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

1) Award Information: Provided as a separate Cover Sheet.
Reporting period: 01 Apr 2010 – 30 Sep 2010

2) Project Summary

NANOOS is engaged, through this NOAA funding, in an active process to develop, implement, and integrate various in-water and land-based systems that will constitute a fully robust and user-driven Regional Coastal Ocean Observing System (RCOOS) for the Pacific Northwest (PNW). This includes all necessary sub-systems to provide PNW, west coast, and national stakeholders with the ocean data, tools, and knowledge they need to make responsive and responsible decisions appropriate to their individual and collective societal roles. Our ongoing knowledge of prioritized issues and user needs is gained through proactive NANOOS interactions with a wide range of PNW stakeholders.

To attain the goals of this project, with adjustments for funding realities, we are:

- **Maintaining existing surface current mapping capabilities and evaluating the use of additional HF radar sites in the PNW.** This tool is a fundamental foundation block for building an observing system for the coastal ocean and serves a multitude of disparate users.
- **Maintaining observation capabilities in PNW estuaries.** The NANOOS objective in this arena is a federated real-time observation network across Oregon and Washington estuaries to address PNW societal needs.
- **Strategically maintaining coverage and range of observations in the PNW shelf, in coordination with emerging national programs.** We have targeted the use of 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.
- **Maintaining core elements of existing beach and shoreline observing programs in Oregon and Washington.** This is improving coastal hazard mitigation by providing better decision support tools for coastal managers, planners, engineers, and coastal hazard mitigation decision makers.
- **Evaluating the creation of a federated system of numerical daily forecasts of PNW ocean circulation.** We are extending utility and availability of operational models from the head of tide of estuaries to the outer edges of the exclusive economic zone (EEZ).
- **Bolstering ongoing Data Management and Communications (DMAC) activities to support routine operational distribution of data and information.** Our DMAC design mandates a collaborative, dynamic distributed system of systems that provides a wide range of products, tools, and services to regional user communities while allowing unfettered access to the IOOS national backbone and national information infrastructure.
- **Building from and strengthening ongoing NANOOS education and outreach efforts.** We are conducting these in coordination with other regional efforts (e.g., NSF-funded STC and COSEE projects), to foster ocean literacy and facilitate use of NANOOS products in the PNW by stakeholders, decision makers, and the general public.

We have delineated a specific NANOOS RCOOS focus 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, we believe, are amenable to being substantively improved with the development of a PNW RCOOS.

3) Progress and Accomplishments

NANOOS reports in this section in the fashion it adopted in the original proposal; specifically, we divide our progress report into the sections of our efforts for: a) observing systems (shelf, estuaries, shorelines, and currents); b) modeling (estuaries and shelves); c) Data management and Communications (DMAC); and, d) Education and Outreach. Administrative efforts orchestrating this RCOOS effort are reported separately in our NANOOS RA progress reports.

a) <u>Observing System efforts</u>

Shelf

1. Washington Buoy and Glider observing network operations: Led by M. Alford, Applied Physics Laboratory and University of Washington (APL-UW), most of the work on this particular observing system over the last reporting period was accomplished with private funding from the Murdock Charitable Trust and accompanying matching funds, and not from direct NANOOS funding. Funding for FY 3 had previously been used in the previous reporting period for system design and to purchase several key instruments that were used on the mooring.

The Washington Coast surface mooring was completed in mid-June and tested locally in Puget Sound before deploying offshore along with the Seaglider in mid-July for a 3-month engineering test deployment. The primary goals of the buoy deployment were to assess wear on the buoy hardware and test the buoy primary systems prior to deploying the buoy over-winter. We were also hoping to get a baseline for Seaglider endurance given its specific mission.

Prior to the July deployment, one of the project PIs and NANOOS Executive Director Prof. Jan Newton organized a public media event held at the APL boat dock. The purpose of this event was to announce the completion of the buoy and the name chosen for the buoy (Cha-Ba, meaning "whale tail") by the Quileute Tribe of La Push, Washington as well as to discuss the scientific and public significance of this observing array. Congressman Norm Dicks was in attendance along with a number of other high-level government officials, IOOS Directorate, University of Washington officials, and local news channels.

As of the end of the reporting period, the buoy remains deployed offshore, with some real-time data available (pCO2). Much of the data not presently available real time is being recorded internally by the various instruments and will be available upon buoy recovery. Plans are to recover the glider and buoy as part of a R/V THOMPSON cruise off the Washington coast from Oct 16--20. Near real-time access to the glider data shows that the glider mission has been very successful, completing 7 one-way transits of its 80-mile trackline and almost 600 dives as of September 30th, 2010.

In early August work began on a sub-surface mooring that will be deployed adjacent to the surface mooring in the spring of 2011. Fabrication of this system has proceeded rapidly, with the sub-surface controller near completion. This system will consist of a McLane Moored Profiler (MMP) crawling up and down the mooring wire and an up-looking ADCP in a subsurface float. The MMP will transmit its data (density, salinity, temperature, pressure, chlorophyll, turbidity, nitrate and currents) to the sub-surface controlled inductively. The data from the MMP and ADCP will then be

relayed to the surface mooring using a small surface telebuoy. These data will be transmitted back to shore along with data from the surface mooring.

2. Oregon Glider operations: The Oregon State University (OSU) glider group led by J. Barth and K. Shearman continued deployments of an autonomous underwater glider off Newport, Oregon, 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 out over the continental slope approximately 45 nautical miles offshore Near real-time, the glider reports position and returns a subset of data to shore every 6 hours. Plots of all variables were linked to the NANOOS Data Products web page. We are working on delivering near real-time data, but need to improve our near real-time data processing and before we can share quality-controlled, near real-time data. We are making progress toward correcting the temperature-conductivity lags present in an unpumped glider CTD. The April through September deployments detailed the development and severity of coastal hypoxia for the 2010 summer season. Also, we began a long offshore section (extending out to 128 W) using a deep diving Seaglider (purchased with NSF funds), focused on the large scale, very low frequency variations in the California Current (e.g., Pacific Decadal Oscillation).

Presentations acknowledging NANOOS support:

1. J. A. Barth, S. D. Pierce, F. Chan and Collaborators. "Spatial and Temporal Variability in Near-Bottom Hypoxia over the Pacific Northwest Continental Shelf." EPOC, September 2010.

2. Piero L.F. Mazzini, J.A. Barth , R.K. Shearman, A.Y. Erofeev, J. Brodersen, L. Rubiano and K. Adams. "Seasonal Variation of Fresh Water Content off the Oregon Coast Estimated from Glider Observations." EPOC, September 2010.

3. Oregon Buoy (mooring) operations: Led by M. Levine (OSU), a mooring about 10 miles off Newport, Oregon, at a site known as NH-10 has been in operation since mid-2006. About twice a year the mooring is recovered and a refurbished mooring is deployed. A successful mooring turn-around was conducted in April 2010. The next turnaround is scheduled for October 2010.

The mooring measured a combination of meteorological parameters and ocean temperature, salinity, velocity, chlorophyll fluorescence, light backscatter and dissolved oxygen. The specific number of sensors on a given deployment depends upon availability, as most sensors are borrowed from other projects. Some of the data are transmitted to shore through a cellular phone modem in near-real time and are available on the NANOOS Visualization System (http://www.nanoos.org/nvs/nvs.php). The data are also displayed by the National Data Buoy Center as station #46094 (http://www.ndbc.noaa.gov/station_page.php?station=46094). The infrastructure is in place to increase the number of real-time sensors as soon as funds become available.
We continue to make progress enhancing the survivability of the mooring and its sensors. Winter time deployments remain challenging; significant wave heights of about 30 feet (reported by the nearest NDBC buoy) had dragged the mooring anchor about 4 miles. The recent addition of a section of compliant nylon line may have helped prevent a failure in the mooring line.

Buoy support field work requires the use of a medium-sized UNOLS vessel or equivalent for a minimum of 1 day, twice per year. Funding for ship time is not included in this project; ship time

was provided by NSF through the Science and Technology Center for Coastal Margin Observation and Prediction (CMOP).

