

Measurement and Modeling of Wave-induced Sediment Resuspension in Nearshore Water

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Overview

To date, this project has concentrated on analyzing the extensive set of observations collected in 1998-2000. Subsurface pressure sensors were deployed during the unstratified period at various locations in southern Lake Michigan to measure the heights and periods of surface waves. Measurements of bottom current velocity and suspended sediment concentration were also made. Analysis of that data is now well advanced, and the effort will shift toward:

1. Analyzing additional data collected since 2000.
2. Incorporating the resuspension model developed previously into the lake circulation model.

The resulting sediment transport model will be used to determine how well sediment transport paths can be simulated and to determine how sensitive the model is to different conditions of sediment availability.

Proposed Work

The resuspension model developed in 2004 will be incorporated into the 2d lake circulation model. The resulting model will then be run for different scenarios to determine how well the model can 1) simulate large-scale advection of suspended sediment in the lake, and 2) simulate sediment resuspension and transport under different conditions of sediment availability.

Revision of 2 previously submitted manuscripts - one describing the 1998-2000 data, and the other describing the fall 2003 data - will be completed, and analysis of the 2004 data will begin. Analysis of the 2004 data set will concentrate on the effects of temporal changes in particle size during resuspension events.

Accomplishments

Field measurements were used to test the sensitivity of a simple two-dimensional sediment transport model for Lake Michigan. The analysis was completed and a manuscript describing the results was submitted. The model was applied to several transects in southern Lake Michigan using observations of waves and currents recorded during the spring of 2000. Conditions during this period included several storms that are among the largest observed in the lake. The results show that changing the physical forcing (waves and currents) or the initial bottom sediment size distribution affected the results more than varying the particle properties or the size classes used to describe the sediment size distribution. The results indicate that a relatively simple sediment transport model should produce reasonably accurate simulations of

suspended transport in the lake, and that further improvements in specifying the input parameters are more likely to increase the accuracy than including other sediment processes, such as flocculation and bed consolidation.

Surface wave parameters derived from subsurface pressure measurements at 6 sites (Fig. 1) were compared to those measured by either acoustic doppler current profilers or surface buoys. The preliminary results show that although the algorithm derived last year does a good job of determining the significant wave height (Fig. 2a) it does a poorer job of determining the peak energy wave period (Fig. 2b). Because the data were collected primarily during the summer and early fall, relatively few measurements of large waves are available. To remedy this we have deployed a mooring in Lake Huron (x) that will make measurements throughout the coming winter.

