03 for several weeks prior to deployment on the buoy. Sufficient data is collected from the co-deployment to clearly define the relationship between the buoy chlorophyll fluorometer and the calibrated SATURN-03 chlorophyll fluorometer, such that the calibration of the SATURN-03 sensor, based on months/years of sample data can be translated to the buoy-fluorometer (Figure 2a). In addition to collecting the in-situ data from SATURN-03, as of November 2021 we have begun running a fluorescent standard (Fluorescein 100ppb) through the SATURN-03 system while sensors are co-deployed. The standard is particularly helpful when sensors are co-deployed during a period of low *in-situ* chlorophyll (Figure 2b). This combination of data is now allowing for the calibration of remotely deployed sensors and for direct comparison of chlorophyll data from stations across the network. While there are caveats to this approach (such as the possibility that different algal assemblages at different stations are not captured) the resulting data are more clearly inter-comparable than previously has been the case and will be much closer to true chlorophyll concentrations, despite potential differences in community composition.

Co-deployments and calibrations for the fluorometers deployed to Baker Bay (SATURN-07), the plume buoy (SATURN-02), and Youngs Bay (SATURN-09) have been calibrated using this pre-deployment method (Figure 3).

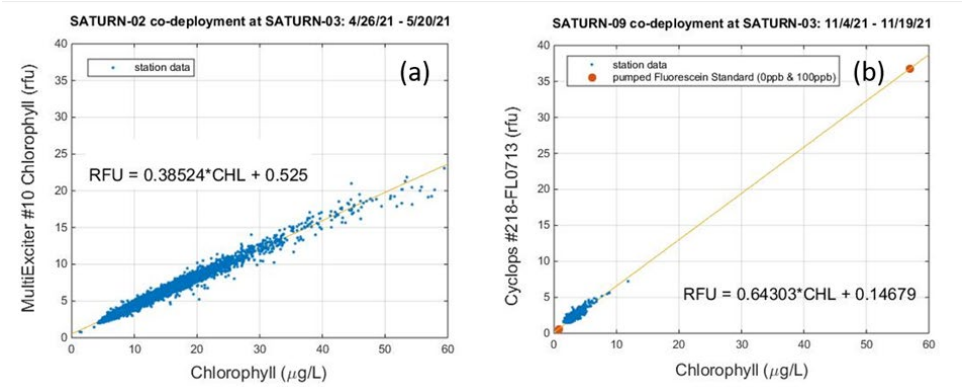

Figure 2. *Data from the co-deployments of the SATURN-02 fluorometer (a JFE Adventech Multi-Exciter) and the SATURN-09 fluorometer (a Turner Designs Cyclops Chlorophyll fluorometer) at SATURN- 03.The output of the buoy fluorometers is plotted on the y-axis in relative fluorescent units (rfu's) against the calibrated output of the SATURN-03 fluorometer. Because chlorophyll concentrations were low in the estuary, Fluorescein standards were also run during the SATURN-09 co-deployment (panel b). The resulting relationship was used to calibrate the buoy sensor output to chlorophyll concentration (µg/L).*

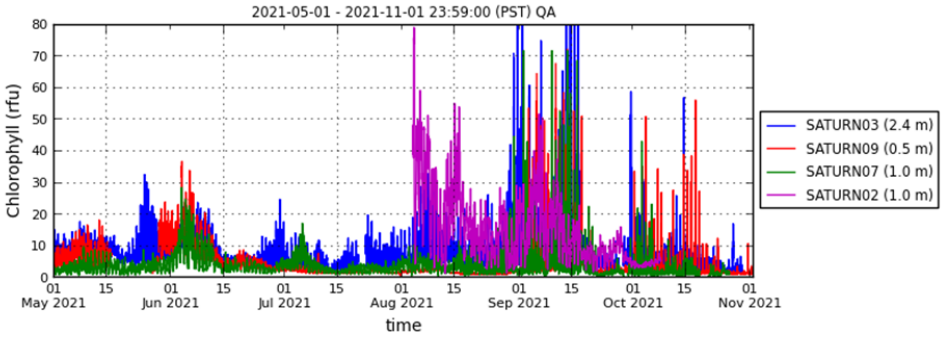

Figure 3. *Calibrated data from chlorophyll fluorometers at SATURN-03 (Pt. Adams), SATURN-09 (Youngs Bay), SATURN-07 (Baker Bay), and SATURN-02 (offshore plume) plotted with the Data Explorer.*

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 water temperature, salinity, dissolved oxygen, pH, turbidity, and water level measurements every 15 minutes over the period 06/01/21 – 11/31/21. Tom's Creek weather station provided measurements of air temperature, relative humidity, barometric pressure, and wind speed/direction. Telemetry transmissions were continuous for Winchester Arm, Elliot Creek, and Tom's Creek platforms. The Valino Island and the Charleston Bridge stations continued data collection, but telemetry is offline in preparation for installation of new data collection platforms with Yellow Springs Instruments Turnkey Storm3 systems. In collaboration with the Confederated Tribes of the Coos, Lower

Umpqua and Siuslaw Indians (CTCLUSI), SSNERR maintains telemetry for the North Spit BLM water quality station, located in the lower Coos estuary with data available through NVS. Monthly instrument deployments and retrievals, station maintenance, and data download, QA/QC, and management were completed for the water quality and weather stations following NOAA NERRS Centralized Data Management Office.

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 with data collection and grab data analyses in collaboration with Oregon State University (Chan, Magel, and Hales) completed 2019.

The SSNERR water quality and weather stations provide real-time data for shellfish growers in the Coos estuary. 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 environmental modeling analyses to characterize drivers of eelgrass declines. The Reserve's current Margaret Davidson Fellow (Taylor Dodrill) is utilizing water quality data for her research on phytoplankton communities and prediction of HABs. The Reserve education and science programs used water quality data for outreach on tidal marsh metrics for evaluating wetland resilience to sea level rise and are developing a SWMP water quality exhibit for the Reserve Visitor Center.

COVID-19 impacts affected routine SWMP field and laboratory work during the Summer and Fall 2021 due to restrictions for fieldwork, vehicles, boat use, lab space, and housing accommodations.

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 spring seasonal beach monitoring surveys in the Columbia River Littoral Cell (CRLC) in June 2021. Forty-six beach profiles and two surface maps were collected. Seasonal beach profile data and contour change plots are made available through the NANOOS Visualization System. Additional topographic mapping of the scarp and dune top and toe was conducted at Cape Disappointment State Park to help inform management strategies near North Jetty. NANOOS funds from this grant period ran out one week prior to the start of CRLC summer seasonal beach monitoring surveys, and those surveys will be detailed in a subsequent report.

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 June, 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. CMAP continued detailed topographic mapping of the constructed dune in front of the condos, which was extended alongshore since the previous seasonal survey.

CMAP continues to monitor the performance of the dynamic revetment at North Cove. Beach topography surveys were conducted in June 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. In addition, topographic features and design features were mapped along approximately 2 kilometers of the project area. Results indicate the revetment is functioning as expected, with a dynamic upper beach and a steady lower beach, effectively holding the upland in place.

CMAP also continues to collect seasonal beach profiles near Kalaloch at South Beach on the Olympic Peninsula, where 14 profiles were collected in June of 2021. Monitoring results from Kalaloch will be used for comparison to the North Cove dynamic revetment site, which is intended to mimic functions of a natural composite beach similar the setting and conditions at Kalaloch.

