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Title
Development of Nested 3-D Large Eddy Simulation Modeling of the Mobile Bay Estuary

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Research Category
Modeling

Project Period
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Objectives of the Research Project
Develop a large-scale comprehensive numerical model that can be used for simulating hydrodynamics and water quality of the Mobile Bay estuary. Such a model will be validated first by comparing with other model simulation results, and then by comparing with field measurement data of Mobile Bay, if those data are available at ACES. The model can be used to simulate circulation, tidal current, Mobile Bay flow in/out migration, ship channel deepening and effects of local land use change on circulation flow patterns. The model will also be applied, with the flow field as the base solutions, to simulate other transport phenomena in Mobile Bay such as sediment transport, specie transport, oxygen depletion and other biological activities.

Progress Summary
Numerical simulations of shallow water equations have been performed on both body-fitted coordinate systems and the Cartesian grids for a depth-averaged Mobile Bay model. The two-dimensional simulations were used to test the grid generation capability, particularly, for Cartesian grids which can be easily adapted for grid-nesting techniques. A semi-implicit algorithm has been used to solve a penta-diagonal system for water elevation. The performance of this method has been further improved when an alternating-direction-implicit technique is combined. A blended first- and second-order upwind approximation has been employed to discretize convection terms. Staggered grids have been used in these methods where each cell is numbered at its center.

A mechanism to automatically identify wetting and drying of computational cells was implemented with the Cartesian grid approach. This simplifies the computer algorithm in that the surface elevation equation can be applied to all points throughout the domain. The presence of islands and other permanently dry areas as well as tidal flats can be accounted for appropriately and automatically.

The following figures are for a test case of the Mobile Bay area using uniform Cartesian grids. The coastline and water depth data are searched out from the geographical data system produced by NOAA (Geophysical Data System for Hydrographic Survey Data, National Geophysical Data Center, National Ocean Services, NOAA, 9/04/98, Vols. 1 and 2). The search algorithm used the minimum-distance criterion to get the data on the grid points. The case is for the simulated ebb tidal condition. A sinusoidal wave is assumed for a tidal period of 24 hours. The magnitude of the tide is chosen to be 0.275 meter based on the NOAA observation data at Fort Gaines, Dauphin Island. Three to four periods have been simulated to reach the periodic solutions.

Figure 1 is the velocity vectors of the flow. The upper-left high-velocity region in Fig. 1 represents the Mobile River and Tensaw River area, and the upper-right high-velocity region represents the Blakeley River area. The inflow rates from these rivers were specified at their average flow rates. Another major river, Dog River, located on the mid-left coast line in Fig. 1, does not have inflow in this test case, because its average flow rate is very small. Figure 2 is the water elevation contours for the same case for the ebb.

Publications

"A Hydrodynamic Simulation for Mobile Bay Circulation," by Z. C. Zheng and N. Zhang, under review for publication in the Proceedings of the International Mechanical Engineering Congress 2002, New Orleans, LA, Nov., 2002.

Future Activities

The current computational program will be extended to include 3D, grid-nesting capabilities for Boussinesq or non-Boussinesq equation sets. In corporation with ACES, experimental data will be explored to validate the model. Other transport models for sediment and biological activities will also be integrated into the model.

Acknowledgments and Disclaimers

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Figure 1: Velocity vectors

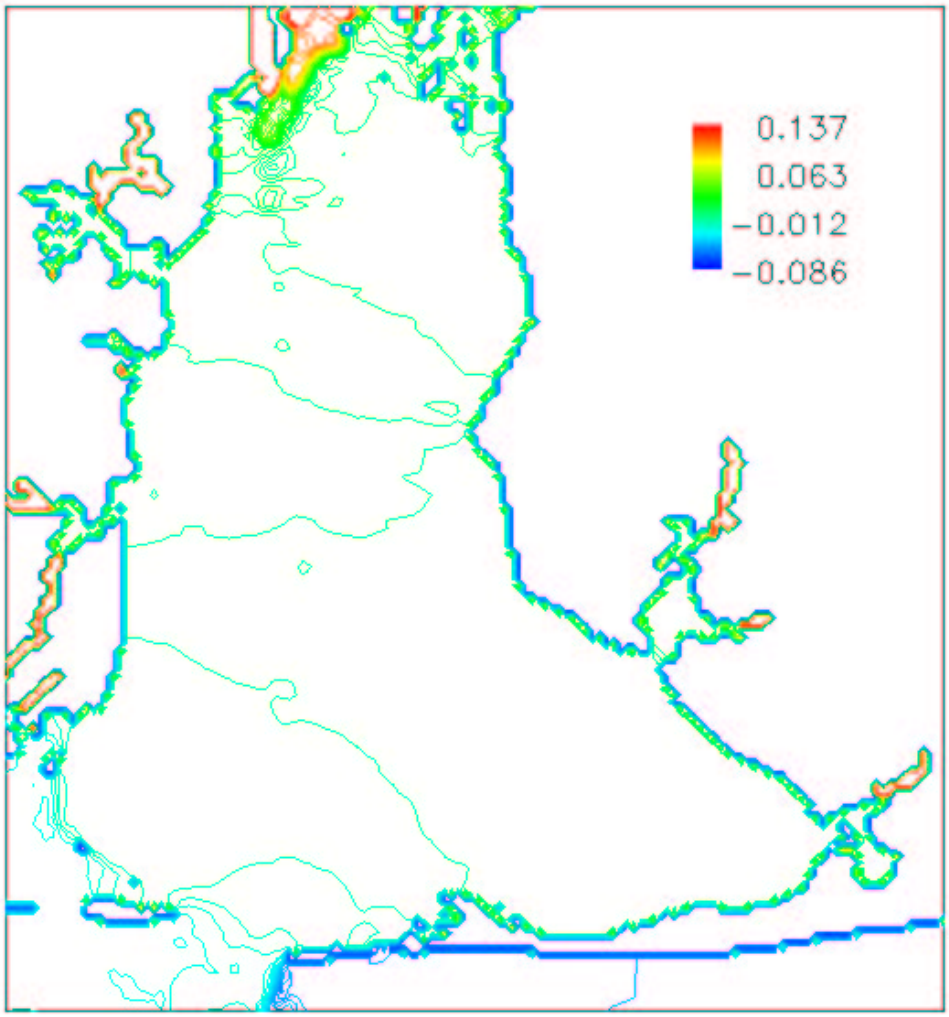

Figure 2: Elevation contours