

MORPHOLOGICAL EVOLUTION OF A SHORELINE ON A DECADAL TIME SCALE

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DRAFT

The objective of this paper is to demonstrate the use of shoreline change data, two-dimensional cross-shore profiles and three-dimensional LIDAR coverage to capture morphological change in areas impacted by long term erosion, short term storm erosion and anthropological manipulations. The analysis of a washover area south of Oregon Inlet on the Outer Banks of North Carolina is presented as an illustrative. The impact of significant storms (Hurricanes Dennis and Isabel) as well as the impact of the continued dredging of the navigation channel through Oregon Inlet and disposal of sand by the US Army Corps of Engineers is discussed.

INTRODUCTION

Study Area

The objective the study is to demonstrate the use of robust temporal datasets to explore the morphological evolution of a barrier island system due to both natural and man-induced impacts. The area selected is in the US Fish and Wildlife Pea Island National Wildlife Refuge on the Outer Banks of North Carolina on the east coast of the United States, Figure 1. Because of the protected status of the Refuge, the area is undeveloped with the exception of the two lane highway, NC12, which is parallel to the beach throughout the length of the Refuge. Because NC12 is the only land based transportation link for communities south of the Refuge, the maintenance of this highway corridor and the bridge connecting Pea and Bodie Islands is considered essential for hurricane evacuation. These factors with a long history of shoreline erosion and storm damage on the Outer Banks have served to provide us with a very rich morphological dataset to explore changes within the system. Shoreline position and sub-aerial dune cross-sections are available from a long-term monitoring project of the area conducted at North Carolina State University. In addition, the North Carolina Outer Banks have been a ‘testing ground’ for the use of LIDAR

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technologies for pre and post-storm evaluations. Federal agencies including USGS, NOAA and USACE have together a total of ten missions from 1996 through 2005 with some coverage in the Pea Island Refuge. These data are available from NOAA Coastal Services Center Topographic Change Mapping website.

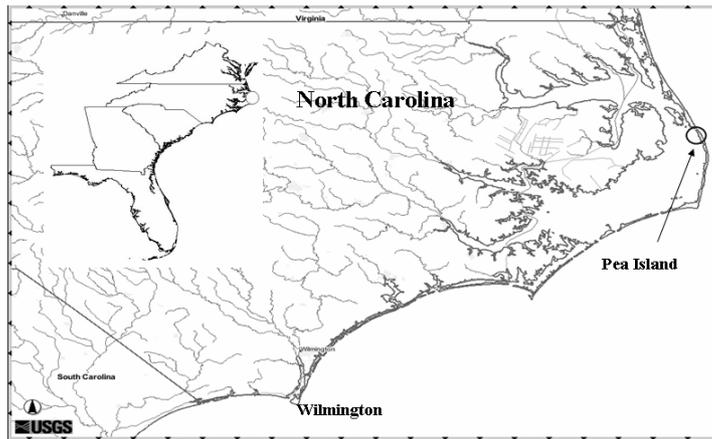
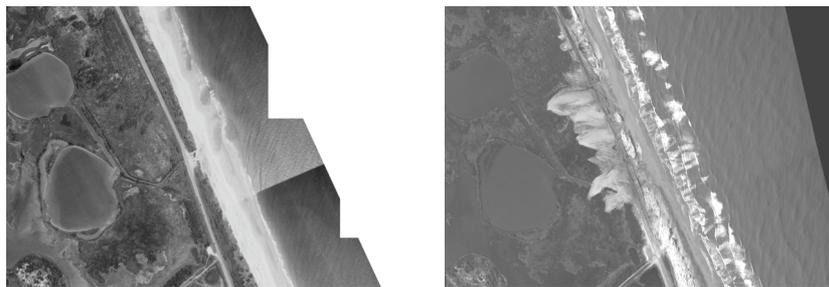


Figure 1. Location of the study area.

