Annual Report

Period Covered by the Report: 9/01/01-12/30/02

Date of Report: 1/25/03

Title: Characteristics of Ship Waves and Wind Waves in Mobile Bay

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Research Category: Water/Engineering

Project Period: 9/01/01-2/30/03

Objectives of the Research Project:

Mobile Bay is a relatively wide and very shallow estuary. The natural forcing of high-speed winds associated with storms and hurricanes can generate surface waves that are responsible for the loss of wetlands and habitats in Mobile Bay. The wind waves generated by the frequent, moderate wind speed may be significant to the sedimentary dynamics of Mobile Bay. On the other hand, the large volume of ship traffic through the deep ship channel and in the Port of Mobile can also generate surface waves that could have the similar impacts as the wind waves do. In comparison with the understanding of wind waves, however, little is known about the characteristics of the ship waves in Mobile Bay. Furthermore, the effects of the surface waves caused by either winds or ships on the sediment suspension or the turbidity in this shallow estuary are virtually unknown.

The long-term goal of the study is to quantify the natural and human-induced impacts on the physical processes in Mobile Bay and to understand the consequences of those impacts on the ecosystems and habitats. The specific objectives of the project are to develop a platform for the investigation of wave processes in the Mobile Bay estuary, and to characterize the surface waves generated by the natural forcing of episodic winds (storms and hurricanes) and sustained winds (with the most frequent occurrence of wind speed and direction) as well as by the human activity of cargo transport. This will allow us to compare the impacts of both types of surface wave on sediment suspension and alongshore sediment transport in Mobile Bay.

Progress Summary/Accomplishments:

Significant progress has been made in developing a platform for modeling the wind waves and ship waves in Mobile Bay. Work completed includes mining and analysis of the wind, wave, ship, and bathymetric data collected in the Mobile Bay estuary, development of curvilinear grids of the entire Mobile Bay estuary for numerical computations of surface waves and currents, and setup of a state-of-the-art wave model, SWAN (Simulating WAves Nearshore) for the Mobile Bay estuary. Verification of the SWAN model against the wind wave data collected in Mobile Bay has been carried out. A graduate research assistant has been working on the project under the PI's direction since February 2002.

First, we obtained the wind wave data collected by the USGS (Pendygraft and Gelfenbaum, 1994). Because no electronic form of the data is available, we have digitized the plots of wind speed, wind direction, wave height, wave period, and water depth in the USGS report. An analysis of the data has led to the selection of a dozen representative events for the calibration and verification of the numerical model. These digitized data sets are valuable for the study of wind waves in Mobile Bay. We also obtained the bathymetric data of Mobile Bay and its adjacent area from the Northern Gulf of Mexico Littoral Initiative (NGLI) program and the National Ocean Service (NOS) Hydrographic Survey Data. Data reduction and interpolation were carried out to determine the water depth at each point on the curvilinear grids for Mobile Bay. The bathymetry on the curvilinear grid of Mobile Bay will serve as the basis not only for wave modeling, but also for simulations of wind-driven circulation in the Mobile Bay estuary. In addition to the surface wave and bathymetric data, we have obtained an access to the vessel/barge data via Captain Dave Carey, harbormaster at the Port of Mobile.

In order to set up a numerical model for the prediction of surface waves and currents in Mobile Bay, computational grids need to be generated. Traditionally, rectangular grids with fixed grid spacing are used for numerical models based on finite difference methods. Though this type of grid is easy to generate, it is not suitable for modeling waves and currents in shallow estuaries, such as Mobile Bay, where the geometry of the shoreline is rather complex and there often exist deep ship channels. Moreover, the shallow water depth near the shoreline requires very fine resolution in the near-shore areas where detailed wave information is needed in order to mitigate wetland losses and shore erosion. Consequently, modeling waves and currents in estuaries needs computational grids that are able to fit the complex boundaries and provide fine enough resolution near the shoreline and ship channels. As part of the wave modeling effort of the project, we have developed methods to generate such curvilinear computational girds for the Mobile Bay estuary. Figures 1a and b respectively show the bathymetry and a computational grid for Mobile Bay. Notice that such a grid can be used not only for wave modeling, but also for the simulation of estuarine circulation that interacts with the surface waves.

