Final Report for
Enhancing Northwest Association of Networked Ocean Observing Systems (NANOOS): The Pacific Northwest IOOS Regional Association
#NA08NOS4730290
1 June 2008 – 31 May 2012

This final report describes activities carried out over a three year period in support of enhancing the Northwest Association of Networked Ocean Observing Systems (NANOOS) as the Regional Association (RA) of the United States Integrated Ocean Observing System (U.S. IOOS) for the U.S. Pacific Northwest. This report was compiled by Jan Newton, NANOOS Executive Director and David Martin, NANOOS Governing Council Board Chair; the co-PIs for this grant. Newton and Martin, in consultation with the NANOOS Governing Council and Executive Committee, have managed the activities of this award. The focus of this report is on RA planning activities, though we note that outcomes from NANOOS' Regional Coastal Ocean Observing System (RCOOS) awards were enabled and accelerated by collaborative resource allocations from these complimentary RA Planning award efforts.

I. Project Summary and Outcomes

The goal of this project remained consistent over the three year period and was achieved. Our goal was to foster and enhance Pacific Northwest (PNW) regional partnerships in order to grow constituencies and to implement a governance structure and business plan that permit official federal certification of NANOOS as the PNW Integrated Ocean Observing System (IOOS) Regional Association and allow for the installation and long-term maintenance of a PNW Regional Coastal Ocean Observing System (RCOOS).

Stated NANOOS objectives of the project and our final status are listed here:

1) **Continue to identify and engage the full and expanding spectrum of stakeholders** having significant interests in the waters of the Pacific Northwest to ensure their views and opinions are fully recognized and taken into account in all aspects of planning, science and governance, and that this partnership building effort takes advantage of their scientific, economic, social, cultural and operational expertise.

Outcome: NANOOS successfully achieved this on-going objective. Over the project period NANOOS continued to engage with a large spectrum of stakeholders, as witnessed by our well-attended IOOS/IOOS-led "Pacific NW Waters – Gateway to our Future" workshop in February 2012, hosted by Microsoft Research in Redmond, WA, which was attended by >150 people and included panels from 5 diverse user groups: Fisheries; Alternative Energy; Aquaculture; Coastal Engineering; Hazard Response and Marine Operations who were filled by federal, tribal, state, academic, industry, and public speakers. Our NANOOS Governing Council membership grew from 32 organizations in 2008 to 46 in 2012, with several new memberships in the works currently (e.g., USACE).

2) **Proactively engage the regional ocean science community** in this partnership-building project to ensure their expertise helps guide the eventual design and evaluation of the system. This approach will ensure that PNW Regional IOOS evolves to take advantage of new knowledge and technology as they are developed.

Outcome: NANOOS achieved major advances in this on-going objective. NANOOS benefits from having 19 PIs from several institutions involved in the funded RCOOS activities of NANOOS. Additionally, NANOOS is well-networked with several major scientific endeavors, including the NSF-funded Ocean Observing Initiative (OOI), NSF-funded Center for Coastal Margin Observations and Prediction (CMOP), Canadian Victoria Experimental Network Under the Sea (VENUS) and several sub-regional groups. NANOOS's data visualization system, NVS, serves VENUS and CMOP data and will work with OOI do have data interoperability. Newton, Martin, and several NANOOS PIs participated in numerous scientific meetings including Ocean Sciences, ASLO, AGU, IEEE/MTS, Coastal Zone, several national interest meetings (e.g., National Environmental Monitoring Conference, National Water Quality Monitoring Conference), and many topical scientific workshops and meetings (e.g., ocean acidification (OA), harmful algal blooms (HABs), tsunami debris, climate science, etc.) detailed in our Progress Reports over the 3-y project period.

Throughout the reporting period, Martin and Newton remained deeply involved with a complimentary research ocean observing effort in the Pacific Northwest, the NSF-funded Science and Technology Center (STC) for Coastal Margin Observation and Prediction, which NANOOS leverages heavily in the areas of Observations, Modeling, DMAC and Education and Outreach. Martin serves as Co-Director for the Center and Newton directs the UW Education efforts for this multi-institution project.

3) **Obtain input about sub-regional scale oceanographic concerns** by engaging with local stakeholders to ensure these factors are addressed at the Regional level. NANOOS will work within these smaller groups to build a sense of community and partnerships at the sub-regional scale and then translate this into strong regional partnerships through larger gatherings and workshops.

Outcome: NANOOS achieved major advances in this on-going objective. Certainly the "PNW Waters" workshop is a strong example of the engagement NANOOS has, as witnessed by having ~150 attendees from diverse sectors. But this task has been on-going since the start of the NANOOS RA. Currently NANOOS' Governing Council is comprised of 46 organizations, including tribes (e.g., Quinault Indian Nation; Port Gamble S'Klallam Tribe), state government agencies (e.g., OR Dept of State Lands; WA Dept of Ecology), regional governments (e.g., King County, WA; Port of Newport, OR), non-governmental organizations (NGOs, e.g., Surfrider; Hood Canal Salmon Enhancement Group), and regional industry trade associations (e.g., Marine Exchange of Puget Sound; Columbia River Crab Fisherman's Association). These entities participate in our annual Governing Council meetings. NANOOS treasures its diverse GC composition, which is fairly evenly divided between industry, governmental, academic, and NGOs. Per GC vote, our Memorandum of Agreement (MOA) was revised to make our elected Board representational by sector, with seats now assured for academia, federal, tribal, state/local, industry, NGO, and at-large members. Our proposal's for our NANOOS funds from IOOS are always approved by our Board on behalf of the GC, and reflect consensus priorities.

