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

NOAA Award: NA16NOS0120019 Reporting period: 6/01/2019 to 11/30/2019

1) Project Summary

Our overall project goal is to sustain the Northwest Association of Networked Ocean Observing Systems, NANOOS, as the Regional Coastal Ocean Observing System for the U.S. Pacific Northwest that serves regional stakeholders in alignment with the vision of U.S. Integrated Ocean Observing System (IOOS®). NANOOS, with its essential subcomponents (integrated in-water and land-based Observing Systems, Data Management and Communications, Modeling and Analysis, and Education and Outreach) that are closely integrated within the national IOOS® system, provides significant societal benefits across a wide spectrum of users including federal, tribal, state and local governments, marine industries, scientific researchers, Non-Governmental Organizations (NGOs), educators and the general public.

For this FY19 period (= Y4 of this award; Y13 of NANOOS RCOOS operations) our objectives were to:

1) **Maintain NANOOS as the U.S IOOS PNW Regional Association:** Sustain our proven role for regional coordination, administrative infrastructure, and stakeholder engagement, engaging federal and non-federal (tribal, academic, state, local, industry, NGO, etc.) partners.
2) **Maintain and expand surface current and wave mapping capability.** Maintain existing HF-radar foundational capability providing critical national capacity; continue, to the extent possible, existing investment in wave mapping at critical ports.
3) **Sustain existing buoys and enhance gliders in the PNW coastal ocean, in coordination with national programs.** Maintain these essential assets providing regional observations, with focus, to the extent possible, on hypoxia, HABs, ocean acidification (OA), climate change detection.
4) **Maintain observation capabilities in PNW estuaries, in coordination with local and regional programs.** Maintain these to aid sustainable resource management, water quality assessment and sub-regional climate change evaluation. Sustain observing ability including to the extent possible, hypoxia and OA.
5) **Maintain core elements of beach and shoreline observing programs.** Contribute to hazard mitigation by providing, to the extent possible, essential observations and better decision support tools for coastal managers, planners and engineers.
6) **Provide sustained support to a community of complementary regional numerical models.** Contribute, to the extent possible, to the operation of regional models, and the tools and products they support, covering the head of tide of estuaries to the outer edges of the EEZ in both OR and WA.
7) **Maintain NANOOS' Data Management and Communications.** Sustain, to the extent possible, the DMAC system NANOOS has built, including the NANOOS Visualization System (NVS), for dynamic and distributed data access and visualization for IOOS.
8) **Continue to deliver existing and, to the extent possible, create innovative and transformative user-defined products and services for PNW stakeholders**. Continue our NVS innovation to succeed in this vital translation: meaningful and informative data products that connect with user applications and serve society.
9) **Sustain NANOOS outreach, engagement and education.** Foster ocean literacy and facilitate use of NANOOS products for IOOS objectives, the core task for which NANOOS was constructed, via existing approaches for engaging users and increasing ocean awareness.

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

10) Support (a) collection of OA measurements on our La Push [J. Newton, J. Mickett, UW] and (b) CB-06 [B. Hales, OSU] moorings, and (c) working with NOAA PMEL on mooring test beds.
11) Support collection of OA measurements at shellfish hatchery locations via technical expertise ((b) B. Hales, OSU and (c) B. Carter, UW JISAO), as part of Ocean Technology Transition in support of ocean acidification observing in support of Pacific coast shellfish growers.
12) Support the GOA-ON data portal (J. Newton, UW; E. Mayorga, T. Tanner, UW)
13) Support evaluation of LiveOcean in IOOS cloud sandbox (P. MacCready, UW)
14) Support OceanHackWeek 2019 (E. Mayorga, UW)
15) Support biological data stewardship (E. Mayorga, UW)
16) Support a west-coast wide regional collaboration team project (J. Newton, UW)

2) Progress and Accomplishments

During the project period, NANOOS accomplished its objectives outlined above. NANOOS maintained the RCOOS subsystems it has developed, implemented, and integrated with NOAA IOOS funding and substantial external leverage. NANOOS remained focused on delivering data-based products and services that are easy to use to diverse stakeholders to address high-priority issues and aid decision making. NANOOS continued its proactive interactions and regional coordination with a wide range of PNW stakeholders, to prioritize and refine our observations, products, and outreach efforts as funding allowed.

NANOOS milestones for this award are provided in Table 1. Our assessment is that NANOOS has met these milestones for the reporting period. We report here progress for following: a) observing systems (shelf, estuaries, shorelines, and currents); b) modeling (estuaries and shelves); c) Data management and Communications (DMAC); d) User Products; e) Education and Outreach; and, f) Administrative.

Table 1. NANOOS Milestones for FY 19; Y4 specific milestones are in bold.

Area	**Y4 Award = Y13 NANOOS**
Observations	
Shelf:	-Maintain La Push buoy; deliver NRT data streams via NANOOS Visualization System (NVS) **-Support collection of OA data from La Push buoys with NOAA OAP funding** -Maintain Coos Bay buoy CB-06; deliver NRT data streams via NVS **-Support collection of OA data from CB-06 buoy with NOAA OAP funding** -Maintain Columbia R. buoy; deliver NRT data streams via NVS -Maintain N CA shelf glider transect; deliver data via NVS **-Re-establish Columbia glider; deliver data via NVS** **-Procure a glider for La Push operations** **-Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA** -Bring all data QA/QC to meet Certification standards
Estuaries:	-Maintain Puget Sound estuarine moorings; deliver data via NVS -Maintain US-Canada ferry-box; deliver data via NVS -Maintain Columbia R. estuarine moorings; deliver data via NVS -Maintain South Slough estuarine moorings; deliver data via NVS -Bring all data QA/QC to meet Certification standards

Shorelines:	-Maintain shoreline observations in WA; deliver data via NVS -Maintain shoreline observations in OR; deliver data via NVS -Maintain bathymetric observations in WA and OR; deliver data via NVS -Bring all data QA/QC to meet Certification standards
Currents:	-Maintain OR Priority-One HF radar sites to the national operations standard; deliver data via NVS and the National HF Radar system **- Fill gaps in HF Radar operations and maintenance by OSU to complete west coast coverage for health and safety** -Maintain X-band radar sites; deliver data via NVS -Bring all data QA/QC to meet Certification standards
Modeling	
OR/WA estuaries and coast models	-Maintain modeling & forecasting capabilities at UW; deliver model output via NVS -Maintain modeling & forecasting capabilities at OHSU; deliver model output via NVS -Maintain modeling & forecasting capabilities at OSU; deliver model output via NVS -Model verification and validation -**Support evaluation of LiveOcean in IOOS cloud sandbox**
DMAC	
Data Portal and Web Site Improvement	-Sustain & enhance existing data streams, IOOS web services, GTS submission -Sustain, refresh and enhance hardware and software environment; appropriate staffing; and operations documentation -Initial, limited implementation of NCEI data archiving, Glider DAC submission, QARTOD -Engage new local providers (not NANOOS funded), integrate their data into NVS and IOOS DMAC services, and assist with their data management & workflows -Strengthen DAC capabilities and resources through regional and thematic partnerships -Deploy ERDDAP to leverage web services, serve NANOOS applications and users -Sustain participation in IOOS DMAC community activities, including QARTOD development, semantic mapping, OGC WMS/WFS support, climatology data development, UGRID support, and shared code development and testing -Engage and leverage OOI and NSF EarthCube, international GOA-ON activities and Canadian collaborations -Engage West Coast and Pacific efforts, including WCGA and IPACOA -Improve ease of usability and user tracking capabilities -Develop and implement user customization and notification capability on NVS -Depth vs. time plots and multivariate plotting **-Enhance GOA-ON data portal an OA dashboard to the world** **-Enhance biological data stewardship within NANOOS** **-Support OceanHackWeek 2019**
Tailored Product Development	-Climatology, Tsunami Evac, Seacast, Surfer, and Beachview web app development -Tsunami mobile app re-build -With E&O committee, evaluate usefulness of web and product suite
Education and Outreach	

Networking	-Maintain existing and build new relationships to stakeholder user groups and the education community enabling NANOOS to achieve affective outreach, engagement, and education -Engage with regional formal education communities to use ocean observing and NANOOS products to support STEM education.
Product Development	-Work with DMAC and User Products Committee on tailored product development to meet specific user needs, as per above, and through Tri-Committee meetings; for each new product engage users in product development. -Evaluate website and product suite annually; interpret evaluation results with recommendations discussed at weekly Tri-Com tag-up calls
User Engagement	-Gain feedback and conduct self-assessment after product release. -Conduct trainings to broader user groups and evaluate trainings to optimize NANOOS help functions -Engage with regional non-formal education communities to facilitate the use of NANOOS products to engage citizens to increase their ocean literacy. -Maintain up-to-date success stories, employing effective use of social media -Be responsive to regional and local events (e.g., blooms, floods, etc.) to enhance relevancy to public and highlight regional stories with NANOOS members and partners. -Support national communication through IOOS Program Office and IOOS Association collaborations.
Administration	
Meetings	-Represent NANOOS at IOOS Program Office and IOOS Association meetings, and at national meetings of significance (e.g., Oceans 20xx, or bi-annual meetings of CERF and Ocean Sciences). -Engage at a regional level at meetings and workshops affecting PNW stakeholders and NANOOS. -Conduct annual GC meeting.
Project oversight	-Provide NANOOS with oversight, coordination, and management of the full suite of activities that comprise NANOOS. -Share project evaluation at the annual PI meeting.
Coordination	-Assure that NANOOS has transparent, effective, and representational governance via its Governing Council and the NANOOS Executive Committee composed of its elected Board and its functional committee chairs. -Assure these bodies are engaged in NANOOS prioritization of regional needs, work effort, and product development. -Assure balance of stakeholders represented in NANOOS reflects the diversity found in PNW. -Conduct annual all-PI meetings and Tri-Committee meetings, providing clear feedback and direction. -Coordinate with West Coast RAs and other RAs to optimize and leverage capabilities and assure consistencies. -Engage in sub-regional and user-group specific workshops to aid coordination and optimization of effort. **-Coordinate a west-coast wide regional collaboration team workshop with NOAA West**

Accountability	-Submit required IOOS progress reports and respond to other requests. -Comply with certification as a Regional Information Coordination Entity of US IOOS.

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

• ***Shelf***

***Washington Shelf Buoy Observations*:**

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

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

The Washington Coast buoy observation program, now led by Z. Szuts, Applied Physics Laboratory, University of Washington (APL-UW), continued to maintain and operate two real-time moorings 13miles NNW of La Push, Washington. The two summer moorings deployed on 20-22 May 2019 were successfully recovered on 27-28 Oct 2019, and winter Chaba was deployed on 27 Oct 2019. The fall cruise was on the R/V Pacific Storm out of OSU's Marine Mammal Institute; she was highly capable and will be even more effective for future work now that we have experience with her systems and crew.

The second deployment of the newly-designed winter surface mooring was this year. As last year, it has a reduced number of sensors to avoid loss or damage by winter storms, and most sensors record internally (SeaFET v2 at 45 m, SeaFET+CTD at surface and 85 m) except for a real-time pCO_2 and pH system from NOAA PMEL (Drs. Sutton, Alin and Feely). After the October cruise, a detailed CTD transect and OA/HAB water sampling was collected along the Strait of Juan de Fuca and up to Seattle. HAB sampling was coordinated with the Quileute Tribe through biologist J. Hagen, who participated on this cruise. Unfortunately, a mistake in the mooring geometry caused a deep shackle to break open under high wave conditions on Thanksgiving Day. An emergency recovery cruise on a fishing vessel out of Neah Bay succeeded in recovering the buoy and all scientific sensors two days later.