Outside of the CRLC, CMAP conducted boat-based lidar surveys of three locations near Port Townsend funded by ESRP in June 2021. CMAP also conducted a topographic and bathymetric survey of Makah Bay funded by the Makah Tribe in July of 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 – summer surveys – were successfully collected in the Neskowin littoral cell (15 sites, August 2021), Rockaway littoral cell (25 sites, October 2021), along the Clatsop Plains (6 sites, October 2021), the Newport littoral cell (58 sites, August 2021) and in the Beverly Beach littoral cell (15 sites, August 2021). Due to ongoing problems with our ATV vehicle (15 years old), used to conduct work on Oregon beaches, including the collection of datum-based shorelines, the State of Oregon invested ~$38K in a new ATV vehicle and trailer to replace aging equipment. The vehicle was successfully adapted to meet our surveying needs over the summer period and eventually used in our summer fieldwork that occurred between August and October 2021. In addition to measurements of the transects, datum-based shorelines were also collected at each of the littoral cells.

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 fall 2021, our monitoring data indicated that beaches in the Neskowin cell had mostly recovered from the anomalous 2020/21 winter storm waves. The exception is a northern section at Pacific City where the beach remains in a degraded (reduced beach volume) state, making it susceptible to further erosion in the 2021/22 winter season. Conditions along the Rockaway sub-cell remain at the more eroded range of our monitoring data, making it also susceptible to ongoing erosion in the ensuing 2021/22 winter. At Manzanita, in the far north of the Rockaway Cell, the beach did not fully recover over the summer, and remains in an eroded state not seen since 1998. Significant time was spent during this period refining our data processing techniques for reducing and archiving our beach shoreline surveys. Having completed this now for the majority of sites being monitored, we were able to process the data using the USGS Digital Shoreline Analysis System to extrapolate meaningful change (erosion/accretion) rates for the entire Rockaway, Neskowin, Newport (Figure 4) and Beverly Beach littoral cells.

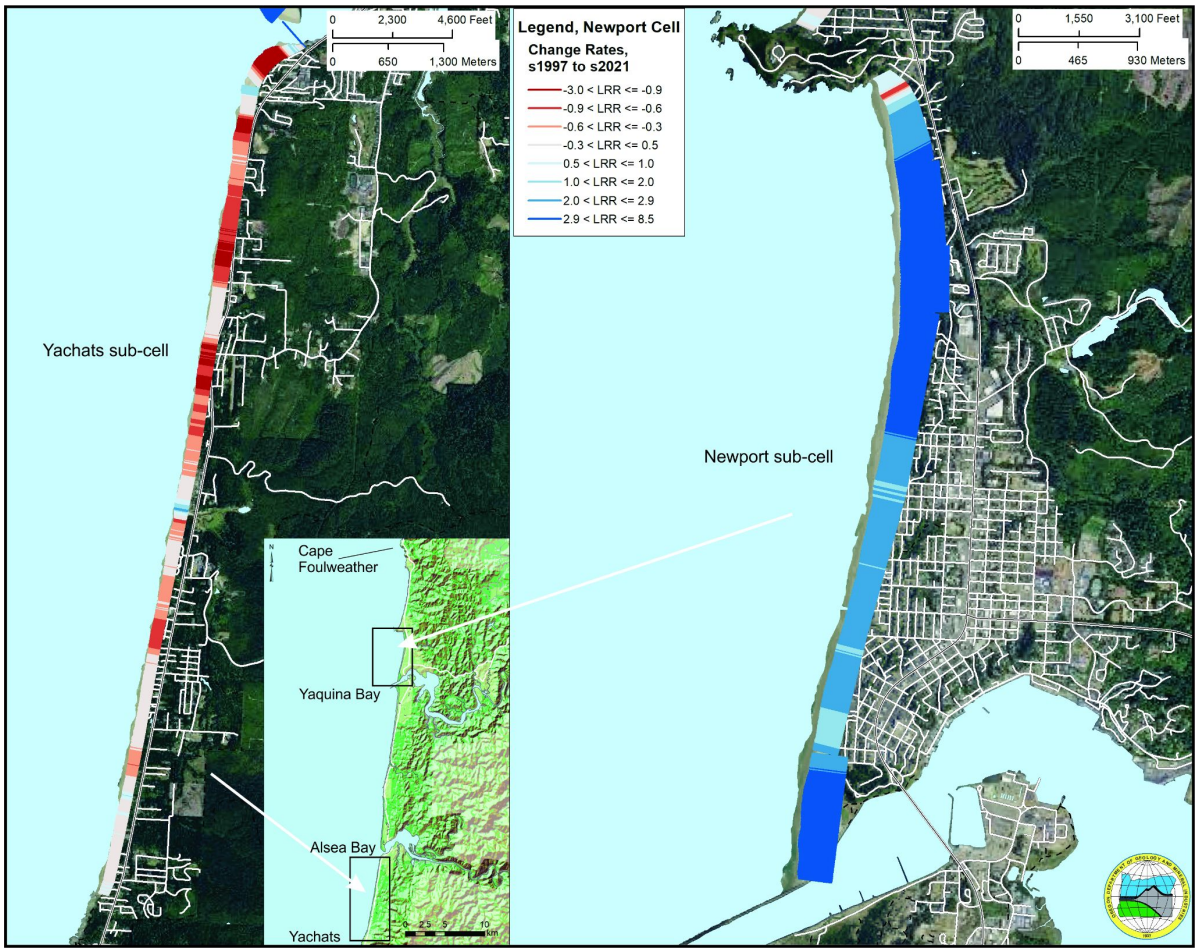

Figure 4. *Calculated MHHW shoreline change rates (10 m interval) derived from annual GPS and lidar surveys (n=11) in the Yachats sub-cell (left), from summer 1997 to summer 2021. Similar analyses at Newport in the north (right), indicate considerable accretion. Together these data imply sustained alongshore drift over the past two decades. Hot colors indicate erosion, blue indicate accretion.*

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
In collaboration with the Washington State Department of Ecology and the U.S. Geological Survey, P. Ruggiero's group at Oregon State University collected nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC). Over 220 individual cross-shore profiles were collected during summer 2021 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 ~6 days of field data collection. These data have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. In all cases, these nearshore bathymetry measurements have been combined with topographic measurements collected by Ecology developing complete maps of the nearshore planform. These data continue to provide a critical source of information for improving coastal hazard mitigation along the coastlines of the CRLC and portions of the Oregon coast and for understanding the morphodynamics of high-energy beaches (Figure 5). For example, nearshore and beach data were heavily relied upon in the development of the Pacific Northwest National Shoreline Management Study, a product of the US Army Corps of Engineers National Shoreline Management Study. The report, which will be released in January of 2022, provides a regional assessment of coastal change and current management actions based on existing available data (i.e., NANOOS supported data) and input from stakeholders and tribal partners. It considers the effects of erosion and accretion on socioeconomics and the environment and provides recommendations and example actions to restore and maintain resilient shorelines. The recommendations of the report are intended to inform the U.S. Congress and other decision-making parties interested in future investments in the nation's coasts. As with summer 2020, field data collection was impacted due to the pandemic, and we were unable to collect additional data along the Oregon coast during summer 2021.