4) **Implement the results of the consensus agreement on the overall Governance structure for NANOOS**.

Outcome: NANOOS has successfully achieved this objective. NANOOS has an on-line MOA (http://www.nanoos.org/documents/key/NANOOS_MOA_v2.pdf) that was drafted in 2005 and

has been revised as needed, by GC vote. A revision was made in 2010 to provide a process to make the composition of our Board more representational of sectors, as noted above. The NANOOS MOA contains the Governance structure that guides NANOOS and which we successfully are implementing.

5) **Develop and implement a Business Plan** to guide NANOOS budget formulation, involvement of users, all aspects of linkages between observations and products, research and development decisions, training, and alternate funding opportunities.

Outcome: NANOOS successfully achieved this objective. NANOOS' Business Plan was drafted in 2008-09, adopted in June 2009, and is available on-line at http://www.nanoos.org/about_nanoos/documents.php. Our Business Plan was drafted with much assistance by some of our industry GC members, notably Casey Moore (WET Labs, Inc.) and Carol Janzen (Sea-Bird Electronics, Ltd). The Business Plan is fully compatible with our MOA and continues to guide the vision for NANOOS.

6) **Strengthen international and inter-Regional partnerships** by engaging with Canadian colleagues and other western Regional Association efforts to build bridges to these efforts and ensure seamless integration of these efforts.

Outcome: NANOOS achieved major advances in this on-going objective. Internationally, NANOOS has Canadian members and, as noted above, serves VENUS data through our NANOOS Visualization System. NANOOS has informal ties with NEPTUNE Canada as well. Martin is a member of the International Science Advisory Board for Ocean Networks Canada's Ocean Observatory efforts. As such, he represents the importance of the U.S. national IOOS effort in meeting the operational needs of citizens and stakeholders and how such efforts require a robust and competent ocean research component to sustain and evolve their capabilities.

Inter-regionally, in order to further the mission of the U.S. IOOS and serve the requirements for ocean observations, data, and information at the scale of the California Current Large Marine Ecosystem, during the project period NANOOS signed a Memorandum of Understanding (MOU) with its sister RAs on the continental U.S. West Coast, CeNCOOS and SCCOOS (http://www.nanoos.org/documents/key/mou_nanoos-cencoos-sccoos.pdf). These three RAs agree to work collectively on California Current-wide issues, including HF currents, modeling, HABs, OA, etc. The three RAs submitted a proposal to the NOAA Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Federal Funding Opportunity (FFO), which was reviewed highly successfully but the FFO funds for MERHAB were pulled. The three RAs worked to establish a MOU with the West Coast Governors' Alliance (WCGA), which at the end of the project period is still going forward and anticipated. NANOOS has engaged with the WCGA separately and with its sister RA's effectively. Newton and Emilio Mayorga, NANOOS DMAC Co-Chair, is on one of their Action Coordination Teams for Regional Data Framework. Additionally, NANOOS has participated in NFRA RA workshops on user products. NANOOS has collaborated directly with other RAs, including SECOORA and PacIOOS in answering questions and sharing NVS resources in support of the development of their user products.

7) **Continue to engage at the national level** to ensure the PNW activities of NANOOS are fully supportive of the national effort to implement and maintain an IOOS.

Outcome: NANOOS achieved major advances in this on-going objective. Throughout the project period Newton, Martin, and NANOOS Board Co-Chair Kosro participated in the NFRA Board teleconferences, Newton participated in NFRA Executive Committee teleconferences, and Sprenger and Mikulak participated in the NFRA-IOOS led Education and Outreach teleconferences. Newton and Martin participated in IOOS and NFRA meetings and Newton participated in NFRA Ex-Com meetings and planning activities.

During the project period, NANOOS worked extensively with the U.S. IOOS Program Office to supply milestone information, input to the Independent Cost Estimate, and to support other information requests from the IOOS Program Office or other federal entity. A major effort, NANOOS submitted documentation for its 10-year horizon Build-Out Plan, based on NANOOS PI and user input, using the templates and guidance from this IOOS/NFRA- led exercise to fulfill the Congressional mandate to scope regional IOOS. Newton participated in the sub-group scoping this effort and in the IOOS/NFRA meeting in Portland, Maine to consolidate the RA input to this effort. Newton and Mike Kosro, NANOOS Board, participated in the National Ocean Council listening sessions in WA and OR, respectively. Martin and Newton also participated in meetings each year with PNW congressional staff dealing with NANOOS and IOOS matters. Newton is the Co-Chair of Advisory Council of the Alliance for Coastal Technologies (ACT), which is supported by the U.S. IOOS Program Office. Newton participated in meetings and teleconference calls and worked with ACT's Mario Tamburri and NFRA's Josie Quintrell to bring synergies between the NFRA-IOOS and ACT-IOOS activities.

Newton and Martin are both playing key roles in the upcoming IOOS Summit to be held in November 2012 in Reston, VA. Newton was asked to be one of the four Co-Chairs for the meeting and Martin agreed to serve as Co-lead with Zdenka Willis on Chapter One of the Proceedings. As such both have participated in numerous teleconferences and planning activities for that meeting and remain actively engaged at the national level

II. Major accomplishments

Key highlights of NANOOS' accomplishments to cumulatively address the project objectives were listed above. To achieve these objectives, Newton and Martin extensively interacted with the NANOOS Governing Council, the NANOOS Executive Committee (= the elected Governing Council Board plus Standing Committee Chairs), and three Standing Committees (Data Management and Communication = DMAC; User Products = UPC; Education and Outreach = EOC) throughout the project period. Reports from each of the three standing committees, summarizing NANOOS' major accomplishments follow below. While there is overlap in these three Standing Committee reports, this shows the inherent and intentional integration of these three related efforts.

