Sustaining the NANOOS Regional Coastal Ocean Observing Systems (RCOOS)

A proposal to the Nation Ocean Service, National Oceanic and Atmospheric Administration,
FY2010 Integrated Ocean Observing System Implementation
NOAA-NOS-IOOS-2010-2001799

Type of Funding: Cooperative Agreement

Recipient Institution: The University of Washington will serve as the funding administrator.

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Funding Requested:	$2,975,000	For partners via University of Washington
	$25,000	For NOAA National Marine Fisheries Science Center
	$3,000,000	Total Funding

Period of Performance: 1 October 2010 to 30 September 2011

Partnering Organizations:

Partner	Lead Investigator	Funding
UW, Applied Physics Laboratory	D. Martin	$1,062,448
UW, School of Oceanography	A. Devol	$87,552
Oregon State University	M. Kosro	$905,000
Oregon Health and Sciences University	A. Baptista	$380,000
The Boeing Company	S. Uczekaj	$200,000
WA Dept of Ecology (Shoreline)	G. Kaminsky	$100,000
WA Dept of Ecology (Marine water)	C. Maloy	$50,000
Oregon Department of State Lands	S. Rumrill	$50,000
OR Dept. of Geology & Mineral Industries	J. Allan	$90,000
Cooperative Institute for Marine Resources Study	W. Peterson	$50,000
NOAA Marine Fisheries Science Center	V. Trainer	$25,000

Please reference our proposal number _A53966_ on all correspondence concerning this proposal.

2. PROJECT SUMMARY

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Project Summary

The Governing Council of the Northwest Association of Networked Ocean Observing Systems (NANOOS), on behalf of its members, submits this proposal to sustain and enhance, pending funding level, our Regional Coastal Ocean Observing System (RCOOS). Established in 2003, NANOOS has used results of nearly three year's NOAA-funded planning efforts and ongoing regional contributions to build regional association partnerships in the Pacific Northwest (PNW) and to identify high priority user needs and requirements. Through NOAA IOOS funds, we have sustained a robust RCOOS that partially addresses these needs on flat-level funding for three years. We propose here the minimum amount needed to sustain the basics of this RCOOS as well as critical enhancements that would further develop the NANOOS RCOOS. This PNW managed and operated RCOOS that is closely integrated with the National system has already provided societal benefits across a wide spectrum of users including federal, state, tribal and local governments, marine industries, scientific researchers, non governmental organizations, educators and the general public. NANOOS members identified their priority areas for product development within this end-to-end RCOOS to be maritime operations, fisheries, ecosystem impacts, and coastal hazards. The NANOOS RCOOS we need to sustain includes its essential subcomponents: Observing System; Modeling and Analysis; Data Management and Communications; and Education and Outreach. As with our submission in 2007, this is the singular RCOOS proposal submission for the PNW region and represents the cumulative, collaborative consensus of stakeholders from the region. NANOOS has produced this proposal through its established governance structure, a Governing Council composed of representatives from all NANOOS members and an Executive Committee of officers and standing committee chairs.

Partners

Partnering is strong within NANOOS. As detailed in the text, the proposed efforts will be conducted in partnership by NANOOS membership organizations (*proposal partners: University of Washington; Oregon State University; Oregon Health & Science University, including the National Science Foundation's Science and Technology Center for Coastal Margin Observation and Prediction; The Boeing Company; Oregon Department of Geology and Mineral Industries; Oregon Department State Lands; Washington Department of Ecology; NOAA Northwest Fishery Science Center; and NOAA-OSU Cooperative Institute for Marine Resources Studies)*. Beyond the immediate PIs, NANOOS membership, the guiding body for this work, currently is at 44 members (for list, see http://www.nanoos.org/about_nanoos/members.php), composed of academic and research institutions (9), tribal governments and tribal organizations (4), state and local governments (12), industries (7), and non-governmental organizations (12). All NANOOS members have signed the NANOOS MOA and participate in its Governing Council, which has approved this proposal for submission. Additional partners in this work include *the Olympic Region Harmful Algal Bloom (ORHAB) collective, USGS, and the Padilla Bay and South Slough National Estuarine Research Reserves (NERRS).*

3. PROJECT DESCRIPTION

A. Goals and Objectives

i. Goal: To sustain and, depending on funding, enhance NANOOS - the Regional Coastal Ocean Observing System (RCOOS) for the Pacific Northwest (PNW). With NOAA IOOS funding, over the last 3 years NANOOS has developed, implemented, and integrated in-water and land-based systems, data management and communications, analyses and products, and education and outreach subsystems that together can provide diverse stakeholders with the ocean data, tools, and knowledge needed to make decisions. We remain focused on delivering products and services that are easy to use to address high-priority issues. The goals are developed and refined via proactive NANOOS interactions with a wide range of PNW stakeholders.

ii. Objectives: NANOOS identified eight initial objectives for the RCOOS. Budgetary levels were reduced, but we retained seven, with revisions (below), which we have been meeting to date. We propose to sustain these seven objectives in this proposal (Year 4) and have added two to guide our future build-out direction and focus:

1) **Maintain surface current mapping capability.** A fundamental foundation block for the coastal ocean observing system serving divers users spanning maritime operations to ecosystems and fisheries.
2) **Sustain buoys and gliders in the PNW coastal ocean, in coordination with national programs.** These assets give advance information on hypoxia/anoxia, ocean acidification, and HABs.
3) **Maintain observation capabilities in PNW estuaries.** These address sustainable use and management.
4) **Maintain core elements of beach and shoreline observing programs.** This helps hazard mitigation by providing better decision support tools for coastal managers, planners and engineers.
5) **Sustain a system of numerical models of PNW circulation.** This covers from the head of tide of estuaries to the outer edges of the EEZ. Modeling tools support users, e.g., marine operators, first responders, and environmental managers.
6) **Maintain NANOOS' Data Management and Communications (DMAC) system for routine operational distribution of data and information.** This dynamic distributed system of systems supports users' needs and allows free access to the IOOS backbone and national information infrastructure.