4. Northern Oregon to Central Washington shelf: Led by A. Baptista (OHSU), the Center for Coastal Margin Observation & Prediction (CMOP) continued to maintain a glider and two offshore buoys (SATURN-02 and OGI-01).

The CMOP glider operates Spring through Fall, in a collaboration with the Quinault Indian Nation (QIN) Department of Fisheries. A typical mission flows a radiator pattern for 1 to 5 weeks, across the WA shelf from Grays Harbor to Quinault. Data is collected in support of fisheries management (QIN), scientific discovery, and modeling; of particular interest is the characterization of upwelled water, for detection of hypoxia (e.g., see "oxygen watch") and biological blooms. Measurements consist of vertical profiles of salinity, temperature, dissolved oxygen, chlorophyll, colored dissolved organic matter and turbidity. Sub-sets of data are reported near real-time every 4 hours. Five deployments were conducted during the reporting period.

The SATURN-02 buoy is installed in the northern OR shelf, at 30m depth, within the region of influence of the Columbia River ebb tides. It is deployed year-round, in two settings: extensively equipped from Spring to Fall; and minimally equipped (single surface CT) in Winter. Spring-to-Fall measurements include looking-down velocity profile (since 2004); multi levels of salinity and temperature (since 2004; starting 2010, 4 levels: 1m, 6m, 11m, and 16m); and, starting 2010, one level (1m) of chlorophyll, colored dissolved organic matter and turbidity. As funding allows, the multi-disciplinary sensor package will be expanded to all 4 levels. Data is collected in support of salmon ocean-survival biological opinions (with NOAA/NWFSC), scientific discovery, and modeling. Sub-sets of data are reported near real-time every hour (Spring-to-Fall only) via spread-spectrum radio; position is reported year-round via satellite.

The OGI01 buoy is installed in the northern OR shelf, at 100m depth. It is deployed year-round (since 2005), and has over time been instrumented (physical sensors only) in alternative configurations to support calibration and validation of circulation models covering the far-field of the Columbia River plume.

Data from all the above platforms are 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 web site, 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.

For the reporting period, funding for the operation and maintenance of the glider and SATURN-02 was primarily through the National Science Foundation (OCE 0424602.)

Publications acknowledging NANOOS support:

1) 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)
2) 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.

- **Estuaries**

1. Puget Sound, ORCA Buoy program: Led by A. Devol and J. Newton (UW), during this report period the ORCA (Oceanic Remote Chemical Analyzer) group had 4 buoys in operation in Hood Canal and one in the main basin of Puget Sound (see http://orca.ocean.washington.edu via the NANOOS web portal for buoy locations). 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.

In April we added a fifth Puget Sound profiling buoy to the NANOOS assets in Puget Sound. This buoy is located of in the main basin of Puget Sound near Point Wells (on the east side of the Sound between Seattle and Everett). Alter a few initial problems; the buoy has been in near continuous operation.

The major observation of note was the low oxygen below the euphotic zone that developed in southern Hood Canal over the summer (Twanoh and Hoodsport buoys). The low oxygen concentrations probably result from late and weak re-oxygenation the previous year. Beginning in May information notices about low oxygen concentrations were issued to selected press and government agencies by NANOOS scientists. By early September oxygen concentrations at the Hoodsport buoy had decreased to below 1 mg/l from 20 meters to the bottom (130m). This is the lowest oxygen inventory in southern Hood Canal ever recorded. At that point NANOOS Scientists issued an information notice to selected press and government agencies. Indeed in early mid-September there were fish kill events on two occasions. The NANOOS buoys in Hood have been instrumental in predicting and observing the low oxygen and fish kill events. The NANOOS assets and personnel have been featured in at least 13 articles in the Seattle times, 9 articles in the Kitsap Sun and 8 articles in the Tacoma news tribune. Currently, oxygen conditions have improved substantially at the Hoodsport buoy, but oxygen concentrations at the Twanoh buoy are essentially zero from 15 meters to the bottom (32m). NANOOS scientists Dr. Newton and Dr. Devol have been interviewed repeatedly by the press. All buoy data was continuously available in real time on the NANOOS website. These observations are leveraged with the Hood Canal Dissolved Oxygen Program and NSF funding.

In May we moved one of the Hood Canal buoys north into Dabob Bay. This move was in response to an "oyster emergency" declared by the state of Washington and Dabob Bay is the site of several oyster hatcheries. The objective was to monitor surface water acidity and water column conditions as they might relate to hatchery failure. Through collaboration with NOAA (C. Sabine, R. Feely), we added a second pCO2 sensor to this mooring and it has been working continuously ever since. This work was leveraged by a grant from the State of Washington.

Presentations acknowledging NANOOS support:

1) Newton, J.A., A.H. Devol, M.H. Alford, C.L. Sabine, R. A. Feely, S.R. Alin, B. Hales. 2010. How NANOOS is contributing to understanding ocean acidification in the Pacific Northwest: a model for regional coordination. California and the World Oceans Conference, 7-10 Sept, 2010, San Francisco, CA.

2) Newton, J.A., A.H. Devol, M.H. Alford, C.L. Sabine, R. A. Feely, S.R. Alin, B. Hales. 2010. NANOOS contributions to understanding ocean acidification in the Pacific Northwest. Oceans 2010 IEEE-MTS Conference, 21 September 2010, Seattle, WA
3) Newton, J. 2010. NANOOS and data access for Puget Sound. Northwest Indian Fisheries Commission, 12 August, 2010, Olympia, WA.
4) Newton, J. 2010. Observations from the RCOOS' relevant to ocean acidification. Ocean Acidification Effects on West Coast Shellfish Industry Workshop, 7-8 July, Costa Mesa, CA

2. Washington State estuarine monitoring: Coordinated by C. Maloy, the WA State Department of Ecology (Ecology) continues to contribute to regional estuarine *in situ* observations by maintaining monthly-calibrated moorings in Willapa Bay and Puget Sound. This work is funded by WA State, augmented by NANOOS.

The Department of Ecology, with the help of collaborative partnerships, continued to maintain a network of moored sensor packages throughout Puget Sound and Willapa Bay. Ecology's deployment locations are primarily designed to capture interbasin exchange signals of temperature, salinity, and oxygen. Moorings are located in Admiralty Reach, Shannon Point, Manchester (two depths), Mukilteo, Squaxin (2 depths), and Willapa Bay (2 depths). Key collaborative partners include Everett Community College, Western Washington University, University of Washington APL and NOAA.

In early August, Ecology attained their commitment to telemeter and post real time data from Ecology's Willapa Bay station. They deployed a second sensor package in a fixed position at 3 meters above sea bottom (about 5 meters depth). The new Bay Center package consists of an SBE 37 with pressure sensor (temperature, conductivity, pressure, and salinity).

Ecology significantly upgraded their telemetry system by 1) switching from radios to cellular modems for data transmissions, enabling two-way communication; and 2) capturing our own data transmissions instead of relying on CMOP for this service. These moves have improved reliability, decreased a burden on CMOP, and increased quality control capacity. Ecology resolved initial difficulties such as phone time outs and power budget shortfalls by using automated reboots, timer switches, and doubling up on the power supply batteries. Ecology began initial phases of implementing their new Marine Data Architecture Plan, which fully integrates all of Ecology's marine monitoring data and provides data feeds for internal and external use. Ecology designers worked with NANOOS to assure that data feeds were compatible with NANOOS web postings. In addition, Ecology is developing unique display tools such as TS density plots, see ftp://ecy.wa.gov/eap/Mooring_Raw/Puget_Sound/Manchester/MCH01BR_REALTIME.png. Ecology significantly improved quality of dissolved oxygen data through implementation of an improved sensor performance check program. Ecology's new test bath procedure (of drawing numerous verification samples pre and post deployment) allows the description of uncertainty regarding measurements, provides higher confidence in data adjustments, and allows rapid diagnosing and servicing of poorly performing instruments. Previously, Ecology relied upon one point, in situ, verification sampling, which is less than ideal given the potential for near surface stratification and provides no opportunity to apply descriptive statistics.

