Final Report for the Enhancement of the
Northwest Association of Networked Ocean Observing Systems (NANOOS)
Regional Coastal Ocean Observing System (RCOOS)
NA10NOS4730018

1) Award Information: Provided as a separate Cover Sheet.
Reporting period: 01 October 2010 – 30 September 2012; a one-year award with a one year no-cost extension

2) Project Summary:
The funds from this award provided for the fourth year of operation of NANOOS' Regional Coastal Ocean Observing System (RCOOS) for the Pacific Northwest (PNW). Through this NOAA funding NANOOS achieved its goal to engage in the development, implementation, and integration of various in-water and land-based systems that lay the foundation of a fully robust and user-driven RCOOS. This includes several subsystems necessary to provide PNW, west coast, and national stakeholders with the coastal ocean data, tools, and knowledge they need to make responsive and responsible decisions appropriate to their individual and collective societal roles. NANOOS gained its ongoing knowledge of prioritized issues and user needs through proactive interactions with a wide range of PNW stakeholders.

NANOOS satisfied all seven of its objectives designed to meet the goal of the project. Over the project period NANOOS:

- **Maintained existing surface current mapping capabilities from HF radar sites in the PNW.** This foundational building block for our coastal ocean observing system served a multitude of disparate users.
- **Maintained observation capabilities in PNW estuaries.** The NANOOS sustained a federated real-time observation network across Oregon and Washington estuaries to address PNW societal needs.
- **Strategically maintained coverage and range of observations in the PNW shelf, in coordination with emerging national programs.** We used both fixed (buoys) and mobile (glider) assets to provide advanced information on hypoxia/anoxia and Harmful Algal Blooms (HABs), which are major regional concerns affecting ecosystem and human health, fisheries, and coastal economies.
- **Maintained core elements of existing beach and shoreline observing programs in Oregon and Washington.** This improved coastal hazard mitigation by providing better decision support tools for coastal managers, planners, engineers, and coastal hazard mitigation decision makers.
- **Evaluated the creation of a federated system of numerical daily forecasts of PNW ocean circulation.** We took advantage of existing operational models from the head of tide of estuaries to the outer edges of the exclusive economic zone (EEZ), extending their utility and availability.
- **Bolstered ongoing Data Management and Communications (DMAC) activities to support routine operational distribution of data and information.** Our DMAC provided a wide range of products, tools, and services to regional user communities with a direct link to the IOOS national backbone and national information infrastructure.

- **Built from and strengthened ongoing NANOOS education and outreach efforts.** We conducted our education and outreach activities to foster ocean literacy and facilitate use of NANOOS products in the PNW by stakeholders, decision makers, and the general public in coordination with other regional efforts (e.g., NSF-funded STC and COSEE).

The NANOOS RCOOS specifically focused on high-priority PNW user-driven applications of: **a) maritime operations; b) ecosystem impacts including hypoxia and harmful algal blooms; c) fisheries; and, d) mitigation of coastal hazards** as these issues represent applications having the greatest impact on PNW citizenry and ecosystems and were amenable to being substantively improved with the development of a PNW RCOOS.

3) Final Technical Accomplishments:

NANOOS reports here as in our original proposal; specifically, we divide our final technical report into sections of our RCOOS efforts: a) Observing Subsystem (shelf, estuaries, shorelines, and currents); b) Modeling (estuaries and shelves); c) Data Management and Communications (DMAC); and, d) Education and Outreach. In each section we note the impact of the work and the names of NANOOS-funded PIs are underlined. Oversight duties, performed by J. Newton and D. Martin, were also supported through NANOOS' RA awards, reported separately.

a) **Observing Subsystem:** *Data from all assets reported here are served via NANOOS NVS.*

- Shelf

Washington Buoy and Glider observing network operations: Y4 funding was used by M. Alford and J. Mickett (APL-UW) to recover and re-deploy the Cha'ba surface buoy and Seaglider in fall of 2010, and to service, upgrade and repair these assets between deployments. Additionally, these funds covered salary and supplies that allowed the completion of the subsurface mooring component to this observation system. Equipment and instrumentation for this system was purchased primarily via an award from the Murdock Charitable Trust to the University of Washington (PIs Newton, Alford, Devol, Martin).

Though the subsurface profiling mooring, which was deployed in May 2011, along with the surface mooring, was largely a success in that data from the CTD and ADCP were being transmitted in near real-time back to shore via Cha'ba, the mooring was recovered just a day after deployment because data were not being sent from the profiler due to a damaged jacket on the mooring wire, which prevented inductive communications. The mooring was re-deployed in early August 2012 from the R/V Thompson in conjunction with field servicing of Cha'ba. Although Cha'ba performed well up until about mid-July, power was being consumed and batteries were being depleted at much faster rates than expected. To partly address the power issue, a number of changes were made during August field servicing including changing the entire system from 24 V to 12 V. All systems on NEMO subsurface operated as planned for about the first week of deployment, then MMP data transfer stopped unexpectedly, which turned out to be because a firmware error. Given the unresolved engineering issues, both moorings were recovered in October 2012 for servicing and upgrade. Run courtesy of collaboration with Dr. Craig Lee and his APL-UW team on primarily leveraged funds, Seaglider 187 was recovered in mid-September 2012 with assistance from the Olympic Coast National Marine Sanctuary, after completing a successful 4-1/2 month deployment of more than 800 dives. The glider was adapted to carry an acoustic receiver to detect Pacific salmon and Humboldt squid, done in collaboration with the Pacific Ocean Shelf Tracking project (POST).

Additionally, with Alford and Mickett, J. Newton (APL-UW) worked with NOAA PMEL scientists, Drs. Chris Sabine, Richard Feely, and Adrienne Sutton to maintain the Cha'ba mooring with pCO_2 with pH sensors as part of NOAA's efforts to begin equipping coastal moorings with such sensors to measure ocean acidification parameters in surface waters (http://www.pmel.noaa.gov/co2/story/La+Push).

We note that ship time for all mooring operations was generously donated through the University of Washington, School of Oceanography's state-funded underway days and by individual PIs (Dr. J. Mercer, APL-UW), which was a significant cost-savings for NANOOS. Maintaining the moorings would have not been possible without this additional support.

Impact:
Despite engineering problems, the data sets from Cha'ba, NEMO subsurface and the Seaglider 187 over the summer of 2011 have provided an unprecedented picture of Washington shelf dynamics yielding new scientific findings regarding wind-driven shelf current reversals, ubiquitous and intense non-linear internal waves, and a robust internal tide field. The buoy and glider sensor array revealed 30-40 m internal waves never before resolved off the Washington coast. These waves have implications far beyond just ocean physics. The waves with strong vertical displacements could affect coastal productivity, through transport of nutrients, and also the localized expressed of hypoxia and ocean acidification found in surface nearshore waters, because of the transport upwards of deeper more hypoxic and more corrosive waters. The first scientific paper from these data was published, Alford et al., 2012, attached as an appendix to this report. This paper is the first documentation of internal waves on the Washington continental shelf. The results were also shared widely with the community (e.g., presentations to the Olympic Coast National Marine Sanctuary Advisory Council, the four outer Washington coast tribes (Quileute, Quinault, Hoh, Makah), the State of Washington (including the WA Dept. Ecology, Puget Sound Partnership), and the public at large).

Dr. Sutton (NOAA PMEL) presented a poster at the American Geophysical Union Fall Meeting 2011 comparing the magnitude and diurnal to seasonal variability of pCO_2 and pH measured at 3 hour intervals during the first year of observations at 2 sites in the Atlantic and Pacific coastal margins of the U.S.: the Gulf of Maine and outer coast of Washington state, our Cha'ba buoy. The data show that both the magnitude and range of pCO_2 and pH values were greater at the coastal sites (Gulf of Maine and La Push) compared to open ocean Station Papa, in the Gulf of Alaska and also varied between the two coastal sites. The range of pCO_2 and pH values during the coastal time series were as much as 4.5 times the range observed at Stn Papa. This is groundbreaking research. Only a few studies in coastal systems have documented short-term variability of carbon chemistry and the factors governing ocean acidification variability. This information was also supplied to the Washington Governor Christine Gregoire's Blue Ribbon Panel on Ocean Acidification, which Newton was a member of.

Publications acknowledging NANOOS support:

Alford, M. H., J. Mickett, S. Zhang, P. MacCready, Z. Zhao, and J. Newton. 2012. *Internal Waves on the Washington Continental Shelf.* Oceanography, 25, 32-46 http://tos.org/oceanography/archive/25-2_alford.pdf

Feely, R.A., Klinger, T., Newton, J.A., M. Chadsey. 2012. *Scientific Summary of Ocean Acidification in Washington State Marine Water*s. NOAA OAR Special Report. https://fortress.wa.gov/ecy/publications/SummaryPages/1201016.html

Washington State Blue Ribbon Panel on Ocean Acidification. 2012. *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*. H. Adelsman and L. Whitely Binder (eds). Washington Department of Ecology, Olympia, Washington. Publication no. 12-01-015. https://fortress.wa.gov/ecy/publications/SummaryPages/1201015.html

PSEMP Marine Waters Workgroup. 2012. *Puget Sound Marine Waters: 2011 overview.* S.K. Moore, R. Runcie, K. Stark, J. Newton and K. Dzinbal (Eds). Puget Sound Partnership Report. http://www.psp.wa.gov/downloads/psemp/PSmarinewaters_2011_overview.pdf

J. Patterson, J. Thomas, L. Rosenfeld, J. Newton, L. Hazard, J. Scianna, R. Kudela, E. Mayorga, C. Cohen, M. Cook, M. Otero, and J. Adelaars, "Addressing ocean and coastal issues at the West Coast scale through regional ocean observing system collaboration," Proceedings of the MTS/IEEE Oceans 2012, Hampton Roads, VA.

Presentations acknowledging NANOOS support:

Newton, J., M. Alford, J. Mickett, J. Payne, and F. Stahr, "*The Northwest Association of Networked Ocean Observing Systems (NANOOS) and opportunities for acoustical applications*" Invited talk at the 161st Meeting of the Acoustical Society of America, May 2011, Seattle, WA.

Sutton, A.J., C.L. Sabine, R.A. Feely, J. Newton, J. Salisbury, D.C. Vandemark, S.B. Musielewicz, S. Maenner-Jones, R. Bott, N. Lawrence-Slavas, "*Natural variability of pCO2 and pH in the Atlantic and Pacific coastal margins of the U.S.*" Poster at American Geophysical Union Fall Meeting, OS33B-1650, December 2011, San Francisco, CA.

Mickett, J.B., M. Alford, J. Newton and A. Devol, "*The NANOOS Northwest Enhanced Moored Observatory—A Novel Three-tiered Approach to Observations on the Washington Coast*" Presentation at Ocean Sciences Conference, February 2012 Salt Lake City, UT.

Zhang, S., M. Alford, J. Newton, "*Internal Waves off the Washington Coast*" Presentation at Ocean Sciences Conference, February 2012 Salt Lake City, UT

2. Oregon Glider operations: The Oregon State University (OSU) glider group led by J. Barth and K. Shearman made nearly continuous measurements off Newport, Oregon, with autonomous underwater gliders using a combination of NANOOS, NSF, and private funding (Moore Foundation). The gliders measure vertical profiles of temperature, salinity, dissolved oxygen, chlorophyll fluorescence, colored dissolved organic matter fluorescence, and light backscatter from near the shore in about 20 m of water to approximately 300 km offshore. Near real-time, the glider reported position and returns a subset of data to shore every 6 hours. The Newport Hydrographic Line was sampled using two different gliders: a 200-m Teledyne Webb Research Slocum glider on the inshore side out to 45 nautical miles offshore; a 1000-m University of Washington Seaglider to sample the deeper waters. The two gliders overlapped over the continental slope to allow data comparison and inter-calibration. From October 2010 to September 2011, the OSU gliders on the Newport line accumulated the following statistics: ~507 days of operation; 23 separate deployments; 112 cross-margin sections; about 31,852 vertical profiles; 10,698 km of track line.

Impact:

The glider data are useful for assessing changes in water column properties in support of studies of hypoxia, harmful algal blooms, coastal productivity, etc. For example, glider data were used to monitor the progress of the 2009-2010 El Niño. We also used the dissolved oxygen data from the gliders in a variety of ways to understand the increasing occurrence of hypoxia in Oregon shelf waters (e.g., Pierce et al., 2012).

We maintained a working web page to monitor the health and status of our at-sea gliders (http://gliderfs.coas.oregonstate.edu/gliderweb). The page also includes information about OSU glider group personnel and the goals of our project. We provided near real-time plots of glider data to the NANOOS Visualization System. We supplied quality-controlled glider data to our NANOOS colleague, Dr. Alexander Kurapov, for assimilation into his Oregon coastal ocean circulation model.

During each summer, an undergraduate student from outside OSU joined our glider research team as a Research Experiences for Undergraduates fellow: Rosalinda Fortier (University of Rhode Island, 2008); Meghan Flink (Linfield College, Oregon, 2009); Derrick Monroy (New Mexico State University, 2010); Kelly Mauser (Colorado State University, 2011).

J. Barth represented NANOOS at the North Pacific Marine Science Organization (PICES) Annual Meetings during 2007-2011.

Publications acknowledging NANOOS support:

Pierce, S. D., J. A. Barth, R. K. Shearman and A. Y. Erofeev, 2012. Declining oxygen in the Northeast Pacific. J. Phys. Oceanogr., 42, 495-501.

Presentations acknowledging NANOOS support:

Barth, J. A. "Observing change in the Northeast Pacific: Past, present and FUTURE," North Pacific Marine Science Organization (PICES) 19th Annual Meeting Keynote Lecture, October 2010.

Barth J. A., S. D. Pierce and F. Chan. "The changing coastal ocean: Low-oxygen water off the Pacific Northwest." American Geophysical Union Fall Meeting, GC12A-04 (Invited), December 2010.

Adams, K. and J. A. Barth. "High- to low- frequency variability of moored temperature, currents, and dissolved oxygen on central Oregon's mid-shelf to inner-shelf and intertidal regions." Eastern Pacific Ocean Conference, September 2011.

Mazzini, P. L. F., C. M. Risien, J. A. Barth, and Ocean Observing Colleagues. "Observations of anomalous near-surface low-salinity pulses off the central Oregon Coast." Eastern Pacific Ocean Conference, September 2011.

Pierce, S. D., J. A. Barth, R. Kipp Shearman, and A. Y. Erofeev. "Declining oxygen in the Northeast Pacific." Eastern Pacific Ocean Conference, September 2011.

Outreach activities acknowledging NANOOS support:

"X-Ray Earth," National Geographic Channel, May 15, 2011, http://channel.nationalgeographic.com/episode/x-ray-earth-5102/Overview, http://natgeotv.com/uk/x-ray-earth (J. Barth)

"Robots Plumb the Depths," American Society of Mechanical Engineers, July 2011, http://www.asme.org/kb/news---articles/articles/robotics/robots-plumb-the-depths (J. Barth)

"Underwater Gliders," Hatfield Marine Science Center Career Day, October 2011 (C. Ordonez)

***3. Oregon Buoy (mooring) operations**:* Led by M. Levine (OSU), a mooring about 10 miles off Newport, Oregon, in 80 m of water (site NH-10) was maintained throughout the project period. This buoy has been maintained since mid-2006, primarily through support by NANOOS. Ship time to enable the mooring recoveries and deployments has been funded by the NSF Science & Technology Center CMOP. About every six months the mooring is recovered and a refurbished mooring deployed.

In October 2010 on a cruise of the R/V Oceanus the summertime mooring was recovered. On the same cruise the wintertime mooring was deployed. The mooring measured a combination of

atmospheric and ocean parameters. Ocean sensors measured temperature, salinity and water velocity at a number of depths. A few sensors measuring CO_2, dissolved oxygen, turbidity and chlorophyll fluorescence were also attached. A meteorological package measured wind velocity, air temperature, atmospheric pressure, and incoming solar radiation. Unfortunately the mooring chain broke free at the anchor after about 70 days of operation. Luckily most of the mooring and instrumentation was recovered on a beach in Washington with minimal damage.

In April 2011 the summertime mooring was deployed from the R/V Oceanus. It contained a similar suite of instruments as the wintertime mooring. After about 6 months operation it was successfully recovered in September 2011 and replaced with the wintertime mooring.

Impact:

Data: Some of the data are transmitted to shore in near-real time through a cellular phone modem and are available on the NANOOS Visualization System (NVS). These data are also displayed by the National Data Buoy Center (NDBC) as station #46094 and complement the data obtained from the NDBC station #40650 located about 10 nmiles farther west. The data can also be found on the website of the NSF Science and Technology Center CMOP. All data are archived and available to all.

Emergence of the OOI (Ocean Observatories Initiative): This NH-10 mooring has contributed significantly to the historical data taken near this site. Observations have been made along the NH line since as far back as the 1960's, providing a non-continuous, but valuable data set to explore interannual variability and possibly climate change. The value of maintaining this time series going forward is heightened by the upcoming initial deployment over the next several years of the NSF OOI endurance array near the NH line. The OOI will extend this time series for several decades.

Navigation: The mooring also serves as an Aid to Navigation, registered with the US Coast Guard as OSU *Yaquina Research Lighted Buoy, Light #652*.

Platform of Opportunity: The mooring has been used as a platform for testing and developing instrumentation, such as sensors to measure ocean pCO_2 and pH.

Model verification: The time series data are valuable for checking and calibrating numerical circulation models, such as the NANOOS-supported forecast model developed and maintained by A. Kurapov.

