A Sensitivity Study of the Storm Surge from Hurricane Katrina

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Introduction

In August 2005, Hurricane Katrina developed into a category-5 hurricane over the Gulf of Mexico. Although Hurricane Katrina steadily weakened before it made two points of landfall along the northern coast of the Gulf of Mexico, near Buras, LA and at the MS / LA border, a catastrophic storm surge accompanied the hurricane and devastated the coasts of MS and eastern LA.

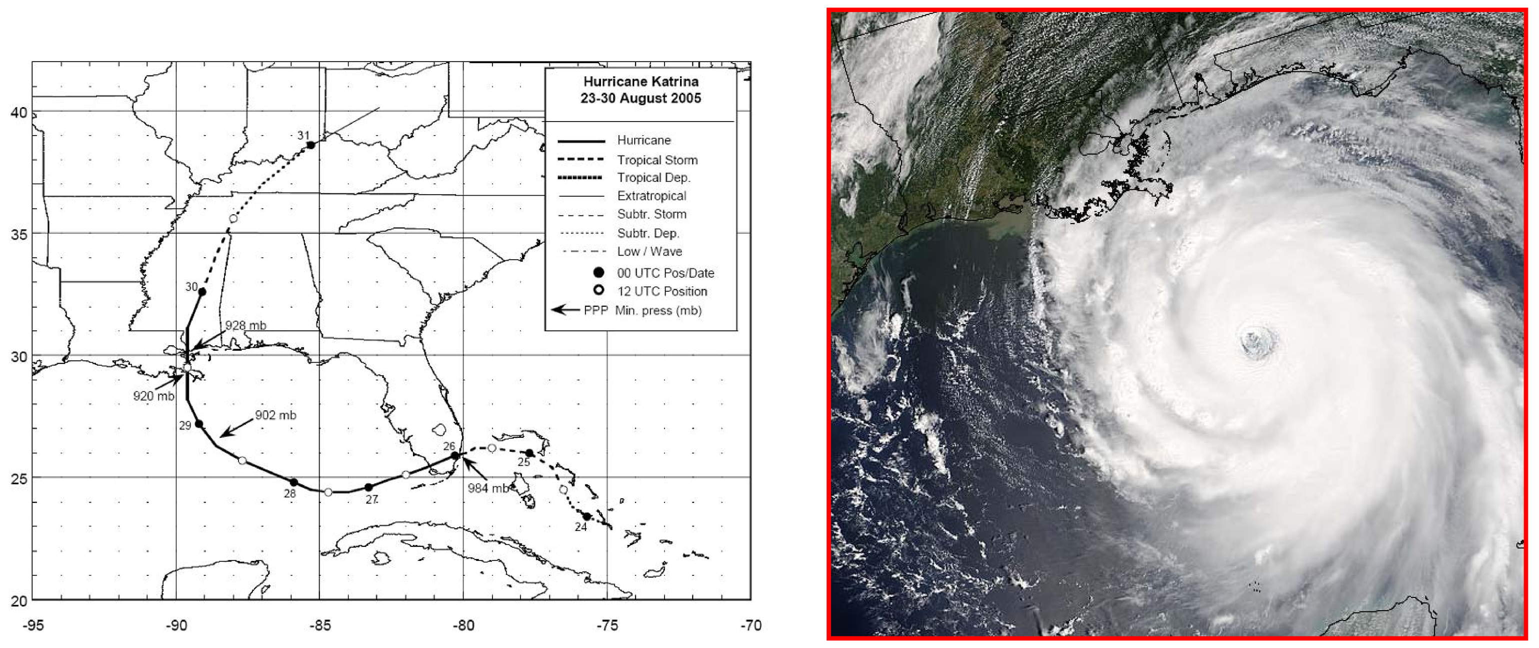

Figure 1. Best track position map prepared by the National Hurricane Center (left) and MODIS-Terra image of Hurricane Katrina (right).

