Hydrodynamic Model of Lake Michigan Mass Balance (LMMB)

Primary Investigator: David Schwab - NOAA /GLERL

This project ended in 1999

Overview

This project is a part of the EPA sponsored Lake Michigan Mass Balance Study (LMMB). The purpose is to develop a hydrodynamic model to estimate the three-dimensional circulation in Lake Michigan at space and time scales adequate to resolve sediment resuspension and transport events. These events are important to determine the ultimate fate of toxic contaminants in the lake.

The objectives of this project are to (1) implement a three dimensional hydrodynamic model for Lake Michigan, (2) calibrate the model with GLERL current meter and thermistor data from the GLERL 1982-83 Lake Michigan field program, (3) use the model to simulate three dimensional transport and thermal structure in Lake Michigan during the 1993 mass balance study field season, and (4) couple the hydrodynamic model with a sediment resuspension and transport model being developed at the EPA Large Lakes Research Station (LLRS).

We are using a modified version of the Princeton Ocean Model (Blumberg and Mellor, 1987), a primitive equation numerical hydrodynamic circulation model, to calculate the three-dimensional current field in the lake. The model is based on the three-dimensional, nonlinear Navier-Stokes equations. It employs a terrain-following vertical coordinate (sigma coordinate) to provide high vertical resolution even in shallow areas. We will use observed meteorological data as the forcing function for the model. Over the past 5 years, the Princeton hydrodynamic model has been adapted for use in the Great Lakes and has been successfully applied to Lake Erie, both for long-term climatological simulations and for use in a real-time coastal forecasting system (see Project 1-1). The model will eventually be coupled with the EPA sediment deposition-resuspension-transport and fate model to assist in the mass balance calculations for Lake Michigan toxics.

1999 Plans

The results of the LMMBS hydrodynamic modeling program will be incorporated into several scientific papers.

1999 Accomplishments

The Hydrodynamic Modeling project started in 1993 and was completed in 1998. A final report on the results along with a series of CDROMs containing numerical and graphical representations of the results, as well as documentation of the computer programs, were delivered to EPA in November 1998. An FY 1999 First Quarter Milestone Report was submitted by David Schwab based on final report. One example of the output of the model is a comparison of a prediction of the thermal structure of Lake Michigan with observed data (Figure 1).

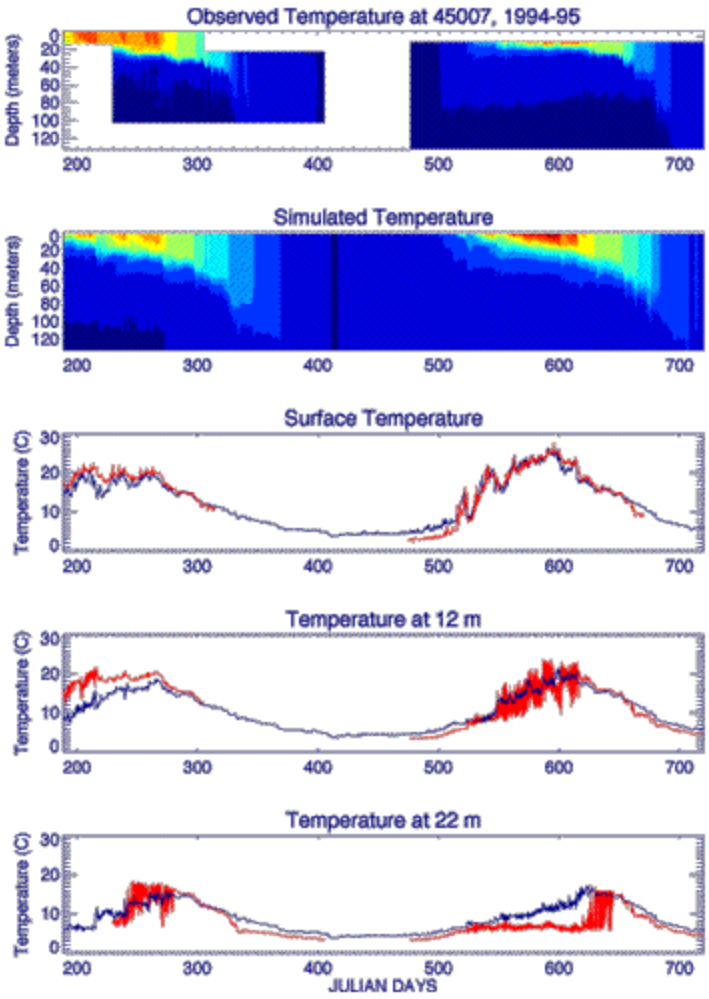

Figure 1: *Comparison between observed and computed thermal structure in Lake Michigan during Lake Michigan Mass Balance Study (1994-1995)*

1998 Accomplishments

A. 1994-95 5 km Simulation

We have re-assembled the meteorological data for the 1994-95 simulation and have eliminated some stations (mainly Coast Guard stations) that were not contributing to the fidelity of the interpolated meteorological data. We have re-run the wave model for this period. Calculated wave heights and periods match well with observations from NDBC buoys, indicating that interpolated wind speed and direction fields are good. Significant ice cover on Lake Michigan in the beginning of 1994 made it difficult to specify the initial temperature distribution field for the circulation model, so we have used a uniform lake temperature for the first 90 days of the model simulation. We then experimented with different initial conditions for the 3-d water temperature field on Julian day 91 of the 1994-95 hydrodynamic simulations. In particular, we compared model results obtained by assuming a uniform lake temperature on Julian day 91 with results

obtained by imposing a condition consisting of a surface water temperature derived from satellite imagery with different vertical distributions based on thermistor data. We also have analyzed the results of the 1994-95 simulation by comparing computed temperatures and currents to data from current meter moorings, buoys, shipboard CTD's, and municipal water intakes.

B. 1994-95 10 km Simulation

After a series of meetings with personnel from EPAs Large Lakes Research Station (LLRS), Gross Ile, MI and Corps of Engineers Waterways Experiment Station (WES) to discuss links between Level II water quality models and Level III hydrodynamic models, it was decided to develop a coarser resolution Level III grid that could also be used for water quality simulations. Therefore, we developed a 10 km Lake Michigan grid and the appropriate forcing and initial condition fields for this purpose. The computer code and associated files were transferred to WES for their use in developing the links to LLRS water quality models.

Products

We have provided a complete set of preliminary gridded meteorological data and wave model output to D. Endicott at LLRS, J. DePinto at SUNY Buffalo, J. Keeler at University of Michigan, Ann Arbor, and E. Cooter at NOAA RTP. During 1997 we provided considerable advice on the interpretation and use of this data. Output from the wave model was provided to N. Hawley for his use in analyzing transparency measurements from his tripods. We also provided ice cover and thermal structure data to J. Keeler's students, and a copy of the all the 10 km circulation model files to J. DePinto's student. In addition we provided a copy of a 3-d particle transport code we developed for the lake circulation model to M. Settles, LLRS, and worked with him on implementing this code at LLRS.

A final report on the LMMBS hydrodynamic modeling program was delivered to EPA. The report consisted of a descriptive text with some examples of the results, plus a CD-ROM with graphics of all the model inputs and outputs and data comparisons.

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