Student experience: Graduate students are invited to participate in the deployment and recovery cruises. This has been a great opportunity for those involved in marine sciences to gain some experience in oceanographic field work aboard a UNOLS vessel. Undergraduate student workers are also used to help with buoy refurbishment.

Glider operations: The mooring data has provided data input to help those flying ocean gliders along the NH line (J. Barth and K. Shearman). The time series observations also provide a useful complement to the glider's spatial mapping.

Education: Graduate students have used these moored time series observations to aid in their thesis research--for example, OSU students W. Evans, K. Adams, P. Mazzini and C. Ordonez.

4. Northern Oregon to Central Washington shelf:
During the reporting period, OHSU-CMOP, A. Baptista, operated a glider in the WA shelf and maintained two buoys in the OR shelf off the mouth of the Columbia River, with applications to ecosystem impacts, fisheries, and interdisciplinary science and modeling.

Glider: First deployed on 17 May 2009, the glider has since flown 351 days. The glider operation was run seasonally (spring through early fall), and conducted in collaboration with the Quinault Indian Nation (QIN) Department of Fisheries. Missions typically lasted a few weeks at a time and were flown in a modified radiator pattern across the WA shelf, from Grays Harbor to Quinault. In 2012, the original glider was lost and replaced leading to loss of data for the year.

Impact:
The glider missions:

1. Support QIN fisheries management, via the characterization of hypoxia in the WA shelf.
2. Address a spatial gap (WA coast) in sustained observations of hypoxia and harmful algal blooms in the California Current system.
3. Characterize variability in the physical and biogeochemical ocean conditions that affect the function of the Columbia River as an estuarine bioreactor.
4. Support the definition of boundary conditions for emerging ecosystem models for the Columbia River coastal margin.
5. Support a multi-purpose operational Oxygen Watch, geographically focused on the Columbia River coastal margin. The Watch is maintained by OHSU-CMOP, to address needs of three partner agencies (NOAA, QIN and Columbia River Inter-Tribal Fish Commission-CRITFC) with mandates on the management of fisheries resources, including the management of various ESA-listed salmon and steelhead stocks.

The glider missions captured the sharp differences in the oxygenation levels for the WA shelf through 2009-2011, a time series that will continue to be maintained on a long-term basis.

Buoys: Two seasonal buoys (OGI01 and SATURN-02) were maintained in the OR shelf off the mouth of the Columbia River. Both were designed to operate from spring to early fall, with skeletal configurations over the winter. While both stations are envisioned as inter-disciplinary multi-level endurance stations, only SATURN-02 was operated in this mode, due to funding restrictions; OGI-01 was operated permanently in its winter configuration.

SATURN-02 is a multi-depth buoy. The buoy sensor configuration changed seasonally, with the "summer" configuration addressing regional and scientific goals, while the "winter" configuration is minimalistic. The capabilities of the summer "configuration" were considerably extended during the reporting period, as follows: At the surface: telemetry (spread spectrum radio); velocity profile via a downward-looking acoustic Doppler profiler (ADP); atmospheric data (winds, air temperature and humidity); and water properties: salinity, temperature, chlorophyll fluorescence, turbidity (via backscatter), CDOM, DO and nitrate. At 6, 11, 16 and 21 m below the surface: salinity and temperature; At 35 m below the surface: DO, salinity and

temperature. The OGI01 buoy is installed in the northern OR shelf, at 100m depth. Instrumentation was limited during the reporting period to surface temperature and salinity.

Impact:
The SATURN-02 buoy, located in the northern OR shelf, at ~40m depth, is within the region of influence of the Columbia River ebb tides and was designed to capture the vertical structure of the near-field freshwater plume, as well as the ocean sources into the estuary. The information was used to understand the variability of estuary-ocean exchanges, which is critical in order to understand (a) hypoxia and acidification in the river-to-ocean continuum in the PNW, a major interest of various stakeholders including NOAA, CRITFC and QIN; (b) the role of the estuary and the plume in salmon life cycle, which is subject to ESA-related biological opinions and is a target of multiple regional projects led by the NOAA Northwest Fisheries Science Center (some of which with the participation of OHSU-CMOP); and (c) the role of the estuary as a bioreactor that transforms biogeochemically the biogenic and anthropogenic river inputs, thus modulating water quality and ocean productivity in the OR and WA shelves near the Columbia River (a major scientific target of multi-institutional CMOP science initiatives).

Data from all the above platforms, and those from the Columbia River estuary (below), were publicly available. NANOOS NVS functions as the PNW-integration portal, displaying real-time data and allowing downloads of recent data; it also contains links to the CMOP SATURN website, which offers access to both the near real-time data and since-inception archival data, besides allowing interactive analysis of data within and across stations through the SATURN Data Explorer. For presentations and publications, see the related section on Columbia River estuarine monitoring, below.

- **Estuaries**

1. Puget Sound, ORCA Buoy program: Led by A. Devol and J. Newton (UW), the ORCA (Oceanic Remote Chemical Analyzer) group maintained 4 buoys in operation in Hood Canal (Twanoh, Hoodsport, Dabob Bay, North Buoy), one in the main basin of Puget Sound (Point Wells), and one in south Puget Sound (Carr Inlet). This buoy provided information about South Sound now as well as allowed historical comparison of current conditions with water properties observed ten years ago. Full location details for all the moorings are available online (see http://orca.ocean.washington.edu). Each buoy measured vertical profiles of temperature, salinity, dissolved oxygen, chlorophyll fluorescence, and meteorological data. Additionally, some buoys also measured currents, nitrate, PAR (photosynthetically active radiation) and turbidity. All buoy data were available in near real-time on the NANOOS website (http://www.nanoos.org). These observations were leveraged with funds from the Navy, Ecology, the Hood Canal Dissolved Oxygen Program and NSF funding.

Through collaboration with NOAA PMEL, we continued to provide field support and power to the pCO_2 sensors installed on the Twanoh and Dabob Bay moorings, as well as trouble-shooting the system and collecting water samples to aid in system calibration. Data from the pCO_2 sensors were available online through the NANOOS web portal. The Dabob Bay work was leveraged by a grant from the State of Washington to monitor surface water acidity and water column conditions as they might relate to shellfish hatchery failure.

Over the Y4 reporting period we performed routine maintenance on the moorings as well as repairs to the system ranging from flooded solar panels, aging winch components, and the recovery of a sensor package using an ROV after the package got stuck in the mud. We also continued work started during Y3 to upgrade the mooring systems, including new weather stations, wind generators, and new solar chargers that allow query and logging of battery state to aid troubleshooting power issues. These upgrades allowed increased profiling frequency during periods of high wind and low solar energy, which in turn allowed profiling to continue through the winter even at the deeper moorings.

Impact:
Between 1 October 2010 and 30 September 2012, over 22,000 profiles were collected in Hood Canal and the Puget Sound basin and were available to the public. Though we continued to observe significant inter-annual variability in Hood Canal, the general seasonal cycles reported in the Y1-3 final report continued to be consistent during this period, including an early spring blooms observed at Twanoh, which occurred before any other buoys registered increased surface chlorophyll concentrations. For example, the spring bloom in southern Hood Canal in March 2011 had surface chlorophyll concentrations of 20 mg/m^3 or greater, while in Puget Sound surface chlorophyll concentrations were still less than 10 mg/m^3. These differences in timing may have implications for salmon survival and are of interest to efforts to study marine survival.

An extensive fish kill (1000s of fish) was observed near Hoodsport in September 2010. Dissolved oxygen concentrations at depth in southern Hood Canal during this period were some of the lowest recorded during the study, < 1 mg/L. Dynamics of the fish kill, covered in detail in an HCDOP report published online (http://www.hoodcanal.washington.edu/documents/FISHKILL/fish_kill_sep_2010.doc), were similar to those observed in 2006; low oxygen waters from depth gradually shoaled towards the surface as the annual dense ocean water intrusion began, followed by a storm with southern winds that blew the high oxygen surface layer north, thereby upwelling low oxygen waters to the surface. This dynamic is used by the Washington Dept. of Fish and Wildlife for assessing risk.

In comparison, 2011 and 2012 were moderate years in terms of bottom water dissolved oxygen concentrations in southern Hood Canal. Oxygen concentrations observed in the bottom water at Twanoh in 2012 trended at the top of the ranges observed in the previous 7 years, and were similar to those observed in 2009. At both Hoodsport and Twanoh, the values and trends of water temperature observed at 30 meters were also similar to values observed in 2009, with both years trending significantly below average. However, salinity observations at 30 meters in 2012 were significantly below average, whereas in 2009 values were solidly above average. These interannual differences enable increased understanding of the influence of watershed, oceanic, and climate drivers on Salish Sea water property/water quality variation.

Presentations acknowledging NANOOS support:

Newton, J. Current ocean acidification monitoring in Washington waters: How can citizens learn more? Ocean Acidification: An evening seminar with scientific experts, Northwest Maritime Center, Port Townsend, WA, November, 2010.

Ruef, W., A. Devol, J. Newton, C. Bassin. Quantifying the Role of Marine Nutrient Loading to Upper Layer Production and Bottom Water Hypoxia in a Coastal Estuary. Aquatic Sciences Meeting, San Juan, Puerto Rico, February, 2011.

Newton, J., A. Devol, C. Sabine, R. Feely, S. Alin, D. Fagergren, W. Palsson, and D. Hannafious. Using real-time buoy and citizen monitoring data for measuring hypoxia and ocean acidification to aid decisions on aquaculture, fisheries management, and water quality in Puget Sound, Washington, through NANOOS/IOOS. Coastal Zone 2011 Meeting, Chicago, IL, July 17-21, 2011.

Newton, J., S. Alin, R. Feely, C. Sabine, A. Devol, A. Suhrbier, D. Cheney, B. Eudeline, J. Davis, B. Allen, B. Peabody, and C. Krembs. Ocean acidification in Puget Sound: Recent observations on water chemistry and implications for larval oyster success. Second Annual PNW Climate Science Conference, Seattle, WA, Sept. 13-14, 2011.

Newton, J., A. Devol, C. Krembs, and K. Stark. Observing Climate Influenced Variation in Puget Sound Marine Waters. Second Annual PNW Climate Science Conference, Seattle, WA, Sept. 13-14, 2011.

Newton, J. and J. Apple. The Value of Peer-to-peer Knowledge Transfer for Engaging Pacific Northwest Tribes in STEM Education and Oceanographic Studies. Oceans '11 MTS/IEEE, Kona, Hawai'i, Sept 19-22, 2011

Alin, S., B. Allen, A. Suhrbier, J. Davis, R. Feely, J. Newton, A. Devol, C. Sabine, B. Peabody, B. Hales. Water chemistry and larval oyster success in Puget Sound as impacted by ocean acidification. Salish Sea Ecosystem Conference 2011, Vancouver, BC, Canada, October 25-27, 2011.

Feely, R.A., S.R. Alin, C.L. Sabine, J. Newton, M. Warner, and A. Devol. Ocean acidification in the Salish Sea. Salish Sea Ecosystem Conference 2011, Vancouver, BC, Canada, October 25-27, 2011.

Keister, J.E., J.A. Newton, J.K. Bos, and L.B. Tuttle. Zooplankton community variability in the Strait of Juan de Fuca and Puget Sound. Salish Sea Ecosystem Conference 2011, Vancouver, BC, Canada, October 25-27, 2011.

Newton, J., A. Devol, J. Richey, M. Kawase, M. Warner, S. Parker-Stetter, D. Hannafious. Hypoxia in Hood Canal: Lessons learned from HCDOP. Salish Sea Ecosystem Conference 2011, Vancouver, BC, Canada, October 25-27, 2011.

Newton, J. and T. Klinger. Integrating ocean acidification research across the Salish Sea. Salish Sea Ecosystem Conference 2011, Vancouver, BC, Canada, October 25-27, 2011.

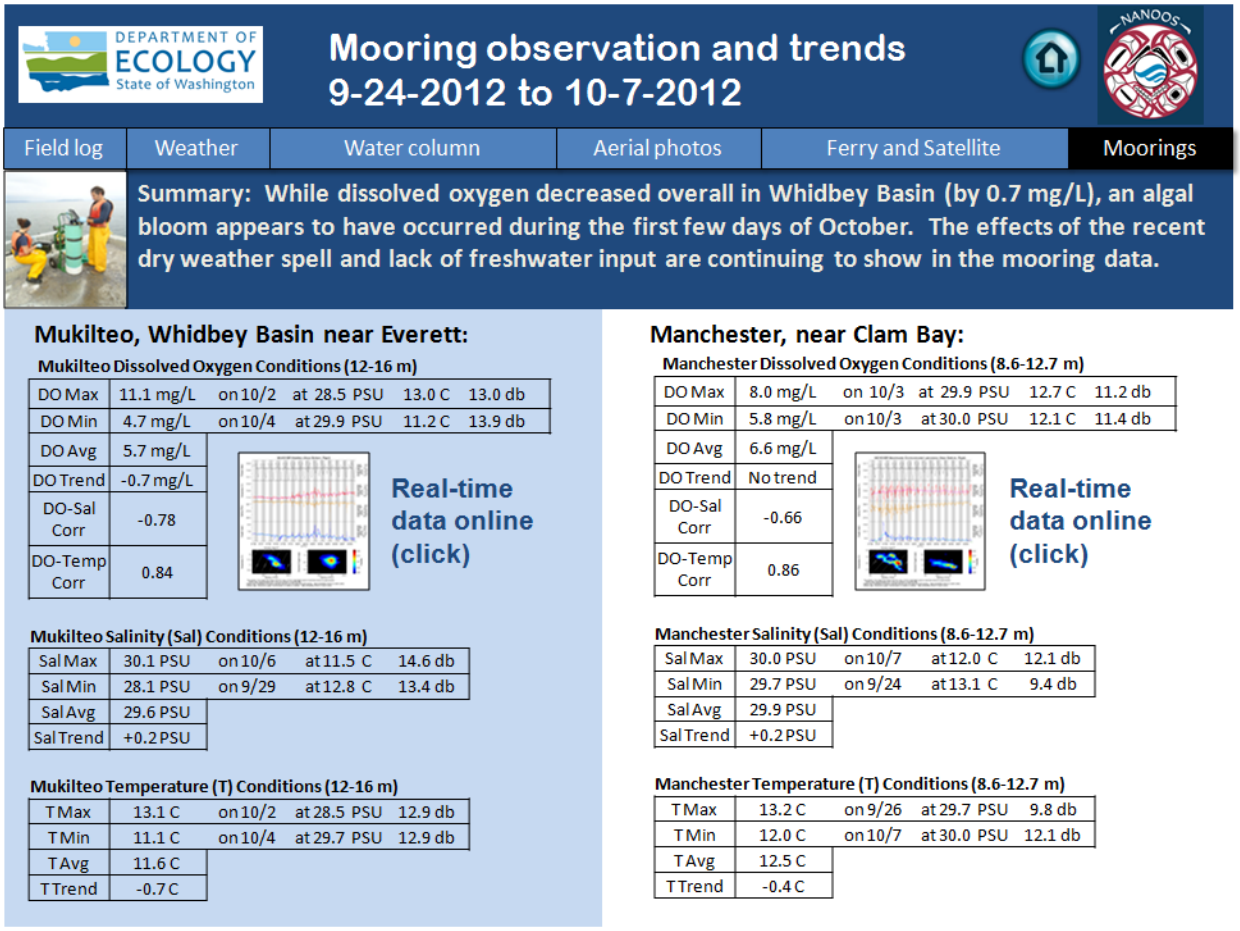
Newton, J., A. Devol, M. Alford, and J. Mickett. NANOOS contributions to understanding ocean acidification. National Shellfisheries Association Meeting, 2012, Seattle, WA, 26-29 March.

2. Washington State estuarine monitoring: Directed by C. Maloy (Marine Monitoring Manager), led by C. Krembs (Senior Oceanographer) and coordinated by D. Mora (Mooring Coordinator), the WA State Department of Ecology (Ecology) maintained five Puget Sound mooring stations and one Willapa Bay station. This report covers Ecology activity from October 2010 through September 2012. Ecology contributed to regional estuarine observations by maintaining moorings and evaluating data on a monthly basis. In Willapa Bay we monitored salinity, temperature, and chlorophyll fluorescence. In Puget Sound we monitored tidal height, salinity, temperature, and dissolved oxygen. During this reporting period NANOOS funding helped maintain and advance monitoring efforts in the face of austere and uncertain state budgets. We continue to place a high focus on data quality, routinely holding data review sessions with our lead oceanographer and using control baths for dissolved oxygen sensor verification.

Impact:

Dissolved oxygen is an important ecological stress indicator that is useful toward understanding Puget Sound water quality dynamics. At the end of the last reporting period (2007-2010) we placed moorings in key inter-basin exchange zones, e.g., Admiralty Inlet, Guemes Channel, Rich Passage, Squaxin Passage, and Possession Sound (Mukilteo). Now that we have collected three or more years of data we are in a position to report on seasonal change points and interannual variability. Our mooring data provides important context to profile data and is important toward verifying modeled predictions.

Each month Ecology publishes on the web up-to-date observations of water quality conditions in Puget Sound and the Strait of Juan de Fuca. These reports, known as Eyes Over Puget Sound (EOPS) Surface Condition Reports include: flight observations, weather conditions, water column measurements, aerial photographs, en route ferry data, satellite images, and mooring data. http://www.ecy.wa.gov/programs/eap/mar_wat/surface.html



DEPARTMENT OF ECOLOGY State of Washington

Mooring observation and trends 9-24-2012 to 10-7-2012

Field log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

Summary: While dissolved oxygen decreased overall in Whidbey Basin (by 0.7 mg/L), an algal bloom appears to have occurred during the first few days of October. The effects of the recent dry weather spell and lack of freshwater input are continuing to show in the mooring data.

