MODELING NEARSHORE WAVES FOR HURRICANE KATRINA

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1. INTRODUCTION

Hurricane Katrina struck the Louisiana and Mississippi coasts on 29 August 2005. Numerous levees and flood protection systems in Louisiana were overtopped and breached, and the storm resulted in billions of dollars in damage. To assess the impacts of the storm, a modeling study was conducted that included wind modeling, Gulf of Mexico- and regional-scale wave modeling, surge modeling, and nearshore wave modeling (including one-way and, for nearshore waves and surge, two-way interactions) (IPET 2006). Nearshore waves were modeled by nesting STWAVE grids into regional WAM simulations. STWAVE was run at 200-m resolution using four model grids, covering an area of approximately 60,000 km^2. The modeling effort required relatively high resolution to capture the coastal features and large coverage to include the extent of the storm impact. The interactions between the surge and short waves were key to capturing the correct surge and waves at the flooded coastline. Some of the challenges for the nearshore wave modeling included interactions with the large surge (3-9 m), complex wind fields, wave propagation in marshes, and the lack of nearshore measurements for validation. Model results were used to evaluate design performance and will support design of a system with a higher level of protection.

2. NEARSHORE WAVE MODEL STWAVE

The numerical model STWAVE, version 5.0 (Smith et al. 2001, Smith and Sherlock, in preparation), was used in this study. STWAVE numerically solves the steady-state conservation of spectral action balance along backward-traced wave rays:

$$(C_{ga})_x \frac{\partial}{\partial x} \frac{C_a C_{ga} \cos(\mu-\alpha) E(f,\alpha)}{\omega_r} + (C_{ga})_y \frac{\partial}{\partial y} \frac{C_a C_{ga} \cos(\mu-\alpha) E(f,\alpha)}{\omega_r} = \sum \frac{S}{\omega_r} \qquad (1)$$

where

C_{ga} = absolute wave group celerity
x,y = spatial coordinates, subscripts indicate x and y components
C_a = absolute wave celerity
μ = current direction
α = propagation direction of spectral component
E = spectral energy density
f = frequency of spectral component
ω_r = relative angular frequency (frequency relative to the current)
S = energy source/sink terms

The source terms include wind input, nonlinear wave-wave interactions, dissipation within the wave field, surf-zone breaking, and bottom friction. The terms on the left-hand side of Equation 1 represent wave propagation (refraction and shoaling), and the source terms on the right-hand side of the equation represent energy growth or decay in the spectrum.

The assumptions made in STWAVE are as follows: mild bottom slope and negligible wave reflection; steady waves, currents, and winds; linear refraction and shoaling; and depth-uniform current. STWAVE can be implemented as either a half-plane model, meaning that only waves propagating toward the coast are represented, or a full-plane model, allowing generation and propagation in all directions. Wave breaking in the surf zone limits the maximum wave height based on the local water depth and wave steepness:

$$H_{mo_{\max}} = 0.1 L \tanh kd \qquad (2)$$

where

H_{mo} = zero-moment wave height
L = wavelength
k = wave number
d = total water depth

STWAVE is a finite-difference model and calculates wave spectra on a rectangular grid. The model outputs include H_{mo}, peak wave period (T_p), and mean wave direction (α_m) at all grid points and two-dimensional spectra at selected grid points. For Katrina applications, an option was added to input spatially variable surge fields. The surge significantly alters the wave transformation and generation for the hurricane simulations in shallow areas (such as Lake Pontchartrain) and where low-laying areas are flooded. Spatially varying wind input was also added as an option to STWAVE for Katrina applications.

The inputs required to execute STWAVE are as follows: bathymetry grid (including grid size and grid resolution); incident frequency-direction wave spectrum on the offshore grid boundary; current field (optional); surge and/or tide fields; wind speed and wind direction (optional); and bottom friction coefficients (optional).

Fields of radiation stress gradients were calculated in STWAVE and passed to the numerical circulation model ADCIRC (Westerink et al. in preparation) to calculate wave-driven setup.

3. NEARSHORE WAVE MODELING METHODOLOGY

STWAVE was applied on four grids for the southern Louisiana area: Lake Pontchartrain, Louisiana Southeast, Louisiana South, and Mississippi/Alabama (Figure 1). Four grids were used to take advantage of the efficient half-plane version of STWAVE for the three outer grids (which must approximately align with the shoreline) and to concentrate grid coverage in the areas of interest. The input for each grid includes the bathymetry (interpolated from the ADCIRC domain), surge fields (interpolated from ADCIRC), and wind (interpolated from the ADCIRC wind fields, which apply land effects to the wind fields generated by Ocean Weather, Inc.). The wind applied in STWAVE is spatially and temporally variable for all domains. STWAVE was run at 30-min intervals from 0030 UTC on 28 August 2005 to 0000 UTC on 30 August 2005.

3.1 LAKE PONTCHARTRAIN GRID

The first grid covers Lake Pontchartrain at a resolution of 200 m. Earlier runs were made at finer resolution, 50 m by 100 m, but the results were essentially the same, so the more efficient coarse grid was used for these simulations. The domain is approximately 41.6 by 67.4 km. Lake Pontchartrain was run with the full-plane STWAVE to include generation and transformation along the entire lake shoreline.