The two summer moorings worked well, with real-time data provided by the surface mooring until mid-August due to a problem with the control unit. The profiler on the subsurface mooring stopped at the beginning of August due to a worn drive wheel. Both faults have been diagnosed and software fixes or new components are in place for the next deployment. We continue to provide useful feedback to Seabird as a first-user of their new SeaFET v2 sensor, and provided one of the first records of deep pH at 85 m on the coast.

-Task 10a: Support collection of OA data from La Push buoys with NOAA OAP funding *[Szuts, Mickett, Newton]* We have continued to work with NOAA PMEL scientists Drs. Adrienne Sutton, Simone Alin, and Richard Feely, to maintain 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 over the entire reporting period. Newton, Mickett, and Szuts have also continued to work closely with both Olympic Coast National Marine Sanctuary and the Quileute Tribe in maintaining and operating the two moorings, with Quileute Marine Biologist J. Hagen participating on deployment cruises.

A summary of the 2018 observations collected by these moorings were submitted for inclusion in the

2018 Puget Sound Marine Waters Report.

- Task 10c: Support NOA-ON OA Mooring Test-beds *[Mickett, Newton]* To fulfill the need for verification data for the NOAA PMEL prototype mooring (Prawler), this work involves using NEMO-Subsurface McLane profiler data to compliment concurrently-deployed Prawler data and to evaluate and publish an assessment of high-frequency, depth-dependent variability of pH/carbon variables on the shelf, with implications to shelf ecology. The NEMO profiler data have been processed and will undergo further QA/QC before use for analysis.

Oregon Shelf Glider Observations:
-Maintain N CA shelf glider transect; deliver data via NVS [Barth]
-Bring all data QA/QC to meet Certification standards [Barth]
Starting in early December 2014, the Oregon State University glider research group has been obtaining vertical sections of ocean properties from off Trinidad Head, CA (41° 3.5'N) using an underwater glider. We use a 1000-m capable Seaglider equipped with the following sensors: CTD, dissolved oxygen (Aanderaa 4831 optode), light backscatter (700 nm), chlorophyll fluorescence and Colored Dissolved Organic Matter (CDOM) fluorescence (WET Labs Ecopuck). The gliders also measured depth-averaged velocity, which can be combined with geostrophic estimates of relative velocity to get absolute velocity and hence transport. The glider samples from approximately the 100-m isobath (~10km offshore) to 130W (~500 km offshore), repeating the line every 30 days. We collaborated with Dr. Eric Bjorkstedt (NOAA Southwest Fisheries Science Center, Humboldt State University) to facilitate fieldwork off Trinidad Head. We used two of our Seagliders in order to "hot swap" them on the line when their batteries run low. During this reporting period, this effort was jointly funded by NANOOS and CeNCOOS.

From its first occupation of the TH line on December 4, 2014, until the end of this reporting period (11/30/2019), the glider was on the TH line for 1594 days during eight deployments, sampled along approximately 29,104 km of track line covering the transect about 80 times, and collected about 12,800 vertical profiles of ocean properties. For the reporting period 6/1/2019 to 11/30/2019 the glider was on the TH line for 161 days during two deployments, sampled along nearly 2921 km of track line covering the transect about 7 times, and collected about 1303 vertical profiles of ocean properties. Glider uptime was 88% with one 27-day gap due to delayed delivery of a refurbished glider from the manufacturer. Data are being sent in near real-time to the IOOS Glider Data Acquisition Center and, simultaneously, to the CeNCOOS and NANOOS data centers. When an individual glider deployment is complete, we submit the data to NODC.

Data from the Trinidad Head glider line are being used to monitor the demise of the 2014-2017 "Warm Blob" and the 2018-2019 El Niño (Figure 1). Water at depth was warm during mid-2019, similar to the subsurface warming associated with the 2015-2016 El Niño (Figure 1). The much-reported upper-ocean temperature anomaly from later summer 2019 was very shallow and has dissipated with the advent of winter storms. Calculation of these temperature anomaly data is being automated and anomaly data delivered to both NANOOS and CeNCOOS for plotting alongside other glider data.

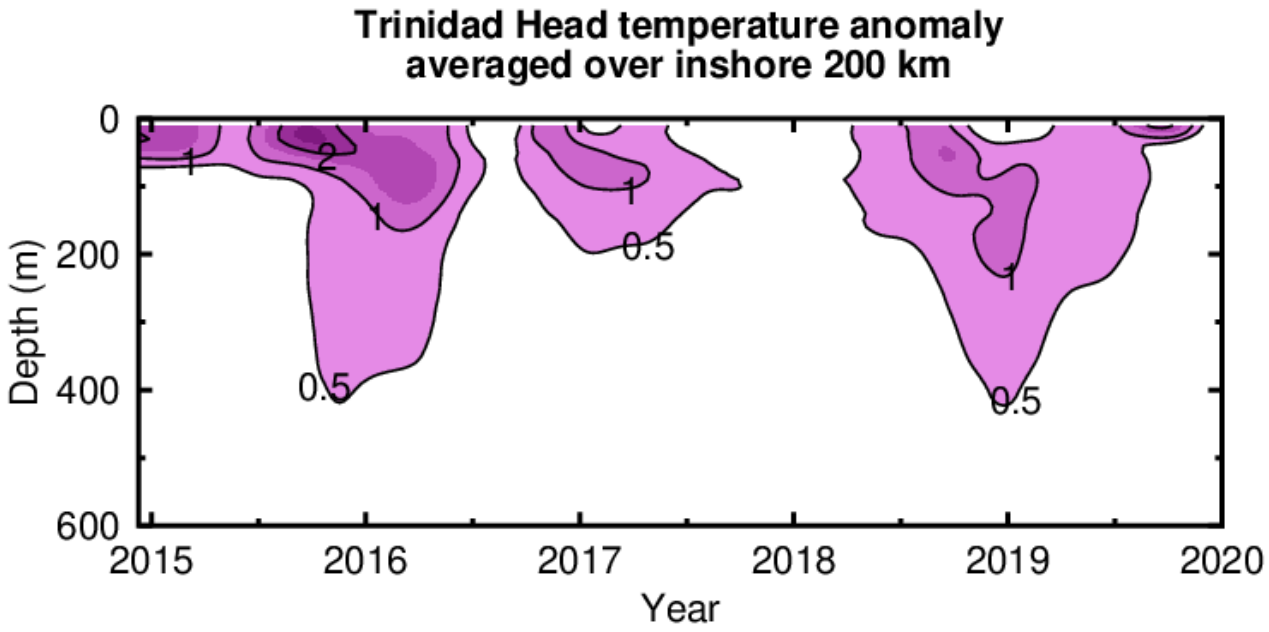

Figure 1: *Temperature anomaly from the Trinidad Head, CA (41° 3.5'N) glider line.*

-Re-establish Columbia glider; deliver data via NVS [Baptista]
We are in the process of re-establishing the capability to fly gliders off the Columbia River, in a mostly S/N transect in the Oregon/Washington continental shelf. The first mission is planned for spring 2020, and will be coordinated with the Quinault Indian Nation.

We will fly two existing gliders, in rotation, with each mission expected to last about a month. Existing instrumentation allows measurement of salinity, temperature, DO, chlorophyll, backscatter and CDOM. The calibration tank has been re-established at the OHSU MERTS Field Station, in Astoria.

Oregon Shelf Mooring Observations:
-Maintain Coos Bay buoy; deliver NRT data streams via NVS [Kosro, Hales]
-Bring all data QA/QC to meet Certification Standards [Kosro, Hales]
The Oregon shelf mooring, CB-06, was lost during a strong storm on April 6-7, 2019, possibly having been struck by a container vessel. Despite having three position reporting systems on board, the buoy did not transmit any updated locations, and no physical trace was found by ships or helicopter.

On Aug 3, 2019, the backup buoy was deployed nearby (43° 17.944 N, 124° 32.006 W) with a somewhat reduced instrument suite. Most notably, no ADCP was available for this deployment. Data have been gathered via cell transmission (physical and meteorological data) and satellite transmission (bio-geochemical data). Data are plotted in near-real time for the NANOOS Visualization System (NVS) and on a local server (http://bragg/CB06_Telemetry/Plots/). They were also forwarded to NDBC, which displayed them as buoy ID 46128. Buoy turnaround is anticipated in March 2020.

-Task 10b: Support collection of OA data from CB-06 buoy with NOAA OAP funding *[Hales]*
The buoy has survived several major wind events, including the notorious 'bomb cyclone' on

Thanksgiving weekend, where wind speeds exceeded 40 kts at the buoy. These events were associated with high-amplitude (~8m) short-period (<12 second) waves and presented a rigorous test of the buoy construction and anchoring system. During these conditions, an NDBC buoy off the northern CA coast was actually run over by a cargo vessel and destroyed.

The pCO_2 data appears robust throughout the interval, with summer values generally undersaturated with respect to the atmosphere, with a few brief instances of slightly supersaturated pCO_2 associated with upwelling source-water outcrops with high S and low T. O_2 data shows close coherence with pCO_2, as expected. Two late-season high pCO_2 events are apparent in the record, and appear to coincide with high wind events. This suggests fall-storm mixing of high CO_2 waters to the surface and significant off-gassing, which is a phenomenon we have not observed previously. pH data are of low quality with large noise apparent, but the broader trends suggest coherence with the pCO_2 data.

-Task 11a: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA
[Hales] Hales continued to work with Whiskey Creek Shellfish Hatchery to provide technical assistance to maintain the Burke-o-Lator and field-test the ACDC sensor. Hales offered significant assistance to the new installation at Hog Island's Humboldt Bay hatchery over the last year, trouble-shooting and training multiple on-site personnel. Similarly, Hales has provided significant assistance to the operation of the BoL at the Kodiak Fisheries lab and in the training of new personnel there. Hales is refurbishing the instrument formerly at Hog Island's Marshall grow-out facility, ultimately destined for a new location, possibly Cal Poly SLO. Hales is refurbishing the system from the Taylor Shellfish Hatchery at Quilcene to bring the fluidic systems up to state of the art. Hales is refurbishing the system formerly at SIO to be deployed at the Northwest Indian Fisheries Commission lab in Forks, Washington.

-Task 11b: Support OA observing as an aid to Pacific coast shellfish growers; deliver data to IPACOA
[Carter] Mr. Herndon continued to provide ongoing technical assistance for the Burke-o-lator seawater chemistry analytical system at Taylor Shellfish Hatchery. In addition, he provided technical support for deploying and maintaining an ACDC CO_2 sensor at a Puget Sound shellfish-growing location. Unfortunately, the actual deployment of the ACDC has been delayed by personnel turnover with project partners, who have not yet been able to supply the repaired sensors in support of the final stages of this technology transfer project.