7) **Sustain and strengthen NANOOS education and outreach efforts.** This work fosters ocean literacy and use of NANOOS products.

8) *(new)* **Make selected improvements to RCOOS, anticipating possible enhanced funding.** NANOOS has identified priority areas of enhancement in all of the sub-systems of the RCOOS and a modular plan.

9) *(new)* **Quantitatively evaluate assets, products and efforts of the RCOOS, in light of stakeholder input and evaluations, to assess payoffs and see where improvements and/or re-direction are needed.** This will allow NANOOS to plan for the 3 years (FY 2011-13) following this proposal.

This project meets regional priorities, and fully supports the national IOOS agenda through strong external ties with other regional and national programs, e.g., by ensuring that the tools, techniques, and knowledge we develop are expressly exportable to others.

B. Background

PNW waters are critically important to the societal and ecological health of the region. They modify and moderate regional weather, serve as highways for marine commerce involving the entire Pacific Rim, are part of an oceanic buffer for the Nation's national security, are a reservoir for natural resources, serve as a natural laboratory, and provide exceptional recreational opportunities.

NANOOS engaged representatives from a diverse set of stakeholders who are directly involved in the definition and execution of NANOOS' RCOOS, from providing observing assets (App. 1.A) to governance. Stakeholders are deeply involved in NANOOS governance, guided by its formal NANOOS MOA, Conceptual Design (App. 1.B) and Business Plan. The NANOOS Governing Council membership has grown from over 25 in 2007 to over 40 today and is diverse: 27% local, state, and federal government, 10% tribes and tribal organizations, 27% NGO/education organizations, 16% industry, and 20% academic institutions. NANOOS has an Executive Committee of nine elected Officers and operational standing committee Chairs.

NANOOS also has close involvement with British Columbia (e.g., Canadian VENUS project is a Council member) and is well-integrated with regional systems in AK (AOOS) and CA (CeNCOOS, SCCOOS), and PaCOOS (aka ACCEO). NANOOS also participates in US IOOS and the National Federation of Regional Associations (NFRA).

The physical, ecological and societal aspects of the region that guided NANOOS's development have been described and referenced elsewhere (NANOOS RCOOS Y1-3 proposal: http://www.nanoos.org/about_nanoos/documents.php). A key developmental factor has been an equitable focus on coastal ocean, estuarine, and shoreline observations and product development. Stakeholders have appreciated this balance and explicitly view this as one of our strengths. To build the NANOOS RCOOS, we integrated regional scientists, agencies, and other entities who maintain coastal ocean observing assets (App. 1.A). Data and data products from these assets are currently available through the NANOOS website (http://www.nanoos.org).

C. Audience

We continue our specific focus on high-priority, PNW stakeholder-defined applications: a) maritime operations; b) ecosystem impacts including hypoxia, ocean acidification, and HABs; c) fisheries; and, d) mitigation of coastal hazards. We identified in our Y1-3 RCOOS proposal our targeted audience: subsets of the PNW user communities that stand to benefit from RCOOS products in the above four areas. This reflected several years of NANOOS effort to directly engage the diverse range of PNW stakeholders as we built an understanding of their user needs and requirements. We have made significant strides in each area:

<u>**i. Maritime Operations**</u>: **Currently, NANOOS offers forecasts and observations of interest and utility to this audience for safety and planning.** <u>Audience</u>: Many commercial Port Authority Offices in Puget Sound and on the Columbia River, and along the coast, pilotage services, the Vessel Traffic System, and the USCG District 13. **NANOOS members engaged in this area include** the Maritime Exchange of Puget Sound, the Ports of Newport, OR and Neah Bay, WA, Council of American Master Mariners, and the Puget Sound Harbor Safety Committee.

<u>**ii. Ecosystem Impacts**</u>: **Currently, NANOOS provides observations and predictions used to evaluate HABs, hypoxia, ocean acidification, climate change, and water quality.** <u>Audience</u>: U.S. EPA Regional Offices, OR, WA and CA natural resource, environmental quality and ecology departments; Tribal governments; and local county resource divisions. **NANOOS members engaged include** the WA Dept. of Ecology, OR Dept of Land Conservation & Development, Puget Sound Partnership, Quileute Indian Tribe, Port Gamble

S'Klallam Tribe, Quinault Indian Nation, Olympic Coast National Marine Sanctuary, WETLabs, Western Assn. of Marine Labs (WAML), Seattle Aquarium, Surfrider Foundation, and The Nature Conservancy.

iii. Fisheries: **Currently, NANOOS's forecasts and data on the bio-physical environment permit better better-informed management decisions.** Audience: OR, WA and CA health and natural resource departments; Tribal governments and enterprises; Aquaculture companies, commercial and academic researchers and shellfish trade associations. **NANOOS Members engaged in this area are** the NOAA NWFSC, Quileute Tribe, NW Indian Fisheries Com., Port Gamble S'Klallam Tribe, Quinault Nation, WA Dept of Fish and Wildlife, OR Dept of Fish and Wildlife, Hood Canal Salmon Enhancement Group, PNW Salmon Center, Pacific Ocean Shelf Tracking Project, Columbia River Crab Fisherman's Association, and the Puget Sound Partnership.

iv. Mitigation of Coastal Hazards: **Currently, NANOOS provides observations and analysis of beach profiles and waves to coastal managers to improve planning and response.** Audience: WA and OR natural resource departments, USACE, USGS, local government planners, geotechnical engineers, shipping interests and the public-at-large. **NANOOS Members engaged include** the OR Dept of Geology and Mineral Industries, the WA Dept of Ecology, OR Dept State Lands, and Northwest Research Associates.

