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.

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 & Intermediate Maintenance Facility (PSNS & IMF), and Ocean Inquiry Project. The partnership will develop, maintain and operate a system of flexibly linked simulation models of the 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 using the model CH3D for the receiving waters and HSPF for the watershed [1]. The modeling framework will be used to conduct specific model applications to support risk analysis, watershed studies, regulatory studies, and respond to stakeholder input [2]. The final modeling product will provide the capability to simulate, on an Inlet-scale basis, various risk management and policy alternatives. Drs. Johnston and Wang have been coordinating with the partnership on aspects of coupling the Inlet-scale model (CH3D/HSPF) with the larger scale Puget Sound model (Puget Sound POM), sharing data and information, and visualizing model simulations and results. Current work includes testing the linkage between the modified numerical grid for Sinclair and Dyes Inlet to provide for linkage with the meso-scale model, incorporating a common data format (NetCDF-network Common Data Form) to facilitate exchanging model output with other project partners, and initiating a one-way coupling with the meso-scale model to satisfy the boundary conditions of the Inlet-scale model.

WORK COMPLETED

During FY04 the PSNS Partners have been developing an Inlet-scale integrated modeling system for Sinclair and Dyes Inlets and the surrounding watershed (Figure 1). The modeling system includes hydrodynamic mixing and transport in the receiving waters, dynamic loading from the surrounding watershed, and coupling with the Greater Puget Sound System [1]. To initiate the linkage between the Inlet scale model (CH3D/HSPF)

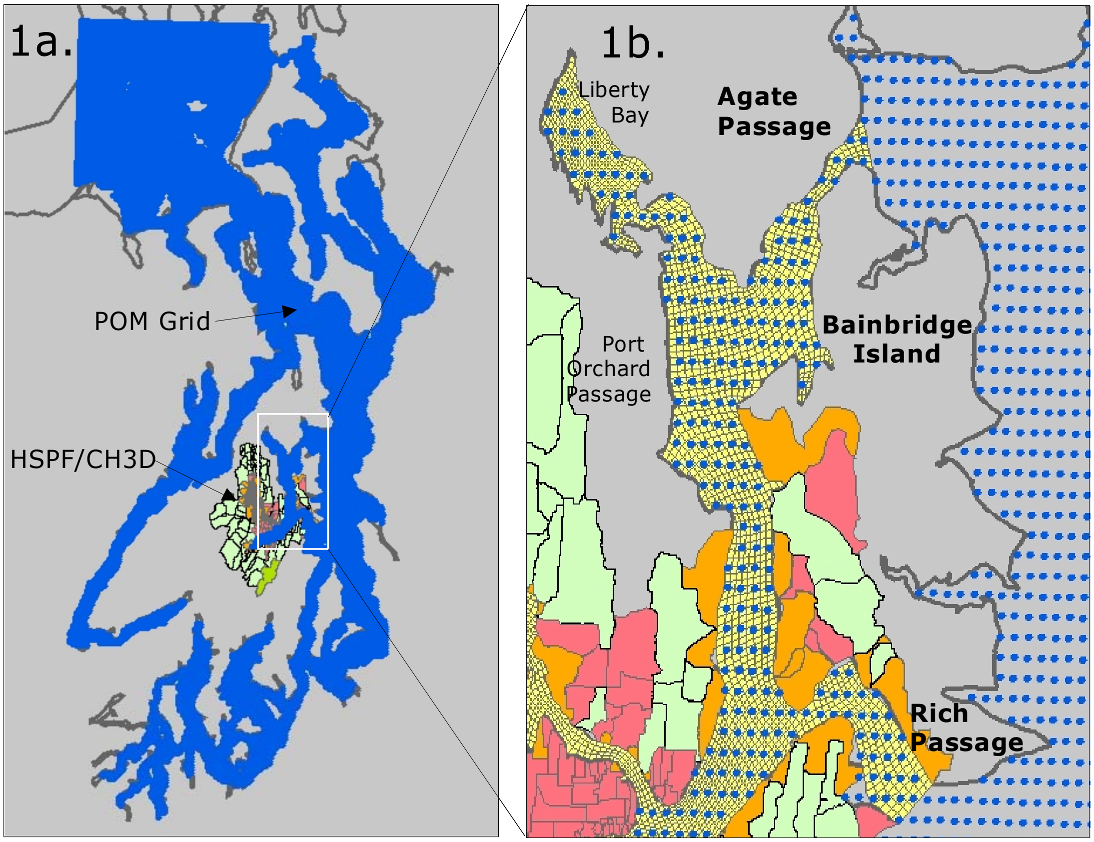

Fig. 1. The domains of the Puget Sound POM model (blue) and the CH3D/HSPF models for Sinclair and Dyes Inlet (1a). The nodes of the numerical grid for the Puget Sound POM model (blue points), the numerical grid for CH3D (yellow polygons), and Rich and Agate Passage boundaries around Bainbridge Island (1b).