Northern Oregon to Central Washington Shelf Observations:
-Maintain Columbia R. buoy; deliver NRT data streams via NVS [Baptista]
-Bring all data QA/QC to meet Certification standards [Baptista]
Led by PI A. Baptista, OHSU maintains observational assets in the Columbia River coastal margin. These assets are anchored on SATURN-02, a seasonal inter-disciplinary buoy, with real-time telemetry, located off the mouth of the Columbia River at ~35m depth. SATURN-02 data routinely contributes to model validation, capturing near-field Columbia River plume dynamics. Data also routinely offer local temporal context and for specialty buoy deployments and for cruises.

SATURN-02 was re-deployed on May 17, 2019, and recovered on November 8, 2019. Parameters measured are (a) wind speed, direction and gust, air temperature and atmospheric pressure; (b) water velocity; and (c) the scalar water parameters: temperature, salinity, dissolved oxygen/oxygen saturation, chlorophyll, turbidity, CDOM, phycoerythrin and nitrate. Scalar water measurements were made through single at-

surface sensors and a multi-level pumping system. Levels measured are 1, 6, 11, 16, 21 and 35m depth.

OHSU also deployed North Head, a temporary real-time buoy to support NOAA/USACE studies of the impact of dredged disposal on crabs. The station was deployed north of the Columbia River mouth on June 12, 2019. It came loose and was recovered after running ashore at Jetty A on September 26. Most instruments were recovered intact, having been adequately protected by the sheltering frame. Measurements included: (a) wind speed, direction and gust, air temperature and atmospheric pressure; and (b) scalar water parameters: temperature, salinity, dissolved oxygen/oxygen saturation, chlorophyll, and turbidity. Scalar water measurements were made with a set-up similar to SATURN-02, but only at three levels: 1, 6 and 14m below sea level.

Real time data from SATURN coastal stations are already being displayed on NVS. OHSU also provides access to SATURN long-term datasets via THREDDS, inclusive of a catalog summary—both essential building blocks to support the NVS display of long term datasets. Charles Seaton attended the October 2019 IOOS Hackathon, with the goal of advancing QARTOD flagging for real-time data.

- **Estuaries**

Puget Sound Buoy Observations:

-Maintain Puget Sound estuarine moorings; deliver data via NVS [Szuts]
-Bring all data QA/QC to meet Certification standards [Szuts]
Led by Z. Szuts, J. Mickett, and J. Newton, during this report period ORCA (Oceanic Remote Chemical Analyzer) mooring system continued to undergo significant refurbishment and upgrades, while the field team carried out regular maintenance and repairs to keep this real-time system operational.

Two of the ORCA buoys were swapped with new anchors and new-style surface hulls in June 2019, at Hoodsport and Hansville. The heavy bio-fouling on Hoodsport after 5 years in the water was responsible for the reduced buoyancy of the system. With these upgrades, most of the ORCA buoys have the same floats and mounting hardware which will greatly facilitate future upgrades. Most important is an extra through-hull tube for mounting SeaFET v2 sensors.

Upgrades to the ORCA system and lab protocols continued in this reporting period. The most important is a very thorough testing protocol for ground faults and the root cause of issues over the past few years traced to the power switcher. More complete diagnosis has led to upgraded protocols for making cables, caring for bulkhead connectors, and servicing the profiling winches (greasing and level-wind). Electronics upgrades (firmware, increased serial input ports, battery voltage testers) are making the system more robust, as well as improved mounts for batteries and controllers. Sea Lion fences are being put out on more buoys to prevent future damage - one field visit to Hoodsport saw 6 sea lions on the sitting on the buoy. A simpler mounting method for more powerful solar panels has been created, to be rolled out during the winter. The team has continued regular dives at each buoy to inspect them and anticipate pending failures, and also perhaps to work with SeaFET sensors mounted onto the mooring chain. One limitation on field activity the past 6 months was a lack of a dedicated small service vessel. A promising vessel was identified at the end of the reporting period. It is needed to efficiently support the many system upgrades that have been designed. The Bellingham Bay Buoy Se'lhaem which was added to this network last year, had one turn-around and has provided near full data up-time.

The buoys are close to being fully implemented with real-time pH measurements. We continue to beta test the SeaFET v2 sensor from Seabird Scientific. The data is being sent and plotted in real-time from 5 of the 7 moorings. A new software architecture on the server-side has been identified for supporting data archiving and quality control (QARTAD), and is being built incrementally with the pH data stream as a simple first case. For work with A. Sutton, S. Alin, and R. Feely (NOAA PMEL Carbon Group), we supported deploying pCO_2 systems on Twanoh and Dabob Bay, including water sample for system calibration. A project was continued to support a biofouling study on 3 buoys led by investigators at the Smithsonian Museum of Natural History. Data continue to be made available through NANOOS NVS and through the NWEM ORCA server. We have established a protocol of annual calibrations for CTDs and other sensors (dissolved oxygen, pH).

Washington State Estuarine Observations:

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

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

Led by C. Maloy and C. Krembs (WA State Department of Ecology), en-route ferry-based monitoring and moorings are two parts of Ecology's extensive long-term monitoring program that covers Puget Sound and the Washington coastal estuaries. Ferry monitoring complements Ecology's larger program by focusing on surface processes (e.g., temperature variations, frontal systems, tidal currents, blooms, river plumes, etc.). It also provides a means of continuously ground-truthing remote sensing techniques to greatly leverage and expand capabilities for Puget Sound environmental monitoring. Moorings were previously deployed to provide continuous information on estuarine water conditions and to complement Ecology's monthly marine water sampling. Since the moorings program ended, we also focus efforts on performing data quality control and conducting data analysis.

Due to staffing issues no work was conducted on this aspect during the reporting period. As the support provided by this award is partial, we expect to conduct sufficient work in the next period to meet our work plan.

Columbia River Estuarine Observations:

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

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

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

The NANOOS supported estuarine stations that are maintained on a permanent or seasonal basis are SATURN-01, SATURN-03, SATURN-04, SATURN-07, SATURN-09, CBNC3 and Elliot Point. All except CBNC3 have real-time telemetry. All but CBNC3 and Elliot Point (which currently only measure salinity and temperature) are inter-disciplinary (physics and biogeochemistry). Each of the stations is designed to capture specific features of the estuary. For illustration, Elliot Point captures the occasional extreme extent of upstream salinity intrusion in the estuary (Fig. 2).

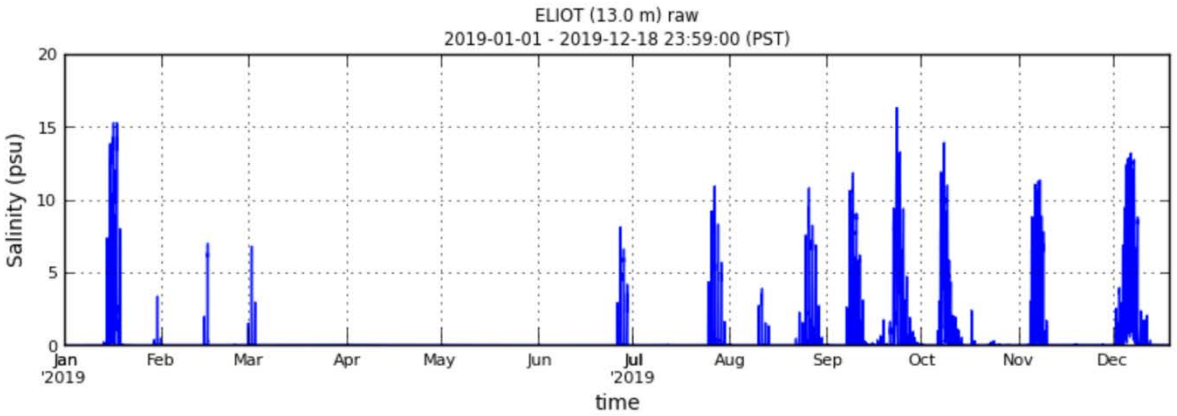

Figure 2: *Bottom salinity data at Elliot Point shows that salinity only occasionally reaches this station. Penetration of salt this deep in the estuary requires (not shown) a combination of low flows and neap tides. The station's data set constitutes a stringent test for numerical models, and is used for calibration and validation of the Virtual Columbia River. The data shown here is for 2019, but the station was re-established in 2017, complementing earlier deployments (2004-2008).*

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

Data from all real-time estuarine stations are already displayed on NVS. Data from stations without telemetry are not currently displayed on NVS, but are retroactively stored in national oceanographic archives. OHSU also provides access to SATURN long-term datasets via THREDDS, inclusive of a catalog summary—both essential building blocks to support the NVS display of long term datasets.
Charles Seaton attended the October 2019 IOOS Hackathon, with the goal of advancing QARTOD flagging for real-time data.

We are assisting NOAA/NOS in their planned major effort to conduct extensive deployments in the estuary to create tidal current predictions. We have provided data and documentation from select historical ADP deployments, which are currently being quality assessed by NOAA.

South Slough Estuarine Observations:

-Maintain South Slough estuarine moorings; deliver data via NVS [Helms]
-Bring all data QA/QC to meet Certification standards [Helms]
Oregon South Slough Participation by the Oregon Department of State Lands (ODSL) in NANOOS is led by A. Helms (Estuarine Monitoring Coordinator) and A. DeMarzo (Estuarine Monitoring Assistant) at the South Slough National Estuarine Research Reserve (SSNERR). South Slough NERR continued operation of a network of moored water quality observing stations as part of the NERRS System-Wide Monitoring Program with additional support provided by NANOOS. Four real-time water quality monitoring stations located along the salinity gradient of the South Slough estuary provided continuous water temperature, salinity, dissolved oxygen, pH, turbidity, and water level data over the period 06/01/19 –11/30/19. Telemetry transmissions were continuous for the Valino Island and Winchester Creek stations. The Charleston Bridge station collected continuous data but did not

transmit real-time data for the reporting period because the station was recently relocated and staff are planning for installation of a new data collection platform and telemetry equipment. The Elliot Creek station had a gap in telemetry transmission from 10/23/19 – 11/30/2019 that was fixed with replacement of the signal output adapter. Tom's Creek weather station stopped transmitting 10/14/19 – 11/30/19 and will resume with replacement of the transmitter. Monthly instrument deployment and retrievals, station maintenance, and data QA/QC, upload and management were completed for the weather and water quality stations during the reporting period following NOAA NERRS Centralized Data Management Office protocols.

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

South Slough expanded the network of water quality stations into the Coos estuary, which currently includes three stations located at Isthmus Slough, Catching Slough, and Coos River. The Reserve added pCO_2/ pH monitoring equipment at the Valino Island and Charleston Bridge water quality stations through Oregon State University collaboration and continued data collection and instrument maintenance through August 2019.

The South Slough water quality stations provide real-time data access for shellfish growers in South Slough, including North Bend and Coos Bay Oyster Companies, Clausen Oysters, and Qualman Oyster Farms. The South Slough Reserve and CTCLUSI stations provide environmental data for research, monitoring, and education programs conducted at the reserve. During this reporting period data from SWMP/NANOOS stations were incorporated into research and education projects at the Reserve, including long-term changes in water quality (water temp, salinity, turbidity, and DO) from three stations (Charleston Bridge, Valino Island, and Winchester Creek) to understand eelgrass declines in South Slough estuary and a NOAA Hollings Scholar project that used salinity and turbidity data for evaluating variability in salt marsh accretion rates. NANOOS Visualization System tools were presented for a Teachers on the Estuary Climate Workshop in June 2019 and an Estuarine Ecology class from Oregon State University in October 2019.

