Coastal Change During the 2008 Hurricane Season: An Overview

USGS *National Assessment of Coastal-Change Hazards*

The U.S. Geological Survey *National Assessment of Coastal Change Hazards* project predicted, and then measured, the coastal changes that occurred during the most intense land falling hurricanes of 2008. Changes were characterized and quantified using photography and airborne lidar, providing data to test model predictions. This overview report summarizes the 2008 coastal-change observations and the implications for emergency and coastal-zone managers.

Figure 1. The remains of a Gulf-front home destroyed by Hurricane Ike on the Bolivar Peninsula, Texas. Waves and currents eroded the large depression. The piles tilt in the direction that the waves were propagating (Photo: 3/8/2009).

The Threat: During extreme storms, homes, infrastructure, the environment, and people are threatened not only by wind loading and storm-surge flooding, but also by the land changing.

- **Evacuation routes can be blocked** by waves overtopping dunes and transporting sand onto roads.
- **Evacuation routes can be severed** by breaches cutting through barrier islands, such as happened near Hatteras Village on the North Carolina Outer Banks during Hurricane Isabel in 2003. (See http://coastal.er.usgs.gov/hurricanes/isabel/lidar.html)
- **Storm-surge can be increased** on the mainland by the destruction of barrier-island dunes, allowing seawater to flow across the islands into the back bays and raise bay water level.
- **Coastal vulnerability can be increased**, such as the erosion on the Florida east coast during Hurricane Frances in 2004, making the impacts of Hurricane Jeanne three weeks later more severe. (See http://coastal.er.usgs.gov/hurricanes/jeanne/photos/index.html)
- **Structural failures can be caused**, or exacerbated, by waves undermining buildings, such as in Figure 1 and also the collapse of 5-story condominium towers in Alabama during Hurricane Ivan in 2004. (See http://coastal.er.usgs.gov/hurricanes/ivan/photos/index.html)
- **Habitat destruction and permanent land loss can result** from storm-wave action.

The Storms: Of the eight hurricanes that formed in the North Atlantic during the 2008 hurricane season, three made landfall in the United States: Dolly, Gustav, and Ike. Hurricane Dolly was relatively weak as it came ashore in south Texas with maximum winds estimated at 139 km/hr (Category 1 on the Saffir-Simpson Scale). The *National Assessment* focused on the two more intense land falling storms: Hurricane Gustav (166 km/hr; Category 2; landfall 9/1/08) and Hurricane Ike (175 km/hr, Category 2; landfall 9/13/08).

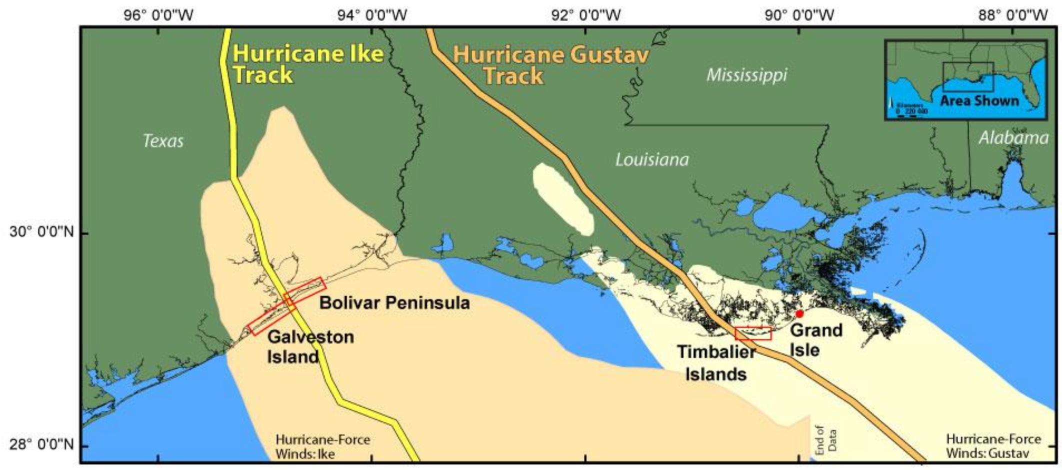

Figure 2: Hurricane-force wind fields and tracks of Hurricanes Gustav and Ike. Red boxes show the extent and location of areas referred to in the text.