A 500 m section, approximately 4.2 km south of the inlet was chosen initially for analysis due to the damage which occurred during Hurricane Isabel at the site. Hurricane Isabel made landfall south of Cape Hatteras on September 18, 2003. The orientation of the storm produced damage throughout the Outer Banks most notably the breach which occurred between Cape Hatteras and Hatteras Inlet. At the selected site, overwash occurred spreading sand approximately 150 m landward of the road. Figure 2 provides an aerial view of the pre and post storm conditions at the study site.



a) 1998 ortho b) 2003 ortho

Figure 2. Pre and post storm aeriels of the study site.

The two ponds on the landward side of the road and the access road in the lower center of the orthophotos provide reference points for comparisons.

DATA ANALYSIS

Aerial photography data analysis

Shoreline positions data has been collected since 1989 in two month intervals using aerial photography. The shoreline proxy used in the monitoring project is the wet/dry line as identified from the orthophotos. Shoreline position is measured relative to an offshore baseline at 150 ft (45.7 m) intervals or transects. The data presented below in Figure 3 are the average position within the overwash area as determined from 12 transects relative to the 16 year monitoring period. In the first seven years, the shoreline was eroding at about 4.9 m/yr. From 1998 to 2006, the shoreline change rate was 1.2 m/yr of accretion. The change in the behavior of the shoreline provides a focal point of discussion as well as the outlier occurring in the fall of 2003 as a result of Hurricane Isabel.

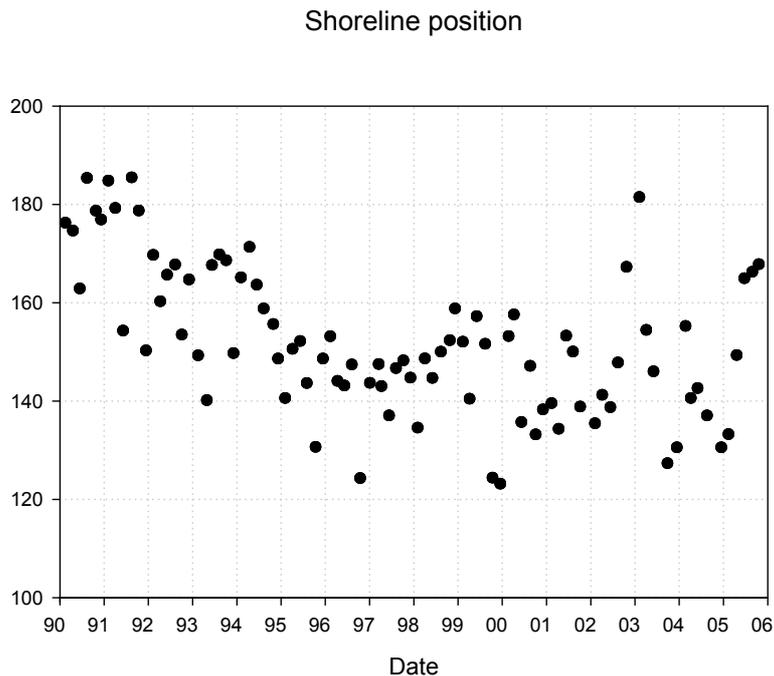


Figure 3. Shoreline position data from orthophotography is the position in meters?.

Ground surveys

In addition to the aerial photography, ground surveys from the centerline of NC12 to the water's edge are conducted twice a year in April and October. Examination of a single profile within the study area illustrates the changes that have been documented.

