CHAPTER 213

THE IMPACT OF AN EXTREME EVENT ON THE SEDIMENT BUDGET: HURRICANE ANDREW IN THE LOUISIANA BARRIER ISLANDS

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Abstract

This paper examines the influence of Hurricane Andrew on the sediment budget of an 80-kilometer section of the Louisiana barrier islands west of the modern Mississippi delta. Because long-term bathymetric change has been extensively studied in this area, excellent baseline data are available for evaluating the impact of Hurricane Andrew. Results show that despite the high intensity of the storm and a storm track optimally positioned to impact the study area, the storm did not have an overwhelming influence on the sediment budget when compared to the changes occurring over the previous 50 years. For the Louisiana barrier islands, a 50-year record appears to be adequate for averaging the long-term contributions of both major and minor storm events to the sediment budget.

Introduction

The coastal sediment budget, i.e., the identification of sediment sources, sinks, and transport pathways, is essential information for predicting rates of shoreline erosion and for planning beach nourishment projects (e.g., Kana, 1995). Unfortunately, most investigators have had to assume that the sediment budget, derived from past measurements, is an adequate representation of future trends as well. This assumption is weakened by the commonly unknown influence of changing and difficult to predict processes, such as the impact of infrequent but high-energy storm events. Few studies have been able to assess their potentially important impact. In one exception, Morton et al. (1995) monitored changes in beach volume associated with a major hurricane along the Texas coast, concluding that large storms can

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significantly alter the long-term sediment budget and hence, shoreline evolution. They demonstrate that short term sediment budget data (< 10 yr) are inadequate for modeling and predicting future changes because of the variable influence of great storms. It remains unclear whether longer term data, which would potentially include the effects of many major storm events, would be more representative of future conditions.

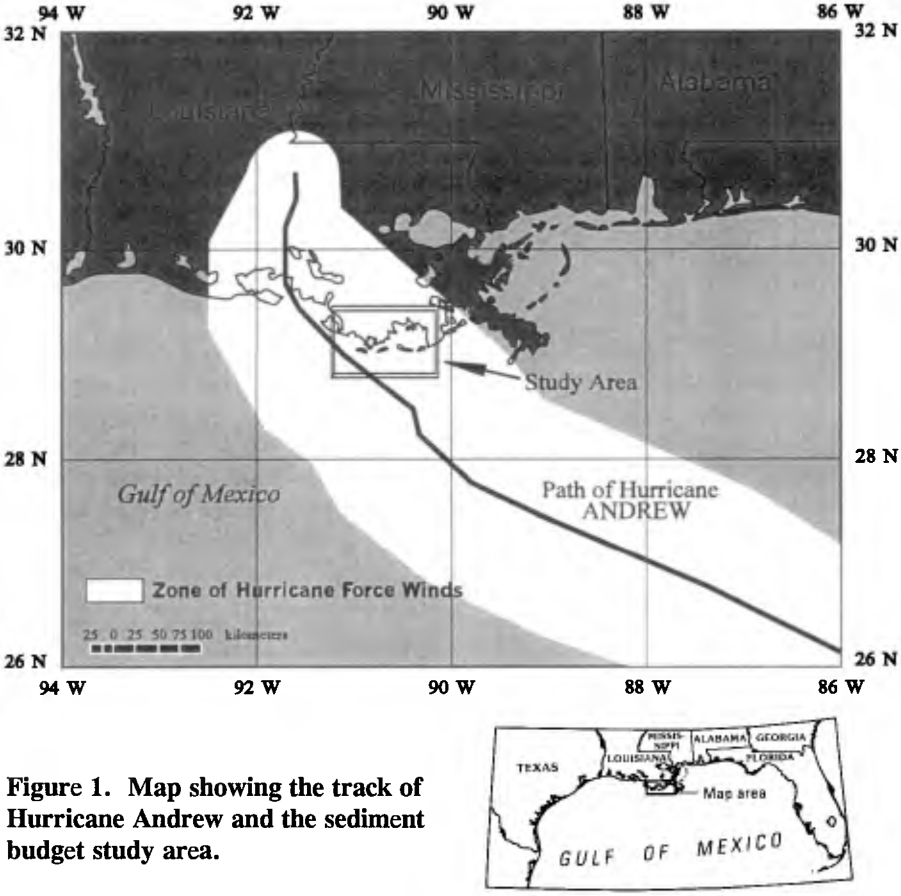

Figure 1. Map showing the track of Hurricane Andrew and the sediment budget study area.