D. Approach

We address the four PNW application areas and directly respond to the objectives listed in section A. We advance three levels of work and funding: maintaining core capability (A) and two levels of enhancement (B and C). Level A will support only essential existing observing assets in the water, operations, and their data delivery. For B, we will add spare operational supplies and equipment, relieve system support personnel that are over-stretched, and increase our product and analysis capabilities. For C, we will add additional capabilities, seeking to enhance product development and delivery in areas of high stakeholder interest. **With this modular plan (App. 4), NANOOS can meet its objective to strategically nourish improvements, if funding exists.**

i. Observing system subcomponent: We propose to sustain observing assets within our four observational domains the coastal ocean surface currents, coastal ocean shelf, estuaries, and shorelines (App. 1.B).

Coastal ocean surface currents: Our objective is to **maintain existing surface current mapping capability.** Surface currents are fundamental ocean data, serving many (most) users.

WA-OR-CA coast HF assets: Time-series mapping of near-surface ocean currents is being conducted full-time, across all seasons, continuously along 500 km of coastline in northern CA, OR, and southern WA, using an array of eleven SeaSonde HF surface-current mappers, by M Kosro's group at OSU. This system is fully integrated into the national HF array (www.ioos.gov/hfradar) per the National Surface Current Mapping Plan. Instrument ranges are up to 180 km for the six long-range systems (4-5 MHz) and 40-50 km for the five standard-range systems (12-14 MHz), with range bins of 6 km and 2 km respectively, and angular bins of 5 degrees in azimuth. Data are logged at each field site, returned electronically, QC'ed, archived, mapped, and analyzed at the OSU processing center. They are also provided to the national IOOS servers in near-real time. Daily average fields of surface currents are published to the web, both as maps and columnar ASCII data at 3 scales, through http://www.nanoos.org. These data apply to marine navigation and safety (vessel routing, search and rescue), trajectory estimation (oil-spill, HABs), detection/of interannual variability (e.g. "subarctic invasion" of 2002, response to ENSO), as well as providing measurements for model validation and data assimilation.

This component works closely with the user-products, DMAC, and education/outreach efforts of NANOOS. Increasingly operational use of these observations in marine navigation, search-and-rescue, HABs, and data-assimilating models, means that IOOS must lead in funding ongoing operations and maintenance.

Level A supports a technician to maintain data acquisition, processing and delivery from all operating systems, but cannot sustain an instrument technician for on-site repairs. At Levels B and C the instrument technician is supported, increasing reliability of data delivery. That would bring us closer to (but still below) the personnel levels recommended in the National Plan.

Port HF asset: We have deployed a real-time X-band wave radar for short-term marine wave forecasting at Newport, OR. This developing NANOOS product will contribute to marine safety for many coastal user groups including the commercial fishing industry, the port industry, and recreational boaters. Level A will maintain data acquisition (barring equipment failure). Basic wave field image products and wave frequency observations will continue in real-time. Most effort at Level A must focus on maintaining operational capabilities.

At Level B, we will replace the five-year-old data acquisition computer and update the operating system. We will also better synchronize the data stream with in-situ sensors. At Level C, we will add real-time wave-modeling capability. A SWAN spectral-wave real-time wave modeling component for the Newport site will be added. We expect our SWAN model system to be of local scale (~30-50 km alongshore domain) and to simulate waves across the shelf and at high-resolution around the entrance to Yaquina Bay. The model would be verified against in-situ wave data, coupled with real-time wave radar observations. Coastal currents, especially near the bay entrance, can be used as added input when available. M. Haller (OSU) will lead this effort and integrate the data into a local wave forecasting model.

Coastal ocean shelf: Our objective is to **sustain buoys and gliders and strategically expand coverage in coordination with emerging national programs.** We target these assets to provide advance information on hypoxia/anoxia, ocean acidification, and HABs, which are major regional concerns affecting ecosystem and human health, fisheries, and coastal economies. We will support two offshore buoys, one in OR waters and one in WA waters. We propose to sustain cross-margin autonomous underwater vehicle glider lines. The moorings and gliders will measure T, S, pressure, chlorophyll, suspended particle load, dissolved oxygen and nitrate. Surface moorings will measure standard meteorological parameters (wind, radiation, air temperature, etc.).

Newport, OR buoy: Here we have moored time-series measurements, continuously since 1998, at mid-shelf (44° 37.9'N, 124° 18.2'W, 10 nm offshore, 80 m depth); hydrographic measurements have been made along this transect since the 1960s. This long time series helps resolve interannual variability and provides a context for interpreting new observations. The mooring has had NANOOS funding since Nov 07; it is station 46094 per National Data Buoy Center, and it appears on their website. It measures meteorological parameters and ocean T, S, velocity, chlorophyll, light backscatter and oxygen. The sensors on a given deployment vary, because most are borrowed. Some data is transmitted to shore via cellular phone modem in near-real time and becomes part of the NANOOS data stream posted on the web (http://www.nanoos.org/data/products/buoy_NH-10/buoy_NH-10.php). We will increase the number of sensors that can be added to real-time acquisition as funds permit.

Mooring recovery and deployment (2x/yr) requires a medium-sized UNOLS vessel for a minimum of 1 day; ship time is NOT included in this proposal and will be obtained from the NSF-funded STC for Coastal Margin Observation and Prediction (CMOP), a NANOOS partner, directed by OHSU. At Level A we will maintain the mooring. Levels B, C allow replacement of damaged instruments, and an increased suite of bio-geochemical sensors. Instruments on the mooring have been provided at no cost to IOOS. M. Levine (OSU) is the lead for this Newport OR buoy.

Newport, OR glider: Water-column hydrographic, velocity, bio-optical and oxygen data will be collected along the Newport Hydrographic Line (44 39.1N) to track seasonal development of coastal upwelling and hypoxia, and provided to numerical circulation and ecosystem models. At Level A we will continue sampling along the Newport Line with a glider to measure T, S, chlorophyll, light backscatter, colored dissolved organic matter (CDOM) and oxygen. Data are sent to shore and become part of the NANOOS data stream. NANOOS will fund deploying the glider for three months, Mar-May, to capture the spring transition. Levels B, C allow Mar-June deployments with better support. J. Barth and K. Shearman (OSU) lead this work.