Mukilteo, Whidbey Basin near Everett:

Mukilteo Dissolved Oxygen Conditions (12-16 m)

DO Max	11.1 mg/L	on 10/2	at 28.5 PSU	13.0 C	13.0 db
DO Min	4.7 mg/L	on 10/4	at 29.9 PSU	11.2 C	13.9 db
DO Avg	5.7 mg/L				
DO Trend	-0.7 mg/L				
DO-Sal Corr	-0.78				
DO-Temp Corr	0.84				

Real-time data online (click)

Mukilteo Salinity (Sal) Conditions (12-16 m)

Sal Max	30.1 PSU	on 10/6	at 11.5 C	14.6 db	
Sal Min	28.1 PSU	on 9/29	at 12.8 C	13.4 db	
Sal Avg	29.6 PSU				
Sal Trend	+0.2 PSU				

Mukilteo Temperature (T) Conditions (12-16 m)

T Max	13.1 C	on 10/2	at 28.5 PSU	12.9 db	
T Min	11.1 C	on 10/4	at 29.7 PSU	12.9 db	
T Avg	11.6 C				
T Trend	-0.7 C				

Manchester, near Clam Bay:

Manchester Dissolved Oxygen Conditions (8.6-12.7 m)

DO Max	8.0 mg/L	on 10/3	at 29.9 PSU	12.7 C	11.2 db
DO Min	5.8 mg/L	on 10/3	at 30.0 PSU	12.1 C	11.4 db
DO Avg	6.6 mg/L				
DO Trend	No trend				
DO-Sal Corr	-0.66				
DO-Temp Corr	0.86				

Real-time data online (click)

Manchester Salinity (Sal) Conditions (8.6-12.7 m)

Sal Max	30.0 PSU	on 10/7	at 12.0 C	12.1 db	
Sal Min	29.7 PSU	on 9/24	at 13.1 C	9.4 db	
Sal Avg	29.9 PSU				
Sal Trend	+0.2 PSU				

Manchester Temperature (T) Conditions (8.6-12.7 m)

T Max	13.2 C	on 9/26	at 29.7 PSU	9.8 db	
T Min	12.0 C	on 10/7	at 30.0 PSU	12.1 db	
T Avg	12.5 C				
T Trend	-0.4 C				

Figure 1: Summary statistics from Eyes Over Puget Sound edition 10-8-12.

Mooring data helps provide context to other sections of EOPS. Figure 1 is an example of one segment of Ecology's mooring data contribution to EOPS. The mooring contribution to EOPS is a summary of observations from the previous two week window. Mooring data reported includes average, max, min, trend, and strength of correlations between salinity and temperature, and salinity and dissolved oxygen.

As shown in Figure 2, EOPS also reports on the thickness of the freshwater layer between Whidbey Basin and Central Basin to understand freshwater input to Puget Sound. Ecology tracks the depth of the isohaline where salinity is 28.55 (±0.05) to measure the thickness of the freshwater layer at our Mukilteo station. The sensor experiences tidal pressure variations of 11.8 to 15.6 meters (or dbar).

EOPS also includes a two week summary, characterization of water mass observations. As shown in Figure 3, this segment provides observed dissolved oxygen trends and highlights in red the most frequently observed condition in temperature-salinity and dissolved oxygen-salinity space.

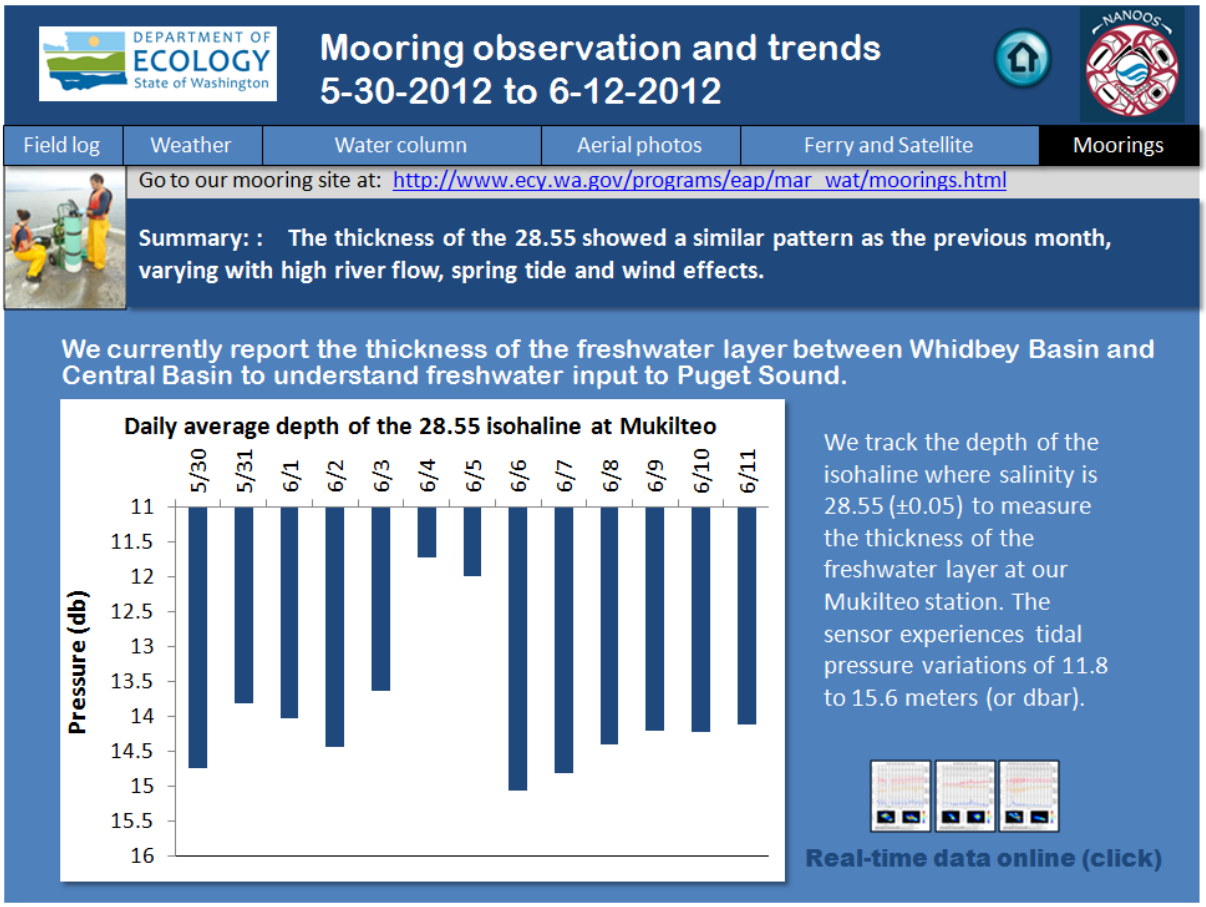


Figure 2: Depth of 28.55 isohaline observed at Mukilteo mooring, from the Eyes Over Puget Sound edition 6-12-12.

Significant changes and events in Ecology's mooring program in Y4 included:
Willapa Bay: As a continuance of monitoring efforts that began in 1997, we maintained our Bay Center mooring station where we monitor near surface temperature, salinity, and chlorophyll. In 2010 at Bay Center we installed a second sensor package that we secured at a fixed vertical position. The sensor package measured pressure, temperature, and salinity. From this sensor we established a telemetry system for transmitting data real-time. In 2011 we were forced to pull the sensor out due to problems with our mooring data retrieval system. We plan to modify the retrieval system, redeploy, and reestablish telemetry.

Puget Sound: Through collaborative partnerships we maintained five fixed mooring stations monitoring near-bottom water temperature, salinity, and dissolved oxygen. In 2010 we discontinued chlorophyll monitoring at our Rich Passage and Squaxin Passage stations but continued to monitor near-surface temperature and salinity. We established telemetry for real-time data reporting at three stations (Squaxin Passage, Rich Passage, and Possession Sound). We made advances with our telemetry system/data retrieval system striving for gained efficiencies at database aggregation, quality control, and data analysis. In 2011, in order to better understand the representativeness of our mooring data, we ran ADCP/CTD transects throughout a full tidal cycle at three of our stations. From these data we can see the relationship between pressure changes at mooring stations to flow across the channels. From the CTD data we can better understand cross channel variability and assess similarity of water mass between moorings and various points along the transects. In 2012, due to staff shortage and potential budget cuts, we decommissioned the Squaxin Passage station.

In 2012 we hired a new mooring technician, S. Pool, to replace A. Carle who left Ecology in 2011. This position is partially funded by NANOOS. Over 2010-2012 we have maintained key collaborative partnerships, including: Possession Sound with Everett Community College (ORCA) and the Port of Everett; Guemes Channel with Western Washington University's Shannon Point Marine Center; Admiralty Inlet with University Washington Applied Physics Lab.

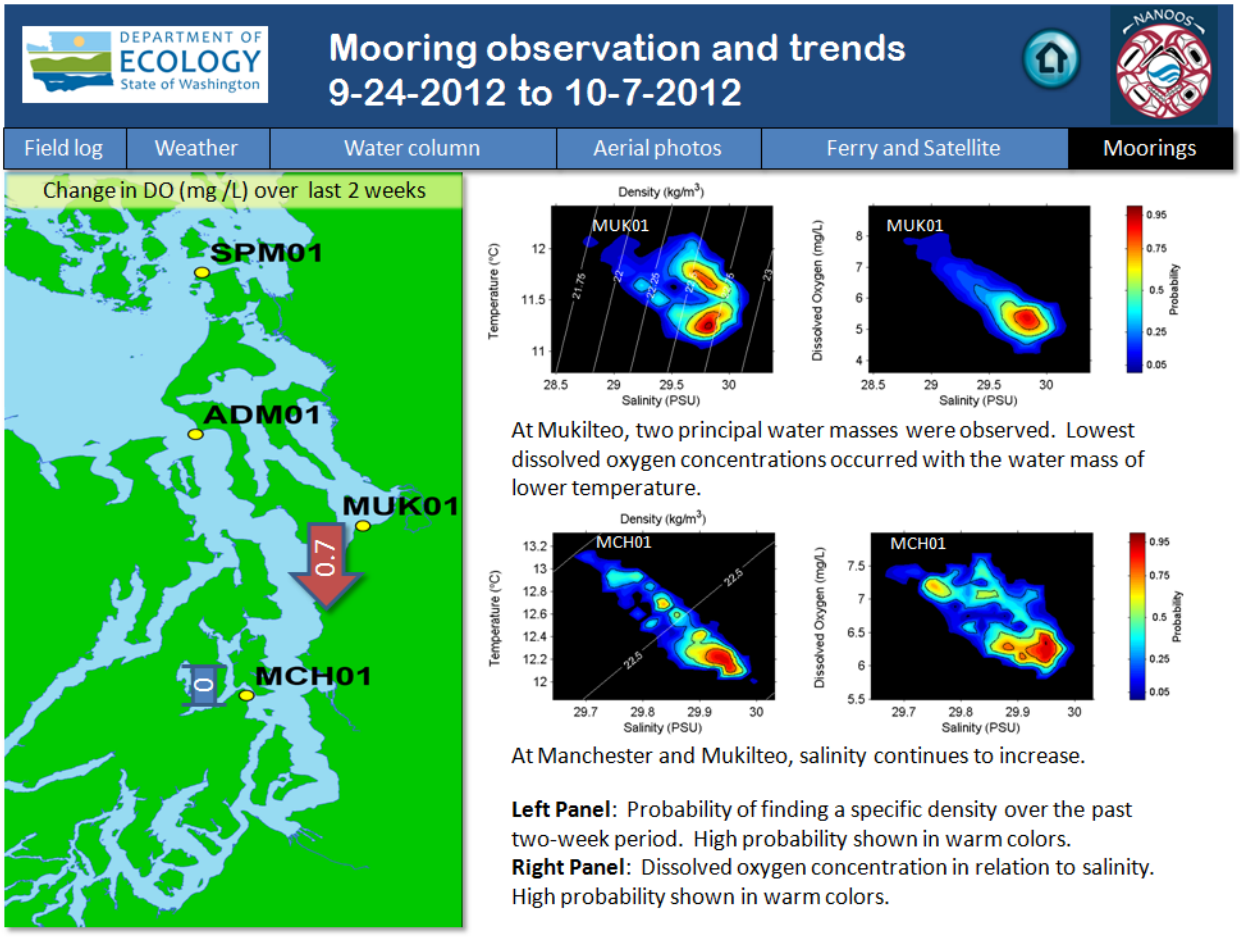


Figure 3: Water mass observations from Eyes Over Puget Sound edition 10-8-12. Left Panel shows locations of Ecology's moorings and recent trends in dissolved oxygen (DO). Right side of figure shows plots of temperature vs. salinity and DO vs. salinity at 2 mooring locations.

Presentations acknowledging NANOOS support:

Eyes Over Puget Sound, http://www.ecy.wa.gov/programs/eap/mar_wat/surface.html

Albertson, S., Carle, A., Krembs, C., Mora, D., Thomson, J., 2011. "*Admiralty Reach as Conduit for Low Oxygen Water Intrusions Into Puget Sound.*" 2011 Salish Sea Ecosystem Conference, Vancouver, BC.

Albertson, S., Carle, A., Krembs, C., Mora, D., 2010. "*Transport of Heat, Salt, Oxygen, and Freshwater within the Southernmost Extent of South Puget Sound: Year 2010 in Review.*" 2010 South Puget Sound Science Symposium, Shelton, WA.

3. Columbia River estuarine monitoring: OHSU-CMOP (A. Baptista) continued to maintain an extensive network of endurance stations in the Columbia River estuary, including both physical and biogeochemical stations. Primary funding came from NANOOS and NSF/CMOP, with complementary funding from USACE and other regional stakeholders.

Physical endurance stations: These stations were originally deployed as a part of an autonomous observation and prediction system (CORIE), one of the pioneer estuarine observatories in the US, now subsumed by the SATURN collaborator and part of NANOOS. At most stations, measurements were at single depth. Variables were salinity, temperature, water levels, and velocity profiles. Two former CORIE stations were upgraded to biogeochemical stations.

SATURN biogeochemical stations: Six biogeochemistry stations were maintained during the reporting period to characterize Columbia River river-to-shelf gradients. SATURN-02 is in the near-field plume (and was described earlier); SATURN-01, 03 and 04 are in the estuary (in two channels and a low-salinity lateral bay); SATURN-05[1] is in the main stem of the Columbia River at river mile 53; and SATURN-06[1] is in the Willamette River (a major tributary that joins near Portland, OR). All stations experience tidal fluctuations.

Each SATURN biogeochemical station consisted of a horizontally-fixed platform. River stations SATURN-05 and 06 monitored the water surface only, while estuary and plume stations were designed to capture the vertical structure of the water column (using either winch- and pump-based technologies). Most stations monitored the following variables: salinity, temperature, CDOM, turbidity, chlorophyll *a*, nitrate and dissolved oxygen.

Salinity, temperature and water level data were quality controlled on a monthly basis, using documented procedures developed for physical endurance stations. Data were available through NANOOS NVS. Data, analyses tools, quality control procedures, and performance metrics were available through the CMOP web site. Quality control procedures for an increasing number of biogeochemical data have been developed during the reporting period.

All stations were supported by the CMOP cyber team and the NANOOS DMAC team (which synergistically overlap). Sensor-to-user handling of information flow, including database and web interface, were the same as for physical data. SATURN-06 was also a USGS station, and reported as such via the USGS web site. SATURN-05 was also a LOBO station, and reported as such by the LOBO network. LOBO is an industry-led national biogeochemical network.

Impact:
To address important questions regarding the ecological function of the estuary, sensors for DO and phycoerythrin (PE) were installed at SATURN-01 and SATURN-03, and demonstrated substantial, ocean-driven, oxygen depletion at levels of concern for salmon. An Oxygen Watch, covering both the estuary and the WA shelf was maintained. A red water bloom watch is under development.

We have began the characterization of estuarine acidification in the Columbia River, by installing pCO_2 and pH sensors at stations off the navigation channel (SATURN-03) and in a tidal freshwater lateral bay (SATURN-04).

[1] While most SATURN stations are partially supported by NANOOS, neither SATURN-05 nor SATURN-06 receives NANOOS funding. SATURN-05 is operated under the direction of Dr. Joseph Needoba, with funding from NSF/CMOP and the Bonneville Power Administration and in collaboration with the USGS and WETLabs; originally maintained in part by Dr. Needoba, SATURN-06 is now fully operated by the USGS.

