REFERENCES

Hughes, Steven A. (2006). "Uses for Marine Mattresses in Coastal Engineering," ERDC/CHL CHETN-III-72, US Army Corps of Engineers.

NOAA (2010a). Tide Data, National Oceanic and Atmospheric Administration, http://tidesandcurrents.noaa.gov.

NOAA (2010b). Wave Data, National Oceanic and Atmospheric Administration, http://www.ndbc.noaa.gov.

NOAA (2010c). Wind Data, National Oceanic and Atmospheric Administration, http://www.ndbc.noaa.gov.

Tensar (2010). Durability of Tensar Geogrids in Marine Applications, Letter to the Author.

Monitoring Shore Protection Projects along the Florida Panhandle using Three-Dimensional Spatial Data

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Abstract: Shore protection projects are designed to improve the resiliency of the coastal area, particularly for areas that are vulnerable to extreme storm events. Having multiple surveys for the area allows for change detection of geomorphic features and the condition of the nourishment project to be identified. Methods to identify geomorphic features for change detection have been developed using three-dimensional spatial data to assist in the monitoring efforts of shore protection projects. The spatial variation for the beach system, including the dune peak elevations, beach width, and volume, are monitored for several surveys for change detection and to identify areas of vulnerability, since having dunes and a wide beach increases the resiliency of a coastal region.

INTRODUCTION

Shore protection projects are designed to mitigate erosion effects and improve the resiliency of the coastal area during extreme storm events. Beach nourishment is the most common type of shore protection project because it provides less intrusive impacts compared to structures while providing storm protection and additional benefits for recreation (Dean and Dalrymple, 2002). Having dunes and a wide beach protects upland infrastructure during extreme storm events by reducing the wave energy and allowing sediment to be eroded. The sacrificial sediment is eroded to the nearshore environment, but is not lost from the system and can return during periods of quiescence.

Assessing the morphology of geomorphic features is important for routine monitoring as well as evaluating the impact to the shore protection project after a storm event. Pre- and post-storm surveys are vital to the assessment of damage caused by extreme storm events. The use of airborne lidar (light detection and ranging) to collect topographic and bathymetric data has greatly improved the efficiency and accuracy of monitoring morphological changes as compared to traditional survey methods.

Several studies have shown that lidar data can be used to extract features, such as

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dunes, to assess the vulnerability of the region (Houser et al., 2008; Saye et al., 2005; Stockdon et al., 2009), monitor beach nourishment projects (Gares, et al., 2006), and identify the shoreline and change rates (Stockdon et al., 2006).

Engineering projects that are constructed in the coastal environment must perform to the design specification while being resilient to extreme storm events. Shore protection projects are designed to provide improved protection under normal conditions as well as maintain resiliency during storm events. Mapping the spatial variation for a coastal region is invaluable for monitoring coastal engineering projects. High-resolution elevation and imagery data is collected along the U.S. coastline as part of the National Coastal Mapping Program (NCMP) which is funded by the U.S. Army Corps of Engineers (USACE) Headquarters. The NCMP is executed by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JABLTCX) and the data products are intended to support the coastal engineering and research needs within USACE. Three-dimensional spatial data can be used to enhance the assessment of projects, which are typically monitored using two-dimensional profiles.

The objective of this research is to utilize the three-dimensional spatial data for the development of methods to efficiently monitor geomorphic morphology at a shore protection project site. To show the applicability of using lidar data for change detection and monitoring coastal projects, a 30 km stretch of Bay County, Florida is used to demonstrate the procedure.

METHODS

Study Area

The study area along the Florida panhandle is considered to be critically eroded from the Walton County and Bay County line to St. Andrews Inlet which provides access to Panama City, FL (FDEP, 2007). The narrow beach width of this coastal region makes the area vulnerable to erosion and overwash. The study area is shown in Figure 1 for the 30 km stretch of coast in Bay County, FL. Efforts to slow or mitigate the erosion of sand were initiated by bypassing sand from the inlet to the downdrift beach and constructing a beach nourishment project. The beach nourishment project was constructed after Hurricane Katrina in 2005 due to the severity of erosion caused by the hurricanes of 2004 and 2005. The hurricane seasons of 2004 and 2005 were extremely active with Hurricane Ivan (2004), Hurricane Dennis (2005) and Hurricane Katrina (2005) impacting the area and causing erosion. The beach nourishment project extended the width of the beach which in conjunction with the dunes will provide a natural defense to the upland area.