NANOOS DMAC:

The Northwest Association of Networked Ocean Observing Systems (NANOOS) Data Management and Communications (DMAC) activities are managed by a multi-organization committee that is Co-Chaired by Steve Uczekaj (The Boeing Company) and Emilio Mayorga (Applied Physics Laboratory - Univ. of Washington). The NANOOS DMAC Committee is composed of members from Boeing, Oregon Health and Science University (OHSU), University

of Washington (UW), Oregon State University (OSU), and Oregon Dept. of Geology and Mineral Industries (DOGAMI).

DMAC team members coordinate tasks through weekly "tag-up" calls that include members from other NANOOS committees to ensure that DMAC efforts align with NANOOS stakeholder needs. In addition to these weekly meetings over the project period, DMAC members participated in annual regional NANOOS Tri-Committee meetings and Governing Council meetings, as well as various annual national IOOS DMAC meetings and workshops. During the period of performance, the DMAC team successfully integrated a large number of regional data sets and fielded IOOS recommended standard data services across multiple team member sites including OSU, OHSU, and UW. These services included access services for gridded and large archival data sets (Thredds server), Sensor Observation Services (SOS) for observation data access, and a Web Map Service (WMS) for Geographic Information System (GIS) layers. In addition DMAC also installed a data aggregator across several of these services called ERDDAP. NANOOS DMAC members have also played a key role in establishing IOOS standards and best practices. Specific accomplishments by year follow.

In 2008 the DMAC team successfully completed an initial operating capability (IOC) as defined by the IOOS program office. This initial offering consisted of a Sensor Observation Service (SOS) that provided access to regional core observation data (salinity, temperature, wave height, currents) by area and timeframe, two Web Mapping Service (WMS) data products for accessing model data including sea color, one OpenDAP data product for accessing Princeton Oceanographic Model (POM) data, a comprehensive community-maintained Asset List for the Northwest Region, and a Web Portal containing a NANOOS Service Explorer application. The SOS code base was made available to other IOOS regions through an open source license.

During 2009 the DMAC team played a key role in the implementation and support of the NANOOS Visualization System (NVS) data services and web portal. Significant accomplishments were made in maturing the NANOOS DMAC architecture including addition of new data sources. During this time period, extensions to the NANOOS data services were made including a second SOS server for assets based in Washington State and Canada; addition of an experimental open source ERDDAP server as a data aggregation service; and addition of an open source THREDDS data service for OSU model output.

The year 2009 saw the expansion of NANOOS observation and model-based gridded data sets. New observation data providers included fixed moorings from Environment Canada, Water Quality from King County Marine Moorings, PRISM Cruises from University of Washington, Fixed platforms from National Estuarine Research Reserve System (NERRS), Tides and Currents data from Center for Operation Oceanographic Products (CO-OPS). Other additions included Climate Station Papa, Far-offshore buoy from Environment Canada, and a Port Angeles buoy from ICM-Mobilisa. New gridded data providers included meteorological forecasts from the NAM model, sea level forecasts derived from the NOAA Co-Ops, wave forecasts, derived from NCEP's WaveWatch III model, and temperature and salinity derived from CMOP model. During this period, gridded data overlays were also added to NVS. These data include HF-Radar and X-Band Radar. Additionally overlays from remote sensor data from NOAA CoastWatch and Modis were made available as well.

In 2010, an iPhone version of NVS was created and posted on the Apple® App Store. The NVS app allows for the browsing all NANOOS observing assets on one's iPhone. Also during this period, datasets continued to be added including: four Washington Department of Ecology moorings, APL-UW La Push Glider, ORCA Dabob Bay Buoy, two OSU Newport-Line (NH-10) Slocum Gliders, CMOP Columbia Estuary Model extracts at 19 stations, ORCA Twanoh and Hoodsport buoy data for Near-Bottom Depth, APL-UW Cha'ba Buoy, CMOP South West Washington Slocum glider, and CMOP Staturn03 and Saturn02 moorings.

NANOOS engaged its IOOS national and regional partners by sharing our experience gained in the development of the NANOOS Visualization System (NVS). NANOOS DMAC members led an IOOS Regional Developers conference call discussion on technical aspects of the NVS presentation of asset information. We collaborated directly with SECOORA and PacIOOS in answering questions and sharing NVS resources in support of the development of their user products. We also worked closely with the Padilla Bay NERR to overhaul Washington data access for the Real-time Water Quality Data application for Shellfish Growers and provide access to NVS' user-friendly data services.

In 2011, the DMAC team supported continued NANOOS Visualization System (NVS) enhancement through an important new release to the online platform and mobile apps, and the development of new, customized applications focused on tsunami hazards;. NVS enhancements also encompassed continuous asset additions and updates reflecting platform, sensor, telemetry and model reconfigurations, including: in-situ monitoring assets from a new provider for NANOOS (CeNCOOS/Humboldt State University in Northern California); and new deployments, new offerings and re-deployments from existing NVS providers (CMOP, OSU, WADOE, UW, ICM-Mobilisa, King County, PSI, VENUS, CDIP, NOAA NDBC, USGS, CO2 sensor data from NOAA PMEL leveraging NANOOS buoys), including new forecast model site time-series extractions and a new regional high-resolution wave forecast model from OSU based on the WaveWatch III code.