The Virtual Columbia River and other physical and ecological numerical models (including NOAA PORTS circulation forecasts) have relied on data of the SATURN stations for calibration and validation. A large number of publications, addressing the ecological function of the estuary, have relied on physical and biogeochemical data from the SATURN stations

Publications acknowledging NANOOS support:

Needoba JA, Peterson TD, Johnson KS. In Press. Method for Quantification of Aquatic Primary Production and Net Ecosystem Metabolism using in situ Dissolved Oxygen Sensors. Molecular Biological Technologies for Ocean Sensing. Google Scholar RTF Tagged XML

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Anderson CR, Davis RE, Bandolin NS, Baptista A, Tebo BM. 2011. Analysis of in situ manganese(II) oxidation in the Columbia River and offshore plume: linking Aurantimonas and the associated microbial community to an active biogeochemical cycle. Environmental Microbiology. DOI Google Scholar RTF Tagged XML

Roegner GC, Seaton C, Baptista A. 2011. Climatic and tidal forcing of hydrography and chlorophyll concentrations in the Columbia River estuary. Estuaries and Coasts. 34(2):281-296.DOI Google Scholar RTF Tagged XML

Roegner GC, Needoba JA, Baptista A. 2011. Coastal Upwelling Supplies Oxygen-Depleted Water to the Columbia River Estuary. PLoS ONE. 6(4):e18672.DOI Google Scholar RTF Tagged XML

Bräuer SL, Adams C, Kranzler K, Murphy D, Xu M, Zuber P, Simon HM, Baptista A, Tebo BM. 2011. Culturable Rhodobacter and Shewanella species are abundant in estuarine turbidity maxima of the Columbia River. Environmental Microbiology . 13(3)DOI Google Scholar RTF Tagged XML

Herfort L, Peterson TD, McCue LA, Crump BC, Prahl FG, Baptista A, Campbell V, Warnick R l, Selby M, Roegner GC et al.. 2011. Myrionecta rubra population genetic diversity and its cryptophyte chloroplast specificity in recurrent red tides in the Columbia River estuary. Aquatic Microbial Ecology. 62DOI Google Scholar RTF Tagged XML

Fortunato CS, Herfort L, Zuber P, Baptista A, Crump BC. 2011. Spatial variability overwhelms seasonal patterns in bacterioplankton communities across a river to ocean gradient. ISME Journal. DOI Google Scholar RTF Tagged XML

Dang T, Bulusu N, Feng W, Frolov S, Baptista A. 2010. CoTrack: A Framework for Tracking Dynamic Features with Static and Mobile Sensors. INFOCOM, 2010 Proceedings IEEE . :1-5.DOI Google Scholar RTF Tagged XML

Burla M, Baptista A, Casillas E, Williams JG, Marsh DM. 2010. The influence of the Columbia River plume on the survival of steelhead (Oncorhynchus mykiss) and Chinook salmon (Oncorhynchus tshawytscha): a numerical exploration. Canadian Journal of Fisheries & Aquatic Sciences. 67(10):1671-1684.DOI Google Scholar RTF Tagged XML

Hickey BM, Kudela RM, Nash JD, Bruland KW, Peterson WT, MacCready P, Lessard EJ, Jay DA, Banas NS, Baptista A et al.. 2010. River Influences on Shelf Ecosystems: Introduction and synthesis. Journal of Geophysical Research. 115(C00B17)DOI Google Scholar RTF Tagged XML

Burla M, Baptista A, Zhang Y, Frolov S. 2010. Seasonal and interannual variability of the Columbia River plume: A perspective enabled by multiyear simulation databases. Journal of Geophysical Research. 115(C00B16)DOI Google Scholar RTF Tagged XML

Smith MW, Herfort L, Tyrol K, Suciu D, Campbell V, Crump BC, Peterson TD, Zuber P, Baptista A, Simon HM. 2010. Seasonal Changes in Bacterial and Archaeal Gene Expression Patterns across Salinity Gradients in the Columbia River Coastal Margin. PLoS ONE . 5(10):e13312.DOI Google Scholar RTF Tagged XML

Presentations acknowledging NANOOS support:

Baptista, A. M. (2012) The SATURN collaboratory for the Columbia River coastal margin: capabilities and applications. Columbia River Estuary Conference, May 17, 2012. Astoria, OR

Baptista, A. M. (2012) SATURN model for the Lower Columbia River Estuary. Corps Climate Change Workshop, June 11, 2012 . Portland, OR
Baptista, A. M. (2012) Salinity Intrusion and Productivity. Bonneville Power Administration, August 2012. Portland, OR
Baptista, A. M. (2012) Estuarine hypoxia and acidification in the Columbia River. Eastern Pacific Ocean Conference - EPOC 2012, September 19-22, 2012. Mt. Hood, OR
Baptista, A. M. (2012) The SATURN Collaboratory. Washington State University, October 22, 2012. Vancouver, WA
Welle, P., Baptista, A. M., Spitz, Y., Lopez, J. E., Needoba, J. A., Peterson, T. D., Seaton, C. (2012) Understanding Oxygen Depletion in the Columbia River Estuary through Data- Supported Numerical Modeling. Columbia River Estuary Conference, May 17, 2012. Astoria, OR
Baptista, A. M; Spitz, Y. H; Needoba, J. A; Peterson, T. D; Zuber, P.; Herfort, L. M; Seaton, C. M; Cho, K. H; Welle, P.; Lopez, J. E (2011) Collaboratory Enabled Ecological Forecasts. ASLO Aquatic Sciences Meeting, February 14, 2011, San Juan, Puerto Rico.
Baptista, A., Lothrop, R., Schumacker, E., Roger, P., Hudson, C., Heinith, B., Green, V., Wegner, K., Peterson, T. (2011) Bringing Together Tribal And Quantitative Oceanographic Perspectives In A Scientific Framework For Coastal Margins. 2011 ASLO Aquatic Sciences Meeting, February 13-28, 2011, San Juan, Puerto Rico
Baptista, A. M. (2011) The NSF Science Technology Center for Coastal Margin Observation & Prediction: A National and Pacific Northwest Asset. Marine Technology Society - Puget Sound Section Annual Meeting, April 21, 2011, Beaverton, OR.
Baptista, A. M. (2011) A virtual journey through the mighty Columbia River estuary: ocean science that fits in your classroom? Hispanic Engineering, Science and Technology Week, September 26, 2011, Edinburg, Texas
Baptista, A. M. (2011) Coastal margin 'Collaboratories': a scientific foundation for decision-making towards sustainability. 2011 International Conference on Water, Energy and Environment (ICWEE), November 15, 2011, Sharjah, United Arab Emirates
Bandolin, N. (2010) Towards Long-Term Time Series of Sediment Concentrations in the Columbia River Estuary. Pacific University Student Poster Sessions, November 16, Forest Grove, Ore.

4. Oregon South Slough: Participation by the Oregon Department of State Lands (ODSL) in NANOOS was led by A. Helms (Estuarine Monitoring Coordinator) and A. DeMarzo (Estuarine Monitoring Assistant) at the South Slough National Estuarine Research Reserve (NERR).

Staff members from the ODSL/South Slough NERR operated a series of moored observing stations within the South Slough estuary as part of the NERR/SWMP network of NANOOS anchor stations. The monitoring stations, equipped with YSI-6600 multi-parameter dataloggers located 50 cm above the bottom, are located at:) 1) Charleston Bridge 2) Valino Island, 3) Winchester Arm, and 4) Elliot Creek/Sengstacken and provide continuous near real-time data along the estuarine gradient. There is one fifth water quality station (BoatHouse) which provides 15 min datasets of water temperature, salinity, specific conductivity, and water level but currently is not real-time. There is also a real-time meteorological station that collects information every 15 minutes on air temperature, relative humidity, rainfall, barometric pressure, solar radiation, wind speed, and wind direction.

The NERR-SWMP/NANOOS water monitoring stations in the South Slough estuary were in continuous operation throughout the period of 1 Oct 2010 to 30 Sept 2012, and the dataloggers deployed on a monthly basis. Time-series measurements generated by four of the monitoring stations are available in near real-time from several websites including NANOOS, the NOAA /

Hydro-Meteorological Automated Data System, and via the NOAA/NERRS data access website operated by the NERRS Centralized Data Management Office.

The fourth real-time station Elliot Creek was installed and began transmitting on 5/31/2012. However, the site experienced low transmission signal strength until 8/9/2012 when we replaced the Satlink transmitter. The new station data was added to NVS on 9/25/2012.

South Slough NERR purchased two YSI-6600 V2 dataloggers, two 12VDC sealed batteries, and miscellaneous datalogger equipment. We also converted an older 6600 datalogger to a V2, replaced pH probes and a turbidity probe, and replaced the weather station sensors in 2012.

We began site selection for the 5th real time water quality station (Boat House) this summer and have determined a location on the Coos Bay entrance range front light structure (LLNR 8740) just inside the mouth of Coos Bay. We are currently in the process of obtaining a licensing agreement by the US Coast Guard Shore Infrastructure Logistics Center (SILC). We received temporary authorization to access the structure for six months on September 17, 2012 until they are able to process the agreement. The current Boathouse station consists of a smaller datalogger (600XLM) that samples water temperature, specific conductivity, salinity, and water level every 15 minutes from ~ 1 m off the bottom of one of three pilings from a dilapidated range marker located inside the mouth of Coos Bay near Coastguard Beach. The pilings are too high to install telemetry equipment and there is not a stable platform to service this station, so we pursued an alternative range marker that has a stable platform and several levels at which to consider placement of telemetry equipment. This station will be upgraded to collect the full suite of water quality parameters using the 6600 V2 instruments and real-time equipment.

Impact:
Real-Time Water Quality Data informs Oyster Growers: Staff members provided site descriptions, metadata, and local reference water quality condition information by season for the Real-Time Data Application for shellfish growers (Figure 4) and participated in conference calls for development and upgrades to the product.

Staff members from the South Slough NERR interacted directly with the four commercial oyster growers (Clausen's Silverpoint Oysters, North Bend Oyster Company, Coos Bay Oyster Co LLC, and Qualman Oyster Farms) in Coos Bay to provide technical assistance with access to water-quality data, including discussing real-time data issues and aiding with navigation and understanding of the NANOOS data product (Real-Time Water Quality Data for Shellfish Growers in the Pacific Northwest). In person interviews with oyster growers were conducted to contribute data to the shellfish grower surveys to inform changes to the NANOOS data product.

In order to help minimize anomalous or erroneous chlorophyll data and improve the datasets, staff worked with Mindfly Web Design in 2010 to place a data filter on transmitted chlorophyll data that excludes extremely high values or spikes. The time-series measurements of temperature, salinity, DO, pH, and fluorescence are of primary interest to the local oyster shellfish growers because they provide the essential information to characterize estuary water quality conditions for shellfish mariculture and an indicator of the concentration of phytoplankton available in the estuarine water column as food for filter-feeding oysters.

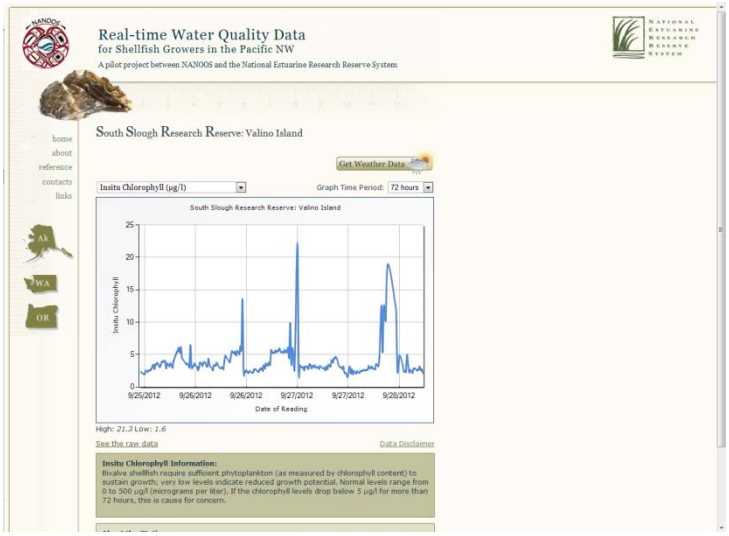

Figure 4. Shellfish Growers' web application data product on the NANOOS website with South Slough NERRS data.

Analysis of water quality data reveals interesting shift in estuarine pH: Recent observations of elevated pCO_2 values in the nearshore ocean waters along the Pacific coast of North America (Feely et al., 2008) provide an opportunity to investigate the relationship between ocean acidification and variability in pH values in Pacific coast estuaries. As reported in Y1-3 Final Report, staff members from the South Slough NERR examined time-series measurements of water column parameters recorded at the NANOOS/SWMP stations (YSI-6600 EDS multi-parameter dataloggers equipped with a YSI 6561 pH probe (resolution 0.01 pH unit; accuracy $\pm$ 0.2 pH unit)). The datasets that were analyzed recorded about 208,500 measurements of estuary pH values at one site (Charleston Bridge), which ranged between 7.7 and 8.3 throughout each day. A strong tidal signal as well as a diurnal cycle was observed with lowest pH values in mid-morning and highest pH values in mid-afternoon. The estuary pH at all monitoring stations showed a long term shift toward increased pH values (more alkaline) over time, which is unexpected and interesting because it is in the opposite direction of ocean measurements (more acidic). The daily pH cycle may be driven by photosynthesis and respiration of phytoplankton, macroalgae, and submerged aquatic vegetation within the estuary. This estuary pH shift data was included in the Oregon Climate Assessment Report in December 2010: http://occri.net/ocar.

Recently, the South Slough received a small award from NOAA Ocean Acidification funds to acquire a Sunburst Sensor $SAMI^2$- $C0_2$ sensor which will be deployed alongside the Valino Island water quality sonde station to determine correlations between pH and pCO_2 and other water quality parameters including temperature, salinity, and dissolved oxygen in South Slough NERR waters and to determine the seasonal (winter/summer) and temporal (day/night) influences on pH and pCO_2.

Water quality data informs research on Olympia Oysters: Datasets generated by the NANOOS/SWMP observation stations were also used to help guide general research plans for the restoration and recovery of native Olympia oysters, including locations for the placement of experimental outplants of Olympia oysters (*Ostrea lurida*).

- **Shorelines**

1. Washington Shorelines: During the 2-year period from October 1, 2010 to September 30, 2012, the Washington State Department of Ecology (Ecology) Coastal Monitoring & Analysis Program (CMAP) was supported by YR 4 funds between October 1, 2010 and December 18, 2011. Led by G. Kaminsky, CMAP continued a beach and shoreline monitoring program in the Columbia River littoral cell (CRLC) and at the Elwha River delta. In the CRLC, quarterly beach profiles (46) beach surface maps (typically 14 in summer, 2 in fall and spring, and 5 in winter) were collected. At the Elwha River mouth, beach and nearshore profiles were collected semiannually in collaboration with the US Geological Survey (USGS). During each summer, Ecology collaborated with Oregon State University (OSU) and USGS to collect nearshore bathymetry in the CRLC with the Coastal Profiling System.

After 367,000 cubic yards of dredged material were placed in the intertidal zone of Benson Beach adjacent to the Columbia River mouth during summer 2010, CMAP began implementing the Southwest Washington Littoral Drift Restoration project monitoring program, including the initial 6 surveys. During this YR 4 effort, an additional 15 surveys were performed monthly between October 6, 2010 and November 4, 2011, including 4 combined with nearshore bathymetry led by P. Ruggiero of OSU. Each topographic survey collected ~30,000 data points over 64 km of transects, while each bathymetric surveys collect ~600,000 data points over 88 km of transects. Nearshore bathymetry collected in collaboration with OSU at Benson Beach on October 6 and December 5, 2010 represented the first late-fall/early-winter season nearshore surveys since beach morphology monitoring began in 1997. The beach and nearshore surveys documented changes in the movement of beach sand, particularly erosion throughout the winter months and the beach recovery during spring and summer. CMAP also collected monthly beach sediment samples to document changes in sediment grain size.

During this period CMAP acquired a 28 x10' twin-hull vessel (beach-landing craft) specifically de-signed for shallow water hydrographic and topographic surveying in Puget Sound. The vessel is named after George Davidson (1825-1911), the pioneer west coast scientist who was responsible for producing the first U.S. Coast and Geodetic Survey charts of the U.S. Pacific coast beginning in the 1850s and who subsequently authored voluminous initial editions of the Coast Pilot of California, Oregon, and Washington. A shallow-water beach-landing craft is the only feasible way to access and survey the vast majority of Puget Sound shorelines because more than two-thirds (2,620 km) of the shoreline lacks public access and at least 27% (1,072 km) of the beaches are armored. Equipped with a drop-down bow door, the vessel enables all-terrain vehicle, personnel, and cargo loading and offloading at remote beaches. Initial efforts will focus on surveying a select number of beaches and bluffs that are vulnerable to coastal storms and on leveraging funds to sustain a Puget Sound beach monitoring program into the future.

CMAP collaborated with USGS in surveying the beaches at Fay Bainbridge State Park and adjacent shorelines during October 19-21, 2010. CMAP surveyed locations of approximately 150 sediment samples that were collected to study the concentration and distribution of forage fish eggs relative to beach state parameters.

CMAP also collaborated with USGS in surveying the beaches and nearshore at the Elwha River delta from 16-17 May and 25-26 August 2011. These were the last two surveys performed in

advance of the removal of 2 river dams which began in September 2011. CMAP surveyed approximately 260 cross-shore transects and 6-8 alongshore lines. Data results were presented by USGS collaborators at the Elwha River Science Symposium in September 2011 at Port Angeles.

CMAP researched terrestrial laser scanning technology and purchased an Optech ILRIS scanner for high resolution coastal topography surveys. The scanner is capable of 360° static scans and can be mounted to the R/V Davidson to perform mobile laser scanning of beaches and bluffs.

Beach erosion trends occurred along the northern tip of Long Beach Peninsula at Leadbetter Point, where the beachface between 2- and 3-m elevation contours retreated by over 20 m. The dunes along the northern entrance to Willapa Bay retreated roughly 11 m since summer 2010, while the beach along a 5-km reach to the north accreted as part of a shore-connected ebb-tidal shoal that continues to migrate northward over time. The 3-m contour (shoreline proxy) along this feature has shifted horizontally seaward by as much as 110 m since summer 2010. Along the southern end of Ocean Shores the dunes adjacent to the emergency rock revetment placed in November 1996 continued to retreat on the north end by 10 m, exposing more of the previously covered geotubes that were installed in December 1998 (Figure 5). The entire beach profile experienced lowering of at least 1 m.