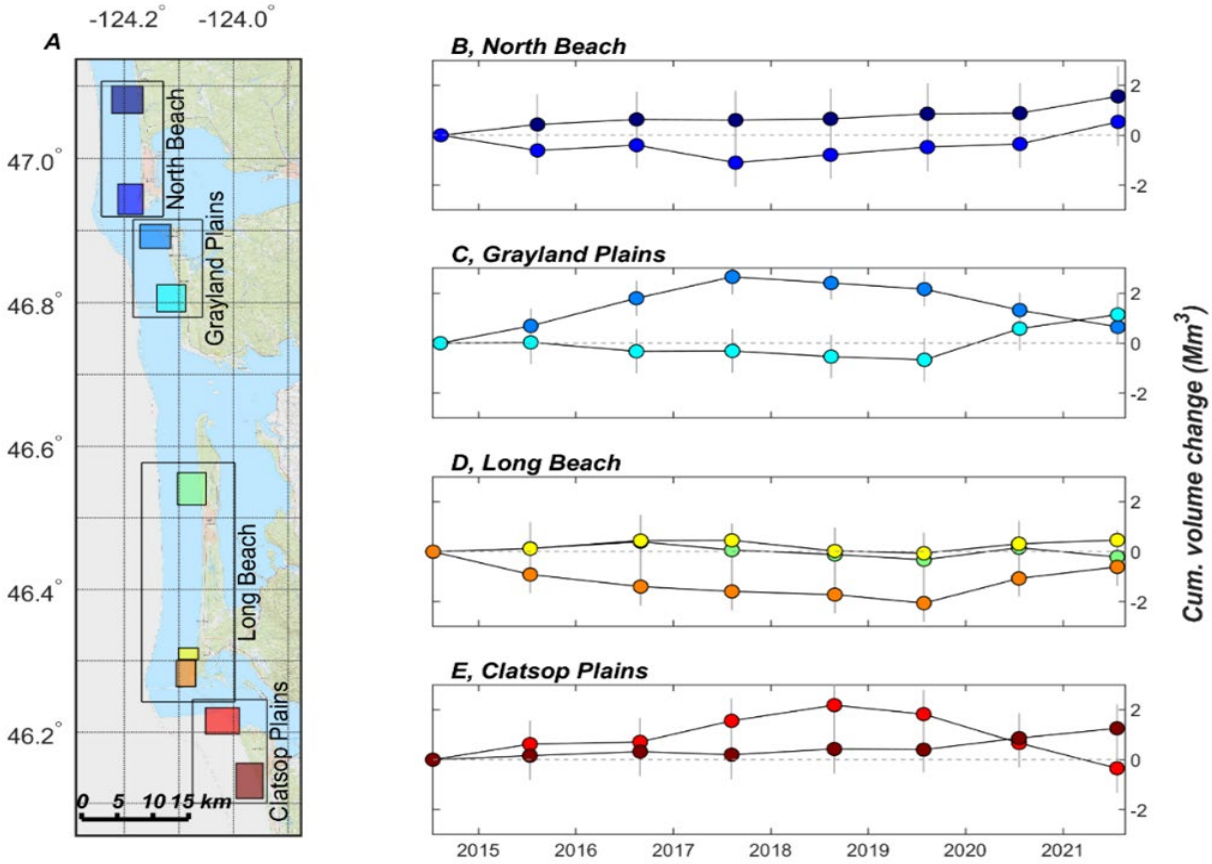

Figure 5. *Integrated cumulative net volume changes in 2015, 2016, 2017, 2018, 2019, 2020, and 2021 for each region having intensive sampling. Map (A) shows locations of intensive sampling regions within each sub-cell. Time-series plots show integrated net volume changes for regions within North Beach (B), Grayland Plains (C), Long Beach (D), and Clatsop Plains (E) sub-cells. Colors of rectangles in A correspond to colors of dots in plots in B–E. Abbreviations: km, kilometer(s); Mm3, million cubic meter(s).*

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 (Q4 of 2021 and Q1 of 2022) of 84% and 96% respectively (https://hfrnet.ucsd.edu/diagnostics), ranking 3rd and 1st respectively among the nine measured regions.

Site STV2 at Fort Stevens, OR, was troubled by extremely high temperatures during the heat wave in July, causing the HF transmitter to cycle off. This was traced to a failure of the web-controlled power switch at the site, which also appeared to have been caused by the heat wave. We replaced the UPS and the web power switch.

Our technical team has experienced one retirement (Anne Dorkins) and one member taking up a teaching job at the community college (Erik Arnesen). Both have been outstanding contributors and will be missed. In November we hired Matthew Sroufe to work with the HF systems.

Progress in siting at Kalaloch was slowed by surgery for Kosro in August, COVID restrictions, and personnel changes; we plan to restart this effort in the new year.

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

The change-over of FCC licensing of oceanographic HF radars from experimental licenses to operational licenses has been a major effort so far. This is requiring changes to operational frequencies, which in turn will require some (many) of the long-range antennas and electronics to be retuned or replaced, and the standard-range systems to be re-fitted with GPS timing, to allow multiple systems to broadcast on the same frequencies (long-range systems already require this). The program manager Brian Zelenke has organized this effort nationally, and has been very helpful in addressing the numerous issues that come up. On December 10 and 14, NANOOS submitted new applications for FCC licensing in the ITU bands for its 13 radars. One of these submitted sites is WSP1, the installed site near Westport, WA, and another is for KAL1, a site to be proposed to the National Park Service, near Kalaloch, WA.

Port X-band Radar Observations:

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

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

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

In this period, we have fully operationalized our new radar and data acquisition system. With the new OSU-

designed-and-built open-source data acquisition and recording software the Coast Guard watchstanders are able to make use of the live radar display in the watchtower.

A final note, through new leveraged funding (new project with the USACE) we are planning to expand both our bathymetric estimation capabilities at this Newport site as well as collect more in situ wave and current observations. We will have more to update on this in 2022.

b) NANOOS Modeling Subsystem:

Shelf Modeling:

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

-Model verification and validation [Zaron]

Computer circulation modeling and forecasting of PNW coastal ocean shelf conditions has been conducted by Zaron'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 fishers and the public via the NANOOS Visualization System, e.g., as the Tuna Forecast and SeaCast applications.

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), using the WCOFS Viewer as a paradigm for the interactive model displays and quality control (https://coastaloceanmodels.noaa.gov/WCOFS/Viewer/). We developed a new product prototype based on finite-time Lyapunov exponents for identification of ocean frontal features for fishers, following on the work reported in Watson et al, "Fishermen Follow Fine-Scale Physical Ocean Features for Finance" (Front. Mar. Sci., 19 February 2018). We are currently validating this product and assessing its potential usefulness for public dissemination.

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. During this period MacCready used a small amount of salary and equipment support to continue enhancing LiveOcean forecast reliability.

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 completed evaluating the results of experimentation with the next generation SCHISM model and are preparing a new multi-year simulation database.

Task 12: 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 12) 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 skill assessment of a 3-D basin-scale simulation, incorporation of high resolution meshes for Taiwan and the Columbia River, and improved representation of the Oregon and Washington coastal shelf.

Task 6: Columbia River extension of Salish Sea model *[Khangaonkar]*
Progress Report Prepared by the Salish Sea Modeling Center (SSMC), University of Washington Tacoma
Subaward Title: Addition of Columbia River to SSM-OFS - Refinement and Robust Testing
Scope of Work Summary: The overall goal 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 (SSM). The SSM Operational Forecast System (SSMOFS) is currently undergoing 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 the 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.

Task1 Review and Processing Data: Columbia River ADCP/CTD Survey
Originally, the proposed approach was to use current and stratification data collected from a previously planned field survey of the Columbia River by NOAA NOS CO-OPS for 2020-2021. However, the survey has been postponed indefinitely due to the COVID19 impact. In consultation with NOS, the approach was modified, and the data set was replaced with historical monitoring data (from 2015-2017) from available sites in the Columbia River. These data were collected by three organizations: NOAA COOPS, USGS, and the Center for Coastal Margin Observation & Prediction (CMOP). Available data include (a) water surface elevation, (b) temperature, and (c) salinity data, the skill assessment has been conducted in continuous

refinement of the Columbia River grid. Figure 6 below shows the locations of the monitoring stations corresponding to these data sources.

