Impacts of Hurricane Rita on the Beaches of Western Louisiana

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Hurricane Rita made landfall as a category 3 storm in western Louisiana in late September 2005, 1 month following Hurricane Katrina's devastating landfall in the eastern part of the State. Large waves and storm surge inundated the low-elevation coastline, destroying many communities and causing extensive coastal change including beach, dune, and marsh erosion.

Introduction

Just 3 weeks after Hurricane Katrina made landfall on the Mississippi River Delta in Louisiana, Tropical Storm Rita had formed and was headed toward the Gulf of Mexico. On September 22, 2005, over the warm waters of the Loop Current in the Gulf of Mexico, Rita reached its maximum intensity as a category 5 hurricane. With 155-kn (knots, or nautical miles per hour) winds and a minimum pressure of 897 millibars—the fourth-lowest central pressure on record for an Atlantic hurricane (Knabb and others, 2006)—Rita turned toward the north-northwest, taking aim at western Louisiana and its already hurricane-weary residents. In the early morning hours of September 24, 2005, Rita made landfall as a category 3 storm in southwestern Louisiana near the Texas border (fig. 1).

Successive landfalls of Katrina and Rita in the northern Gulf of Mexico region devastated many of the barrier islands, mainland beaches, and coastal communities in Louisiana. Across the impacted region, a wide variety of coastal responses to the hurricanes were observed. In some areas, such as the Chandeleur Islands during Katrina, the barrier islands were completely stripped of sand, and marsh areas were eroded (see Sallenger and others, this volume). In other locations, large overwash deposits were formed, contributing to the landward migration of the barrier islands. On some beaches, the effects were less severe, and coastal change was confined to the foreshore region. Using topography data acquired before and after the storm, we begin to quantify these observed responses and work towards an understanding of the