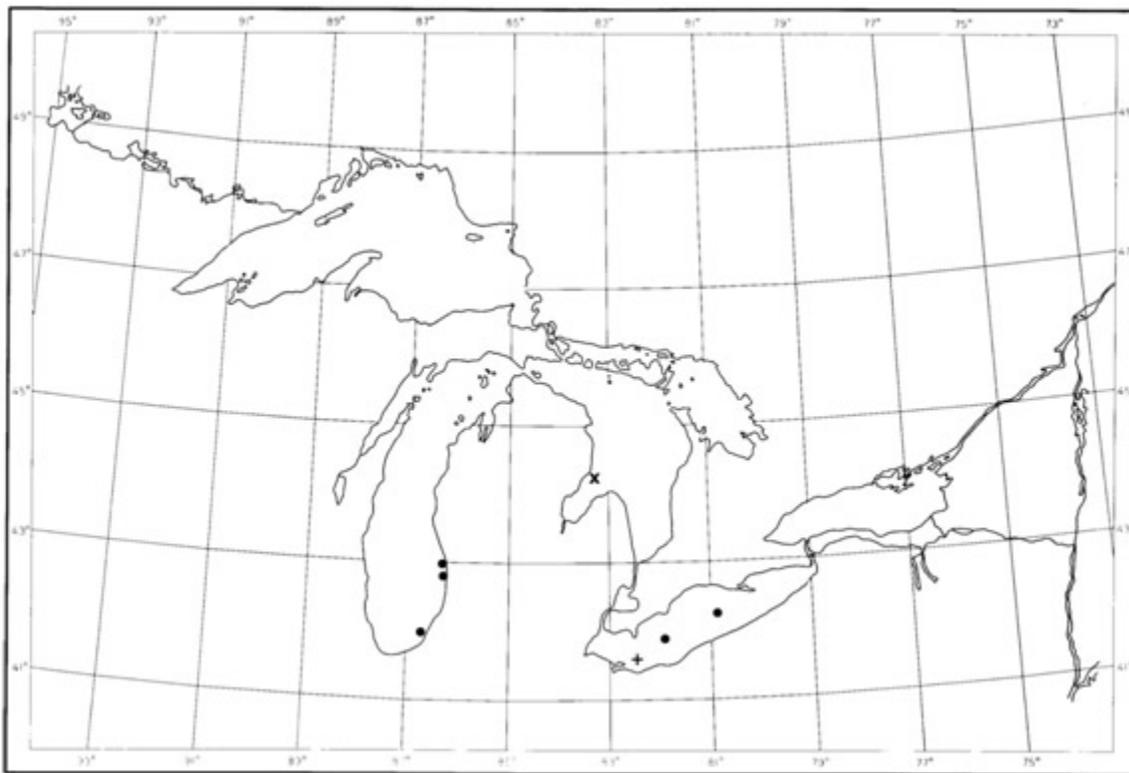


Figure 1: The dots indicate sites where waves were measured with adcps, the cross is the site where waves were measured with a surface buoy. The x is the site where measurements are begin made during the winter of 2008-2009.

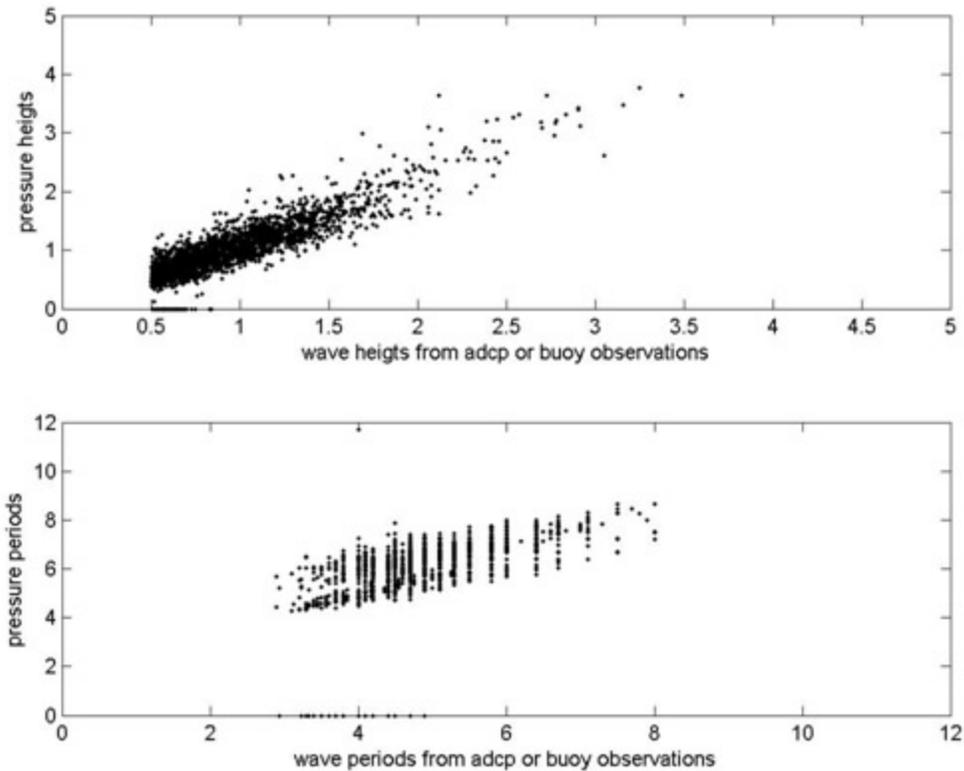


Figure 2: Comparison of wave parameters derived from subsurface pressure measurements (Y axis) to those obtained from either acoustic doppler current profilers or surface buoys (X axis).

A 2005 fall deployment in Lake Michigan was made in conjunction with Dr. Chin Wu from the University of Wisconsin in order to examine in detail the vertical distribution of resuspended sediments. An analysis of the fall 2003 deployment was completed. The results appear to show that the vertical distribution of sediment does not increase with increasing distance from the bottom. This is probably due to a change in the particle size with elevation.