and the meso-scale model for Puget Sound (Puget Sound POM) a new numerical grid for CH3D was created to resolve all of Port Orchard Passage and Liberty Bay with the model boundaries defined at Agate Passage and Rich Passage around Bainbridge Island (Figure 1). One-way coupling of the models is being accomplished by forcing the CH3D model with output from the Puget Sound POM model at the boundaries for specified simulation periods. Work has also been completed incorporating the NetCDF (network Common Data Form) format to output a common data format from CH3D. Developed by the Unidata Program Center, NetCDF provides an interface for accessing and displaying array-oriented data [3]. Recently, the NetCDF protocol was modified to incorporate curvilinear arrays such as CH3D [4] and this algorithm was incorporated into the CH3D model code. A presentation on the modeling studies for Sinclair and Dyes Inlet was presented at the regional PSMEM workshop on April 23, 2004 [5].

RESULTS

The one-way coupling between the Puget Sound POM and CH3D is being implemented using example output from selected Puget Sound POM nodes located near the boundary of the CH3D grid (Figs 2 and 3). A data extraction tool for Puget Sound POM was

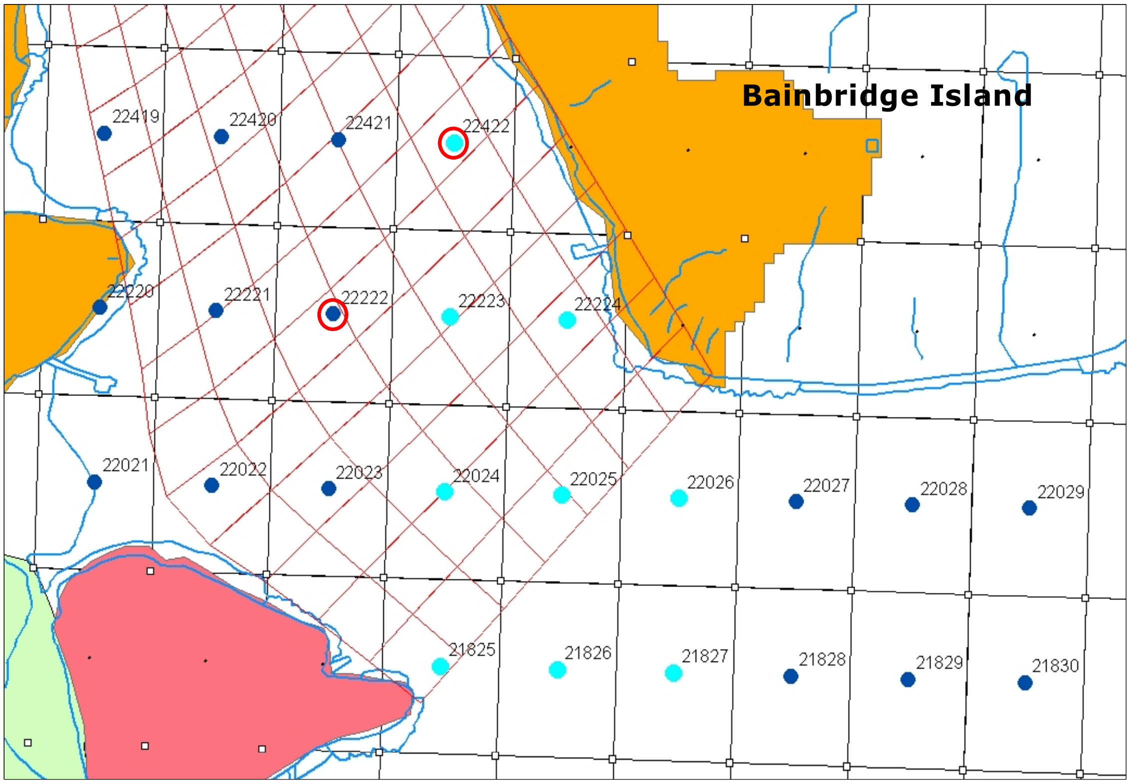

Fig 2. The linkage between the Puget Sound POM Model (light blue nodes) and the curvilinear grid for CH3D (maroon polygons) at the Rich Passage boundary. Red circles denote POM nodes from which the example data were extracted.

