Studying the Importance of Hurricanes to the Northern Gulf of Mexico Coast

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A pilot study was recently begun dealing with the impacts and post-storm adjustment of barrier islands to severe storms along the northern Gulf of Mexico. The study, funded by the National Science Foundation, may lead to a more comprehensive understanding of coastal morphodynamics and longer term evolution of the coast in that area. Study of the recent impacts and post-storm adjustment of the area to Hurricane Georges is playing a very important role in enhancing our comprehension of the significance of these high-energy events in coastal dynamics.

Hurricane Georges

A few hours before dawn on September 28, 1998, Hurricane Georges made landfall near Biloxi along the Mississippi Gulf Coast (Figure 1) as a strong Category 2 system (as defined by the Saffir/Simpson scale: Simpson, 1974). Waves off the Mississippi/Louisiana coast exceeded 10 m in height and storm surge varied between 2-3 m. The entire stretch of coast from the modern Mississippi delta to the Florida Panhandle, a distance in excess of 200 km, was severely impacted by the hurricane through overwash and breaching of the barrier islands, and erosion of the distal ends of the sub-deltas and major distributaries comprising the Birdsfoot delta in Louisiana. Near the landfall zone, the Category 2 storm impacted the coastline with estimated sustained winds of over 45 ms⁻¹ and rainfall between 300 and 400 mm in coastal Mississippi. Georges was the sixth storm to impact this stretch of coast since 1995, the most severe being Hurricane Opal, at its strongest a powerful Category 4 system that made landfall east of Pensacola Beach, Florida, as a marginal Category 3 hurricane [see Eos article by Stone et al., 1996; Lawrence et al., 1998]. The cumulative impact of storms during this period of intense hurricane activity has altered significantly the morphology of the Northwest Florida coast. A review of historical photographs dating back to the early 1900's suggests that the entire coast is now in quite probably the most degraded morphological condition of the 20th century.

Several investigators in the Coastal Studies Institute at Louisiana State University have ongoing research projects along the section of coast impacted by Hurricane Georges. Much of the work centers on quantifying, through direct field measurement, the impacts of extratropical storms and hurricanes on the dynamics of beaches along the predominantly barrier coast. This research has resulted in developing a comprehensive pre-hurricane geomorphology of the beach and nearshore environments, particularly in Mississippi and Western Florida. After landfall of Hurricane Georges, the study sites were reoccupied and surveys undertaken to establish a quantitative assessment of the storm's effects.

Fig. 1. Thermal IR image of Hurricane Georges, on September 28, 1998, nearing landfall at Biloxi, Mississippi (GOES-8 GVAR Ch. 4). Original color image appears at the back of this volume.
impact on the geomorphology of the system. The resultant data are unique and add to a longer time series of differential responses of barriers in the northern Gulf to catastrophic events.

Storm History and Sea State

Satellite imagery clearly shows the origins of Hurricane Georges as a tropical wave that moved off the African coast during the second week of September. The system achieved hurricane status on September 17th and reached Category 4 strength on the 19th, while located approximately 750 km east of the Lesser Antilles (Figure 2). During the following days, interaction with the northern Caribbean islands and their mountainous terrain weakened the storm to a minimal hurricane. Georges began to re-intensify immediately after moving off Cuba, and assumed a west-northwest-to-northwest track across the central Gulf, a heading that directed the system dangerously close to the New Orleans metropolitan area. Through September 27th, estimated peak sustained winds remained near 50 ms$^{-1}$, nearing Category 3 intensity. The system began to display a more northwesterly track as it neared the Louisiana/Mississippi coast, passing approximately 15 km to the west of NDBC Buoy #42040 (Figure 2); this track placed the buoy in the intense front-right quadrant of the system as it approached, and suggests that the buoy was within the eye of the storm for a considerable period of time. Figure 3 provides evidence of the buoy being positioned inside the radius of maximum winds, close to the storm center, as both sustained winds and gusts briefly decrease at the time that surface pressure reaches a minimum of 963 mb. Storm waves at that location exceeded 10 m, with dominant wave periods on the order of 12-14 s (Figure 3), a combination that indicates extremely steep waves. Hurricane Georges' forward motion began decreasing as it approached the coastline. The storm turned to the northwest and then north-northwest before making landfall near Biloxi, Mississippi, at approximately 1130 UTC September 28, with maximum sustained winds estimated at 47 ms$^{-1}$. Upon landfall, the system wobbled over the coastline for six hours causing significant damage to the area. As discussed below, the concave-sea­ward configuration of this reach of coast was optimal for a slow-moving system, counterclockwise rotating wind field and the resultant wave field to maximize beach erosion, overwash and breaching from Louisiana to the Florida Panhandle.