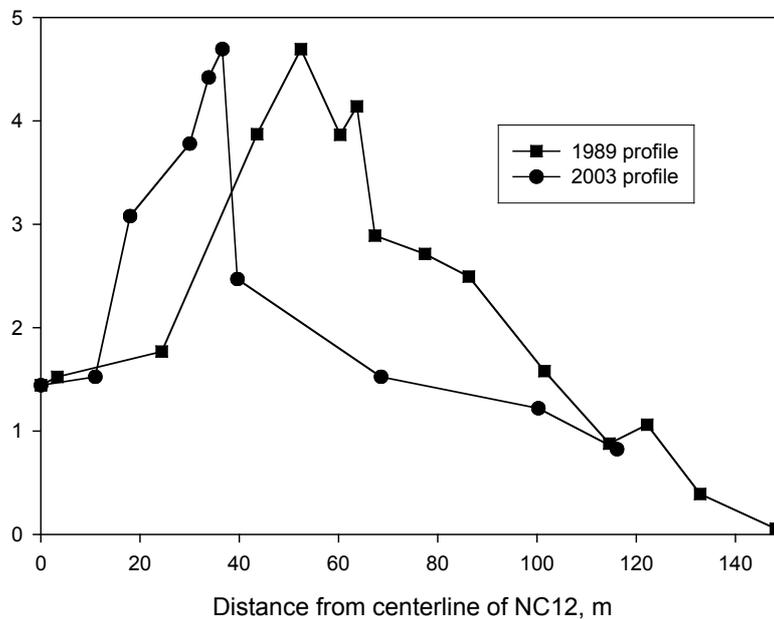


Figure 4. Example cross-sectional profile data.

Subaerial volumes were calculated from the ground surveys. Volume included everything above 0.36 m NAVD from the centerline of the road seaward. The elevation 0.36 m was chosen since it represents MHW based on the data from the US Army Corps of Engineers Field Research Station at Duck, NC approximately 35 km north of the site. The subaerial volume change mimics the shoreline change in that the volume decreases from approximately 120,000 cu m in 1990 to less than 80,000 cu m in 1997. From 1997 until 2006, the volume remains about the same until 2003. This change of 40,000? cu m represents approximately 0.5 m of depth on a rectangular section taken to be 550 m long

and 75 m wide. Correlating the volume change to shoreline change, 20,000 cu m of loss in volume relative to 40 m loss in shoreline position is consistent with a beach slope of approximately 1:20 which is a reasonable approximation at this location.

Cross section data

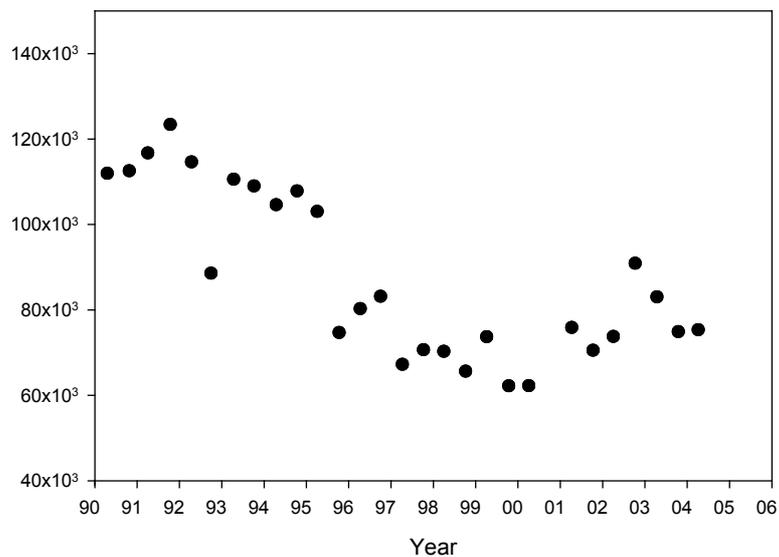


Figure 5. Volume ? based on subaerial ground surveys.

LIDAR data

The Outer Banks of North Carolina have been a focal point for LIDAR should we use lidar rather than LIDAR? application since 1996. Coinciding with a period of increased storminess, the development of LIDAR and its use in post-storm reconnaissance has provided researchers in NC with a wealth of 3D coastal terrain data. A variety of federal agencies have flown missions in NC and provided the data to NOAA CSC for distribution. The data sets available in this study area are presented in Table. 1. In addition, the USGS made available data taken pre and post Hurricane Isabel on September 16 and September 21, 2003 and additional data were downloaded from the NC Floodplain Mapping Program (NCFMP) website. The NC Floodplain data was collected in 2001. Thus a robust set of spatially extensive, high resolution elevation data is

available to examine morphological change in the subaerial beach and dune system.

