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Erosional Patterns of the Isles Dernieres, Louisiana, in Relation to Meteorological Influences

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ABSTRACT

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Over the past 100 years, the Isles Dernieres, a low-lying barrier-island chain along the central Louisiana coast, has eroded extensively. This erosion has resulted in more than 1 km of northward beach-face retreat and the loss of 71 percent of the total island area. The primary causes for the erosion are wind and wave attack, diminished sand supply, and relative sea-level rise. Over the short term, wind and wave attack, which produce backshore transport, beach-face erosion, and overwash deposition, are the major morphodynamic processes modifying the Isles Dernieres. These processes are driven by recurrent cold fronts that move through the area every few days between autumn and spring and by hurricanes that impact the area every few years during the summer and autumn.

Five years of detailed topographic surveys show that a beach on the central Isles Dernieres changed significantly in both shape and sediment volume; however, the pattern of change was not the same each year. Between August 1986 and July 1988, cold-front-generated waves eroded the entire beach face and caused an average of 35 m of retreat at mean sea level and a sediment loss of about 60 m^3 per meter of beach width. In contrast to the relatively slow erosion caused by cold fronts, hurricane Gilbert, a category 5 hurricane that passed about 800 km south of the Isles Dernieres in September 1988, produced differential beach-face retreat of about 9 m at mean sea level and 40 m at an elevation of 0.5 m. Most of the sediment eroded from the beach face was deposited on the backshore, which resulted in only a small loss of sediment from the beach and a noteworthy decrease in beach-face slope. During the two years following hurricane Gilbert, the mean-sea-level contour remained stationary while the beach face slowly returned to its pre-Gilbert shape. Having regained that shape, the beach face began again to retreat at a rate that approximates the earlier cold-front-driven rate. That magnitude of retreat is expected to continue until another large hurricane alters the erosional pattern. The average rate of berm-crest retreat for the five-year period was 0.5 cm/day; the actual retreat, however, primarily occurred during the winter.

ADDITIONAL INDEX WORDS: *Barrier island, beach-face erosion, land loss, overwash, sediment volume, wave attack.*

INTRODUCTION

Land loss is a significant problem on the Isles Dernieres, a Louisiana barrier-island chain (Figure 1) where rates of beach-face retreat between 10 and 30 m/yr were documented by comparing nautical charts made in 1891 and 1934 (PENLAND *et al.*, 1985). Retreat could be due to net sediment loss from the barrier, landward migration of the beach sand fronting the barrier, or some combination of the two. Sediment loss diminishes the volume of a barrier chain, whereas landward migration of the sand primarily changes the position of the barrier without reducing its volume.

Two morphodynamic processes that affect Louisiana barrier islands, beach-face erosion and overwash deposition, primarily occur during the passage of cold fronts and hurricanes. This paper, which is based on five years of study at a beach site on the Isles Dernieres, describes the morphologic changes to the beach due to both numerous cold fronts and two hurricanes and discusses the cross-shore beach shape produced by each type of storm.

Location and Erosional History of the Isles Dernieres

The Isles Dernieres is a 32-km-long arcuate barrier-island chain located about 150 km west of the modern delta of the Mississippi River (Figure 1). Between the mid-1800's and the present, the chain evolved from an erosional headland with flanking barriers to its present configuration (PENLAND *et al.*, 1988). In the 1850's the chain was only 0.5 km from the mainland and consisted of one island; now it is 7 km from the mainland and consists of four islands separated by tidal inlets. Except for completely sandy terminal spits, each island consists of a fine-sand beach fronting and, in part, overlying marsh deposits (Figure 2). Island widths

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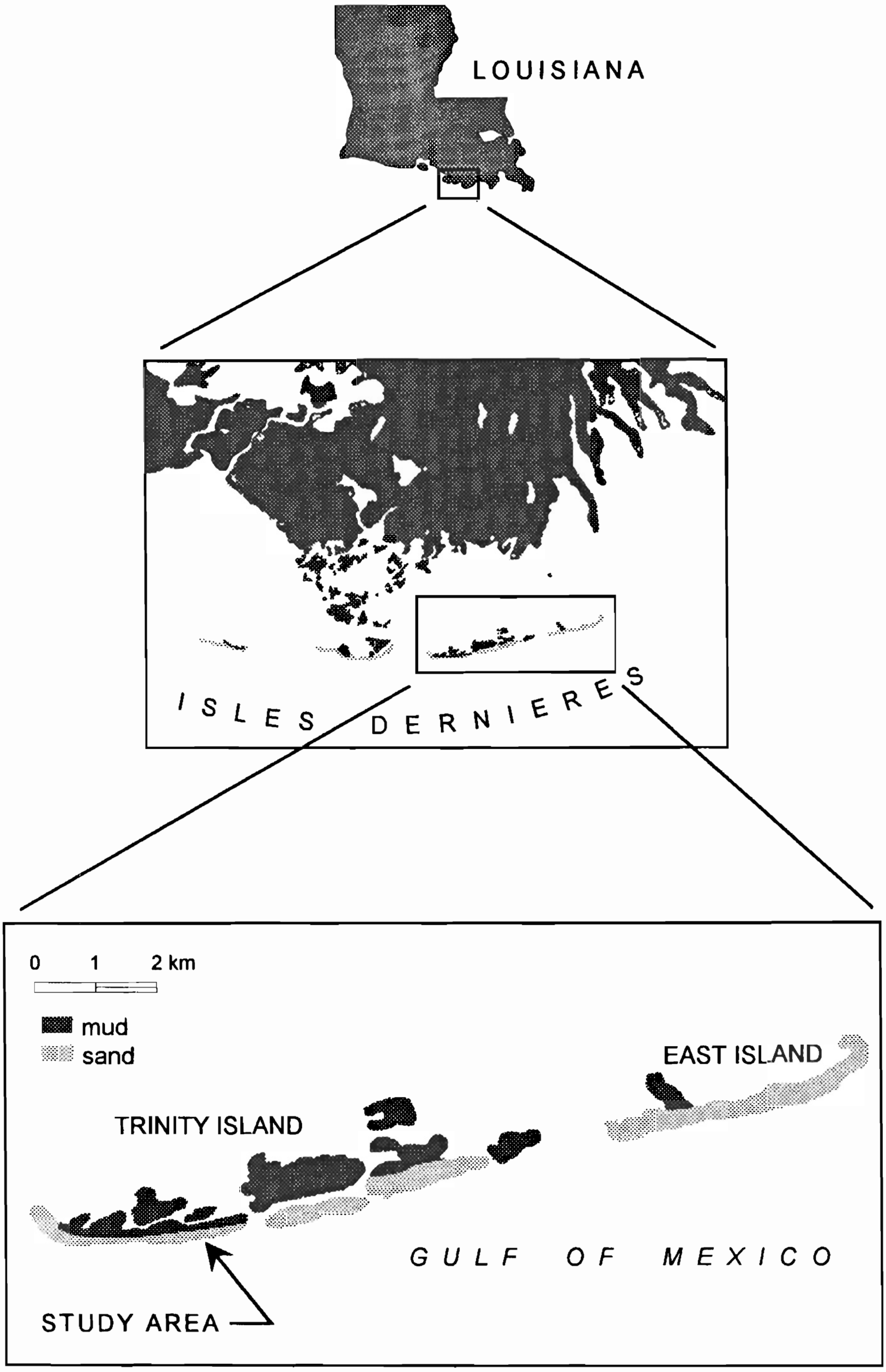

Figure 1. The Isles Dernieres barrier-island chain, off the central coast of Louisiana, and location of study area.