NANOOS played a key role in the IOOS SOS Reference Implementation working-group. In coordination with this IOOS DMAC community effort, in mid-November 2011, NANOOS released a new SOS service connected to the NVS data store providing access to in-situ data from regional providers. This service has been fully integrated into the IOOS Catalog, seamlessly joining an existing NANOOS SOS service from CMOP OHSU.

The DMAC team continued to advance partnerships and efforts for expansion into relatively new areas of importance to national IOOS and regional stakeholders. These include regional and West Coast coordination for coastal and marine geospatial data; collaboration with IOOS and POST to start a pilot project addressing animal acoustic tracking data; collaboration with OBIS-USA to publish species occurrence data from a NANOOS dataset on the OBIS-USA node; collaboration with SCOOS, CeNCOOS and other organizations on a proposal addressing Harmful Algal Bloom data along the West-Coast; and data management and coordination at national and West-Coast scales regarding ocean acidification.

The 2012 DMAC activities supported enhanced asset-health monitoring capabilities. NANOOS has been a leading participant in the IOOS SOS RI working-group, including the SOS RI workshop in February that resulted in substantial advances to data services and metadata conventions. E. Mayorga received IOOS funding in May to help document and coordinate the completion of the first SOS RI project Milestone by September. NANOOS DMAC is co-leading a new IOOS-supported project addressing animal acoustic tracking data, in collaboration with IOOS and POST (http://postprogram.org). NANOOS hosted the project kick-off meeting in March, with local and remote attendance by partners from across the country and Canada; the project is making steady progress.

Regarding West-Coast Coastal and Marine Geospatial Data, NANOOS coordinated closely with SCCOOS and CeNCOOS to co-lead collaboration with the West Coast Governors Alliance (WCGA) and its partners that will enhance regional discovery, access, coordination and prioritization of coastal and marine geospatial data. The RA's presented a common vision at the WCGA Regional Data Framework workshop in Oakland, CA, and NANOOS actively supported follow-up activities, including coordination of the IT working group. NANOOS DMAC strongly supported the ongoing, NOAA-led Ocean Acidification Data Management project, participating in its Steering Committee, a March workshop in Seattle NANOOS also supported the asset inventorying activities of the California Current Acidification Network, as well as data dissemination and access needs of the regional shellfish aquaculture industry.

NANOOS UPC:
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, Oregon Sea Grant, and NOAA. NANOOS UPC chair Allan participates in weekly "tag-up" calls with a smaller sub-group comprised of members from DMAC, UPC, E&O, and Web development in order to facilitate consistent work efforts, synergy across the committees, and improvements to product development and enhancements. Activities for this 2008-2012 period included: 1) multiple weekly NANOOS DMAC and UPC teleconferences; 2) annual meetings of a core sub-group of NANOOS DMAC-UPC-WEB staff; and, 3) annual meetings of the full NANOOS DMAC-UPC-WEB-E&O Tri-committee members.

The objective of the NANOOS UPC is to guide the conceptual development of the data/analysis products (i.e. observations, time series, models, applications, etc.) identified by NANOOS stakeholders, and 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 Education/Outreach teams to ensure product concepts are effectively developed and tested prior to their release.

Website: Efforts by the UPC/DMAC and E&O have focused on three important goals to facilitate the development of a regional NANOOS RCOOS during the study period. These included:

1. Developing the overall conceptual look and design of the NANOOS website, including the identification of ***existing*** web-based products that meet the core thematic areas (i.e. Maritime Ops, Ecosystem Impacts, Marine Fisheries, and Coastal Hazards) adopted by

the NANOOS Governing Council. In June 2008, NANOOS released version 1 of its website;

2. Conceptualize, design and build the NANOOS Visualization System (NVS). NVS remains the flagship portal for the integration and dissemination of complex information such as oceanographic data from a wide and disparate group of data providers, in forms that can be easily accessed and interpreted by PNW stakeholders; and,
3. Conceptualize, design and build additional NVS web applications that target specific user groups and stakeholder needs in the region.

Since 2008, NANOOS has successfully accomplished each of these goals, and in many respects NVS has exceeded our initial expectations. Currently, NANOOS provides links to 43 products, of which 22 are custom built to meet the needs of NANOOS stakeholders. Several of these products are discussed in more detail below.

NVS: The backbone of the NANOOS RCOOS is the NANOOS Visualization System[1] (NVS) that currently distributes data from a myriad of regional and federal assets. While, it is recognized that a single visualization tool is unable to meet all user needs throughout the NANOOS region, such a tool can still provide the necessary framework on which additional applications[2] are based and subsequently developed that meet specific user needs. It is this latter approach, which now forms the basis for future enhancements to application development within the NVS platform.

Early in 2008 NANOOS UPC/DMAC/E&O committee members met to strategize through visioning processes, the necessary data management and communication (DMAC) components that ultimately would comprise the NVS. To facilitate the web development process, a white paper was developed by UPC chair Allan, with significant input from NANOOS committee members. The NVS platform had four primary requirements (***Risien et al. 2009***):

1)Interoperability with national-scale applications;
2) Reliable, efficient ingest of data from observational assets;
3) Access to models, application tools and information products; and,
4) A rich yet simple interface enabling decision making by end users on a routine, unassisted basis.