With the bathymetry data in place and the development of the curvilinear grids, we set up the state-of-the-art, third generation wave model, SWAN for Mobile Bay. The model successfully simulates the significant wave height and peak wave periods measured at the mid bay location indicated by the star in Figure 1b under non-stationary wind conditions. Good agreement between the model results and measurements has been found. Figures 2a and b illustrate a snapshot of the modeled wave field in the entire Mobile Bay estuary during a wind event. The colors and contours indicate the spatial distributions of the predicted significant wave height and peak wave periods. The arrows depict the mean wave direction at each location. A northerly wind drives this wave field and the measured wind speed at 10 m above the water surface is 15 m/s. Figures 3 illustrate the comparisons of the SWAN predictions and measurements.

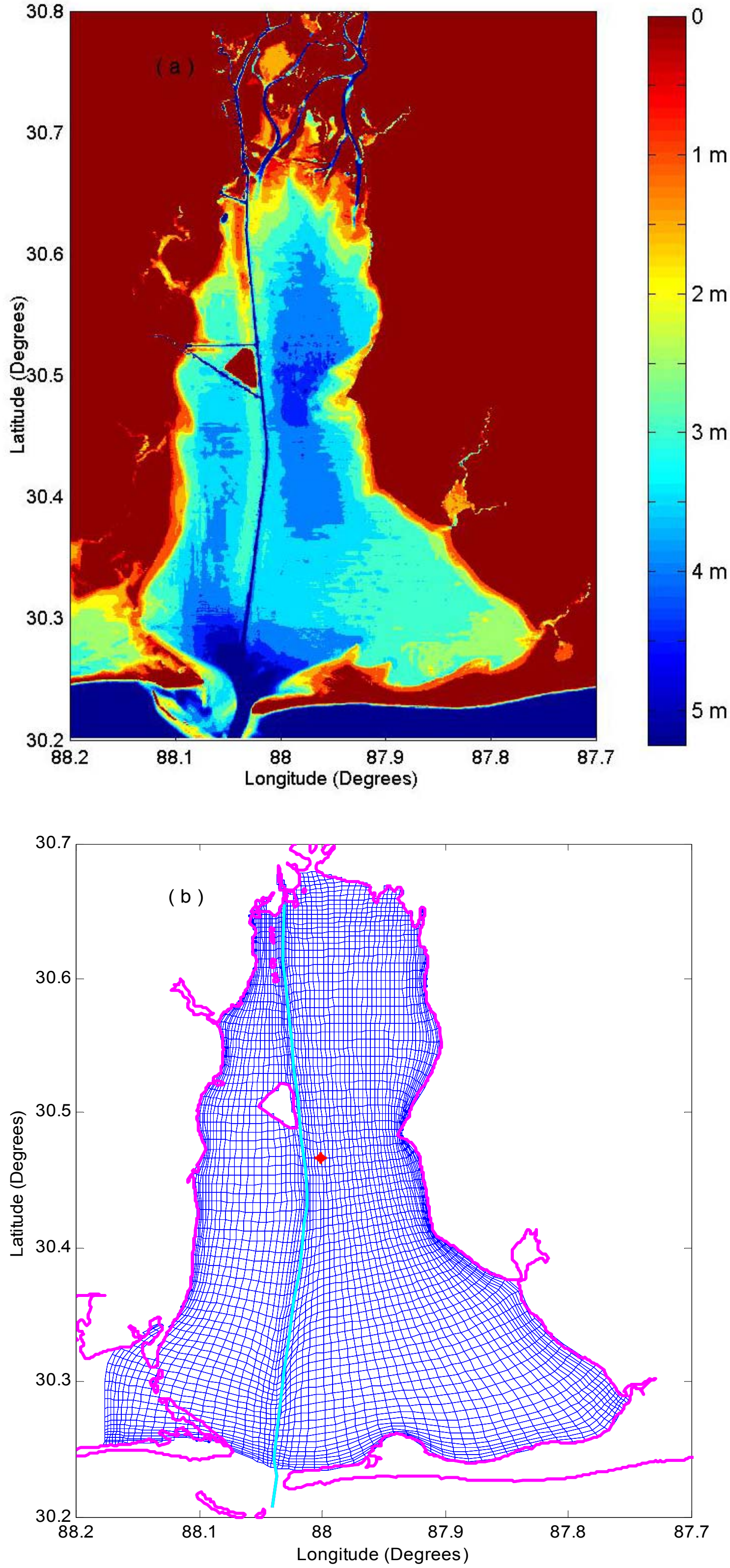

Figure 1. (a) Bathymetry in Mobile Bay, (b) curvilinear grids with varying spacing.