Figure 5. Dune erosion at Ocean Shores during winter 2010/2011 further exposed the rock revetment and geotubes that had been installed in 1996 and 1998 to protect condominiums and houses along this vulnerable shoreline reach.

Kaminsky collaborated with colleagues at USGS, Oregon DOGAMI, OSU and the University of California Santa Cruz on an abstract presented at the AGU Fall 2010 Meeting, Session on Coastal Geomorphology and Morphodynamics. The presentation was on the impact of the 2009-10 El Niño on West Coast beaches. Along the Oregon and Washington coasts, many beaches exhibited classic El Niño shoreline responses, with significant shoreline retreat occurring

immediately north of jetties and tidal inlets as well as the southern ends of pocket beaches and littoral cells. In Washington in particular, these areas eroded rapidly during the winter of 2009-10, comparable to the response seen in the El Niño winter of 1997-98. Wave buoy data from buoys in California and Washington that captured both the 1997-98 and 2009-10 El Niño show that the two events were comparable in wave energy. While the impacts of the 2009-10 winter were substantial, impacts on coastal infrastructure likely were moderated by an unusually mild wave climate in 2008-09, which left beaches more accreted prior to the severe wave season of 2009-10. As climate change accelerates sea level rise and potentially increases the magnitude and frequency of storms in mid-latitudes, the beach erosion seen in 2009-10 will become less unusual, making it critical that we continue to monitor beach morphology to provide data for coastal managers and to improve our understanding of beach dynamics.

This initial work was subsequently developed as a journal paper in Geophysical Research Letters. The beach morphology data collected along much of the U.S. West Coast were synthesized to evaluate the coastal impacts of the 2009-10 El Niño. The increase in extreme waves in the 2009-10 winter was coupled with elevated water levels and a more southerly wave approach than the long term mean, resulting in greater shoreline retreat than during 1997-98, including anomalously high shoreline retreat immediately north of jetties, tidal inlets, and rocky headlands. The morphodynamic response observed throughout the U.S. West Coast during the 2009-10 El Niño is principally linked to the El Niño Modoki phenomena, where the warm sea surface temperature (SST) anomaly is focused in the central equatorial Pacific (as opposed to the eastern Pacific during a classic El Niño), featuring a more temporally persistent SST anomaly that results in longer periods of elevated wave energy but lower coastal water levels.

Impact:
The Washington beach monitoring data informed a wide range of coastal management decisions, involving permitting, planning, and assessments of coastal change and hazards on public and private infrastructure. Scientific findings regarding El Niño responses demonstrated the value of both long-term and seasonal monitoring data in documenting the effects of these climate fluctuations. The data and information obtained from the monitoring proved to be a critical component to ongoing work on regional sediment management at the mouth of the Columbia River. Information derived from this monitoring include the economic value and utility of utilizing dredged sand to both restore littoral drift as well as protect and mitigate damages to vital infrastructure, natural resources, and the local economy supported by commercial Dungeness crab fishing. In addition, the documentation of sand accumulation and erosion hazard reduction due to the installation of sand fences at the mouth of the Columbia River motivated discussions with the U.S. Army Corps of Engineers to consider this approach at other coastal inlets experiencing coastal erosion and wave overtopping. The monitoring program provided numerous opportunities for educational outreach. CMAP provided information on coastal erosion along the southwest Washington coast to news reporters, including local newspapers—The Chinook Observer and The Aberdeen Daily World—and public radio stations—KQED and KPLU. CMAP observations of a series of sinkholes along the Columbia River North Jetty during November 2011 revealed subsurface leakage of sediment through the jetty into the inlet, indicating jetty deterioration. Out of concern for public safety, the U.S. Army Corps of Engineers used this information on the sinkholes as part of a notice to the public regarding safety hazards for pedestrians.

Publications acknowledging NANOOS support:

Barnard, P. L., J. Allan, J. E. Hansen, G. M. Kaminsky, P. Ruggiero, and A. Doria (2011), The impact of the 2009–10 El Niño Modoki on U.S. West Coast beaches, Geophys. Res. Lett., 38, L13604, doi:10.1029/2011GL047707.

Presentations acknowledging NANOOS support:

Barnard, P.L., Kaminsky, G.M., Hansen, J.E., Allan, J., Ruggiero, P., and Hoover, D., The impact of the 2009-10 El Niño on West Coast beaches, AGU Fall 2010 Meeting, Session on Coastal Geomorphology and Morphodynamics, (EP21D-05).

Kaminsky, G.M., 2011. Regional Sediment Management at the Mouth of the Columbia River, Coastal Sediments '11 conference, Coastal Inlet Modeling Short Course, 2 May 2011, Miami, Florida.

2. Oregon Shorelines:

Leveraging NANOOS, the Oregon Beach and Shoreline mapping Analysis Program (OBSMAP) efforts are led by J. Allan and V. McConnell of the Oregon Department of Geology and Mineral Industries (DOGAMI). Monitoring was undertaken at 46 NANOOS sentinel sites on multiple occasions at a reduced scale during the period between 1 October 2010 and 30 Sep 2011. In addition to the core 46 sites, DOGAMI leveraged additional funds through FEMA to expand the monitoring network along the length of the Tillamook County coastline, adding an additional 135 transects to the observation network for the purposes of defining new FEMA flood insurance maps for Tillamook County. However, these latter sites will only be monitored on an ad hoc basis (e.g. after an extreme storm(s) or hazard related event). Aside from the beach and shoreline monitoring, PI J. Allan also provides equipment and field support for PI P. Ruggiero (OSU) in order to assist Ruggiero with the collection of nearshore bathymetry (Mean Higher High Water (MHHW) out to a depth of approximately 20 m (~65 ft)) using personal water crafts along the length of the Tillamook County coastline. These latter surveys occurred in Jul-Sep 2011 at the same time as our regular beach monitoring to provide overlap and quality control checks of the land-based and bathymetry data. These latter surveys provided the first ever assessment of the nearshore bathymetry offshore from Tillamook County.

During NANOOS Y4, beach cross-section surveys were specifically carried out as follows:

- October 2010 (late summer survey, Rockaway cell and Clatsop Plains: 31 sites);
- December 2010 (fall survey, Rockaway cell and Clatsop Plains: 31 sites);
- January 2011 (fall survey, Neskowin cell: 15 sites);
- March 2011 (winter survey, Rockaway cell and Clatsop Plains: 31 sites);
- May 2011 (spring survey, Neskowin and Alsea littoral cells: 36 sites),
- August and September 2011 (late summer, Rockaway cell, Clatsop Plains, and Neskowin Cells: 46 sites).

Results of the beach profile measurements and contour excursion plots (time stack plots that show contour changes near the dune toe (e.g. the 6.0 m and 5.0 m contour) and lower down the beach face near the Mean High Water mark (e.g. the 3.0 m contour)) have been disseminated via the Oregon Beach and Shoreline Mapping and Analysis Program (OBSMAP) website[2] and linked through the NANOOS website to the NVS – Beaches and Shorelines web mapping portal[3] as part of a technology transfer between NANOOS and DOGAMI.

[2] http://www.oregongeology.org/sub/Nanoos1/index.htm

[3] http://www.nanoos.org/nvs/nvs.php?section=NVS-Products-Beaches-Mapping

Results from analyses of the OBSMAP beach and shoreline data have been integrated into a Geophysical Research Letters paper (Banard et al., 2011) that explored the US West Coast beach response to the 2009-10 El Niño. The results from the various monitoring efforts demonstrated strong coupling between coastal change measurements and ocean processes operating in the North Pacific, including increased (decreased) wave energy levels along the California (Oregon and Washington coasts) and anomalous increases in regional sea levels along the entire West Coast due to the El Niño Modoki climate phenomena. In the Pacific Northwest, although wave energy levels were lower, the tracks of the storms forced ocean waves to arrive from an increasingly oblique angle relative to the coast that produced anomalously high shoreline retreat north of jetties, tidal inlets, and rocky headlands affecting critical infrastructure in several of those areas.

Impact:
Oregon State Parks and Recreation Department (OPRD) use the OBSMAP data to assist with beach management, including the permitting of engineering structures. This has included the development of "hotspot" hazard maps for selected communities preceding a winter season.

Beach surveys are being used in the Rockaway community to assess ongoing problems relating to the loss of sand from the beach system and the increased incidence of damage to engineering structures, including overtopping by ocean waves and inundation of backshore properties.

Beach change data measured adjacent to the mouth of Tillamook Bay has been used to evaluate the potential effects of wave energy development offshore from Tillamook Bay.

Beach surveys are being used in the Neskowin community to assess ongoing problems relating to the loss of sand from the beach system and the increased incidence of damage to engineering structures, including overtopping by ocean waves and inundation of backshore properties.

Beach change data adjacent to the Columbia River south jetty is being used by the USACE to monitor the erosion of the dunes adjacent to the jetty, which exhibits signs that it may breach in the not too distant future.

The combined beach observation dataset now available for Tillamook and Clatsop Counties are being used to assess 1% (100-year) coastal flood and erosion risk along the shorelines of both counties for the purposes of developing FEMA flood insurance rate maps.

Other stakeholders include the Coastal Hazards Processes Working Group (an ad hoc group of planners, geotechs, engineers, agencies, and environmental groups that periodically meet to discuss coastal hazard issues), practicing geotechnical consultants, planners, and the public.

3. Nearshore Bathymetry: P. Ruggiero's group at Oregon State University is responsible for collecting nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC) and relevant littoral cells within northwest Oregon. This data collection is coordinated with the Washington State Department of Ecology (PI Kaminsky's group) and the Oregon Department of Geology and Mineral Industries (PI Allan's group). Well over 200 individual cross-shore profiles are typically collected in the summer extending from the lower inter-tidal to

approximately 12 - 25 m of water depth (~2000 m from the shoreline). Data is collected with a 4th generation Coastal Profiling System, a platform for a physical/biological sampling system for the nearshore ocean. The platform essentially consists of a pair of personal watercrafts (PWCs) outfitted with fixed sampling equipment for high-resolution surveying of sea bottom topography and for physical and ecological sampling in the previously inaccessible surf zone. The Coastal Profiling System is a unique asset that is supporting emerging research into nearshore ocean processes in the PNW.

In fall 2010 – summer 2011, we participated in The Southwest Washington Littoral Drift Restoration (SW LDR) project at the Mouth of the Columbia River. A series of nearshore surveys were performed along Benson Beach, WA during this time.

In summer 2011, we collected nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC). Over 200 individual cross-shore profiles were collected, 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 PI Kaminsky's group at Ecology developing complete maps of the nearshore planform. As of the end of summer 2011, 13 years of nearshore bathymetric profiles have been collected along the CRLC.

In summer 2011, we also completed the collection of nearshore bathymetry data in Tillamook County, Oregon in close collaboration with the Oregon Department of Geology and Mineral Industries. Over 250 individual cross-shore profiles were collected in 3 weeks of field collection. These data have been combined with topographic data collected synoptically by DOGAMI, and have been processed from their raw format into deliverable text files and have passed a rigorous quality assurance process. This is the first time that nearshore bathymetry data has been collected in this region of the Oregon coast. This data will be used extensively in DOGAMI's planned flood studies of Tillamook County.

Impact:
The data and information obtained from the monitoring efforts supported by NANOOS continues to be a critical component to ongoing work on regional sediment management at the mouth of the Columbia River (MCR). Partial support from NANOOS enabled our group to participate in the Southwest Washington Littoral Drift Restoration (SW LDR) project at the Mouth of the Columbia River. The aim of this project is to assess the long-term viability of placing dredged material from the mouth of the Columbia River (MCR) directly on Benson Beach to supplement the littoral sediment budget. Approximately 300,000 m^3 of dredged material from the MCR was placed along the intertidal area of Benson Beach during the summer of 2010. An extensive monitoring effort extending through summer 2011 attempted to evaluate the effectiveness of the SW LDR project. One component of the monitoring program is to track the morphological response of the beach and nearshore areas during and after the SW LDR sand emplacement. Oregon State University, the Washington State Department of Ecology and the US Geological Survey are collaborating on collecting morphological change data to address these questions and

completed 5 nearshore survey of the region in 2010 (Figure 6, Stevens et al., 2012, personal communication).

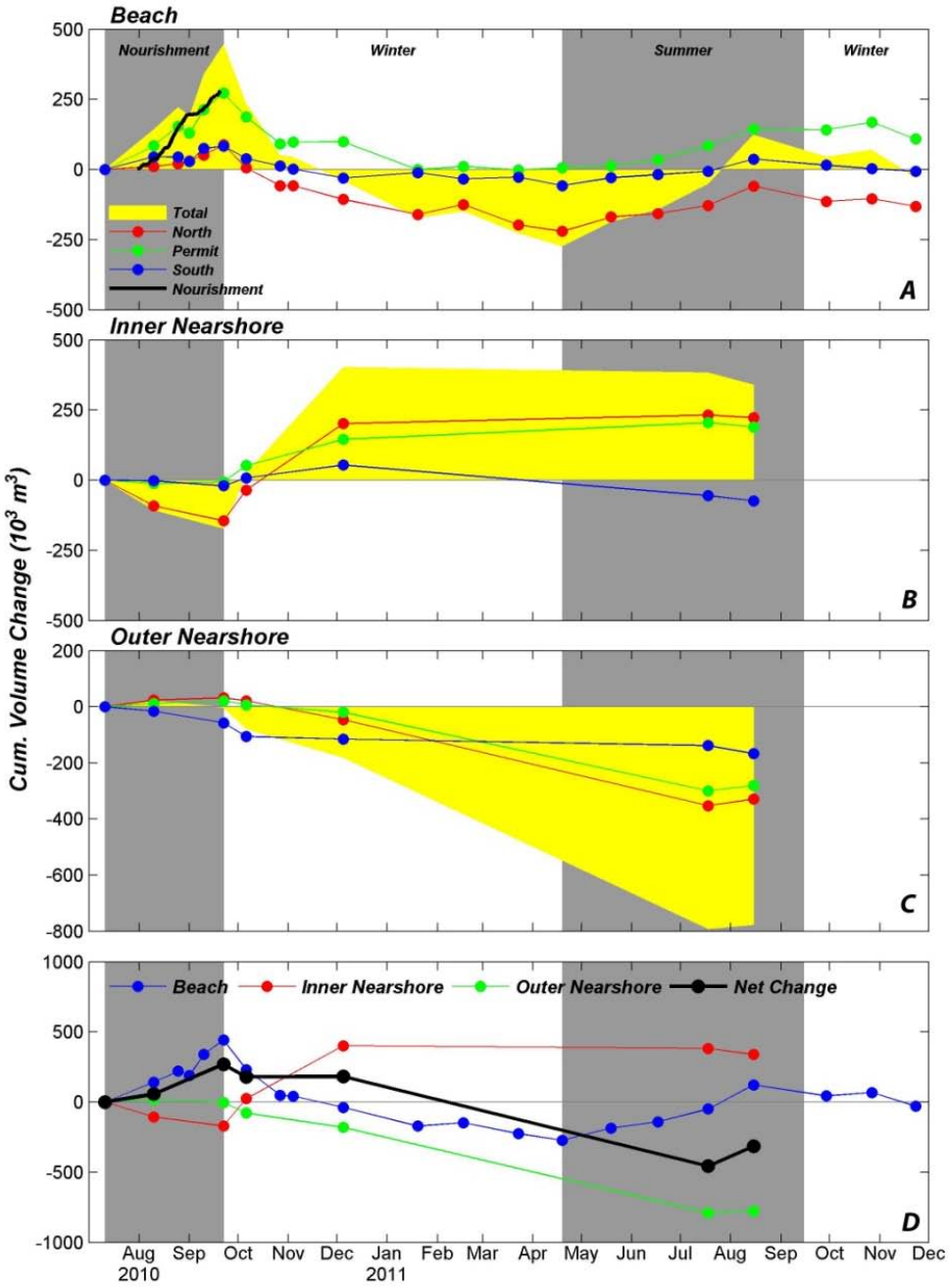

Figure 6. NANOOS supported beach and nearshore surveys monitored the fate of a beach nourishment project at Benson Beach, WA just north of the Columbia River.

Understanding sandbar dynamics and variability is integral to developing a predictive capacity for nearshore flows, sediment transport, morphological change, and ultimately for determining coastline exposure to damaging storm waves. Unfortunately, the large scale behavior of nearshore morphology is still poorly understood, partially because of the difficulty, expense, and danger of collecting data in this highly dynamic region. The time series of nearshore bathymetry along the CRLC is being used in fundamental studies of sandbar dynamics and PI Ruggiero

collaborates with numerous scientists on these issues while partially supported by NANOOS.

Ruggiero continues to use NANOOS supported data and knowledge in his Coastal Geomorphology and Coastal Hazards classes taught at Oregon State University. NANOOS efforts are highlighted during guest lectures and in advising students. Ruggiero's Graduate Research Assistant, D. Di Leonardo, is using nearshore bathymetry data collected as part of this project for her Master's thesis work. In December, 2011, Diana presented her initial findings at the Fall AGU meeting. With partial support from NANOOS, Ruggiero's group has hired a full time field technician, J. Wood, to assist with data processing, archiving, and field equipment maintenance. Jeff came on board in January of 2012 after working for Ruggiero's group as a student worker for over 1.5 years.