A unique opportunity to address this issue was presented to us in 1992 when Hurricane Andrew impacted the Louisiana coast with wind speeds of more than 50 m/s (Grymes and Stone, 1995), offshore significant wave heights of more than 10 m (DiMarco et al., 1995; Stone et al., 1995), and a maximum storm surge of more than 2.5 m (Halford, 1995). This Class 3 storm on the Saffir-Simpson scale passed just west of a series of barrier islands (Figure 1) which had been the focus of an intensive study on the physical and geological processes responsible for the rapid erosion and disintegration of these islands (the Louisiana Barrier Island Erosion Study, Sallenger et al., 1987, 1991). In response to Hurricane Andrew, several components of the original study were repeated, including measurements of shoreline position, nearshore profiles (Dingler, 1995), and near-island bathymetry. In this paper we compare the bathymetric changes in a six-year period including Hurricane Andrew with the bathymetric changes observed for the 50 years prior to the storm, and evaluate the impact of Hurricane Andrew on the sediment budget.

Data Sources and Processing Techniques

Bathymetric surveys from three time periods were used as the basic source of sediment budget information considered here. Two surveys, from the 1930's and 1980's, were processed or collected as part of the U.S. Geological Survey's Louisiana Barrier Island Erosion Study (1986-1991). The third bathymetric survey was conducted in 1993/1994 following Hurricane Andrew.

The data sources, processing techniques, and error assessment for the 1930's and 1980's surveys are described in detail by List et al. (1991, 1994), and will only be briefly summarized here. The 1930's survey consists of soundings obtained in digital form from the National Geophysical Data Center in Boulder, CO. Data were digitized by the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA) from U.S. Coast and Geodetic Survey (USCGS) hydrographic smooth sheets for the years 1933, 1934, 1935, and 1936. The 1980's bathymetry was constructed from soundings obtained in digital form from hydrographic surveys conducted in 1986, 1988, and 1989 by companies under contract to the USGS. In addition to bathymetric data, shoreline data were obtained for each of these time periods to provide a mean high water (MHW) line to constrain the bathymetry surrounding the study area's many small islands. Shorelines for the 1930's were digitized from USCGS topographic smooth sheets, while for the 1980's, shorelines were photo-interpreted and digitized from National Aeronautics and Space Administration (NASA) high-altitude photography. A detailed description and analysis of shoreline data for the Louisiana barrier islands are found in McBride et al. (1992).

The post-Andrew bathymetric data were collected by the U.S. Geological Survey in 1993 and 1994, using an Innerspace 448 echosounding fathometer and a Global Positioning System (GPS) for navigation. Although we originally intended to correct soundings for tide effects using post-processed differential GPS vertical measurements, processing difficulties resulted in unreliable depth values. Thus the data were corrected using the same methods as were used in the 1980's survey, i.e., by applying corrections based on local tide observations. Shoreline data assumed to represent the MHW line were also incorporated into the 1993/1994 data set; post-Andrew shorelines were digitized by the Louisiana State University in 1993 (Penland, pers. comm.). The 1993/1994 bathymetric survey was processed exactly as were the 1930's and 1980's surveys, as described by List et al. (1994). Figure 2 shows the 1993/1994 bathymetric coverage area; for comparative purposes, analysis of the 1930's and 1980's data is restricted to the same area.

