DEVELOPMENT OF A STORM SURGE PREDICTION SCHEME, COUPLING WIND, AND WAVE FORCING using ADCIRC

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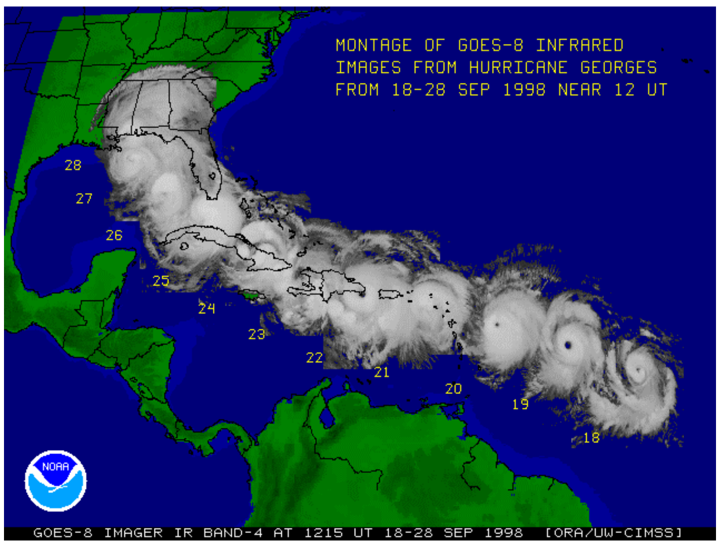
PROJECT OVERVIEW

The work presented is our part in the NOPP project titled, "Real – Time Forecasting System of Winds, Waves and Surge from Tropical Cyclones" (Graber et al., 2002) .



Hurricane Georges swept over the Caribbean and through the Gulf of Mexico. We are performing various hind-casts of the storm using the Advanced Circulation Model for Shelves, Coastal Seas and Estuaries (ADCIRC) (Leuttich and Westerink), attempting to recreate in our models the water levels that were measured at the shore during the hurricane. In order to do this we must have an appreciation for which parameters and forcing have an effect on the water level. For those that do have an effect, we must also have an idea to what degree they influence the change in water level.

There are two types of parameters we must look at, those present in the natural domain (drag coefficient, friction coefficient, etc.), and those present in our models (grid size and resolution, time step, etc.). For the latter, we concentrated our sensitivity tests on grid resolution, and used a corresponding time step for which the model was stable. For the physical parameters we concentrated on testing the drag coefficient. We have tested two types of forcing, wind and pressure, and are in the process of testing the effects of adding wave forcing to these. The final step is to incorporate the effects of tides for a complete set of forcing.

The real interest here is in coupling the different forcing with the ADCIRC model to create the most realistic forecasts. The data we are attempting to match is given below, in table 1, as ranges of surge. We are trying to first get results in the desired range, and then work out location specific surge levels.

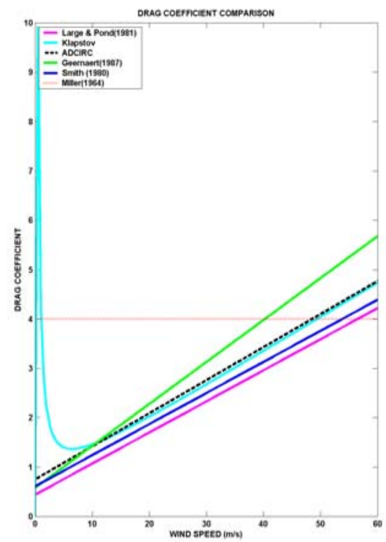
Storm Surge Estimates

Louisiana & Mississippi coasts: 1.5 to 2.7 m
(max at Point La Hache, LA and Point Cadet, MS)

Alabama coast:	1.5 to 3.6 m
Mobile County:	1.5 to 3.0 m
Baldwin County:	2.1 to 3.6 m
Florida Panhandle:	1.5 to 3.0 m