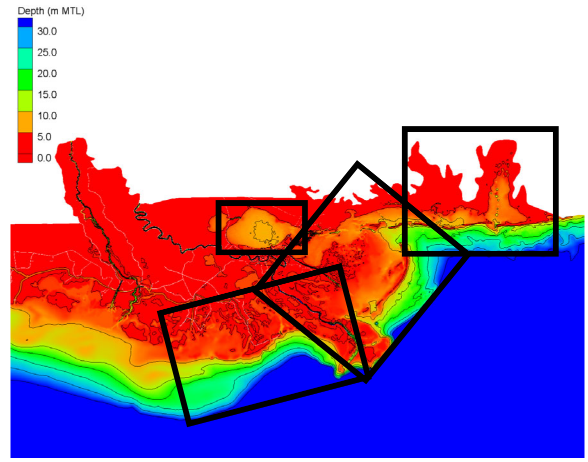

Figure 1. STWAVE modeling domains.

3.2 LOUISIANA SOUTHEAST AND SOUTH GRIDS AND MISSISSIPPI/ALABAMA GRID

The second, third, and fourth grids cover the coastal area east, southeast, and south of New Orleans at a resolution of 200 m. The domain for the Louisiana southeast grid is approximately 136.6 by 148.8 km and extends from Mississippi Sound in the northeast to the Mississippi River in the southwest. The domain for the Louisiana south grid is approximately 132.8 by 167.8 km and extends from the Mississippi River in the east to the Atchafalaya River in the west. The domain for the Mississippi and Alabama coasts was added to simulate the wave momentum fluxes that increase the surge in Mississippi Sound and Lake Pontchartrain. The Mississippi/Alabama domain is approximately 112.6 by 121.0 km and extends from east of Mobile Bay to Biloxi, Mississippi. These three grids are run with the half-plane STWAVE for computational efficiency. These simulations are forced with both the local winds and wave spectra interpolated on the offshore boundary from the regional WAM model.

4.0 RESULTS

4.1 LAKE PONTCHARTRAIN

The peak wave conditions on the south shore of Lake Pontchartrain occur at approximately 1330-1430 UTC on 29 August 2005. Figure 2 shows a snapshot of wave height and wave direction at 1430 UTC. The wind is approximately 30 m/sec from the north through northwest. The maximum wave height is 2.7 m with a peak wave period of 7 sec. Figure 3 shows the maximum wave height for each grid cell within the domain for the entire simulation period. Areas contoured in darkest blue with no vectors (zero wave height or period) are land areas. Figure 4 shows the peak wave period corresponding to the maximum wave height for each cell. The maximum wave heights range from 2.4 to 2.7 m on the New Orleans lakefront and the associated peak periods are 7-8 sec.

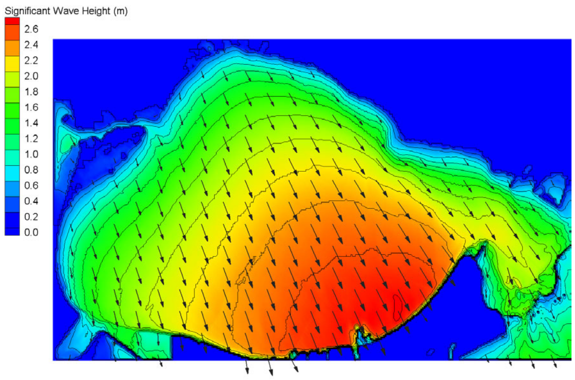

Figure 2. Lake Pontchartrain modeled wave height and direction for 1430 UTC on 29 August 2005 (wave heights in meters).

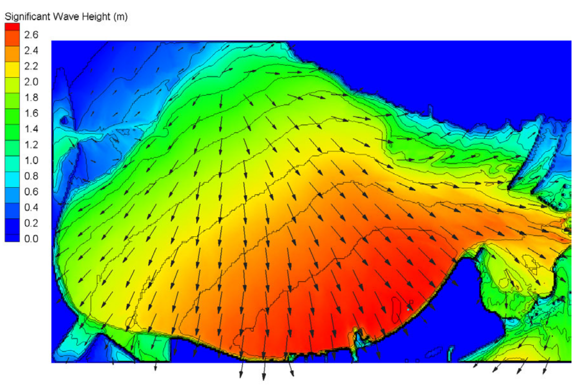

Figure 3. Lake Pontchartrain maximum modeled significant wave height and corresponding mean direction for 0030 UTC on 28 August to 0000 UTC on 30 August 2005 (wave heights in meters).

Three small wave buoys were deployed in Lake Pontchartrain on 27 August 2005 to capture wave conditions in Hurricane Katrina. Two of those gauges were recovered and provide valuable comparison data. The deployment locations were 30 deg 2.053' North, 90 deg 7.358' West for Gauge 22 and 30 deg 1.989' North, 90 deg 7.932' West for Gauge 23. Gauge 22 was directly north of the 17th Street Canal entrance and Gauge 23 was west of Gauge 22. Both gauges were in approximately 4 m water depth. The sampling records were a relatively short 8.5 min, so there is a lot scatter in the data. At the peak of the storm (~29 August 2005 1200 to 1530 UTC), the measured wave heights drop from approximately 2.4 m to 1.5 m. This is the time of maximum wind speed and thus the time when the maximum wave height would be expected. The wave height measurements do not appear to be reliable during the storm peak. The buoys may have experienced excesses tilt due to the extreme winds or may have been submerged or overturned. Figures 5 and 6 show comparisons of significant wave height and peak period, respectively, for the buoy locations. The blue lines are the measurements with the spectra averaged over 3 records (25.5 min), and the red line is the modeled parameters (30-min average). The STWAVE results give essentially the same results for the two gauge sites. The modeled wave heights are average of 0.3 m lower than the measurements in the growth stage of the storm (0000-1200 UTC 29 August 2005) and 0.15 m lower than the measurements in the decaying stage of the storm (1530-2200 UTC 29 August 2005). Comparisons at the storm peak are not meaningful. The modeled peak periods are consistent with the measurements, but 1.0 sec shorter in the decaying stage of the storm.