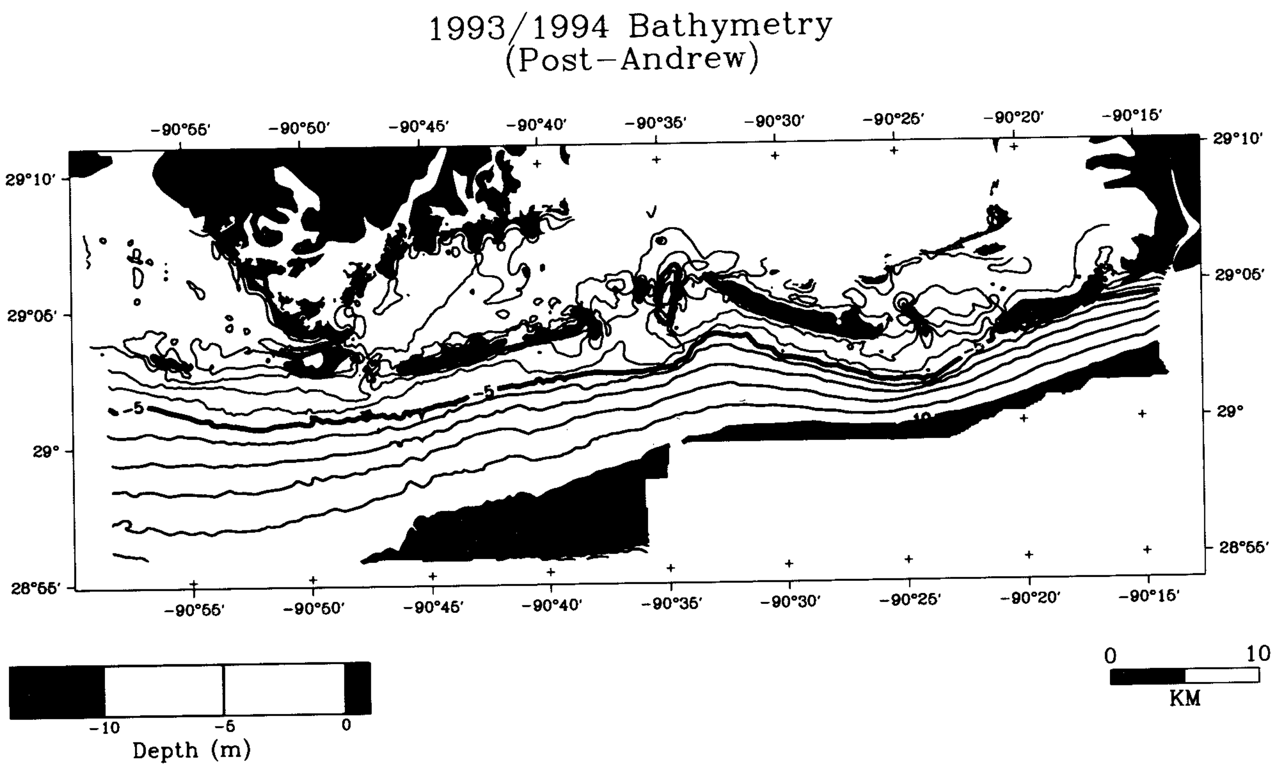

Figure 2. Post-Hurricane Andrew bathymetry collected in 1993 and 1994, showing the coverage area for this study. Depths are relative to Mean Low Water. For comparison purposes, data from the 1930's and 1980's data sets are analyzed within this same region.

After constructing surface models of each survey period's bathymetry using a minimum-tension gridding technique (Briggs, 1974; Dynamic Graphics, Inc.), we calculated bathymetric change grids for the 1930's to 1980's and 1980's to 1993/1994 periods. These change grids, with a spacing of 135 m (see List et al., 1994), form the basis for this study's comparison between long-term changes and changes occurring during a six-year period which included a major storm. Because of the approximate 1 cm/yr relative sea-level rise in the study region (Penland and Ramsey, 1990), a sea-level correction was necessary to prevent a strong bias toward erosion and to permit calculations of erosional and accretionary volumes. As continuous tide records were not available for the entire study period, we employed an alternate means of correcting for relative sea level using an area of sea floor which was judged to have minimal accretion or erosion (Jaffe et al., 1991). The error associated with this datum correction constitutes a large part of the overall data uncertainty.

The total error associated with sea-floor change calculations is a complex combination of many potential sources of error, including sounding measurement error, tidal correction problems, vertical and horizontal datum inconsistencies, computer gridding errors, and non-synoptic sources of data for each survey period. Although some errors can be quantitatively evaluated, others, such as the tidal datum correction problem mentioned above, could only be evaluated qualitatively. Therefore, a combination of quantitative and qualitative approaches were employed to assess the error in bathymetric comparisons (List et al., 1994). As a conservative estimate, a ±0.5 m range of sea-floor change was designated as a zone of no significant change.

Results

Regional

Figures 3 and 4 show the patterns of erosion and accretion associated with the 1930's to 1980's and 1980's to 1993/1994 change periods respectively. Overall, the strikingly coherent and large-scale patterns of erosion and deposition observed in the 1930's to 1980's change period are lacking in the 1980's to 1993/1994 change period. (For a description and analysis of the changes occurring in the 1930's to 1980's change period, see List et al., 1991, 1994, 1997a, 1997b; Sallenger et al., 1992; Jaffe et al. 1989, 1997).

Figure 5 quantifies the total volumes of erosion and accretion within the area enclosed by the data limit polygon in Figure 4, excluding areas of no significant change. In Figure 5A, both erosional and depositional volumes are significantly smaller for the change period encompassing Hurricane Andrew, indicating that the storm did not have an overwhelming influence on the sediment budget of the study area.