Publications acknowledging NANOOS support:

Baron, H. and Ruggiero, P., 2011. Developing probabilistic coastal change hazard zones to evaluate community vulnerability in a changing climate, *Proceedings of the Solutions to Coastal Disasters Conference* 2011, ASCE, Anchorage, AK.

Baron, H., Ruggiero, P., and Harris, E., 2010. A socioeconomic assessment of climate change-enhanced coastal storm hazards in the U.S. Pacific Northwest, Abstract NH21C-1417 presented at 2010 AGU Fall meeting, San Francisco, CA, 13-17 December.

Di Leonardo, D. and Ruggiero, P., 2011. Applying a long-term data set to understand large scale coastal behavior, AGU Fall meeting, San Francisco, CA.

Gelfenbaum, G., Stevens, A., Ruggiero, P., and Kaminsky, G., 2010. Southwest Washington Littoral Drift Restoration: Beach and Nearshore Morphological Monitoring AGU Fall meeting, San Francisco, CA.

Hacker, S.D., E. Seabloom, P. Ruggiero, P. Zarnestske, and J. Mull. 2011. Invasive grasses, climate change, and effects on coastal dune ecosystem functions and services, 2nd World Conference on Biological Invasions and Ecosystem Functioning, Mar del Plata, Argentina.

Hacker, S., Zarnetske, P., Seabloom, E., Ruggiero, P., Mull, J., Gerrity, S., and Jones, C., 2011. Subtle differences in two non-native congeneric beach grasses significantly affect their colonization, spread, and impact, *Oikos*, doi: 10.1111/j.1600-0706.2011.01887.x.

Komar, P.D., Allan, J.C., and Ruggiero, P., 2011. Sea level variations along the US Pacific Northwest coast: tectonic and climate controls, *Journal of Coastal Research,* (27) 5, 808-823, DOI:10.2112/JCOASTRES-D-10-00116.1.

Ruggiero, P., Zarnetske, P., Mull, J., Hacker, S., and Seabloom, E., 2010. Coastal foredune evolution: evidence for physical control, AGU Fall meeting, San Francisco, CA.

Ruggiero, P., Baron, H., Harris, E., Allan, J., Komar, P., and Corcoran, P., 2011. Incorporating uncertainty associated with climate change into coastal vulnerability assessments, *Proc. Solutions to Coastal Disasters Conf.*, ASCE, Anchorage, AK.

Ruggiero, P., J. Mull, P. Zarnetske, S. Hacker, and E. Seabloom. 2011. Interannual to decadal foredune evolution. Proceedings of Coastal Sediments 2011, ASCE, Miami, FL, 698-711.

Stevens, A.W., Gelfenbaum, G., Ruggiero, P., and Kaminsky, G.M, 2012, Southwest Washington littoral drift restoration—Beach and nearshore morphological monitoring: US Geological Survey Open-File Report 2012-1175, 67 p.

Zarnetske P., S.D. Hacker, E. Seabloom, P. Ruggiero, and J. Mull. 2011. Connecting process with pattern: towards a mechanistic understanding of invasions. 96th Ecological Society of America Meeting, Austin, TX.

Presentations acknowledging NANOOS support:

"Incorporating uncertainty associated with climate change and variability into coastal vulnerability assessments," 2011. II Workshop Brasileiro De Mudancas Climaticas em zonas Costeiras, Salvador, Brazil, November, 2011, ~100 attendees.

"Risk mapping on the coast of Oregon", 2011 PNW Climate Decision Support Consortium (CDSC) Stakeholder Meeting, Seattle, WA, June, 2011. ~50 attendees

"Risk mapping on the coast of Oregon", 2011 PNW Climate Decision Support Consortium (CDSC) Stakeholder Meeting, Portland, OR, June, 2011. ~50 attendees

"Erosion and flood hazards on the Oregon and Washington coast due to Earth's changing climate," National Research Council Committee: Sea level rise in California, Oregon, and Washington, Portland, OR. March, 2011.

- **Currents**

1. Coastal Currents: The HF surface current mapping program at Oregon State University (PI M. Kosro, RAs A. Dorkins and D. Langner), with NANOOS support, has been providing near-real-time maps of ocean surface currents along the Pacific Northwest coast (41.5N to 46.5N), as well as downloadable text files containing the data values, to the public via the NANOOS Visualization System (NVS). These data are also being provided to NOAA/NDBC, and from there to other agencies such as USCG and NOAA/OR&R, via the national HFR-net. They also are assimilated in regional ocean circulation model forecasts being done by Alexander Kurapov's group, which in turn are made public via NANOOS.

In addition during Y4, we have leveraged an internal OSU grant to upgrade two of our long-range systems to GPS timing, allowing their continued future operation. We have transitioned to a wholly-redesigned HFR processing software from NPS, and hosted Mike Cook for training. We are collaborating with CODAR Ocean Sensors to beta-test "bistatic" HF operation, which can increase the spatial HF footprint. We also provided a special data collection opportunity with Steve Anderson, Arete Associates, for intercomparison of his airplane-based photo-analysis for current mapping with our HF surface currents.

Kosro also served as a member of the IOOS HF Radar National Steering Team. He reported on HF surface current mapping to the Eastern Pacific Ocean Prediction Forum (ePOPf) in fall 2010 in Portland, and addressed the National Academy of Sciences Subcommittee on Radio Frequencies on the radio-spectrum needs of HF users (May 2011). He served as an external member of the PhD committee for Phil Muscarella at University of Delaware, who used HF measurements to study circulation outside Delaware Bay, and as committee member for John Osborne at OSU, examining tides in models and comparing with data, including HF.

Impact:

The data generated are used extensively, as shown by the diversity of presentations and publications listed below. A paper describing the West Coast HF system and preliminary results of the large-scale array, showing features the large-scale spring transition, alongshore-propagating features in several speed classes, and the length-scale dependence of energy in current variability, was published in *Journal of Geophysical Research* (Kim et al., 2011). Other publications included a discussion of the recirculation feature north of the Columbia River in JGR (Kudela et al., 2010) and an analysis of internal tide generation along the Oregon coast, using a model informed by in-situ data (Osborne et al., 2011). In addition, the surface current mapping data were essential for six conference presentations during the period, for which Kosro was a co-author.

Publications acknowledging NANOOS support:

Osborne, J.J., A.L. Kurapov, G.D. Egbert, P.M. Kosro, 2011. Spatial and temporal variability of the M2 internal tide generation and propagation on the Oregon shelf. *Journal of Physical Oceanography*, 41(11), 2037-2062, doi: 10.1175/JPO-D-11-02.1.

Kim, S.Y., E. Terrill, B. Cornuelle, B. Jones, L. Washburn, M. Moline, J. Paduan, N. Garfield, J.L. Largier, G. Crawford, P.M. Kosro, 2011. Observations of high-resolution coastal surface circulation on the U.S. West Coast. *Journal of Geophysical Research*, 116, doi:10.1029/2010JC006669.

Kudela, R. M., A. R. Horner-Devine, N. S. Banas, B. M. Hickey, T. D. Peterson, R. M. McCabe, E. J. Lessard, E. Frame, K. W. Bruland, D. A. Jay, J. O. Peterson, W. T. Peterson, P. M. Kosro, S. L. Palacios, M. C. Lohan, and E. P. Dever (2010), Multiple trophic levels fueled by recirculation in the Columbia River plume, *Geophys. Res. Lett*., **37**(L18607), 1-7, doi:10.1029/2010GL044342.

Presentations acknowledging NANOOS support:

Kurapov, A.L., P. Yu, S. Erofeeva, P.M. Kosro, "Effects of Assimilating GOES SST, alongtrack altimetry, and high-frequency radar surface currents on the coastal ocean surface topography", Ocean Sciences Meeting, Salt Lake City, Feb 20, 2012.

Osborne, J., A.L. Kurapov, G.D. Egbert, P.M. Kosro, "Modeling slope-shelf interactions in the coastal ocean", Ocean Sciences Meeting, Salt Lake City, Feb 21, 2012.

Terrill, E., et al., "Role of a Networked Ocean in Assessing Large Marine Ecosystems – Monitoring Ocean Currents at a Cascade of Scales with HF radar", Ocean Sciences Meeting, Salt Lake City, Feb 20, 2012.

Hickey, B.M., S.L. Geier, N.B. Kachel, S.R. Ramp, P.M. Kosro, "Alongcoast structure of seasonal water properties and velocity on the northen California Current shelf". Ocean Sciences Meeting, Salt Lake City, Feb 23, 2012.

Osborne, J., A.L. Kurapov, G.D. Egbert, P.M. Kosro, "Modeling shelf, slope and river plume flow interactions in the coastal ocean", 58th Eastern Pacific Ocean Conference, Fallen Leaf Lake, California, Oct 14, 2011.

Osborne, J., A.L. Kurapov, G.D. Egbert, P.M. Kosro. "Modeling the internal tide in combination with wind-driven circulation on the Oregon shelf". American Geophysical Union Fall Meeting, San Francisco, 13 Dec 2010, paper OS11B-1199.

2. Port X-band Radar: Led by M. Haller (OSU), the X-band wave imaging marine radar (WIMR) station at the Newport South Jetty has had a significant improvement during Y4 and it is currently operating satisfactorily. From the beginning of the reporting period and through early February of 2011, the WIMR recorded 64 image sequences of radar backscatter every hour. Data was processed on site and individual images were made available in real-time through the NANOOS Visualization System. During the second quarter of 2011, however, the system went offline due to failure of the radar transceiver, signal conditioning box and acquisition PC. With the arrival of a new field technician in October of 2011, the system was repaired and became ready for re-deployment on February of 2012. Unfortunately, a major storm that hit the Oregon coast on March 12–13 damaged the power-line at the blockhouse, leaving all the systems hosted in this facility powerless for several months. Finally, five months later and at a cost of ~55K provided through the OSU College of Engineering, a new underground electrical conduit was run out to the blockhouse and the wiring was brought up to code.

While the WIMR was offline, we implemented an algorithm to compute the 3D wave spectrum in wavenumber and frequency domains $S_w(k_x,k_y,f)$. Integrating S_w with respect to f delivers an unambiguous 2D spectrum $S_w(k_x,k_y)$ from which the dominant wavelength L_p and associated propagation direction θ_p are readily estimated. An example of this kind of wave spectrum is presented in Figure 7. From the 3D spectrum it is also possible to compute the 2D wavenumber-

frequency spectrum $S_w(k,f)$ from which surface currents may be estimated. With the objective of increasing the frequency resolution and statistical significance of this spectrum, we decided to extend the number of recorded images from 64 to 256, thus increasing the observation period to 6 minutes every hour.

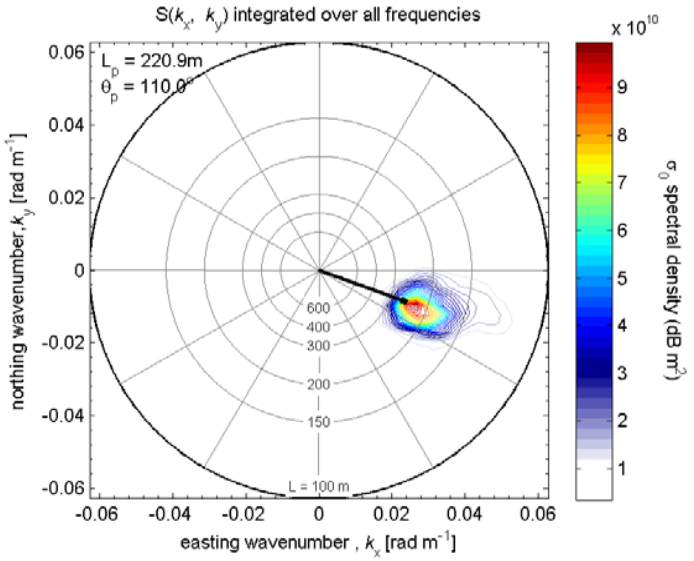

Figure 7. 2D wavenumber spectrum $S_w(k_x,k_y)$ determined from marine radar image intensity data.. Black line points in the direction waves are traveling, shore is to the right (east).

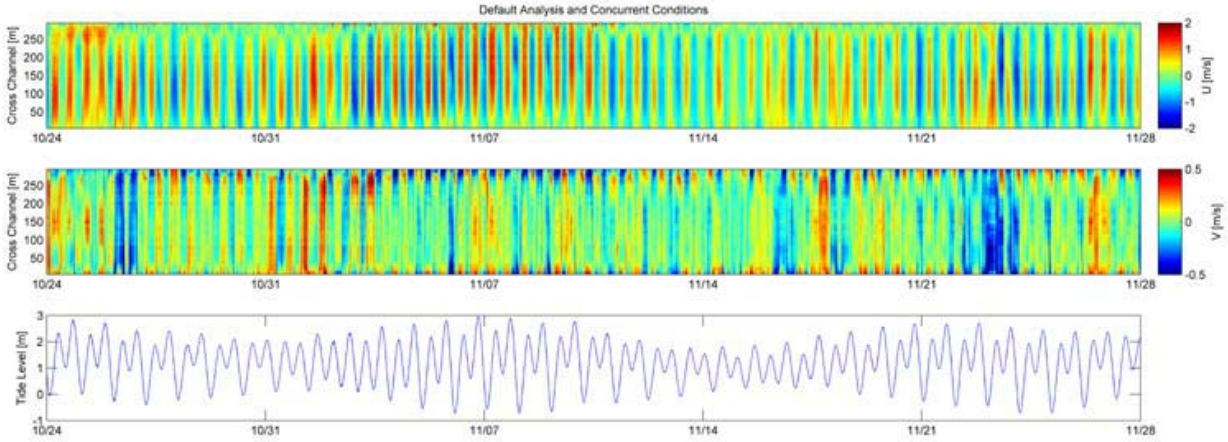

Figure 8. Top panel shows the along-channel surface current as a function of time, the middle panel the cross-channel currents. The lower panel is the corresponding tidal elevation. Tidal signals are clearly evident in the surface currents, interesting cross-channel structure is evident as well.

We have continued quality control of data from the UHF-radar system (RiverSonde by CODAR, described in previous reports) deployed for measuring inlet currents at the Newport field site. This system was operational from 13/Oct/2010 to 23/Jan/2011 and its main goal was to investigate the influence of the tidal currents on the occurrence of dangerous wave conditions near the Yaquina bar. Initial comparisons with co-located in-situ ADCP data, collected in collaboration with J. Lerczak, OSU, look very promising. The system offers the capability to observe a cross-channel profile of inlet currents at half-hourly resolution and, potentially, surface

currents over an even larger footprint (300m x 300 m, 10 m resolution). Figure 8 shows a summary of these results, which were presented at the AGU's 2012 Ocean Sciences Meeting.

On March 9 2012 we surveyed the WIMR station as well as the Newport Jetties with a high–precision GPS device. The campaign's goal was to enhance the spatial accuracy (i.e., geo-reference) of the radar measurements.

Impacts:
In addition to establishing and maintaining the WIMR station at the mouth of Yaquina bay and uploading one of the hourly recorded backscatter images to the NANOOS website in near real-time, associated accomplishments through leveraged funds were as follows:

Recent enhancements allow us to provide additional products, not only qualitative but even quantitative information on the sea-state in the vicinity of Yaquina Bay inlet. From November 2012 on, the 2D wavenumber spectrum and associated integral parameters are uploaded to the NANOOS web, in addition to the single image or snapshot, which has been supplied since Y3.

A PhD student (David Honegger, funded through ONR) was awarded a student grant from CODAR (well-known HF radar vendor) in order to deploy a UHF radar current observation system (RiverSonde) at our Newport South Jetty wave radar site. The purpose was to map the surface currents through the jetties in order to better characterize the influence of opposing currents on the wave breaking conditions on the Yaquina Bar (as imaged by the marine radar).

The new power-line at the blockhouse, sponsored by the OSU College of Engineering, has a major positive impact for the project, since it ensures a modern and reliably power supply for the radar system. This investment has been very beneficial to the different groups who are hosted within this facility (OSU, HMSC, ODFW, etc.).

In support of broader IOOS efforts, M. Haller was an invited scientist to the Alliance for Coastal Technologies: Waves Protocol Development Workshop at the University of South Florida (February 2011).

Publications acknowledging NANOOS support:

Holman, R.A. and M.C. Haller, Nearshore remote sensing, *Annual Review of Marine Science*, to appear in Volume 5, January 2013.

Honegger, D.A., M.C. Haller, and J.A. Lerczak, Horizontal and vertical current structure via UHF radar and ADCP at a tidal inlet mouth, in preparation for *J. Atmos. Ocean. Tech.*, 2013.

Presentations acknowledging NANOOS support:

Honegger, D.A., M.C. Haller, J.A. Lerczak, and P. McEnaney, Concurrent remote and in situ wave and current observations at a tidal inlet, *AGU Fall Meeting*, San Francisco, CA, 2010.

Honegger, D.A., M.C. Haller, J.A. Lerczak, C. Teague, and H. Aguilar, Remote observations of surface current structure at an engineered tidal inlet mouth, *AGU Ocean Sciences Meeting*, Salt Lake City, 2012.

Einolf, A.E., J.A. Lerczak, and M. Haller, Tidally-dependent stratification, shear and secondary currents in Yaquina Bay estuary, Oregon, *AGU Ocean Sciences Meeting*, Salt Lake City, 2012.