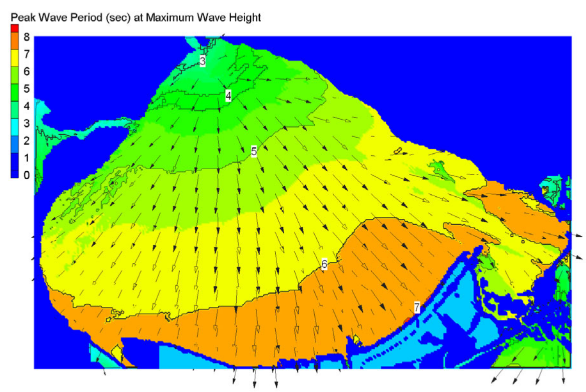

Figure 4. Lake Pontchartrain modeled peak wave period corresponding to the maximum wave height for 0030 UTC on 28 August to 0000 UTC on 30 August 2005 (periods in sec).

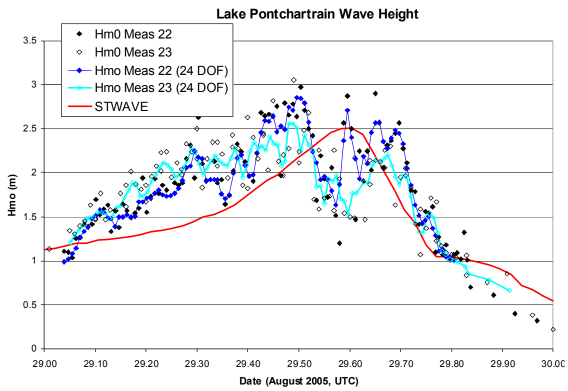

Figure 5. Lake Pontchartrain measured and modeled significant wave height, modeled wind speed, and measured wave height.

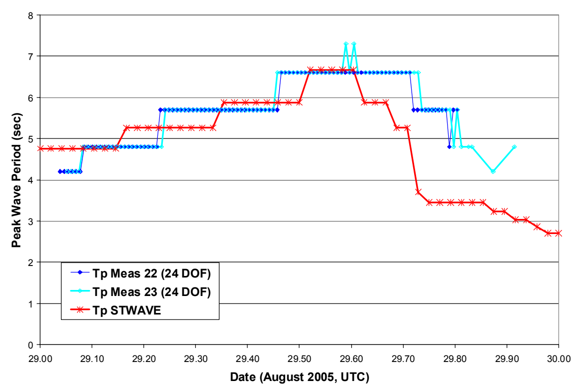

Figure 6. Lake Pontchartrain measured and modeled peak wave period.

4.2 LOUISIANA SOUTHEAST

The peak wave conditions on the southeast grid occur between approximately 1000 and 1500 UTC on 29 August 2005. The highest waves along the Mississippi River levees occur around 1000-1200 UTC and along the Lake Borgne shoreline around 1400-1500 UTC. Figure 7 shows a snapshot of wave heights and directions at 1200 UTC. Figures 8 and 9 show the maximum wave heights and corresponding wave periods for the entire simulation period for each grid cell within the domain. The maximum wave heights range from 1.2 to 3 m along the shoreline and the associated periods are 7-16 sec. The longer wave periods originate from wave energy traveling between the islands from the Gulf of Mexico. Figure 9 shows only the periods corresponding to the maximum wave height, indicating that peak period at the shoreline can change appreciably as the offshore wave direction varies, allowing swell to propagate through the island gaps. Larger wave heights occur in lower Plaquemines Parish (1.8 - 3 m) and smaller heights in upper Plaquemines and St. Bernard Parishes (1.2 – 1.8 m). The peak periods are relatively large (up to 16 sec) because of wave penetration through the barrier islands.

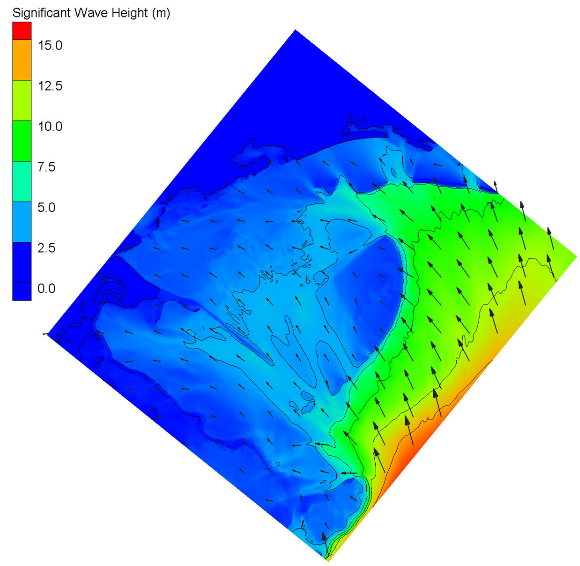

Figure 7. Southeast Louisiana modeled wave height and direction for 1200 UTC on 29 August 2005 (wave heights in feet).