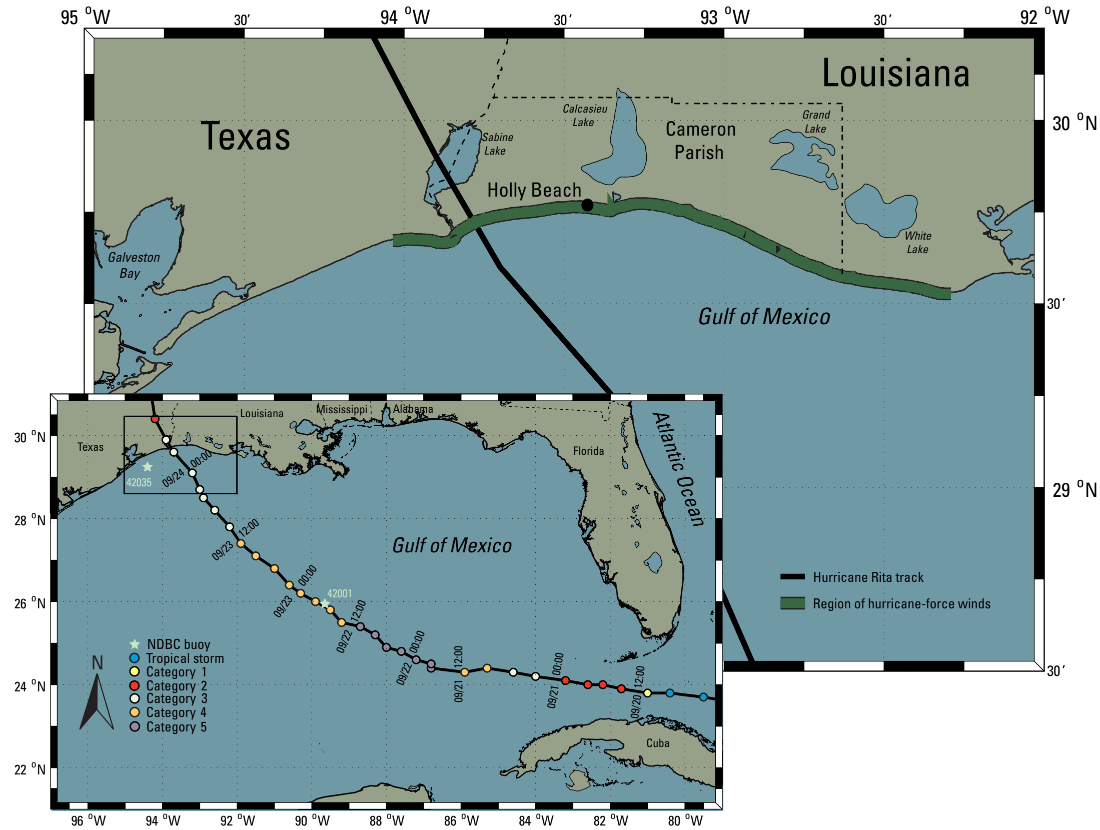

Figure 1. The track of Hurricane Rita making landfall in the southwest corner of Cameron Parish, La., in 2005. Symbol colors indicate the strength of Rita as it moved through the Gulf of Mexico (lower left panel). The green band along the shoreline in the upper right panel shows the area of coast subjected to hurricane-force winds. The locations of National Oceanic and Atmospheric Administration's National Data Buoy Center (NDBC) wave buoys 42035 and 42001 are shown with stars in the lower left panel. Times are given in Coordinated Universal Time (UTC).

nature, magnitude, and spatial variability of the response of barrier islands and sandy beaches to the landfall of a major hurricane.

Aerial Photography and Lidar Topographic Surveys

Oblique aerial photographs were collected by the U.S. Geological Survey (USGS) and the University of New Orleans on September 28, 2005, 4 days after Rita made landfall, and were compared to prestorm photography that had been collected on June 16, 2001. Comparison of these images documents hurricane-induced coastal change including beach and dune erosion, overwash deposition, and island breaching, as well as damage to structures. In a cooperative program between the USGS and the National Aeronautics and Space Administration (NASA), the beaches affected by Rita were mapped on September 27 and 28, 2005, with high-resolution light detection and ranging (lidar) surveys of beach topography. (See Sallenger and others, 2003, for details on lidar technology and instrument accuracy.) These topographic maps, constructed from spatially dense estimates of elevation, were compared to baseline maps derived from a lidar survey collected on October 10, 2002, to quantify the change in shoreline position and beach volume resulting from the storm. The lidar topographic surveys, combined with a qualitative assessment of the pre- and poststorm oblique aerial photography, provide a comprehensive assessment of hurricane impacts.

Hurricane-induced Coastal Change

The strength of Rita was felt over a large area of the coast: hurricane-force winds (speeds greater than 73 mi/hour (32.6 m/second)) extended almost 120 mi (193 km) along the coast, from McFaddin National Wildlife Refuge in Texas to Tigre Point in Louisiana (area indicated with green band in fig. 1), generating large waves and storm surge. Observations of storm surge (the super elevation of water levels near the coast caused by hurricane winds and atmospheric pressure) are limited because no open coast tide gages were functional throughout the duration of the storm. Therefore, high-water marks were surveyed throughout the area by the USGS and contractors to Federal Emergency Management Agency (FEMA) to document the maximum extent of surge. Surveyed marks in Cameron Parish, La., where Rita came ashore indicate a mean coastal surge of 10.2 ft (3.1 m) (Federal Emergency Management Agency, 2006). The maximum deepwater wave height measured at National Oceanic and Atmospheric Administration's (NOAA) National Data Buoy Center (NDBC) buoy 42001, located 205 mi (330 km) south of Southwest Pass, La., was 38.1 ft (11.6 m) with a corresponding peak wave period of 13 seconds (National Data Buoy Center, 2006). Nearshore wave heights at landfall, as measured by NDBC buoy 42035 (water depth = 45 ft (13.7 m)), were approximately 19.7 ft (6 m); however, because this buoy is located about 50 mi (80.5 km) west of the hurricane track and outside of the extent of hurricane-force winds (see fig. 1), the actual wave heights at landfall may be somewhat higher than reported values.