***Table 1**. Values of the estimated storm surge levels for various locations during hurricane Georges*

SENSITIVITY TESTS
Drag Coefficient



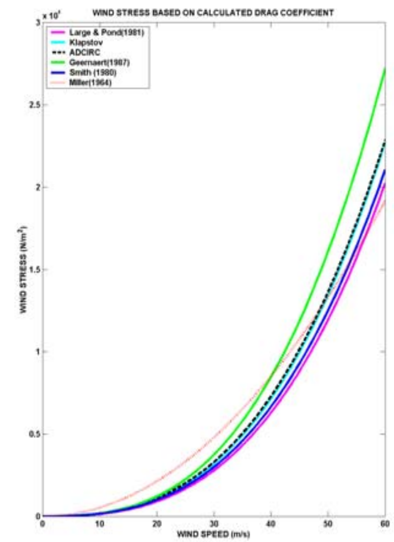


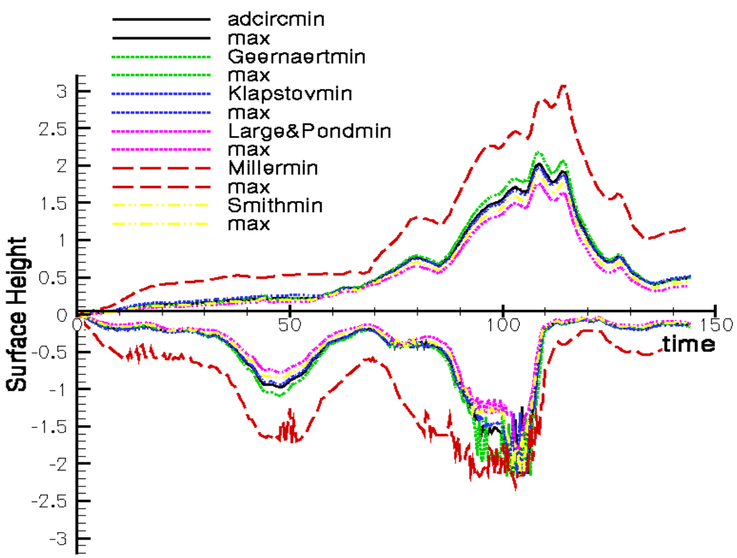
***Figure 1**. Drag Coefficient vs. Wind Speed; The different formulas for the Drag Coefficient are given above.*

***Figure 2**. Wind Stress magnitude vs. Wind Speed; where:* Wind Stress $= C_D * |u| * \mathbf{u}$

One of the first parameters we checked was the Coefficient of Drag for the wind stress calculation. We tested six different Drag Coefficients (Table 2). Five came from *Geerneart, et al., Surface Waves and Fluxes, Vol. 1, 91-172,* the sixth was the formula currently used in the *ADCIRC* model.

For open ocean applications the results of Large & Pond (1981) and Smith (1980) are currently most widely used. We picked Geernaert since we got these formulas from his book. Klapstov has suggested a general purpose formula (where we took Ta-Ts = -1 as per buoy data for the storm. This could be read in for each time period and a more accurate estimate obtained). Miller (1980) seems to be the maximum value accepted, and has been inferred using the geostrophic technique for wind speeds of 52 m/s.

These five were compared to the formula currently used by ADCIRC, and the results plotted in Figures 1 and 2 (above). The surge levels corresponding with each drag coefficient were calculated, using the ADCIRC model.

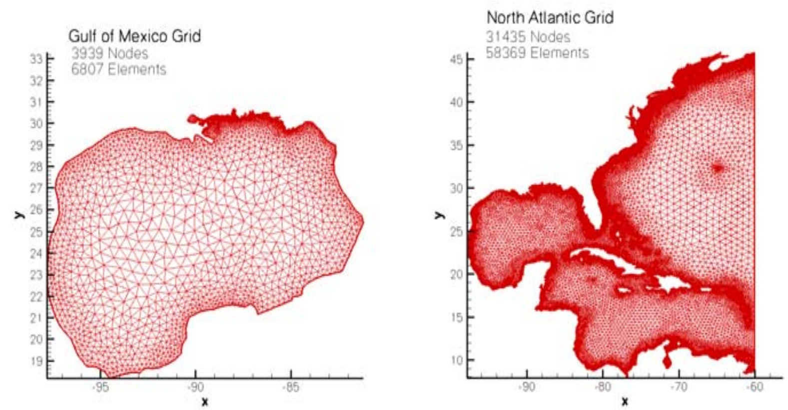


Surge Comparison – Hurricane Georges

Figure 3*. Plots of the Maximum and Minimum water levels for the five different drag coefficients*

SENSITIVITY TESTS
Grid Resolution

The second goal was to test the sensitivity of the model to the grid resolution. A lower resolution grid would reduce the computational time. So it is of interest to see how the maximum and minimum water levels are affected by this parameter. We used two grids, and they are presented below in Figures 4 and 5.



Figures 4 &5. The finite element grids used for comparing grid resolution.

For each grid we ran the same parameters through ADCIRC and, after some post-processing, were able to plot out the maximum and minimum water levels on each grid. The results are shown in Figure 6, below. We increase our surge levels, bringing them closer to measured values, by increasing our grid resolution. With the speed of today's computers it is worthwhile to use a finely resolved grid in order to produce an accurate result. A typical 72 hour surge forecast takes about 2 hours of CPU time.