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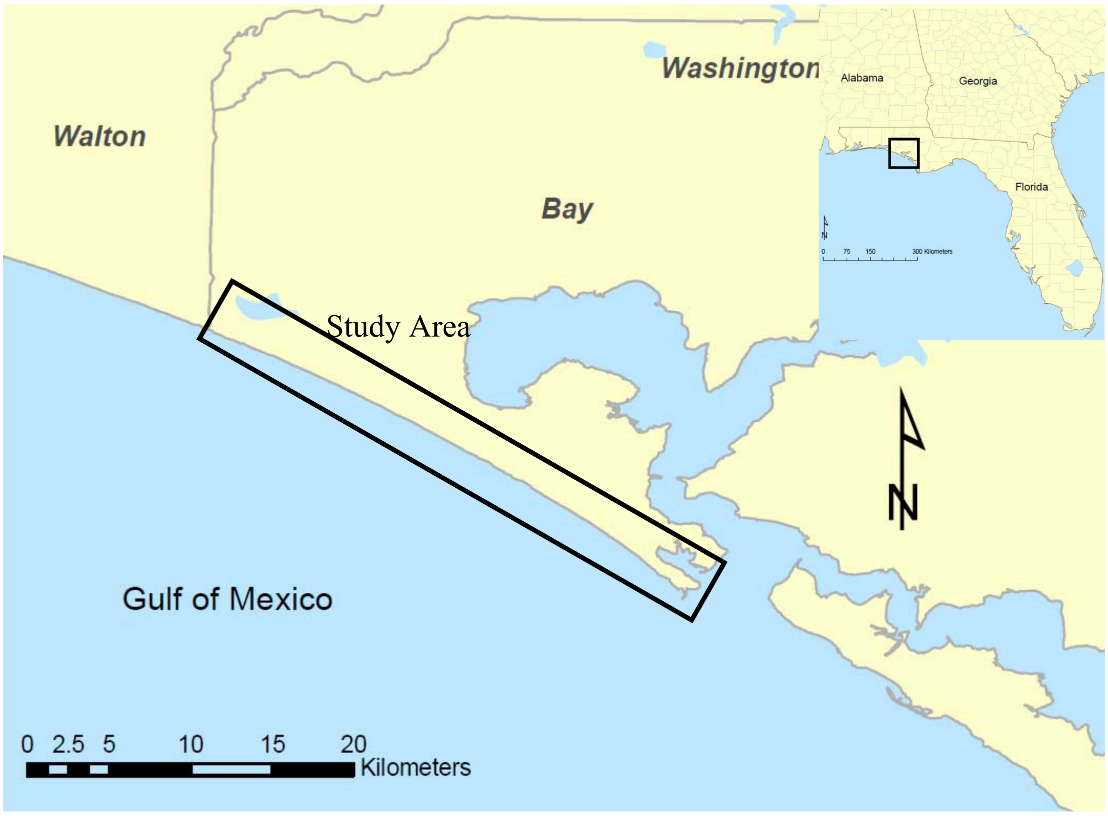

Figure 1. Study area in Bay County, FL

Data

The surveys conducted as part of the NCMP provide complete coverage of the coastal zone on a recurring basis and therefore are ideally suited for monitoring changes to geomorphic and bathymetric features. The data used for this analysis was collected by the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system which is shared between the USACE and U.S. Naval Oceanographic Office (NAVOCEANO). The CHARTS system includes a 3 kHz bathymetric laser, a 20 kHz topographic laser, an Itres Compact Airborne Spectrographic Imager (CASI)-1500, and DuncanTech-4000 RGB digital camera (Wozencraft and Lillycrop, 2006). The lidar and imagery data collected by the CHARTS system is processed into Geographic Information System products and include bathymetric and topographic Digital Elevation Models (DEMs), RGB orthomosaics, North Atlantic Vertical Datum 88 (NAVD88) shorelines, building footprints, and bare earth grids (Wozencraft et al., 2007). The data is divided into 5km stretches of the coast. This data is uniquely available to address the need for three-dimensional analysis of shore protection projects.

