A National Oceanographic Partnership Program Award

***A Partnership for Modeling the Marine Environment of Puget Sound, Washington -- University of Washington Report***

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## Long-Term Goals

Estuaries, fjords and sounds are important, major components of marine ecosystems worldwide. Because of this, and their generally poor treatment by man, large estuaries should be the focus of large-scale, multidisciplinary, integrative modeling efforts. We need to both understand how these systems work, and be able to predict how they will respond to changes, whether natural or anthropogenic. Puget Sound, Washington State's largest inland sea, is both the largest fjord in the lower forty-eight states and closest to the substantial urban centers of Seattle, Tacoma, Everett and surrounding communities. Relative to other coastal systems, Pacific Northwest fjords have seasonally high annual phytoplankton standing stock and primary production, and they support several economically valuable fisheries. Our long-term goals are to develop quantitative understanding of the seasonal and longer time-scale variabilities of the Sound's circulation, roles

of water column stratification, nutrients, and light (and their interactions) on phytoplankton and zooplankton dynamics, and the sensitivity of the physical and the biological system to natural and human perturbations. We will develop models of Puget Sound that can aid agencies with responsibilities for environmental management in making informed decisions and serve as marine science education tools.

Objectives

The Partnership for Modeling the Marine Environment of Puget Sound consists of five separate organizations: University of Washington (School of Oceanography and College of Education), King County Department of Natural Resources, Washington State Department of Ecology, Puget Sound Naval Shipyard, and Ocean Inquiry Project. The partnership will develop, maintain and operate a system of flexibly linked simulation models of Puget Sound's circulation and ecosystem, a data management system for archiving and exchanging oceanographic data and model results that are accessible to all members of the partnership as well as to the regional and oceanographic community, and an effective delivery interface for the model results and observational data for research, education and policy formulation. The partnership engages in research activities aimed at developing fundamental understanding of the Sound's working, as well as addressing practical questions raised by the regional community concerning management of the Sound and its resources. The partnership will function as an estuarine research node within the NOPP Ocean Information Commons.

Approach

The partnership is administered from School of Oceanography, University of Washington. The lead P.I. (Kawase) will be responsible for project oversight and coordination. Kawase is also responsible for maintenance of the UW Puget Sound Circulation Model based on the Princeton Ocean Model (POM) code, as well as development of more specialized physical models in the years 3-5 of the project.

Devol is the UW Co-P.I. responsible for the development of the Aquatic Biogeochemistry (ABC) model together with Jan Newton at the Washington State Department of Ecology. The ABC model will be coupled to the circulation model, and existing models run by the partner members will be brought into coupling in the second year of the project.

Logsdon and Warner are responsible for the design and implementation of the NOPP data and information architecture for the partnership. Logsdon is primarily concerned with the issues of distribution and archiving of available data; his responsibilities include spatial data connectivity and compliance with metadata standards. Warner will oversee the development of the database for marine observations from the standpoint of the marine scientist.

Winn is the UW Co-PI responsible for developing educational applications of the Partnership's data and models. The Education and Visualization team is developing interfaces that will support learning about the ocean by a wide range of students and other end-users. The team is also developing learning modules that will be used in middle and high schools and in undergraduate courses, and ways to assess what students from them.

Work Completed

The overarching goal of the Partnership for FY02 was to establish working teams, bring each of the independent models to a fully functional state, and begin connecting them with each other and in-situ data. Additionally, a data management system is being designed along with a web interface for basic visualization of the both model and in-situ data.

The UW Puget Sound Circulation Model is being readied for routine one-day hindcasting of the Sound's circulation. A custom-built dual-processor computer has been purchased for the model runs. We are currently developing coupling modules with the MM5 regional weather forecasting model, and we expect the routine hindcasting to begin in early October. The model will be used as a part of a study of circulation and biological productivity in Carr Inlet in the southern Puget Sound next spring. As the first entry into the data stream system described below, two undergraduate research assistants are working this summer on plotting and calibration of all hydrographic, chemical and biological data collected during the semi-annual PRISM cruise since 1998. We intend to make this data set available for public download through the data stream this fall.