Ecology has improved the timeliness of quality control data evaluations, usually within 30 days, and is using GOMOOS QAQC codes as a tool for describing data quality. Timely reviews of data have enabled Ecology to more rapidly analyze data, provide a statistical and historic context, and better

communicate the message of what is happening out there. Ecology's mooring data that has been reviewed can be found at: ftp://ecy.wa.gov/eap/Mooring_Reviewed/

Presentations acknowledging NANOOS support:

1. Carle, A., Mora, D., Krembs, C., Albertson, S., 2010. "Transport of heat, salt, oxygen, and freshwater within the southernmost extent of Puget Sound: The year 2010 in review". Poster presented at the 2010 South Sound Science Symposium, Squaxin Island Tribal Center, Shelton, WA, October 2010.
2. Albertson, S., Krembs, C., Sackmann, B., Maloy, C., Mora, D., Carle, A, Bos, J., and Jones, M. "Tidal to subtidal timescales of variability for telemetered moorings in Puget Sound". Presented at the MTS/IEEE Oceans 2010 Conference, Seattle, WA, September 2010.

3. Columbia River estuarine monitoring: With a mix of NSF, NANOOS and regional-stakeholder funding, CMOP continues to maintain 14 endurance stations in the Columbia River estuary (under the direction of A. Baptista) and two in the tidal freshwater (under the direction of J. Needoba). Eleven of those stations measure one of more physical parameters (temperature, salinity and/or water level), while five have an extensive array of biogeochemical sensors. All endurance stations operate year round, as a part of CMOP's SATURN observation network, a member of the NANOOS federation of systems. Data is collected in support of salmon ocean-survival biological opinions (with NOAA/NWFSC, BPA and others) related to hydropower management, estuarine management and restoration projects (with NOAA/NWFSC, LCREP and others), monitoring of impact of channel deepening (with USACE), scientific discovery, and modeling.

All data from all the above stations are 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 web site, 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.

New during the reporting period:

- To address important questions regarding the estuary, sensors for dissolved oxygen (DO) and Phycoerythrin (PE) were installed at SATURN-01 and SATURN-03.
- The new DO data (Fig. 1) shows that the estuary incurs substantial, ocean-driven, oxygen depletion at levels of concern for salmon. An 'oxygen watch', covering both the estuary (SATURN-01 and SATURN-03 data) and the WA shelf (CMOP glider data) was developed (http://www.stccmop.org/datamart/observation_network/hypoxia).
- The new PE data shows promise as an indicator for timing and intensity of *M. rubra* blooms in the estuary. Work is in progress to create a "*M. rubra*" watch based on these sensors; among the remaining challenges are calibration of PE signal to cell counts, and filtering the influence of confounding signals (e.g., turbidity and chlorophyll).
- We have continued to make progress in data quality control procedures for a range of biogeochemical sensors.

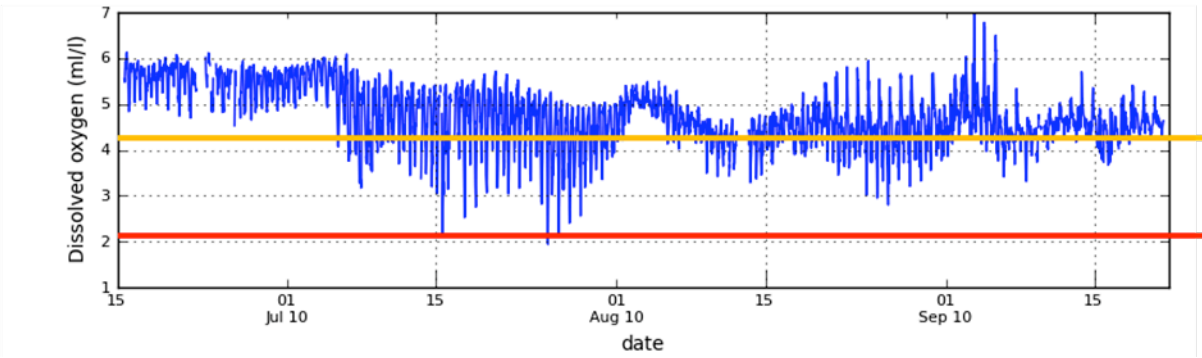

Figure 1: Measurements of DO are being made in the South Channel of the Columbia River estuary (at SATURN-03, at 2.4m, 8.2m and 13m below MSL), since June 15, 2010. The data shows moderate (below 4.3ml/l) to severe (below 2.1ml/l) summer oxygen depletion even in near surface waters; the source of depletion is oceanic. Oxygen spikes in early September are associated with *M. rubra* blooms. See also http://www.stccmop.org/datamart/observation_network/hypoxia.

Presentations and Publications acknowledging NANOOS support:

1) Baptista, A. M., C. Seaton, J. Needoba, M. Wilkin, K.Rathmell, P. Turner, S. Riseman, C. Roegner (2010). The Columbia River estuary as an ocean sentinel: temperature, hypoxia and other tales. EPOC 2010, September 22-25, 2010, Mt. Hood, OR.

(The following are abstracts that were omitted from previous progress report.)

2) Baptista, A. M., E. V. Armbrust, B. C. Crump, L. Herfort; B. M. Howe, M. D. Levine, D. Maier, C. L. McNeil, J. Needoba, T. D. Peterson, F. G. Prahl, T. B. Sanford, H. M. Simon, M. Smit, Y. H. Spitz, B. M. Tebo, P. Zuber (2010). Coastal margin collaboratories: from reactive to anticipatory science. AGU Ocean Sciences Meeting, February 21-26, 2010, Portland, OR.
3) Baptista, A. M. (2010). Coastal Margin Science in the Era of Collaboratories. AGU Ocean Sciences Meeting, February 21-26, 2010, Portland, OR.
4) Cho, K., A. M. Baptista, Y. J. Zhang, C. L. McNeil, M. P. Wilkin, K. Rathmel, M. Kosro, Y. H. Spitz, B. C. Crump, M. D. Levine, S. D. Pierce, T. D. Peterson, C. Wingard (2010). Sub-tidal circulation in the Columbia River estuary-plume-shelf system in spring and summer 2009. AGU Ocean Sciences Meeting, February 21-26, 2010, Portland, OR.

4. Oregon South Slough: Participation by the Oregon Department of State Lands (ODSL) in NANOOS activities is led and coordinated by Steve Rumrill (Chief Scientist and Research Program Coordinator for the ODSL / South Slough National Estuarine Research Reserve (NERR)). Staff members from the ODSL / South Slough NERR continued ongoing operations for the series of moored observing stations located within the South Slough estuary as part of the NERR/SWMP network of NANOOS anchor stations. The monitoring stations are located at: (1) Oregon Institute of Marine Biology – Boat House, (2) Charleston Pier, (3) Valino Island, (4) Winchester Arm, and (5) Sengstacken Arm. These moored monitoring stations have been established along the estuarine gradient of the South Slough estuary where they provide continuous near real-time characterizations of the marine (euhaline), marine-dominated (polyhaline), mixing (mesohaline), and riverine (oligo-haline) hydrographic regions of the estuary. Each of the water monitoring stations is equipped with a YSI-6600 multi-parameter datalogger with the array of electronic sensors located 50 cm above the bottom of the estuarine tidal channel. A sub-set of the stations are equipped with Sutron SatLink2 data telemetry systems that transmit the digital datastreams via the Geostationary Operational Environmental Satellite (GOES) system.

The NERR-SWMP / NANOOS water monitoring stations in the South Slough estuary were in continuous operation throughout the period of March to October 2010, and the dataloggers were re-

trieved, downloaded, recalibrated, reprogrammed, and redeployed on a monthly basis during the spring, summer, and fall seasons. Each datalogger records measurements of the following parameters every 15 minutes: water level, temperature, conductivity, salinity, pH, dissolved oxygen, turbidity, and fluorescence. Time-series measurements generated by four of the monitoring stations are available in near real-time from several websites including NANOOS (http://www.nanoos.org), the NOAA / Hydro-Meteorological Automated Data System (www.weather.gov/oh/hads), the NOAA/NERRS (http://www.nerrs.noaa.gov/monitoring/water.html), and via the data access website operated by the NERRS Centralized Data Management Office (http://cdmo.baruch.sc.edu/QueryPages/Stationmap.cfm Site ID=SOS).