• **Shorelines**

Washington Shoreline Observations:

-Maintain shoreline observations in WA; deliver data via NVS [Kaminsky]

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

NANOOS funds contribute to the Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) led by G. Kaminsky. In June 2019, CMAP completed spring seasonal beach monitoring surveys in the Columbia River Littoral Cell (CRLC). Forty-six beach profiles and two surface maps were collected. During July-September 2019, CMAP conducted summer seasonal beach monitoring surveys in the CRLC, collecting 50 beach profiles, 14 surface maps, and 56 sediment samples from multiple cross-shore locations along 13 of the profiles. In addition, over 200 beach profiles were collected to extend the nearshore bathymetry profiles collected by the USGS and OSU using personal watercraft. Seasonal beach profile data and contour change plots are made available through the NANOOS Visualization System.

Also in June 2019, G. Kaminsky gave two presentations at the Coastal Hazards Resilience Network (CHRN) 2019 Annual Meeting in Tacoma, WA. The theme for the meeting was Coastal Flooding & Erosion, and over 60 persons participated from agencies, local governments, academics, Tribes, and non-profits affected by and involved in coastal hazards planning. G. Kaminsky presented on the Coastal Erosion Assessment for Grays Harbor County Hazard Mitigation and the Nature-Based Dynamic Revetment for Shoreline Stabilization at North Cove.

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 and September, CMAP collected 15 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 collected additional data around the Columbia River North and South Jetties for the Army Corps of Engineers during the summer. In July 2019, CMAP collected 14 supplemental profiles spaced at 50-m intervals north of the North Jetty at Benson Beach. South of the Columbia River, in Oregon, CMAP collected an extra surface map on Clatsop Spit in September 2019, as well as 7 beach profiles on the Spit, 4 south of the South Jetty, and 4 perpendicular to the South Jetty on the north side to capture the ridge-runnel morphology. The high rates of coastal erosion observed north of the North Jetty motivated the U.S. Army Corps of Engineers to place a record 85% of dredged material from the Mouth of the Columbia River placed in nearshore sites this year to help reduce the erosion rates.

CMAP continues to monitor the performance of the dynamic revetment at North Cove with funding from the Pacific County Conservation District. Beach topography surveys were conducted in June, August, and November 2019, where 52 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, individual rocks that were tagged in early 2019 with PIT tags were tracked during each survey. Additional rocks were tagged and placed in November 2019. CMAP also continues to collect seasonal beach profiles near Kalaloch at South Beach on the Olympic Peninsula. In October 2019, tagged cobbles were also placed on the beach to track their movement and compare with observations at North Cove.

Building from the success of the North Cove dynamic revetment project, the Washington State Department of Ecology and Department of Transportation successfully proposed and were awarded a grant from the National Fish & Wildlife Foundation to develop the final engineering designs and permitting for the construction of an innovative nature-based dune and cobble berm to restore and protect Graveyard Spit along the northern entrance to Willapa Bay, Washington. The project, The Graveyard Spit Dune Restoration and Community Resilience Project, is intended to halt the ongoing loss of the spit and the vulnerable back-barrier estuary and habitat, while also protecting community infrastructure that is threatened by coastal erosion and sea level rise.

Outside of the CRLC, CMAP performed a third boat-based laser scan in July 2019 of the shoreline at Edgewater Beach in South Puget Sound after the removal of 800 ft of shoreline armoring in 2016. Also in July 2019, CMAP worked with surveyors from the USGS to collect beach profiles at the Elwha River delta. In September 2019, CMAP conducted the first ever high-resolution topographic and bathymetric survey of Makah Bay on the northern Olympic Peninsula. Paired with a follow up survey next summer,

this data will help the Makah Tribe in managing their coastal resources and understanding shoreline change in the area.

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 collected in the Neskowin (15 sites) and Rockaway littoral cells (25 sites), as well as along Clatsop Spit (6 sites) this past summer (August/September 2019). In addition to transects, datum-based shorelines were also collected during the same beach monitoring campaigns. Beach profile data have been processed, QA/QC'd, and archived both locally and remotely. The reduced profile plots, change plots, and trends have been posted to the NANOOS beach and shoreline portal (http://nvs.nanoos.org/BeachMapping). As of late summer 2019, our monitoring data indicated that the suite of beach observation sites were within the typical summer range determined from 22 years of beach monitoring. This is an ideal state to be in given the transition to winter conditions, bringing with it generally above average wave and water level conditions that tend to promote beach and shoreline erosion.

Results of NANOOS beach change information were recently presented at a public meeting on coastal hazards held in Astoria, Oregon on November 15th. Technical advice on coastal hazards utilizing NANOOS information was also provided to Oregon State Parks to address erosion hazards developing along Siletz Spit from early fall storms.

Finally, having completed our summer surveys, our ATV was scheduled in October to have its engine (15 years old) replaced. This was necessary since the ATV is important for safe and efficient travel on Oregon's sand beaches when transiting between transects and for operations in the intertidal zone, and is thus essential for maintaining continuity of operations.

***Nearshore Bathymetry Observations*:**
-Maintain bathymetric observations in WA and OR; deliver data via NVS [Ruggiero]
-Bring all data QA/QC to meet Certification standards [Ruggiero]
P. Ruggiero's group at Oregon State University 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 2019 extending from the lower inter-tidal to ~12 m of water depth (~2000 m from the shoreline). Approximately 400 kilometers of nearshore mapping took place within 10 days of field data collection. These data have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. In all cases, these nearshore bathymetry measurements have been combined with topographic measurement collected by Ecology developing complete maps of the nearshore planform.

Following our 2018 data collection efforts, Ruggiero's group continued to collect nearshore bathymetry in the Newport area during summer 2019. This data is being used, among other applications, to ground-truth the radar derived bathymetry products that PI Haller's group is developing in the region.

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

• **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 HFRNet Performance metric for the 2 main reporting quarters (Q4FY2019 and Q1FY2020) of 73% and 92% respectively (https://hfrnet.ucsd.edu/diagnostics), or 83% for the full FY2019 (tied for third highest in the national system). This exceeds the target figure of 80%. The biggest outage comes from our MAN1 site, which was struck by lightning with large losses of equipment. A self-insurance claim to OSU is pending.

We have purchased and set up replacement field-site computers capable of running the Mojave OS and Release 8 acquisition software; some technical glitches are being solved in collaboration with Codar. The heads-up display has been modified to add new watched variables. Reprocessing has been ongoing to eliminate interference in some long-range data sets. Anne is continuing to train Erik on data processing and archival tasks. Erik tracked down the source of site outages at SEA1, identifying the EMI filter circuit which can short to ground and trip the GCFI. Failure in the same board at WSH1 caused an outage which was diagnosed and repaired. Power loss at the site shelter for YHL1 was repaired by the BLM after consultation with us. Data outages at PSG1 were solved with an update to the AWG firmware. Erik's use of Raspberry Pi's for power monitoring and alerting of power outages has been quite valuable. Replacement of the fences at MAN1 was completed, and removal of the lightning-damaged cables is nearly finished.

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

Work is continuing on permission to install a long-range HF at Westport State Park in Washington State. Forms are being coordinated between IOOS, Washington State Parks, and UW Real Estate. This work has benefitted greatly from the participation of Paul Rudell, NANOOS Operations Coordinator (UW/APL). One roadblock is the uncertainty about licensing through the FCC for the new ITU frequencies; this is to be done in coordination with the new IOOS frequency allocation consultants.

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.

This summer we completed a comparison of radar-derived bathymetry estimates (using the cBathy algorithm) with ground-truth surveys by Peter Ruggiero's group as well as with a 2015 NCEI digital elevation model. Figure 3, left, shows the radar-derived cBathy estimate alongside the 2015 DEM. Figure 3, right, shows the difference between each survey transect by P. Ruggiero's team with the cBathy estimate and the DEM. The white areas along transects indicate better agreement between the bathymetry dataset and the survey. Overall, the RMSE of the DEM is 1.06m while the RMSE of the radar-derived estimate is 0.86m. From this data we made the following observations:

- The radar-derived estimate had low errors in the region nearest and just north of the radar (the radar is located near the base of the north jetty of the inlet).
- Accuracy of the radar-derived estimates degrades at large alongshore distances from the radar where waves are traveling oblique to the radar look direction.
- The radar-derived estimate had overall much lower errors in the vicinity of the Newport bar (just west of the jetties). This may be in part due to the age of the DEM as that area is dredged frequently.

This September (2019) we once again performed survey transects. We look forward to performing another comparison with this data and evaluating how the radar is able to resolve temporal changes in the bathymetry.

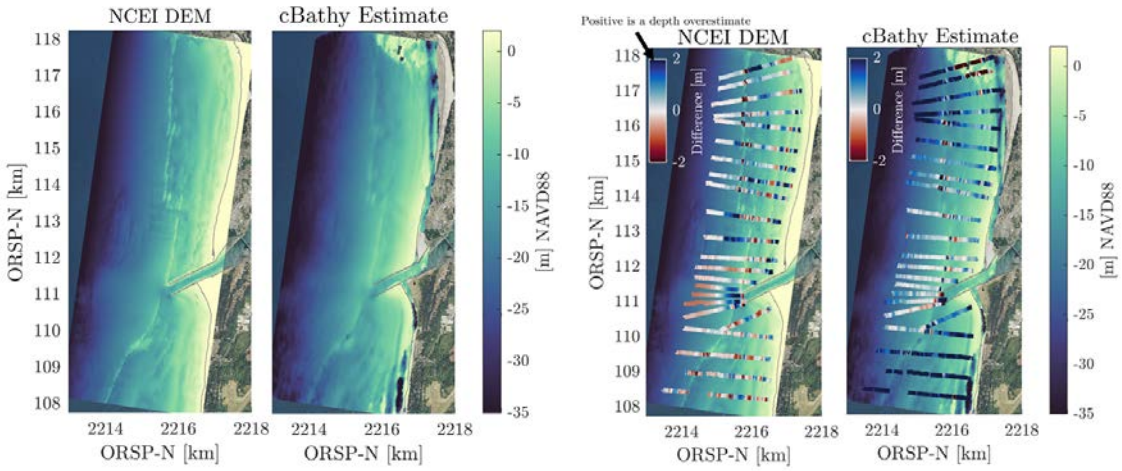

Figure 3. *Left panel: Bathymetry from 2015 NCEI DEM and 2018 radar-derived. Right panel: Same data as left panel with differences from 2018 jet ski survey shown as colored transects.*

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

Shelf Modeling:

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

-Model verification and validation [Kurapov]

Computer circulation modeling and forecasting of PNW coastal ocean shelf conditions has been

conducted by A. Kurapov's group at OSU. The system utilizes the Regional Ocean Modeling System (ROMS) as the forecast model. Along-track altimetry observations from Jason-2, CryoSat, and Altika, hourly GOES SST, and surface currents from land-based high-frequency (HF) radars have been assimilated to improve initial conditions for the forecasts, using the assimilation system developed at OSU. Results are provided to fishermen and public via the NANOOS Visualization System, e.g., as the Tuna Forecast and SeaCast applications. Via the OpenDAP server, forecast currents are also provided to the NOAA Office of Response and Restoration Lab in Seattle, where they can be used with the tools for oil spill mitigation. The OpenDAP link provides access to the real-time fields by the Cyberinfrastructure group of the IOOS-sponsored Coastal Ocean Modeling Testbed (COMT) project.