La Push, WA buoy and glider: The WA coast enhanced moored observatory has a surface mooring, a sub-surface profiling mooring, and a Seaglider AUV. This network documents temporal and spatial oceanic variability. The surface mooring will have both surface meteorological instruments (for air-sea fluxes) and sub-surface oceanographic instruments at fixed depths to measure water properties (T, S, density, velocity, oxygen, nitrate, etc.) at high time resolution (<10 min). The surface mooring will have an Iridium modem for sending meteorological and oceanographic data to shore. This effort will be led by M. Alford (UW).

The sub-surface profiling mooring (~400 m from the surface mooring), will have a buoyancy-driven profiler (SeaTramp) for water column profiles of properties like those measured on the surface mooring, but at a much higher vertical resolution (~1 m) but lower time resolution (~1-2 hours). Seaglider will make transects near the moorings to provide spatial coverage to be integrated with the mooring time series to provide a clearer picture of the structure and time-evolution of the coastal ocean.

Level A funding will maintain and operate the moorings and allow for two maintenance/turnaround cruises necessary to change batteries and clean up bio-fouling. It will permit reduced-interval/data to be telemetered to shore (~250 kb per day). Level B will enable more data telemetry (~500 kb/day) and a more realistic budget for repair, calibration and maintenance.

For Seaglider, Level A allows one 4-month deployment chosen to optimize its lateral spatial information, not the desired continuous deployment. Level B allows two 4-month deployments. Level C, year-round.

Coast-wide coordination: The two moorings will both be at 80m to aid comparisons and for uniformity. Shelf observing assets will provide timely information about the severity and extent of recurring summertime hypoxia, ocean acidification, and HAB dynamics, and potentially predict PNW-wide ocean ecology impacts. Coordination will be specifically addressed by UW (M. Alford) and OSU (J. Barth/K. Shearman).

Relationship to NSF's Ocean Observatory Initiative (OOI) Program: NANOOS collaborates closely with the offshore observing plans and capabilities of the NSF OOI PNW observatory elements, as they are coming on line. The NANOOS buoys at La Push and Newport complement the OOI assets planned for Grays Harbor and help maximize spatial coverage of important oceanographic features and major ocean user focus areas.

Relationship to NSF's Center for Coastal Margin Observation and Prediction: CMOP maintains a far-field plume mooring (OGI01; physical sensors; NANOOS funding) at 100m just south of the Columbia River on the OR shelf, a near-field plume mooring (SATURN-02; NSF funding) at 30m just south of the Columbia River on the OR shelf, and a Slocum glider ("Phoebe"; NSF funding) on the WA shelf, which will sample (at least seasonally, possibly year-round) in a radiator pattern between Grays Harbor and Quinault. The glider is operated in coordination with the Quinault Indian Nation, a NANOOS member, which has had input on the sampling pattern, and provides logistical support for deployment and recovery.

<u>Estuaries</u>: Our objective is to **maintain observation capabilities in PNW estuaries.** We will sustain our federated real-time observation network across OR and WA estuaries, with assets prioritized against various societal needs including ecosystem assessment and management, maritime operations, fisheries, marine spatial planning and climate change. Large observation networks are maintained at the two PNW estuaries with largest economic and ecological footprints (Columbia River and Puget Sound). Smaller networks in Willapa Bay and the South Slough/Coos Bay provide geographic breadth and diversity and locally needed information.

Both the Columbia River and Puget Sound observation networks manage complex real-time observatories, set regional examples, and export technology and standards. Both will have lead responsibility in setting the NANOOS standard for "operational" maintenance and data quality control of estuarine observatories. Both observatories will seek ways to assist other observation assets in their regions, to help create replicable models of system-specific optimal coordination and integration of resources thus entraining existing sub-regional assets such as community colleges, Marine Labs (e.g. WAML, a NANOOS member), and tribal colleges (e.g., the Northwest Indian College).

Columbia River, OR and WA: Led by OHSU (A. Baptista) the multi-institutional "collaboratory", SATURN (http://www.stccmop.org/saturn) includes an extensive observation network in the Columbia River estuary, with river, plume and shelf assets. SATURN collects physical and interdisciplinary data, which are openly available (real-time & archival) and are extensively used in fisheries, navigation improvements, ecosystem restoration and hydropower management, numerical modeling and scientific exploration. NSF supports the pioneer array and the development and early-life deployment of new capabilities for the endurance observations. Regional stakeholders support the creation and/or maintenance of stations for project-specific purposes. NANOOS provides long-term support for mature endurance components – e.g., most of the purely physical endurance stations ('CORIE' sub-network). Level A supports this effort, but will not allow a temporary summer/fall staffer to prepare the stations for winter, and will thus affect reliability. We expect other SATURN elements to progressively be transferred to NANOOS support over time, as they mature beyond initial deployment and assessment.

Puget Sound, WA: Staff and resources will be managed by UW (A. Devol/ J. Newton). Puget Sound is the site of two highly leveraged programs to build and instrument profiling buoys with physical, chemical, and biological sensors. The sensor package measures a depth profile of variables every hour from the sea surface to the sea bed. Issues of concern include hypoxia (low oxygen concentrations), algal blooms, and climate effects (especially on T, S, and sunlight penetration. One ORCA has pCO2 sensor from C. Sabine (NOAA) as a pilot program; the Puget Sound Partnership, a NANOOS member, is funding another to study effects of ocean acidification on shellfish larvae viability. The buoy can add other sensors, e.g., for studying HABs, and oil spills, technologies evolve. There are now four ORCA buoys in Hood Canal, as part of the Hood Canal Dissolved Oxygen Program (http://orca.ocean.washington.edu/index.html), and one Networked Profiling Buoy, as part of a collaboration between UW and Intellicheck – Mobilisa, Inc. to outfit Puget Sound with dual-use environmental and security buoys (http://www.nanoos.org/data/products/npb/npb-1/overview.php).

Level A funding will help to sustain this buoy infrastructure, but has no contingencies for servicing sensors or for breakdowns, which are afforded in Level B. Level C provides more reliable and consistent data.