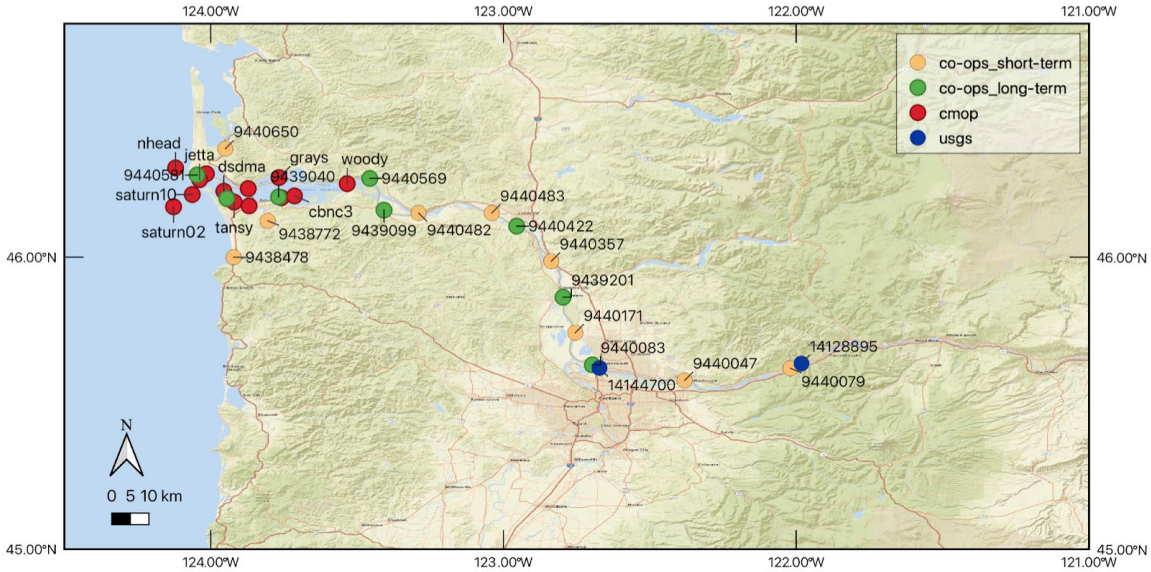

Figure 6. *NOAA CO-OPS, CMOP, and USGS stations that were available with data suitable for SSM-OFS skill assessment effort*.

Task 2: Iterative Refinement of Columbia River Grid and Testing with SSM-OFS

The existing SSM-OFS model already included a reasonably high-resolution representation of the Columbia River domain. As part of this effort, we further improved the model grid using new bathymetry information provided by NOAA. This information was used to ensure intertidal channels and bathymetric features particularly in the estuary including the navigational channel were reproduced accurately. Figure 7 below highlights the improvement in bathymetric representation with grid refinement. Further refinement and adjustments were conducted as part of model tests to ensure SSM-OFS functions as a single model of the Oregon-Washington continental shelf with Salish Sea, Columbia River, and Canadian waters surrounding Vancouver. The grid refinement fine-tuning continues along with skill assessment and includes adjusting the SSM-OFS model grid iteratively until the best match with observed data (water surface elevation, temperature, and salinity) is obtained with the imposed constraint that the external model time step of > = 1 s.

Task 3: Skill Assessment of Hydrodynamics – Columbia River Focus:

Task 3 includes two phases: (1) evaluating the model performance using established assessment procedures for the Salish Sea (Phase 1), and (2) focusing on skill assessment at stations in the Columbia River using CO-OPS and USGS current data from Columbia River (Phase 2).

In Phase 1, we ensured that the model performances in the Salish Sea and Puget Sound region are not adversely affected by grid modification. We compared water surface elevation (WSL) with nine X-Tide stations, and salinity (S) and temperature (T) with data from Ecology's 26 monthly monitoring stations. The model performance is consistent with the prior SSM results (relative error of < 10% for water surface levels and root mean square error (RMSE) of < 1 °C and RMSE 0f 1- 2 ppt for salinity).

In Phase 2, we have conducted skill assessment with water surface elevation at 8 stations in the Columbia River. The water surface level skill assessment is nearing completion and examination of skill for temperature and salinity has been initiated. This will be followed by model-data comparison for available currents. Figure 8 below shows a comparison of predicted model water surface elevations with measured data from two stations in the Columbia River. The Vancouver, WA station is near the upstream end of the domain at river mile 105 while Cape Disappointment station is near the mouth at river mile 2. As shown in the figure, tidal effects propagate all the way up to Vancouver, WA.

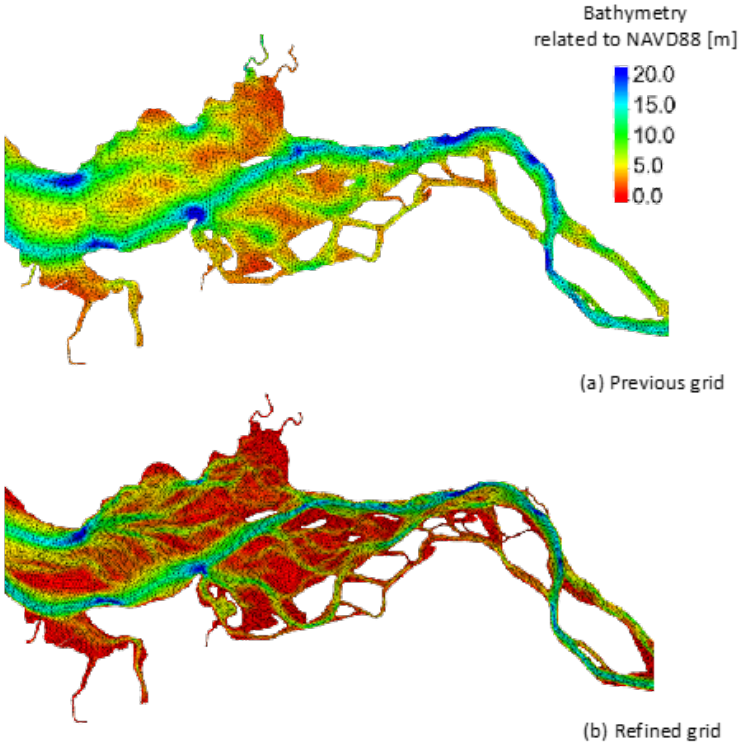

Figure 7. *Model grid (a) before refinement and (b) after refinement at Columbia River. Note-color contours show depth (negative elevations) relative to NAVD88 datum.*