However, as the 1980's to 1993/1994 change period represents only about six years compared to the 50 years in the 1930's to 1980's change period, a better comparison between these two periods may be the rates of volume change, as shown

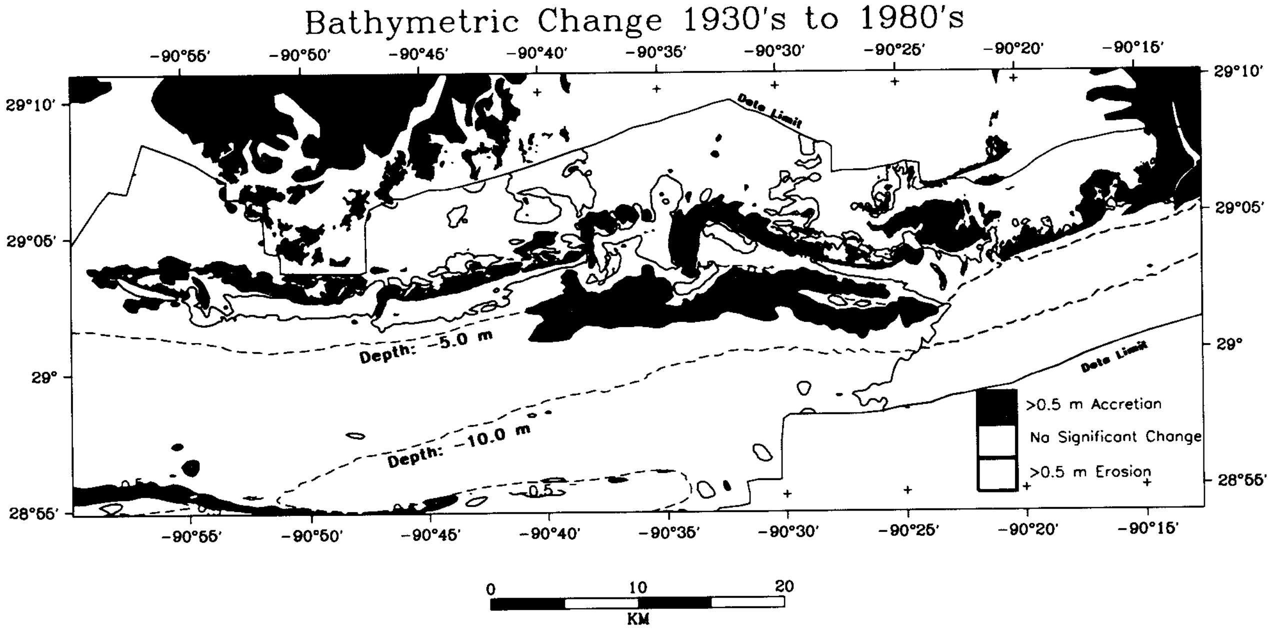

Figure 3. 1930's to 1980's bathymetric change within the complete study region. The -5.0 and -10.0 depth contours are from the 1980's bathymetry. The region encompassed by the line marked "data limit" is the area of overlap between the 1930's and 1980's bathymetries.