Willapa Bay, WA and South Slough/Coos Bay, OR: NANOOS will also help support observation networks in the Willapa Bay and South Slough/Coos Bay estuary clusters, which include major ecological reserves plus industries (e.g. oysters, fisheries). Level A funds will supplement existing field staff and non-personnel resources from WDOE (C. Maloy) for Willapa Bay and OR Dept of State Lands (ODSL; S. Rumrill) for the South Slough/Coos Bay. Both institutions were effective participants in the NANOOS Pilot. The latter cluster links NANOOS' estuarine network to the NOAA network of National Estuarine Research Reserves. WDOE will continue to add real-time capabilities in Willapa Bay. Enhanced funding would allow WDOE to reestablish moorings in Willapa Bay. ODSL would expand its South Slough network to include three Coos Bay stations and speed up adding real-time capabilities. Both groups will strengthen collaborations with OHSU and UW towards compatible standards and protocols in data collection and quality control.

Shorelines: Our objective is to **maintain core elements of beach and shoreline observing programs.** This work helps to improve coastal hazard mitigation through better decision support tools.

WA and OR shoreline observations: Beach and shoreline observing systems are a joint program between WDOE and USGS. Components include: geodetic control; topographic beach profiles collected quarterly at 52 locations, spaced @~2-4 km along the 165 km Columbia River littoral cell; sediment size distributions; topographic 3D beach surface maps covering ~4 km of shore and surveyed annually at 16 sites; and nearshore bathymetry to depths of 10-20 m (~1500 to 2500 m out). Beach monitoring uses GPS surveying techniques. The beach and shoreline data (now >12 years) are a valuable regional resource, providing insight into the impact of climate variability (e.g., ENSO cycles, extreme storms) on beach morphology as well as resolving seasonal to interannual beach variability and trends. Nearshore bathymetry data helps detect interannual trends in shoreface behavior and sediment budgets and are fundamental to shoreline and beach profile modeling. In 2004, the NANOOS Pilot monitoring network set up a beach observation program in the Rockaway littoral cell on the northern OR coast, later expanded. It includes: Topographic beach profiles quarterly at 46 sites ~1 km apart; datum-based shorelines relative to the local MHHW tidal datum; and beach profiles, collected biannually at 70 sites ~5-700 m apart on Central OR beaches. WDOE (G. Kaminsky), DOGAMI (J. Allan/V. McConnell), and OSU (P. Ruggiero) collaborate on this effort.

At Level A, WDOE will maintain a reduced-level beach and shoreline monitoring effort in the Columbia River littoral cell. The monitoring program will perform beach profile surveys quarterly at 46 locations in 3 sub-littoral cells in WA. Beach surface maps in these sub-littoral cells are reduced from 16 sites during both summer and winter and 3 sites during fall and spring, to only 8 sites during summer and 5 sites during winter. For OR shorelines, DOGAMI will continue the core program of collecting beach profile data along 5 littoral cells on the OR coast, but monitoring will be reduced to two surveys per year elsewhere. Annual surveys will be done in the Beverly Beach and Newport cells. Reduction to semi-annual surveys in some areas will end a 12-year time series of quarterly surveys. To address nearshore bathymetry, we will continue the core program of collecting nearshore bathymetry along 3 (sub) littoral cells in WA and 2 littoral cells in OR.

Level B funding will add 2 surface maps during fall and spring, and 7 surface maps during summer to the Columbia River cell, and initiate pilot-level observations in Puget Sound at 3 sites annually. For OR shorelines, we would monitor seasonally in established cells and add some annual surveys. DOGAMI proposes to expand the OR monitoring program to include grain-size statistics at transect sites. This will provide a spatially dense beach grain-size database, important for engineering purposes and for establishing baseline conditions for future comparisons. For nearshore bathymetry, we would expand collection of nearshore bathymetry.

At Level C, we would establish a Puget Sound observation network of >6 sites measured annually or semi-annually. For OR shorelines, a new beach monitoring effort would be implemented on the southern OR coast. We would expand nearshore bathymetry in north-central OR.

ii. Modeling and products subcomponent: Our objective is to **sustain a federated system of numerical models of PNW circulation.** Our vision requires a range of modeling tools in support of user needs.

The ultimate goal is an ability to respond 24-7 to the need for routinely integrating all forecasts of PNW circulation, to aid emergency responders and environmental managers, via a phased approach: 1. Sustain existing modeling systems; 2. Seek synergies and integration across systems; 3. Create a user-oriented multi-institutional modeling center serving the PNW forecasting needs, with NOAA and other IOOS regions.

Budgets have forced us to focus primarily on sustaining the existing modeling systems. We have, however, also initiated the transfer of one forecasting system to NOAA, and have participated in the NFRA modeling sub-group and in IOOS-wide exercises (led by R. Signell, NOAA IOOS) for modeling inter-operability.

We propose to sustain daily circulation forecasts of PNW circulation at OSU, OHSU and UW, with context and boundary conditions for the Eastern North Pacific circulation provided by NSRL forecasts. The PNW system includes: daily forecasts of circulation in the Columbia River coastal margin, from the tidal freshwater through the estuary and near plume, and (at lower resolution) into the OR and WA shelves; daily forecasts for the OR continental shelf; for Puget Sound; and for multiple small PNW estuaries.

The modeling group at OHSU (A. Baptista) will maintain multiple daily forecasts for the Columbia River (CR) river-to-shelf circulation, within SATURN. The vision is of a "virtual CR coastal margin", with near real-time capability plus long-term databases to characterize variability, and simulations to analyze the effects of human activity, climate change and coastal subsidence. Simulations are highly resolved, and model skill is evaluated against SATURN observations and cruise data. The effort leverages funding of the NSF's CMOP, and of fisheries-, navigation-, hydropower-, and ecosystem restoration-oriented projects requested by regional stakeholders. The CR daily forecasts are being transferred to NOAA, with 24/7 support at NOAA (starting 2010) plus continued parallel development at OHSU. This will help upgrade NOAA's capabilities.