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

Task 5: Project Management:
Ongoing

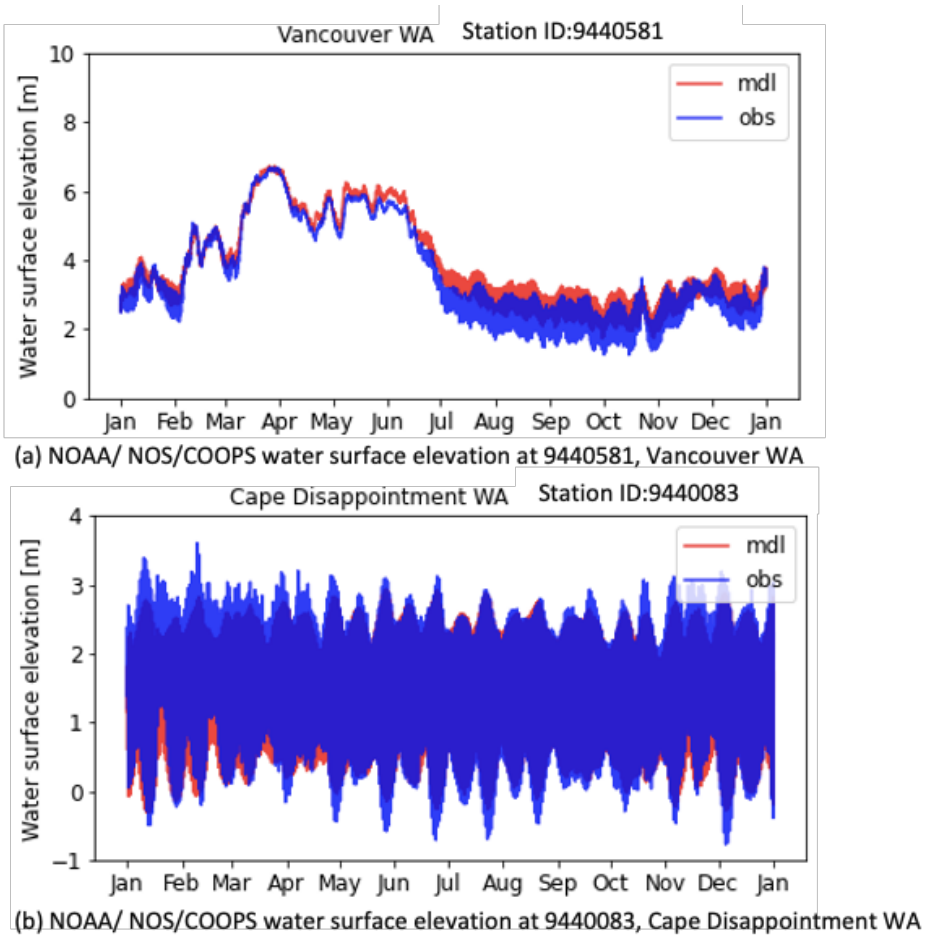

Figure 8. *Salish Sea model (red) and NOAA/NOS/COOPS observation (blue) water surface level [m] at upstream of the Columbia River from 2017-01-01 00:00 UTM to 2017-12-31 23:54 UTM. The data interval is 6 minutes.*

c) NANOOS Data Management and Communications (DMAC) Subsystem:

See Table 1 for milestones [Risien, Tanner, Carini]

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, renewed/updated data streams were established for the Friday Harbor Labs Land Station and Fixed Shore Platform. Additionally, the Glider app framework was updated to accommodate the new automated Glider plotting capabilities.

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

- Data Archiving with NCEI. 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.

- Data Archiving with NDBC. NANOOS worked closely with NDBC to implement data archiving via an ERDDAP pull method rather than the traditional XML FTP push method for CB-06 (WMO #46128) and all NANOOS ORCA buoy moorings (Pt Wells WMO #46120, Carr Inlet WMO #46121, Dabob Bay WMO #46122, Twanoh WMO #46123, Hoodsport WMO #46124, Hansville WMO #46125), though only 46120, 46121, and 46125 are currently providing data at least every 6 hours.
- 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 8: Enhance GOA-ON data portal an OA dashboard to the world and support for GOA-ON co-chair *[Tanner, Newton]*

The GOA-ON Portal content is constantly updated, often with 2-3 new slideshow items, information pages, or resource links per week. Past and archived webinars are also listed to allow users to revisit past talks. Newton provided duties as GOA-ON's co-chair, as outlined in section f. These are placed in this section as there are multiple synergies between NANOOS and GOA-ON.

Task 14: Support OceanHackWeek *[Mayorga]*

OceanHackWeek (OHW, https://oceanhackweek.github.io) successfully concluded 4 days of collaborative data exploration, peer learning and software development on August 6th. Expanding on a successful transition to a virtual format in 2020, OHW 2021 was a hybrid event designed to accommodate more diverse learning environment preferences, better address the spread of virtual participant time zones, and expand to a larger number of participants. 70 participants from 13 countries gathered in three coordinated sub-events: in person (19) at the Bigelow Laboratory for Ocean Sciences in Maine, the main (42) virtual event spanning time zones from the US West Coast to Israel, and a smaller (9) virtual event for Australia - India time zones. Participants were joined by 16 organizers and 13 additional presenters and helpers. Tutorials and projects spanned oceanographic sub-disciplines (turtle movement from drone video to surface currents from high-frequency radar), data sources (remote sensing, ocean and climate models, the Ocean Observatories Initiative, US IOOS, OBIS, etc.) and open-source programming languages (Python and R), supported by a common computational infrastructure on the cloud and coordination that enabled extensive project collaborations across the three sub-events ("I found the organisers and fellow OHW 2021 participants were extremely welcoming and supportive, so my concerns about not being an expert coder soon vanished. I also really enjoyed participating with people from all over the world because they brought completely different perspectives, which meant we could solve problems a lot faster"). Presentations, tutorials and project presentations are openly accessible from the event website (https://oceanhackweek.github.io/ohw-resources/) as computational notebooks (Jupyter or R Markdown), pdf presentations and video recordings on YouTube. This event was co-led by the Bigelow Laboratory for Ocean Sciences and the University of Washington (Emilio Mayorga), together with co-organizers from multiple institutions in the US and Australia. Funding support was provided by NSF, US IOOS (to NANOOS and NERACOOS), the Ocean Carbon & Biogeochemistry program and the Gordon and Betty Moore

Foundation. Going forward, the cloud computing platform has been maintained online for continued use by participants, and a virtual meeting is being planned for Ocean Sciences Meeting 2022 that will bring together OHW organizers, past contributors, and invited guests to synthesize successful practices, discuss strategies for broader leveraging of OHW learning resources, and brainstorm partnerships with existing initiatives having similar goals.

Task 13: Enhance biological data stewardship within NANOOS *[Mayorga]*
E. Mayorga (UW) continued to engage with the Biological Data Standards working group and the new ESIP Biological Data Standards Cluster. He also initiated and made substantial progress in the alignment to Darwin Core of a Hood Canal (Salish Sea) zooplankton densities dataset from Prof. Julie Keister, UW School of Oceanography. The dataset is based on depth-stratified net tow sampling at several stations in Hood Canal, carried out monthly June to October in 2012 and 2013. Zooplankton density is reported by taxon, with discrimination by life stage in most cases. We have created draft Darwin Core Event and Occurrence tables using a Python-based workflow, and will soon create a corresponding draft "measurement or fact" table. Events have been hierarchically partitioned into cruises (10), station visits (64) and samples (271). 130 taxa are reported as 3,726 unique occurrences, spanning approximately 6,800 zooplankton density measurements. The Darwin Core alignment will be completed in early 2022. We plan to submit the aligned dataset to OBIS and MBON in the first half of 2022. This work is expected to lead to the processing of the broader and longer-term Salish Sea Marine Survival Project Zooplankton Dataset that is also conducted by Prof. Keister, as well as additional biological datasets in the NANOOS region.

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

Chaired by J. Allan (DOGAMI) this committee is composed of members from OHSU, UW, OSU, NANOOS E&O, and NOAA. NANOOS UPC chair Allan participates in weekly “tag-up” calls with 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 2021 period mainly centered around weekly NANOOS DMAC and UPC teleconferences.

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 modernising 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 will continue to preclude any new app development or enhancement until the harvesters have been completely updated; during this reporting period the web/DMAC team have made excellent

progress with the majority of platforms now having been updated to the new enterprise system. In parallel with rebuilding the harvesters, the web team also spent a considerable amount of time building and then testing a new harvester that provides data to the NOAA NDBC via ERDDAP.

Refinements to the 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, continue to be rolled out. This effort reflected a collaboration between DOGAMI, University of Oregon (UO) Infographics experts and NANOOS. During this period, the UO team refined the evacuation road routing capability to include actual turn-by-turn instructions, which was operationalized through a web service that is called by NANOOS. The completed product (Figure 9) 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, recommended evacuation speed needed to reach high ground in time to outrun the impending tsunami wave, along with turn-by-turn instructions. The user can then either save/or print a pdf of the map.