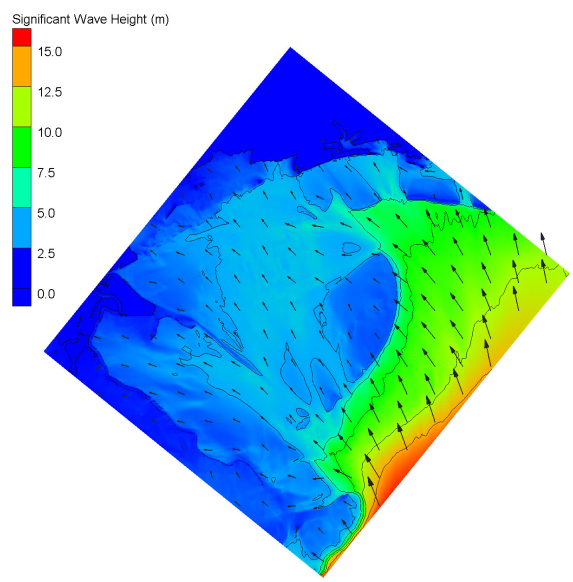

Figure 8. Southeast Louisiana maximum modeled wave height for for 0030 UTC on 28 August to 0000 UTC on 30 August 2005 (wave heights in feet).

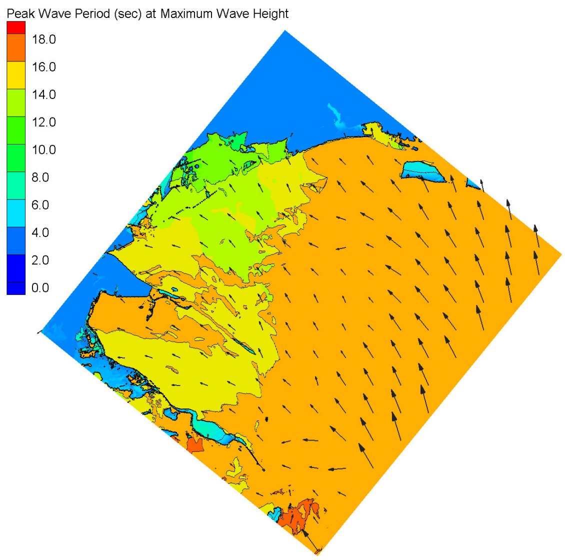

Figure 9. Southeast Louisiana modeled peak wave period corresponding to the maximum wave height for 0030 UTC on 28 August to 0000 UTC on 30 August 2005 (periods in sec).

4.3 LOUISIANA SOUTH

The peak wave conditions on the south grid occur between 0800 and 1030 UTC on 29 August 2005. The water level changes due to surge on this grid are generally less than the Southeast Louisiana grid; therefore, wave penetration over the marsh is less severe. Figures 10 and 11 show the maximum wave heights and corresponding wave periods for the entire simulation period for each grid cell within the domain. The maximum wave heights at the barrier islands are approximately 3-4 m (depth limited) and associated periods are 15-16 sec. Wave heights were significantly lower along the west bank Mississippi River levees. The barrier islands dissipated much of the wave energy arriving from the Gulf of Mexico and help protect the interior shorelines. These simulations were made with pre-Katrina bathymetry, so as barriers eroded, this protection may be overstated in the modeling results. The local winds were less important on this grid because the winds generally blow along the shore or offshore in the area. The portion of the south Louisiana grid east of the Mississippi River should be disregarded because the model is not forced along the lateral boundary (that area is modeled with the southeast Louisiana grid).

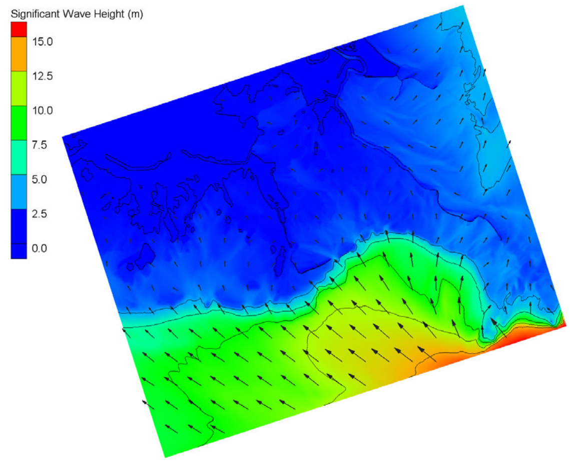

Figure 10. South Louisiana maximum modeled wave height for 0030 28 August 2005 to 0000 UTC on 30 August 2005 (wave heights in feet).

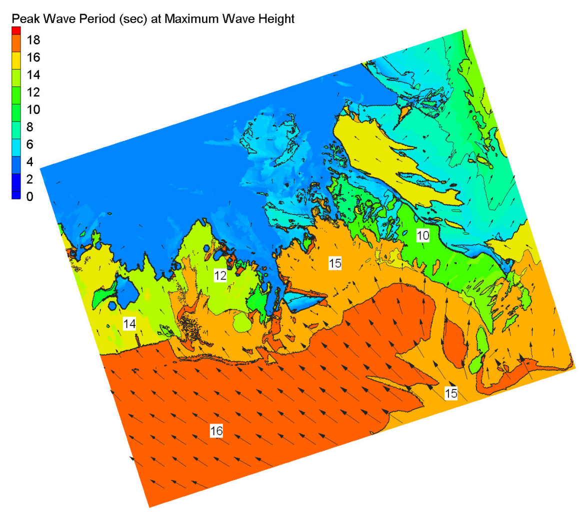

Figure 11. South Louisiana modeled peak wave period corresponding to the maximum wave height for 0630 to 1800 UTC on 29 August 2005 (periods in sec).