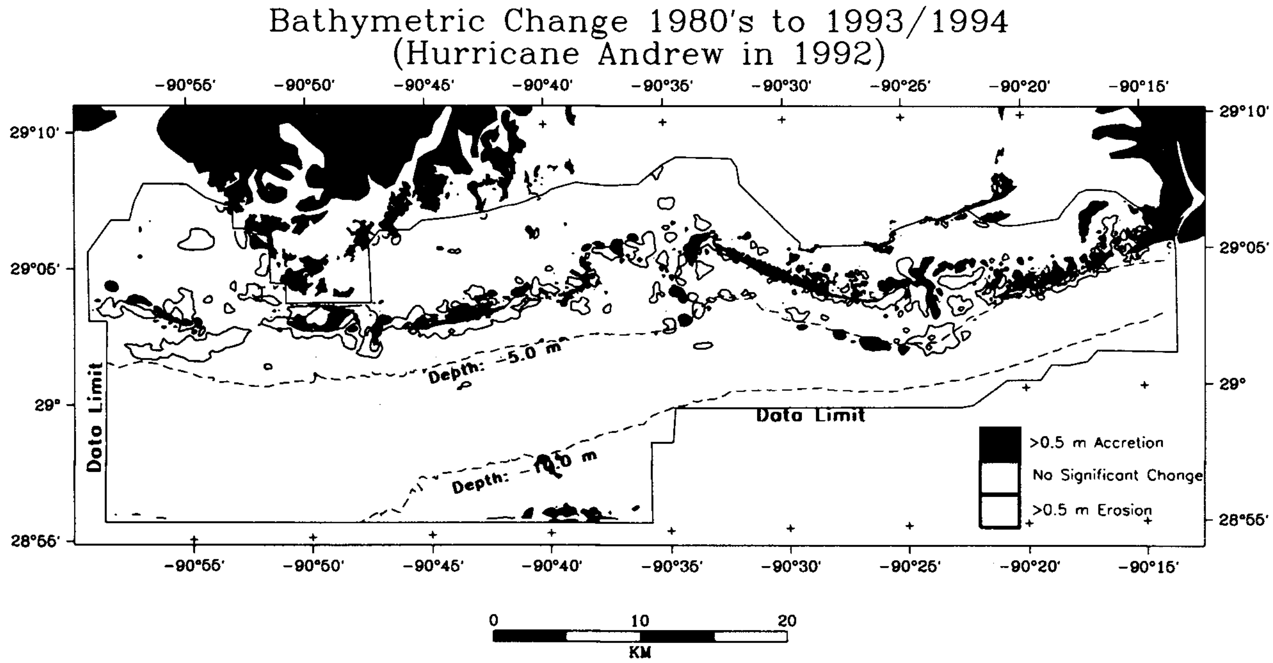

Figure 4. 1980's to 1993/1994 bathymetric change within the complete study region. The -5.0 and -10.0 m depth contours are from the 1993/1994 bathymetry. The region encompassed by the line marked "data limit" is the area of overlap between the 1980's and 1993/1994 bathymetries.

in Figure 5B. This figure shows that two change periods' erosional and deposition rates do not differ significantly, within the error bars resulting from the assumption of a ±0.5 m zone of no-significant change (after List et al., 1994).

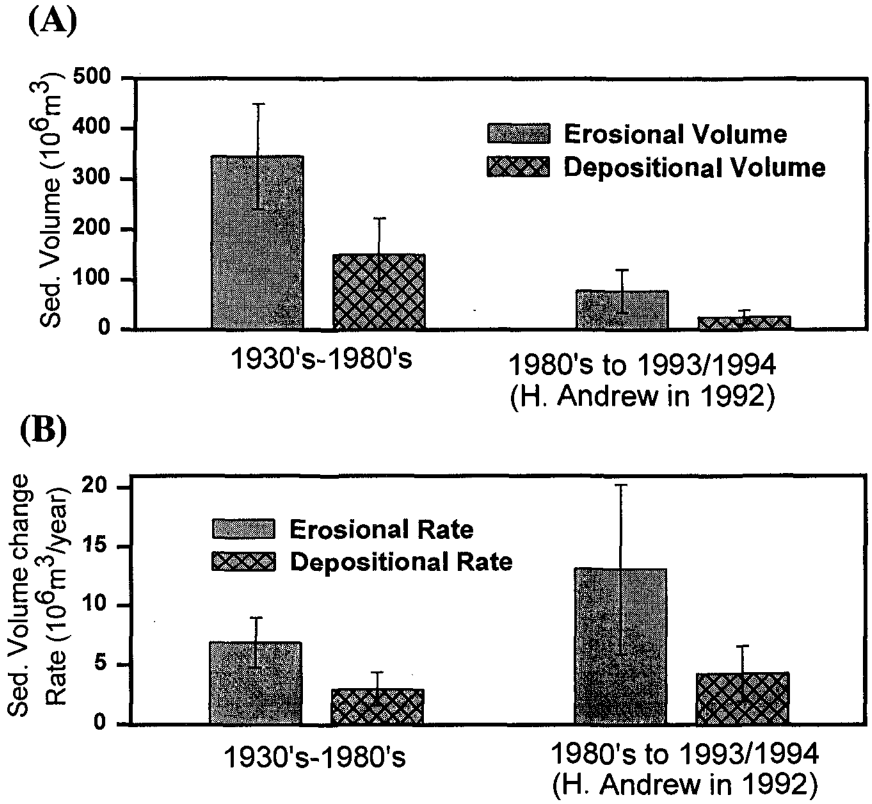

Figure 5. Volumes of sediment change within the area enclosed by the data limit region shown in Figure 4, excluding areas of no significant change. Error bars are based on the assumed ±0.5 m range of no significant change following List (1994). For comparison purposes, the same data limit region is applied for calculating volumes within the 1930's to 1980's change period. (A) Total erosional and depositional volumes for the 1930's to 1980's and 1980's to 1993/1994 change periods. (B) Corresponding yearly rates of erosion and deposition, using intervals of 50 and 6 years for the 1930's-1980's and 1980's-1993/1994 change periods respectively.

Eastern Portion of the Study Area

Figures 6 and 7 focus on changes in the eastern portion of the study area. Again, the 1980's to 1993/1994 change period exhibits few of the large and coherent patterns of erosion and deposition observed in the 1930's to 1980's change period. Still, it is noteworthy that there are *any* coherent patterns of erosion and deposition in the 1980's to 1993/1994 period , given the short six year period of change and the ± 0.5 m range designated as no-significant change. While the extensive area of offshore erosion present in the 1930's to 1980's comparison is lacking in the 1980's to 1993/1994 period, many of the smaller patterns, especially in depositional areas, appear to duplicate the later change period, albeit at reduced magnitudes.