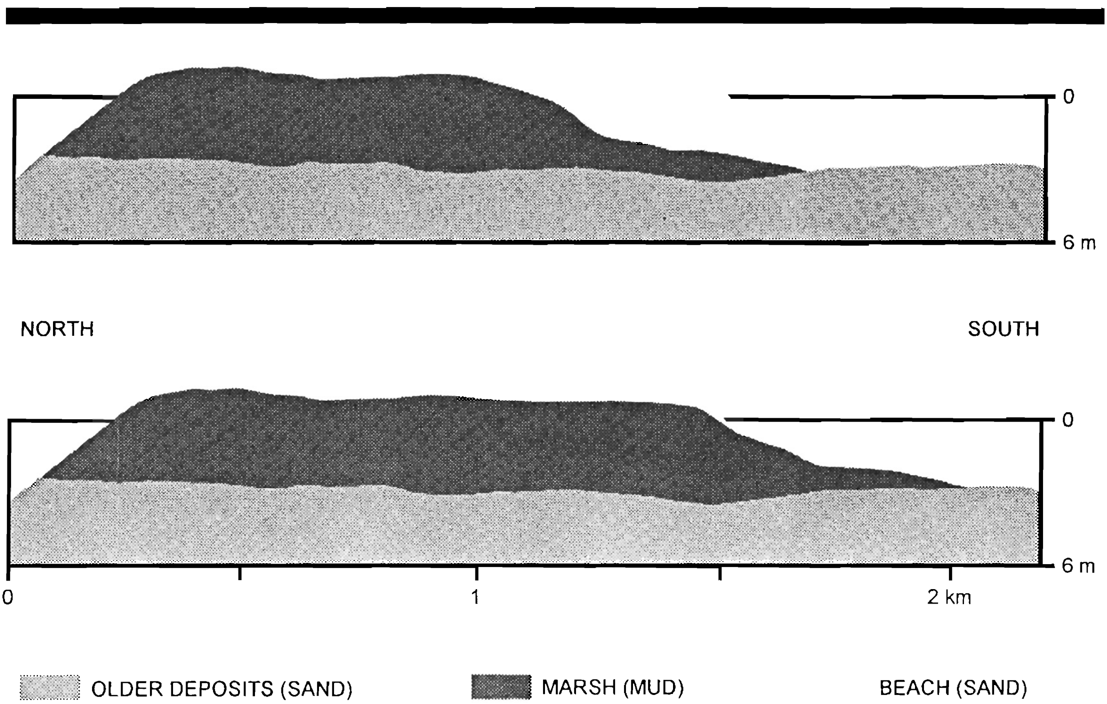

Figure 2. Typical cross sections of the Isles Dernieres; Gulf of Mexico to the right. Light gray, modern sand; medium gray, delta complex of older sandy deposits; dark gray, mud. Zero depth at mean sea level. Top, after KWON (1969) occurs where the shoreline intersects old inter-marsh ponds; bottom, after DINGLER and REISS (1989).

vary from 1.5 to 2 km in the central part to less than 1 km on the flanks; elevations generally are less than 1.5 m above mean sea level (MSL) because dune heights are minimal, and the berm crest generally lies within 30 m of the Gulf of Mexico shoreline. The beach, which typically is wedge-shaped, is less than 2 m thick at the berm crest (PEYRONNIN, 1962; DINGLER and REISS, 1988). Beach sand is well to very well sorted and diameters vary between 0.13 and 0.20 mm (RITCHIE *et al.*, 1989).

Since 1887, the Isles Dernieres has decreased in size from 34.8 km^2 to 10.2 km^2, a decrease of 71% (PENLAND and BOYD, 1981; PENLAND *et al.*, 1985). During the past 100 years, the Gulf of Mexico shoreline of the Isles Dernieres has migrated northward more than 1 km, and an average beachface retreat rate of 10 m/yr has been documented near the study site (PENLAND *et al.*, 1985; B. Jaffe, *personal communication*, 1988). Over the long term, the lack of an external sand supply has probably contributed to the erosion of the Isles Dernieres (SALLENGER *et al.*, 1987) because there is insufficient sand to protect its muddy core during repeated winter storms (DINGLER and REISS, 1990). PEYRONNIN (1962) concluded that there have been no external sources of sand for the Isles Dernieres region since at least 1904 when Bayou Lafourche, 40 km to the east, was dammed.

PENLAND *et al.* (1988) developed a model of "transgressive submergence" to explain the erosional history of abandoned deltas of the Mississippi River. A major element of this model is the fragmentation and decrease in area of the barrier islands until, eventually, only an offshore shoal remains. Within the scope of that model, the Isles Dernieres was a Stage 1 (Erosional Headland and Flanking Barrier Island) sand body until the early or middle 1800's. It is now a Stage 2 (Barrier Island Arc) sand body, and, if erosion continues at the current rate, will be a Stage 3 (Inner-Shelf Shoals) sand body sometime between 2038 (BOYD and PENLAND, 1988) and 2062 (PEYRONNIN, 1962).

Wind, Wave, and Water-Level Variations Along the Central Louisiana Coast

On the basis of regional climatological and geological studies, earlier researchers concluded that

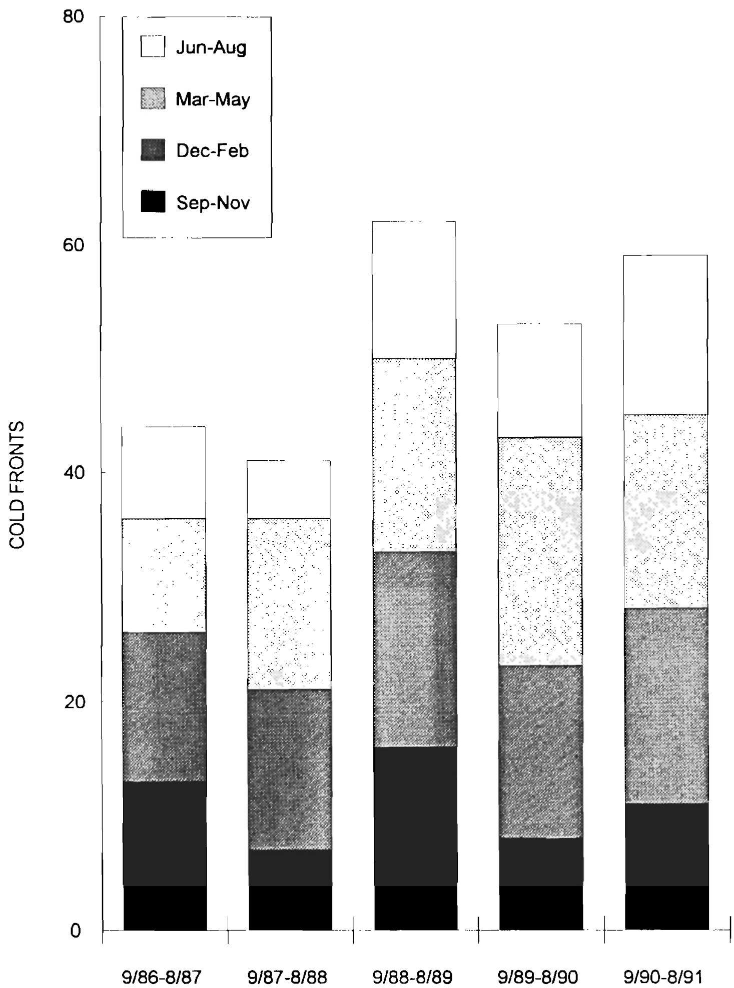

Figure 3. Occurrence of cold fronts in coastal Louisiana inferred from the frequency of the Frontal Gulf Return synoptic weather type at New Orleans, Louisiana (from R. Muller, *personal communication*, 1991).