4.4 MISSISSIPPI-ALABAMA

The peak wave conditions on the Mississippi-Alabama grid occur around 1430 UTC on 29 August 2005, near the time of the hurricane landfall in Mississippi. Figures 12 and 13 show the maximum wave heights and corresponding wave periods for the entire simulation for each grid cell within the domain. The maximum wave heights at the barrier islands are approximately 6.1 m (depth limited) and associated periods are 15 sec. The barrier islands dissipated much of the wave energy arriving from the Gulf of Mexico and help protect the interior shorelines. These simulations also were made with pre-Katrina bathymetry, so as barriers eroded, this protection may be overstated. Wave heights in Mississippi Sound and Mobile Bay generally range from 1.5 to 3 m, but are 3 to 6 m in the lee of the inlets on the Mississippi coast. Similar to the Louisiana south domain, the barrier islands on the Mississippi and Alabama coasts dissipated much of the wave energy arriving from the Gulf of Mexico and help protect the interior shorelines. Large wave periods (15 sec) penetrate to the interior shorelines. The depth-limited wave breaking on the Mississippi and Alabama coasts generates wave setup in Mississippi Sound and Lake Borgne, which then forces additional water into Lake Pontchartrain (simulated with ADCIRC).

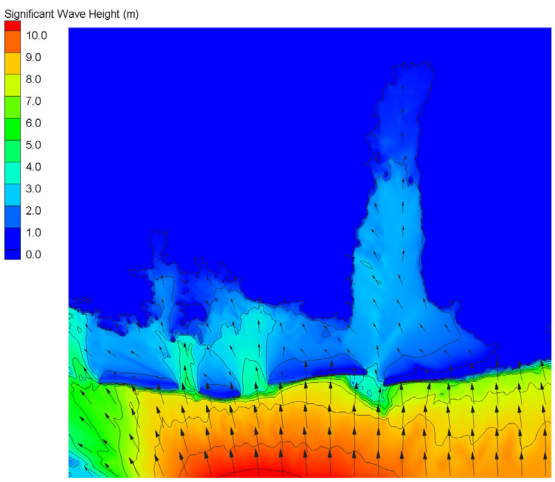

Figure 12. Mississippi-Alabama maximum modeled wave height for 0030 on 28 August 2005 to 0000 UTC on 30 August 2005 (wave heights in meters).

5.0 SENSITIVITY ANALYSIS

STWAVE was not calibrated or turned in any way for the Hurricane Katrina applications, but all numerical models are sensitive to the quality of the input data. For STWAVE, these inputs include offshore waves, winds, surge, bathymetry, and bottom roughness. To investigate the sensitivity of the STWAVE results to critical input, three sets of sensitivity runs were made: wind input, degradation of the Chandeleurs Islands, and bottom roughness. These runs were made in coordination with the offshore wave and surge modeling, so modifications were made consistently in all three models: WAM, ADCIRC, and STWAVE.

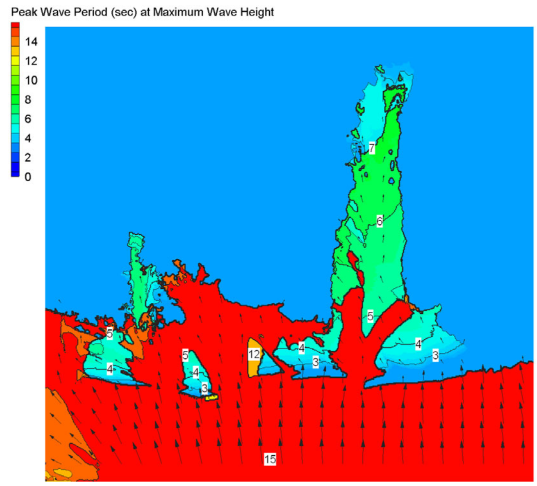

Figure 13. Mississippi-Alabama modeled peak wave period corresponding to the maximum wave height for 0030on 28 August 2005 to 0000 UTC on 30 August 2005 (periods in sec).

5.1 WIND INPUT SENSITIVITY

Wind input enters into STWAVE in three ways: through the offshore waves input at the boundary, through the surge, and through the local wave generation within the STWAVE grids. The importance of each component varies with location in the grid (offshore areas are influenced more by the offshore input and nearshore, protected areas by the local winds and surge). Two wind sensitivity runs were made, one increased the wind speed by 5 percent and one decreased the wind speed by 5 percent. Wind errors are likely to be random and partially cancel out through the integration of modeling, but a simplistic approach was selected to put realistic bounds on the solution. STWAVE was run for all four grids with the plus and minus 5 percent winds (and the offshore wave and surge generated from the same plus and minus 5 percent wind fields).

In Lake Pontchartrain, the maximum increase in wave height due to the plus 5 percent winds is approximately 0.2 m on the southeast shore of the lake (Figure 14) and the maximum decrease due to the minus 5 percent winds is approximately 0.1 m (Figure 15). For both cases there are some larger differences on the periphery of the lake, particularly the northeast shore, where the surge is a large percentage of the water depth. The differences in wave height increase across the lake (northwest to southeast), then decrease where the waves are locally depth limited, and then increase again very near the shore due to the increase in local water depth due to the differences in surge in very shallow water.