Hindcast simulations are performed to assess the effects of the circulation of Hurricane Katrina in generating the historic surge at key locations along the northern Gulf Coast. The impact of the Mississippi River levee system has been examined. Sensitivity simulations of the storm size and speed have also been performed. Future work will study the influence of the eyewall location and the Louisiana wetlands.

Methodology

The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model (Jelesnianski et al. 1992), is used to simulate the storm surge generated by Hurricane Katrina along the MS / LA coast. SLOSH is a hydrodynamic model which solves the depth-integrated equations of motion and continuity equation. The model is forced by a two-dimensional parametric wind equation based on storm's track, radius of maximum winds (RMW), and pressure deficit (environmental pressure minus central pressure). SLOSH incorporates bathymetry, topography, channels, and barriers (levees) on a stretched finite difference regional grid system. The computational cells are designed such that resolution increases toward the coastline on a telescoping polar grid mesh.

Sensitivity tests are performed on the effects of the RMW parameter, which alters the radius of the eyewall but also increases the distance of tropical storm-force winds for larger RMW. The formulation follows that of Myers and Malkin (1961), which assumes a balance between the centrifugal force, friction, Coriolis force, and pressure gradient force parallel and perpendicular to a wind trajectory. Future work will examine whether the resulting relationship of eye size and storm size can be relaxed from these strict mathematical requirements.

Additional tests examine the possible impacts of the Mississippi River levee system in enhancing the storm surge. In simulations with no river levees, land elevation is reduced to 4 feet to mimic the natural ridge along the river system and allow surge overflow into Barataria Basin. This "removal" of the man-made levee system (which are 10-15 ft tall) extends northward to near Chalmette where secondary levee systems exist.

All simulations are conducted for the period of 18 UTC 26 August 2005 to 18 UTC 29 August 2005.

Results

The control run of the observed surge evolution is shown below (Fig. 2). The simulation shows the surge gradually rising, then quickly inundating Plaquemines Parish followed by St. Bernard Parish between 09 UTC and 12 UTC. The surge later peaks along the Mississippi coast between 14 and 16 UTC with the record surge.