most of the land loss and beach-face retreat on the Isles Dernieres was a result of the erosive effects of storm waves generated by hurricanes and cold fronts (Roberts *et al.*, 1987; Ritchie and Penland, 1988). The highly erosive nature of hurricanes on barrier islands is widely recognized (*e.g.*, Simpson and Reihl, 1981; Penland and Suter, 1985); recently, however, scientists realized that, cumulatively, winter cold fronts produce significant annual barrier-island erosion (Boyd and Penland, 1981; Roberts *et al.*, 1987; Ritchie and Penland, 1988).

Throughout the year, cold fronts are an important component of the mid-latitude atmospheric circulation system in the northern hemisphere. Between any autumn and spring, when they create the most intense storms, 30 to 40 fronts cross coastal Louisiana (Roberts *et al.*, 1987). Muller and Willis (1983) portray the weather patterns in Louisiana with eight synoptic weather types. One type, the Frontal Gulf Return, which occurs when a cold front approaches Louisiana, is characterized by stormy weather and northwesterly winds. The change in weather from the Frontal Gulf Return type to one of the other types generally marks the passage of a cold front through

Table 1. *Potential overwash elevations in coastal Louisiana (from* Boyd *and* Penland*, 1981).*

Event	Overwash Elevation (m)	Frequency
Minor Cold Front	1.42–1.73	10–15 per yr
Major Cold Front	1.73–2.02	5–10 per yr
Force 1 Hurricane	1.73–2.92	1 per 8 yr
Force 3 Hurricane	2.66–4.46	1 per 10 yr
Force 5 Hurricane	3.90–7.00	1 per 32 yr

the area. Applying that criterion to the twice daily synoptic weather type data for New Orleans gives an estimate of the trimonthly and yearly distribution of cold fronts crossing the Isles Dernieres (Figure 3; R. Muller, *personal communication*, 1991).

In coastal Louisiana the wind most frequently blows from the southeast, but is strongest from the north and northeast (Murray, 1976). Southerly (onshore) winds are important for barrier-island change because the southeast through southwest winds that precede cold fronts cause high seas and sea-level setup, which erode the beach face and facilitate overwash. The northerly (offshore) winds that follow these fronts calm the seas, locally lower sea level (Roberts *et al.*, 1987), and blow sand back onto the beach face and into the ocean (Dingler *et al.*, in press).

The mean diurnal tidal range near the Isles Dernieres is 0.36 m (National Ocean Service, 1987), but the actual water level deviates substantially from the tidal level during certain weather conditions. Boyd and Penland (1981) estimate that cold fronts elevate local sea level a minimum of 1.42 m above MSL at least 15 times per year in coastal Louisiana (Table 1). During the highest tides, an additional sea-level rise of 1.42 m will put most of the Isles Dernieres below sea level.

Tropical storms, including hurricanes, occur less frequently than do cold fronts, but the resulting impact on the coastline can be much more dramatic. Simpson and Lawrence (1971) estimate that the recurrence interval for tropical storms and hurricanes at any point along the Gulf Coast is 1.6 and 4.1 yr, respectively. Such storms have the potential to elevate sea level as much as 7 m above MSL (Table 1). Prior to the 1988 hurricanes discussed herein, the last hurricanes to impact the Isles Dernieres occurred in 1985.

Except during storms, low wave-energy conditions exist along the Louisiana coast. Modal wave conditions offshore are characterized by waves less than 1 m high with periods of 5 to 6 sec (Bretschneider and Gaul, 1956). Cold fronts, which produce sea-like conditions (variable wave heights, periods, and propagation directions) along the coast, often generate waves that are 2 to 3 m high, whereas local average wave heights during calm weather are about 60 cm (Ritchie and Penland, 1988). Waves produced by tropical storms vary greatly with storm intensity and location, but they can be far more powerful than those generated by cold fronts.

STUDY SITE AND SURVEYING TECHNIQUES

The primary objective of this study is to document the timing and magnitude of the morphologic changes to the Isles Dernieres caused by waves and winds. Data collection for this study began in August 1986 and ended in July 1991. The study was conducted at a site on the central part of the Isles Dernieres (Figure 1) that was chosen because it is typical of most of the chain, having a straight shoreline and a sandy beach fronting marshy land (Figure 4). Mean sand-grain diameters along a shore-normal transect across the center of the site vary between 0.26 and 0.19 mm except for the last point on the lower beach face, which came from an elevation where the underlying mud often crops out. All the sand is well sorted to very well sorted ($\sigma_\phi < 0.5$).

Morphologic changes were determined by comparing profile lines and contour maps obtained from repeated surveys within an area that extended 400 m alongshore and from the marshy part of the island behind the beach into the Gulf of Mexico. Within that area, surveys were conducted several times a year along eleven shore-normal and two shore-parallel lines; the former were located in the center of the site and 25, 50, 100, 150, and 200 m to either side of the centerline, and the latter along the two rows of reference markers (Figure 5). Distances were referenced to a post located on the centerline near the back of the beach, and elevations were referenced to MSL. Positive cross-shore (X-axis) values represent distances landward of that post, and positive alongshore (Y-axis) values represent westerly distances. Survey data were collected using an electronic distance meter (EDM) that measures azimuth, instrument tilt, and travel time of an infrared beam between the instrument and a mov-