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

Shelf and Salish Sea Modeling:

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

-Model development, verification and validation [MacCready]

NANOOS PI P. MacCready (UW School of Oceanography), working with Drs. Siedlecki (Univ. Of Connecticut), McCabe (UW Joint Institute for the Study of Atmosphere and Ocean), and Banas (U. Of Strathclyde) run a pre-operational forecast model, called LiveOcean, of ocean circulation in Puget Sound and adjacent coastal waters. The model has 500 m horizontal grid size in the Salish Sea and coastal estuaries and 45 rivers. In the past six months a new 100 m nested sub-model covering the San Juan Islands was added to the daily forecast system; Figure 4 shows a recent forecast from this nested model.

Extensive model validation and movies of the daily forecast focused on different stakeholders are presented at: http://faculty.washington.edu/pmacc/LO/LiveOcean.html. Model fields are available through NANOOS NVS. The model fields are also made available through the NOAA IOOS EDS system, and are used as open boundary conditions by Dr. Susan Allen at UBC and Co-PI Baptista for their forecast systems. NANOOS also supported salary for Dr. MacCready's system administrator, David Darr, who oversees computer operations and assists with the gathering and archiving of model atmospheric fields from Dr. Cliff Mass (UW). The forecast work is also supported by a grant of state funds made through the Washington Ocean Acidification Center (WOAC), and by ONR, greatly accelerating the work and leveraging the impact of NANOOS funds. During this past six months, in addition to the model development, MacCready gave two outreach talks and a podcast interview. MacCready is a member of the NOAA West Coast Ocean Forecast System Technical Working Group, and this model is a candidate for nesting inside of the NOAA operational models of the California Current that are being developed. The model system is being used in the NOAA-funded MERHAB PNW project to make short-term forecasts of when *Pseudo-nitzschia* HABs may reach WA beaches.

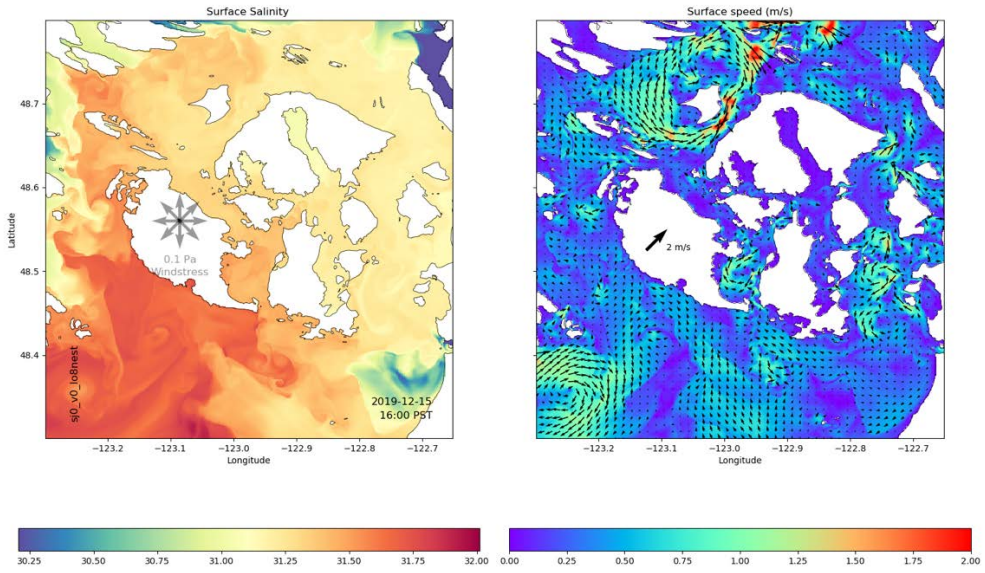

Figure 4. *Surface salinity (left) and current speed (right) from the 100 m LiveOcean nested sub-model forecast for the San Juan Islands. This model was used extensively by grad students at a summer school taught July-August 2019 at Friday Harbor Labs by MacCready.*

-Task 13: Support evaluation of LiveOcean in IOOS cloud sandbox [MacCready]
In the past six months MacCready and Darr worked with Tiffany Vance (NOAA) and Patrick Tripp (RPS, a consulting company contracted by NOAA) to port the LiveOcean system to a cloud computing platform. The goal is to evaluate whether or not cloud computing is a cheaper, more reliable, more flexible alternative to PI-based forecast computing. We decided that the intense parallel computing needed by LiveOcean and other forecast models was the key capability to evaluate. We successfully set up the LiveOcean ROMS configuration on the AWS cloud and ran a handful of benchmarks. The performance was comparable to that achieved on the UW supercomputer cluster that MacCready uses, so that was a success. The next steps are to port to AWS the other parts of the LiveOcean system, the pre- and post-processing that go into making a forecast.

Columbia River Modeling:

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

-Model verification and validation [Baptista]

Led by PI A. Baptista, OHSU maintains an extensive modeling system for the Columbia River coastal margin, denoted Virtual Columbia River (VCR). The VCR has evolved from multi-institutional collaborations involving modelers and non-modelers, in academia and across regional, federal, and tribal agencies. The modeling capabilities of the VCR has assisted the region in the study of salmon life cycle, habitat, estuarine pathways, and status under the Endangered Species Act and in relation to hydropower management and climate change (see previous NANOOS reports). They are currently assisting FEMA in creating storm surge flooding maps for Clatsop County, in the lower estuary.

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

To meet the challenges that the highly energetic and strongly stratified Columbia River estuary and plume pose to numerical models, we have experimented with—and contrasted among—multiple codes (Thetis, SLIM, SELFE and SCHISM) representing different classes of unstructured-grid finite element methods.

After extensive calibration of SCHISM for the Columbia River, heavily reliant on the SATURN observation stations, we are developing a new simulation database (1999-2019) that reflects newly optimized parameters. Partial results were presented as keynote address at a workshop in Lisbon (Baptista 2019).

We also continued developing an Individual Based Model (with hydraulic transport swimming and growth modules) to help regional stakeholders understand the use of the estuary by juvenile salmon. This effort is collaborative with the NOAA Northwest Fisheries Science Center, and is at the core of an ongoing PhD thesis research at OHSU (K. Morrice). Morrice was recently awarded a Knauss Fellowship, which she will start at the Department of Energy in February 2020.

c) Data Management and Communications (DMAC) Subsystem:

See table for milestones [Mayorga]

Chaired by E. Mayorga (APL-UW), this committee is composed of members from CMOP-OHSU, DOGAMI, OSU and UW. The DMAC and User Products (UPC) teams work in an integrated fashion on the prioritization, development and evaluation of data services and user products. NANOOS is also an active collaborator in national IOOS DMAC efforts.

Open Data Sharing: With few exceptions, all IOOS-funded observations and model output are already available for public access via the NANOOS Visualization System (NVS), which in addition to data browsing and visualization incorporates custom, machine-readable data services. Most of these data streams are also made available freely and via machine-readable, IOOS-registered, IOOS-recommended services, as described in other sections below.

NANOOS also invests substantial efforts engaging (serving as clearinghouse) non IOOS-supported local and regional data providers, including Canadian ones, to integrate and redistribute their data streams, particularly via NVS. In CY2019 the Baynes Sound Mooring (Salish Sea) from Ocean Networks Canada (ONC) was integrated into NVS, after a substantial expansion of the NANOOS data ingest capabilities for data from the ONC API. A new partnership between NANOOS, SeaGrant, commercial fishermen in Newport, OR, and OSU, led to the deployment of a new monitoring station in Newport (Yaquina Bay) to support Crab fishers, with near-real-time integration into NVS. During the seasonal redeployment of the WA Department of Health networks of temperature-salinity stations, a new station (Kilisut Harbor) was integrated into NVS. Finally, close collaboration with personnel from the Ocean Observatories Initiative (OOI) Coastal Endurance Array resulted in the deployment of a new, much more capable NVS data ingest mechanism for these platforms via an intermediary ERDDAP server hosted by NANOOS at OSU, thus providing more reliable access to a greater number of sensor types; we also made substantial progress towards the integration of OOI Coastal Endurance gliders into NVS. These new data streams are also made available via machine-readable, IOOS-registered, IOOS-recommended services, except where

restrictions from providers exist or have not been clarified, as with OOI.

The climatology work that NANOOS has been supporting was enhanced in CY2019 via new code to download and process complete time series and create climatologies and anomalies for NDBC, CMAN, NOS and CDIP stations. These NANOOS products from OSU (C. Risien) are now accessible via dynamic charts on the NVS Climatology App, and are also available on the new NANOOS ERDDAP server (see below). Another NANOOS product that was enhanced in support of NVS functionality is an OHSU-CMOP particle-tracking engine (C. Seaton) from the SELFE model. Web services were enhanced to support integration into NVS via JSON data and image tile responses.

Data management planning and coordination: As documented in other sections, NANOOS: Enables open data sharing, Offers data in approved common data formats, Provides data feeds to GTS, Implements a service oriented architecture, Implements ontologies, controlled vocabularies and identifiers, Implements metadata standards and metadata management and query capabilities, Provides this information to the IOOS Catalog, and Ensures local storage and offsite, permanent archiving of data at approved facilities.

NANOOS has continually improved its data management and coordination capabilities. Important discussion of problems, new capabilities, and standard operations both among the distributed NANOOS DMAC team and between the team and IOOS and related staff commonly take place on the NANOOS presence on GitHub, http://github.com/nanoos-pnw, and on relevant IOOS GitHub repositories. In CY2019, procedure automation and ongoing improvements included server software updates and continued expansion of a Sphinx-based DMAC documentation system for internal use, as well as server hardware upgrades at UW and OSU. We also made progress with QARTOD implementation testing, with an anticipated initial implementation in early 2020.

In early July, NANOOS submitted to the IOOS Program Office its Data Management Plan (DMP) following the NOAA EDMC DMP Template.

NANOOS DMAC Lead E. Mayorga attended the 2019 IOOS DMAC coordination meeting. NANOOS DMAC also actively engaged overlapping communities, including the Ocean Acidification monitoring community (from cross-regional to national and global), the West Coast Ocean Data Portal (WCODP), and NSF-supported Cyberinfrastructure initiatives, including EarthCube, CUAHSI and particularly OOI. As described above, engagement with the OOI Coastal Endurance Array team led to more robust and deeper data integration into NVS (ongoing), and usability feedback and IOOS DMAC guidance to OOI. Canadian engagement focused on ONC, including participation in the ONC International Science Advisory Board, overhaul of the ONC data ingest, and feedback to ONC on their API. Mayorga also contributed to regional geospatial data activities, including the Puget Sound Spatial Data Coordination Workshop (October), NOAA Regional Data Sharing Network Meeting (November), and West Coast Ocean Data Workshop (December). In addition, Mayorga was one of the co-organizers of OceanHackWeek 2019 in August in Seattle (https://oceanhackweek.github.io), which featured a strong IOOS presence and was co-sponsored by IOOS and NSF. In October, Mayorga and C. Seaton (OHSU-CMOP) participated in the IOOS Code Sprint, contributing to sessions on QARTOD implementation, biological data, and others.