The combination of large waves and storm surge resulted in extensive flooding of coastal marshes, widespread beach erosion, and limited overwash (overtopping of the beach by waves and the subsequent landward transport of beach sands). In some locations near landfall, cross-island flows cut multiple channels across narrow sandy beaches and back-barrier marshes (fig. 2). These channels ranged in width between 100 and 165 ft (30.5 and 50 m) and were approximately 490 ft (150 m) in length. Cross-shore profiles of lidar-derived beach topography reveal that a considerable amount of sand was removed from the beach; the maximum, prestorm island elevation of 7.2 ft (2.2 m) was reduced to just 4.6 ft (1.4 m) after the storm (fig. 3). The mean horizontal retreat of the mean high water (MHW) shoreline in a 5-mi (8-km) area immediately to the east of landfall was 53.8 ft (16.4 m) with considerable spatial

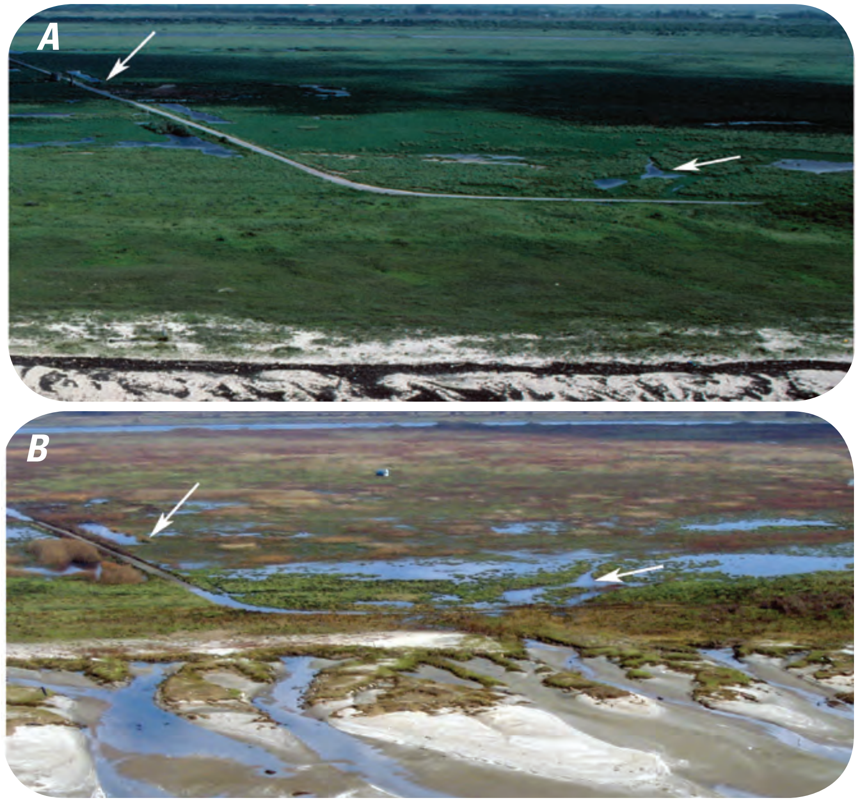

Figure 2. Prestorm (*A*) and poststorm (*B*) aerial photography of a beach located 3.7 mi (6 km) east of Hurricane Rita's landfall in 2005. White arrows indicate a common reference location between the two images. A series of shore-oblique channels were cut in the beach face during the storm. Portions of the beach and marsh have been eroded, and inland areas were flooded. The area depicted in the photographs covers approximately 656.2 ft (200 m) of coastline.