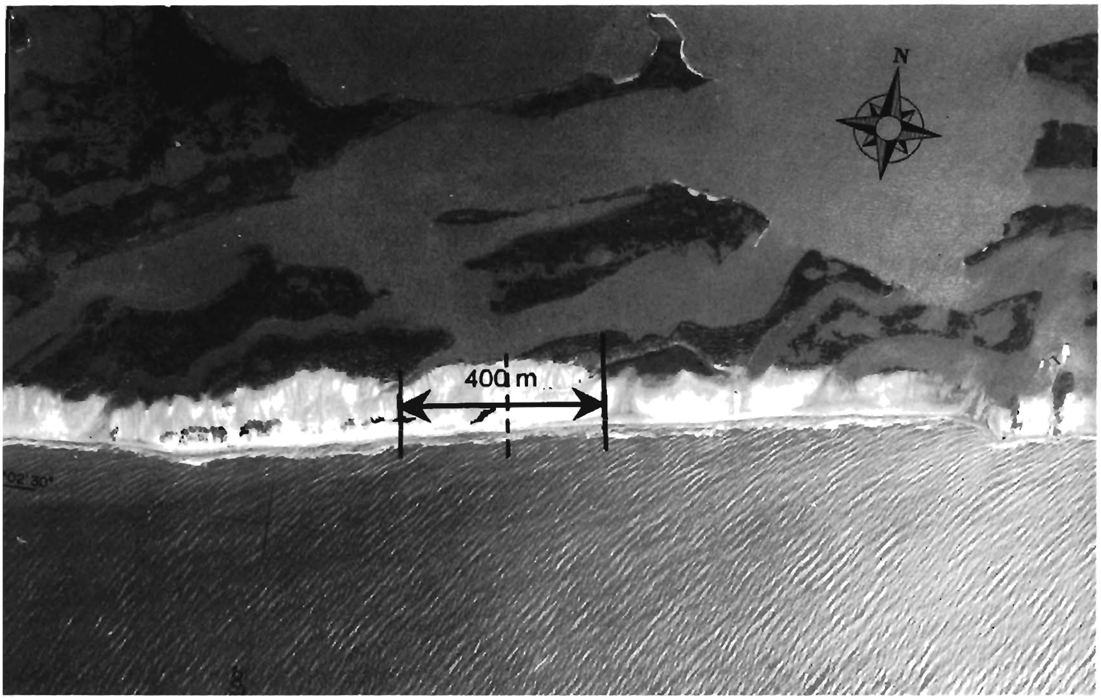

Figure 4. Vertical aerial photograph of the study area on the Isles Dernieres. Gulf of Mexico at bottom. Dashed line, approximate center of the study area; solid lines, east and west limits. Dark areas on island are vegetated dunes. Photograph taken October 1986.

able prism. The EDM outputs distances to 1-mm resolution and angles to 2 sec of arc and is capable of resurveying fixed reference markers on the beach to within 2 mm.

TEMPORAL CHANGES IN THE CROSS-SHORE PROFILE

Beach surveys on the Isles Dernieres between August 1986 and July 1991 show an erosional pattern consisting of a net loss of sediment from the area and a large-scale retreat of the beach face. During that time, the erosional pattern varied in a complex manner relative to the pattern of storms. Erosion was extensive during the first two years and the last two years but accretion occurred during year three even though the numbers of cold fronts were roughly equivalent each year (unless otherwise specified, 'year' refers to the period between September of one calendar year and August of the next). Hurricane-caused erosion of the Isles Dernieres occurred in September 1988 when storm waves from hurricane Gilbert struck the Isles Dernieres and drastically changed the slope of the beach face. The morphologic changes produced by hurricane Gilbert created a different cross-shore profile from that produced by cold fronts and so the impact of ensuing cold fronts was significantly reduced. The nature of the variation in the erosional pattern on the beach is shown in plots of the shore-normal profiles (Figure 6), the location and elevation of the berm crest (Figure 7), the location of the MSL and 0.5-m contours on the beach face (Figure 8), and the volumetric change to the study area (Figure 9). The volumes in Figure 9 were obtained with a surface gridding program by subtracting each of the surfaces from the August 1986 surface. The volumetric calculations are confined to a rectangular area of $-150 \text{ m} \leq X \leq 50 \text{ m}$ and $-200 \text{ m} \leq Y \leq 200 \text{ m}$ (non-shaded area in Figure 5), where X and Y are the shore-normal and shore-parallel axes, respectively. In the cross-shore direction, this area spans the backshore and the beach face, stretching from the bayou behind the study site to the inner surfzone. The X-axis limits were set to ensure that all surveys would be compared over a common cross-

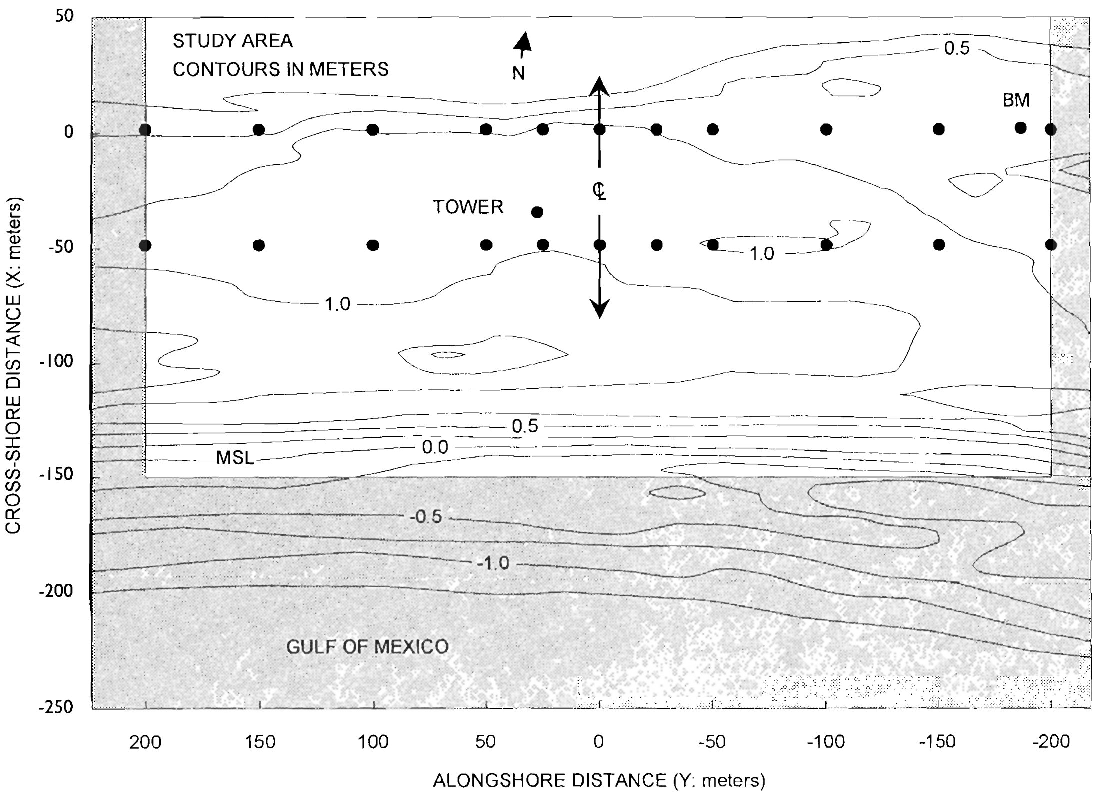

Figure 5. Contour map of a section of the Isles Dernieres drawn from surveys made in August 1986. Dots show reference stakes for 11 shore-normal lines; ℄ is centerline. Contour interval, 0.25 m; zero contour is at mean sea level (MSL). Unshaded rectangle locates area herein called the 'study area'.

shore distance. In the following discussions this rectangular area will be referred to as the study area.

