Storm Surge Issues of Hurricane Katrina

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Overview

Category 3 Katrina generated a U.S.-record storm surge which impacted a wide region from Grand Isle, LA, to Mobile Bay, AL, and killed about 1350 people with hundreds still missing. Sensitivity experiments by WorldWinds using the ADvanced CIRCulation (ADCIRC) storm surge model show a large hurricane produces water elevations 20-40% higher than a small hurricane with the same intensity and with considerably more widespread inundation. The previous U.S.-record surge was Hurricane Camille (1969) which impacted the same region, an intense but smaller Category 5 hurricane. Camille's hurricane-force winds extended 60 miles from the storm center, while Katrina's extended 120 miles. Camille's tropical storm-force winds reached 180 miles outward, while Katrina was 230 miles. It is likely Katrina's wide eye of 37 miles also played a role (Camille's eye was approximately 11 miles wide).

The inland penetration of Katrina's storm surge was truly remarkable. The Mississippi River levee system held and confined most of the surge east of the river except for the landfall region of Buras, LA. Regions west of the Mississippi River experienced little surge, suggesting that the river levee system may have augmented Katrina's surge on the east side. Most of Plaquemines, St. Bernard, and eastern Orleans Parishes were inundated with surge which overflowed levees and destroyed them with scouring action. Buildings outside the levee system became cement slabs. Tide gauges also show the surge traveled up the Mississippi River, with elevation spikes reaching 14 feet at the Bonnet Carre Spillway 10 miles west of New Orleans. Levees along some canals south of Lake Pontchartrain were not overtopped but experienced failures that are still under investigation, causing well-publicized flooding of New Orleans. The surge also penetrated through inoperative flood pumps which, when combined with the inability to remove rainwater, caused moderate flooding in the suburban region west of New Orleans. The eastern end of St. Tammany Parish suffered an extreme surge which came from Lake Borgne as well as up the Pearl and Bonfouca river systems, traveling miles inland in Slidell. St. Tammany experienced a second surge when the wind shifted, sloshing piled-up water in Lake Pontchartrain northeastward. A video is shown of the surge along northern Lake Pontchartrain.

The entire Mississippi coast experienced the storm surge. The western region from Pearl River to Bay St. Louis suffered the worst, as the surge traveled past Interstate 10 (Figure 1). The official peak surge occurred in this region, estimated at 28 feet. However, high water marks indicate even higher elevations, although some may be impacted by wave action (Table 1). Comparisons to Hurricane Camille's surge are shown in Table 1. The surge also traveled far up the Jordan River and Biloxi River, decimating towns such as Kiln, MS. An ADCIRC simulation of Katrina's surge evolution is shown in Fig. 2. The surge occurred at high tide, adding another foot of water.

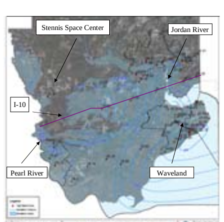

Fig. 1. The maximum storm surge in Hancock County according to FEMA. Some high water marks also shown. The shaded region represents the inland penetration. Note the surge traveled past Interstate 10 and up the Jourdan River and Pearl River. (Figure courtesy of Nvision Solutions Inc.)

Table 1. Hurricane Katrina high water marks, compiled by Haag Engineering, National Weather Service (NWS), the USGS, and Fitzpatrick along the immediate coast. Available Hurricane Camille values from the Army Corps of Engineers is also shown for comparison.

Location	Katrina high water mark (feet)	Source	Camille surge (feet)
Buras, LA	20-25 (estimated)	Storm surge models, eyewitness accounts	15
Slidell, LA (inland)	15	Haag, Rt. 433 and HWY 90	
Slidell, LA (Lake Pontchartrain)	18	Fitzpatrick	8
Grand Isle, LA	12	NWS	
Lake Pontchartrain Causeway	6.8	NWS	
Lake Maurepas, LA	3	NWS	
Hopedale, LA	20	Fitzpatrick	
Lafitte, LA	4	USGS Tide Gauge	
Waveland, MS	31	Haag, Waveland School	20
Bay St. Louis, MS	27	Haag, Post Office on rt. 190	21
Pass Christian, MS	28	USGS, 1320 Scenic Drive	23.4 (previous record)
Gulfport, MS	22	Haag, First Baptist Church on Rt. 90	21
Biloxi, MS	20	Haag, Grand Casino	17
Biloxi, MS	24	USGS Isle of Capri Casino	15.6
Ocean Springs, MS	19	Haag, House on Beach BLVD	16
Pascagoula, MS	17	Haag, House on Beach BLVD	12
Bayou La Batre, AL	14	NWS	8
Mobile State Docks, AL	11.5	NWS	6
Dauphin Island, AL	6.2	USGS Tide Gauge	
Perdido Pass, FL	5.8	NWS	4