Four of these depositional areas in the 1930's to 1980's change period are labeled A through D in Figure 6, with 1980's to 1993/1994 deposits interpreted to be of the same origin similarly labeled in Figure 7. Area A represents a shoreface deposit that appears to extend from erosional areas to the east. In the 1930's to 1980's change period, this depositional area extends from the extensive area of shoreface erosion it adjoins to the east to the next chain of barrier islands to the west, suggesting a mode of sediment bypassing of a wide inlet complex (Figure 3 here, see also Jaffe et al., 1991, 1997). In the 1980's to 1993/1994 change period, deposit A is much less coherent, but still occupies approximately the same location along the 5 m depth contour. Erosion of an ebb-tidal delta to the east suggests a source for the deposit in this change period (compare the bathymetry in Figure 2 with the bathymetric change in Figure 4). Area B represents a bay-side deposit that seems to be associated with landward migration of small barrier islands within a large inlet complex (similarly, they may be, in part, migrating flood-tidal delta deposits). In the 1980's to 1993/1994 period, depositional area B comprises several small areas that are clearly associated with the landward migration (and submergence) of small barrier islands (the depositional area between the two parts of B is associated with inlet migration). Area C represents another bay-side region of accretion, similar in both change periods. This deposit takes the form of a flood-tidal delta, but arguably could also be related to strong landward-directed flows associated with storm surges. Finally, area D in both change periods is a result of inlet infilling at the terminus of a westward migrating barrier island.

Similar to Figure 5, Figure 8 gives the total volume and yearly rates of deposition within areas A-D for the 1930's to 1980's and 1980's to 1993/1994 change periods. Again, while the total volumes associated with the 1980's to 1993/1994 period are much less than in the 1930's to 1980's period (Figure 8A), the *rates* of accretion are not significantly different (Figure 8B).

Discussion

Because the average rates of change in the period bracketing Hurricane Andrew were not significantly different from the average rates of change in the previous 50 years, we cannot conclude with certainty that *any* of the bathymetric changes are