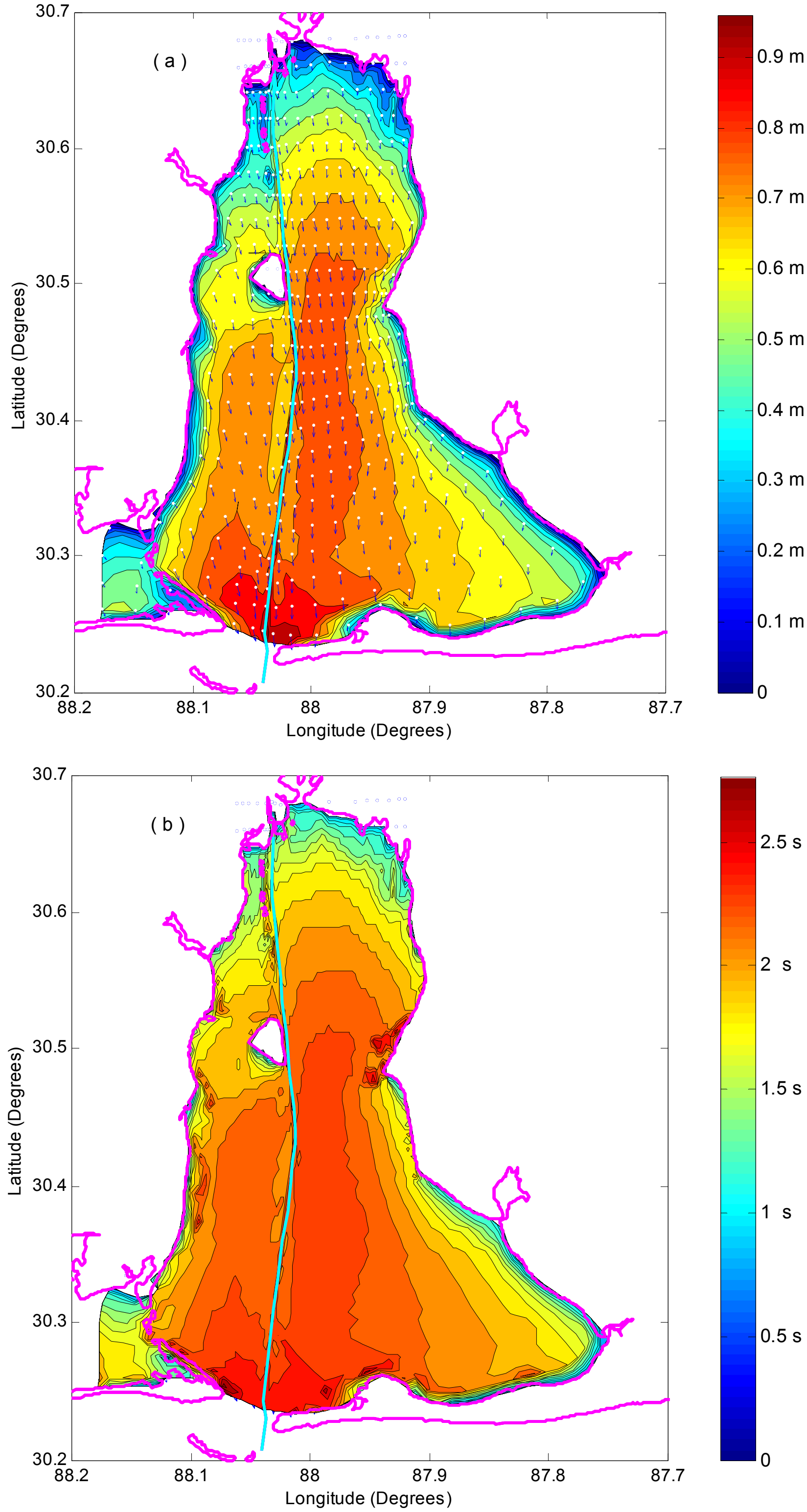

Figure 2. (a) Distribution of modeled significant wave height (contours) and mean wave directions (arrows), (b) distribution of average wave periods. The blue lines represent the ship channel.