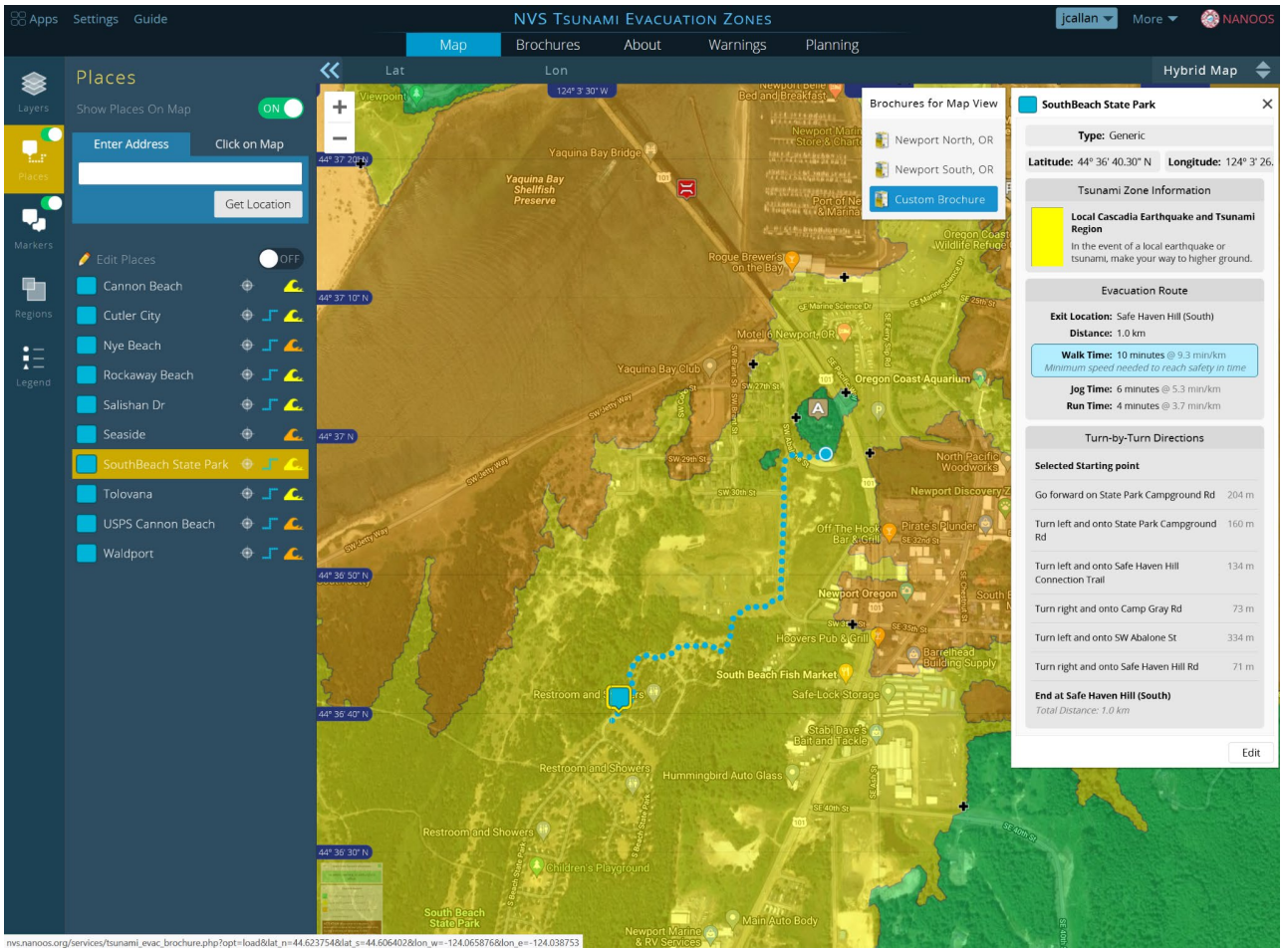

Figure 9. *Screenshot of the web-based Tsunami Evacuation App, highlighting new evacuation routing functionality at South Beach State Park, Newport, Oregon, including turn-by-turn guidance instructions.*

Modifications to the NVS Glider Apps were also completed during this period, as we strive to make a more uniform and user friendly application. During this period, significant time was spent by DMAC Team Member Carini to rewrite and automate the glider processing scripts in python. The goal was to

make real-time display of glider data (while the glider is in the water) available to our users so they can actively monitor conditions, such as the evolution of upwelling and near-bottom low-oxygen water through the "hypoxia season" each year. Color schemes and treatment of raw glider data was undertaken in consultation with NANOOS PIs Barth and Seaton for initial development on the Washington Shelf (Figure 10) and Trinidad Head gliders. Next steps will include implementation of the new code on all other NVS-served glider assets and unifying the displays under a single application, rather than separate apps for each glider.

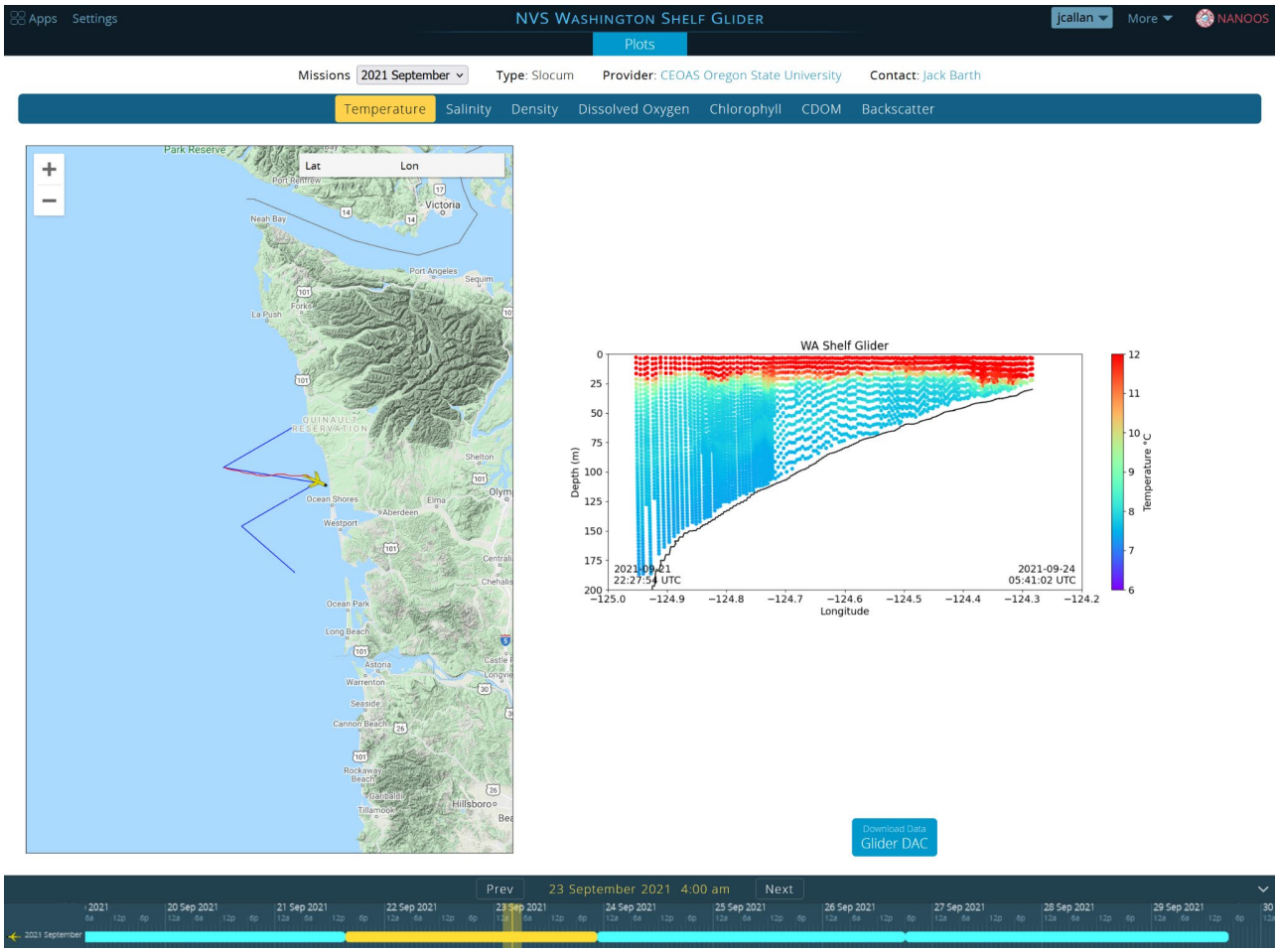

Figure 10. *Screenshot of the NVS Glider App for the Washington Shelf glider, highlighting new profile visualizations for temperature.*

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 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.
- A new Maritime High School welcomed its inaugural freshmen class in September 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.