Daily forecasts are also done at OHSU for most of the estuaries in OR and WA (Puget Sound excluded) but their resolution is lower, and skill assessment heavily constrained, due to scarcity of observational data. This forecasting will be sustained: any improvements will require regional stakeholder funding.

The UW modeling group (D. Jones) will sustain the Puget Sound Princeton Ocean Model (PS-POM) in an operational 24/7 mode. The PS-POM data are provided to the NANOOS user community in several formats e.g., via an OpenDap server and Google Earth overlays. PS-POM will be evaluated against observations from the Puget Sound region. NANOOS will support the development of an enhanced Puget Sound/WA coast model "Salish Sea ROMS" by providing data sets for model validation, and will also study the operational potential of the model, which will have much greater resolution and accuracy but also greater computational requirements. We will help build the ability to do quantitative and visual comparisons between data and multiple models, for both hindcasts and nowcasts. Eventually, this capability will be available through the web to non-specialists, but for the next two years, the UW modeling team will focus on backend tools that let NANOOS scientists and staff respond quickly and flexibly to requests for model output and inter-comparison of model products.

The OSU modeling group (A. Kurapov) will continue to support and develop a pilot real-time modeling system, providing daily 3-day forecasts of SSH, currents, and hydrographic variables on the OR shelf and in the coastal transition zone (http://www.nanoos.org/data/products/oregon_coastal_ocean_simulator/oregon_coastal_ocean_simulator.php). This system has run quasi-operationally since June 05. The model is forced with outputs from the operational NOAA-NAM forecasts. Boundary conditions have been obtained from the 9-km resolution real-time forecast Navy Coastal Model of the CA Current System (NCOM-CCS, I. Shulman et al., NRL).

Model output is available via a Thredds server using OpenDAP protocols (in collaboration with R. Signell). Users of forecasted SST include local fishermen (200 unique web hits/week during tuna season). We have also responded to EPA's requests about SST forecasts and to NOAA-HAZMAT for surface velocity fields.

With Level A funds, we will continue development of the data assimilation component of our prediction system, based on tangent linear and adjoint components compatible with the nonlinear ROMS model, and the variational representer-based algorithm. We will follow up our current work assimilating satellite altimetry and HF radar currents with assimilation of GOES SST composites and glider hydrographic section observations. We plan a real-time demonstration case to assess issues specific to real-time predictions.

We will run routine day-to-day data assimilation in the real-time forecast model, and develop a larger scale regional model which will use SSH altimetry, SST, and ARGO float profiles. Using tests for recent years, we will assess whether this regional model can represent climate variability better than NCOM-CCS. The coastal ocean forecast model will be nested to obtain boundary conditions from the regional model. Funding-dependent, we will run the best and most stable version of the assimilating coastal ocean forecast system in real time, 24-7, and will continue to collaborate with NANOOS-DMAC to disseminate results to the public.

To enable real-time data assimilation in a rapidly changing coastal ocean, using observational sets of quality and coverage that vary from day to day, enhanced funds for skilled personnel are required. Funding at Level C is needed to fully meet the needs for daily data assimilation and quality control.

Model synthesis: In addition, with Level C funding, the NANOOS modeling team would address issues of integration and quality control. Specifically, OHSU would organize a hands-on multi-day workshop with broad multi-institutional representation. The aims would be: (a) refine the vision for an integrated NANOOS regional modeling system for the next decade; (b) define multi-scale benchmarks to measure performance and skill; (c) map the vision against existing elements, and identify strengths and weaknesses; (d) learn from the experience of other regional associations; and (e) make recommendations to the NANOOS ExComm for scientific and operational requirements for future modeling.

iii. DMAC subcomponent: Our objective is to **maintain NANOOS' Data Management and Communications (DMAC) system for routine operational distribution of data and information.** NANOOS DMAC has developed as a collaborative, dynamic distributed system of systems. It provides a wide range of products, tools and services to regional and local user communities while allowing unfettered access to the IOOS national backbone and national information infrastructure. NANOOS DMAC complies with IOOS data standards for data exchange and service, and will so continue going forward.

Our DMAC's architecture supports observing, processing, archiving and disseminating data under a set of IOOS interoperability standards. Available DMAC data resides at UW, OHSU, and OSU. These installations are run on a best effort basis. Currently no national guidelines exist to define maturity and service levels for such data centers. DMAC will work with IOOS to define service and maturity levels for DAC instillations.

NANOOS users want real time data, value-added products, sustained information, and global interoperability. Therefore NANOOS will continue to emphasize creation of standard products that are interoperable and sustainable over the long term. Access to the standard product suite includes metadata-driven query and browse interfaces, dynamic 2D plots for scattered observations, and interactive mapping for geo-referenced GIS layers.

NANOOS has made considerable progress in the development of its web interface and the many products it now serves. We continue to develop, improve and enhance our existing suite of products, via our User

Products Committee, and to develop new protocols and procedures for accessing and querying the data.

A key focus has been to develop a web mapping portal, the NANOOS Visualization System (NVS), that aggregates, displays and serves near real-time coastal, estuarine, oceanographic and meteorological data, derived from buoys, gliders, tide gauges, HF Radar, meteorological stations, satellites and shore based coastal stations, as well as oceanographic cruise data and model forecast information. It presents output to end users as a rich and informative experience (App. 1.C). NVS Version 1.0, going public on Nov. 01, 2009, will let users query multiple assets and generate 24h, 7- and 30-day plots of oceanographic and meteorological parameters.

Critical to the success of the NVS and other derivative products is enabling the seamless delivery of coastal, estuarine and ocean data to any and all users. The DMAC architecture that underpins the NVS (and other products) meets four primary requirements: 1) interoperability with national-scale applications, 2) reliable, efficient ingestion of data from observational assets, 3) access to models, application tools and information products, and 4) rich yet simple interfaces enabling unaided, routine decision making by end-users. DMAC will continue to extend NVS to meet the needs of our stakeholders as well as the IOOS national effort.