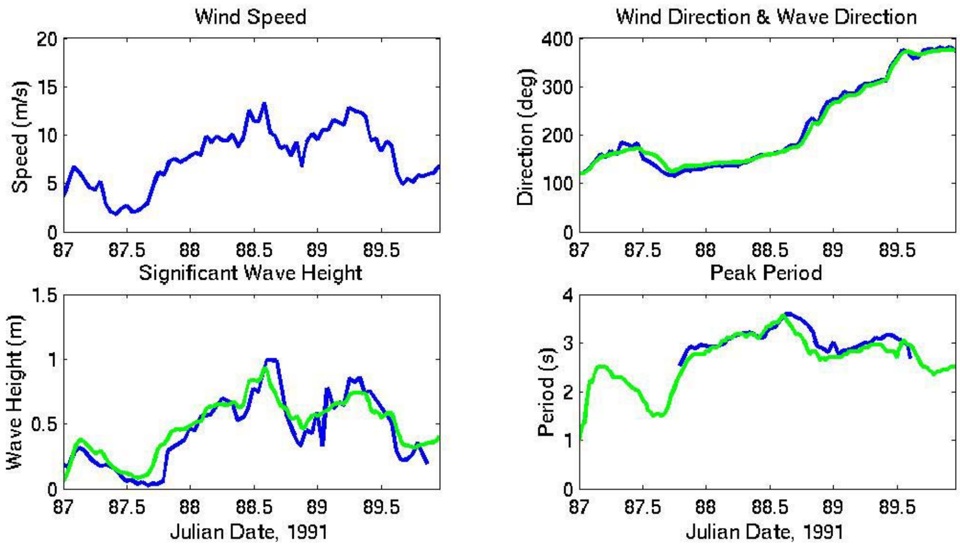

Figure 3. Measured (blue lines) wind speed and direction, measured and computed (green lines) significant wave heights and wave periods, and computed wave direction. (Chen et al., 2002)

In addition to the comparison with the field data, the SWAN model was also tested against laboratory experiment. Figure 4 shows a computational grid over a laboratory wave basin with a circular shoal on an otherwise flat bottom. The physical experiment on wave propagation over the shoal was conducted at the University of Delaware. We tested SWAN against the laboratory data collected at seven instrument arrays A to G, where the small circles indicate the wave gage locations. The large circle in Figure 4 represented the footprint of the circular shoal. Directional, random waves were generated at the south boundary and propagated northward in the absence of wind forcing. The computational grid for the wave prediction model features finer resolution on top of the shoal in order to resolve the large gradients of the water depth and wave field.

Figure 5 depicts model/data comparisons at those seven arrays. Circles are the measurements and solid lines are the model results given by SWAN. Excellent agreement is found. In comparison to the model prediction given by a rectangular computational grid, it was found that the curvilinear grid agrees better with the data in the area near the top of the shoal. This demonstrates that curvilinear grids with variable grid spacing are superior to rectangular grids with fixed grid spacing wherever there are large gradients of water depth or wave field. The test supports the PI's choice of curvilinear computational grid in the present study to develop a wave model for the entire Mobile Bay where abrupt changes in water depth do exist.

With this model, we are not only capable of predicting the wind wave fields in Mobile Bay with remarkable accuracy, but also able to simulate the propagation of vessel wakes by splitting Mobile Bay into the eastern and western bays about the ship channel and specifying the wakes as a boundary condition along the ship channel. The validated numerical model will serve as a platform for the study of the wave dynamics in Mobile Bay. A direct, practical application of this model is the development of a wave atlas for Mobile Bay on the basis of the wind statistics at Dauphin Island.

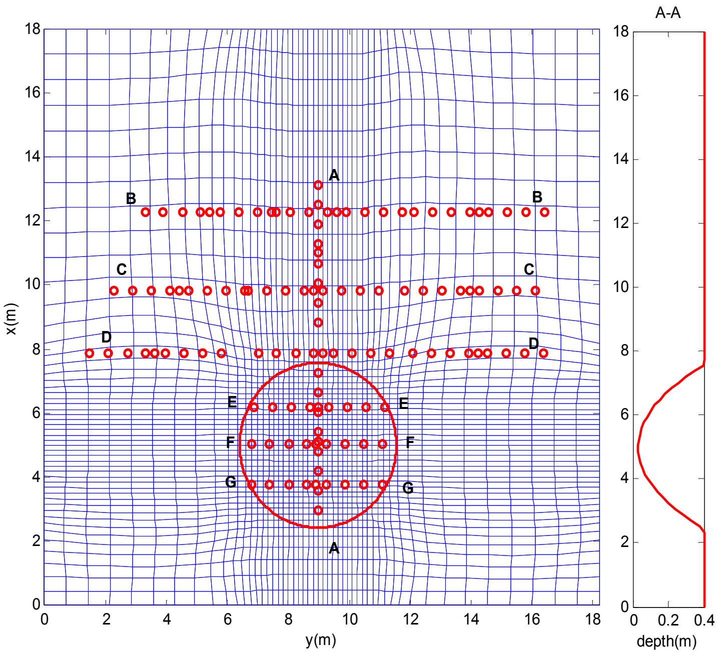

Figure 4. Computational girds for wave propagation over a circular shoal in the laboratory. Small circles indicate the measurement locations. The large circle is the footprint of the circular shoal on an otherwise flat bottom. (Chen et al., 2003)