The surveys of Bay County, FL used for this analysis were flown for 1) April-May 2004 (Pre-Ivan), 2) November-December 2004 (Post-Ivan), 3) November-December 2005 (Post-Katrina), and 5) April-May 2006 (Post-Nourishment). This data is uniquely available to assist in storm event assessment when pre- and post-storm surveys exist as well as aid in change detection to identify trends for a complete

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understanding of the impacts to the coastal zone due to storm events and assist with monitoring beach nourishment projects.

Data Analysis

Lidar elevation data can be used to monitor morphological changes at shore protection projects when multiple surveys of the area exist. Geomorphologic metrics that are important for monitoring include the seaward dune and the mean high water (MHW) line. The MHW was considered to be a constant elevation of 0.22m which is the MHW relative to the North Atlantic Vertical Datum 1988 (NAVD88). For this analysis, the beach width is considered to be the distance from the seaward boundary at the MHW line to the 2m contour which is considered to be the average elevation for the seaward dune toe. Although the dune toe elevation can vary in elevation and location, a constant value was used for the entire length of the study area. The volume of the beach width can be used to identify areas of vulnerability since having dunes and a wide beach provides protection to upland infrastructure in addition to providing recreational benefits. The assessment of volumetric change from multiple surveys lends insight into the movement of sediment.

The analysis for the study area was divided into 5km sections (Figure 2). Transects were extracted from the bathymetric and topographic DEMs with the resolution of the spot elevation at 1 m with 30 meter spacing interval between profiles. The MHW and dune feature were extracted from these transects using a series of MATLAB codes. The transects were analyzed profile-wise to find the MHW line, 2m contour, peak of the dune, width of the beach, and volumetric changes for the beach width. The data was not smoothed since the raw lidar data was processed before the grids were generated to remove noise. The peaks were found by using the MATLAB signal processing function, "findpeaks" which compares neighboring data points and classifies the local maxima. The volumetric change was determined for each transect for the length of the study area using trapezoidal integration for the beach width. The multiple surveys were analyzed to show the impact from Hurricane Ivan in 2004 and the condition of the nourishment project compared to the survey in 2005 Post-Katrina.

The methods developed for this study could be applied at any shore protection project that has sufficient lidar coverage. The volumetric change of the beach width for individual transect and the total volume change for the entire section were determined to assess the impacts of extreme storm events to the coast and to monitor the beach nourishment project. Having multiple surveys for the area allows for change detection of geomorphic features and the condition of the nourishment project to be identified to assist with recovery efforts and understanding of the movement of sediment.

