A National Oceanographic Partnership Program Award

A Partnership for Modeling the Marine Environment of Puget Sound, Washington – Puget Sound Naval Shipyard 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, Bremerton 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. A special emphasis for this component of the project is to develop an inlet-scale integrated modeling system that will include the hydrodynamic and contaminant transport within the receiving waters of Sinclair and Dyes Inlets, the surrounding watershed, and the boundaries with the Greater Puget Sound System [1].

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.

Under tasking from the Puget Sound Naval Shipyard, the Space and Naval Warfare Systems Center is conducting modeling studies to develop an Inlet-scale integrated modeling capability for the Sinclair and Dyes Inlet watershed. The modeling framework will be used to conduct specific model applications to support risk analysis, watershed studies, regulatory studies, and respond to stakeholder input. The final modeling product will provide the capability to simulate, on an Inlet-scale basis, various risk management and policy alternatives.

Drs. Johnston, Wang, and Richter will be coordinating with the partnership on aspects of coupling the Inlet-scale model with the larger scale Puget Sound model, sharing data and information, and visualizing model simulations and results.

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 Partners are preparing the Puget Sound Circulation Model for routine one-day hindcasting of the Sound's circulation. A custom-built dual-processor computer has been purchased for the model runs. They 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. This data set will be made available for public download through the data stream this fall.

The UW, King Co, and Ecology Partners have been developing a computer model to describe key biogeochemical processes in Puget Sound. The Aquatic Biogeochemical Cycling (ABC) model is spatially explicit, based on published equations for biological and chemical reactions, externally forced by hydrodynamics and sunlight, and ultimately is designed to interface with a variety of circulation models including the POM. The ABC model simulates three-dimensional concentrations of dissolved oxygen, nutrients (NO_3, PO_4, NH_4); phytoplankton biomass (three types); zooplankton biomass (three types); and dissolved and particulate organic matter (C, N, P; refractory and labile).

The PSNS Partners have been developing an Inlet-scale integrated modeling system for Sinclair and Dyes Inlets and the surrounding watershed. The modeling system will include hydrodynamic mixing and transport in the receiving waters, dynamic loading from the surrounding watershed, and coupling with the Greater Puget Sound System [1].

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. This work will also support force protection deployments and assist in maintaining mission readiness for the U.S. Navy stationed in Puget Sound waters.

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/informal education and aid regulatory agencies in developing appropriate and effective environmental requirements. 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 to assess the long-term effects of environmental regulations and policies. Our work will extend current "best practices" in science and technology to support development of environmental requirements and regulations to better understand and manage the resources of the Puget Sound.

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. The U.S. Navy will also be able to access and utilize this data and information to maintain mission readiness, assure force protection, and implement training and maintenance schedules that will not adversely impact environmental quality.

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 and regulatory agencies 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. Also the development of problem-based, curriculum that uses web-based and stand-alone visualizations and simulations, will assist regulatory agencies and environmental managers in developing appropriate and effective environmental requirements and management policies.

Related Projects

PSNS Project ENVVEST

The U.S. Navy Puget Sound Naval Shipyard (PSNS), Region X of the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) have entered into an agreement to protect and improve the health of surface waters of Sinclair and Dyes Inlets and surrounding watershed by developing a more environmentally protective strategy for managing pollutant sources in the Inlets than the regulatory framework that is currently in place Phase I of the PSNS Project ENVironmental InVEStment (ENVVEST). The general approach for the project is to develop and test a working model for watershed-based assessment and partnering. The approach would build on mutually beneficial and cooperative efforts among stakeholders and agencies by pooling resources to get better products and solve environmental problems. The ENVVEST modeling studies have three thrusts (1) developing a capability to do modeling, (2) applying models to answer specific Total Maximum Daily Loading (TMDL), ecological risk, and other regulatory questions, and (3) using calibrated and verified models to conduct scenario simulations [1].

The models selected for PSNS Project ENVVEST are Hydrological Simulation Program Fortran (HSPF) for the watershed and Curvilinear Hydrodynamics in 3-dimensions (CH3D) and Water Analysis Simulation Program (WASP) for the receiving waters. Although HSPF is a lumped parameter model, it is the only public-domain model currently available that can simulate both hydrological and water quality parameters at the watershed scale [2]. The HSPF model has been widely used, it has a large user group, and it is a commonly accepted regulatory tool [2].

Originally developed by the Army Corps of Engineers for the Chesapeake Bay estuarine system, CH3D calculates time-varying 3-dimensional numerical flow fields for water surface, velocity, salinity, and temperature to simulate vertical and horizontal mixing [3]. CH3D uses curvilinear boundary-fitted numerical grids in the horizontal plane (Figure 1). The gridding in the vertical direction is z-grid, which divides the water column into many layers of equal thickness, with number of layers varying from several layers for deeper regions to one layer for extremely shallow regions (< 3m). CH3D is capable of handling a variety of external forcing, including tides, winds, tributary flows, point and non-point sources, as well as baroclinic effects due to density differences between freshwater inflows and saline Inlet water [4]. Its open code, flexibility in defining model grids, and process-based numerical scheme makes CH3D very versatile in developing applications for coastal and estuarine systems [5]. Presently, CH3D models are being used to simulate hydrodynamics for a variety of Navy harbors including Sinclair/Dyes Inlet, Norfolk/Hampton Roads, Little Creek, and Pearl Harbor (P.F. Wang, SSC, personal communication).