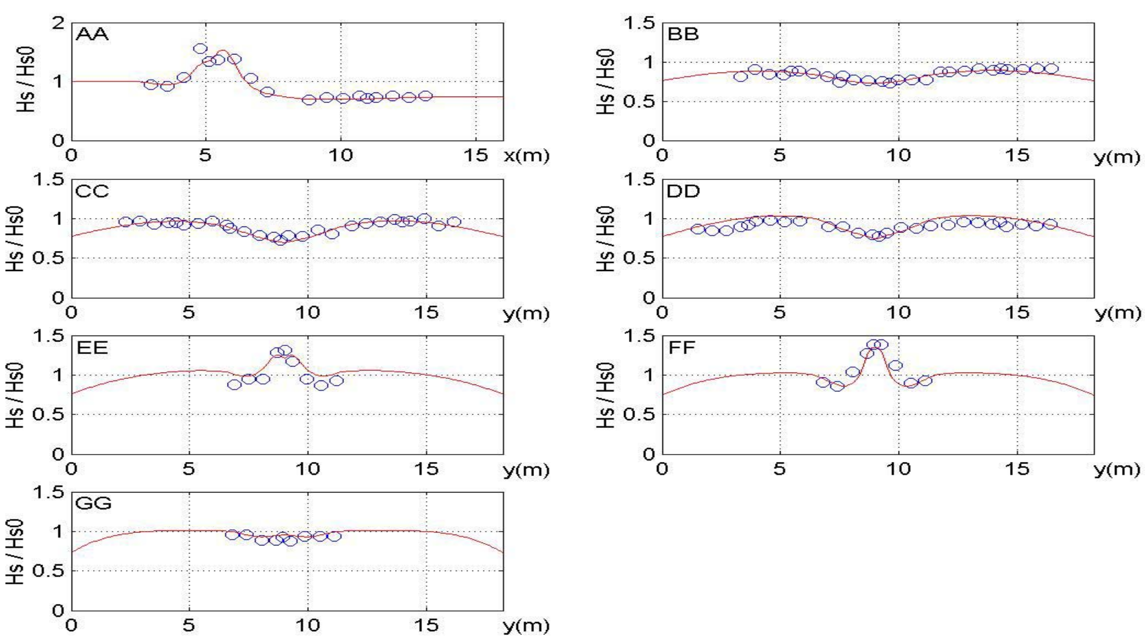

Figure 5. Model (solid lines) and data (circles) comparisons at seven transects. (Chen et al., 2003)

A journal article is under preparation based on the results of the project. Findings of this research have been presented at the Dauphin Island Sea Lab and the American Geophysical Union Fall Meeting in San Francisco in 2002.

Publications/Presentations:

Chen, Q., Hu, K. and Douglass, S. L., 2002. Characteristics of ship waves and wind waves in Mobile Bay. *Dauphin Island Sea Lab.*

Chen, Q., Hu, K., Douglass, S. L., and Zhao, H., 2002. A test of the curvilinear SWAN model under unsteady conditions. *EOS, Transactions AGU.*

Chen, Q., Hu, K., Douglass, S. L, and Zhao, H., 2003. Prediction of wind waves in shallow estuaries. Prepared for *Journal of Waterway, Port, Coastal and Ocean Engineering.*

Future Activities:

The PI has filed a request for an 8-month no-cost extension, from June 30, 2002 to February 30, 2003, for this project. The PI has also redirected the funds for his salary and fringe benefits to supporting a graduate research assistant. The final report of the project will include

1) Mining and Analysis of more vessels data
2) Simulations of ship wave propagation from the ship channel to the shoreline

Supplemental Keywords: None

Relevant Web Sites:

http://www.southalabama.edu/civileng/douglass/index.htm

Acknowledgments and disclaimers

This research has been supported by a grant from the U.S. Environmental Protection Agency's Science to Achieve Results (STAR) program.

Although the research described in the article has been funded wholly or in part by the U.S. Environmental Protection Agency's STAR program through grant (F-827072-01-1), it has not been subjected to any EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.