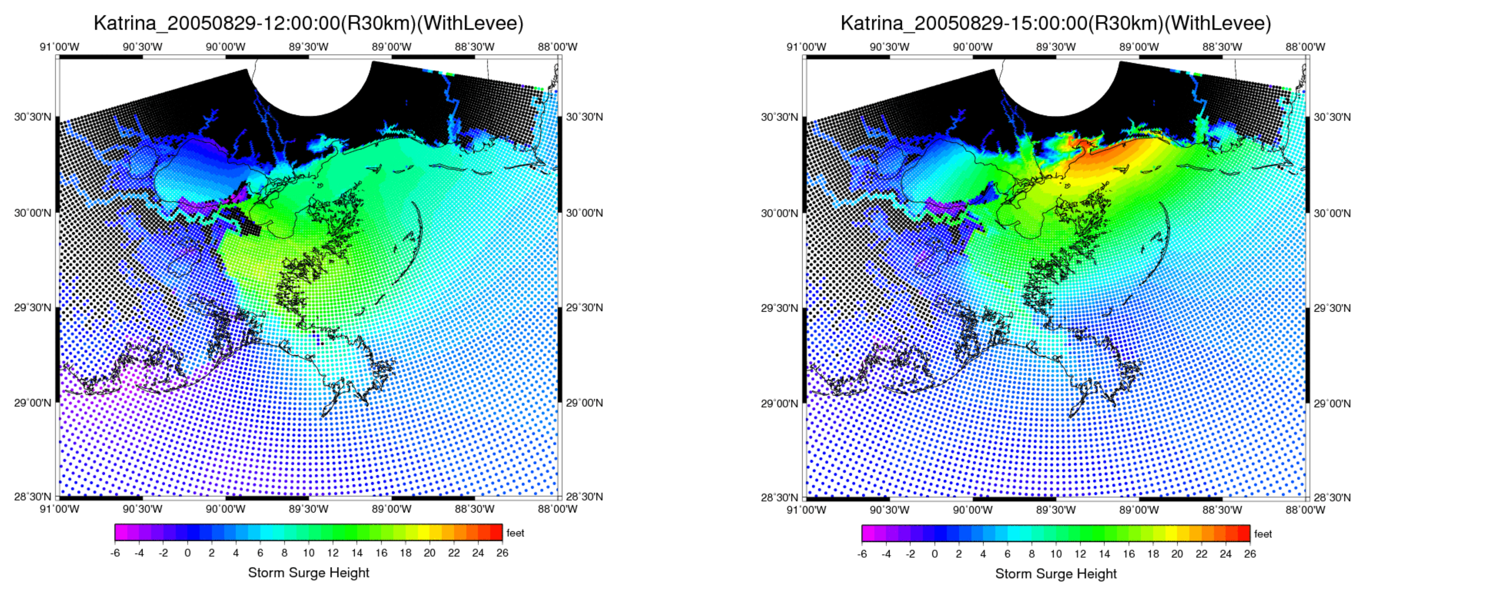

Figure 2. Katrina's storm surge in control run at 12 UTC and 15 UTC 29 August 2005 (ft)

The impact of the Mississippi River levee system is shown in Fig. 3 at 13 UTC, contrasted to a simulation with only a natural river system south of Chalmette. Shades of yellow are seen east of the river where water is either trapped by the levees or has restricted overflow. Note also that the Barataria Basin west of the Mississippi River has higher surge.