Morphological Impacts

Chandeleur Island, located in Louisiana (Figure 2), was extensively breached during Hurricane Georges. Virtually all of the unconsolidated, coarser-grained material (shell-rich fine sands) was stripped from the barrier exposing sediment bound by an organic core of marsh material. This response is typical for hurricanes along the Louisiana coast and is critical in that the exposed marsh vegetation and root bound barrier sediments serve as the nucleus for post-hurricane deposition of coarser sediment [see Stone and Finkl, 1995, for a more detailed review]. Impacts along the barriers of Mississippi, Alabama, and Northwest Florida were also significant. Examples of the morphological response to the hurricane are shown in Figure 4. A considerable wedge of material was removed from West Ship Island (Figure 2: upper) resulting in a reduction of the berm and foredune elevations by over 1 m. On the soundside of the island, however, the beach prograded by approximately 10 m, with sediment apparently supplied by dunes that were reduced in elevation by 1.5 m (Figure 2: middle). Approximately 200 km to the east, the western flank of Santa Rosa Island experienced
Fig. 3. Time series of sea-level pressure, wave period, wave height (upper), pressure, and sustained (8 minute average) wind speed and gusts (lower) before, during, and after passage of Hurricane Georges over NDBC buoy 42040.

Towards a Better Understanding

The institute's work on hurricanes over the years is now beginning to present new evidence indicating a considerable variation in the response of barrier islands to catastrophic events along the Northern Gulf of Mexico. For example, unlike the Mississippi and Louisiana barriers, the Florida barrier most extensively studied over the past 20 years has demonstrated an ability to conserve mass during catastrophic events such as Hurricane Georges. Comparison of pre-hurricane and post-hurricane profiles using a common datum, indicates that very little sediment was removed from the barrier during Hurricane Georges since over 90% of the sediment was accounted for through profile measurements obtained shortly after the event. This phenomenon was also documented after Hurricane Opal in 1995 [Stone et al., 1996]. Data also indicate that less intense, although more frequent winter storms associated with the anticyclones following cold front passage over the Northern Gulf of Mexico coast, play an important role in eroding the bay/lagoon shorelines of these barriers. In addition, the barriers are particularly prone to deflation during strong northerly winds in areas where overwash processes have removed vegetation. The overwash fans deposited in the bays during severe storms such as Hurricanes Georges and Opal, are eroded rapidly during post-frontal periods during which high frequency, locally generated waves dominate sea state in the larger bays and sounds along the northern Gulf of Mexico.

Pilot Study

The interaction and cumulative impacts of tropical cyclones during summer and fall and post-frontal circulation in winter and spring appear to play an integral role in the longer-term morphodynamics and evolution of the coast along the northern Gulf of Mexico. Additionally, our preliminary investigations indicate that the longer-term evolution of fluvially dominated systems in a coastal environment, such as the modern Mississippi River delta plain, are significantly influenced by catastrophic events such as Hurricane Georges—particularly on their seaward margins where subdelta growth is occurring and distributaries are prograding. The post-storm adjustment of sediment rich, retrogressive systems has not been investigated in any detail. In addition, our understanding of the initial phases of barrier island recovery after severe storms is...
Fig. 4. Profiles showing the extent of morphological change due to Hurricane Georges at West Ship Island (upper and middle) and Santa Rosa Island (lower).

Based primarily on supposition, largely governed by our interpretation of the day-to-day dynamics of coastal systems and associated processes during fairweather and storms of lesser magnitude.

To begin addressing these issues, a pilot study funded by the National Science Foundation, Earth Surface Processes program, has been implemented along the stretch of coast from Louisiana to Florida. If the results from the pilot project show merit, the preliminary findings will be used to carefully develop a more comprehensive program on the morphodynamics of coastal response and adjustment to severe storms in the Gulf of Mexico. Future work will likely concentrate on the sources and mechanisms responsible for sedimentation in these environments over various temporal and spatial scales and the development of models that elucidate the morphosedimentary dynamics of two contrasting environments. Over the last century, more than 60 tropical storms/hurricanes have impacted the study area [Stone et al., 1997]. While their high frequency of occurrence would imply that these events play an important role in the longer-term evolution of these coastal systems, we do not as yet understand their precise role. In addition, we do not understand, in a quantitative manner, the post-storm adjustment of these systems during lower energy conditions between hurricane landfalls.

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References


Fig. 1. Thermal IR image of Hurricane Georges, on September 28, 1998, nearing landfall at Biloxi, Mississippi (GOES-8 GVAR Ch. 4).