In addition, a simple twelve-box model of Puget Sound circulation has been developed by Amanda Babson, a graduate student supported from this grant. This model is forced with river inflow and an imposed salinity boundary condition at the mouth of the sound. It predicts salinity in different basins of the Sound and has simple parameterizations of transport and mixing between boxes. The model is coded in Matlab, and is simple enough that it is trivial to run a large number of cases and generate an ensemble of runs. Amanda has demonstrated that the model has statistically significant skill to hindcast interannual salinity change in the Sound, and hence, presumably, changes in circulation.

The Data and Information Management Team has established two focused working groups. The first group is focused on the data content, its quality, description, and application, available from the existing partners in the NOPP project. This group is following up on the results of a Partnership User Needs Survey involving twenty six respondents representing various state (40%), federal (20%) and county (13%) agencies, while the remaining respondents represented local, private and tribal interests. The second group is focused on the information management and distribution system for the shared data collection. The emphasis of this group has been on the implementation and integration of the Distributed Oceanographic Data System (DODS) and the NSF UNIDATA Internet Data Distribution (IDD) system. The two groups working together are implementing an architecture designed to communicate data between project partners as well as archive and distribute modeling results to end user. Currently the two working groups have completed the initial survey of user needs, drafted project specific metadata tags, outlined a management plan for review by project partners, placed a data server online and begun testing data source, sink and relay services using the DODS and IDD protocols.

The Partnership's Education and Visualization Team, which consists of members of the UW School of Education, UW Human Interface Technology Lab and Ocean Inquiry Project, have been meeting weekly to coordinate and work on various tasks. These fall into four broad categories: 1) moving the "Virtual Puget Sound" (VPS), a 3-D navigable learning environment based on M. Kawase's numerical model, from an SGI computer to a PC-based platform, 2) developing curricula using model output and VPS, as well as OIP's in-situ techniques, to educate

students about circulation and oceanographic properties of Puget Sound, 3) developing assessment techniques that can measure learning in these environments, and 4) developing a browser-based interface for all (students and partners) to examine model and real data generated by the Partnership. A good start has been made on all of these, as well as working with other teams in the Partnership (e.g., the aquatic bio-geochemistry modeling team). Specifically, the team has: Moved the VPS software to a desktop computer; Completed an initial analysis of the content that can be used in learning activities that is both supported by data and models from NOPP partners and is compliant with State and national requirements for science education; Made progress in developing web-based tools that allow visualizations and manipulations of partners' data; Developed a prototype of a tool that assesses how students organize concepts and principles they have learned.

## Results

Because we are only five and half months into the project by the end of FY 2001-2002, no significant results to report at this point in time.

## Impact and Applications

### National Security

The environmental security of the marine environment of Puget Sound (and by extension the people of the Pacific Northwest) is vulnerable to both natural hazards and acts of terrorism. Through our regional collaboration and partnership between academia and government institutions we will improve our ability to address the five (five) major stages of Emergency Management – Planning, Preparedness, Response, Recovery, and Mitigation. To fully impact each of these stages in a comprehensive application will require that our modeling partnership address many scenarios and engage a wide variety of economic sectors. An improved modeling capability of the circulation and marine ecosystem will help local and regional government devise procedures to deal with, for instance, chemical/biological attacks involving harmful agents that may be/need be flushed down into our marine waters, and with terrorism aimed at military and industrial installations that may result in environmental contamination.

### Economic Development

From the coastal marine fisheries and aquaculture to shipping and municipal waste management, the Puget Sound economy depends upon its marine resources. Our modeling partnership is designed to specifically address the temporal and spatial variability of these resources, understanding of which will aid businesses better plan their operation and improve productivity and efficiency. Prediction and early warnings will be a natural outcome of our work: For instance, forecasting of harmful algal blooms (HABs) in the Sound will help shellfish growers better deal with this threat to their livelihood. Detailed knowledge of currents and hydrography will help diving operators with their underwater work.

### Quality of Life

A better understanding of the Sound's circulation and a better ability to model it will have positive impact on all aspects of the maritime life in our region. The Puget Sound region has always enjoyed a quality of life directly related to the quality of our environment. Yet our economic and social systems continue stress the resiliency of both the terrestrial and marine

resources. Our project provides a major tool in understanding the trade-offs between regional scale actions and impacts to the ecological function of the marine environment. The sustainability of historical landuse, recreational opportunities, shoreline development, and Nearshore and marine economies, all characterize the Puget Sound quality of life. To sustain that quality we must understand the likely response of the marine environment to potential stressors. Oceanographic knowledge also has direct uses and benefits for those who work and live at sea. For instance, knowledge of currents will help Coast Guard and regional law-enforcement agencies with search and rescue operations and contaminant spill containment; it will also help recreational boaters make better trip decisions.