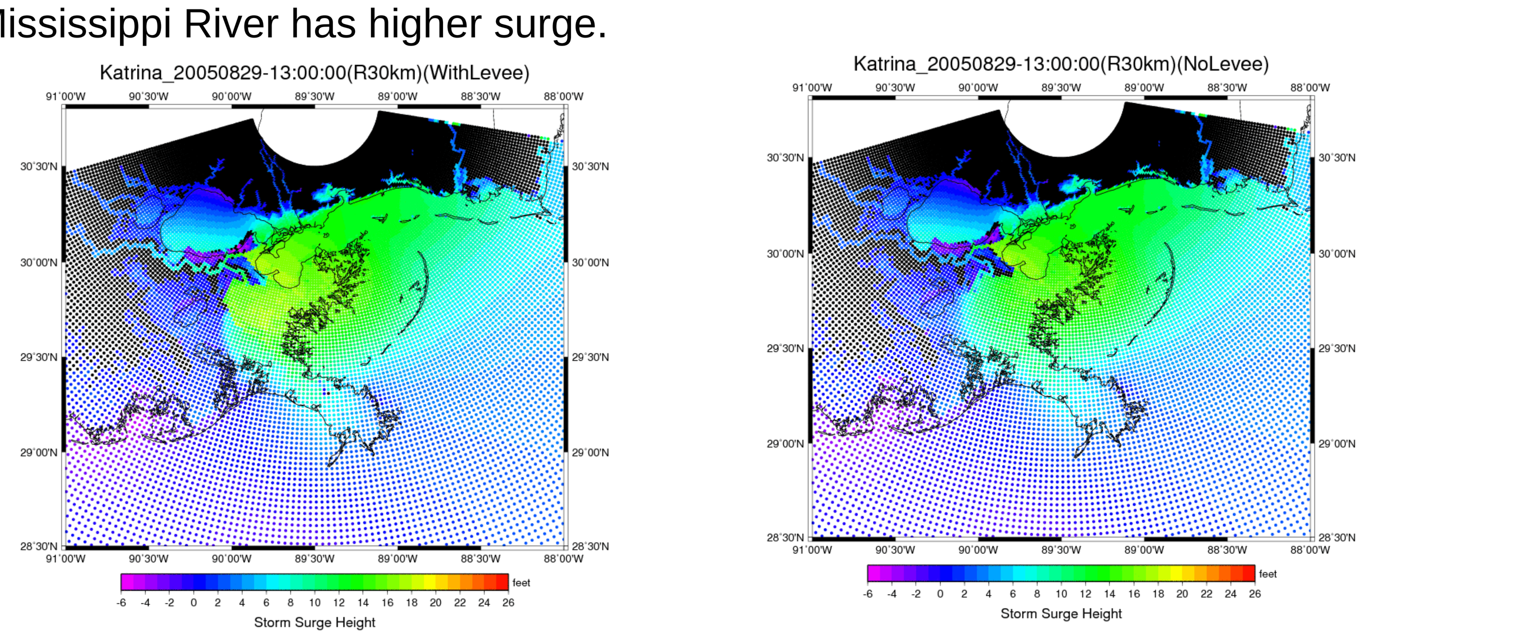

Figure 3. Katrina's storm surge in control run at 13 UTC compared to same simulation without a man-made levee along the Mississippi River up to Chalmette.

Maximum water elevation values were computed for each grid cell. The difference of the peak water values for levee and no-levee runs are shown in Fig. 4. They show that the levees only increase the surge between 0.5 to 1.0 feet along the Mississippi coast. However, major differences are seen east of the River and in Barataria Basin, summarized below. It is also interesting that, without the levees, hard-hit Chalmette and the 9th Ward may have experienced significantly less flooding. However, it should be pointed out this is an idealized situation, and that SLOSH only accounts for overtopping of the Chalmette levees, not breaches. The levees north of Chalmette experienced numerous breaches from a combination of overtopping, wave action, and poor soil levee composition.

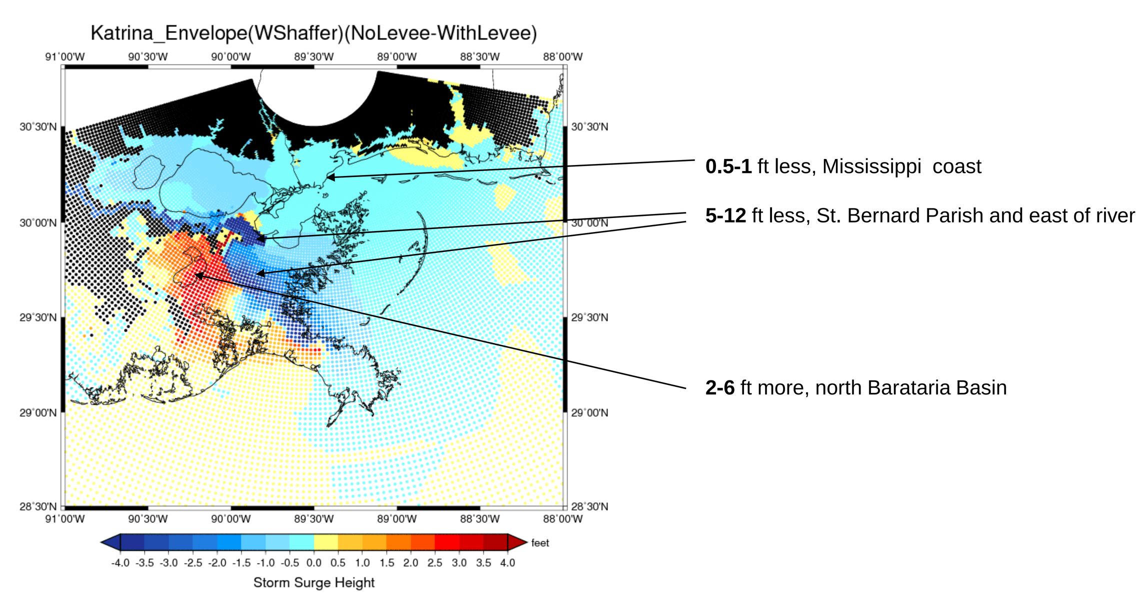

Figure 4. Difference of peak water elevations (No-levee minus levee).