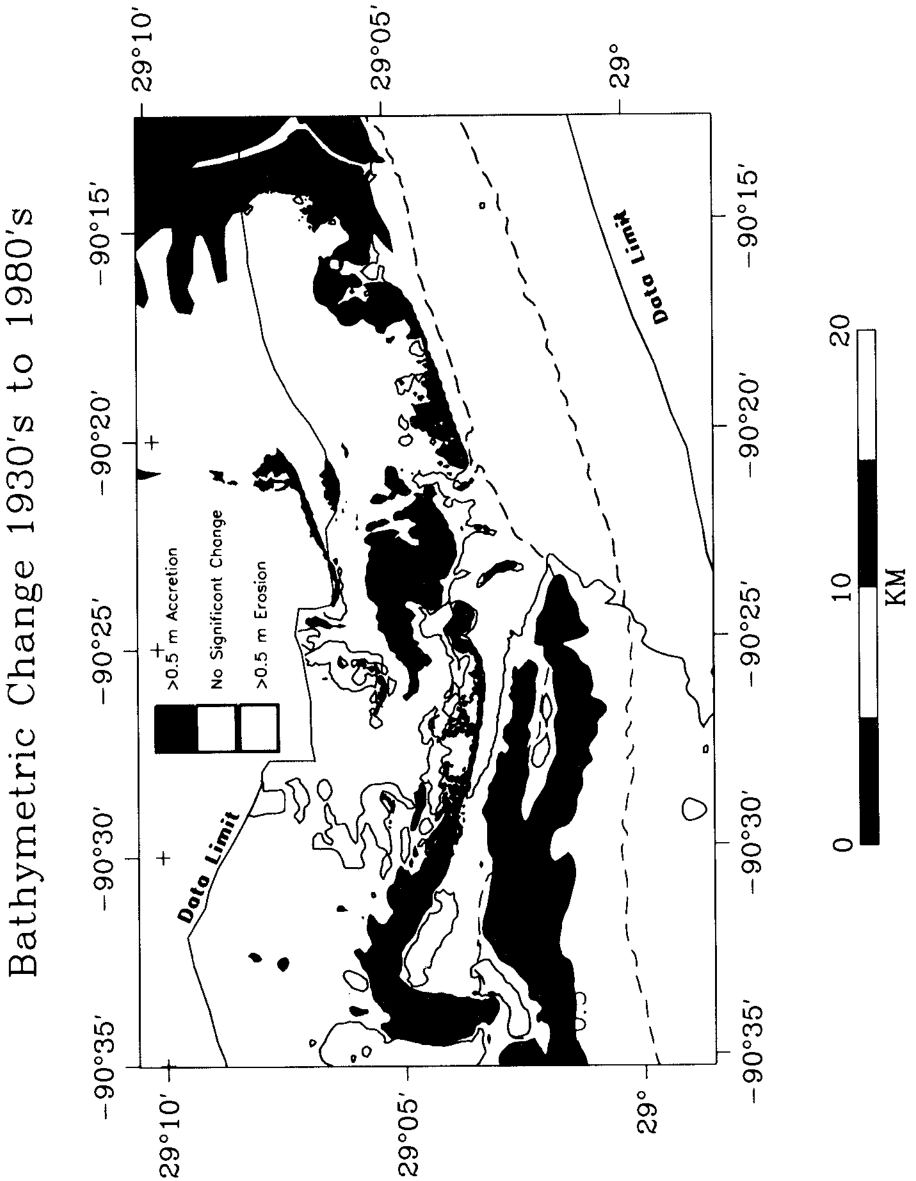

Figure 6. 1930's to 1980's bathymetric change within the eastern portion of the study region. The depth contours (unlabeled) and data limit boundary are the same as in Figure 3. Letters A through D represent areas of accretion for which volumes are shown in Figure 8. In the volume calculations shown in Figure 8, area A is limited to the area east of longitude -90°34', and Area D is limited to the area west of the adjoining barrier island.

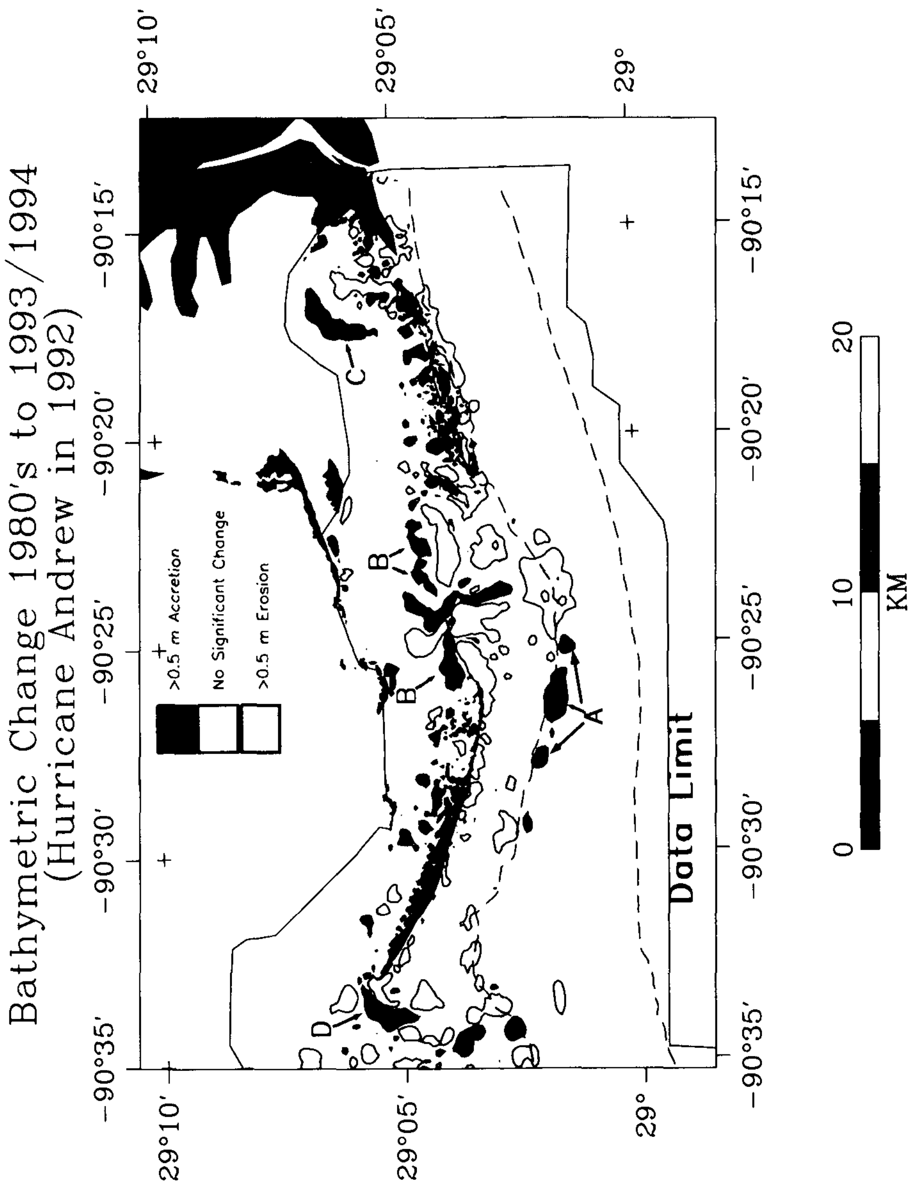

Figure 7. 1980's to 1993/1994 bathymetric change within the eastern portion of the study region. The depth contours (unlabeled) and data limit boundary are the same as in Figure 4. Letters A through D represent areas of accretion for which volumes are shown in Figure 8.

attributable to Hurricane Andrew, rather than typical storm conditions that occur much more frequently. However, as Hurricane Andrew was without doubt the largest storm in the 1980's to 1993/1994 change period, it is reasonable to assume that many of the changes are, in fact, due to this storm. With this assumption, we surmise that Hurricane Andrew had a moderate, through not overwhelming, contribution to the area's sediment budget.