Provision of data to the Global Telecommunication System (GTS): NANOOS makes all its IOOS-supported, near-real-time observing data streams available to the GTS via NDBC (for fixed in situ assets) and the Glider DAC. We plan to extend this capability to non-RA stations operated by local providers in 2020, as an opt-in service contingent on provider engagement.

Data access services: NANOOS serves observing and modeled data via IOOS recommended services. These include two THREDDS server and one Hyrax server for model output, historical observing data and data synthesis products (Hyrax server provides model output only); and an IOOS 52North SOS server for recent and near-real-time fixed-location observing data. These services are registered with the IOOS Registry. System improvements in CY 2019 focused on development of a new public ERDDAP instance (http://data.nanoos.org/erddap/index.html, released in late November and now registered with the IOOS Catalog) initially serving 111 datasets including NANOOS gliders from three transects, NANOOS-processed time series, and climatologies from NDBC, CMAN, NOS and CDIP, and NANOOS-originated remote sensing products. An additional NANOOS ERDDAP server hosted at OSU is providing an increasing number of datasets primarily for internal NANOOS use, including a comprehensive set of datasets from the OOI Coastal Endurance Array. Glider and HFR data are distributed via IOOS supported thematic DACs. In addition, NANOOS hosts standard-compliant OGC WMS and WFS services via GeoServer.

Catalog registration: Four NANOOS WAFs (Web Accessible Folders) at http://data.nanoos.org/metadata/ host metadata records registered at https://registry.ioos.us, including a new WAF for records from the new NANOOS ERDDAP. These WAFs currently provide 154 metadata records to the IOOS Catalog (https://data.ioos.us/organization/nanoos). The extent, comprehensiveness and currency of these records continues to be refined and expanded to match IOOS catalog capabilities. In addition to these IOOS Catalog records provided directly by NANOOS, 25 additional metadata records with a NANOOS tag are also available in the Catalog at https://data.ioos.us/dataset?q=NANOOS, and 54 NANOOS Glider DAC records are found in the Catalog but are not properly attributed to NANOOS.

Common data formats: All data served by NANOOS via IOOS recommended services (see #4) are provided via IOOS recommended data formats, including IOOS SOS SWE and NetCDF-CF. Similarly, such formats are also used in data submitted via thematic DACs (Glider DAC and HFR DAC) and to NCEI.

Metadata standards: All metadata served by NANOOS via IOOS recommended services (see #4) are also provided via IOOS recommended metadata formats, including IOOS SOS SensorML (Network and Station), NetCDF-CF ACDD, and ISO 19115-2. The quality and extent of the metadata content are under regular revision, as areas of improvement are identified, particularly via engagement with IOOS.

Storage and archiving: NANOOS continued to submit data for NCEI archiving from the NANOOS-supported OHSU-CMOP SATURN network. The NANOOS DAC automatically stages monthly incremental archive updates on the 10th of the month at http://data.nanoos.org/ncei/ohsucmop/, and these are pulled by NCEI by the 15th of the month. Archival files are in the NCEI NetCDF Templates v2.0 format and follow ACDD and CF conventions. In CY2019, the metadata conventions, file segmentation and archival procedures developed for this NANOOS dataset were compiled into an internal document that will be used for application in 2019 and 2020 to other NANOOS in-situ datasets. Archiving plans and expectations were discussed with NANOOS monitoring platform operators at the annual NANOOS PI

meeting in August 2019. We continued internal work and communication with NCEI regarding the archiving of an ongoing nearshore elevation profile data from Oregon, now spanning approximately 15 years. This communication was initiated in CY2018, but we have experienced substantial, repeated delays due to non-responsiveness by NCEI, which we have discussed with the IOOS Program Office. We have also started internal preparations and designs for archiving sensor data from NANOOS moorings in the Washington shelf and the Salish Sea. In addition, all CY 2019 IOOS supported glider data from NANOOS were archived with NCEI via submission to the Glider DAC. Data from the operational OSU Trinidad Head Glider are submitted to the DAC by CeNCOOS, as part of a collaboration with NANOOS that supports and co-funds this glider.

Ontologies, vocabularies, common identifiers: NANOOS makes comprehensive use of IOOS recommended ontologies and vocabularies in all its hosted, IOOS recommended services and metadata. IOOS recommended identifiers (urn's, as well as WMO/NWS ID's when available) are used in the NANOOS SOS service and ERDDAP server.

-Task 12: Enhance GOA-ON data portal an OA dashboard to the world [Mayorga, Tanner, Newton]
The GOA-ON data portal received important enhancements in both coverage and capabilities. New near-real-time data sources were integrated, particularly the U.S. Ocean Observatories Initiative (OOI) Coastal Endurance Array moorings and benthic platforms in the Pacific NW, and a network monitoring platforms in Chile. The capability to support the United Nations Sustainable Development Goal (SDG) Target 14.3, focused on ocean acidification, was scoped, developed and tested as a new data portal App, to be released once SDG information becomes available. Finally, work was greatly advanced to include in the asset inventory presentation the set of Biogeochemical Argo floats that have pH sensors, together with the path they have followed since deployment; this addition will be released in 2020.

-Task 14: Support OceanHackWeek 2019 [Mayorga]
OceanHackWeek (https://oceanhackweek.github.io) is a learning hackathon aimed at exploring, creating and promoting effective computation and analysis workflows for large and complex oceanographic data. The University of Washington event took place August 26-30, and was co-organized by a group of ten scientists and data specialists from the UW and other institutions, with support from IOOS and the National Science Foundation. NANOOS DMAC Lead E. Mayorga was a co-organizer and presented tutorials on data access from IOOS resources, Argo floats and NASA satellites. The event brought together over 50 participants from across the country and abroad, focused on early career scientists including graduate students, postdoctoral associates and later-stage scientists. A similar OceanHackWeek event is being planned for 2020.

-Task 15: Enhance biological data stewardship within NANOOS [Mayorga]
NANOOS is actively working to advance the integration of biological data into its products and the delivery of regional biological data to national IOOS networks, including the Marine Biodiversity Observation Network (MBON) and the international Ocean Biogeographic Information System (OBIS). This is being done through engagement with regional partners to identify and prioritize a set of important biological survey and measurements datasets that can be reprocessed and standardized for delivery and integration into these systems; and development of internal capacity for handling biological data. To these ends, DMAC staff contributed to the biological data sessions at the recent IOOS Code Sprint and is participating in new and emerging biological data projects in the region.

d) User Products Committee (UPC):

See table for milestones [Allan]

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

Chaired by J. Allan (DOGAMI) this committee is composed of members from OHSU, UW, OSU, NANOOS E&O, OR Sea Grant, and NOAA. NANOOS UPC chair Allan participates in weekly "tag-up" calls with a smaller sub-group comprised of members from DMAC, UPC, E&O, and Web development to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this 2019 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; 2) Attendance at the annual NANOOS governing council and all PI meeting on August 1-2, 2019; 3) helped co-author an NVS review paper that was presented at the Oceans19 meeting; 4) updated various matlab codes for downloading, processing and plotting NDBC, CDIP, C-MAN and NOS time-series data for inclusion in the climatology app; 5) commenced work to update the bathymetric contour overlay that is included in the NVS Tuna Fisher app.

NVS: The backbone of the NANOOS RCOOS is the NANOOS Visualization System (NVS) that currently distributes data from a myriad of regional and federal assets. During this period, NANOOS released one major update. V6.3 released in June, which included the following: 1) a major enhancement to NVS, namely the ability to click anywhere in the NANOOS region and be able to visualize time series information for the selected model parameter; 2) when selecting model or satellite overlay and data is not available for the current time, the user is prompted with a request for NVS to automatically move to the nearest time period when data is available. If a user has a myNANOOS account, the prompt is saved to the user's settings so that when they return they don't have to check the prompt again the next time they use NVS; 3) minor updates and functionality were added to the NVS Boaters app.

During this period work commenced to build an integrated plotting tool that would be included in the Climatology web app (http://nvs.nanoos.org/Climatology), the goal being to eventually replace the existing static time-series plots that have been part of the app since its inception. In order to build this capability, the complete time-series for each of the NDBC, CDIP, C-Man, and NOS stations had to be written to netcdf format, along with the parameter climatologies, and made available to NVS through the NANOOS ERDDAP server (see latest DMAC report). Additional code had to be developed to take the netcdf data and convert it to JSON format in order for it to be plotted. The final step was to build the integrated plotting functionality in NVS. For the latter we use capabilities developed through Highcharts (https://www.highcharts.com/). Figure 5 displays the current Climatology app.

With the completion of the plotting functionality, the user is now able to selectively turn on/off time-series information (for any given year of data) to meet their needs and interests; additional functionality included adding the ability to turn on/off the parameter climatologies. Furthermore, as a user scrolls across the time series, a data tip pops up displaying the parameter value, date, and time of

measurement. Other functionality included the ability to change the color scheme used to plot the time-series, output the data in csv form, and generate a static plot for inclusion in presentations or documents (Figure 6). Finally, updates were implemented for the various climatology model overlays and climate indices.

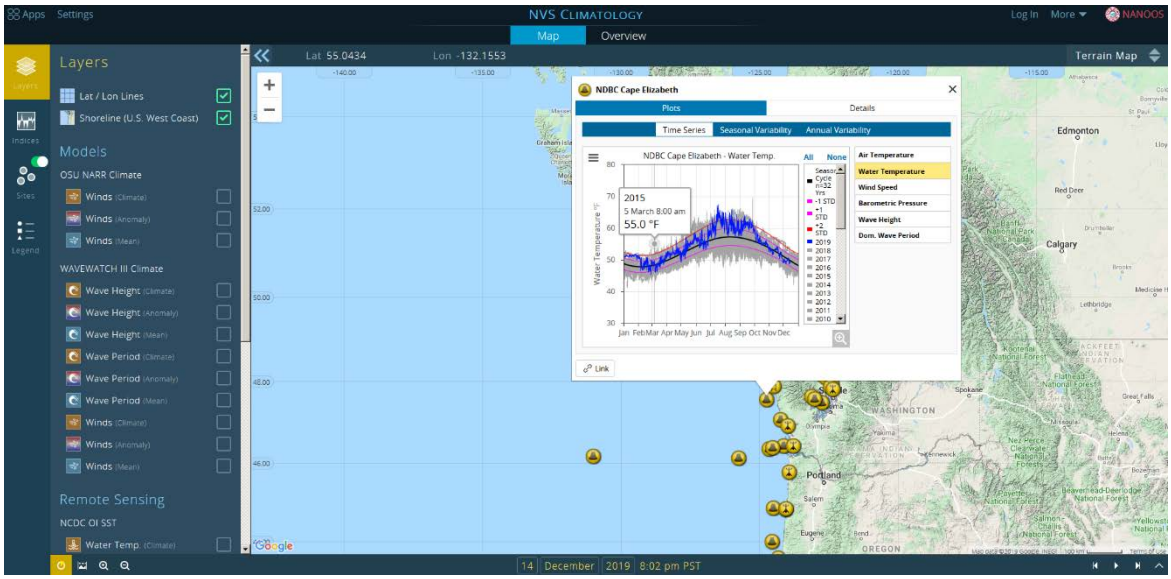

Figure 5. *NVS Climatology app showing the recently completed Highcharts plotting functionality now used to depict time-series information for various assets.*