Date	Agency	Mission Notes
October 10, 1996	NOAA, NASA, USGS	ALACE
September 26, 1997	NOAA, NASA, USGS	ALACE
September 1, 1997	NOAA, NASA, USGS	ALACE
September 7, 1998	NOAA, NASA, USGS	ALACE post Hurricane Bonnie
September 9, 1999	NOAA, NASA, USGS	ALACE post Hurricane Dennis
September 18, 1999	NOAA, NASA, USGS	ALACE post Hurricane Floyd
October 6, 1999	NOAA, NASA, USGS	ALACE
August 28, 2004	USACE	CHARTS
September 28, 2005	USACE	CHARTS post Hurricane Ophelia

Table 1. LIDAR data downloaded from the NOAA CSC website.

In order to use the various LIDAR datasets, a work flow had to be developed to integrate, process and analyze the variety of data obtained. Both technologies and missions specifications changed throughout the 10 year data collection period, yielding datasets with different overall coverage as well as different point densities. For example the 2001 NC Floodplain mapping program survey was designed for statewide coverage, including a complete coverage of the barrier island; therefore the mission was flown from higher altitudes using 2001 technology leading to lower point density (0.2 point per 2 m grid resolution) as compared to the CHARTs 2004 mission which sampled only a 750m swath from the ocean shoreline landward with a 15 point per 2 m grid resolution. These differences are illustrated in Figure 7 below.

Based on the range of point densities in the entire multitemporal data set, and our analysis of impact of interpolation on elevation and volume estimate accuracy from lidar data (Mitasova et al., 2003, 2005), a 6 ft resolution was chosen to create the DEMs. Open source GRASS was used for all the processing of the LIDAR data and surface comparisons (Neteler and Mitasova, 2004). Initial results were quite promising in that detailed features of the beach, dune and overwash area were revealed in the data. An example of the comparison between two dates, 2001 and 2004 is shown below.

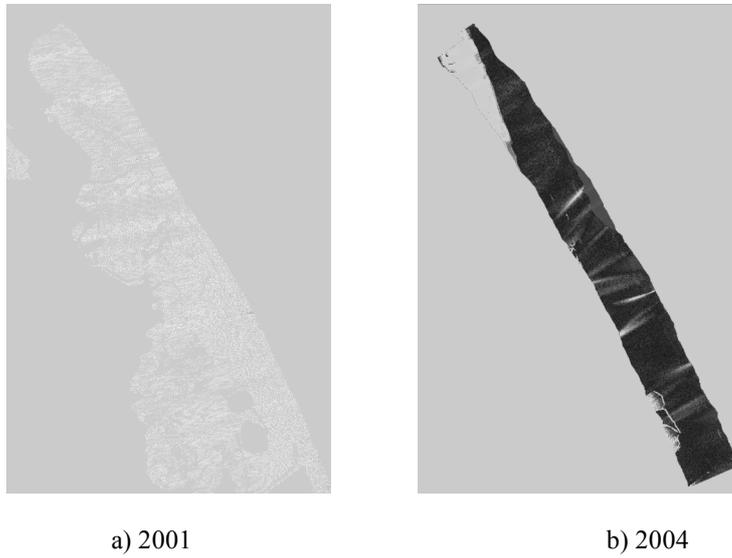


Figure 6. Illustration of point density and coverage 2001 (left) and 2004 (right).

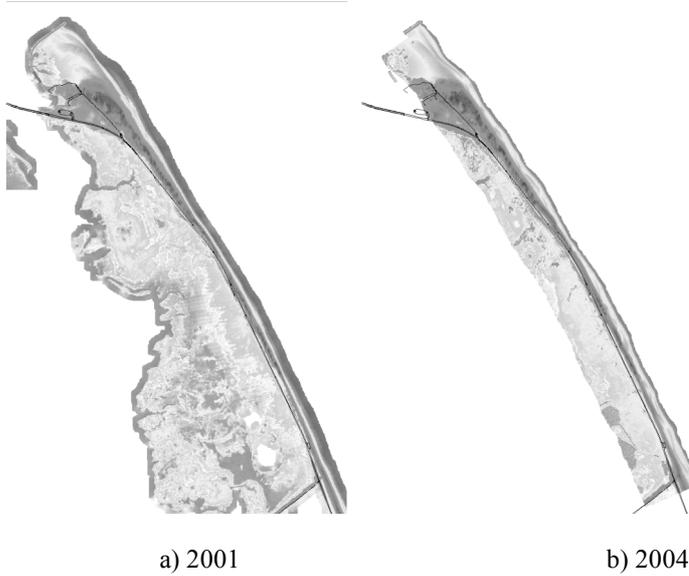


Figure 7. Surfaces created from the 2001 and 2004 LIDAR. However, important differences were found when we tried to calculate change in volumes between the surfaces. Using the road as an assumed stable feature, we investigated the elevation difference of the road between the 2004 LIDAR