Hurricane-force winds of Gustav impacted approximately 280 km of the Gulf Coast. This was an unusually widespread impact, partly because the storm itself was broad and partly because the track was about a 45^o angle to the shoreline (Fig. 2). The strongest onshore winds were located east of landfall in the right-front quadrant of the storm. Here, onshore hurricane-force winds extended from landfall to the east for 160 km. In contrast, the track of Hurricane Ike was near 90^o to the shoreline, and hurricane-force winds extended along the shore about 200 km. To the east of landfall, onshore hurricane-force winds extended for about 125 km.

Open-coast storm-surge heights generated by these hurricanes just east of landfall locations ranged from 2.4 m near Grand Isle, Louisiana for Hurricane Gustav (McGee et al., 2008) to between 4.6 and 6.1 m on the Bolivar Peninsula for Hurricane Ike (Berg, 2009). Under such conditions, waves at the coast will be breaking in broad surf zones, and their heights will be controlled by water depth. The maximum wave heights in the surf will be roughly as tall as the water is deep. Hence, if a barrier island is submerged during a storm, the deeper the water over the island, the larger the waves to batter structures and erode the coast.

The Coastal Change: For each storm, coastal changes were determined by comparing airborne-lidar topographic surveys conducted before and after landfall (for methodology, see Doran et al., 2009). In this overview, we focus on average changes of shoreline position and dune elevation for the sandy portion of coast swept by the right-front quadrant of each storm (i.e., the shoreline from where the track crosses the Gulf shore to the east limit of hurricane-force winds; Fig. 2.) Significant changes also occurred outside these limits and are discussed for Hurricane Ike in Doran et al. (2009) and for Hurricane Gustav in a forthcoming paper.

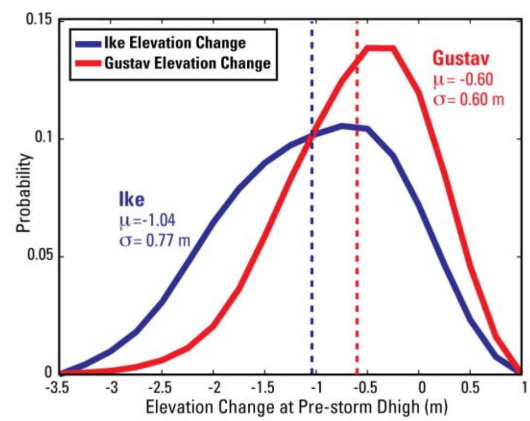

Fig. 3. Distributions of vertical change of dunes. Average of the distribution is μ; standard deviation is σ.

Figure 4. Deterioration of East Timbalier Island between 2001 and three days after Hurricane Gustav.

Within the 160 km of coast impacted by the right-front quadrant of Hurricane Gustav, sandy beaches eroded landward an average of 41 m (± 27 m, the standard deviation of the change distribution). In comparison, the measures of average shoreline erosion for the coasts impacted by the right-front quadrants of the four 2004 storms that came ashore in Florida were substantially less (Sallenger et al., 2006). The closest magnitude was Hurricane Ivan that forced erosion of 20 m (± 14 m). Furthermore, the shoreline retreat observed for Hurricane Gustav was about 4 times greater than the average erosion during Hurricane Ike, 11 m (± 29 m).

The central Louisiana coast where Hurricane Gustav made landfall has historically undergone rapid erosion. Between 1887 and 1988, the Gulf shore of the Timbalier Islands (just east of landfall, Fig. 2) eroded landward 1515 m, an average rate of 15 m/yr (Williams et al., 1992). The time between pre- and post-Gustav lidar surveys was only 6 months; if the long-term erosion proceeded steadily, then this period included about 8 m of long-term erosion. Hence, the remaining shoreline erosion that occurred in a few hours during Hurricane Gustav (33 m) represents over two years of the average long- term change of the island.

In contrast, Hurricane Ike in Texas forced greater changes in dune elevation than did Hurricane Gustav in Louisiana, leading to a greater increase in storm vulnerability in Texas than Louisiana (Fig. 3). Waves overtopping and eroding dunes during Hurricane Ike reduced the Texas elevations by an average of 1.0 m (± 0.8 m); during Gustav, elevations in Louisiana were reduced by 0.6 m (± 0.6 m). In places on the Bolivar Peninsula, Texas, the measured dunes were not natural, but were composed, in part, of fabric tubes filled with sand. Whether natural or artificial, ground observations and topography acquired after Hurricane Ike showed few signs of remaining dunes.