An evaluation of the ability of the GLERL-Donelan wave model to predict resuspension events was completed. The results from 15 deployments (Fig. 5) show that although the errors introduced by using modeled wave parameters in place of observed waves can be almost completely compensated for by adjusting the resuspension coefficient in the resuspension model, the computed concentrations are frequently quite different from the observed sediment concentrations (Fig. 3). In addition, the values of this coefficient must be determined empirically for each site, since at present there is no way to predict the coefficient from either the water depth or the properties of the bottom sediment (Fig. 4). The results also show that most of the resuspended sediment is silt-sized (less than 0.06 mm) even in areas where silt-sized material is absent from the bottom sediment.

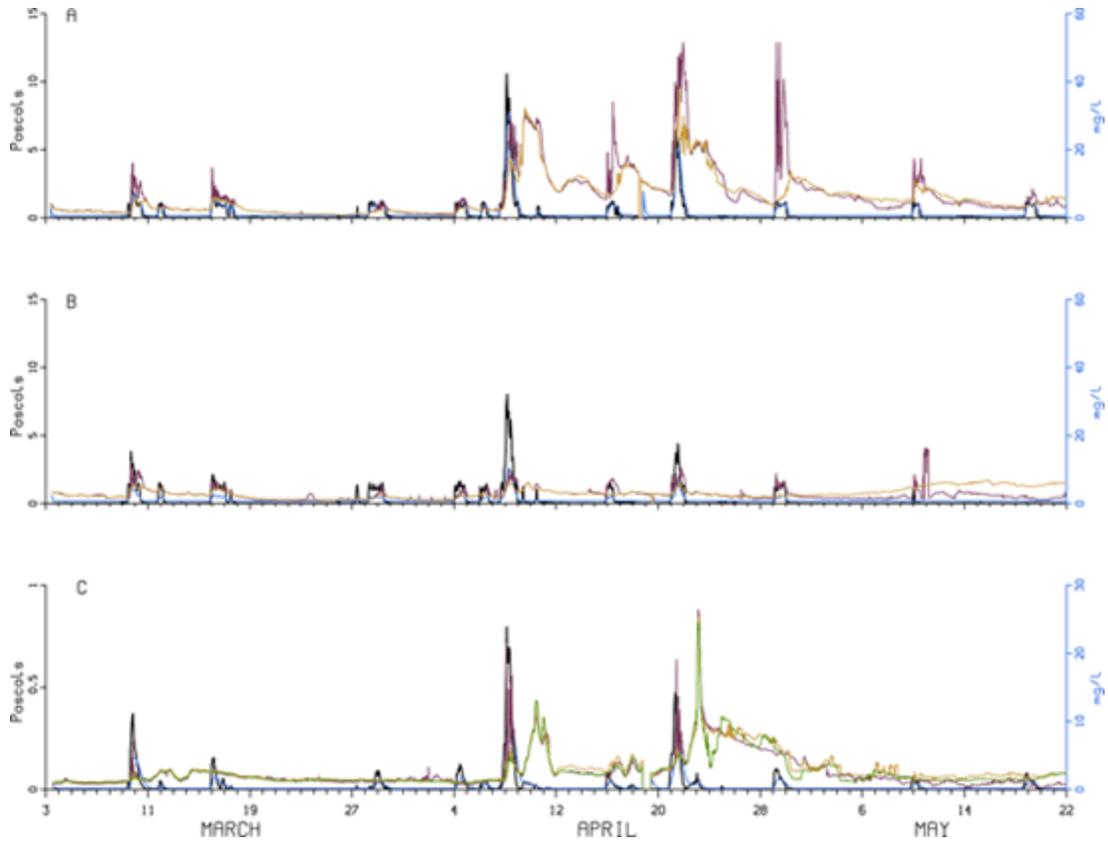


Figure 3: Results from stations M04 (A), M09(B), and M11 (C). All observations were made in 2000. The black line is the bottom stress, the blue line the modeled sediment concentration near the bottom, the red line the observed concentration near the bottom, the yellow line the observed concentration 10 meters above the bottom, and the green line (M11 only), the observed concentration 25 meters above the bottom.