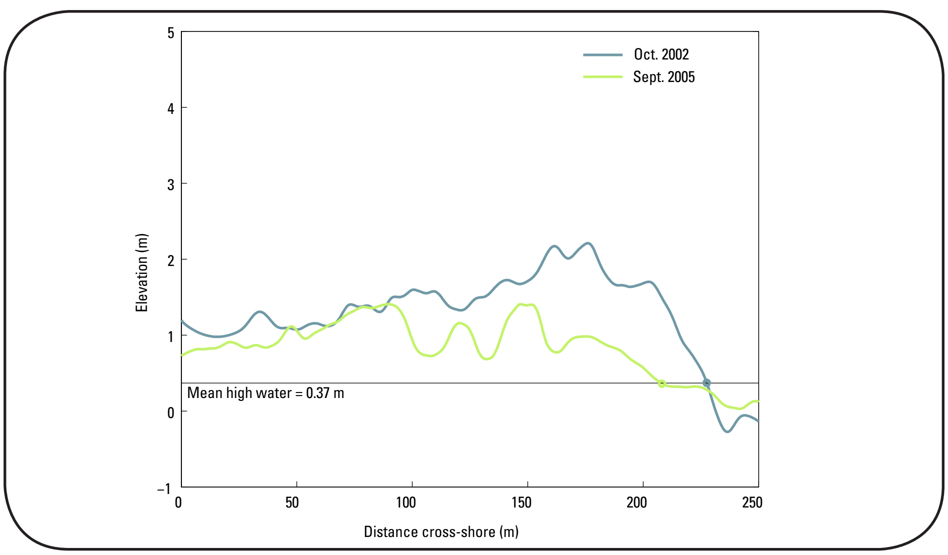

Figure 3. Cross-shore profiles (cross sections) of beach topography derived from pre- and post-Hurricane Rita light detection and ranging (lidar) surveys. The profiles show variations in land elevation from the shoreline to 820 ft (250 m) inland. The Gulf of Mexico is located to the right. The profiles were located 3.7 mi (6 km) east of landfall (corresponding photography shown in fig. 2). As a result of Rita, the shoreline moved inland almost 65 ft (20 m), and the maximum elevation of the beach was reduced by approximately 2.5 ft (0.75 m).