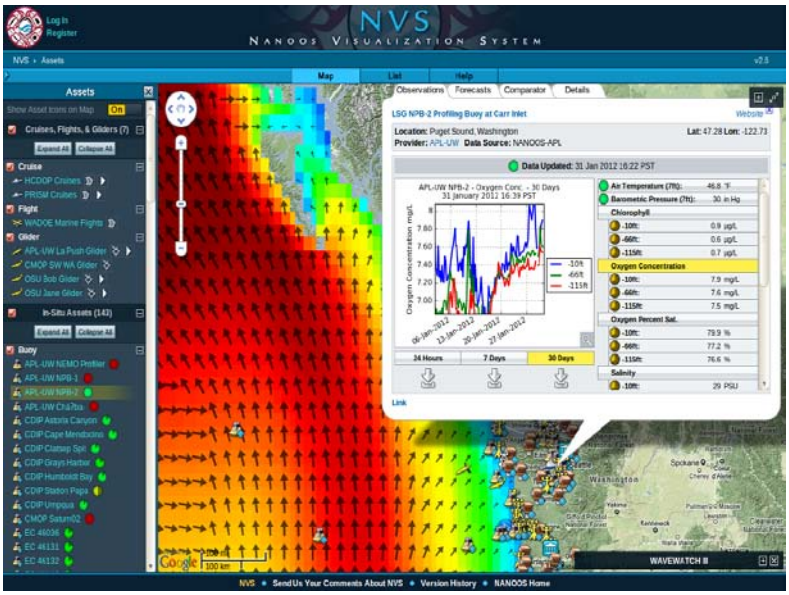
To meet these requirements and ultimately the end user, NVS was designed in such a way that it provides a suite of interfaces that included: *map views of observational asset locations and model domains, comparison of multiple variables, changes in variables over time, changes in variables with depth, geographical map views of parameter values, cross-sectional map views that include comparisons of depth with distance along transect(s) or comparisons of depth versus time changes at a range of geographic locations and spatial scales.* Access to the asset data is accomplished by clicking on specific icons, where the user is presented with a variety of distinct time windows and plots contained in a 'tabbed' interface that provide access to *current conditions, forecasts* and a *comparator* tool that enables access to both observations and modeled results at the same location. In time we anticipate adding additional tabbed views, most

[1] http://www.nanoos.org/nvs/nvs.php?section=NVS-Assets
[2] NVS Web Applications

important of which is providing access to long-term (currently under development) and eventually archived datasets.

With these concepts in mind, NVS version 1 was developed over a period of several months between May (completion of the NVS white paper) and 2 November, 2009, when it was publicly released. At the time of its initial release, NVS provided all the necessary capabilities to aggregate, display and serve near real-time coastal, estuarine, oceanographic and meteorological data, derived from a suite of assets including buoys, tide gauges, meteorological stations, and shore based coastal stations. Subsequent releases to the NVS platform included the following:

- v1.5 (March 2010): Added the capability to include several new enhancements including an improved user interface, the addition of forecast capabilities at selected asset locations, and the incorporation of glider and cruise assets into the NVS platform;
- v1.6 (May 2010): Added map image overlays derived from a suite of products including HF Radar plots, model overlays, and satellite imagery. v1.0 of NVS for iPhone smartphones was released;
- v2.0 (Aug 2010): Added the comparator capability (enabling model vs. measured time series plotting and assessment of goodness of fit), as well as model forecast overlays. v1.0 of NVS for Android smartphones was released;
- v2.5 (Mar 2011): Added a MyNANOOS account option enabling users to establish an account that would remember predefined user settings. This version resulted in the release of customized unit settings for plots and data display as well as a settings feature.
- v1.5 iPhone NVS app released (Apr 2011);
- v2.0 iPhone/Android NVS app released (Jun/Sep 2011);
- v2.6 (Nov 2011): Developed the Pacific Northwest Tsunami Evacuation Zones web application. Included tsunami evacuation zones for the PNW coast and added the capability to create user defined places, and store those in their MyNANOOS account. v1.0 of TsunamiEvac-PNW app released for iPhone/Android smartphones was released; and,
- v3.0 (scheduled for Sep/Oct 2012): Currently under development.



The NANOOS Visualization System (NVS) data explorer. Users can access information about ocean/climate conditions that range from real-time to 60-day time series.

Oregon Coast Tsunami Hazards portal[3]***:*** Many communities located in exposed, low-lying areas along the PNW coasts of Oregon, Washington, and northern California face the risk of tsunami inundation. The hazard originates from two main sources: distant tsunamis (e.g., Tōhoku, Japan) that cross the expanse of the Pacific Ocean, and local tsunamis spawned by a great subduction earthquake on the CSZ and accompanying giant tsunamis. Of these, local Cascadia tsunamis pose the greatest hazard to people living along the PNW coast.