The Water Analysis Simulation Program (WASP) is supported and distributed by the U.S. EPA Center for Exposure Assessment Modeling (CEAM). WASP "is a generalized framework for modeling contaminant fate and transport in surface waters. Based on the flexible compartment modeling approach, it can be applied in one, two or three dimensions and is designed to permit easy substitution of user- written routines into program structure. Problems studied using WASP framework include biochemical oxygen demand and dissolved oxygen dynamics nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination" [6].

The models are being used to develop an integrated Inlet-scale modeling framework. A WASP box model has been setup to run long-term simulations (years to decades) and the kinetic subroutines from WASP have been linked directly to CH3D so that short-term dynamic simulations with finer spatial and temporal resolutions (days to months) can be calculated [7]. Presently, the grid for CH3D had been refined, a Lagrangian particle tracking module within CH3D has been used to calibrate the model with data from a drogue study [8, 9], and a module to simulate fecal coliform die off as a function of salinity, temperature and sunlight in the marine environment based on the Mancini Equation [10] has been added to the model code — CH3D-FC (P.F. Wang, SSC, personal communication). The validation of CH3D-FC with data from a dye release study conducted in the Port Washington Narrows in March 2002 [11] is ongoing and modeling scenarios are being developed to model combined sewer overflow events (CSO) within the Inlets. The model grid has been refined to provide higher resolution of the hydrodynamics in Dyes Inlet. A PC-based user-friendly graphics software to animate CH3D modeling results is also being developed. A beta-version of computer graphic software to animate model results has been developed to visualize model performance and develop specifications for advanced graphics display. Addenda and updates for the CH3D manual will be developed to document additions and revisions to the software code [12]. Training workshops have also be held to assist in applications of the model.

Additional work is being conducted to integrate the receiving water models with fresh water inflows from the watershed [13, 14, 15], incorporate benthic flux from the sediments into the contaminant transport model [16], and apply the models to support the development of Total Maximum Daily Loads (TMDLs) for the Inlets and contributing watershed [17].

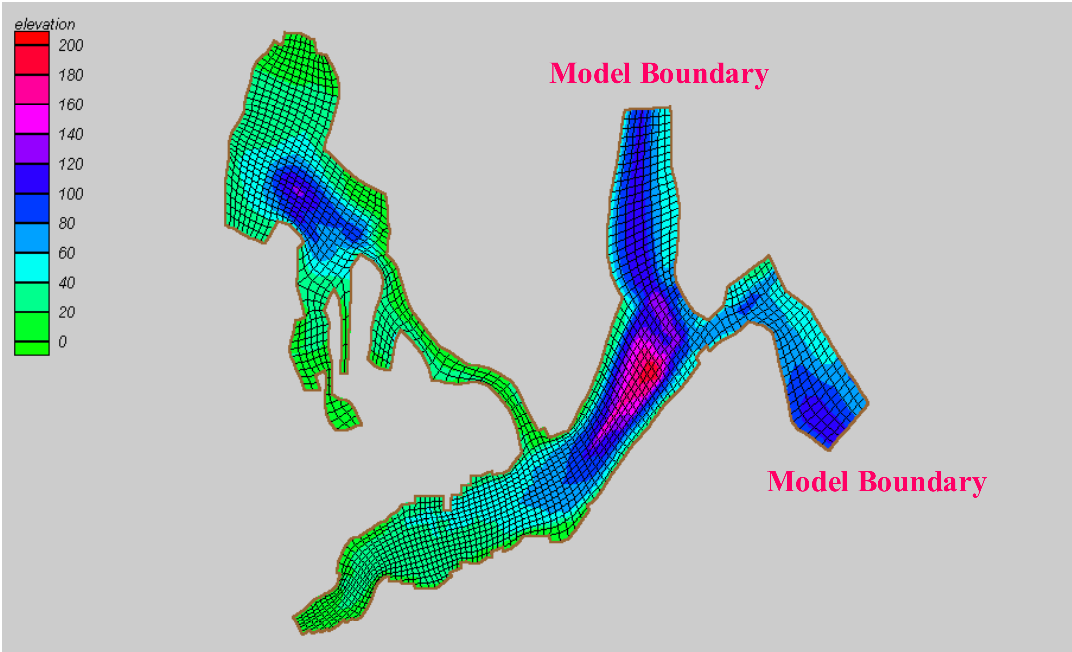

Figure 1. CH3D model grid and bathymetry for Sinclair and Dyes Inlets and the model boundary with the Central Puget Sound.

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