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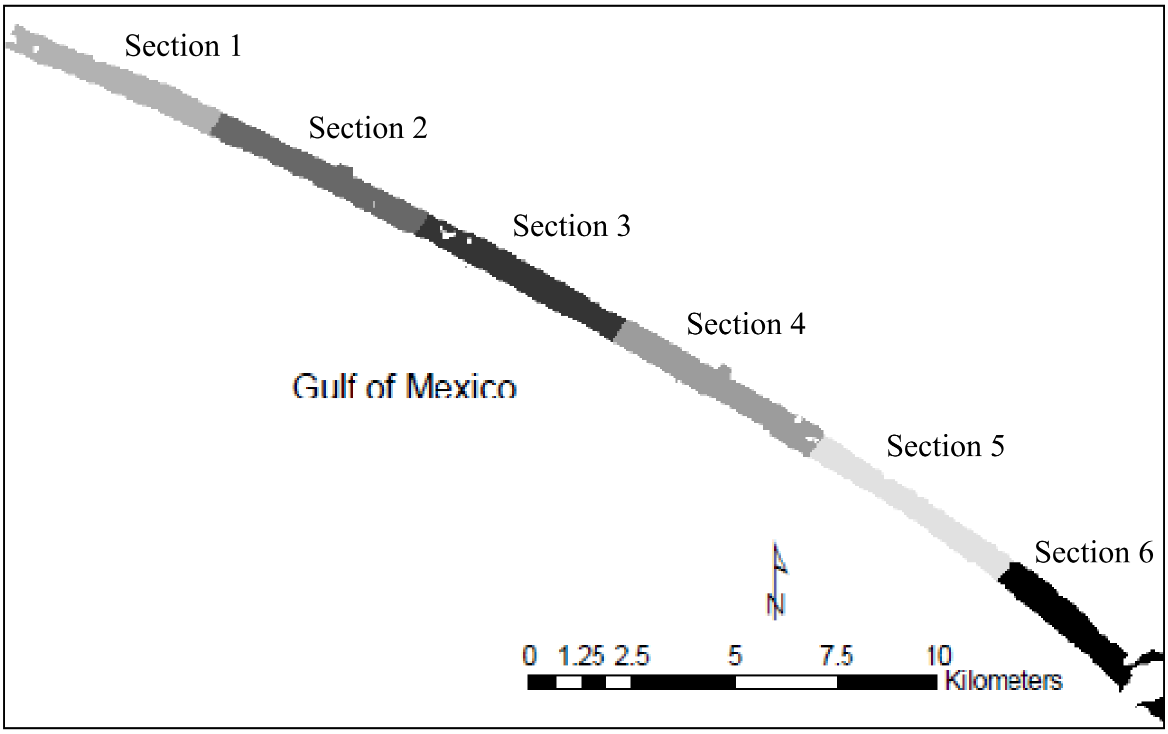

Figure 2. Sections of the study area

RESULTS

Geomorphic Metrics

As mentioned previously, having dunes and a wide beach can provide increased protection during a storm event, so being able to assess these geomorphic metrics and compare the results for multiple surveys is invaluable to understanding the condition of the nourishment project and vulnerability of the region. Dunes with the highest elevation also typically have a wider beach which is measured as the distance from the MHW to the dune toe. The 2004 Pre-Ivan NCMP survey was used as the base survey to compare the 2004 Post-Ivan. Table 1 gives the average dune peak elevation and the average beach width for the sections of the 30km stretch of coast starting at the Walton and Bay County line going east towards St. Andrews Inlet (Figure 1). The average dune peak elevation ranges from 2.5 to 3.5 for the 2004 Pre-Ivan survey. The dune peak elevation location comparison is shown in Figure 3 left. The 2004 Pre-Ivan dune line is seaward of the 2004 Post-Ivan dune line. This is likely a result of erosion to the seaward most dunes caused by the increased wave action during the hurricane. Since the seaward most dunes would provide the first line of defense during a storm event, the increase in the average dune height for the 2004 Post-Ivan survey correlates to having erosion of the seaward dune due to the methodology of the analysis. This is further evidenced by the substantial loss of the beach width for the majority of the sections from the 2004 Pre-Ivan survey to the 2004 Post-Ivan survey. The beach width for the 2004 Pre-Ivan survey is wider for sections 1, 2, and 6. These sections are about 30m wider than the middle sections. However, the 2004 Post-Ivan beach widths are narrower for sections 1 and 2 with the other sections gaining beach

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width compared to the 2004 Pre-Ivan survey. The cause of the beach width gain is likely due to the landward shift of the 2m contour location as a result of erosion to the seaward dune. The MHW line for the 2004 Pre-Ivan survey is seaward of the 2004 Post-Ivan MHW line in section 3 (Figure 3 right) as a result of erosion. Since this section experiences beach width gain, the cause is determined to be related to the landward shift of the 2m contour. After Hurricane Ivan in 2004 and Hurricane Katrina in 2005, it was apparent that the area would continue to experience erosion and a beach nourishment project was initiated.

The seaward most dunes from the 2005 Post-Katrina survey and 2006 NCMP are very similar and more consistent with the 2004 Pre-Ivan survey signifying recovery of the seaward dune. In addition, the beach width is the narrowest for the 2005 Post-Katrina survey for all section except section 6 that is adjacent to St. Andrews Inlet. After the beach nourishment project, the beach width increases substantially for the 2006 NCMP survey. The total average beach width for the entire study area increases by about 97m from the 2005 Post-Katrina survey to the 2006 NCMP survey. The beach nourishment project adds sediment to the beach system and thus can influence the location of the 2m contour which is used for the landward extent of the beach width.