Cold-Front Erosion Between August 1986 and September 1988

From multiple surveys taken between August 1986 and September 1987, DINGLER and REISS (1990) developed a model for cold-front driven beach-face erosion and overwash deposition on the Isles Dernieres. The model ascribes a net annual beach-face retreat of greater than 10 m/yr to a combination of late-fall through early-spring cold-front-driven storms that remove sediment from the beach face and low-energy, static conditions the rest of the time. For example, during the 1986–1987 study year, 27 cold fronts between November 1986 and April 1987 (Figure 3) produced an average of 20 m of beach-face retreat at MSL and 25 m at an elevation of 0.5 m. Between April and September 1987, there was essentially no beach recovery, resulting in a net beach-face retreat of about 20 m at MSL and a slight decrease in the slope of the upper beach face (Figure 8). During that year, the volumetric loss from the study area was ~10,000 m^3 (Figure 9), which occurred as a combination of beach-face erosion and backshore deposition. The sediment deficit was, presumably, a result of sand transported away from the beach face (either offshore or differential longshore transport) and mud eroded from the underlying marsh deposits and carried into deep water (DINGLER and REISS, 1989).

A similar erosional pattern occurred between September 1987 and July 1988. The passage of 28 cold fronts between November 1987 and April 1988 (Figure 3) caused most of the beach-face retreat, which averaged between about 15 and 25 m at the MSL and 0.5 m elevation, respectively (Figure 8), and a volumetric loss of ~16,000 m^3 (Figure 9).

Hurricane Erosion During September 1988

On 11 September 1988, Florence, a category 1 hurricane, struck land on the gulf side of Florida after moving up the eastern Gulf of Mexico. The study area on the Isles Dernieres was ≥600 km to the left of Florence's track (as measured to its eye). An abbreviated survey taken only along the centerline on 14 September showed little change and indicated that the hurricane's impact was minor with small amounts of deposition on both the beach face and upper backshore.

On 16 September 1988, Gilbert, a category 5 hurricane described as one of the most powerful hurricanes ever to enter the Gulf of Mexico (HUH *et al.*, 1988), struck land in eastern Mexico after traveling along an east-to-west path in the northern Caribbean Sea and southern Gulf of Mexico. Even though Gilbert's track was ≥800 km to the left of the study area, a survey on 27 September showed dramatic changes in the beach profile (Figure 6) with negligible loss of sediment from the study area (Figure 9). Beach-face retreat varied from about 9 m at MSL to about 40 m at an elevation of 0.5 m (Figure 8) as a substantial volume of sand was shifted to the backshore. Cross-shore profiles showed a substantial decrease in beach-face slope; alongshore the contours realigned to the 1986 orientation (Figure 8).

Cold-Front Erosion Between September 1988 and September 1991

Between September 1988 and September 1991 no hurricanes struck the Isles Dernieres, but cold fronts frequently passed through the area during the winters. The number of cold fronts in the year following the Gilbert period was comparable with the pre-Gilbert average number, but the erosional pattern at the study site during that year was much different from the pre-Gilbert pattern in that the beach-face built up and the study-area sediment volume increased. That trend reversed in the second post-Gilbert year with the result of little net erosion and beach-face retreat after two years.

Even though 35 cold fronts passed through coastal Louisiana between November 1988 and April 1989 (Figure 3), the beach accreted (Figure 9), and the beach face advanced a few meters at the 0.5-m contour while remaining stationary at MSL (Figure 8). Much of the accretion occurred near the berm crest, which had been greatly degraded by hurricane Gilbert (Figure 6). Between the end of September 1988 and the end of August 1989, sand volume in the study area increased by ~9,000 m^3 (Figure 9).

Between November 1989 and April 1990, 31 cold fronts passed through coastal Louisiana (Figure 3). During that year, the MSL contour retreated slightly, the 0.5-m contour remained stationary (Figure 8), and the berm crest remained at the same elevation and location (Figure 7). The volumetric loss of ~6,000 m^3 from the study area (Figure 9) approximately balanced the previous year's gain, and, in September 1990, the net volume of sediment removed from the study site approximated the September 1988 value (Figure 9).

Between November 1990 and April 1991, 34 cold fronts passed through coastal Louisiana (Figure 3), causing significant beach-face retreat (Figure 6) as both the MSL and 0.5-m contours shifted landward (Figure 8), and the berm crest reached its highest elevation and most landward location of the five years (Figure 7). The volumetric loss of ~10,000 m^3 during that year resulted in a net volumetric loss from the study area of ~33,000 m^3 over the five years of the study (Figure 9).

EROSIONAL SIGNATURES

Five years of survey data from a beach on the Isles Dernieres suggest that a season of cold fronts and, perhaps, small tropical storms produce one erosional signature, whereas large hurricanes produce another. Although both storm types contribute to the long-term annual beach-face retreat rate, which has been estimated to be about 10 m/yr, the erosional patterns differ in detail. Storms generated by cold fronts attack the beach face in such a way that its slope remains fairly constant; large hurricanes reduce beach-face slope. For some period of time after a large hurricane, beach-face retreat ceases while the cold-front-generated storms expend their energy steepening the beach and rearranging the sand presumably moved to the nearshore by the hurricane. When the beach reaches a steepness commensurate with the cold-front waves, more rapid beach-face retreat resumes.

During the passage of cold fronts, sea level is only slightly elevated, and so the storm waves expend their energy on both the beach face and the nearshore bars and troughs. Because the lower beach face often consists of muddy deposits under

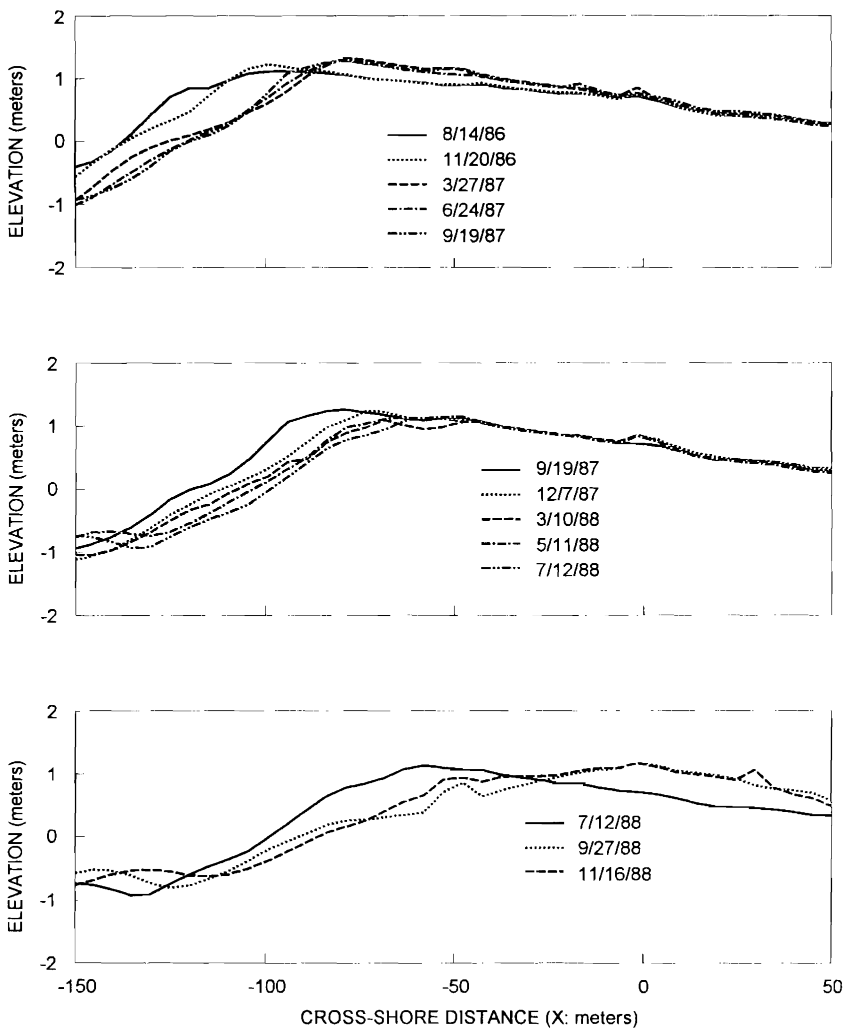

Figure 6. Shore-normal profiles for each of the topographic surveys taken between August 1986 and July 1991. Each profile is the average of the eleven profiles taken that day. The last profile on each plot is repeated on the next plot for continuity. Gulf of Mexico is to the left.