Diaz Mendez, G. M., M. C. Haller, R. Pittman, G. Garcia Medina. Monitoreo de oleaje cerca de la costa utilizando radares de navegacion, *Memorias de la Reunion Anual de la Union Geofisica Mexicana*, GEOS 32(1), pp 232, Puerto Vallarta, Mexico, October 2012.

b) Modeling efforts:

- **Shelf:**

Computer circulation modeling of PNW coastal ocean shelf conditions has been conducted by A. Kurapov's group at OSU, which produces daily updates of 3-day forecasts of ocean conditions, including currents, temperatures and salinities through the water column (at 3-km horizontal resolution). The system has assimilated along-track altimetry from Jason-1, Jason-2, (until April 2008) EnviSat, hourly GOES SST, and surface currents from land-based high-frequency (HF) radars. Results have been provided to fishermen and general public via the NANOOS Visualization System. Via the OpenDAP server, the forecast currents are also provided to the NOAA Office of Response and Restoration (ORR) Lab in Seattle, where they can be used with the tools for oil spill mitigation.

During the report period, we included assimilation of the CryoSat alongtrack altimetry. Also, our system was augmented to improve pre-assimilation quality control of the data. This allowed detecting some deficiencies of a NOAA GOES SST product utilized, requiring a new mask during sunrise and sunset hours. This was reported to the NOAA partners; meanwhile we are providing our own masking.

The forecast model is extended to 40.5-47N in the alongshore direction and is focused on the Oregon coast. We also developed and tested a 2-km resolution model in the extended domain (40.5-50N), which includes both the WA and OR coasts. Forcing of this model includes tides and the Columbia River fresh water discharge. In preparation to assimilation, we are studying the influence of the river plume on SST and other variables that can be assimilated.

- **Estuaries**

1. Puget Sound:

a. Puget Sound Princeton Ocean Model (PS_POM): Overseen by D. Jones, APL-UW, NANOOS/IOOS funding allowed for continued collaboration with Dr. Parker MacCready (UW School of Oceanography) to develop a ROMS model of the Salish Sea, named MoSSea. Included in this effort was the implementation of a shared code management tool called Mercurial (Figure 9). This tool allows our development team to share code revisions and contribute to the process from anywhere in the world.

Also in Y4 APL-UW worked with UW oceanographers to test the behavior and sensitivity of the model to perturbations in surface forcing, boundary conditions, and extent of the domain. Simultaneously, APL-UW built code used to run the model in a hindcast mode. This code downloads and pre-processed atmospheric model output, interpolates global and/or regional NCOM ocean model output, calculates tidal forcing, and uses USGS and Washington State Dept. of Ecology river gauge observations to force the surface and boundaries of the MoSSea.

An additional modeling function that APL-UW (with assistance from the OSU NANOOS team) provided was the daily downloading and processing of atmospheric and oceanographic model data for specific geographic locations where NANOOS has observational assets. This data is then

made available in a visualization that allows the user to compare model forecasts to the actual observation of specific parameters such as wave height, surface wind and temperature.

Presentation acknowledging NANOOS support:

Martin, D.L., J.*C. Allan*, J. Newton, D.W. Jones, S. Mikulak, E. Mayorga, T. Tanner, N. Lederer, A., Sprenger, R. Blair, and S.A. Uczekaj (2011). Using Web-based and Social Networking Technologies to Disseminate Coastal Hazard Mitigation Information within the Pacific Northwest Component of the Integrated Ocean Observing System (IOOS). *Proceedings of the MTS/IEEE Oceans 2011 Conference, Kona, HI, September 19-22, 2011.*

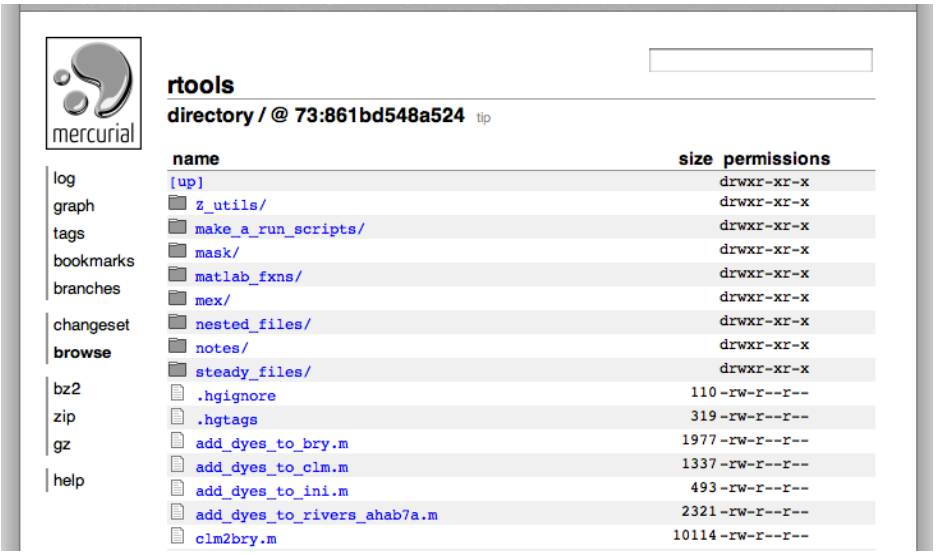

Figure 9. Mercurial tool for developing code with many programmers in multiple geographic regions

2. Columbia River coastal margin: OHSU-CMOP (A. Baptista) has maintained an extensive modeling system for the river-to-shelf circulation of the Columbia River. Primary funding is from NSF/CMOP, complemented by NANOOS and regional stakeholders. Stakeholders include the Bonneville Power Administration (BPA), NOAA, U.S. Army Corps of Engineers (USACE), Lower Columbia River Estuary Partnership (LCREP), and Columbia River Inter-Tribal Fish Commission (CRITFC).

The modeling system is integral to CMOP's SATURN collaboratory, and is informed by SATURN and other NANOOS observation networks. It is envisioned as a "virtual Columbia River," with an array of products readily available for the use by a broad community of scientists, educators, and managers. Virtual Columbia River products include daily circulation forecasts (partially available through NANOOS NVS), decade-long hindcast simulation databases of circulation, a Climatological Atlas, and scenario simulations. Grids are 3D, horizontally unstructured, and extend across river-to-ocean domains.

During the reporting period, we expanded the geographic scope of the Virtual Columbia River, began expanding its disciplinary scope, and continued the systematic enhancement of its modeling skill for circulation. Activities included:

Geographic scope: We incorporated regions and refined the spatial resolution of the Virtual Columbia River's underlying (unstructured) numerical grids to account for regional needs, in

particular related to salmon recovery, navigation improvements, and hydropower operations. Of primary significance, we added to our grids the tidal freshwater of the estuary, between Bonneville Dam and Beaver Army, creating a truly river-to-ocean representation of the system. We also progressively refined the spatial representation of the confluence of the Willamette River, and added the confluences of the Lewis and Cowlitz rivers. We added refinement in bays and tidal marshes, and explored different resolutions for the two main channels in the estuary.
Disciplinary scope: Driven by the requirements of CMOP science, and aided by SATURN observations, we are developing bio geochemical models that will progressively become operationalized. In particular, we are currently calibrating a dissolved oxygen model to help understand in-estuary biological mediation of ocean-driven estuarine hypoxia. We are also developing a "bioreactor" model to represent the nitrogen (and, as a next step) carbon cycles in the lower estuary.
Modeling skill: We developed structured circulation benchmarks that capture weaknesses in the modeling skill, and allow progressive improvement of skill through a systematic analysis of sensitivity to key parameters (from turbulence and friction parametrization to algorithmic choices and temporal resolution). For some of the benchmarks, targeted field observations were conducted during CMOP cruises. Outcomes include a drastically improved representation of water levels in the tidal freshwater part of the system, and a substantially improved understanding of the skill/cost trade-offs in the representation of salinity intrusion and vertical resolution.

Impact:
We have continued applications of the Virtual Columbia River to multiple issues of regional significance, typically in partnership:

- Studies associated with the impending review of the Columbia River Treaty between the US and Canada; these studies have been conducted in partnership with USGS, Corps of Engineers, Bonneville Power Administration, CRITFC and other state and federal agencies.
- Studies of the influence of the Columbia River plume on salmon survival; these studies have been conducted in partnership with NOAA and with funding from BPA.
- Studies of the contemporary variability and change under sea level rise scenarios of physical characteristics and salmon habitat opportunity in the Columbia River estuary and tidal freshwater; these studies were conducted in partnership with NOAA and with USACE funding.
- Studies of habitat suitability in the Columbia River estuary and tidal freshwater, funded by LCREP and conducted in collaboration with the Pacific Northwest National Laboratory.
- Creation of maps of coastal storm inundation in the Columbia River estuary and Pacific County, funded by FEMA and conducted in collaboration with a consulting company (PBS&J) and DOGAMI.
- Retrospective studies of impact of the Columbia River Channel Improvement Project, funded by USACE and conducted in collaboration with NOAA.

In addition, the circulation forecasts of the Virtual Columbia River were transferred to NOAA to serve as the basis of the now operational NOAA PORTS 24/7 forecasts for the Columbia River. We will continue to maintain and enhance a CMOP/NANOOS version of the forecasts, and to collaborate with NOAA staff in the improvements of that agency's 24/7 forecasts.

Presentations acknowledging NANOOS support (in addition to those in the Observing section):

Lopez, J., Baptista, A. M., Spitz, Y. (2012) Enhancing Modeling Skill Of The Vertical Structure And Trapping Ability Of Density Gradients In The Lower Columbia River Estuary. Ocean Sciences Meeting, February 2012. Salt Lake City, UT.

Lopez, J., Baptista, A.M., Spitz Y. (2012) Modeling sediment dynamics in the Columbia River estuary. Columbia River Estuary Conference, May 17, 2012. Astoria, OR

Rostaminia, M., Baptista, A. M., Spitz, Y. (2012) Impact Of Changes In Climate And Hydropower Operations On Habitat Opportunity And Survival Of Columbia River Juvenile Chinook Salmon . Ocean Sciences Meeting, February 2012. Salt Lake City, UT

Rostaminia, M. (2012) Impact of changes in climate and hydropower operation on habitat opportunity of the Columbia River juvenile Chinook salmon. Ocean Sciences Meeting, Salt Lake City, UT

Rostaminia, M. (2012) Impact of sea level rise on habitat opportunity of Columbia River juvenile Chinook salmon. EBS Research Symposium, Oregon Health and Science University, March 2012, Portland, OR

Rostaminia, M. (2012) Impact of sea level rise on habitat opportunity of Columbia River juvenile Chinook salmon. OHSU Research Week Conference, Oregon Health and Science University, May 2012, Portland, OR

Rostaminia, M. (2012) Impact of sea level rise on habitat opportunity of Columbia River juvenile Chinook salmon. Columbia River Estuary Conference, May 2012, Astoria, OR

Welle, P., Baptista, A. M., Spitz, Y., Lopez, J. E., Needoba, J. A., Peterson, T. D., Seaton, C. (2012) Understanding Oxygen Variability In Relation To Biological Processes In The Columbia River Estuary Through A Biophysical Model . Ocean Sciences Meeting, February 2012. Salt Lake City, UT

Law. G., A. M. Baptista (2010) The Virtual Estuary: From Modeling to Climatologies. November 16, Forest Grove, Ore.

c) Data Management and Communications Committee (DMAC):

1. Managerial*:* Co-chaired by E. Mayorga (APL-UW) and S. Uczekaj (Boeing Research and Technology) this committee is composed of members from APL-UW, OHSU-CMOP, OSU, members of NANOOS User Products Committee (UPC), Education & Outreach (E&O) Committee, and Web Portal team. Steve Uczekaj is a member of the NANOOS Governing council and responsible for coordination of DMAC activities and reporting. Boeing hosts a NANOOS DMAC weekly developers 'tag-up' conference call to facilitate open dialog, common vision, synergy of efforts, and consistent progress across a diverse team of university and industry participants. DMAC committee members also participate in cross regional coastal ocean observing activities and national workshops.

Activities for the Y4 period included: 1) yearly kickoff meeting to plan out prioritized list of goals and activities, 2) weekly NANOOS DMAC teleconferences; 3) annual IOOS DMAC workshops, 4) annual meeting of NANOOS tri-committees including DMAC, UPC and E&O, 5) annual NANOOS PI meeting, 6) annual NANOOS Governing Council meeting, 7) progress reporting including bi-annual regional RCOOS and RA progress report.

2. Purpose of Committee*:* The purpose of NANOOS DMAC is to coordinate the development and maturation of a Northwest region Data Management and Communications computing system architecture and services for open access and delivery of ocean observing sensor data and models to Northwest regional and IOOS national stakeholders. NANOOS is one of 11 regional projects supporting the overall vision of the IOOS DMAC.

***3. Achievements**:*
NANOOS maintained its highly successful DMAC operations. Highlights include:
NANOOS Web: In Y4 the NANOOS web portal infrastructure started to experience latency issues due to the increased popularity of NANOOS products and the addition of the processing-intensive map tiles used for composite products (e.g., satellite mosaic overlays on observation data). The IT infrastructure in Y4 included a high-end server and a separate database archive.

Web traffic on the NANOOS portal increased significantly following the March 11, 2011 earthquake off the coast of Japan. As described in Martin et al. (2011), the unique page visits increased over 300% on the day of the earthquake (Figure 10). Following the earthquake the NANOOS team noticed a marked increase in daily visits. Before the earthquake, the average was less than 50 a day, after the earthquake, visits grew steadily to 200 or more per day. This is attributed to new users learning about NANOOS due to the earthquake and then realizing the usefulness of the data in their daily operations.

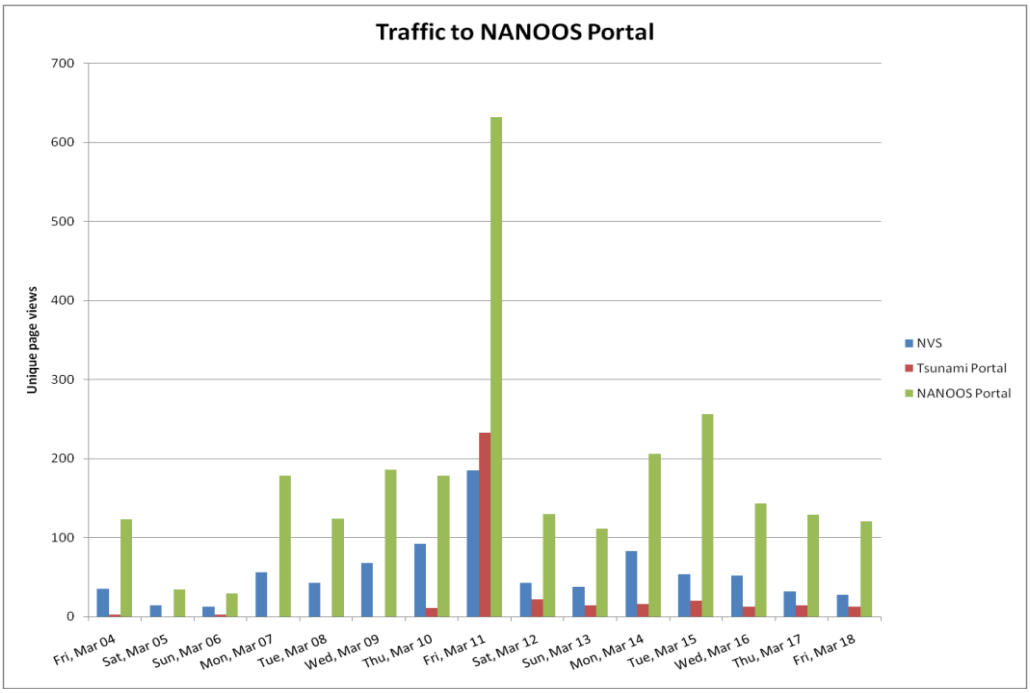

Figure 10. Unique page visits for the NANOOS Portal, NVS and the Tsunami Portal for the period 3/4/11 to 3/18/11.

The one downside to the growing popularity of the NANOOS Portal was that the infrastructure was pushed to its maximum capacity. A new server, dedicated to processing the large amount of map tiles of was scheduled for purchase and implementation in Y5 (Note: map tiles are pre-processed from environmental data, and they are the images that the web browser uses to build user maps and provide zoom in capability.)

The NANNOS Visualization System (NVS): In Y4 APL-UW continued to enhance the data viewer called NVS. NVS Version 2.0.5 was released on November 8, 2010. It main new features were new composite overlays and a dynamic asset list (includes observations, models, cruises, etc.). NVS Version 2.5 was released on March 30, 2011. New features included: a myNANOOS

support which allows users to create settings that can be saved to their user ID; the user can now specify units mode; and new plot y-axis range controls.

New Observational data on the NANOOS Portal: During Y4 new datastreams included: two Humboldt State Univ./CeNCOOS sensors (Humboldt Bay Dock B and Trinidad Pier); five ICM/Mobilisa Puget Sound/Strait of Juan de Fuca buoys. Restorations included: ORCA Dabob Bay CO_2 sensors that were redeployed and the near-real-time weather sensors restored. The buoy itself was redeployed in late May 2011, after a 6 month absence; and VENUS assets were brought back on-line after a maintenance cruise was completed.

d) NANOOS User Products Committee (UPC):

1. Managerial: Chaired by J. Allan (Oregon Department of Geology and Mineral Industries) this committee is composed of members from Boeing, OHSU-CMOP, APL-UW, OSU, OR Sea Grant, and NOAA. NANOOS UPC chair Allan participates in weekly "tag-up" calls with a smaller sub-group comprised of members from Data Management and Communication (DMAC), UPC, (Education & Outreach) E&O and Web development in order to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this Y4 period included: 1) weekly NANOOS DMAC and UPC teleconferences; 2) annual meeting (Nov 18-19, 2010) of a core sub-group of NANOOS DMAC-UPC-WEB staff; and, 3) annual meeting (May 12-13, 2011) of the full NANOOS DMAC-UPC -E&O Tri-committee members.