Posting of the datasets generated by the South Slough NERR (Charleston Pier monitoring station) has been periodically interrupted over the reporting period, and many technical adjustments to the Sutron SatLink2 set-up menu, YAGI antenna, and solar power system were completed in an effort to increase reliability of the transmissions of the near real-time datasets. All aluminum YAGI transmission antennae were replaced with stainless-steel versions in April, and non-corrosive Stevens / Top-Hat antennae were installed in June. Staff members from the South Slough NERR have continued to work together with technical staff from the NERR – SWMP Centralized Data Management Office to troubleshoot the telemetry problem at the Charleston Pier station which now appears to be due a combination of weak satellite transmission strength and periodic over-step interruptions by a second non-NANOOS GOES data signal that is assigned a similar/identical transmission frequency and interval. It is likely that the telemetry over-step interruptions may be generated by the nearby NOAA National Water Level Observation Network (NWLON – Tide Station) operated at the US Coast Guard – Life Saving Station in Charleston, or by remote communications associated with periodic opening and closing of the Charleston draw-bridge operated by the Oregon Department of Transportation.

Datasets generated by the NANOOS/SWMP observation stations were used to help guide and confirm local decisions over the summer about the optimum location in the estuary for the placement of experimental out-plants of Olympia oysters (*Ostrea lurida*). In particular, time-series data from the Charleston and Valino Island monitoring stations were used to evaluate variability in summer and winter temperature and salinity regimes and to identify the region of the tidal channel that will be most conducive to survival and growth of juvenile Olympia oysters. A total of 200 bags of Olympia oyster cultch were out-planted in July 2010 following the successful out-planting of 300 bags of oyster cultch in the summer of 2009.

Recent observations of elevated pCO2 values in the nearshore ocean waters along the Pacific coast of North America provide an opportunity to investigate the relationship between ocean acidification and variability in pH values in Pacific coast estuaries. Staff members from the South Slough NERR continued to examine time-series measurements of water column parameters recorded at the NANOOS/SWMP stations (YSI-6600 EDS multi-parameter dataloggers equipped with a YSI 605091 pH/ORP sealed gel probe (resolution 0.01 pH unit; accuracy $\pm$ 0.2 pH unit)). The dataloggers have been operated continuously over the period of 2002-2010. Estuary pH values typically ranged between 7.7 and 8.3 throughout each day, and 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 daily pH cycle appears to be driven by photosynthesis and respiration of phytoplankton, macroalgae, and submerged aquatic vegetation within the estuary. In addition, the time-series measurements of estuary pH values indicate a long-term shift toward increased alkalinity at the Charleston

SWAMP/NANOOS station, which may be more indicative of increased net estuary photosynthesis and productivity and an early indicator of the onset of eutrophication.

Staff members from the South Slough NERR continued to interact directly with the commercial oyster growers in Coos Bay to provide technical assistance with access to water-quality data, and to further promote utility of the NANOOS Data Product (Real-Time Water Quality Data for Shellfish Growers in the Pacific Northwest). In particular, the datasets generated by the monitoring stations were used to provide answers to questions about pH and Dissolved Oxygen levels in estuary waters raised by local commercial oyster growers during the summer months when the Coos Bay estuary is regularly flooded by nearshore ocean waters that have experienced periods of strong upwelling.

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.

Presentations acknowledging NANOOS support:

1. Rumrill, S. 2010 (April). Potential vulnerability of oysters and other shellfish to ocean acidification and declining water quality conditions within Coos Bay and the South Slough estuary, Oregon, USA. Seminar and poster presented at the International Conference on Climate Change Impacts on Fish and Shellfish, Sendai, Japan
2. Helms, A. 2010 (April). The effects of seasonal and long-term ocean cycles on water quality dynamics within the South Slough estuary, Oregon. Seminar presented during the Pacific Estuarine Research Society – Annual Conference, Nanaimo, BC
3. Rumrill, S. 2010 (August). Nearshore oceanography, upwelling, and ocean acidification: the potential influence of acidified waters in Pacific northwest estuaries. Seminar presented during Rogue Valley Manor – continuing education seminar series, Medford, OR
4. Rumrill, S. 2010 (October). Potential vulnerability of oysters and other shellfish to ocean acidification and declining water quality conditions within Coos Bay and the South Slough estuary, Oregon, USA. Poster presented at the National Estuarine Research Reserve – Annual Conference; Shepherdstown, WV

Shorelines

1. Washington Shorelines:

The Washington State Department of Ecology's (Ecology) Coastal Monitoring & Analysis Program (CMAP) led by George Kaminsky continued to maintain a beach and shoreline monitoring effort in the Columbia River littoral cell (CRLC) during this semiannual period between April 1 and September, 30 2010. This effort also supported data collection using the Coastal Profiling System (i.e., nearshore bathymetry survey platform) in collaboration with Oregon State University (OSU). The monitoring program performs beach profile surveys on a quarterly basis and performs beach surface mapping on a semiannual basis. These field campaigns serve the ongoing monitoring project that is now in its 13th year of operation.

CMAP collected geospatial data on transects at 46 locations in the CRLC twice during this semiannual period. In addition, 21 surface maps were collected (2 in spring, 19 in summer (including 5 extra maps at Benson Beach in support of a beach nourishment experiment) each containing an average of 10,000 data points over a distance of 3 to 4 kilometers alongshore.

- Shoreline retreat along the entrance to Willapa Bay and southern Grayland Plains continued even during the summer beach recover phase along most beaches of the CRLC. Between June and October the beach scarp has receded another 4 m and destroyed more road surface.
- CMAP took on additional beach monitoring this summer in support of the Southwest Washington Littoral Drift Restoration Project at Benson Beach, sponsored by the Washington Department of Ecology and the U.S. Army Corps of Engineers. Since July, CMAP performed 7 surveys that include sixty 50-m spaced topographic profiles, 5 surveys that include a surface map, and 4 surveys in collaboration with OSU and the U.S. Geological Survey (USGS) that include bathymetry on approximately seventy-one 50-m spaced lines – roughly 1 million data points each survey when merged with topography.
- CMAP assisted the installation of a new high resolution ARGUS camera system that observes Benson Beach morphology on high frequency temporal scale (http://www.planetargus.com/north_head/). CMAP's field crew, in cooperation with Northwest Research Associates, OSU and USGS, helped to obtain precise control points in the nearshore and on land to increase the accuracy of the cameras. The images and data products from this system provide information about beach dynamics in between CMAP's quarterly surveys.
- CMAP staff performed bathymetric and topographic surveys along Fay Bainbridge State Park and adjacent shorelines in collaboration with the USGS during June 21-23, 2010. The work included eelgrass surveys to study their importance to forage fish which currently use the beach but the eelgrass is reportedly in decline.

Presentations acknowledging NANOOS support:

1. Gelfenbaum, G., and Kaminsky, G.M., 2010. Large-scale coastal change in the Columbia River littoral cell: An overview, Marine Geology, 273, 1–10.
2. Ruggiero, P, Buijsman, M., Kaminsky, G., and Gelfenbaum, G., 2010, Modeling the effects of wave climate and sediment supply variability on large-scale shoreline change, Marine Geology, 273, 127–140.
3. Kaminsky, G.M., Ruggiero, P., Buijsman, M., McCandless, D., and Gelfenbaum, G., 2010, Historical evolution of the Columbia River littoral cell, Marine Geology, 273, 96–126.