Numerous simulation for different storm sizes were also performed. It is well-known that storm surge increases for larger hurricanes. This is due to the prolonged period of wind stress pushing water inwards over a large region, and also sometimes because of the influence of the Coriolis force (Freeman, Baer, and Jung 1957). Mississippi and Louisiana are prone to high surges due to the shallow bathymetry and gentle sloping ocean floor, but Katrina's record surge was largely due to the storm's size. Katrina's tropical storm-force winds extended 230 miles eastward from the center. The difference between a large and small hurricane (like Camille) is shown in Fig. 5.

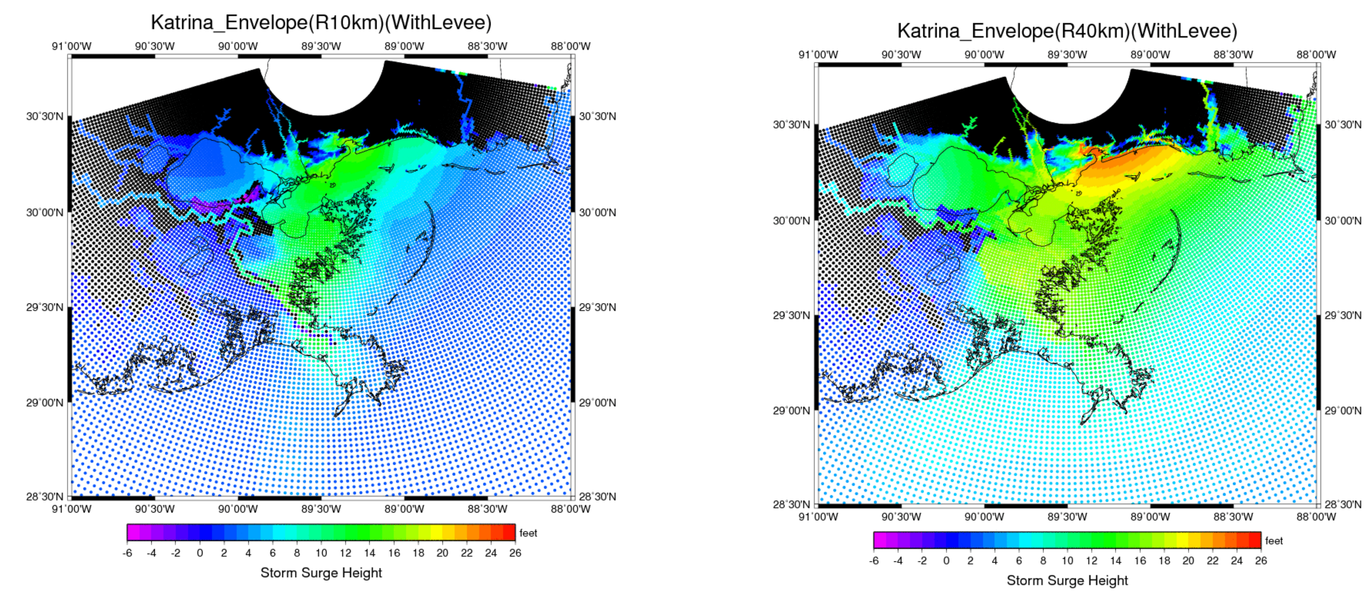

Figure 5. Peak storm surge values for a small (left) and large (right) hurricane with a pressure deficit similar to Katrina..

Future work

An additional issue involves the impact of the Louisiana wetlands and the Mississippi River. It is widely believed that wetland erosion has increased storm surge vulnerability in southeast Louisiana. Grids will be created based on historical wetland data, and new SLOSH runs will be performed to examine the impact of wetland loss in the last 75 years. Specifically, we will investigate: 1) a hurricane moving over the less-eroded marsh of Louisiana in 1930; and 2) a weaker hurricane due to more marshland.

Much of this work will be repeated using the finite element Advanced CIRCulation (ADCIRC) model (Luettich, Westerink, and Scheffner 1992; Westerink et al. 1992). This code has been installed and tested on the MSU Linux cluster, and the grid generation software SMS is being installed this month.

References

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