Table 1. Geomorphic metrics (m) for each section and survey period

	2004 Pre-Ivan	2004 Post-Ivan	2005 Post-Katrina	2006 NCMP
Dune Height				
Section 1	3.5	4.2	3.4	3.7
Section 2	3.5	4.0	3.3	3.0
Section 3	2.9	3.8	3.0	2.7
Section 4	2.5	3.8	2.7	2.3
Section 5	3.1	3.9	2.7	2.7
Section 6	3.3	4.0	3.5	3.7
Beach Width				
Section 1	138.0	115.5	96.6	112.2
Section 2	137.7	117.5	84.3	107.8
Section 3	103.6	128.1	67.2	104.4
Section 4	103.5	139.7	70.6	99.3
Section 5	120.5	130.2	113.6	115.6
Section 6	143.3	143.8	147.8	138.6

An example of the dune peak line is shown in figure 4 left. The dune peak for 2005 Post-Katrina is landward of the dune peak from the 2006 NCMP survey. The 2006 NCMP survey dune line is likely seaward of the 2005 Post-Katrina survey dune line since the beach nourishment project added additional sediment to the beach system, thereby altering the location of the seaward most dune peak.

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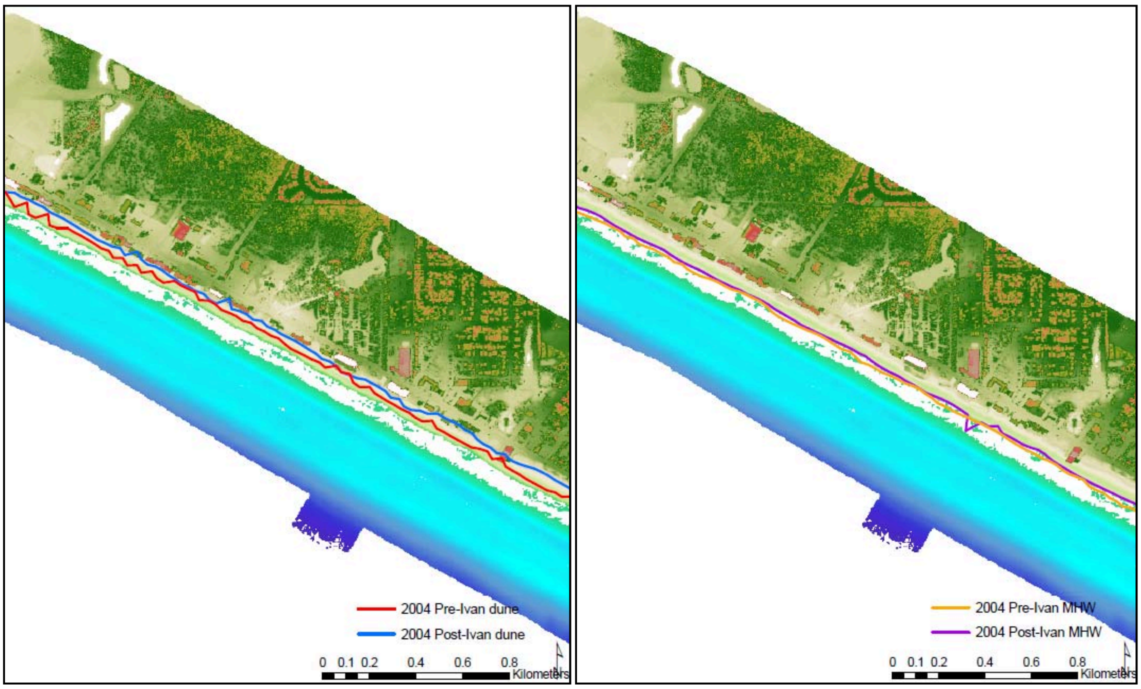

Figure 3. Dune peak and MHW location for the 2004 Pre-Ivan and 2004 Post-Ivan surveys

The MHW line for the 2005 Post-Katrina and 2006 NCMP survey is shown in figure 4 right. As expected, the MHW line for the 2006 NCMP survey is seaward of the 2005 Post-Katrina survey. Interesting to note is that the MHW line from the 2006 NCMP survey is fairly linear where as the MHW line from the 2005 Post-Katrina survey has more of a cuspate trend which is likely a result of the increased waves from the hurricane.