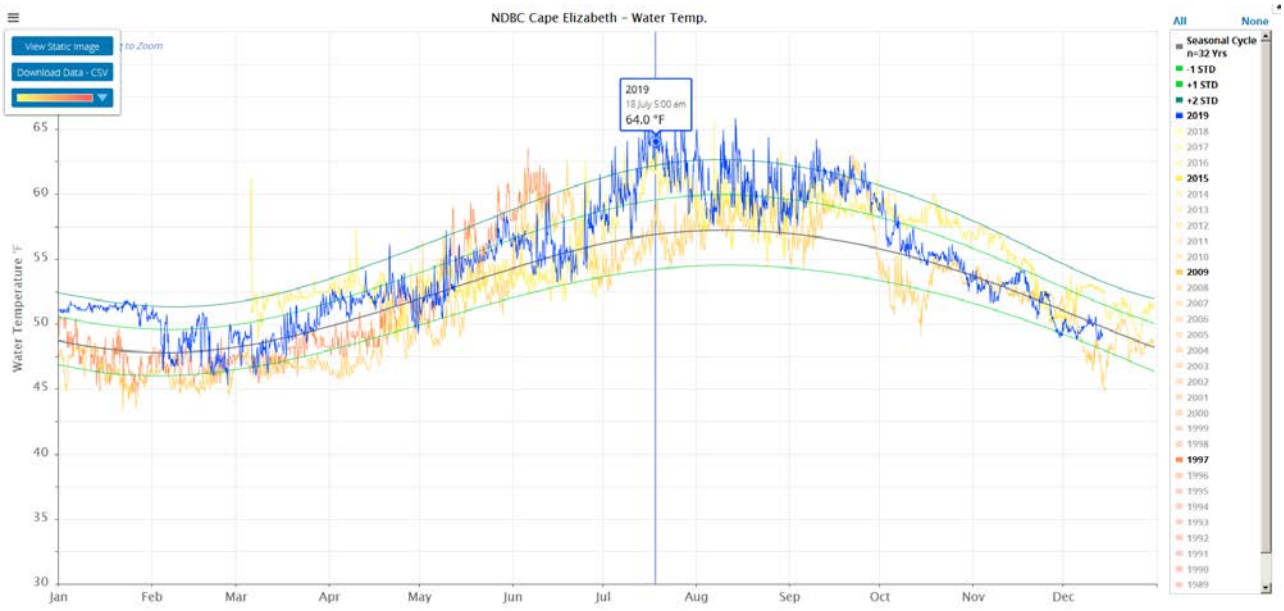

Figure 6. *NVS Climatology app showing the data tips, ability to change color schema, and select discrete years of interest.*

During this period, minor work continued on the particle tracking capability under development for eventual inclusion in NVS.

NVS Mobile App: NANOOS released a minor update to the TsunamiEvac mobile phone app to bring it in line with updates implemented in to the web app.

e)**NANOOS Education and Outreach Subsystem:**

See table for milestones [Wold, Rudell, Newton]

NANOOS Education and Outreach efforts focused on growing NANOOS' audience of engaged citizens, promoting and facilitating the use of ocean observing data and increasing ocean literacy in our region. These efforts were largely completed by NANOOS staff Newton, Wold, and Rudell, with support from DMAC and UPC subsystems and many NANOOS member collaborators. Newton, Wold, and Rudell were active members of the weekly DMAC/UPC tag-up conference calls, regularly providing support and feedback on UPC and DMAC developments. Rudell and Wold continued participation with IOOS E&O calls as they occur.

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

- For the ninth year, NANOOS E&O partnered with WA Sea Grant to provide equipment and instructional support to the NOAA Science Camp's Junior Leadership Program's research project.
- 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 two separate classes (June 2019 and Oct 2019), students designed, built, and deployed buoys at the Langley Marina then retrieved and analyzed their data.

Summary of Outreach Accomplishments: NANOOS outreach efforts have been focused on engaging with target user groups, including shellfish growers, boaters, and scientists, improving, and updating the content on the NANOOS web portal, and energizing social media outreach efforts.

- Rudell represented NANOOS on 22 June with an exhibit table and a presentation at the Ilwaco Tuna Club, Ilwaco, WA, to promote the NVS Tuna Fishers App, Seacast App, and to engage with the Washington and Oregon fishing communities.
- NANOOS had an exhibit table during the Pacific Coast Shellfish Growers Annual Conference in Portland, OR, 16-19 September; Rudell demonstrated and gathered feedback on NVS applications, including the NVS Shellfish Growers application.
- Rudell and Wold continued to update content on the NANOOS portal.
- NANOOS maintained Facebook and Twitter accounts, each with growing audiences. NANOOS also has a growing audience for its bimonthly newsletter, the "NANOOS Observer."

f) **NANOOS Administration:**

See table for milestones [Newton]

J. Newton (NANOOS Executive Director) and D. Martin (NANOOS Board Chair) continued to provide leadership to NANOOS operations and connection to the US IOOS enterprise. They and M. Kosro

(NANOOS Board Vice Chair) participate in IOOS Program Office and IOOS Association calls. Newton is a member of the IOOS Association Executive Committee and participated in their teleconferences during the period. Newton participated in weekly Tri-Comm calls. Key events for this period included:

- Newton and Martin led the annual NANOOS PI meeting and the annual NANOOS Governing Council meeting over 1-2 August, at the Washington State University – Vancouver campus. Newton led the PI meeting discussions and Martin served as Chair of the NANOOS Board during the GC meeting. This year, IOOS Deputy Director Krisa Arzayus and IOOS Association Director Josie Quintrell joined us. Over 35 attendees from diverse NANOOS member institutions were present to review progress to date as well as plans for the upcoming year. PIs stayed on for a second half-day to discuss and present observing and modeling results and issues.
- New members of the NANOOS Governing Council include WeatherFlow and the Oceans Blue Corp. The NANOOS Executive Council has no current vacancies.

Additional coordination and representation included:

- Newton attended the IOOS RA and Program Office Leadership Retreat on 23-24 July, in San Francisco, CA. Additionally, Newton served on the IOOS Association Executive Committee and attended IOOS Program and IOOS Association calls as available.
- Newton contributed NANOOS updates on oceanographic conditions in the Pacific Northwest for the NOAA WestWatch webinar series on September 10, along with the other two west coast RAs, and a similar but local-scale Salish Sea Marine Conditions webinar on 27 June, 22 August, and 24 October.
- Newton was a Program Committee member for the OceanObs'19 Conference that was held in Honolulu, HI, on 16-20 September 2019. Over the period, she participated in several teleconference calls and a site visit in May 2019, with follow-on meetings with PacIOOS and the Western Pacific Fisheries Council for coordination to develop Indigenous participation in the conference.
- Newton represented NANOOS and IOOS at the OceanObs'19 conference in Honolulu, HI, on 16-20 September, leading a plenary session September 19 on how to balance needs, capabilities and knowledge worldwide, and leading a panel session September 20 on charting the way forward and including community views. Participation from NANOOS included: PIs/staff Jack Barth, Zoli Szuts, Craig Risien, GC members Andrea Copping, Jay Pearlman, NANOOS' NOAA partners Adrienne Sutton, Sophie Chu, and other NANOOS family like Ted Strub and Melanie Fewings.
- During OceanObs'19, NANOOS GC Board Chair David Martin provided an inspirational address at the IOOS reception celebrating its 20th birthday at the Waikiki Aquarium 17 September, in Honolulu, HI, with many from NANOOS attending.
- Newton attended the Oceans19 Conference on 27-31, October, in Seattle, WA, and was joined by IOOS Director Carl Gouldman and NWFSC PI Stephanie Moore to present on harmful algal blooms in the Northwest and provide a demonstration of the Environmental Sample Processor (ESP). Newton also participated on two panels: on follow up to OceanObs19 Conference, and on Ocean Best Practices supporting a transparent and accessible ocean.
- Also at Oceans 19, Craig Risien presented a 10-year view of how NVS has evolved and, through our partnered work with data users of diverse types, has bloomed into the versatile and user-friendly system we have today. In addition, Fritz Stahr, MRV Systems & NANOOS GC was the General Chair of the conference.
- Newton participated in a site visit to scout a potential location for installing High Frequency radar

at Tatoosh Island on the Makah Tribes land near Neah Bay, WA, on 4 June.

- Newton serves on the Salish Sea Ecosystem Conference steering committee, attending a program planning meeting in Bellingham, WA, on 10 June.
- NOAA West invited Newton and NANOOS PI Mayorga to attend the 2019 NOAA Environmental Data Management Workshop held on 4-5 September, in Seattle, WA. Newton gave a talk on data interoperability and integration helping to promote transdisciplinary solutions for data management.
- Newton and nine NANOOS GC member representatives from OR and WA participated in the IOOS Coastal and Ocean Modeling Testbed Stakeholders Workshop on 5-6 September, in Moss Landing, CA, to assess user requirements for ecological forecasting in the California Current System. NANOOS reps included Patrick Corcoran, OR Sea Grant; Andy Lanier, OR DLCD; Matt Hunter, OR DFW; Dan Ayers, WA DFW; Joe Schumacker, Quinault Indian Nation; Tommy Moore, NWIFC; Issac Kaplan, NOAA NWFSC; Casey Dennehey, WA Ecology; and Alex Kurapov, OSU/NOAA.
- At the 2019 Program on Climate Change Summer Institute and Friday Harbor Symposium held 11-13 September, in Friday Harbor, WA, Newton presented on the global condition and local effects of ocean acidification.
- Newton is a new member of the NOAA Science Advisory Board's Ecosystem Sciences and Management Working Group, which met on 7-8 October, in Portland, OR. The work group is charged with providing scientific advice and broad direction for research, monitoring, and ecosystem management, including underlying observations and data management issues.
- Newton was invited to participate in the Pew Charitable Trust's Lenfest Ocean Program Ideas Lab Workshop on 21-23 October, in Washington, D.C., to identify research for managing impacts of shifting marine species.
- NOAA West invited Newton to participate in a Port of Seattle – NOAA Engagement meeting on 1 November, at PMEL in Seattle, WA. The meeting was organized to improve understanding of respective missions and priorities and to identify areas of mutual interest and potential collaboration.
- Newton participated in a NOAA PMEL Strategic Planning Stakeholder meeting on 13 November, in Seattle, WA. Participants were engaged to draft input to PMELs 5-year review and vision going forward.
- Barth attended a briefing for California legislators and staff on 19 November, in Sacramento, CA, about IOOS-funded ocean observing off California. He presented a talk on "Capturing Ocean Heat, Oxygen, and Nutrient Content and Circulation."
- Kaminsky attended and presented twice at the Coastal Hazards Resilience Network (CHRN) 2019 Annual Meeting on 5 June, in Tacoma, WA. Kaminsky presented on the Coastal Erosion Assessment for Grays Harbor County Hazard Mitigation and the Nature-Based Dynamic Revetment for Shoreline Stabilization at North Cove.

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

- Barth participated from June 12-13, 2019 in the semi-annual meeting of the Ocean Networks Canada (ONC) International Science Advisory Board (ISAB) that provides guidance and counsel to the Canadian effort to field, evolve and improve two research-focused ocean observatories (VENUS and NEPTUNE Canada) that simultaneously serve emergent operational societal needs. In this

context, Barth provides both scientific expertise as they communicate the U.S. experience with IOOS and operational ocean observing efforts that are part of the unique hybrid nature of ONC.