a veneer of sand and the nearshore troughs are muddy (DINGLER and REISS, 1990), much of the sediment eroded by storm waves is mud that is subsequently transported completely out of the nearshore zone. Much of the sand removed from the upper beach face fills the void left by the eroded mud, and a smaller amount is carried to the backshore by overwash processes. Furthermore, during overwash the berm crest increases in elevation, which decreases the ability of subsequent storms to overtop the berm. Consequently, whenever the berm has built so high that the cold fronts erode the beach face but do not elevate sea level enough to overtop the berm, the amount of sand deposited by overwash processes on the backshore drops to zero.

A hurricane such as Florence, whose impact on an area is small, may create the same erosional pattern as multiple cold fronts. However, during a large hurricane like Gilbert, the entire island is submerged to a depth of several meters. Waves primarily attack the upper beach face, and the

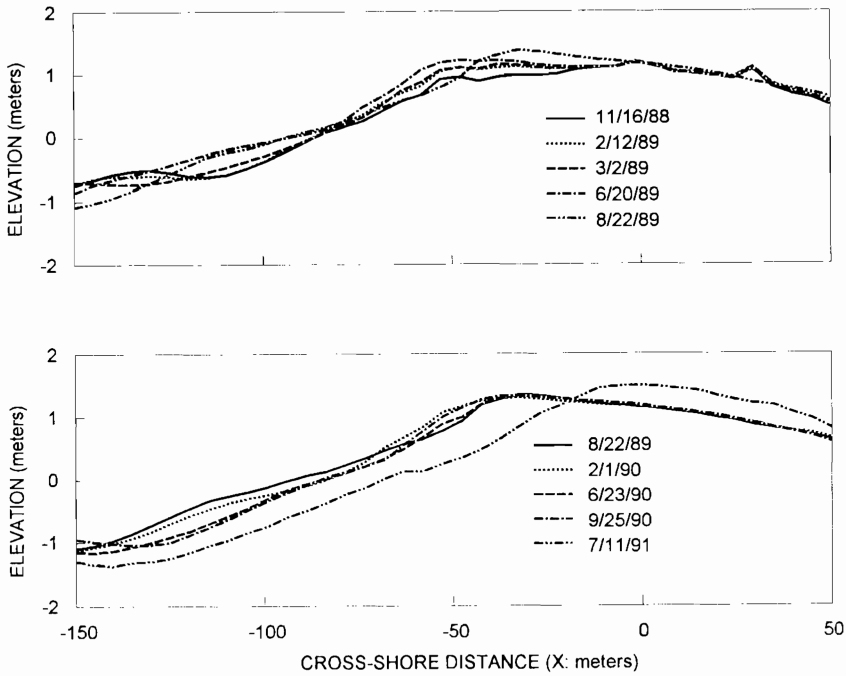

Figure 6. Continued.

amount of beach-face retreat decreases with distance below the berm crest. Because the water is deep over the island, the sediment eroded from the upper beach face, which is all sand, is transported shoreward and deposited on the backshore; the result is a marked decrease in beach-face slope without much sand loss from the beach.

Two factors contributed to the difference in impact of hurricanes Florence and Gilbert on the Isles Dernieres: power and location. Florence was

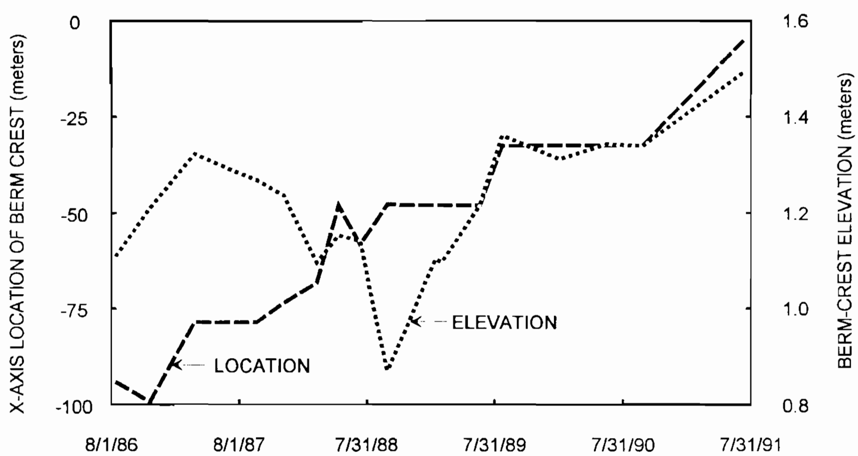

Figure 7. Heights and locations of the berm crest within the study area. Each point represents the average of the eleven values from that day.

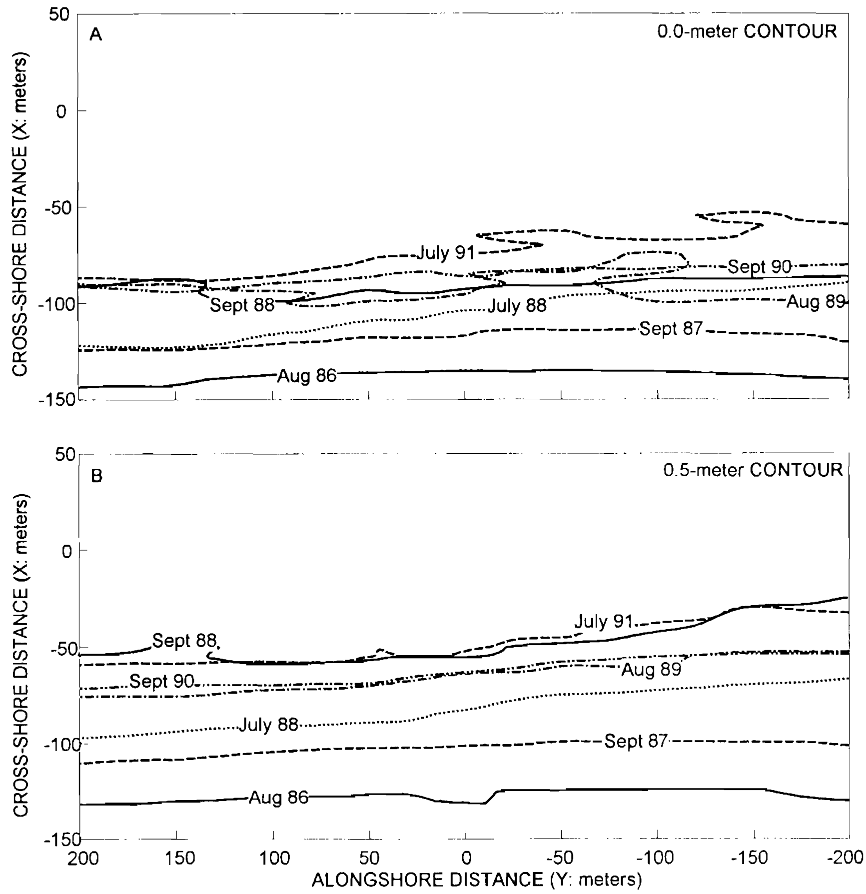

Figure 8. Locations and shape of MSL (part A) and 0.5-m (part B) contours on the beach face in the study area.