The sums of the volumetric change for each section from the 2004 Pre-Ivan survey and 2004 Post-Ivan survey and the 2005 Post-Katrina and 2006 NCMP surveys are provided in Table 2. The beach width volume change is predominately erosional for the 2004 Pre-Ivan to the 2004 Post-Ivan survey. Figure 5 shows the results for the volumetric changes in beach width for the 2004 Pre-Ivan survey and the 2004 Post-Ivan survey. The accretional areas of the beach volume change occurred in locations where the elevation is higher. The beach volume change for Sections 3and 4 was accretional for this time period as was seen in the beach width change and is likely a methodological response. The blue line is the volumetric change per profile. The red line is smoothed using a local regression using weighted linear least squares and a 2nd degree polynomial model that assigns lower weight to outliers in the regression. The method assigns zero weight to data outside six mean absolute deviations.

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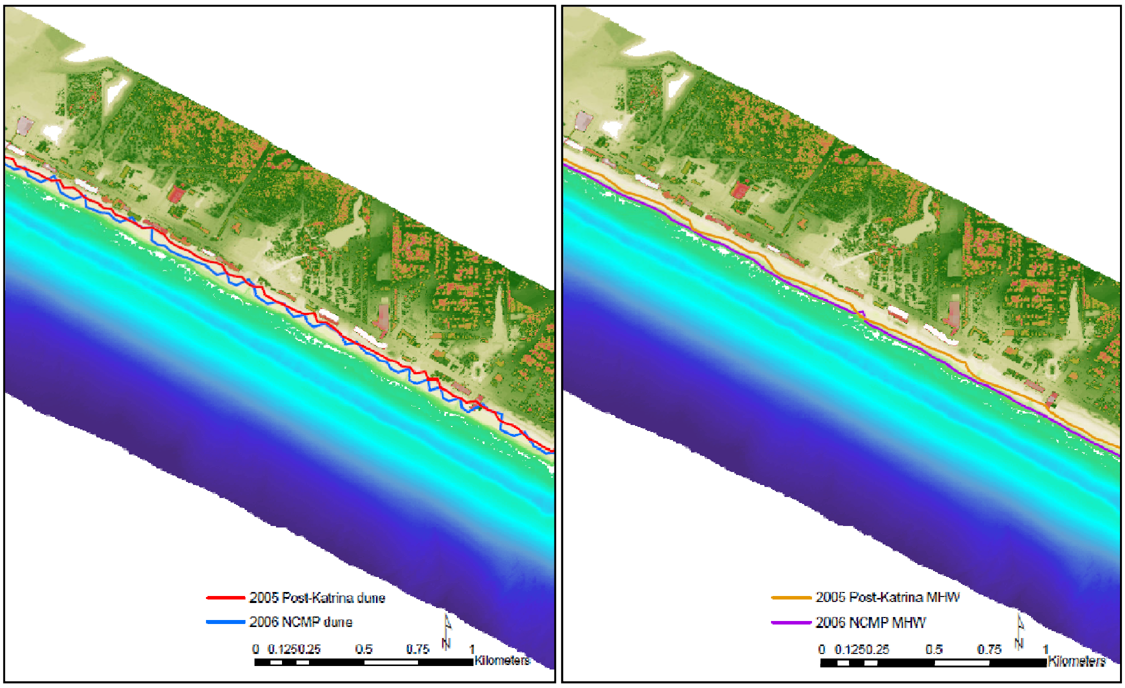

Figure 4. Dune peak and MHW location for the 2005 Post-Katrina and 2006 NCMP (post-nourishment) survey

The volume change of the beach width was predominately accretional for the 2005 Post-Katrina and 2006 NCMP survey except at section 5 where there was slight erosion. As mentioned previously, the location of the landward and seaward extent of the beach width was not fixed; therefore, the volume change could vary and was meant to be an indicator of vulnerability. Figure 6 shows the results for the volumetric changes in beach width for the 2005 Post-Katrina survey and the 2006 NCMP survey that is post-nourishment. As expected, the volume change for the area is predominately accretional. The blue line is the volume change per transect and the red line has been smoothed to remove the peaks associated with the high resolution of the transects.