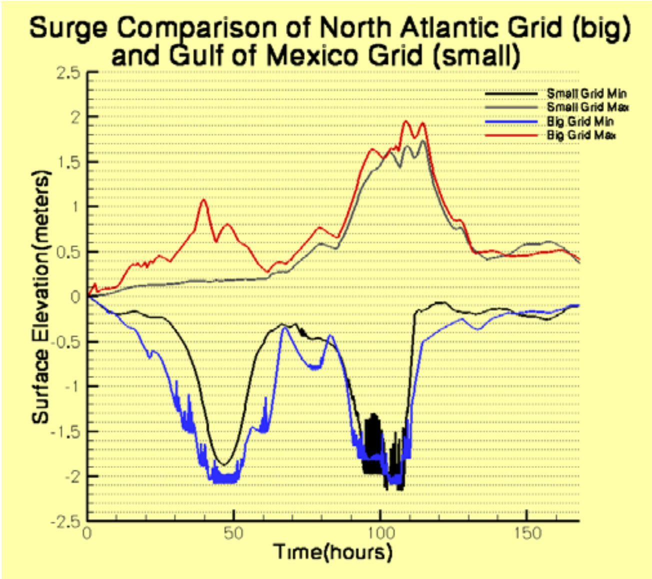


Figure 6. *Comparison of the maximum and minimum water levels produced by the two grids*

Wind Stress C_D Formulations

Authors	$10^3 C_p$
ADCIRC	0.75 + 0.067 * |u|
Large & Pond (1981)	0.44 + 0.063 * |u|
Geernaert (1987)	0.58 + 0.085 * |u|
Smith (1980)	0.61 + 0.063 * |u|
Miller (1964)	4.0
Klapstov	0.49 + 0.07 * |u| + 2.58 / |u| - 1.06 * (Tair-Tsfc) / |u| ^2

Table 2. *The five formulas used to test the sensitivity of the model to the value of the drag coefficient*

FORCING COMPARISONS
Wind and Pressure

Using the North Atlantic Grid and wind data, we ran the model with and without including the atmospheric pressure. We then compiled a pressure field from a series of pressure field data files assimilated by NOPP partner Oceanweather, Inc. These files consist of pressure readings and forecast values. That pressure set was then added to the wind forcing file and a third model run was made. As can be seen below the surge levels for spatially invariant zero pressure and pressure of 1014 Mb are the same. There is a noticable change in the levels of surge when the full pressure field is added (Figure 7).

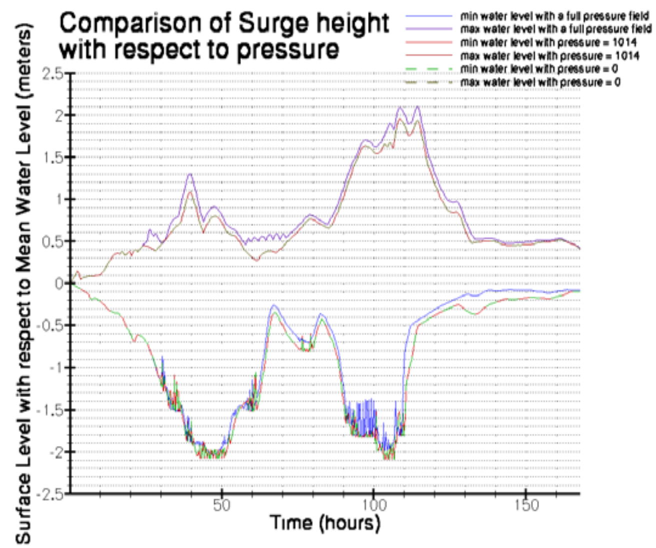
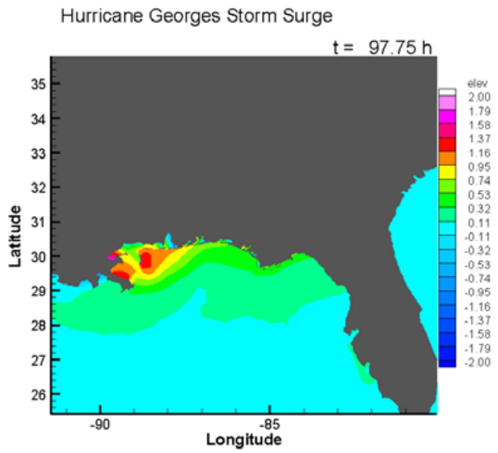
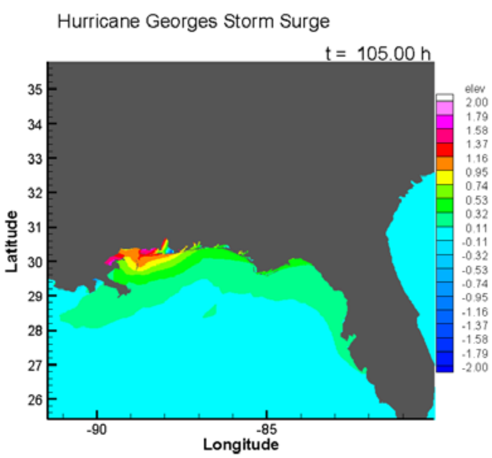
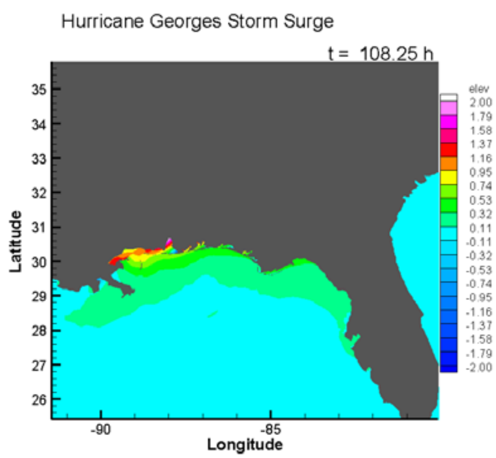