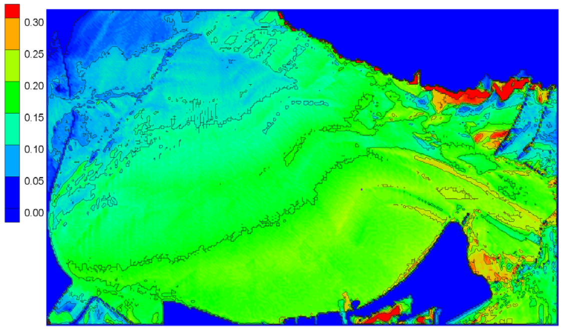

Figure 14. Differences in maximum wave height (in meters) for sensitivity run with 5 percent increase in wind speed for Lake Pontchartrain (plus 5 percent – base).

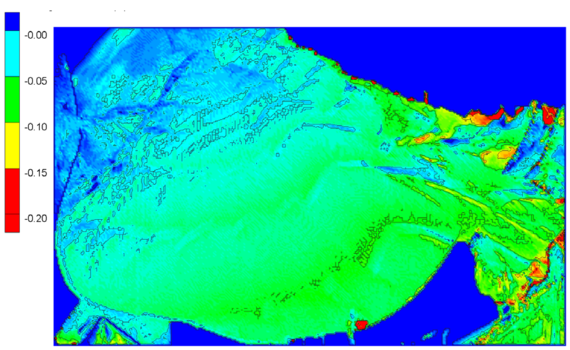

Figure 15. Differences in maximum wave height (in meters) for sensitivity run with 5 percent decrease in wind speed for Lake Pontchartrain (minus 5 percent – base).

For the southeast grid, the maximum increase in wave height due to the plus 5 percent winds is approximately 0.2 to 0.3 m along the levees (Figure 16), and the maximum decrease due to the minus 5 percent winds is approximately 0.2 to 0.3 m. There are larger differences outside the Chandeleurs (increase of 0.6 – 0.9 m for the plus 5 percent winds and 0.5 to 0.8 m decrease for the minus 5 percent winds). For the south grid, the maximum increase along the barrier islands was approximately 0.6 m due to the plus 5 percent winds and the maximum decrease along the barrier islands was approximately 0.6 m for the minus 5 percent winds. Along the Mississippi River levees, waves increased approximately 0.15 m for the plus 5 percent winds and the decrease was 0.15 to 0.3 m for the minus 5 percent winds. In the wetland areas behind the barrier islands there was a decrease in wave height of 0.15 to 0.3 m for both the plus and minus 5 percent winds, most likely because winds were blowing offshore locally (reducing surge for the plus 5 percent winds). At the grid boundary, the wave heights increased 0.5 to 1.0 m for the plus 5 percent winds and decreased 0.5 to 1 m for the minus 5 percent winds. For the Mississippi-Alabama grid, the maximum increase in wave height due to the plus 5 percent winds is 0.3 to 0.6 m at the barrier islands (locally up to 0.8 m offshore of Horn Island) and 0 to 0.3 m at the interior shorelines (average of approximately 0.15 m). The maximum decrease in wave height due to the minus 5 percent winds is 0.3 to 0.6 m at the barrier islands and 0 to 0.3 m at the shore line. The differences in peak wave period over all grids were generally 1 sec or less (increase in peak period for the plus 5 percent winds and decrease in peak period for minus 5 percent winds).

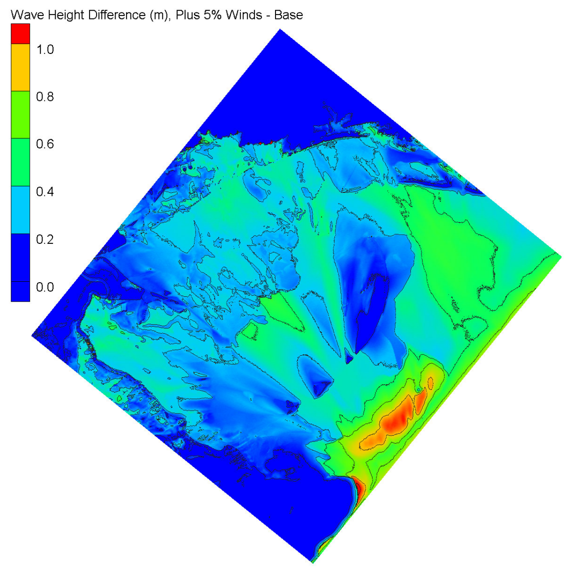

Figure 16. Differences in maximum wave height for sensitivity run with 5 percent increase in wind speed for Southeast Louisiana (plus 5 percent – base).

Although wind is the critical parameter for predicting waves and surge, the 5 percent increase and decrease in winds for the coupled simulations generally produced nearshore waves at the shoreline of ±0.3 m (or less) of the base simulations. The differences were larger, ±0.3 to 1.0 m, offshore of the barrier islands.