- Kosro participated in the Radiowave Oceanography Workshop, hosted by Ocean Networks Canada at the University of Victoria, on 28-30 August, in Victoria, BC. Kosro participated in the Community Working Group on High-Frequency Radar Wind Turbine Interference, led by A. Kirincich, which produced a report in June 2019.
- Barth represented NANOOS at the PICES 2019 Annual Meeting on 16-27 October, in Victoria, B.C., with a presentation to the Monitor working group on NANOOS. He also presenting a talk on using underwater gliders to detect acoustically-tagged green sturgeon. Other NANOOS PIs and collaborators included: Simone Alin – Marine heatwaves in the North Pacific: Predictions and impacts in coastal regions; Burke Hales – Tracer relationships in surface waters of coastal waters from the Gulf of Alaska, Bering and Chukchi Seas; Julie Kiester – Climate controls on zooplankton composition and ocean-estuary exchange in the Strait of Juan de Fuca, USA, and Unexpected changes in zooplankton biomass and juvenile salmon growth during the 2015-2016 warm anomalies, Puget Sound, WA, USA; and Erik Bjorkstedt – Climate-related variability in assemblage and size- structure of euphasiids in coastal waters off northern California.
- Newton, a member of the International Science Advisory Committee for the Canadian Marine Environmental Observation Prediction and Response (MEOPAR) program, presented at MEOPAR's Ocean Acidification Community of Practice workshop, Ocean Acidification in Canada, held on 14 June, in Victoria, B.C., presenting on the benefits of industry partnership for OA research, and provided input and review support throughout the period.
- Newton presented at the Monaco Consuls Visit to the University of Washington College of the Environment on 12 Oct, in Seattle, WA, including Ambassador of Monaco Her Excellency Maguy Maccario Doyle. Newton joined senior faculty to engage the group in discussions on ocean acidification, ice formation, and sustainable development. She and Terrie Klinger, WOAC co-Director with Newton, presented "Puget Sound as a natural laboratory for the study of ocean acidification."
- Newton was invited by the Ocean Conservancy to an information exchange between shellfish growers, scientists and government officials from WA state and Chile on 30 September to 3 October, visiting Santiago, Valpariso, Porto Montt, and other locations in Chile. Newton, three shellfish growers involved w/ NANOOS, and Washington State ocean health senior policy advisor Jennifer Hennessey shared how growers and scientists are working together in the PNW.
- Newton represented IOOS on the Global Ocean Acidification Network Executive Committee calls and activities. She was elected co-Chair of GOA-ON, along with Bronte Tilbrook, CSIRO. Newton was involved in the Biology Working Group and brought NANOOS capabilities for GOA-ON's web and data portal.
- Newton is a member of the Science Advisory Team for the Joint European Research Infrastructure in the Coastal Ocean (JERICO).

Additional NANOOS coordination:

- Newton participated in NOAA meetings for J-SCOPE, the ecological forecasting model for seasonal coastal ocean prediction on NANOOS' portal: http://www.nanoos.org/products/j-scope/.
- Newton continued to represent NANOOS in regional efforts, e.g., C-CAN, PSEMP, Pacific Salmon Marine Survival, the West Coast Ocean Data Portal, and "OA Round Tables" organized by NOAA PMEL and NWFSC.

- Newton continued to fill a research seat as a member of the Olympic Coast National Marine Sanctuary Advisory Council, participating in advisory committee meetings on 19 July, in Tahola, WA, and on 27 October, in Bremerton, WA.
- Barth serves on the Oregon Ocean Policy Advisory Council's (OPAC) Scientific and Technical Advisory Committee (STAC) responsible for providing expertise on ocean issues including the implementation and monitoring of Oregon's marine reserves and ocean acidification monitoring efforts. Oregon is preparing for review of their network of marine reserves due in 2023.
- Barth serves as the Co-Chair of the new Oregon Ocean Acidification and Hypoxia Coordinating Council, enacted as a state law in fall 2017. Oregon issued its Ocean Acidification and Hypoxia Plan in June 2019 (https://www.oregonocean.info/index.php/oah-action-plan).

- Task 16: Coordinate a west-coast wide regional collaboration team workshop with NOAA West and west coast IOOS RAs *[Newton]* Newton has commenced discussions with NOAA West lead Timi Vann and NOAA RVA Co-PI Melissa Poe for scoping date and focus. A follow up call with CeNCOOS and SCCOOS Directors Henry Ruhl and Clarissa Anderson was held to discuss and vet. More progress will follow in the next period.

Presentations and Publications acknowledging NANOOS support: underline indicates NANOOS PI

Presentations:

Allan, J. Oregon Coastal Hazards. Oregon and Southwest Washington Urban and Regional Information Systems Association, Post GIS Day in Astoria 2019, Astoria, OR, November 15, 2019.

Baptista, A. After a quarter century, we know so much and so little about the Columbia River Estuary. UBEST Project Workshop, Universidad do Algarve, December 2019

Barth, J. A. Watching beneath the waves: Ocean observing in the Northern California Current, HMSC, Newport, OR, July 17, 2019.

Barth, J. A. Ocean observing and marine ecosystem challenges in the Pacific Northwest, National Association of Marine Laboratories Annual Meeting, HMSC, Newport, OR, October 1, 2019.

Gouldman, C., S. Moore, and J. Newton. Understanding Harmful Algal Blooms in the PNW: What we've done, what we're going to do, and why it matters. Oceans19 Conference, Seattle, WA, October 29, 2019.

Haller, M.C. "Marine radar observations of internal waves, estuarine fronts, and rip currents from recent field experiments", *Sensing the Ocean with Marine Radars* (*SoMaR-V*), Universidad de Alcalá, Alcalá de Henares (Madrid), Spain, June 11, 2019.

Haller, M.C. Invited Speaker: "The Remote Sensing of Internal Waves, Fronts, Jumps and Rips with X-Band Radar", *Gordon Research Conference on Coastal Ocean Dynamics*, Manchester, NH, June 17, 2019.

Haller, M.C. "OSU Marine Radar Remote Sensing", *6th Annual Young Coastal Scientists and Engineers Conference – Americas*, Newport, OR, August 9, 2019.

Helms, A. Overview of System-Wide Monitoring Program and Data access tools. Oregon State University Estuarine Ecology program, Charleston, OR, October 2019.

Kaminsky, G. Coastal Erosion Assessment for Grays Harbor County Hazard Mitigation. Coastal Hazards Resilience Network (CHRN) 2019 Annual Meeting, Tacoma, WA, June 5, 2019.

Kaminsky, G. Nature-Based Dynamic Revetment for Shoreline Stabilization at North Cove. Coastal Hazards Resilience Network (CHRN) 2019 Annual Meeting, Tacoma, WA, June 5, 2019.

Klinger, T. and J. Newton. Puget Sound as a Natural Laboratory for the Study of Ocean Acidification. University of Washington College of the Environment Monaco Consuls Visit, Seattle, WA, October 12, 2019.

MacCready, P., S. Siedlecki, R. McCabe, N. Banas, H. Stone, E. Brasseale, B. Ovall, and D. Darr. "LiveOcean: Short-term Forecasts of Ocean Acidification for the Washington Coast & Salish Sea." Presentation for a visit to UW from the Van Alen Climate Council, July 17, 2019.

MacCready, P., "News and Brews" talk at Boston Harbor Marina "Above and Below the Waters of the Salish Sea" organized by South Sound Salmon enhancement Group, September 12, 2019.

Newton, J. Benefits of Industry Partnership for Ocean Acidification Research. MEOPAR Ocean Acidification Community of Practice workshop Ocean Acidification in Canada, Victoria, BC, June 14, 2019.

Newton, J. Plenary - How Do We Balance Needs, Capabilities, and Knowledge Worldwide? OceanObs19 Conference, Honolulu, HI, September 19, 2019.

Newton, J. Panel - Charting the Way Forward: Community Views. OceanObs19 Conference, Honolulu, HI, September 20, 2019.

Newton, J. Tackling Wicked Problems: How Data Interoperability and Integration Promote Transdisciplinary Solutions. NOAA Environmental Data Management Workshop, Seattle, WA, September 4-5, 2019.

Newton, J. Ocean Acidification: Understanding this Global Condition and its Local Effects. University of Washington Program on Climate Change Summer Institute, Friday Harbor, WA, September 13, 2019.

Newton, J. Panel - Ocean Best Practices – Supporting a Transparent and Accessible Ocean. Oceans19 Conference, Seattle, WA, October 28, 2019.

Newton, J. Panel - OceanObs19 Follow-up. Oceans19 Conference, Seattle, WA, October 28, 2019.

Publications:

Antolinez, J.A.A., Anderson, D., Mendez, F., Ruggiero, P., Kaminsky, G., 2019. Understanding long term coastal change and variability using a simple and efficient multi-process model, Proceedings of Coastal Sediments 2019, St. Pete Beach, Florida.

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

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Honegger, D.A., M.C. Haller, and R.A. Holman, High-resolution bathymetry estimates via X-band

marine radar: 2. Tidal inlets and river mouths, final revision submitted Coastal Engineering, Nov. 2019.

Kirincich, A., D. Cahl, B. Emery, M. Kosro, H. Roarty, D. Trockel, L. Washburn, C. Whelan, June 2019. "High Frequency Radar Wind Turbine Interference Community Working Group Report", 20pp.

Pasmans, I., and A. L. Kurapov, 2019: Ensemble of 4DVARs (En4DVar) data assimilation in a coastal ocean circulation model, Part I: Methodology and ensemble statistics, Ocean Modelling, 144, DOI: https://doi.org/10.1016/j.ocemod.2019.101493

Pasmans, I., A. L. Kurapov, J. A. Barth, A. Ignatov, P. M. Kosro, and R. K. Shearman, 2018: Why gliders appreciate good company: glider assimilation in the Oregon-Washington coastal ocean 4DVAR system with and without surface observations*, J. Geophysical Research - Oceans*, 124, https://doi.org/10.1029/2018JC014230.

Pasmans, O., A. Kurapov, J. A. Barth, P. M. Kosro, and R. K. Shearman, 2019. Ensemble 4DVAR (En4DVar) data assimilation in a coastal ocean circulation model. Part II: Implementation offshore Oregon-Washington, USA. {\em Ocean Modelling), submitted.

Risien, C.M., Tanner, T., Mayorga, E., Allan, J.C., Newton, J.A., Kosro, M., Wold, R., and Seaton, C., 2019. The NANOOS Visualization System (NVS): A Decade of Development and Progress Addressing Stakeholder Needs, in Oceans'19, Seattle, Washington, p. 8.

Stevens, A.W., Weiner, H.M., Ruggiero, P., Kaminsky, G.M., and Gelfenbaum G.R., 2019, Beach topography and nearshore bathymetry of the Columbia River littoral cell, Washington and Oregon (ver. 2.0, November 2019): U.S. Geological Survey data release, https://doi.org/10.5066/P9W15JX8.

Weiner, H.M., Kaminsky, G.M., Hacking, A., and McCandless, D., 2019. North Cove Dynamic Revetment Monitoring: Winter 2018-2019. Shorelands and Environmental Assistance Program, Washington State Department of Ecology, Olympia, WA. Publication #19-06-008. https://fortress.wa.gov/ecy/publications/summarypages/1906008.html