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.
- Wold, Carini, and Rome continued to update content on the NANOOS portal.
- NANOOS maintained a growing Facebook and Twitter audience, regularly posting on Facebook and Twitter accounts with news, photos and interesting data. 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), Andrew Barnard (NANOOS Board Chair), M. Kosro (NANOOS Board Vice Chair), N. Rome (NANOOS Program Manager), and R. Carini (NANOOS Research Assistant) continued to provide leadership to NANOOS operations and connection to the US IOOS enterprise. R. Carini, NANOOS Research Associate, supported 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:

- NANOOS held its annual GC/PI meetings virtually on 3-4 August 2021 supported by Newton, Rome, Carini, and Barnard. Day 1 was the GC meeting with participation from Josie Quintrell, IOOS Association Director, and Carl Gouldman, IOOS Program Director, a NANOOS Overview by Newton, Craig Risien, Jonathan Allan, and Rachel Wold, followed by afternoon discussions on NANOOS' "Enabling Change" working group efforts and plans as well as planning for a 2022 Community Workshop. Day 2 was focused on PI updates, data management overview by Carini, and discussion of product development ideas. There were 71 participants at the GC meeting on 3 August and 40 participants at the PI meeting on 4 August. The GC presentation slides can be accessed at: *http://www.nanoos.org/documents/general/nanoos_gc_presentations_2021.pdf*.
- Newton was an invited panelist for a Congressional Briefing hosted by NOAA OAR and IOOS focusing on the West Coast on 29 June 2021. She joined IOOS director Carl Gouldman, OAR GOMO director David Legler, and NOAA PMEL director Michelle McClure.
- Congresswoman Bonamici invited several NANOOS representatives and PIs, including Newton,

Barth (OSU), Seaton (CRITFC), and others to a virtual roundtable on Ocean Science, Estuaries, and the Climate Crisis on 13 October 2021.

- Newton worked with Don Boesch (UMCES) to provide Plenary panel speakers for the CERF Biennial International Conference 2021. She moderated one of these, hosting Washington Post reporter Chris Mooney, UNC fisheries scientist Janet Nye, and Quinault Indian Nation Vice President and National Congress of American Indians President Fawn Sharp for a plenary panel discussion entitled 'Climate Change, Coastal Hotspots and Innovative Solutions' on 03 November 2021.
- Newton was elected Vice Chair of the IOOS Association board of directors.

DEI focus:

- Newton continued to support the **NANOOS Enabling Change Working Group**, with meetings every month throughout the period.
- NANOOS celebrated with our Louis Stokes Alliance for Minority Participation (LSAMP) intern for her end of internship virtual celebration on 21 June 2021.
- The NSF Convergence Accelerator proposal NANOOS led with AOOS, PacIOOS, Sofar Ocean (a low-cost buoy and sensor company) and Indigenous partners from the Pacific Islands (villages in the Marshall Islands and American Samoa), the Washington coast (Quileute Tribe and Quinault Indian Nation), and Alaska (Alaska Eskimo Whaling Commission) was funded to collectively work to develop solutions to overcome existing hurdles of observing technologies that are too expensive to purchase and too expensive to sustain when conducted in isolation. The goal of the project is to get oceanographic data into the hands of Indigenous communities in a way that takes advantage of existing, lower cost wave buoy technology and enables sustained community-led stewardship of the buoys. Through co-design, the team aims to revolutionize the status quo by providing new tools and new connections that will focus on the hyper-local scale.

Additional coordination and representation included:

- Newton and AOOS Director Molly McCammon are members of the Ecosystem Sciences and Management Working Group and participated in meetings on 15 July and 15 October 2021. Both are serving as co-chairs of the WG.
- Newton presented NANOOS biology investments to the IOOS Marine Life working group meeting on 5 November 2021
- During the period, Newton was on the working group that helped write the IOOS Coastal Climate Signal white paper, "Detecting the Coastal Climate Signal: The IOOS Contribution." The paper includes examples from the NANOOS region, and high-level recommendations for how IOOS can meet community needs in a changing climate
- Newton represented NANOOS on the California Current Acidification Network (C-CAN).
- Newton worked with other IOOS RA directors to host a virtual CERF scientific session "Detecting the Coastal Climate Signal: Sustained Observations for Decision Making" and gave a talk within that session 'Working Together Toward Increasing Resilience to Ocean Acidification' on 3 November 2021.
- Newton led NANOOS sub-contracts on proposals including one to the Climate Program Office working with the Olympic Coast National Marine Sanctuary on climate indicators.
- Newton was invited to speak about NANOOS and ocean conditions to the Everett Community College's Ocean Research College Academy (ORCA) and the WSU Extension - Island County Community Lecture Series.

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

- Rome led a virtual satellite event entitled 'Engaging Stakeholders in the U.N. Ocean Decade' for the UN Decade's 'A Predicted Ocean Laboratory' on 17 September 2021. Newton participated as facilitator on behalf of the IOOS Ocean Obs'19 paper on stakeholder engagement, which includes examples from NANOOS.
- Newton and Rome were invited to speak about NANOOS to the International Coastal Atlas Network (ICAN) during their 'Local to Global - Benefits of Coastal Web Atlas Sharing & Connectivity' Workshop regarding NANOOS' role as a Nexus Organization of the UN Ocean Decade.
- Newton represented NANOOS at the PICES "MONITOR" committee, which focuses on ocean observing in the North Pacific.
- Newton is a co-Chair of GOA-ON, along with Steve Widecombe, Plymouth Marine Labs. She represented IOOS on Global Ocean Acidification Network Executive Committee (EC) calls and activities. She co-chaired the annual GOA-ON EC Meeting, which spanned sessions on 30 November and 2 December 2021. She spoke to the International CO2 Natural Analogues Network (ICONA) about GOA-ON and OARS on 6 September 2021.
- Newton provided leadership to GOA-ON's UN-endorsed programme "Ocean Acidification Research for Sustainability (OARS)". She provided "Ocean Acidification Research for Sustainability (OARS) Overview and Community Discussion" at an OARS Session during the 'GOA-ON OA Week', 17 September 2021 https://www.youtube.com/watch?v=-cD_JQg8VXw&list=PLZ2ci3xomXhvFPYHxzvrDUfB8tnuNr2Yo&index=53.
- Newton and NOAA OAP RVA co-PI Melissa Poe contributed results from the NOAA OAP Olympic Coast Regional Vulnerability to OA study on the Washington coast during the OA Social Vulnerability Assessment Community Discussion of the GOA-ON OA Week on 16 September 2021. https://www.youtube.com/watch?v=vbc84xgk-hE&list=PLZ2ci3xomXhvFPYHxzvrDUfB8tnuNr2Yo&index=23
- Newton stayed involved in Canadian observing activities including for MEOPAR and CIOOS-Pacific. Newton is a member of the Canadian IOOS (CIOOS) Pacific Regional Oversight Committee, attending meetings on 1 September 2021. Newton chairs the Marine Environmental Observation, Prediction, and Response Network, a Canadian Center of Excellence (MEOPAR) International Science Advisory Committee. She was invited to speak on 'Lessons learned from the Washington and California plans, coordination from regional to global, and an exemplary vulnerability assessment' for the State of Science on Ocean Acidification and Hypoxia in British Columbia, virtual workshop on 26 October 2021.
- Newton is a member of the Science Advisory Team for the Joint European Research Infrastructure in the Coastal Ocean (JERICO).