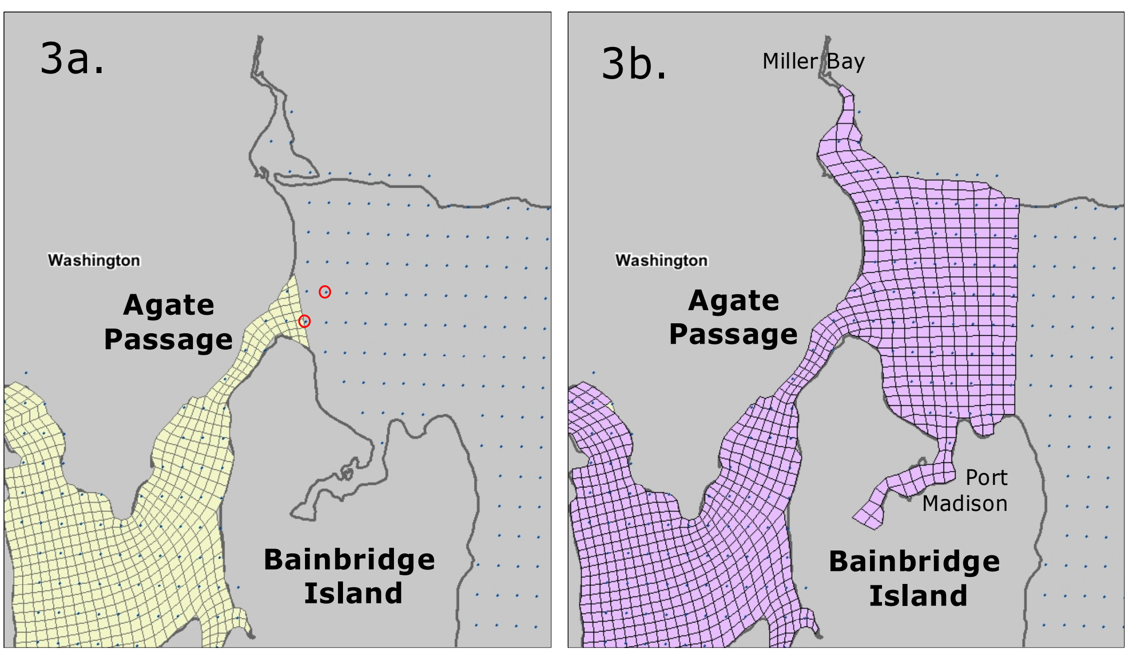

Fig 3. The CH3D grid with boundary at the mouth of Agate Passage (3a), and the extended CH3D grid with boundary that includes Port Madison and Miller Bay (3b). Red circles denote POM nodes from which the example data were extracted.

developed to extract data from the POM output for selected nodes and time periods. The example data, extracted from two nodes located near each of the CH3D model boundaries (Figs 2 and 3), included simulated tidal height, temperature, and salinity from April 28 to June 19, 2004. The example data were processed and read into CH3D as time varying input. Once the testing with example data is completed, POM output from additional nodes near the boundaries will be processed to provide a more accurate forcing function for CH3D. For the boundary at Rich Passage, the outputs from nine POM nodes will be processed to define the input values for seven CH3D nodes (Fig. 2). To develop the best approach for linking, two model configurations are being evaluated for the Agate Passage boundary (Fig. 3). The first configuration consists of a linkage at the mouth of Agate Passage (Fig. 3a) and the second configuration extends the CH3D grid to include Port Madison and Miller Bay, possibly creating a smoother coupling between the models with less chance of errors due to numerical dispersion [6].

Currently, the new CH3D grid is being tested using the Puget Sound POM-generated inputs to determine the model's response to dynamic forcing from two simultaneous boundary conditions. The results will be used to identify the best configuration to accept Puget Sound POM input and optimize the data processing procedures for the inputs. Once the model testing has been completed, the coupled model will be run to compare model predictions with observed data from the Inlets for specific periods corresponding to wet and dry seasons for when data are available. The next step will be to test extracting output data from CH3D for input into the Puget Sound POM to simulate exchange (two-way coupling) between the models. The long-term goal of the coupled models is to simulate salinity around Bainbridge Island as a measure of circulation and exchange between the Inlets and the main basin of Puget Sound. The improvements to the CH3D model of Sinclair and Dyes Inlet have advanced the ability to simulate and display Inlet-scale environmental processes for the study area (Fig 4).

IMPACT/APPLICATIONS

National Security
An improved modeling capability of the circulation and marine ecosystem of Puget Sound at both the sound- and inlet-scale will help local and regional government devise procedures to deal with accidental or deliberate events that release contamination into the marine environment of the Puget Sound. The modeling tools will help develop more effective measures for protecting marine resources and economic assets of the Puget Sound that are vital to our National Security.