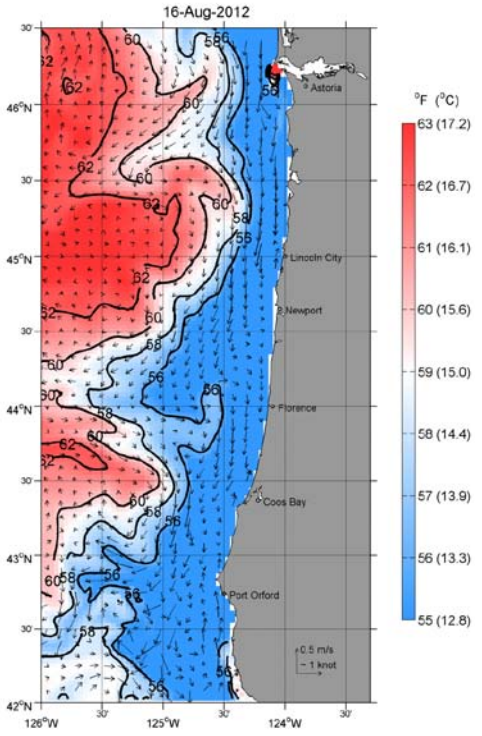
To provide easier access to the tsunami evacuation maps, a collaborative effort between NANOOS DMAC/UPC/E&O and Department of Geology and Mineral; Industries (DOGAMI) staff was initiated to begin development of an online tsunami hazards Google-map portal (***Martin et al. 2011; Allan et al. 2012; NOAA Coastal Services 2012***). This tool allows residents, planners, emergency responders, and others to visualize the extent of areas affected by both local (CSZ) and distant (outside of the immediate Pacific Northwest region) earthquakes and tsunamis. DOGAMI acquired a tsunami hazard web template originally developed by NOAA for Hawaii emergency services. Working with NANOOS DMAC, the template was modified and made operational in June 2009 to include the synthesized Oregon coast tsunami evacuation maps.

Tsunami inundation zones for Cannon Beach, Oregon, along with critical facilities, and real-time information from the West Coast Alaska Tsunami Warning Center displayed through the NVS Pacific Northwest Tsunami Evacuation Zone web application.

Coincident with the release of NVS v2.6, NANOOS released a much improved version of its original tsunami portal. The "Pacific Northwest Tsunami Evacuation Zones" web app released in November 2011, displays evacuation zones for the states of Oregon and Washington for both distant and local earthquakes and tsunamis. Importantly, the PNWTEZ provides the user with the ability to search by street address in order to determine if they are in an inundation zone, and these results may be saved to their myNANOOS account for future retrieval. In addition, the portal contains a situational awareness feature that is linked to the West Coast and Alaska Tsunami Warning Center enabling statements, advisories, watches or warnings to be displayed both verbally and graphically on the PNWTEZ portal as they occur. The portal also contains links to evacuation brochures (PDFs) developed by DOGAMI and by the Washington State Department of Natural Resources. Where available, markers identifying the locations of critical facilities (schools, police, fire, sirens etc.) are also available on the portal. Finally, the portal provides extensive links and information about preparedness, warnings, evacuation procedures, facts and tsunami travel times.

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

Tuna Fishers[4]**:** Albacore tuna is a highly migratory species. This migration typically begins in the spring and early summer in waters off Japan, continues through the late summer into inshore waters off the U.S. Pacific coast, and ends in late fall and winter in the western Pacific Ocean. The timing and geographic extent of the albacore's migration in a given year is strongly influenced by ocean conditions. Oregon and Washington's commercial and recreational fishing fleets tend to catch albacore tuna in coastal areas from July through to November, depending on the surface water temperatures (e.g. most catches occur when SST range from 16 to 18°C (60.8 to 64.4°F) and sea surface chlorophyll-a concentrations vary from 0.2 to 0.4 mg m^{-3}. To assist both recreational and commercial tuna fisheries offshore the PNW coast, NANOOS staff developed a "Tuna Fishers" web page that contains important information about ocean conditions offshore the coast. These data are used extensively today by fishermen in order to identify locations where the tuna tends to feed.



SST/Currents plot for Aug 16th, 2012 showing the abrupt front between cold and warm waters along the Oregon coast.

Mobile Applications[5]**:** Early in 2010, the NANOOS UPC/DMAC sub-working group obtained an Apple Developers License, which enabled NANOOS software engineers to create and distribute an iPhone version of NVS. The NVS iPhone application allows for the browsing of all NANOOS observing assets on an iPhone or iPod Touch; the app does not currently display overlays. The App provides easy access to the most recent data from these assets as well as a plot of the last 7 days of data.

Accompanying the release of the new PNWTEZ portal, NANOOS UPC-DMAC released a brand new mobile application (TsunamiEvac-NW v1.0) for iPhone/Android users. The TsunamiEvac-NW app provides you an at-a-glance view of where the tsunami hazard zones are along the Oregon and Washington coast, and allows users to map whether their home, work, school, etc. is located in a tsunami evacuation zone or not. To help develop plans for evacuation, TsunamiEvac-NW enables users to save their current position or points of interest via GPS or address look-up. As an important tool in preparing for a potentially catastrophic local or distant tsunami event for residents or visitors to the Pacific Northwest coast, TsunamiEvac-NW also displays the locations of places that will be of critical importance prior to, during, and following a tsunami event, including schools, bridges, assembly areas, and various local government buildings. Finally, the tool provides real-time access to the most current tsunami warning bulletins that may be issued from the West Coast and Alaska Tsunami Warning Center.

[4] http://www.nanoos.org/data/products/tuna_fishers/tuna_fishers.php
[5] http://www.nanoos.org/mobile_apps/index.php

NANOOS Education and Outreach Committee (EOC):
Over the course of the four years of this grant, NANOOS Education and Outreach (E&O) personnel capabilities have grown considerably. Throughout this time period NANOOS has had an active E&O committee. The committee has grown to include representatives from OR and WA Sea Grants, South Slough and Padilla Bay NERRs, the two NSF-funded Centers for Ocean Science Education Excellence (COSEEs) in the Northwest - COSEE Pacific Partnerships (COSEE PP) and COSEE Ocean Learning Communities (COSEE OLC), CMOP, Olympic Coast National Marine Sanctuary, Ocean Inquiry Project, Hood Canal Salmon Enhancement Group, OSU COAS and APL-UW. Mike Kosro (OSU) chaired the E&O committee since its inception through the majority of this grant period until June of 2010. At that time, Kosro stepped down and the committee voted Nancee Hunter, Education Specialist for Oregon Sea Grant, as the new committee Chair.