NANOOS has made fine progress on its web interface and many other products. We will continue to develop, improve and enhance existing products, and to develop new protocols and procedures for accessing and querying the data. One example end-to-end recent NANOOS product is the OR coast tsunami viewer (http://www.nanoos.org/data/products/oregon_tsunami_evacuation_zones/index.php) co-developed by DOGAMI, OR Emergency Management, NANOOS and NOAA. It lets users access DOGAMI's tsunami evacuation brochures via a searchable web-based portal. Users can search by physical (street) address, access a pull-down menu of cities' evacuation maps, and print their own copies.

Our DMAC is organized as a distributed team whose responsibilities are to: 1) design and build more robust architecture, 2) integrate new products into the standard product suite, 3) support DMAC long term expansion and evolution and 4) maintain NANOOS's core web presence. Three key support staff are: a system architect (systems design, construction and operation), an interoperability engineer (hardware interoperability and software interfaces), and a user-product specialist (user and public interfaces). The three are closely connected; hence NANOOS implements a Lead–Co-lead approach in each position. Boeing (S. Uczekaj/R. Blair) will lead as system architect, with OHSU (A. Jaramillo/A. Baptista/) as co-lead. OHSU will lead the network-engineering role (Boeing as co-lead). UW (D. Jones) will lead in the user-product role with co-lead from OSU (M. Kosro/C. Risien) and DOGAMI (Allan; NANOOS User Product Committee Chair). Level A funds will sustain this structure and function at base levels and with limited response capability.

Product identification, development, and assessment depend on two-way feedback from stakeholders. Also, products must be designed with awareness of data models and IOOS standards, to promote interoperability across observing regions. With Level B or C funding, our capability to gain critical feedback would be expanded over its current practice at targeted, limited venues. This enhanced activity will provide field-based advice to the team. Effective means of delivery of data and products will be discussed via weekly DMAC phone-cons and NANOOS tri-committee meetings (DMAC, User Products, and Education & Outreach).

iv. Education and Outreach subcomponent (E&O): A critical sub-component of NANOOS is our collective ability to reach users through outreach, training, and education. Our objective is to **sustain and strengthen ongoing E&O efforts**. Our E&O efforts aim at all levels of the public, plus specific user groups.

In coordination with other regional efforts, we are fostering ocean literacy and facilitating use of NANOOS products in the PNW. NANOOS is providing a new level of insight into the PNW ocean via topical "theme pages" and lesson plans involving observational data. Widespread (and often unexpected) uses of our products are leading to increased understanding of the ocean.

We will continue to expand NANOOS' focus on informal/formal education as well as sustain and enhance our existing outreach addressing all four priority user application areas. The work will be done by NANOOS E&O specialists (A. Sprenger, UW, C. Risien, OSU) with support from the web development team, the tri-committees (E&O, User Products, DMAC) and our PIs.

Under education, we will sustain and use NANOOS' "Ed-Web", the education portion of the NANOOS web portal. Under Level A, we will improve and add curricula for K-12 classroom teachers who use our data and data products. These curricula follow national science education standards (www.nap.edu), PNW state standards, and ocean literacy essential principles (www.oceanliteracy.org). We will also add more learning tools to the Ed-Web, such as animations and tutorials to help teachers, students and the general public understand regional coastal ocean processes and how to use NANOOS data products. NANOOS will continue work with regional informal learning centers to make available traveling interactive computer exhibits (modeled upon the exhibit at Hatfield Marine Science Center). WETLabs, Mobilisa-ICM, Port Townsend Marine Science Center and OSU are essential collaborators here. These efforts will develop a community of leaders in using NANOOS products in their classrooms and learning centers. We have engaged the Northwest Aquatic and Marine Educators and the Western Association of Marine Laboratories on this element.

The ability for NANOOS to provide professional development to teachers, and the number of exhibits, extent of informal learning products and outreach depends on funding. At Levels B, C, we would develop a citizen observation input capability in the NVS. We hear of strong desire for such capability from many sources. This will be a key mode for classrooms, citizen science groups, and informal learning programs to expand their interaction with NANOOS by becoming data contributors as well as data users. An ability to accept, display and archive citizen observations (with adequate QC) will be an important tool for education, for meeting needs of small local observing efforts, and for filling data gaps.

Under outreach, NANOOS will continue and enhance informative theme pages on the NANOOS web portal focusing on ecosystem processes and current issues. The extent of these pages and building of tutorials is funding-dependent. Recently NANOOS developed a theme page on Ocean Acidification, and is actively working on others. Under Level A funding, we will continue to develop and sustain theme pages: (1) with NOAA PMEL on acidification; (2) with OSU and HCSEG on coastal and estuarine hypoxia; (3) with OSU and NOAA NWFSC re harmful algal blooms; and (4) with DOGAMI, WA Ecology, and OSU re coastal hazards.

Under Levels B, C, we would focus on training regional groups to use products. A training group of NANOOS tri-committee members and experts would identify and meet with targeted groups to demonstrate NANOOS tools. A member of the user products team would participate in each meeting to get feedback.

v. NANOOS Evaluation of existing work efforts: Our objective for this year will be to **quantitatively evaluate the existing assets, products and efforts of the RCOOS, in light of stakeholder input and evaluations, to assess where payoffs are being obtained and where improvements and/or re-direction are needed.** This will help us effectively plan for beyond this “bridge-year” proposal.

It is prudent for NANOOS to undertake a close self examination of "return on investment" and of how the various observing assets and elements result in products and outputs that are in fact being used. Only so can we be best positioned to propose a fully defensible end-to-end system for the next three-year period that fulfills the goals of IOOS. Through NANOOS Tri-Committee Meetings, metrics and evaluation methods will be specified: management will oversee the process and present results and recommendations to our Governing Council.

vi. New investments: Level A funding barely sustains existing NANOOS assets and capabilities and existing investigators / entities. At Level C, we would add investigators / entities, including regional NOAA personnel and efforts. The NANOOS ExComm chose three areas and efforts that will complement and substantially strengthen our efforts to provide useful products: wave modeling, fisheries forecasting, and HABs.