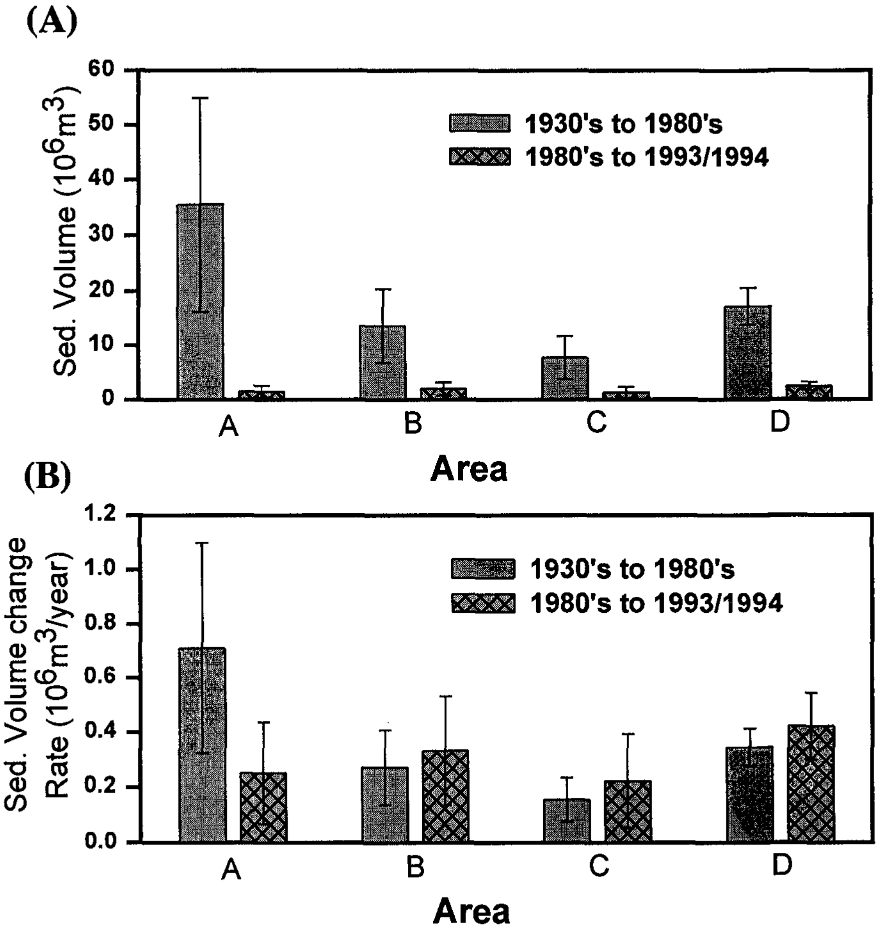

Figure 8. (A) Depositional volumes and (B) rates of deposition within the labeled deposits shown in Figures 6 and 7. Rates are found by dividing the depositional volumes for each region by the 50 and 6 year intervals for the 1930's to 1980's and 1980's to 1993/1994 change periods respectively. Error bars are found as in Figure 5.

Because the rates and patterns of change were similar in both change periods examined here, it seems likely that the processes were similar as well. An examination of the historical database of hurricane tracks (Jarvinen et al., 1984) shows that while Hurricane Andrew might have been the *most* intense storm experienced by the study area in the last 50 years (in terms of both magnitude and track), there were many other hurricanes that could have had a comparable impact. In terms of average rates of change, the 6-year period encompassing Hurricane Andrew (and many minor storms) appears to be representative of the long-term average of processes occurring in the previous 50 years.

Conclusions

Despite Hurricane Andrew's high intensity and a track that was near optimal for impacting the study area, the storm did not have an overwhelming influence on the sediment budget of an 80-km section of the Louisiana barrier islands when compared to the changes occurring over the previous 50 years. However, with the assumption that most of the bathymetric changes observed in the pre/post-Andrew survey were due to the storm, we conclude that the storm had a moderate impact on the sediment budget; however, other storms in the 50-year period prior to Andrew likely had a similar impact. For this study area, 50 years appears to be adequate for averaging the cumulative contributions of both major and minor storm events.

Acknowledgments

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