2. Purpose of Committee: The core focus 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 develop the 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 E&O teams to ensure product concepts are effectively developed and tested prior to their release.

3. Achievements:

Website: Efforts by the UPC and WEB teams during Y4 continued to center on enhancing the NANOOS Visualization System (NVS) web mapping portal. Specific improvements to the NVS platform are summarized in Table 1. Additional enhancements during this period included the development of several new web pages devoted to the Honshu (Tohoku) Earthquake and Tsunami (featuring various news items about the effects of the tsunami observed along the PNW coast), as well as the development of a series of Theme pages by NANOOS E&O members focused on the following topics: Maritime Operations, Ecosystem Assessment, Fisheries & Biodiversity, Coastal Hazards, and Climate.

Table 1. NANOOS Visualization System (NVS) Version History; the complete version history is available at http://www.nanoos.org/nvs/information/version_history.php

Ver. #	Release Date	Feature Additions
2.0.5	11/8/2010	Minor enhancement: enabled compositing of image overlays (vectors and backdrop color image), implemented with NOAA Wavewatch III forecast model output; this version also significantly enhanced the Asset list, which became dynamic enabling assets to be simply filtered and sorted according to user interest and needs.

2.5	03/30/2011	Major enhancement to the NVS platform with several new additions. These include: - The creation of a Settings tab within NVS which provides specific controls to key NVS features; - The creation of a "Units mode" that allows the user to define units of interest. These are distinguished between Common (US Customary System) and Scientific (International System) nomenclature; - Introduction of a dynamic y-axis range that can be modified based on two settings: Global (data are plotted based on predefined y-axis ranges) and Local (the y-axis range is optimized for each asset variable based on statistics observed over the previous 2 weeks; - The creation of a myNANOOS that allows users to login and predefine the look and feel of NVS according to their specific needs; and, - Addition of new image overlays from forecast model assets: 1) NANOOS OSU ROMS model (SST and surface currents composite, and SST and surface currents composite optimized for commercial and recreational tuna fishermen needs); 2) NANOOS CMOP Columbia Estuary model (salinity and SST); 3) NOAA North American Mesoscale (NAM) model (surface barometric pressure, air temperature, wind speed, relative humidity); and 4) NOAA Wavewatch III NE Pacific (wind speed and direction, and wave height, period and direction wave)

Oregon Coast Tsunami Hazards portal: During Y4, the NVS tsunami portal was modified and updated in February 2011. Modifications to the portal included the addition of new evacuations maps developed for the southern Oregon coast (Bandon to the OR/CA border) and for Cannon Beach (provided by DOGAMI), modifications to the "map notes" and "legend" on the front page of the portal, and fixes to the print function that had broken. The portal continues to be used by the public (in lieu of paper maps that are accessible through DOGAMI), with a significant (400%) spike on March 11 in response to the Japan Tohoku earthquake and tsunami. Of this traffic, 76% visited directly, 6.5% came from Google, 4% from Facebook, and 3.25% from IOOS. The increased interest was so significant that it crashed the NANOOS Geoserver that hosted the portal. Future enhancements include a complete reengineering of the existing portal, with the inclusion of evacuation information mapped for the Washington coast. To facilitate this process, NANOOS UPC chair Allan with input for UPC members and staff from the Oregon Department of Geology produced a working document that describes the conceptual look and feel of this new portal.

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

1. Managerial: During the course of the Y4 grant period (10/01/2010 to 09/30/2011), the Education and Outreach Committee, chaired by Nancee Hunter (Oregon Sea Grant), was sustained as previously reported for the Y1-3 grant. Membership remained the same except for one addition: University of Washington, Oregon State University, Ocean Inquiry Project, Hood Canal Salmon Enhancement Group, Oregon Sea Grant, CMOP, Padilla Bay National Estuarine Research Reserve, COSEE Pacific Partnerships, Washington Sea Grant, South Slough National Estuarine Research Reserve, and the Olympic Coast National Marine Sanctuary, and (new addition) OR Dept. of Land Conservation and Development.

During the grant period, NANOOS E&O staff remained unchanged, except for maternity leave taken by Sprenger Aug-Sept 2011. A. Sprenger and S. Mikulak, continued their participation in IOOS-NFRA E&O monthly calls and in the monthly NANOOS E&O committee conference

calls, in collaboration with the E&O Committee Chair. Mikulak became a highly involved and active member of the User Products Committee and participated in weekly DMAC/UPC conference calls, as well as a bi-weekly call with Sprenger and T. Tanner, NANOOS web developer, to discuss improvements to the NANOOS portal.

During the grant period, several NANOOS meetings were attended by E&O staff and committee members, including the NANOOS DMAC/UPC Y4 kick-off meeting (Nov 18-19, 2010 in Corvallis, OR); Hunter, Sprenger, Mikulak, and several other members of the E&O committee at the annual Tri-committee meeting on May 12-13, 2011 in Beaverton, OR; the annual Governing Council meeting (June 15, 2011in Vancouver, WA); and the annual NANOOS PI meeting (Aug 23, 2011 in Vancouver, WA).

Education and outreach efforts during the grant period focused on: improvements to informational content on the NANOOS portal; continued work to connect with educators in the Pacific Northwest; outreach to users groups; partnering with informal education centers; supporting the continued development of the NANOOS mobile apps and the redesign of the NANOOS tsunami web portal; and supporting national IOOS efforts.

With help from the NANOOS E&O Committee and NANOOS web portal team, new introductory theme pages created for NANOOS's five areas of emphasis: Maritime Operations; Ecosystem Assessment; Fisheries & Biodiversity; Coastal Hazards; and Climate. They can be accessed via links on our home page. Other improvements to the NANOOS web portal include a new People page and calendar. The Winter 2011 edition of the NANOOS Observer, our newsletter, was published in February 2011: http://www.nanoos.org/documents/key/NANOOS_Observer_Winter_2011.pdf.

2. Summary of Education Accomplishments:

Formal Education: During this grant period, efforts by Sprenger and Mikulak to engage formal educators were focused on providing content and resources during professional development opportunities to foster understanding of ocean issues and the use of ocean observation data. In total, approximately 250 K-12 and community college educators were reached.

Sprenger continued work that began during the Y1-3 RCOOS grant with NOAA BWET educational grant recipients through a partnership with NANOOS member Ocean Inquiry Project, Edmonds Community College and the nonprofit Service, Education and Adventure. The NOAA BWET grant funded teacher workshops focus on helping teachers bring meaningful watershed educational experiences into their classrooms. The weekend trainings include a day-long cruise on marine waters. Throughout the day, Ocean Inquiry Project staff and Sprenger engage teachers in collecting and analyzing various types of ocean observing data and demonstrating the NANOOS portal, products and lesson plans available for teachers to bring locally focused ocean data into their classrooms. Workshops were held in Everett, WA and Seattle, WA in March 2011, Olympia, WA in May 2011, and Bellingham, WA in June 2011.

Several NANOOS staff and E&O committee members attended the annual NW Aquatic and Marine Educators (NAME) conference in July 2011 on the Olympic Peninsula. Sprenger was the conference chair for this 3 day event attended by more than 120 formal and informal educators

from Oregon, Washington, British Columbia and Alaska. During the conference Newton gave a keynote address, Mikulak presented on ocean acidification, F. Stahr presented on Seagliders, and Sprenger presented on using NVS.

NANOOS staff also participated in many one-day events. Mikulak presented a lesson plan about ocean observing technology at the Science and Math Investigative Learning Experiences (SMILE) teacher workshop in January 2011 at Oregon State University. In Aug 2011, Mikulak shared a session with Dr. Tawnya Peterson from CMOP at the Lincoln County Ocean Literacy Symposium, a day-long ocean literacy professional development symposium for all teachers in Lincoln County. Mikulak presented a tour of NVS, the NANOOS data portal and Peterson presented about CMOP data. Also in Aug 2011, Corinne Bassin (APL-UW) presented NVS to community college educators attending the week-long COSEE Pacific Partnership WA Teacher workshop held in Anacortes, WA. Finally, Sprenger and Newton released a contest to teachers to develop lesson plans about NANOOS or NANOOS data: http://nanoos.org/documents/eo/NANOOS_Classroom_Activity_Contest.pdf.

Informal Education: Mikulak continued work on a real-time data exhibit that began during the Y1-3 RCOOS grant. In April 2011, Mikulak attended a docent training at the Port Townsend Marine Science Center (PTMSC) in Port Townsend, WA, where the exhibit will be installed, to demo the exhibit prototype to the staff and volunteers. Mikulak collected feedback about the exhibit content and design and applied the results to the exhibit prototype.

By invitation of C. Simoniello, Education Chair of the Gulf Coast Ocean Observing System (GCOOS), Mikulak attended the annual GCOOS education meeting held in New Orleans, LA in June 2011. Mikulak presented her experience with designing exhibits that utilize real-time NANOOS data and provided insight on GCOOS's exhibit design process. The collaboration between the two RAs was very positive for all, and continued through the monthly IOOS/NFRA E&O calls through the grant period.

NANOOS is partnering with informal learning centers in both Oregon and Washington. A coastal hypoxia animation created by Mikulak will be featured in a permanent exhibit at the Hatfield Marine Science Center, which is part of Oregon State University, a NANOOS member. The other group providing content to this exhibit is the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), who also provided input on this NANOOS created animation. Mikulak also continues to work with Port Townsend Marine Science Center to develop and field test a modular interactive computer exhibit focusing on helping visitors understand different parameters (salinity, temperature, dissolved oxygen and chlorophyll) coming from buoys in the NANOOS region.

3. Summary of Outreach Accomplishments:

Regionally, NANOOS outreach efforts reached over 600 people during the grant period. Targeted user groups include fishers, coastal community residents, the U.S. Coast Guard, shellfish growers, and scientists. Major events attended by NANOOS staff included: Heceta Head Conference in Oct 2010 in Florence, OR; Saltwater Sportsmen's Show in March 2011 in Salem, OR; SEAchange: From Exxon Valdez to Deepwater Horizon in March 2011 in Seattle, WA; the UW College of the Environment/Washington Sea Grant/COSEE Ocean Learning

Communities event in Seattle, WA; National Ocean Council Listening Sessions during the summer of 2011 in Ocean Shores, WA and Portland, OR; PISCO Pre-season Hypoxia Research Exchange meeting in Sept 2011 in Corvallis, OR; and the Pacific Coast Shellfish Growers Association meeting in Sept 2011 in Salem, OR.

New outreach materials were created: a vertical banner; a new NANOOS brochure (http://nanoos.org/documents/legacy/nanoos_brochure.pdf); the Spring 2011 NANOOS Observer (http://nanoos.org/documents/key/NANOOS_Observer_Spring_2011.pdf) and one-page handouts that are tailored for targeted end-user groups and feature specific NANOOS data products relevant to that group.

Outreach efforts to the U.S. Coast Guard were initiated by M. Kosro (COAS-OSU), NANOOS PI and E&O committee member, and C. Risien (COAS-OSU), DMAC, UPC, and E&O committee member. They scheduled and attended a meeting with U.S. Coast Guard members at the Newport, OR station in September to introduce NANOOS and demo NVS. They were positively received by the USCG, however strict internet security on the base prevented full access to NVS.

Mikulak, along with Newton, continued efforts of communicating with tuna fishers primarily from OR about the NANOOS Forecast Information and Data for Tuna Fishers Product page (http://www.nanoos.org/data/products/tuna_fishers/tuna_fishers.php). Mikulak created an FAQ section based on common questions received from fishers and relayed requests for new functionalities in the plots to the DMAC/UPC teams. During the 2011 tuna fishing season (July-Sept), this product page was the most accessed page on the NANOOS portal with over 19,500 unique pageviews. Also, a fisher independently created a YouTube video about how to use the tuna-oriented SST overlay in NVS: http://amigocharters.com/?page_id=58.

Newton and Mikulak attended a unique event, SEAchange, that brought together researchers, emergency responders, science communicators and journalists, tribal members, seafood-related business owners, and the general public, to start discussions in the local community about the response and impact of the Exxon Valdez and Deepwater Horizon oil spills, as well as potential impacts of oil spills on Puget Sound. The event was hosted by the Dean of the UW College of the Environment and Chair of the UW Department of Communication, with several speakers from NOAA, including representatives from the Office of Response and Restoration, the Emergency Response Division, and the Northwest Fisheries Science Center. Newton presented the benefits of NANOOS and the utility of the NANOOS Visualization System (NVS) as a potential tool for oil-spill response in Puget Sound and Washington's coastal waters.

NANOOS was invited to the 65th Annual Shellfish Conference and Tradeshow in Salem, OR, on Sept 19 – 22, 2011. Mikulak hosted a table and interacted with a variety of growers at this event, many of whom already use NANOOS for water quality conditions.

Newton and Mikulak wrote an article for the West End Natural Resources News, the newsletter of the North Pacific Coast Marine Resources Committee (NPC MRC) based in Port Angeles, WA (http://wdfw.wa.gov/about/volunteer/mrc/files/july_2011_npc_newsletter.pdf). The NPC

MRC is comprised of tribal members, county and city representatives, and citizen volunteers. The article is about the new NANOOS sensor array, which includes the Cha'ba buoy, a subsurface mooring, and a Seaglider, that is deployed off of La Push, WA.

In response to the Japan earthquake and tsunami in March 2011, Mikulak posted updates of NANOOS water level data on Facebook (http://www.facebook.com/NANOOS.PNW) and compiled information from NANOOS PIs about their observations around the region: http://www.nanoos.org/features/honshu_earthquake_2011/overview.php.

On the national scale, Mikulak and Sprenger assisted in the IOOS effort to create one-pagers for each of the RAs by compiling and creating content for the NANOOS specific flyer (http://www.ioos.gov/library/nanoos2011onepager.pdf). They also provided content to populate the new IOOS.gov website and feedback to the IOOS office to help improve the new website.

Presentations acknowledging NANOOS support:

Sprenger, A. Eyes on Washington Waters, Bringing Ocean Observing Data Into the Classroom. Washington Watershed Education Teacher Training Program: Tacoma, WA November 6, 2010; Union, WA November 11, 2010; Everett, WA March 5, 2011; Seattle, WA March 26, 2010.

Hannafious, D. and A. Sprenger. Bringing the Layers of Marine Water to the Classroom. Storming the Sound South, Tacoma, WA October 1, 2010 and Storming the Sound West, Port Angeles, WA October 22, 2010.

Mikulak, S. and A. Sprenger. Habitat, Habitat, Have to Have a Habitat: An Oregon Ocean Habitat Game.Science and Math Investigative Learning Experiences (SMILE) Teacher Workshop, Oregon State University, Corvallis, OR. January 28, 2011.

Sprenger, A. What's in the Water? Puget Sound Marine Science Research for the Classroom. Washington Science Teachers Association/Environmental Education Association of Washington joint Conference, Poulsbo, WA. March 19, 2011.

Newton, J. Keeping Watch Over the Sea (NANOOS). SEAchange 2011. From Exxon Valdez to Deepwater Horizon: Telling Tales of Environmental Disaster, Justice, and Recovery. University of Washington, Seattle, WA. April 2, 2011.

Sprenger, A, and Stahr, F. Eyes on Washington Waters, Bringing Ocean Observing Data Into the Classroom. Washington Watershed Education Teacher Training Program: Olympia WA, May, 2011; Tacoma WA, June, 2011; Bellingham WA, June 2011.

Newton, J. Keynote Speaker: Salish Sea Student Science Symposium; Mountaineers Club, Seattle, WA; June 3, 2011.

Mikulak, S. Ocean Acidification in the Pacific Northwest. Northwest Aquatic and Marine Educators Association Conference. Olympic Park Institute, Port Angeles, WA. July 14, 2011.

Stahr, F. Gliders Observing the Coastal Waters of Washington & Oregon, or "Robots Are Our Friends". Northwest Aquatic and Marine Educators Association Conference. Olympic Park Institute, Port Angeles, WA. July 14, 2011.

Sprenger, A. Using authentic data to teach science concepts: MBARI's EARTH Program, NEPTUNE CANADA and NANOOS. Northwest Aquatic and Marine Educators Association Conference. Olympic Park Institute, Port Angeles, WA. July 16, 2011.

Newton, J. Invited talk about NANOOS: Ocean observing systems: a matter of perspective. Northwest Aquatic and Marine Educators Association Conference. Olympic Park Institute, Port Angeles, WA. July 16, 2011.

Newton, J. Observing Puget Sound. National Environmental Monitoring Conference 2011, Bellevue, WA, Aug 18, 2011.

Bassin, C. Use of NANOOS/NVS for incorporating real-time data into the classroom. COSEE Pacific Partnership WA Community College Educator Workshop. Shannon Point Marine Center, Western Washington University, Anacortes, WA. Aug 23, 2011.

Newton, J. Pacific Northwest ocean acidification observing efforts (from coastal buoys and shellfish farms) and resultant data streams. World University Network Workshop on Ocean Acidification, Friday Harbor Laboratories, University of Washington, Friday Harbor, WA, Aug.29, 2011.

Mikulak, S. OLS Tour of the NANOOS Visualization System (NVS). Lincoln County Ocean Literacy Symposium. Hatfield Marine Science Center, Newport, OR. Aug 30, 2011.