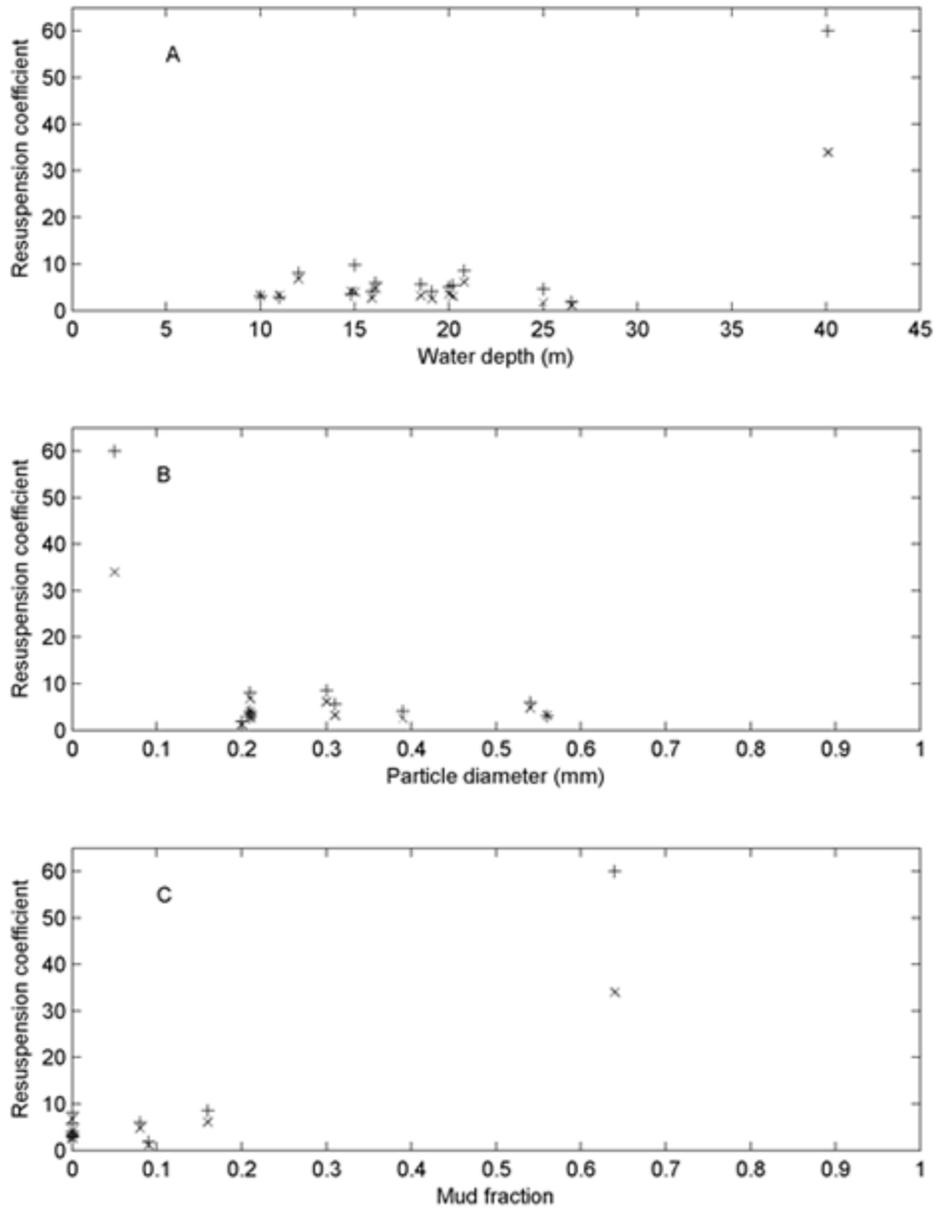


Figure 4: Resuspension coefficients based on the observed (x) and modeled (+) wave parameters for all of the deployments compared to the water depth(A), mean particle diameter of the bed material (B), and mud fraction of the bottom sediment(C).

Scientific Rationale

In shallow water (up to about 30-40 m depth) surface waves are the primary cause of sediment resuspension; accurate modeling of wave-induced resuspension is necessary if a lakewide sediment transport model is to be developed. Deployments of tripods instrumented with sensors to make time series measurements of subsurface pressure (to measure the height and period of surface waves), bottom current velocity, and suspended sediment concentration were made at various locations around the southern basin of Lake Michigan in 1998-2000. Our analysis shows that a simple vertically-averaged model of sediment resuspension does a good job of simulating resuspension events. However, the observations also show numerous periods of high sediment concentration when no resuspension occurs. These episodes are almost certainly due in large part to advection of material resuspended elsewhere and then transported past the mooring sites. One of the current goals of this research is to determine how important advection of suspended sediment is, and how well the model can simulate these movements.