Science Education and Communication

The results of our model will allow us to contribute in important, innovative ways to emerging applications of information technology to formal and informal education. With the aid of suitable visualizations, support material, and curriculum modules, our model results will be a valuable tool for learning about Puget Sound's marine environment that can be used in classroom settings as well as by the public at large in museums and through the web. This work is making important contributions to educational technology generally. Also, the curriculum these technologies support is problem-based and student-centered. Research has shown that this kind of curriculum is the most effective. Our work therefore extends current "best practices" in science teaching to marine education. Finally, our materials allow students to work with real data, rather than "toy" datasets and learning systems so often used in schools. This puts us in the position of being able to help move science education towards studying the marine environment in its true complexity, which will reduce many common misunderstandings about how it works. Our work to date with museums and other forums for informal education will make it easier for us to deploy these materials where they will be accessible by the general public.

Transitions

National Security

We are developing a suite of models for Puget Sound’s circulation, variously based on Princeton Ocean Model, EFDC and CH3D, as well as a marine biogeochemistry model of an original design. We are also developing an information infrastructure, based on Distributed Oceanographic Data System (DODS) and the NSF UNIDATA Internet Data Distribution (IDD) system, through which our modeling results and oceanographic data we hold are exchanged. A web-based access interface for users outside as well as inside the partnership will be created. Municipalities and regional agencies needing to develop strategies to protect citizenry, properties and the environment in the event of an attack will be able to utilize our model results for their planning via the interface, and partnership members will assist them in use and interpretation of model results and oceanographic data.

Economic Development

The same interface to our information infrastructure will be available for the region’s marine businesses as well as consultant working on their behalf. Again, partnership members will provide technical assistance with use and interpretation of model results and oceanographic data.

Quality of Life

Our informational interface and expertise will be available to all members of the Puget Sound maritime community, including municipalities, regional governments, tribes; environmental organizations; recreational boaters and divers; and others. In addition to the interface to the information infrastructure, which will primarily be aimed at technical audience, our web site will also feature visualizations of the models aimed at the general public, along the same line as web sites that feature outputs of numerical weather prediction models.

Science Education and Communication

We are developing technologies and techniques that will allow students to engage in relatively sophisticated online interactions with visual and textual material, built from the results of our model. Our more complex simulations of Puget Sound, currently stand-alone, allow students to interact with visualizations in hitherto unprecedented ways. This work extends earlier development of immersive and desktop virtual environments that allow students to interact with dynamic three-dimensional visualizations of Puget Sound in order to learn key concepts in environmental science. A prototype of this "Virtual Puget Sound" was demonstrated at American Geophysical Union Fall 2003 Meeting in San Francisco. We are also developing problem-based, student-centered curriculum that uses web-based and stand-alone visualizations and simulations, which will be used in an introductory oceanography course in a community college in the Spring Quarter of 2003. Over the course of the grant, we will build and test a variety of units of this kind in classes ranging from Middle School to Undergraduate.

Related Projects

Puget Sound Regional Synthesis Model (PRISM) is an internally funded initiative of the University to develop and consolidate University-wide expertise in natural and human environment of the Puget Sound region. The initiative is formed in response to the urgent need for environmental knowledge about the region, arising from many concerns and controversies such as protection of endangered species and old-growth forests, management of urban growth, The core of the PRISM is a suite of prognostic models that simulate the Puget Sound region's natural and human environment. These include: a mesoscale weather forecast model for the Pacific Northwest based on NCAR MM5; a distributed hydrography model of the Puget Sound watersheds based on DHSVM, the Puget Sound Circulation Model and the Aquatic Biogeochemical Systems Model (both discussed above), as well as an urban hydrology/water resource usage model (CRYSTAL) and an urban growth simulation model (UrbanSIM). PRISM has also developed a data/information management system for the region's geospatial data discussed above. It is the eventual goal of PRISM to operate all of these models in flexible coupling with one another. PRISM will act as the University's host to the Partnership; both the modeling and the data management system of PRISM will provide important leverage to the partnership's activities described here.