In mid-October of 2007 Amy Sprenger (M.Ed.) began working at APL-UW part-time as a NANOOS Education and Outreach Specialist. In 2008/2009 Sarah Mikulak, a graduate student at OSU, was supported in her research through NANOOS funds, and in early 2010 joined APL-UW full-time as an Informal Education Specialist based in Portland, Oregon. The NANOOS EOC has held regular conference calls on a monthly to bi-monthly basis and EOC members have been active participants in the NANOOS tri-committee meetings in all the years of this award. Sprenger, Mikulak, or Newton presented on NANOOS EOC efforts to each of the NANOOS Governing Council meetings in 2008 through 2012.

In terms of national collaboration with the other RAs, Sprenger and Mikulak have been active members of the NFRA Education and Outreach Committee since its inception in 2008 and have supported NFRA EOC and IOOS E&O efforts including partnering with NFRA EOC members to present at national meetings and collaborating on a NFRA EOC grant submission.

Summary of Education Accomplishments: NANOOS education efforts focus on promoting ocean literacy for both for formal K-12 and informal education providers and audiences. We worked with multiple partners including NANOOS members to provide content and resources for educators to use information about and coming from ocean observing systems in the northwest to promote understanding of the ocean and regional ocean issues.

K-12 education: Over the duration of this grant, NANOOS reached over 250 educators through direct presentations and several hundred more through networking, tabling, and exhibit opportunities. Presentations to teachers focused on providing information on ocean observing systems, the technology used to acquire ocean observing data, and examples of research and ocean processes which ocean observing helps us understand. We also demonstrated how to access to data as well as examples and demonstrations on how ocean observing data could be brought into classroom activities. The majority of the contact with teachers was through presentations at national, regional and local conferences for educators. Nationally, NANOOS partnered with the other RAs to present on ocean observing system resources for educators at the 2009, 2010, and 2012 National Marine Educators Association annual conferences. Regionally, the Northwest Aquatic and Marine Educators (NAME), a NANOOS member, held annual summer conferences at which NANOOS was a featured presenter 2008 through 2012. More locally focused presentations on bringing ocean data into the classroom were presented at

Oregon and Washington Science Teachers Association meetings, Hatfield Marine Science Center teacher workshops, and Environmental Education Association of Washington and the Puget Sound based Storming the Sound educator events.

In order to provide educators opportunities to gain familiarity and direct experience obtaining and using ocean data and data products themselves, NANOOS and NANOOS member Ocean Inquiry Project (OIP), a marine science education non-profit in Puget Sound, teamed up with two other education programs, Edmonds Community College's Learn and Serve Anthropology Field School (LEAF) and Service, Education and Adventure (SEA) to engage teachers in collecting and using ocean data to support authentic learning about the ocean. Through funding from the NOAA Bay Watershed Education and Training program (NOAA BWET), 4 weekend-long teacher workshops were provided to classroom teachers in communities throughout Puget Sound. The workshops focused on helping teachers bring meaningful watershed educational experiences into their classrooms and included a day-long research/education cruise on marine waters.

Over the course of the four years, the NANOOS Education area of the NANOOS web-portal was greatly improved to provide ocean observing curriculum pieces for classroom educators to modify and use for their own classrooms. The lesson plans include introductory activities to help students learn about ocean observing, simple data explorations to help students learn to interact with the NANOOS web portal to acquire data, and more involved activities for students to develop their own questions about water conditions and to use data available via the NANOOS web portal to answer these. Most of these lessons have been demonstrated to educators during the various presentations completed over the course of these four years of the grant period. In addition, a resource guide for educators on using real time data was adapted by the NFRA education committee, including Sprenger, and is available via the NANOOS web portal as are many other links to resources to help educators incorporate authentic ocean data into their classrooms.

Informal education: Over the duration of this grant, NANOOS supported the development and installation of an interactive computer exhibit featuring regional ocean observing data and the prototype and partial development of a second exhibit still in progress. Together with NANOOS members WET Labs, Inc and Oregon State University (OSU), NANOOS supported an OSU graduate student, Sarah Mikulak, who developed an interactive exhibit for OSU's Hatfield Marine Science Center (HMSC) using water quality data collected in the neighboring estuary. The exhibit is now available at HMSC and online on the NANOOS Portal (http://nanoos.org/education/learning_tools/lobo/lobo_exhibit.php), and the design and lessons learned from this exhibit are being utilized in another exhibit that is under development for the Port Townsend Marine Science Center in Washington.

NANOOS has also pursued avenues to support the inclusion of citizen science data into its NANOOS Visualization System (NVS). In partnership with the Washington and Oregon Sea Grants, NANOOS applied for a NOAA Environmental Literacy Grant in Informal Education to develop its capabilities for citizen science data. Though the grant was not awarded, the reviews were very encouraging and NANOOS is continuing to look for ways and funds to be able to accommodate this need on behalf of citizen science, volunteer, education and smaller-scale observing programs in this region.