a much smaller hurricane than Gilbert (category 1 versus category 5) and was located so far east of the Isles Dernieres that the delta of the Mississippi River helped shield the Isles Dernieres. Waves that did reach the Isles Dernieres must have been greatly reduced in size because of the long fetch of shallow water they had to cross. Furthermore, because the Isles Dernieres lay to the left of Florence's track, offshore-blowing winds, generated by the counterclockwise rotation of the hurricane, would tend to depress rather than elevate sea level at the study site.

Although hurricane Gilbert was farther away, it was a much more powerful storm. Because it passed south of the Isles Dernieres, there was no land to shelter the islands from its waves. Fetch, duration, and wind speed, all factors that control wave size, were all larger during Gilbert than during Florence, which, we assume, resulted in larger waves reaching the Isles Dernieres. Finally, because the Isles Dernieres lay to the right of Gilbert's path, the onshore winds that Gilbert produced caused sea level to rise substantially. In fact, instrument flooding and flotsam on a data-acquisition tower at the study site (Figure 5) indicated that the water level reached at least 4 m above MSL during Gilbert.

Another difference in erosional signatures between cold fronts and large hurricanes is in their effect on the backshore topography and vegetation. At the start of the study, which was one year after three hurricanes had impacted the Isles Dernieres, most of the backshore was essentially planar and vegetation free. By July 1988 the back-

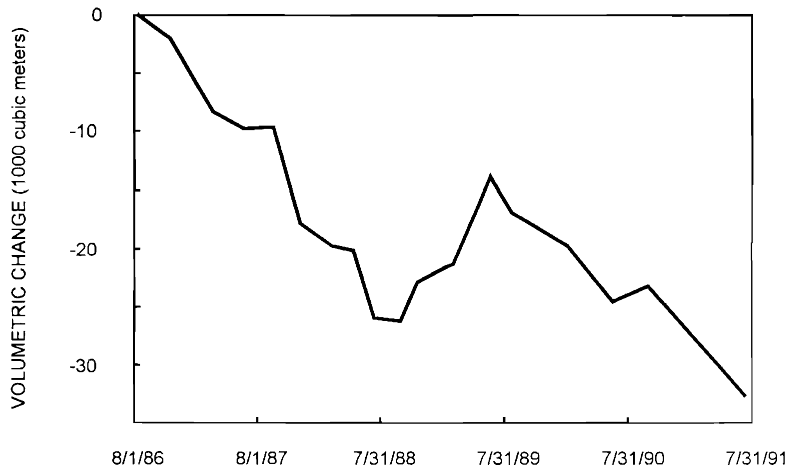

Figure 9. Volumetric changes in the study area (the 200-m by 400-m rectangle shown in Figure 5) based on comparison of gridded surfaces to the August 1986 survey. Value "0" represents the amount of sand at the time of the initial survey.

shore had become markedly irregular because of the development of many small dunes, and the amount of vegetation had increased considerably. Hurricane Gilbert smoothed the backshore to an unvegetated, planar configuration. Before the end of the study, incipient, vegetated dunes had reappeared throughout the backshore.

Average daily rates of sediment loss from the study area were obtained for the data in Figure 9 using a standard linear-regression technique. For the interval from August 1986 through July 1988, the study area lost sediment at the average rate of 37 m^3/day over the 400 m of shoreline, and, for the interval from June 1989 through July 1991, at 25 m^3/day. During the interval from September 1988 through June 1989, the study area gained sediment at the average rate of 46 m^3/day. Consequently, during this study, the area lost 32,600 m^3 of sediment at an average rate of 18 m^3/day. Similarly, berm-crest retreat occurred at a rate of 6 cm/day before Gilbert, 4 cm/day after, and 5 cm/day for the whole study period (Figure 10).

One assumption behind these calculations is that the cumulative effect of a season of cold fronts does not vary greatly from year to year, which is probably a poor one with regard to cumulative intensity, at least. During the five years of this study, the yearly average number of cold fronts between mid-autumn and mid-spring was 31 with a high of 35 in year three. The intensity of those fronts at the Isles Dernieres was not measured, so we cannot directly relate the measured erosion rates to cold-front intensity, whether it be for an individual cold front or over a cold-front season. On the other hand, we have no indication that the 1988–1989 cold-front season was significantly less severe than the other four and by number alone it was the most severe, so we believe that the erosional signatures described above are significant.

CONCLUSIONS

The Isles Dernieres has changed substantially over the past 100 years; the beach facing the Gulf of Mexico has migrated over 1 km north and the islands have been reduced in area by more than 70%. Multiple cold fronts produce a yearly beachface retreat of 10 to 20 m coupled with a large volumetric loss of sediment from the beach. A major hurricane like Gilbert, conversely, produces substantial beach-face retreat initially, but it actually reduces the average erosion rate by modifying the slope of the beach face from that produced by cold-front-generated storms. The different erosional and depositional patterns are related to differences in storm size. Cold fronts, which individually are small storms accompanied by small sea-level elevations, erode the entire beach face to the same degree. Mud is lost from the islands because it is transported to deep water; sand is lost from the islands when it is transported offshore or when there are gradients in