dataset and each of the other eleven sets. As stated in the NOAA CSC website, while the ALACE data have undergone internal consistency checks they have not in general been checked against ground control, although several papers assessed their vertical accuracy at 15cm (Sallenger et al. 2003, Stockdon et al. 2002 – please check these references to make sure that they include the accuracy). The CHARTS data have a published 15 cm rms error (is that what is in the metadata?). The authors are still investigating the 2001 error measure Do you have the official NCFMP accuracy assessment? they have detailed accuracy analysis I believed Jose should have it – the only problem is that they don't include accuracy for sand but that should be somewhere between the paved and vegetated cover. What we should probably say that the existing accuracy assessments focus on rmse and do not address possible systematic error or a vertical shift in the elevation data. When comparing the road elevation captured by the different data sets, we found that data tended to 'float' 10-20 cm above or below the road as defined by the 2004 data. In order to provide an independent investigation of these offsets, we contracted with Geodynamics to provide RTK-GPS positions along the centerline of the road throughout the study area. From these results, we determined a correction factor for each LIDAR dataset by calculating the statistics of the difference between the RTK-GPS and the DEM for each RTK-GPS point collected (approximately 800 points). The correction factors ranged from about +15 cm to -25 cm. Based on these correction factors, the surfaces were adjusted upward or downward to pull the DEM to the road surface. From these corrected DEMs, the volume above the MHW (0.36m) from the road to the shoreline was determined for each set. These data are plotted together with the ground survey data in Figure 8 below.

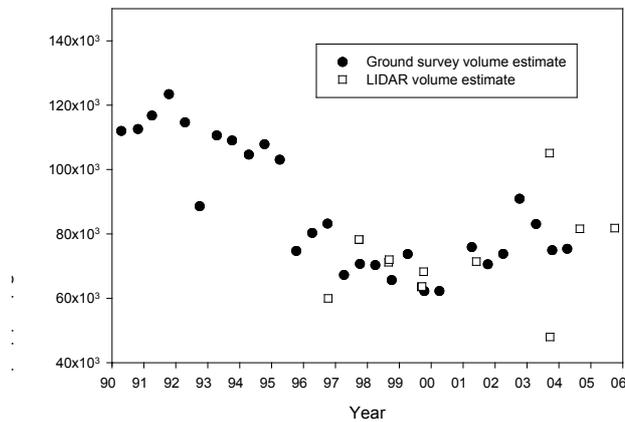


Figure 8. Comparison of the volume estimates from the ground survey data and LIDAR data.

The LIDAR-based volume estimates generally fall within the values provided by the ground survey estimates with the exception of the values pre and post Isabel. In addition to the volume estimates, LIDAR data allowed us to create detailed maps of spatial pattern of elevation change

Discussion

While the loss of volume (Figure 8) and shoreline position (Figure 3) during Hurricane Isabel is what would be expected, the large increases in volume and shoreline position have not been explained. In the two months preceding Hurricane Isabel, the USACE was undertaking a dredge and disposal operation in Oregon Inlet and on the beaches within Pea Island Wildlife Refuge. Between August 21 and September 14, 560,423 cu m were dredged from the inlet and disposed of in the 3.5 km north of and including the study area. Assuming a 20% loss factor, 448,338 cu m were placed on the beach. The project was resumed after the storm and 226,605 cu m (181,284 cu m with 20% loss) were dredged from the inlet and placed on the beach between October 1 and October 14. This material was placed in a 1.0 km area including the study area and south. Therefore it is clear that this activity significantly impacted the volume of material in the subaerial region and thus impacting the values of all the datasets.

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