2. Oregon Shorelines:

In Oregon, leveraging NANOOS funds, 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 119 sites on multiple occasions at a reduced scale during the second half of Year 3. Beach cross-section surveys were specifically carried out in April 2010 (late winter survey due to equipment problems, Rockaway cell and Clatsop Plains), May 2010 (Neskowin cell), June 2010 (Newport cell), August 2010 (Neskowin cell) and September 2010 (Rockaway cell/Clatsop Plains). The beach surveys involved the conventional approach of re-measuring existing transect sites using RTK-DGPS surveying technology developed for PNW beaches. Results of the 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 OBSMAP website (http://www.oregongeology.org/sub/Nanoos1/index.htm) and linked through the NANOOS website. These data are accessed by State resource managers (e.g. Oregon State Parks), Geotechnical consultants and the public for assessing coastal stability and hazard risk. For example, beach surveys are being used in the community of Neskowin to assess problems relating to the continued loss of sand from the beach system and the increased incidence of damage to engineering structures, including overtopping by ocean waves and inundation of back-

shore properties. Beach survey data collected in the Rockaway cell are being used by Coastal engineers to assess the viability of placing wave energy devices either on the jetty or in the surf zone and the likely effects such devices might have to the beach sediment budget. Shoreline variability continues to be measured and involves re-measuring the Mean High Higher Water (MHHW) contour located at an elevation of ~2.5 m above MLLW, a tidally-based proxy for the position of the 17 shorelines, along each of the littoral cells. These data are being used on an annual basis to assist the Oregon Parks and Recreation Department with identifying potential erosion "hotspot" sites prior to the ensuing winter. A major effort was implemented in August/September 2010 to develop a NANOOS 'NVS – Beach and Shoreline Mapping' portal[1]. This was successfully accomplished and will now form the model for integrating beach data being collected on the Washington coast as well as nearshore bathymetry that is being collected along the length of the PNW coast. Finally, outreach efforts in the form of public presentations were carried out at several forums including a Salishan Spit meeting of real estate lawyers in August 2009. The focus of the talk was on the likely effects of climate change on coastal hazards.

3. Nearshore Bathymetry: In summer 2010, P. Ruggiero's group at Oregon State University successfully completed the collection of nearshore bathymetry data along the four sub-cells of the Columbia River littoral cell (CRLC) in close collaboration with the Washington State Department of Ecology and the US Geological Survey. Over 200 individual cross-shore profiles were collected in the cell extending from the lower inter-tidal to approximately 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. In all cases these nearshore bathymetry measurements are being combined with topographic measurement collected by Ecology to develop complete maps of the nearshore planform.

Ruggiero's group completed the collection of nearshore bathymetry data in south Clatsop County, Oregon in close collaboration with the Oregon Department of Geology and Mineral Industries. Over 100 individual cross-shore profiles were collected in 5 days 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 DOGAMIs planned flood studies of Clatsop County.

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). With partial support from NANOOS, Ruggiero's group has participated 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 is underway 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

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

morphological change data to address these questions and completed 4 nearshore survey of the region in summer 2010 (Figure 1, Andrew Stevens, personal communication).

With partial support from NANOOS, Ruggiero's group also collected nearshore bathymetry data along the coast near Reedsport, Oregon in summer 2010. The over-arching objective of this study is to understand if wave energy conversion devices cause changes in the surf zone circulation patterns and alter the shoreline configuration. This project extended a field-based beach monitoring program begun in spring 2009 to document changes to the beach and nearshore bars, and enables comparisons of the measured changes with the natural envelope of variability determined for the Reedsport site and elsewhere.

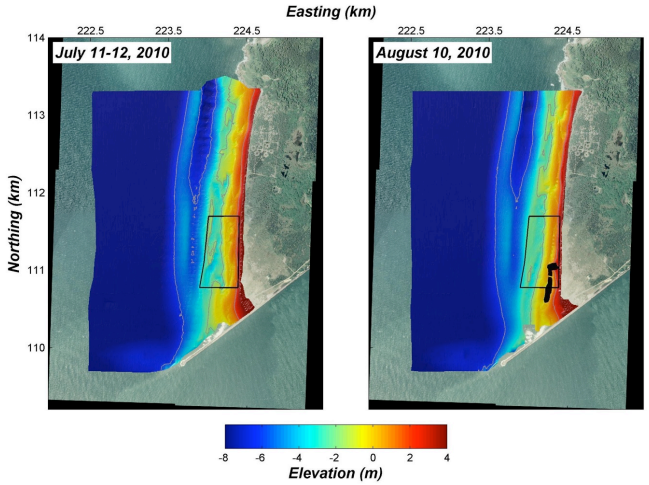

Figure 2. Maps showing interpolated bathymetric and topographic surfaces of Benson Beach derived from data obtained on July 11-12 (left) and August 10 (right). Elevation measurements were interpolated using linear (triangular) interpolation. Grid resolution is 5 m. The black box indicates the Littoral Drift Restoration permit area. The filled black area in the right panel denotes the gap in data coverage in the August 10 survey.

Currents

1. Coastal Currents: The HF surface current mapping program at Oregon State University (PI Mike Kosro, RAs Anne Dorkins and David Langner), has been providing near-real-time maps of ocean surface currents along the Oregon coast to the public via the web (http://currents.coas.oregonstate.edu, plus links to this page from the NANOOS web site), as well as downloadable text files containing the data values. These data are also being provided to NOAA/NDBC via the national HFR-net.

Kosro is a member of the first HF Radar National Steering Team, and participated in their first meeting on July 28, at the Consortium for Ocean Leadership office in Washington D.C. He also attended a meeting of the Eastern Pacific Ocean Prediction Forum (ePOPf) during 20-22 September in Portland, and gave a presentation on surface-current mapping on the west coast and its relation to ocean modeling; Alexander Kurapov and John Osborne of NANOOS also presented results using the NANOOS surface current data for to improve modeling of the offshore circulation and for understanding the tides, respectively. At the end of September, Kosro participated in the 10th International Radiowave Oceanography Workshop, held at Mt. Hood. During this reporting period, David Langner has begun working with our group, taking over some of the HF-related tasks from Walt Waldorf.

We discovered interference from a long-range site in California was degrading our measurements at Point St. George; coordination with CODAR and the COCMP investigators produced a cooperative solution that spread time-delays for transmission so that regional sites could operate without interference. For the future, we anticipate the need to upgrade two of our older sites to allow GPS time-based operation, at an approximate cost of $60K, presently unbudgeted. We have also exchanged electronics between WIN and CBL to move GPS capability where it's most needed, and are installing GPS timing antennas at each site. Renewals of our five-year FCC secondary permits have been proceeding favorably. To increase site resilience, we are installing Web Power Switches at each of our 11 sites; these allow individual plugs in a power strip to be power cycled remotely through a web interface, often averting the need for an in-person site visit. Wireless communications to YHS are being upgraded with installation of a new 10dbi SWOP antenna. At LOO, a lightening strike took out the computer and monitor on 4/19. Service to the site was restored on 7/27, after repairs to the site transmitter/receiver electronics were completed at CODAR. A receive antenna cable at WLD was found above ground and severed; one of the pre-buried spares was swapped in to replace it. The aging site computer at YHL was replaced with a new Mac mini.

Presentations (with published abstracts) acknowledging NANOOS support:

1. Zelenke, B., and P.M. Kosro. "Short-term Current Forecasts from an Empirical Statistical Model". (Invited), Meeting of the Americas, Foz do Iguassu, Brazil, 8-13 Aug 2010.
2. Kurapov, Alexander., Peng Yu, Gary Egbert, P. Michael Kosro. "Variational assimilation of high-frequency (HF) radar surface current observations in the coastal ocean model off Oregon" (Invited), Meeting of the Americas, Foz do Iguassu, Brazil, 8-13 Aug 2010.

Publications acknowledging NANOOS support:

1. 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.
2. Yamada, Sylvia Behrens, and P. Michael Kosro, 2010. Can ocean conditions predict recruitment strength of the invasive European green crab, *Carcinus maenas*? *Biological Invasions*, 12(6): 1791-1804, doi:10.1007/s10530-009-9589-y.
3. Hickey, B.M, R.M. Kudela, J.D. Nash, K.W. Bruland, W.T. Peterson, P. MacCready, E.J. Lessard, D.A. Jay, N.S. Banas, A.M. Baptista, E.P. Dever, P.M. Kosro, L.K. Kilcher, A.R. horner-Devine, E.D. Zaron, R.M. McCabe, J.O. Peterson, P.M. Orton, J. Pan and M.C. Lohan, 2010. River Influences on Shelf Ecosystems: Introduction and Synthesis. *Journal of Geophysical Research*, 115, C00B17, doi:10.1029/2009JC005452.