The Implications: The extreme shoreline retreat observed during Hurricane Gustav will contribute to the long-term degradation of Louisiana's barrier islands. During storms, some U.S. barrier islands migrate landward due to wave overwash while maintaining their surface area. However, due to sand starvation, relative sea-level rise due to land subsidence, and repeated storm impacts, the barrier islands in Louisiana are undergoing long-term reductions in surface area (Fig. 4). Between 1887 and 1988, the Timbalier Islands lost 53% of their surface area (Williams et al., 1992). These islands serve as habitats for endangered birds, as seaward boundaries of richly productive estuaries, and as protection for the mainland against storm waves and, to some extent, surge.

The shoreline retreat observed during Hurricane Ike, although a factor of 4 less than what happened during Hurricane Gustav, was also significant. In places, the average 10 m of erosion encroached on the property lines of the first row of houses on the Bolivar Peninsula, many of which did not survive the storm (Fig. 5).

The reduction of dune elevation during Hurricane Ike leaves the beach systems of the Bolivar Peninsula extremely low-lying and exposed to inundation by the surge and waves during future storms. Simulations of worse case (max of the max) storm surge by the National Hurricane Center showed that the magnitude of a Category 1 surge on the Bolivar Peninsula would be about 2 m. During Ike, the peak elevations of dunes were reduced to an average of 0.95 m, indicating that even low-intensity storms could submerge the post-Ike beaches on the peninsula.

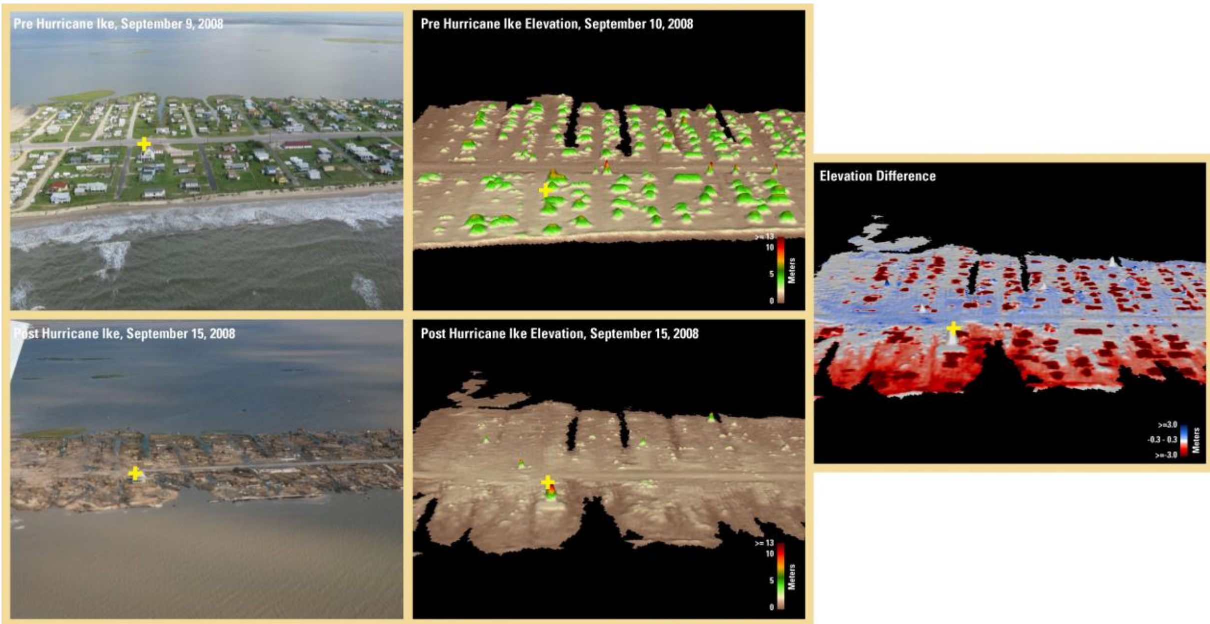

Fig. 5. *[Left]* Aerial photographs from before (upper) and after (lower) Hurricane Ike for Gilchrist, TX. Gulf of Mexico is at the bottom of the images. *[Center]* Topography measured with airborne lidar, before (upper) and after (lower). Green elevations indicate houses. *[Right]* The vertical change in topography that occurred at Gilchrist during Hurricane Ike. Red rectangles indicate loss of houses. Note vertical erosion and irregular shoreline retreat along the Gulf shore.

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***For more information*:** See full coastal-change report on Hurricane Ike: Doran et al., 2009.

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