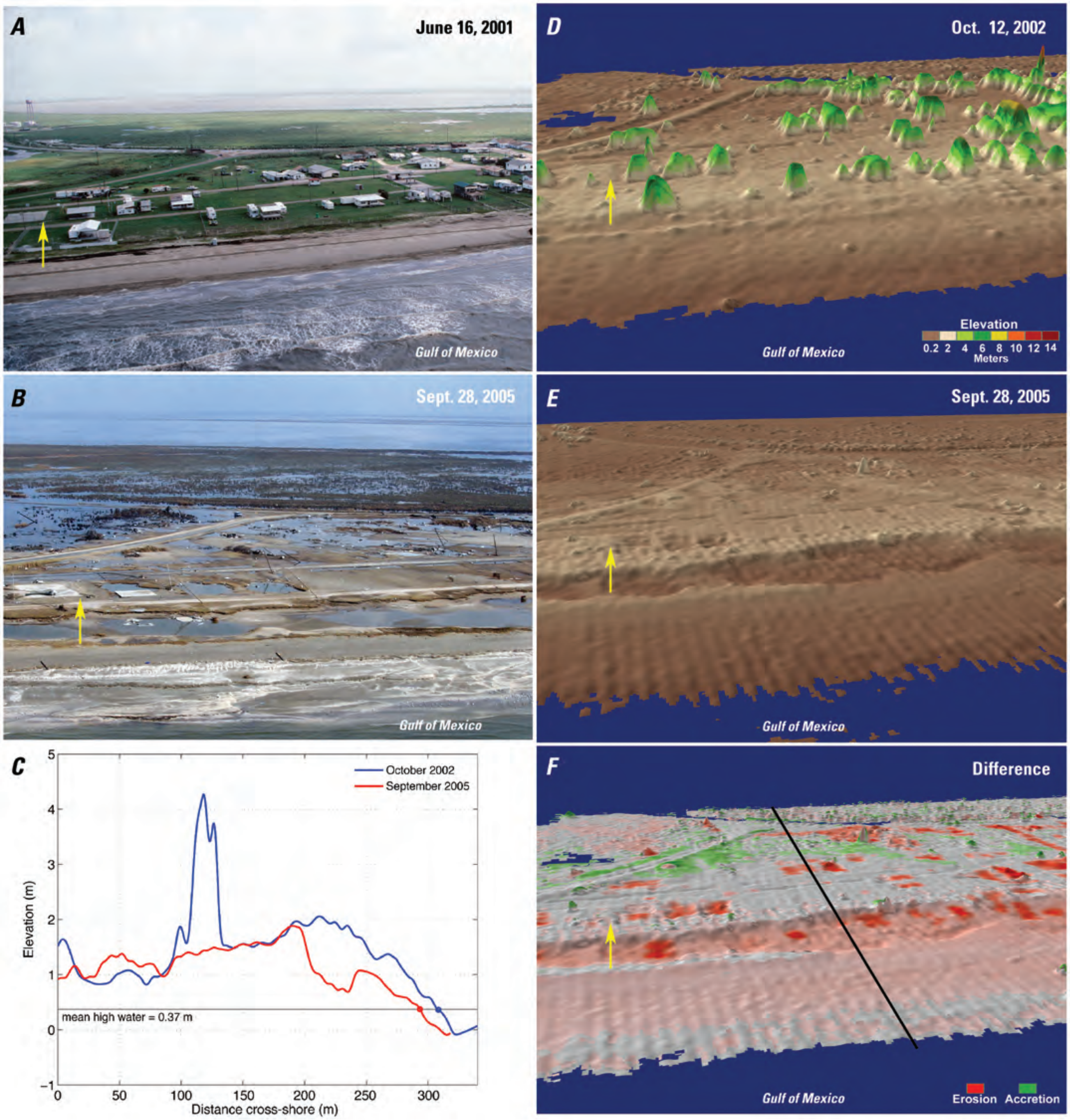

Figure 4. Oblique photographs of Holly Beach, La., taken on June 16, 2001 (*A*), and on September 28, 2005 (*B*), 4 days after the landfall of Hurricane Rita. The yellow arrows indicate a common reference location between the panels. Strong waves and currents removed structures, vegetation, and large amounts of sand, leaving deep scour channels parallel to the shoreline. Oblique light detection and ranging (lidar) elevation maps acquired before (*D*) and after (*E*) the hurricane clearly show the complete destruction of all structures and the formation of the shore-parallel erosional feature. The maximum elevation along this stretch of beach after the storm was 6.5 ft (2 m). Elevation differences between the pre- and poststorm topographies (*F*) indicate erosion of the beach and marsh areas (pink and red shades). There was little evidence of deposition (green shades) of sand or debris in the surveyed area. Gray shades represent locations of no significant elevation change. Profiles (cross sections) of lidar-derived beach topography (*C*; profile location is indicated by the black line in *F*) show 49 ft (15 m) of horizontal shoreline retreat.

variability (standard deviation = 58.1 ft (17.7 m)). No evidence of overwash deposition was observed in this area, suggesting that the channels may have been formed during the seaward return flow of storm surge as the flooded marshlands drained into the Gulf of Mexico.

Large waves and storm surge battered low-lying coastal communities, damaging or destroying most of the homes and businesses in Cameron Parish, La. In some towns, such as Holly Beach, the only human-made features remaining after the storm were power poles, concrete slabs, and roads (figs. 4*A* and 4*B*). Vegetation was stripped from the coastal areas, and extensive flooding covered much of the inland marshes. In some locations along the beach, strong flows removed large amounts of sand, creating deep scour channels parallel to the shoreline. Digital elevation maps of pre- and poststorm conditions quantify the dramatic changes along the coast caused by Rita (figs. 4*D* and 4*E*). While the most striking difference between the images may be the loss of all structures in the area, the elevation-difference image shows that there was also significant erosion along the beach (fig. 4*F*). Along the 1.5-mi (2.4-km) stretch of Holly Beach, La., the mean horizontal shoreline change was -58.7 ft (-17.9 m) (standard deviation = 23.3 ft (7.1 m)). Cross-shore profiles of beach topography show that large volumes of sand were removed from the beach face and that the foreshore elevations were lowered by over several feet (about 1 m) in some places (fig. 4*C*). Because overwash deposits were observed only in limited places along the coast, it is hypothesized that much of the sand that had eroded from the beaches was moved offshore and may eventually be brought back onshore during calmer wave conditions.

A considerable amount of spatial variability was observed in the coastal response to Rita. Shoreline change (calculated from lidar-derived pre- and poststorm MHW positions) within the area of hurricane-force winds revealed areas with over 165 ft (50 m) of shoreline retreat and areas where the position of the shoreline was relatively unchanged. In fact, some of the more stable areas of the beach were found closest to the location of landfall, while the largest magnitudes of shoreline change were observed over 50 mi (80 km) east of where Rita's eye came ashore. The spatial variability of the coastal response may be related to the local geology and the sediment composition of coastal landforms; for example, marsh areas may be more resistant to erosion than are sandy beaches. Another reason for the spatially variable coastal response may be due to a combination of variability in the pre-existing beach morphology (beach elevation, slope, or width) and in the offshore fluid forcing (waves and storm surge). To explain the longshore-variable response to Rita, lidar-derived measures of beach morphology and modeled waves and storm surge will be used in conjunction with a simple model for scaling storm impacts (Sallenger, 2000). As our understanding of the processes driving the spatially variable coastal response to storms increases, we will move towards being able to predict the impact of hurricanes on our Nation's shorelines.

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