Publications in review acknowledging NANOOS support:

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, 2010. Observations of high-resolution coastal surface circulation on the U.S. West Coast. Submitted to *Journal of Geophysical Research*.
2. Hickey, B.M., V.L. Trainer, P.M. Kosro, N.G. Adams, T.P. Connolly, N.B. Kachel and S.L. Geier, 2010. Seasonal differences in sources of toxic *Pseudo-nitzschia* cells on Washington's razor clam beaches. Submitted to *Journal of Geophysical Research*.

2. Port X-band Radar: Led by M. Haller (OSU) the wave imaging marine radar (X-band) station at the Newport jetties has continued collecting regular observations since May 1st 2009. The system

collects hourly image sequences and uploads them to our web database server on the OSU campus. Individual images are also made available in real-time through the NANOOS Visualization System.

This quarter we have expanded our observing capabilities in an effort to calibrate the marine radar system and better characterize the oceanographic conditions in the Newport area. On August 3, 2010 we deployed a WaveRider buoy at 44.37.48 N 124.09.00 W at approximately 40 m water depth off of Newport. We also deployed a wave and current system (Nortek AWAC) at 44.36.34.74 N 124.05.08.34 W near the mouth of the Yaquina. These systems will help us to calibrate the existing marine radar system in order to potentially estimate wave heights. In addition a PhD student, David Honegger, who is funded through a Fellowship and leveraged funds from the Northwest National Marine Energy Center (DOE), has been awarded a student grant from CODAR in order to test deploy a UHF radar current observation system at Newport. This system became operational at the site during Sept 2010 and is being used to map the surface currents through the jetties (300m footprint).

All of these systems (except for the X-band radar) are scheduled to be retrieved Dec 1, 2010. At that time we will begin data analysis in order to 1) calibrate the marine radar system, 2) perform model/data comparisons between ongoing wave modeling and the wave data, 3) better characterize the influence of opposing currents on the wave breaking conditions on the Yaquina Bar (as imaged by the marine radar).

Presentations acknowledging NANOOS support:

1. Honegger, D.A., S. Meskill, and M.C. Haller, X-band radar observations of waves near a tidal inlet and comparisons to the SWAN model, *AGU Ocean Sciences*, Portland, OR, 2010.
2. *INVITED*: "Remote Sensing of Breaking Waves", *Workshop on air-sea interactions under tropical cyclones (hurricanes)*, University of Rhode Island, April 11, 2010.

b) <u>Modeling efforts</u>

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. Maps of the nowcasts and forecasts are posted daily to the web (http://agate.coas.oregonstate.edu/forecast_index.html), available through the NANOOS website.

The forecast model is forced with NOAA NAM atmospheric forecasts and uses the climatologic boundary conditions derived the Navy regional NCOM-CCS model. To improve quality of the forecasts, a data assimilation component has recently been added to our real-time product. Model ocean estimates are constrained by HF radar surface current observations (provided by our NANOOS partner P. M. Kosro) and hourly GOES SST (from NOAA Coastwatch, D. Foley). Assimilation proceeds in a series of 3-day time windows utilizing the variational AVRORA system developed by the OSU group. By using this system, dynamically based time-interpolation between observations is possible, with filtering noise and patching gaps in the data (which is particularly important for the hourly GOES SST images). Assimilation proceeds at the 6-km resolution, and correction is interpolated on a 3-km resolution grid, to facilitate nonlinear ROMS forecasts. Assimilated fields are being tested and will soon appear as part of the NANOOS Visualization System. They are currently available at http://www-hce.coas.oregonstate.edu/~orcoss/ACTZ/SSCforecast.html.

In preparation to assimilation of additional data types in real-time, we have started to work with RADS near-real time altimetry (with L. Miller, NOAA STAR). Our preliminary model-data comparisons suggest that satellite SST assimilation improves accuracy of the SSH slope (and hence surface geostrophic currents). As the season transits in rainy and cloudy winter, assimilation of SST data from a microwave radiometer, which can see through clouds, is also planned.

Publications acknowledging NANOOS support:

Kurapov, A. L., D. Foley, P. T. Strub, G. D. Egbert, and J. S. Allen, 2010: Variational assimilation of satellite observations in a coastal ocean model off Oregon, J. Geophys. Res., submitted.

Presentations acknowledging NANOOS support:
4th Coastal Altimetry Workshop, Porto, Portugal, 14-15 October 2010
Eastern Pacific Ocean Prediction Forum (ePOPf) workshop, 20-22 Sept 2010, Portland, OR
COAS Physical Oceanography Seminar, 5 May 2010
The Meeting of the Americas, Foz do Iguaçu, Brazil, 8-13 August 2010
Regional Ocean Modeling System (ROMS) Workshop, Honolulu, HI, April 2010

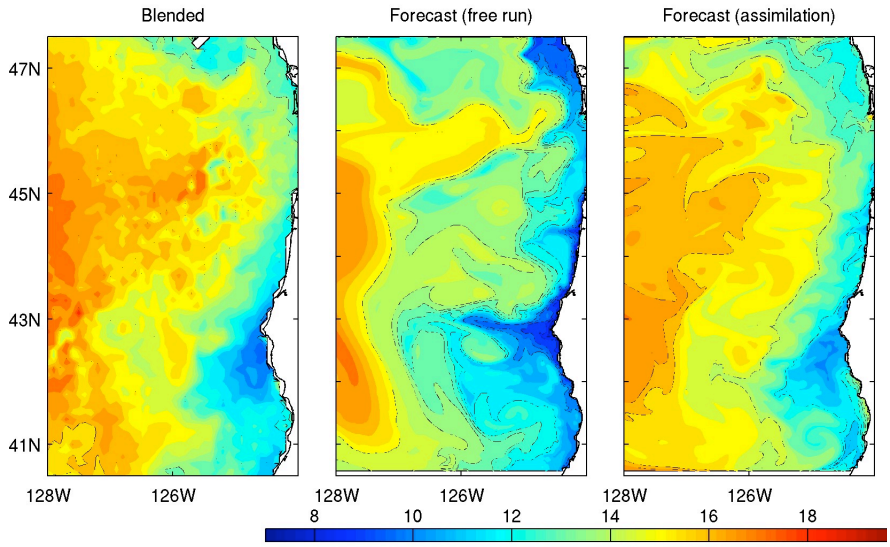

Figure 3. Effect of assimilation on accuracy of the SST forecast (shown are SST fields for 15 September 2010): (left) verification multi-satelite blended product (5-day weighted average), (middle) model forecast without data assimilation, (right) 24-hour model forecast with assimilation of HF radar surface velocities and hourly GOES SST.

Estuaries

1. Puget Sound: Overseen by D. Jones, APL-UW continues to maintain an operational hindcast model of the Puget Sound (PS-POM) based on the Princeton Ocean model, plus they are providing data sets and software engineering assistance to the Salish Sea ROMS model development team operated by Parker MacCready and Dave Sutherland of UW Oceanography and Neil Banas of APL-UW. During this reporting period, we have collaborated with researchers in the Aeronautics and Astronautics Department at the University of Washington (Kristi Morgansen and Laszio Techy) to use PS-POM model output to enhance measurements recorded while testing new sea gliders in Port Susan, Washington.

We have worked on multiple particle tracking codebases that work with current and future ocean models. Some of this code has been shared with researchers in the School of Oceanography at the University of Washington. A recent product of this work is a proof of concept for running particle tracking code in a web browser using technology from the Processing project, an open source development environment based on Java to simplify visualization tasks.

Effort has been spent on creating a version of code used internally to visualize model output, originally written for use in Matlab, to run on a web server. This work has aided the development of numerous NVS plotting features, including the comparator which allows users to compare observations from buoys and other platforms with model output from a variety of models operated within and without the NANOOS project.

2. Columbia River: With a mix of regional stakeholder funding (Bonneville Power Administration, NOAA/NWFSC), NSF funding, and NANOOS funding, CMOP under the direction of A. Baptista, maintains an extensive modeling system for the river-to-shelf circulation of the Columbia River. The goal is to build a "virtual Columbia River" for the use of a broad community of scientists, educators, and managers.
The virtual Columbia River includes daily circulation forecasts, decade-long hindcast simulation databases, and scenario simulations. A description of these products, and their driving applications, can be found in the progress report for October 2009-March 2010. Simulation products are available at http://www.stccmop.org/datamart/virtualcolumbiariver. Forecasts of salinity and temperature at selected stations are also already available through NANOOS NVS.

