An Investigation of Dynamical Processes Influencing Sediment Transport and Morphological Change in Skagit Bay using an Unstructured Grid Coastal Ocean Model

Geoffrey W. Cowles
School for Marine Science and Technology
706. S. Rodney French Blvd.
New Bedford, MA, 02744
phone: (508) 910-6397 fax: (508) 910-6392 email: gcowles@umassd.edu

Award Number: N00014-08-1-1115
http://www.smast.umassd.edu/CMMS/

LONG-TERM GOALS

In this work, we will employ a high-resolution coupled hydrodynamic-sediment model to examine the relative importance of the principal mechanisms controlling the morphodynamics of Skagit Bay. Using the measurements from the extensive observation program supported through the tidal flats DRI, we will examine the capability of a state of the art coastal ocean model, and determine what future extensions may be necessary for continued discovery in this field. Through extensive grid refinement efforts and available high-fidelity bathymetry, a better understanding of the mesh resolution required to resolve the critical processes will be gained. This will guide future application of this class of model.

OBJECTIVES

In this project, we will configure an advanced coupled hydrodynamic-sediment model for simulation of the circulation and sediment transport in Skagit Bay. The model will resolve the range of required scales from the open boundary in Puget Sound (∼50 km) to the channel networks on the flats (∼10-100 m). The coupled model will be validated using available measurements to determine the capabilities and needs of such a system for this class of application. Grid convergence studies will be performed to determine the necessary mesh resolution required to resolve the dominant processes. We will employ the calibrated coupled model to evaluate the relative importance and influence of observed external forcing (fluvial, tidal, wind, wind-wave and surface heating) on sediment dynamics and morphological change of the inter-tidal region of Skagit Bay over a range of time scales from tidal to seasonal.

APPROACH

We will develop and apply a coupled hydrodynamic-sediment model of Skagit Bay. Due to the complexity of the coastline and bathymetry and the large range in dynamical scales in macrotidal estuaries, the unstructured-grid coastal ocean model FVCOM was selected. FVCOM is a Fortran90 software package for the simulation of ocean processes in coastal regions (Chen et al., 2003, 2006). The publicly available model has a growing user base and has been used for a wide variety of applications, including work in Skagit Bay (Yang and Khangaonkar, 2008). The kernel of the code computes a solution of the hydrostatic primitive equations on unstructured grids using a finite-volume flux formulation. For the vertical discretization, a generalized terrain-following coordinate is
The model is fully parallelized using a Single Program Multiple Data (SPMD) approach (Cowles, 2008). FVCOM will be coupled with the Community Sediment Transport Modeling System (http://woodshole.er.usgs.gov/project-pages/sediment-transport/). The model includes transport of both the suspended load and bedload. The number of sediment classes is flexible, and for each class, parameters such as critical shear stress, mean diameter, and settling velocity must be defined. Complex bed dynamics are included with a user-prescribed number of layers defined by the layer number, fractions of each sediment class, an age, and a thickness. Recently, support for cohesive sediment modeling has been implemented in CSTMS and is currently undergoing testing.

Beginning from the aforementioned FVCOM model of Skagit Bay developed at PNNL, we will work to modify this model to resolve the processes that are the focus of the proposed work. This work includes the initialization and parameterization, calibration of the sediment model, modification of the mesh resolution and expansion of the domain outward from Skagit Bay. The updated model will be validated using measurements obtained through observational programs in the tidal flats DRI.

An open loop mesh adaptation procedure will be used to refine the initial model setup to make sure the mesh has the required grid spacing in tidal channels and flats needed to resolve the processes examined in the proposed work. This will ensure that we have a grid refined solution for our morphodynamic studies to constrain the influence of spatial discretization errors in the model results. To do so, we will generate a series of coarser meshes from the initial grid using the method of Maximal Independent Sets. Solutions for the baseline case will be obtained on the coarser meshes and Richardson extrapolation of the bed thickness change and integrated current energy across the mesh levels will be utilized to determine an estimate of local spatial discretization error. The mesh will be adapted locally by inserting and deleting points based on this heuristic. This process will be repeated until suitable grid convergence is achieved for the given forcing and available bathymetry. Using this method we will take advantage of the variable resolution allowed by the unstructured mesh, and rely on the dynamics to drive the background length scale.

We will force the model using idealized and realistic conditions to examine the contributions of external forcing to the morphodynamics of the tidal-flat. In these process studies the rates of freshwater discharge and fluvial sediment supply will be varied, along with the tidal phase, and the sea level to examine the impact on net sediment transport and circulation in Skagit Bay. In addition, we will examine the impact of resuspension driven by episodic wind and wave events. These studies will be used to examine how the intertidal zone adjusts on event time scales, through the spring-neap cycle, and on seasonal time scales.

**WORK COMPLETED**

The existing setup of the Skagit Bay FVCOM model was transferred from Coastal Processes and Watershed Modeling Group at Pacific Northwest National Laboratory. This setup has subsequently been modified to execute on the most recent release of FVCOM, v3.0. In addition, the model domain has been extended south to the entrance of Whidbey Basin near Sandy Point. Bathymetry for the expanded domain was derived from the 30-ft resolution Puget Sound Digital Elevation Model (http://www.ocean.washington.edu/data/pugetsound). The model was configured to run with tidal forcing and monthly mean climatological river forcing for the fall 2008 observation season to provide reference values for these teams. In the interest of providing ease of access to model results for other investigators, a postprocessing program has been coded to convert output from FVCOM to files compatible with the General NOAA Operational Modeling Environment.
This effort was initiated by R. Signell (USGS, WHOI) who also organized interaction with GNOME developers. A THREDDS server is being setup on a local webserver at Umass Dartmouth to provide these GNOME datasets as well as the FVCOM Skagit Bay model output files to other investigators in the tidal flats DRI. A graduate student has been recruited to work on this project and will matriculate in January, 2009.

RESULTS

This project is a new start (funding awarded June, 2008) and thus the work is currently being spun up.

IMPACT/APPLICATIONS

A key component of this work is the development of an unstructured grid coupled hydrodynamic-sediment model for the study of tidal flats. The validation efforts will draw on the intensive observation program supported by this DRI and will help to make conclusions about the potential of such a model as well as define future research needs in terms of development or need for additional data. In concert with the scientific findings of other teams, the coupled system will provide a platform by which the influence of external forcing components on tidal flat sediment processes can be isolated and elucidated.

RELATED PROJECTS

In this work we will be working closely with other investigators participating in the ONR tidal flats DRI. The key collaborators will be C. Sherwood and R. Signell (USGS, Woods Hole) who will be assisting with the development, implementation, and validation of CSTMS within FVCOM.

REFERENCES


