Relocatable Modeling Environment Applications in Coastal, Semi-Enclosed, and Marginal Seas

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LONG-TERM GOAL

To provide the Navy's R&D and operational communities with the means to rapidly relocate, test, and transition increasingly complex numerical models of coastal, semi-enclosed, and marginal seas that can be configured to run in any region of the world's oceans with relative ease.

OBJECTIVES

To complete the validation of the 2-D Colorado University (CU) Rapidly Relocatable Nested Tidal and Storm Surge (CURReNTSS) Model with the entire process integrated into a relocatable modeling environment (RME) provided under a graphical user interface (GUI), and begin the integration of a 3-D baroclinic tidal model into the same environment.

APPROACH

The many steps and logistics of setting up a relocatable numerical model in a new region of interest are quite tedious and labor intensive. Much of this effort can be simplified with modern computer technology. For example, in setting up CURReNTSS one needs to:

- Specify the domain
- Define the model grid and resolution
- Select the appropriate bathymetry database and extract the data
- Edit the bathymetry for errors, such as opening closed channels
- Select and extract ancillary data such as the IHO tidal station data
- Make sure that the stations fall on a grid over water instead of land
- Edit the ancillary data to correct errors
- Define the model boundaries
- Specify the model boundary conditions
- Generate the model header files
- Generate the model input and initialization files

Each of the above steps needs to be completed before the model can be run to obtain the first output. This process can consume anywhere from a couple of days to weeks depending on the complexity of the domain and data. For more complex 3D data assimilating circulation models there are even more steps involved. After the model run, the user is still faced with postprocessing the model output and managing them systematically. But if the above steps can be accomplished quickly, the time saved can be

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reinvested in understanding the oceanographic effects and in responding to Navy needs in a timely manner. In this complementary effort with the CU we proposed developing and testing appropriate tools under RME with a user-friendly GUI that will enable modelers to rapidly relocate ocean models in any region of the world. Two other key individuals in this effort were Mr. Shuvobroto Brahmachari, who conducted model runs, and Dr. Avichal Mehra, who served as a scientific modeling advisor.

WORK COMPLETED

The FY98 tasks, in conjunction with Colorado University, were as follows:

-Task 1: Complete the Validation of the 2D CURReNTSS Model. The fully integrated 2D model had already been validated against tidal station data and sea level observations, and only the barotropic currents needed to be validated [Mehra et. al., 1996]. To verify the model's ability to accurately predict barotropic tidal currents in two varied and complex regions of interest, validation exercises were performed with available observational data in the Yellow Sea and the North Atlantic Bight.

The barotropic influences weigh heavily in the coastal and shallow waters of the Yellow Sea. An enhanced version of the CURReNTSS model, which was now capable of assimilating altimetric tidal gage data (from TOPEX) for improved predictions of tidal elevations and currents, was implemented in the Yellow Sea at a resolution of 1/5 degree. The gridded domain extended from 117 to 131 E and from 24 to 41 N. The grid resolution resulted in a 71 by 86 grid. The bathymetry was interpolated from a 1/6 degree Korean topographical database and other high-resolution accurate databases provided by NAVOCEANO. The GUI provided data from 31 tidal stations which were assimilated into the model with a fixed weight parameter (0.9). Global results available via the GUI were used to set up the boundary conditions for the open boundaries (south and east) and eight primary linear tidal constituents were included, namely M2, S2, N2, K2, K1, O1, P1, and Q1. The model was run for 20 days and forcing was provided from astronomical tides alone. A time series of induced tidal currents was obtained from the model output and compared against observed tidal currents at the nearest available location.

The North Atlantic Bight boasts of some of the highest tidal ranges and fastest tidal currents in the world. CURReNTSS was run in a nested fashion at two resolutions. The larger coarser domain at 1/12 degree covered the entire Bight from 77 to 63 W and from 35 to 45 N. The nested high resolution fine grid at one minute resolution, which mainly covered the Bay of Fundy and some parts of Gulf of Maine, extended from 68 to 64 W and from 44.5 to 45.5 N. The coarse resolution model was run first for ten days with astronomical forcing alone. An accurate bathymetry was generated by fusing ETOPO5, half-minute NOS data, and an accurate (half-minute) USGS topographic database. The boundary conditions were provided from the GUI as before, and tidal station data from 144 gages in the region were assimilated into the model. The model results were saved at the boundary of the nested fine grid. Next, the fine grid model was run with boundary conditions provided from the encompassing coarse model for ten days under similar forcing. The predicted tidal currents at points fixed a priori were used to calculate tidal ellipses which were compared against published Moody charts data for the Bight.