Of note for the reporting period:

- We have built, and are refining, a new river-to-ocean grid extending upstream to Bonneville Dam and Willamette Falls. Leveraging a detailed new bathymetry now available in pre-release form (courtesy Lower Columbia River Estuary Partnership), the new grid is designed to incorporate flood plain and shallow freshwater tidal regions. The driver for the new grid are enhanced resolution upstream of Beaver Army for simulations supporting climate impact studies; salmon and ecosystem restoration projects; flood protection; hydropower and navigation management; and search and rescue operations.
- Circulation simulations are now being conducted with evolving versions of the new grid, in an iterative calibration process, both in the form of daily forecasts and of hindcast simuloations (Fig. 4). A simulation database (DB25) will start being built in the next reporting period, once a final grid has been selected via the on-going process of iterative calibration.
- We have begun developing (in collaboration with Y. Spitz, OSU) an oxygen model for the estuary and tidal freshwater, to advance the understanding of oxygen depletion mechanisms identified through observations at the SATURN biogechemical stations.

Presentations acknowledging NANOOS support:

1) Law, C. G., A. M. Baptista, C. Seaton, S. Frolov, Y. J. Zhang, K. Cho, Y. H. Spitz, S. M. Durski, N. Hyde (2010). Data-informed circulation simulations in the river-to-shelf Columbia River system. AGU Ocean Sciences Meeting, February 21-26, 2010, Portland, OR.

2) Seaton C., A. M. Baptista, P. Turner, A. Jaramillo, D. Hansen, D. Maier, E. Van Matre, A. Johnson, J. Oltmann (2010) Lessons learned from the cyber infrastructure of the SATURN

coastal margin "collaboratory", Eos Trans. AGU, 91(26), Ocean Sci. Meet. Suppl., Abstract IT21C-03

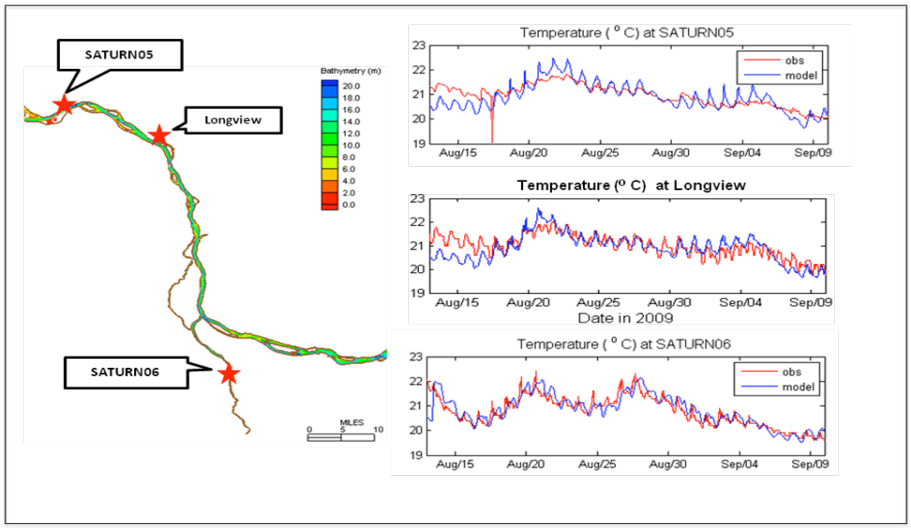

Figure 4.: Model-data comparison for a hindcast simulation conducted as a part of the process of the development of the new grid for the Virtual Columbia River. Comparisons for this particular calibration simulation are shown for three temperature at tidal freshwater stations.

c) Data Management and Communications (DMAC)

1. Managerial: Boeing is lead for managerial duties. Steve Uczekaj (Boeing – DMAC lead) is the Chair of the NANOOS DMAC Committee. DMAC committee technical implementers include Rick Blair (Boeing – Infrastructure and Standards), Craig Risien (OSU – Data Provider Services), Emillio Mayorga (APL UW – Data Provider Services), Troy Tanner (APL UW – Portal Services). DMAC activities for this period included the following:

- NANOOS DMAC Weekly Tag-up telecon.
- IOOS Regional DMAC Implementation (RDI) bi-weekly telecon.
- DMAC Steering Committee weekly telecon.
- NANOOS Tri-Committee meeting in Portland, OR – April 2010
- Obtained Apple Developers License -- May 2010
- Released NVS iPhone and Android application – May 2010, August 2010
- Presented NANOOS Visualization System (NVS) at Oceans '10 conference in Seattle, WA, Sep. 2010.
- Provided information about NVS Web Application to IOOS RDI conf. call - Sep. 2010.
- Provided DMAC section to the FFO response -- Sep. 2010.
- Responded to the FFO Sept. 2010.

2. Summary of Significant DMAC Technical Accomplishments: Significant accomplishments were made in maturing the NANOOS DMAC architecture including a mobile phone NVS application on both iPhone and Android, providing real-time access to NANOOS regional assets and data. Recent progress includes:

- Released NVS 1.6 in May 2010, adding map overlays and other enhancements.
- Released NVS 2.0 in April 2010 with large improvements to the User Interface including addition of overlay time series and support for comparing in-situ observational data with Model output for all regional observing assets.

- Registered CMOP SOS data service to the IOOS registry and catalog. One of only 4 of the 13 regional associations to be registered so far.
- Created iPhone and Android NVS applications that allows access to NANOOS data and assets from mobile phones. Applications are available for download on the Android market place and iPhone App store. Over 500 downloads to date.

Added new assets and data offerings accessible via NVS:

1. Washington Department of Ecology mooring.
2. APL-UW La Push Glider
3. ORCA Dabob Bay Buoy
4. 2 OSU Newport-Line (NH-10) Slocum Gliders
5. CMOP Columbia Estuary Model extracts at 19 stations
6. ORCA Twanoh and Hoodsport buoy data for Near-Bottom Depth
7. APL-UW Chaba Buoy
8. ICM Buoy at Port Angeles
9. HF Radar Overlays
10. AVHRR temperature and MODIS cholorophyll satellite overlays
11. WAVEWATCH III overlays for all forecast time steps.
12. CMOP South West Washington Slocum glider.
13. CMOP Staturn03 and Saturn02 moorings.
14. Environment Canada Far offshore buoy.
15. Ocean Climate Station Papa
16. CDIP buoy at Ocean Station Papa

3. ***Task 1 Progress: DMAC Systems Architecture Definition and Development:*** The DMAC Team continued maturing implementation of IOOS DIF standards through regular participation in Regional DIF(RDI) telecons. During one of these telecons, Troy Tanner and Emilio Mayorga gave a presentation on NVS asset "bubble" implementation. This was the first in a now regular RDI technical exchange meetings. NANOOS DMAC also contributed NVS asset icons to the RDI code sharing project.

The NANOOS DMAC team continues to work closely with the development of the NANOOS Visualization System (NVS) extensible framework. This base NVS architecture provides a flexible and extensible framework for providing IOOS standard data services as well as metadata driven visualization of data. This architecture was presented at the Oceans '10 conference in Seattle, Washington.

Work has also continued on alternate data encodings for DMAC data services. Specifically Java Script Object Notation (JSON) is used to pass data between the NVS framework and the mobile phone applications. Several JSON data encoding patterns are being investigated by various regions including NANOOS for inclusion in future IOOS standard recommendations.

4. ***Task 2 Progress: DMAC Network Engineering Definition and Development:*** Work continued in development of a NANOOS data aggregating server (ERDDAP), UW-APL SOS service and IOOS RDI collaboration. Data set definitions are being developed to provide alternate methods of data discovery. These data set definitions will allow data searching and discovery in a more natural manner. Next step is to integrate ERDDAP with NVS portal.