Figure 7. *Comparison of the maximum and minimum water levels for the three different pressure fields*

Seeing surge levels in the 2 meter range is very encouraging. From the model we also can see the intensification of surge in the gulfs and on the windward side of barrier islands and peninsulas. We also notice the set-down on the leeward side of land as the strong winds blow in the offshore direction. To the right and below, we include 3 frames from the movie created with the wind and pressure field forcing.







***Figures 8, 9, and 10**. These figures show the surge levels along the Gulf Coast as Georges makes landfall. The time is in hours starting from September 24, hour 00:00, 1998.*

WIND. PRESSURE. and WAVES

In order to add wave forcing to the model we must have a predicted radiation stress field over the domain of interest, or minimally a wave height and direction field over that domain. Currently partners in our project at the University of Miami RSMAS are working on a near-shore wave model. Until then we are working with estimates of radiation stresses as calculated using the third generation Wave Action Model (WAM3G) on a nested grid.

The domain we are using is marked on Figure 11. Computed wave height and direction in the domain of interest is shown on Figure 12.

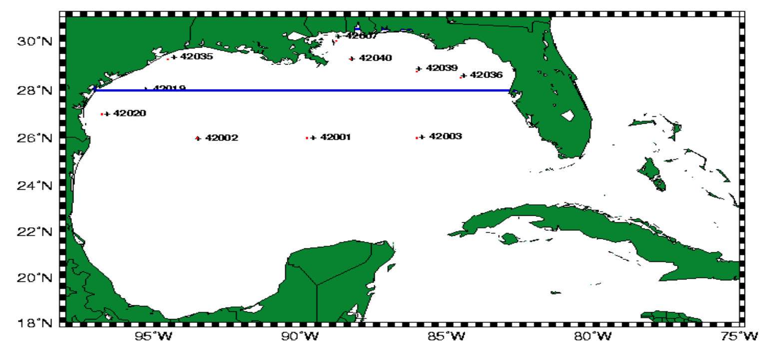


***Figure 11**. This figure shows the boundary of our area of influence for the wave forcing. Currently we are not looking at wave data outside this region.*

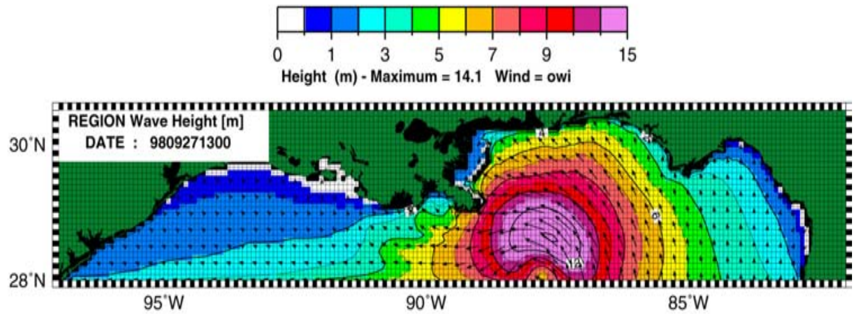


***Figure 12**. Wave Magnitude and Direction in the area of influence to be used for forcing in the model.*

We have written a program to convert radiation stresses to the gradients of radiation stresses, the true forcing of wave induced set-up. As the work progresses we will be able to calculate the added surge due to wave set-up.

FUTURE WORK

The next step in our project is to fully couple the wave radiation stresses. It is believed that this force can make up for as much as 20-30% of the total change in water level. Once the waves have been included, then all that is left is to add in the tidal forcing and we will have a full set of forcing for our model.

Our goals include forecasting the storm surge that would occur if the storm had taken one of the alternate tracks predicted by the National Hurricane Center. Our output will include probabilistic forecast maps of surge.

***Figures 13 and 14**. (Right) Alternate tracks of Hurricane Georges as predicted during the storm's approach to land*