<u>In Maritime Operations and Coastal Hazards:</u> **NANOOS will focus on observing and modeling wave conditions at the mouth of the Columbia River.** The mouth of the Columbia River is both a heavily travelled waterway (30 MT/yr of foreign trade; $16 B in trade value/yr) and a hazardous location. It is hazardous due to large ocean waves being frequently amplified by the shoaling bottom, and then very strongly modified - on very local scales - by strong ebb-tidal outflow jets (up to 3 m/s). The resulting waves can and routinely do sink large vessels. Local users from the shipping, fishing, and pilotage sectors have pressed for improved information on local wave conditions; a June 09 meeting assembled 46 community members to discuss possible solutions. We propose to contribute to meeting this need through two initiatives. We will contribute funds to a pool being organized by a user consortium to establish a CDIP wave buoy for the region; these buoys are operated by CDIP to provide accurate realtime information through a web interface, and have proven very reliable even in severe waves. To allow mapping of the wave field beyond the immediate measurement location, we will support wave model/forecast validation by T. Özkan-Haller (OSU), with the widely-used SWAN model (domain~40km×40km; resolution ~20m×20m), seeking to improve wave forecasts for mariners. This will build on work conducted via NOAA funds for the Coastal Storms program (http://www7320.nrlssc.navy.mil/CNW/). It will complement and benefit from work on open-coast beaches funded by US Army Corps of Engineers and Sea Grant.

<u>In Fisheries</u>: NANOOS will focus on **salmon forecasting.** W. Peterson's group at the Newport NMFS has been using the extensive biological and physical measurements in the PNW to relate zooplankton and fish-

eries fluctuations to ecosystem indicators, in order to enhance fisheries forecasting skill. They have identified ocean conditions that accurately forecast salmon survival and returns of salmon to their natal streams, one year in advance (see http://www.nwfsc.noaa.gov "Ocean Index Tools").

Although the forecasts are accurate, because drivers are not yet fully understood, forecast skill could be improved. This project would develop an index of transport in coastal northern CA Current, based on analysis of the NANOOS Newport buoy current meter and HF surface current data. Current meter data will help show the date of the spring transition, and the dominant water direction at several depths. Water mass analyses will compare NMFS CTD data against ARGO data, as an aid to determining the source waters for the coastal branch of the northern CA Current. If these analysis products lead to improvements in salmon forecasts, then the efforts will be operationalized and included on the salmon forecasting web-page.

In Ecosystem Impacts: NANOOS will focus on **Harmful Algal Bloom (HAB) information and prediction** in both OR and WA. Products will be made available on a NANOOS HAB theme page with regional specificity and focus.

P. Strutton's lab at OSU uses remote sensing and in-situ data to study HABs in OR, and has identified coastal regions that repeatedly experience toxin accumulation in coastal shellfish. They are identifying oceanographic features that generate HAB events, and those features' interactions with the coast. We cannot yet infer toxicity of blooms from satellite data, but logistic regression models are being developed that could incorporate ocean observatory data to do so. Coupling these predictions to future spatial trajectories of blooms is an important step toward a HAB early warning system. We will combine 1 km satellite ocean color data with our surface current maps (from OSU: Kurapov), to predict bloom trajectories. Initial prediction horizon would be 48hrs. Combining bloom trajectories with predictions of toxicity could yield a first generation early warning system.

Partnership for Enhanced Monitoring and Emergency Response to Harmful Algal Blooms in Puget Sound (SoundToxins –V Trainer, NOAA NWFSC) is a broadly-based regional forum for collaboration and cooperation towards management, prediction of, and response to HABs. Toxic outbreaks of *Alexandrium* have become pervasive in the Puget Sound region over the last two decades, escalating threats to human health: a newer algal threat from *Pseudo-nitzschia* appears poised to repeat the problem. Increasing anthropogenic influences have been suggested as causing and/or worsening HABs, but there is preliminary evidence that advection of seed blooms from outside Puget Sound instead may be responsible for some outbreaks. SoundToxins' goal is to provide better predictive capability and sufficient warning of HABs to enable early or selective harvesting of shellfish, thereby minimizing risks to both human health and reducing economic losses. Within this effort, NANOOS funding will be used to hire a database manager to coordinate programs and access to mooring data enabling linkage of environmental parameters to HAB initiation and development.

E. Benefits

The NANOOS proposal for 2007-2009 (http://www.nanoos.org/about_nanoos/documents.php) had strong regional support (e.g., 18 Letters of Support from authors who anticipated benefits). ALL of those organizations have stayed engaged in NANOOS; nearly all are NANOOS members.

We provide in App. 2 information on a variety of NANOOS products identified for development areas outlined in our 2007 proposal, based on numerous workshops. There we include the anticipated specific benefits to users identified in the "Audience" section hereof, arranged in our four product application topics, and we recap what was ***originally proposed*** in order to identify products that have been successfully implemented and the benefits being derived - as well as what we anticipate in this coming Year 4.

F. Milestone Schedule and Project Timeline

All facets of this effort, fully developed in the Approach section, will be managed by PI David Martin and co-PI Jan Newton. Details of deliverables and milestones are in App. 3. The core capabilities of this effort and prioritizations follow NANOOS stakeholder requirements and the NANOOS Business Plan.

G. Project Budget (Form 424-A) and Justification

We submit a one-year, $3M budget, designed to sustain and enhance a robust, end-to-end RCOOS. In App. 4, we provide a modular budget of step-wise capabilities: a core capability budget at $1.8 M (Level A); with modest enhancements at $2.3M (Level B); and the full $3M (Level C). The NANOOS effort is focused along needed RCOOS capabilities, not along institutional lines; hence we show the distribution of work effort (at all three Levels) in App. 4. Per institutional requirements we provide detailed budgets, work statements, and budget justifications for each institution in App. 5.