Additional NANOOS coordination:

- Newton serves as the Research Seat for the Olympic Coast National Marine Sanctuary (OCNMS) Advisory Council; she participated in meetings on 23 July, 22 September, and 19 November. She is a member of the OCNMS science subcommittee for OASeS (Ocean Acidification Sentinel Site).
- Newton participated in the Olympic Region Harmful Algal Bloom (ORHAB) Steering Committee calls throughout the period.
- Newton and NOAA OAP RVA co-PI Melissa Poe contributed results from the NOAA OAP Olympic Coast Regional Vulnerability to OA study on the Washington coast during the North American Hub session of the GOA-ON OA Week on 13 September 2021. This project involves several NANOOS partners, including the four WA coastal treaty tribes (Quinault Indian Nation, Hoh, Quileute, and

Makah), OCNMS, ONP, and NOAA PMEL. https://www.youtube.com/watch?v=CH1P1Mm8WmI&list=PLZ2ci3xomXhvFPYHxzvrDUfB8tnuNr2Yo&index=49

- Newton helped prepare and present 'Olympic Coast RVA Lessons Learned', 'Co-production of Knowledge Tutorial', and 'Gaps in Intellectual Knowledge for RVAs', at NOAA OAP's RVA Meeting, 22-24 September 2021
- 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, and the West Coast Ocean Data Portal.
- Newton contributed NANOOS updates on oceanographic conditions in the Pacific Northwest for the NOAA WestWatch webinar series on 20 July and 28 October, along with the other two west coast RAs. We provided NANOOS contributions to PSEMP Puget Sound Marine Condition Updates on 21 July 2021, 22 September, and 17 November.

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 recommended due to COVID-19, thus this project has been re-scoped. Our re-scope is for a paper on best practices, construction of which began during this period, and a shorter virtual west coast workshop in spring.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

MacCready, P. 'The LiveOcean Daily Forecast System', a talk for NOAA Community Modeling Workshop, Oct. 20, 2021.

MacCready, P., et al., 'Estuarine Circulation, Mixing, and Residence Times in the Salish Sea', a talk at the Coastal and Estuarine Research Federation (CERF) 2021 Conference, Nov. 8, 2021.

Newton, J.A. Keynote speaker for 2021 Possession Sound Student Showcase and Talks: Everett Community College's Ocean Research College Academy (ORCA), virtual, 10 June 2021.

Newton, J.A. 'Biological and Chemical Monitoring Coordination: *Recommendations to the Ocean Protection Council from the California Ocean Acidification and Hypoxia Monitoring Expert Panel',* NOAA OA Bio Indicators panelist, virtual, 18 August 2021.

Newton, J.A. 'The Global Ocean Acidification Observing Network: Observing on Local Scales Globally', International CO_2 Natural Analogues Network (ICONA), virtual, 6 September 2021. https://www.youtube.com/watch?v=G0NZj9-0uzo.

Newton, J.A. and M. Poe. 'The Olympic Coast as a Sentinel: Communicating Best Practices From an Approach to Integrated Social-Ecological Vulnerability Assessments' GOA-ON OA Week North American Hub Session, virtual, 13 September 2021. https://www.youtube.com/watch?v=CH1P1Mm8WmI&list=PLZ2ci3xomXhvFPYHxzvrDUfB8tnuNr2Yo&index=49

Newton, J.A, and S. Widdicombe. 'Ocean Acidification Research for Sustainability (OARS) Overview and Community Discussion,' GOA-ON OA Week OARS Session, virtual, 16 September 2021. https://www.youtube.com/watch?v=-cD_JQg8VXw&list=PLZ2ci3xomXhvFPYHxzvrDUfB8tnuNr2Yo&index=53

Newton, J.A. and M. Poe. 'The Olympic Coast as a Sentinel: integrated social-ecological vulnerability assessments,' GOA-ON Week OA Social Vulnerability Assessments Community Discussion session, virtual, 16 September 2021. https://www.youtube.com/watch?v=vbc84xgk-hE&list=PLZ2ci3xomXhvFPYHxzvrDUfB8tnuNr2Yo&index=23

Newton, J.A. and N. Rome 'Engaging Stakeholders in the U.N. Ocean Decade', "A Predicted Ocean" Laboratory, virtual, 17 September 2021.

Newton, J.A. and N. Rome 'NANOOS: A Nexus Organization for the UN Decade of Ocean Science for Sustainable Development', International Coastal Atlas Network (ICAN) 9 - Virtual Workshop 'Local to Global - Benefits of Coastal Web Atlas Sharing & Connectivity', 28 September 2021.

Newton, J.A. 'NANOOS: A Nexus Organization for the UN Decade on Ocean Science for Sustainable Development', PICES Monitoring Meeting, virtual, 6 October 2021.

Newton, J.A. 'Lessons learned from the Washington and California plans, coordination from regional to global, and an exemplary vulnerability assessment', State of Science on Ocean Acidification and Hypoxia in British Columbia, virtual, 26 October 2021.

Newton, J.A. 'Working Together Toward Increasing Resilience to Ocean Acidification', CERF Session "Detecting the Coastal Climate Signal: Sustained Observations for Decision Making", virtual, 3 November 2021

Newton, J.A. 'Ocean Acidification: Observing a Global Issue on Local Scales', WSU Extension - Island County Community Lecture Series "Our Earth, Our Home", virtual, 18 November 2021.

Nguyen, N. Puget Sound observations from the SoundToxins research and monitoring network. Puget Sound Environmental Monitoring Program Marine Waters Working Group Annual Workshop, Seattle, WA, July 21, 2021.

Seaton, C. 'Coastal Margin Observation and Prediction at CRITFC', Eulachon Technical Recovery and Implementation Team, July 20,2021.

Seaton, C. 'Hydrography and Indigenous Nations', UN Ocean Decade: A Predicted Ocean satellite: Hydrography and Mapping for the Ocean Decade. Sep 17, 2021.

Publications:

Chu, S. N., A. J. Sutton, S. R. Alin, N. Lawrence-Slavas, D. Atamanchuk, J. B. Mickett, J. A. Newton, C. Meinig, S. Stalin, and A. Tengberg. 2020. Field evaluation of a low-powered, profiling pCO2 system in coastal Washington. *Limnology and Oceanography: Methods*, 18(6), 280–296. https://doi.org/10.1002/lom3.10354

Haller, M.C. 2021. "Introduction to Ocean Remote Sensing with Marine Radars". Ocean Remote Sensing Technologies: High Frequency, Marine, and GNSS-Based Radar, edited by Weimin Huang, *IET*.

Honegger, D. and M.C. Haller. 2021. "Bathymetry (and Current) Retrieval: Phase-based Method". Ocean Remote Sensing Technologies: High Frequency, Marine, and GNSS-Based Radar, edited by Weimin Huang, *IET*.

Yamada, S. B., J. Fisher, and P. M. Kosro. 2021. Relationship between ocean ecosystem indicators and year class strength of the invasive green crab (*Carcinus maenas*) in Oregon estuaries, *Progress in Oceanography*, (in press). doi:10.1016/j.pocean.2021.102618.