5.2 BATHYMETRY SENSITIVITY

Southern Louisiana is geomorphically active (wetland and barrier island loss, subsidence, and development). For the base case, an effort was made to use the most up-to-date and accurate bathymetry information to construct the STWAVE grids. These grids were derived from the ADCIRC bathymetry grids. Bathymetry interacts with wave processes through shoaling (which generally increases waves in shallower depths), refraction (which turns waves more shore normal in shallower depths), and depth-limited breaking (which reduces wave height when the breaking threshold is reached). In general, small errors in water depth result in small errors in wave parameters (shoaling is a function of depth to exponent ¼ and breaking is approximately linear with depth) and the impact is typically local. A possible exception to this is wave attenuation across the barrier islands, which protect the areas in their shadow. The Chandeleur Islands experienced significant degradation during Katrina. To investigate the impact of that degradation on the nearshore waves and surge, STWAVE was run with the Chandeleurs in a degraded state. Bathymetry has not been measured since Katrina, but estimates of the new island configuration were taken from aerial photographs. Areas that changed from emergent to submerged were estimated to have a 1 m water depth. The Chandeleurs are on the Southeast STWAVE grid, so only that grid was run. Surge values from ADCIRC with the degraded Chandeleurs were used as input together with offshore waves and winds from the base runs. Figure 17 shows the differences in maximum significant wave height for the degraded Chandeleur run minus the base run. The maximum increase in wave height is approximately 1.8 m directly in the lee of the island. Close the shoreline, the difference are reduced to near zero. There are (very) small differences in other parts of the grid resulting from small differences in the surge. The barrier islands do significantly reduce the wave height in the nearshore area, even in a degraded state. The degraded islands allow more wave energy to pass over them and propagate into the sound. For the Chandeleurs, the impact on the shoreline of the degraded the islands was relatively small (because the wave height is depth limited in the shallow wetland areas between Chandeleur Sound and Lake Borgne), but increased wave energy in Chandeleur Sound would likely cause further degradation of these wetlands. The protection afforded by barrier islands for the shoreline is dependent on the elevation of the islands, submergence of the islands during the storm, distance from the shore, and characteristics of the storm.

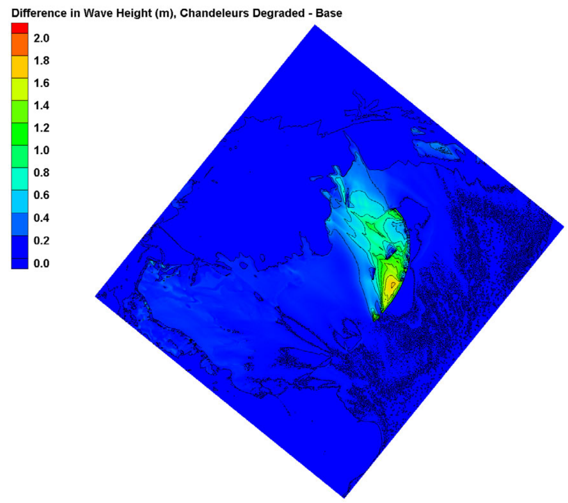

Figure 17. Differences in maximum wave height for sensitivity run with Chandeleur Islands degraded for Southeast Louisiana (degraded bathymetry – base).

5.3 BOTTOM ROUGHNESS

All STWAVE base simulations neglected wave energy dissipation due to bottom friction. Generally, dissipation due to bottom friction in the nearshore is relatively small because the propagation distances are small, so frictional dissipation is neglected. Within the Southeast grid, the propagation distances are significant, the water depths are relatively shallow, and vegetation in flooded areas may be highly dissipative, thus bottom friction may be significant. The bottom friction coefficient in STWAVE was specified as

$$C_f = g \frac{n^2}{d^{1/3}} \tag{3}$$

where g is acceleration of gravity, n is the Manning roughness coefficient, and d is total water depth (including surge). To investigate the impacts of bottom dissipation, STWAVE was run for two cases with bottom friction. These cases represent spatially-varying bottom roughness for the pre-Katrina vegetation cover and the post-Katrina cover (background Manning's n value of 0.02). Maps of the Manning's n are provided in Chapter 5 of the IPET report (IPET 2006). During Katrina, vegetation was stripped from some wetland areas, so the post-Katrina roughness values are reduced in some areas. ADCIRC was run with the same Manning's n values and those surge fields were used as input to STWAVE. For the base case, ADCIRC was run with a constant friction coefficient and STWAVE neglected bottom friction.

Figure 18 shows the differences in maximum significant wave height for the simulation with the pre-Katrina frictional loss minus post-Katrina frictional loss. The largest differences in wave heights between the pre- and post-Katrina bottom friction runs were the larger pre-Katrina wave heights of up to 0.5 m on the Mississippi River delta, 0.2 m across the Chandeleurs, and 0.1 m in Chandeleur Sound and Lake Borgne due to higher surge with the Pre-Katrina friction. Larger post-Katrina wave heights occurred in very limited areas (St. Bernard-Plaquemines border and directly in the lee of the Chandeleur and Ship Islands) (0.1 to 0.15 m). Wave height increased in areas were vegetation was destroyed and where surge increased with post-Katrina friction values.

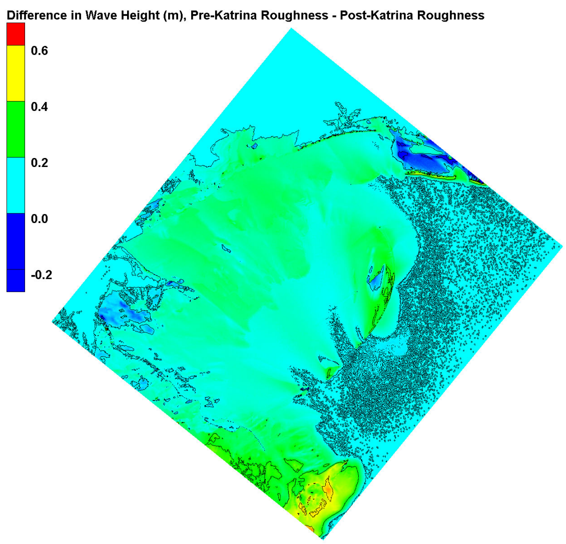

Figure 18. Differences in maximum wave height for sensitivity run with pre-Katrina bottom friction minus post-Katrina bottom friction for Southeast Louisiana.