-Task 2: Integration of the 3D Baroclinic Model. The 3D baroclinic model developed at CU under other ONR funding is a sigma-coordinate based, comprehensive physics 3D tidal model with data assimilation. It has been successfully used by NRL (in the Yellow Sea) and by NAVOCEANO (in the Persian Gulf) to provide estimates of tidal current structure in coastal, marginal, and semi-enclosed seas.

-Task 3: Validation and Comparison of ADCIRC Model. NAVOCEANO's ADCIRC Finite Element Model output was to be integrated into the RME for the purposes of model evaluation and comparison against available observational data. This was to be performed in close collaboration with NAVOCEANO.

RESULTS

Regards Task 1 for the Yellow Sea, the model results compared favorably with the observed values [Mehra et. al., 1998]. The predicted tidal current phases matched well though some discrepancies were found in the magnitudes. These can be attributed to the fact that the model value represents the average value of the current over the grid-cell and not at a fixed point in space. Also, the model predicts depth-averaged currents unlike the observations which were obtained at a fixed depth of approximately 70% of the total depth. For the North Atlantic Bight, the magnitudes of tidal ellipses (major and minor axes) matched well, as did the tidal current phases and tidal ellipse orientations.

Regards Task 2, the RME GUI developed initially to support the 2D barotropic tidal model (CURReNTSS) was enhanced to support the 3D baroclinic model. Additional functionalities were built to address 3D sigma co-ordinate grid generation and 3D pre-processing. The GUI was modified to interpolate a given bathymetry (default DBDB5) to a user defined 3D grid and also to interpolate Levitus '94 (annual or seasonal) data to the model grid for initialization. Enhancements were also made to reduce the time taken for the extraction of climatological fields from the Levitus database for a particular region. The 3D GUI allows a user to visualize and edit horizontal sections of the grid at various sigma (or z) levels and vertical sections at user specified latitudes and longitudes. Similarly, hydrographic fields (temperature and salinity) can be visualized along horizontal and vertical sections. To complete this task, the post-processing modules are being enhanced to provide a time series of velocity components and elevations at any specified level at pre-defined grid points, and animate snapshots of results at any sigma (or z) level or any specified vertical section. The existing post processing modules in the GUI already provided for tidal event logs and performed co-tidal and co-phase analyses.

Regards Task 3, because of a change of priorities at NAVOCEANO, which resulted in a decision to stop further development of ADCIRC in new regions, in favor of using CURReNTSS to meet NAVOCEANO operational needs for tidal predictions, there was no longer any Navy interest in completing this task. Accordingly, no work was expended in this effort by CAST. At present, ADCIRC complements the CURReNTSS model.

IMPACT/APPLICATIONS

The FY98 emphasis was to complete all tasks pertaining to the 2-D version of CURReNTSS which has now been fully validated, and begin the applications and validation of the 3-D baroclinic model. Both models use data assimilation to force realism and a relocatable-nestable capability has been provided under a GUI.

The comprehensive RME/GUI is a valuable tool for Navy modelers. In the long-term, all related numerical oceanographic and atmospheric models (tides, waves, surf, circulation, thermal, and forcing) that are regional or local in scale, will be integrated into the RME/GUI. This will not only improve their utility but will also significantly reduce the learning curve for Navy operational users.

TRANSITIONS

The 2-D tides and storm surge models, as well as an enhanced RME and GUI, have been implemented at NAVOCEANO. The RME, as a separate application, can also be used in a stand-alone mode to provide a GUI for editing bathymetry and tidal station data sets.

RELATED PROJECTS

Transition and implementation of the Tidal Relocatable Modeling Environment (RME) at the Naval Oceanographic Office under NASA Contract NAS13-564 Delivery Order 125 in 1997.

Model development research grants from ONR/NRL with Dr. Lakshmi Kantha of the University of Colorado.

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