Economic Development
Predictive modeling of Puget Sound's circulation and marine ecosystem will have positive impacts on many economic activities taking place in the Sound. For instance, forecasting of harmful algal blooms (HABs) and better understanding of hypoxia-induced fish kills in the Sound will help commercial fisheries better deal with this threat to their livelihood. Detailed knowledge of currents and hydrography will help diving operators with their underwater work. Understanding longer term variability in water quality

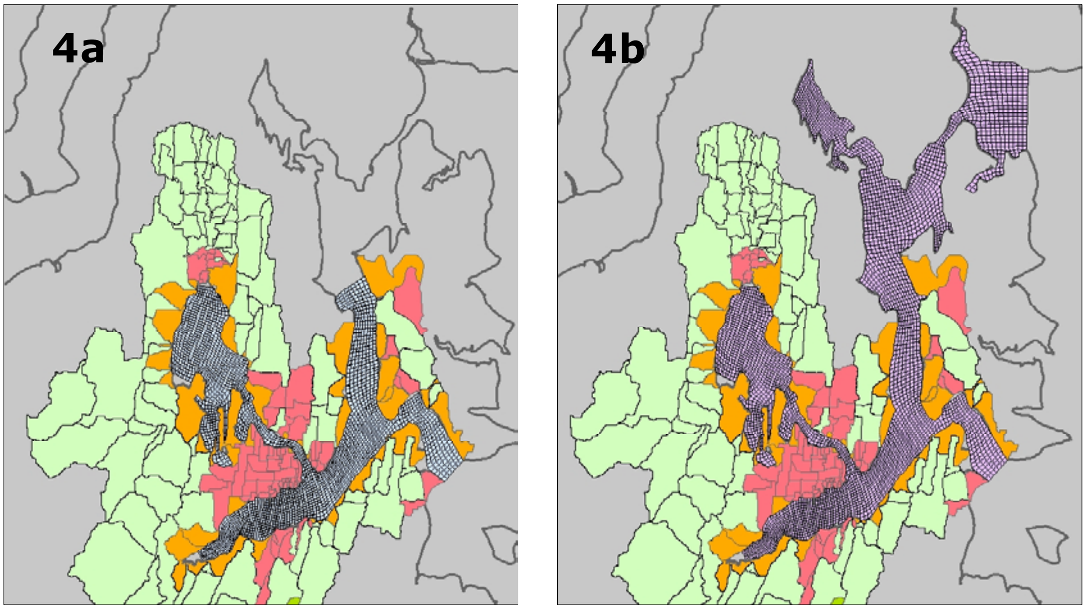

Fig 4. The existing CH3D/HSPF model for Sinclair and Dyes Inlets (4a) and the new CH3D grid for linking with the Puget Sound POM model (4b).

leading to marine ecosystems change will help managers of fisheries resources make better decisions.

Quality of Life

The Puget Sound region has always enjoyed a quality of life directly related to the quality of our environment. Our models provide tools for evaluating the impact of regional scale actions on the marine environment by predicting response of the latter 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, and information about tides and currents will be of interest to boaters and fishermen.

Science Education and Communication

With the aid of suitable visualizations, support material, and curriculum modules, the 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.

TRANSITIONS

The linkage with the watershed model allows the loading from streams and discharges to be simulated and increases the ability to simulate circulation and mixing, conduct total maximum daily load analysis, evaluate juvenile salmonid out-migration, and address other water quality issues for the Inlets [5]. The results of the Inlet-scale model of FC in Sinclair and Dyes Inlets are already being used by the Washington State Department of

Health to reclassify shellfish beds in Dyes Inlet [7]. For the first time since 1969 commercial shellfish harvesting will be conditionally approved for parts of Dyes Inlet [8]. This would have not been possible without the significant improvements by the City of Bremerton in controlling combined sewer overflows and the ability to model FC dispersion in the Inlets [9]. The models will also be used by the Washington State Department of Ecology to establish TMDLs for the Inlets [10, 11].

RELATED PROJECTS

This work compliments work being conducted under PSNS & IMF Project ENVVEST [2] to conduct modeling studies of the Sinclair and Dyes Inlet Watershed to assess the impact of CSO discharges on water quality of the Inlets [8,9] and support the development of TMDLs for the watershed [10, 11].

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PUBLICATIONS

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HONORS/AWARDS/PRIZES

Drs. Robert K. Johnston, P.F. Wang and other members of the Project ENVVEST Technical Team received letters of appreciation from the Puget Sound Action Team (December 16, 2003) and the Washington State Department of Health, Shellfish Programs (November 6, 2003) commending and congratulating efforts to restore the health of Sinclair and Dyes Inlet which resulted in the reclassification of about 1500 acres of shellfish beds from prohibitive to conditionally approved.

Dr. Robert K. Johnston received a Career Service Award in recognition and appreciation for faithful and valued service to the Department of the Navy and the Government of the United States (25 Years), August 20, 2004.

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