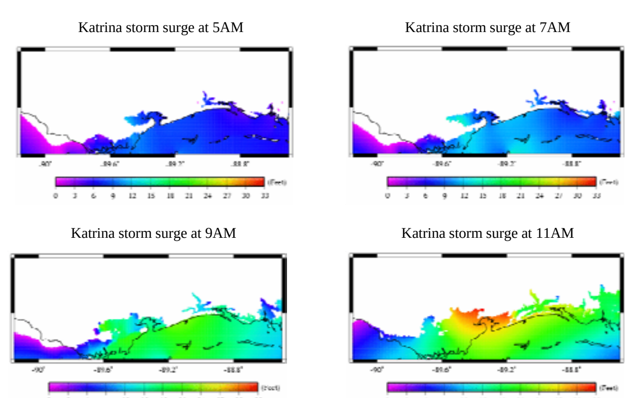

Fig. 2. ADCIRC simulation of Katrina storm surge. Graphics extend from the Northshore of Lake Pontchartrain, LA, across the Mississippi coast to Pascagoula, MS. At 5AM the surge moves up the Pearl, Jordan, and Biloxi River estuaries. Marsh regions near Pearlington and Pascagoula begin to experience inundation. The surge is below 5 feet in most regions. By 7AM, this pattern continues, but with surge values above 10 feet in some regions. Waveland begins to experience inundation. By 9AM, significant storm surge is occurring along the Mississippi coast and Mobile Bay, with 15-25 feet water elevations penetrating miles inland west of Bay St. Louis. Because the wind direction is shifting over Louisiana, piled-up water in Lake Pontchartrain pushes eastward, causing a second wave of inundation in that region. Indeed, damage to the "twin spans" bridge system which connects Slidell and New Orleans, indicates an outward surge, with much of the damage on the east of the bridge system. The peak surge occurs around 11AM period, with extreme inland penetration and record surge values on the order of 25-35 feet. Even though Katrina was less intense than Camille, the record surge can generally be explained by the huge size of the storm.

Timing of Wind and Surge

An important insurance issue involves the timing of wind versus surge. All tide gauges failed at the peak of the storm in the severely impacted regions. However, 17 USGS gauges in the impact region functioned during tropical storm-force conditions. Figure 3 shows a typical gauge measurement at Bay Gardene, LA. All gauges show winds of 50-60 mph with storm surge values of 5-8 feet, typically less than would flood most homes. Printouts of all tide gauges are available for examination at this poster station.

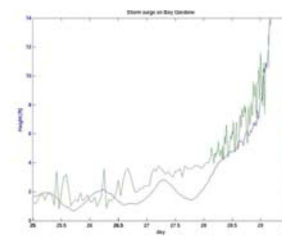

Fig. 3. USGS tide gauge of water elevation (feet) and wind (mph) for Bay Gardene, located in the marsh 20 miles east of Chalmette, LA. This gauge failed after midnight on 8/29/05.

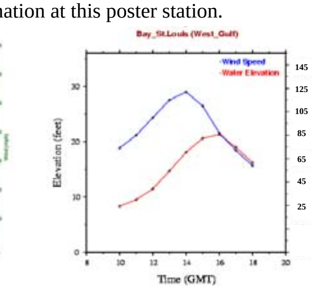

Fig. 4. ADCIRC simulation of the surge (feet) and the wind forcing (mph) for an inland point near Bay St. Louis, MS during landfall.

To examine the possible timing of surge in the storm center, time series plots of individual locations were produced from the ADCIRC simulation. They generally show the peak winds preceding the peak surge between 30 minutes and two hours. An example is shown for Bay St. Louis (Fig. 4).

The Impact of the Mississippi River Gulf Outlet and the Hypothesized "Funneling Effect"

The Mississippi River Gulf Outlet (MRGO) is a 70-mile, deep-draft, man-made channel, completed in 1963. 40 miles was dredged through marshland in St. Bernard Parish. Originally 750 feet wide, MRGO has eroded to 2000 feet wide in many places, destroyed more than 36,000 acres of wetlands, and disrupted a brackish environment with high salinity. Its role in hurricane storm surges is also controversial, with speculation MRGO acts as a conduit. Its intersection with the Gulf Intracoastal Waterway has also been hypothesized to provide a "funneling effect" for the storm surge.

These issues were studied with an ADCIRC simulation of Katrina for a "filled-in" MRGO. Little difference was observed (Fig. 5), because the surge is a widespread event in which one channel will make little impact. Another simulation used a wider levee system at the intersection, and the surge actually increased (Fig. 6), because without restricting the flow, the conveyance increased in this region. The URS report is available at this poster station.

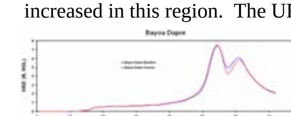

Fig. 5. Comparison of ADCIRC simulations with MRGO open and closed, showing little impact of the MRGO on the storm surge at Bayou Dupre south of Lake Borgne near Violet, LA.

Fig. 6. Comparison of ADCIRC simulations with MRGO closed and a wider levee system at the Gulf Intracoastal Waterway. A wider levee system actually yields higher surge elevations, because the conveyance increases.