NANOOS education efforts have also included Newton's efforts with the Northwest Indian College, leveraged from CMOP and UW College of the Environment. The importance of place-based and hands on education using real-time data streams has found success and was the topic of a presentation/paper presented at IEEE/MTS 2011. From January through May, 2012 Martin was on the Steering Committee for the Seattle Science Festival and conveyed the need for ocean observing science and operations to be included in this event that coincided with the 50th Anniversary of the Seattle Science Center and the 150th Anniversary of the University of Washington. The importance of understanding the ocean was made prominent in this month-long event in June, which featured presentations staffed by Newton and Sprenger.

Summary of Outreach Accomplishments: NANOOS reached out to a variety of audiences over the span of this project period. Groups in particular that NANOOS engaged with included fishers, shellfish growers, scientists, and re-source managers.

Efforts to reach out to fishers resulted in over 600 fishers attending NANOOS presentations or having conversations with NANOOS staff. Two major annual events that NANOOS attends and presents at is the Oregon Sea Grant hosted Scientists and Fishermen's Exchange (SAFE), and the Salty Dog Convention/Saltwater Sportsmen's Show. The result of these interactions is a tailored data product page for tuna fishers on the NANOOS Portal, as well as tailored plots on the NANOOS Mobile Phone App.

NANOOS worked to meet the needs of shellfish growers primarily through supporting and promoting the NANOOS-NERRS Pilot Project that provides real-time data for shellfish growers. This project started before this grant period, but continued to grow during the grant period. NANOOS interacted with shellfish growers at many nationally and regionally focused events, including a Washington Sea Grant Shellfish Growers Meeting, and the annual Pacific Coast Shellfish Growers Association meeting. These efforts resulted in the inclusion of real-time data from tribal and industry shellfish grower operations into the NANOOS Visualization System. This collaboration was highlighted at the National Shellfisheries Meeting that was held in Seattle in March 2012, featuring a talk by Newton and a shared IOOS RA table by NANOOS, CeNCOOS, SCCOOS and AOOS that attracted many conference goers from all coasts.

Outreach to scientists and to resource managers has been on-going throughout the grant period. The NANOOS E&O staff have held informational exhibit booths at many nationally, regionally, and locally focused meetings and events that are widely attended by scientists and managers. In addition, NANOOS PIs, committee members, and members of NANOOS member organizations have, at various conferences, meetings, and publications, presented and published their work they completed as part of NANOOS or utilizing NANOOS data, as has been recorded in our Progress Reports over the project period.

Another more recent group that NANOOS has been targeting is coastal residents concerning tsunami hazards. NANOOS released the updated Tsunami Evacuation Zone Portal (http://nanoos.org/nvs/nvs.php?section=NVS-Products-Tsunamis-Evacuation) web app and newly created Apple and Android smartphone apps in 11/2011. The release of these web and mobile apps were widely announced to the public through a joint press release with the Oregon Department of Geology and Mineral Industries and the Washington Department of Natural

Resources (http://nanoos.org/documents/key/nanoos_tsunami_press_release_final_20_mar.pdf). To assist with understanding how to use the web app, Mikulak created a 4-part video tutorial (http://www.youtube.com/playlist?list=PL324845DBA5FBBFC8).

NANOOS has continued to engage local and regional press with major announcements, three of which are detailed here. In July 2010, NANOOS held a press conference in Seattle, WA announcing the deployment of the new Cha'ba buoy off the coast at La Push, WA. Cha'ba, its profiling buoy NEMO, and the associated glider were built from Murdock Charitable Trust and UW match funds, to be sustained by NANOOS. The event drew Congressman Norm Dicks, UW College of the Environment Dean Lisa Graumlich, IOOS Program Office Deputy Director Suzanne Skelley, NOAA PMEL Senior Scientists Richard Feely and Chris Sabine, and Quileute Tribal Chairwoman Anna Rose Counsel-Geyer, who dedicated the buoy name Cha'ba, meaning "whale tail." There was considerable media coverage of the event. In March 2012, NANOOS released the joint press release mentioned above. This resulted in great coverage in local and regional newspapers as well as a couple radio interviews. Following the release on 20 March 2012, NANOOS tsunami portal web hits went from 39 to 1352 on 3/20, then 887 on 3/21. Web URL links expanded from 5 external links to 23, including MSNBC. Lastly, in April 2012 on Earth Day, Newton was invited to participate in a press conference hosted by Sen. Maria Cantwell in Seattle, WA about Cantwell's on-going support of the shellfish growing industry and ocean acidification monitoring. Cantwell led a letter with 11 other Senators urging the Senate to restore support for ocean acidification monitoring programs. After Cantwell's letter, a subcommittee voted to increase rather than cut support for the NOAA Regional Integrated Ocean Observing Systems (IOOS), which operate acidification monitoring buoys. Cantwell's visit was to help continue federal support for IOOS and ocean acidification programs.

III. Scope of work – We made no changes to our statement of work for this effort.

IV. Leadership personnel – No major changes were made during the project period.

V. Budget analysis – The remaining balance on this award is $2,731, which shall be de-obligated. The project period is complete and expenditures matched our budget request 99.8%.

References Cited:
(NOTE: Numerous publications and presentations from this effort have been recorded in our Progress Reports for this award. Below are only those that were cited within the text of this Final Report.)

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NOAA Coastal Services, Accessing information on tsunami zones in Oregon and Washington to help residents better prepare, in Coastal Services, v15(3), 2012, p. 6-7, and 11.

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