Presentations acknowledging NANOOS support:
Mayorga, E., T. Tanner, R. Blair, A.V. Jaramillo, N. Lederer, C.M. Risien, and C. Seaton. The NANOOS Visualization System (NVS): Lessons Learned in Data Aggregation, Management and Reuse, for a User Application. OCEANS 2010, MTS/IEEE Seattle - Innerspace: A Global Responsibility, September 2010.

d) Education and Outreach

1. User Products Committee: Chaired by Jonathan Allan (Oregon Department of Geology and Mineral Industries) this committee is composed of members from Boeing, OHSU, UW, OSU, NANOOS E&O, OR Sea Grant, and NOAA. NANOOS UPC chair Allan participates in weekly "tag-up" calls with a smaller sub-group comprised of members from both DMAC, UPC, E&O, and Web development in order to achieve consistent work efforts and improvements to products that are being developed through the synergy between these three groups. The NANOOS UPC/DMAC sub-working group continues to play a key role both in terms of providing ongoing support for the NANOOS Visualization System (NVS) and through continued enhancements to its overall usability and functionality. This synergy has been a key element in the overall success of the NVS platform and has resulted in continued progress and expansion of new datasets that previously were inaccessible to the public-at-large as well as enhancements to data viewing and querying in NVS.

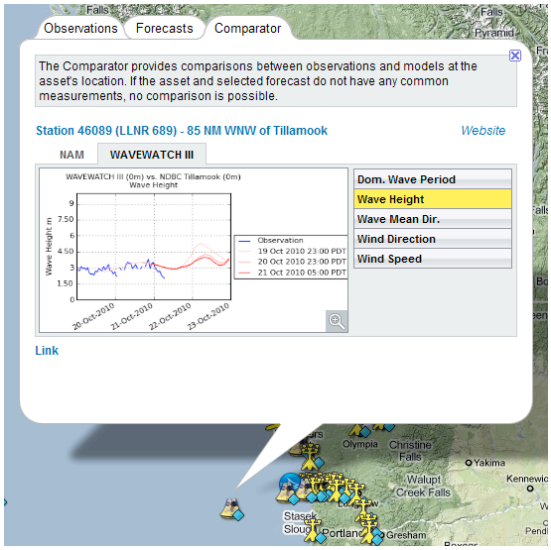

Figure 5: Example of the NVS Comparator tool showing the measured wave height versus the predicted wave height estimated over three days.

Over the past six months, NANOOS DMAC and UPC have continued to focus significant effort at improving NVS as well as the development of several new products. NVS 2.0 was released in August 2010. This release marked a significant step forward for NVS as it includes a completely overhauled user interface that, for example, allows users to quickly select regions of interest and optimizes the available map-based interface as well as the development of several new products. Another enhancement to NVS is the addition of a 'Comparator' tool (Figure 1), which allows the user to visualize comparisons between measurements such as the significant wave height and in this case the modeled Wavewatch III wave height for a particular asset location. The comparator shows the daily changes to the modeled results, which provides an indication of the relative improvements in the modeled results over time (changing red lines in Figure 1). The Comparator tool presently allows user to make comparisons between modeled results for a suite of wave and climate related parameters. These and other NVS enhancements are described in detail in Mayorga et al. (2010)

Aside from ongoing improvements to NVS, NANOOS released a 'Forecast Information and Data Products for Tuna Fishers' web page[2] that synthesizes multiple datasets including satellite-based products (Chlorophyll and SST), HF radar, and modeled forecasts of wave statistics and ocean conditions from 24 hours out through several days, making these datasets more accessible to

[2] http://www.nanoos.org/data/products/tuna_fishers/tuna_fishers.php

commercial tuna fisherman. NANOOS also released the 'NVS - Beach and Shoreline Mapping' portal[3], which presently integrates beach measurements that are being collected by the Oregon Department of Geology and Mineral Industries on the Oregon coast. Having now developed a workable model for integrating such datasets, planned future improvements will include the inclusion of datum-based shorelines collected in Oregon, beach change information that are being collected by the Washington Department of Ecology for the Southwest Washington coast, and nearshore bathymetry data being collected by Oregon State University.

Work continues on an experimental NERDDAP data aggregation service that blends the ERDDAP framework with NANOOS packaging and identified priorities. A prototype of the NERDDAP tool is currently operational. However, additional improvements are required before making this tool publicly available. We anticipate having a public release of this product during the next six months. Work is also progressing on an updated version of the NVS iPhone and iPod Touch app that will eventually integrate overlays such as HF Radar and satellite-based datasets. In addition, DMAC/UPC recently released an Android version of its NVS app.

Presentations acknowledging NANOOS support:
Mayorga, E., T. Tanner, R. Blair, A.V. Jaramillo, N. Lederer, C.M. Risien, and C. Seaton. The NANOOS Visualization System (NVS): Lessons Learned in Data Aggregation, Management and Reuse, for a User Application. OCEANS 2010, MTS/IEEE Seattle - Innerspace: A Global Responsibility, September 2010.

2. E&O Committee and infrastructure
The infrastructure of the Education and Outreach sub-element has been sustained during the past reporting period. NANOOS E&O staff, Amy Sprenger and Sarah Mikulak, have continued participation in NFRA E&O monthly calls, the 2010 NANOOS tri-committee meeting, and organizing and facilitating the NANOOS E&O committee conference calls. Due to the new NANOOS Executive Committee structure enacted in June, Mike Kosro stepped down as NANOOS committee chair and the committee voted Nancee Hunter, the Director of Education for Oregon Sea Grant, the new committee chair. Outreach and networking efforts through Facebook and the NANOOS Observer newsletter also continued. NANOOS supported and staffed IOOS/RA booths at national conferences held within this region. Finally, Sprenger and Mikulak assisted to create E&O related content for the RCOOS proposal recently submitted on Oct 1.

Ocean literacy efforts have continued on two fronts – educator workshops and marine science center exhibit development. Sprenger has been actively involved in partnering with several local and regional groups, including the Northwest Aquatic and Marine Educators, Oregon and Washington Sea Grants, COSEE Pacific Partnerships, COSEE Ocean Learning Communities, Service Education and Adventure, Edmonds Community College and Ocean Inquiry Project to plan and provide professional development for NW educators. Mikulak has continued partnerships and communication with regional educators to develop the modular exhibit looking at seasonal trends of physical and chemical water properties in Puget Sound.

Presentations acknowledging NANOOS support:

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

1. Sprenger, A. *Eyes on Washington Waters, Bringing Ocean Observing Data Into the Classroom*. Washington Watershed Education Teacher Training Program, Port Townsend, WA April 10-11 2010; Anacortes, WA June 12-13 2010.
2. Mikulak, S. and A. Sprenger. *Hypoxia in Oregon and Washington: Using Data to Understand the "Dead Zones".* Northwest Aquatic Marine Educators Conference. July 2010, Florence, OR.
3. Simoniello, C., L. Spence, S. Mikulak, S. Stewart, and J. Dorton. *The U.S. Integrated Ocean Observing System: Eyes on the Ocean, Hands-On Learning.* National Marine Educators Association Conference. July 2010. Gatlinburg, TN.
4. Carlin-Morgan, K., N. Hunter, and A. Sprenger. Using the Ocean to Teach STEM. Northwest Aquatic and Marine Educators Conference. July 2010, Florence, OR.
5. Newton, J.A. Recent research on hypoxia and ocean acidification in Puget Sound. Keynote Speaker, Murdock Partners in Science Workshop, 13 August, 2010. Portland, OR.
6. Newton, J.A. Oceans, Health, and Estuaries. Oceans Health Symposium, 18 June, 2010, APL-UW, Seattle, WA
7. Newton, J.A. Washington's newest buoy: Part of the IOOS-NANOOS system, Olympic Coast National Marine Sanctuary Advisory Council, 16 July, 2010, La Push, WA
8. Newton, J.A. NANOOS: The Northwest Association of Networked Ocean Observing Systems. Keynote Speaker. NORTEK Symposium, 21 May 2010, Seattle, WA

4) Issues (NONE)

5) Key Personnel Changes (NONE)

6) Budget Analysis

NANOOS requested and was granted a 1 year no-cost extension to assure continuity in the RCOOS activities while the new Y4 award is being set up. Thus, the project period for the NANOOS RCOOS award is 77% completed. NANOOS has expended or obligated 93% of the funding. All required financial reports have been submitted.