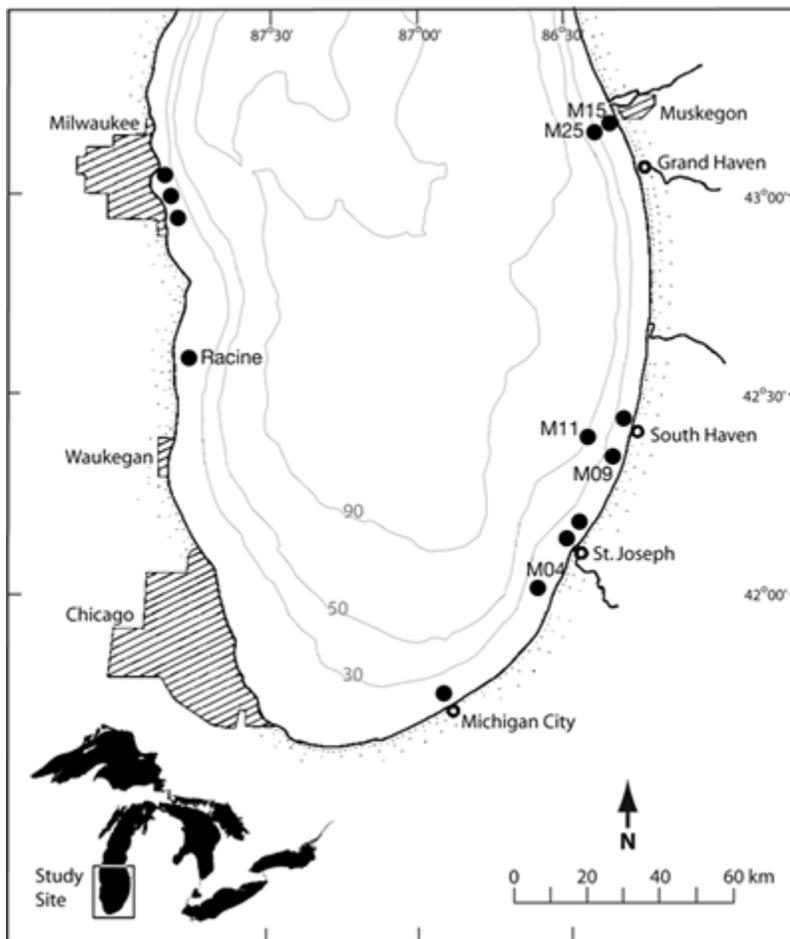


Figure 5: Locations of deployments between 1998-2000.

Products

Publications

Hawley, N., Lesht, B.M., and Harris, C.A., Sensitivity of a sediment transport model for Lake Michigan, submitted to *Journal of Great Lakes Research*. (In Review)

Eadie, B. J., D. J. Schwab, T. H. Johengen, P. J. Lavrentyev, G. S. Miller, R. E. Holland, G. A. Leshkevich, M. B. Lansing, N. R. Morehead, J. A. Robbins, N. Hawley, D. N. Edgington, and P. L. Van Hoof. Particle transport, nutrient cycling, and algal community structure associated with a major winter-spring sediment resuspension event in southern Lake Michigan. *Journal of Great Lakes Research* 28(3):324-337 (2002).

Hawley, N., B. M. Lesht, and D. J. Schwab. A comparison of observed and modeled surface waves in southern Lake Michigan and the implications for models of sediment resuspension. *Journal of Geophysical Research* 109(C10S03):11 (2004).

Lee, C.-H., D. J. Schwab, and N. Hawley. Sensitivity analysis of sediment resuspension parameters in coastal area of southern Lake Michigan. *Journal of Geophysical Research* 110(C03004):16 (2005).

Lesht, B.M., and Hawley, N., 2001. Using wave statistics to drive a simple sediment transport model, *Proceedings of the 5th Conference on Ocean Wave Measurement and Analysis*, 1366-1375.

Liu, P. C., and N. Hawley. Wave grouping characteristics in nearshore Great Lakes II. *Ocean Engineering* 29:1415-1425 (2002).