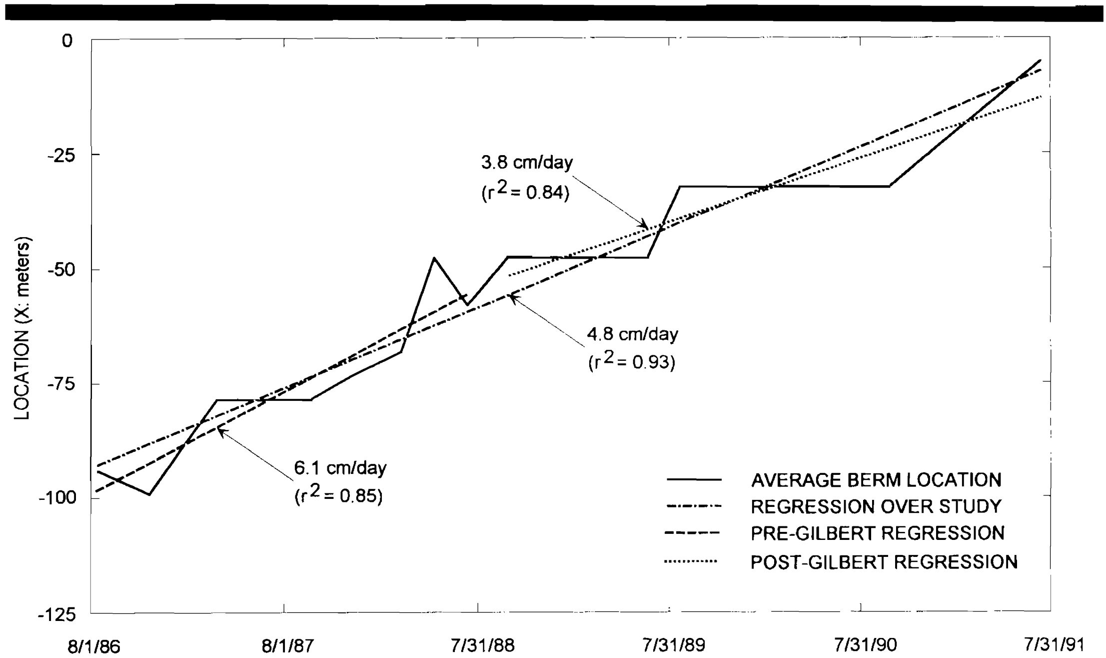

Figure 10. Measured change in berm-crest location and regression lines for the pre-Gilbert, post-Gilbert, and whole-study time periods.

longshore transport. Only a small percentage of the eroded sand is deposited on the backshore during cold fronts because sea level does not usually overtop the berm during those fronts. A small or quite distant hurricane can produce the same pattern. A hurricane whose impact on an area is large, however, substantially raises sea level, erodes primarily the upper beach face, and deposits much of the eroded sand on the backshore. Over a five-year period on the Isles Dernieres, the overall effect of a large hurricane (Gilbert) was to retard the retreat rate of the island by about 50 percent over that produced by cold fronts alone.

ACKNOWLEDGEMENTS

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LITERATURE CITED

BOYD, R. and PENLAND, S., 1981. Washover of deltaic barriers on the Louisiana coast. *Transactions, Gulf Coast Association of Geological Societies,* 31, 243–248.

BOYD, R. and PENLAND, S., 1988. A geomorphologic model for Mississippi Delta evolution. *Transactions, Gulf Coast Association of Geological Societies,* 38, 443–452.

BRETSCHNEIDER, C.L. and GAUL, R.D., 1956. Wave statistics for the Gulf of Mexico off Burrwood, Louisiana. *U.S. Army Corps of Engineers Technical Memo No. 87,* 25p.

DINGLER, J.R. and REISS, T.E., 1988. Louisiana Barrier Island study: Isles Dernieres beach profiles August 1986 to September 1987. *U.S. Geological Survey, Open-File Report 88-7,* 27p.

DINGLER, J.R. and REISS, T.E., 1989. Controls on the location of the sand/mud contact beneath a barrier island: Central Isles Dernieres, Louisiana. *Transactions, 39th Annual Meeting, Gulf Coast Association of Geological Societies,* 349–354.

DINGLER, J.R. and REISS, T.E., 1990. Cold-front driven storm erosion and overwash in the central part of the Isles Dernieres, a Louisiana barrier-island arc. *Marine Geology,* 91, 195–206.

DINGLER, J.R.; HSU, S.A., and REISS, T.E., in press. Theoretical and measured eolian sand transport on a Louisiana barrier island. *Sedimentology.*

HUH, O.K.; HSU, S.A.; ROUSE, L.J., and WILENSKY, D., 1988. Hurricane Gilbert. *American Geophysical Union, EOS,* 69, 978.

KWON, H.J., 1969. Barrier islands of the northern Gulf of Mexico coast: Sediment source and development. *Coastal Studies Institute, Louisiana State University, Technical Report No. 75,* 51p.

MULLER, R.A. and WILLIS, J.E., 1983. New Orleans weather 1961–1980: A climatology by means of synoptic weather types. *Louisiana State University, School of Geoscience, Miscellaneous Publication 83-1,* 70p.

MURRAY, S.P., 1976. Currents and circulation in the coastal waters of Louisiana. *Louisiana State University, Coastal Studies Institute, Technical Report 210,* 33p.

NATIONAL OCEAN SERVICE, 1987. Tide tables, east coast of North and South America (including Greenland). *U.S. National Oceanic and Atmospheric Administration,* 289p.

PENLAND, S. and BOYD, R., 1981. Shoreline changes on the Louisiana barrier coast. *IEEE Oceans, Marine Technology Society,* 209–219.

PENLAND, S. and SUTER, J.R., 1984. Process-response models for Gulf coast barrier island breaching. *Transactions, Gulf Coast Association of Geological Societies,* 34, 397–400.

PENLAND, S. and SUTER, J.R., 1985. Low-profile barrier island overwash and breaching in the Gulf of Mexico. *Proceedings, 19th Coastal Engineering Conference, American Society of Civil Engineers,* 2339–2345.

PENLAND, S.; SUTER, J.R., and BOYD, R., 1985. Barrier island arcs along abandoned Mississippi River deltas. *In:* OERTEL, G.F. and LEATHERMAN, S.P. (eds.), *Barrier Islands. Marine Geology,* 63, 197–233.

PENLAND, S.; BOYD, R., and SUTER, J.R., 1988. Transgressive depositional systems of the Mississippi Delta plain: A model for barrier shoreline and shelf sand development. *Journal of Sedimentary Petrology,* 58, 932–949.

PEYRONNIN, C.A., JR., 1962. Erosion of Isles Dernieres and Timbalier Islands. *Journal of the Waterways and Harbors Division, American Society of Civil Engineers,* 88, 57–69.

RITCHIE, W. and PENLAND, S., 1988. Rapid dune changes associated with overwash processes on the deltaic coast of south Louisiana. *Marine Geology,* 81, 97–122.

RITCHIE, W.; WESTPHAL, K.; MCBRIDE, R.A., and PENLAND, S., 1989. Coastal sand dunes of Louisiana: The Isles Dernieres. *Louisiana Geological Survey, Coastal Geology Technical Report No. 5,* 60p.

ROBERTS, H.H.; HUH, O.K.; HSU, S.A.; ROUSE, L.J., JR., and RICKMAN, D., 1987. Impact of cold-front passages on geomorphic evolution and sediment dynamics of the complex Louisiana coast. *Coastal Sediments '87, American Society of Civil Engineers,* 1950–1963.

SALLENGER, A.H., JR.; PENLAND, S.; WILLIAMS, S.J., and SUTER, J.R., 1987. Louisiana barrier island erosion study. *Coastal Sediments '87, American Society of Civil Engineers,* 1503–1516.

SIMPSON, R.H. and REIHL, H., 1981. *The Hurricane and Its Impact.* Baton Rouge: Louisiana State University Press 398p.

SIMPSON, R.H. and LAWRENCE, M.B., 1971. Atlantic hurricane frequencies along the U.S. coastline. *U.S. National Weather Service, National Oceanic and Atmospheric Administration Technical Memorandum NWSSR-58,* 14p.