The width of the beach from the MHW to the dune toe is an important geomorphic metric to consider since having a wide beach can provide increased protection during a storm event. The elevation of the dune is also important because the dunes act as a barrier during a storm event helping to protect upland portions of the coast. The beach widths as well as the elevations of the dune peak are important geomorphic metrics that can be used to assess the condition of the region and the vulnerability to extreme storm events. Retreat and dune loss were the primary results for the post-storm surveys; however, the area gains sediment during a beach nourishment project constructed before the 2006 NCMP survey.

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Table 2. Volume change of beach width for various sections

Period	Sections	Sum (m^3)
May 2004 - Nov. 2004	Section 1	-2042
	Section 2	-2042
	Section 3	1617
	Section 4	1885
	Section 5	-533
	Section 6	-1565
	Total	-2681
2005 - May 2006	Section 1	1855
	Section 2	2073
	Section 3	3330
	Section 4	2228
	Section 5	-32
	Section 6	453
	Total	9908

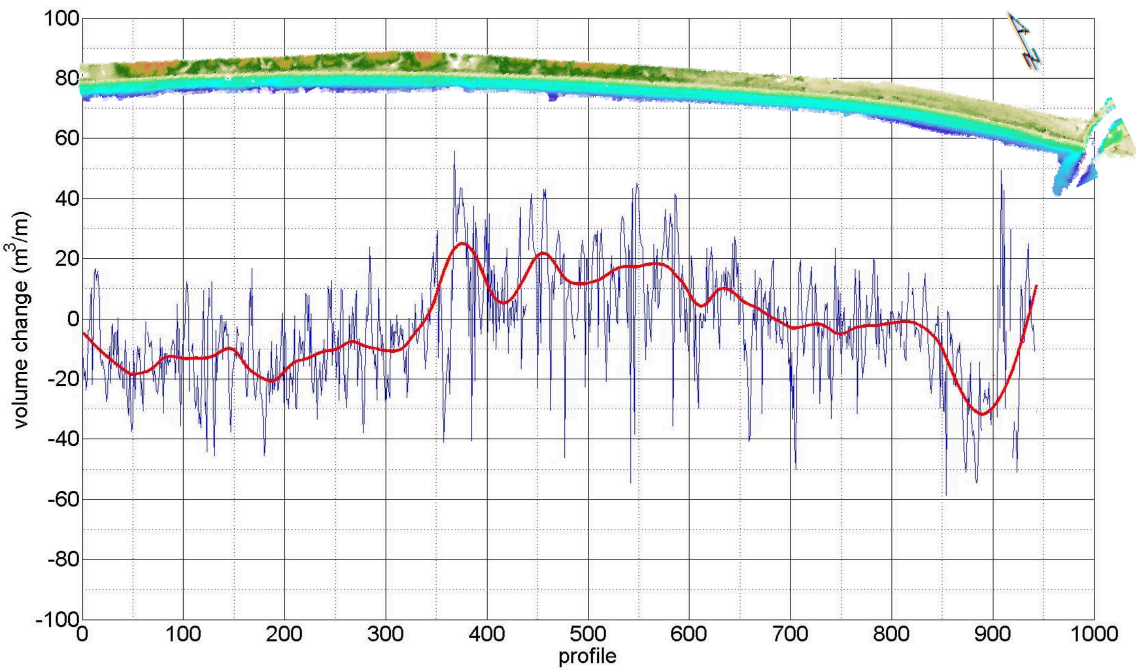

Figure 5. Beach width volume change per profile (blue line) and smoothed value (red line) for the 2004 Pre-Ivan and 2004 Post-Ivan

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