The inclusion of spatially variable bottom friction tied to the vegetation type reduced wave height in very limited areas by up to 1.1 m. Somewhat surprisingly, though, the simulations show increased wave height over broad areas in Chandeleur Sound and Lake Borgne on the order of 0.3 – 0.5 m, which occurs because the surge increased in these areas and dissipation due to depth-limited breaking was reduced. The change in wave heights between the post-Katrina Manning's n values and the pre-Katrina values were relatively small (maximum decrease of 0.5 m and maximum increase of 0.2 m) and limited to small areas. The interaction of waves and surge in wetlands will be an important topic for continued study.

5.4 TIME-DEPENDENT SIMULATIONS

STWAVE is a steady-state wave model, which means that the waves reach equilibrium with the local forcing conditions (wind, surge, and boundary waves). Thus, the STWAVE modeling assumes that the winds and surge vary slowly enough for the waves to reach quasi steady state. For Hurricane Katrina, the winds are time varying and the grid domains are relatively large, so the time-dependent SWAN model (Booij, Ris, and Holthuijsen 1999; Booij et al. 2004) was used to evaluate the importance of time variation. Lake Pontchartrain was chosen for this test because the waves are all locally generated and time dependence is expected to have the greatest impact there. To test the time dependence, SWAN was run in time-dependent and steady-state mode for 29 August 2005 from 0000 UTC to 30 August 2005 0000 UTC. The simulation was made using 1-min time steps for the time-dependent run and forcing the steady-state run to an accuracy of 99 percent with a maximum of 15 iterations (this is more stringent than the default). All other SWAN model defaults were used. SWAN was run with the same spatially varying surge and wind as STWAVE.

Figures 19 and 20 show the SWAN and STWAVE results with the data measured in Lake Pontchartrain. The time-dependent and steady-state SWAN give essentially the same results through the peak of the storm, after a 3-hr model spin up. Thus, the steady-state solution is adequate for the simulations. STWAVE wave heights are 4 percent higher than SWAN at the peak of the storm and lower in height on the building (11 percent) and waning (24 percent) legs of the storm. SWAN results are closer to the measurements on the building portion of the storm and STWAVE results are closer on the waning portion of the storm. The measurements are not reliable at the peak of the storm, when the wave heights are most critical. STWAVE peak periods are 8 percent longer than the SWAN peak periods through the peak of the storm and 23 percent shorter than SWAN periods after the storm peak. STWAVE shows better agreement with the wave period measurements through the storm peak, but both models are generally within 1 sec of each other.

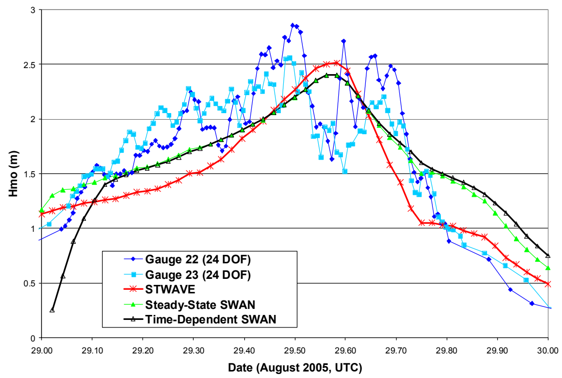

Figure 19. Time-dependent and steady-state SWAN and STWAVE modeled significant wave heights for Lake Pontchartrain measured and measured wave height.

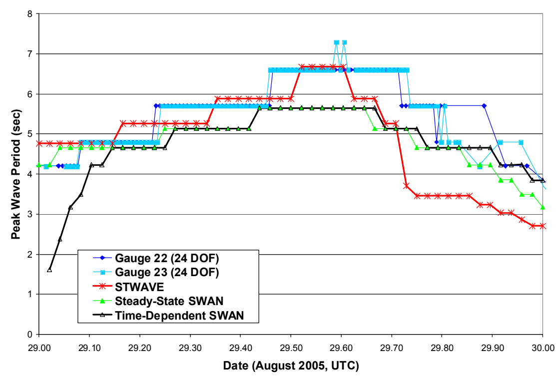

Figure 20. Time-dependent and steady-state SWAN and STWAVE modeled peak wave periods for Lake Pontchartrain measured and measured periods.

6. SUMMARY

Simulations of nearshore waves in coastal Louisiana for Katrina are presented. The nearshore wave modeling required relatively high resolution to capture transformation processes over large, shallow areas and radiation stress gradients that were fed back to the circulation model. Wave propagation and generation are significantly altered by surge in shallow wetland areas and Lake Pontchartrain. The best information possible was used as input to the model (bathymetry, winds, bottom friction), these values have a significant degree on uncertainty. A sensitivity analysis was performed to quantify uncertainty in the results. This analysis examined ±5 percent changes to the wind fields, which resulted in ±0.3 m (or less) changes in wave height at the shoreline (up to ±1 m at the barrier islands). Modeling degraded bathymetry of the Chandeleur Islands, which is known to have occurred during Katrina, resulted in increased wave height of up to 1.8 m in the lee of the island, but near zero difference a the shoreline. Modeling bottom friction to represent pre- and post-Katrina vegetation cover showed that surge and waves were higher in some areas due to the rougher pre-Katrina vegetation cover (larger Manning's n) and lower in other areas. Higher waves occurred in areas where surge increased and lower waves where Manning's n values were larger pre-Katrina. Follow-on work will continue to evaluate the role of wetlands in attenuating surge and waves.

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