Using Terrestrial Laser Scanning to Detect Changes on an Overwash Fan. Pea Island, Outer Banks, North Carolina, 2007 to 2010.

Introduction

Although debate exists on the importance of overwash on the Outer Banks' landward migration, ocean overwash does occur along the Outer Banks, and as a result, changes amongst beach and dune topography can be seen (Hosier and Cleary). Although beach overwash fans may be easily identified through qualitatively inspection (eyewitness, aerial photography), understanding topological morphometrics within fan geometry can be difficult because changes between overwash events may be subtle (<1m) or additionally, so great that no plane of reference may exist within the overwashed area with which to measure event by event changes from. Therefore, accurate depiction of overwash fans have necessitated surveying/monitoring with the benefits of current technology (Total Station, manual survey along predetermined transects (Leatherman and Zaremba; Dingler and Reiss), erosion pins, GPS-RTK, Aerial Lidar). Although these methods produce meaningful insight into current overwash fan topography and temporal change, they lack sufficient resolutions to quantify small scale processes and forms within the larger overwash setting. Because no established literature base is present for the quantified study of overwash fans at <1m resolutions, a need exists for additional field work and analysis.

The Terrain Analysis Lab (TAL) at East Carolina University is equipped with Terrestrial Laser Scanners (TLS) capable of producing overwash fan Digital Terrain Models (DTM), with resolution of 0.05 meters. A DTM resolution of 0.05 meters can capture landforms of 0.1 meter (10 cm) and greater (Maune et al, 2007). Based on site observations and conversations with East Carolina professors (Dr. Gares and Dr. Wasklewicz), surveying at this resolution will more accurately and efficiently depict overwash fans compared to currently used methods. Additionally, because of the exploratory nature of this field work with respect to TLS overwashed areas, analysis will be made of the applicability of TLS in the costal environment (field work, quality of data collected).

Research Questions/Objectives

- Using TLS methods, can overwash fans be captured? Is TLS an efficient manner of surveying overwash fans?

- Can change between scans be quantified? What are the form and size of these changes?

- When scanning an active beach surface, difficulties arise in comparing repeat scans. Can change be quantified without surface differencing? Is RTK-GPS a necessary component to future work?

Study Site

Pea Island, North Carolina is a section of the Outer Banks barrier island chain, and is located approximately 11 miles from the North Carolina mainland (Fig. 1). Because of their location, the Outer Banks experience increased vulnerability to storms (mainly nor'easters), and therefore an increased variability in beach topography with time, making them an ideal location to study beach change. The chosen study site was first surveyed in November of 2007 and again in February of 2010. The surveyed area is approximately 120 meters long (perpendicular to the beach) and 70 meters wide (parallel to the beach).

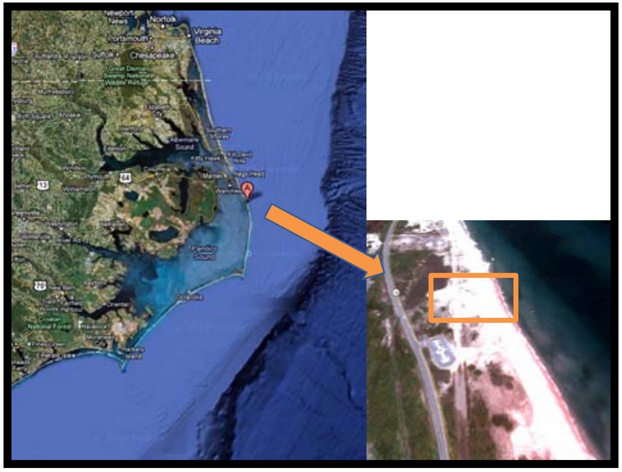

Figure 1 - Map of study site, Pea Island, Outer Banks

Figure 2 - Scan location, at top of the beach. February, 2010

First Scan (Fig. 3) - November, 2007

At the time of the initial survey, the study area was classified as between a Dune Terrace barrier island and an overwash flat. (Dernieres, Ritchie, and Penland, 1988 as cited in Dingler and Reiss; Hoiser and Cleary). Dune terraces have significant intact sections of foredunes with narrow breaches, through which ocean water has penetrated, depositing sediment onto the backshore(Dernieres, Ritchie, and Penland, 1988 as cited in Dingler and Reiss). The baseline survey shows a significant foredune on the left side (looking from the ocean), with a much smaller foredune remnant in the center of the scan. The foredune breaches here are at least as large if not larger than the foredunes, signifying a transitory state between a dune terrace and an overwash flat.

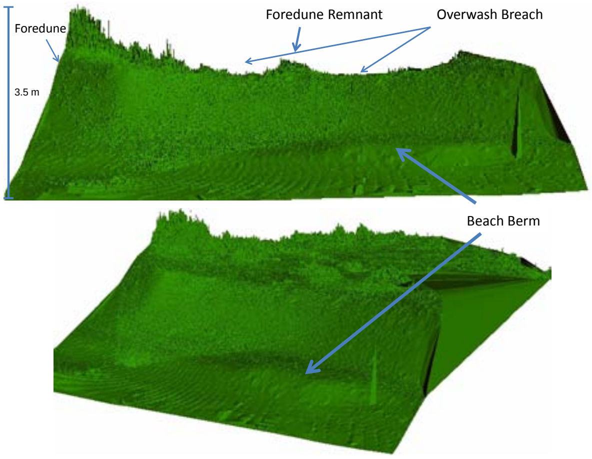

Figure 3. ArcScene baseline survey representation at 5 times vertical exaggeration

Second scan (Fig. 4) - February 2010

By the time of the second scan, the study area was characterized as a washover flat (Fig.4) (Dernieres, Ritchie, and Penland, 1988 as cited in Dingler and Reiss; Hoiser and Cleary). A washover flat describes an area of coastline that is flat, has a relatively vegetation free backshore, with embryonic dunes appearing across the overwashed area and a possible vegetated dune further onshore, delineating the extent of the overwashed area (Dernieres, Ritchie, and Penland, 1988 as cited in Dingler and Reiss).

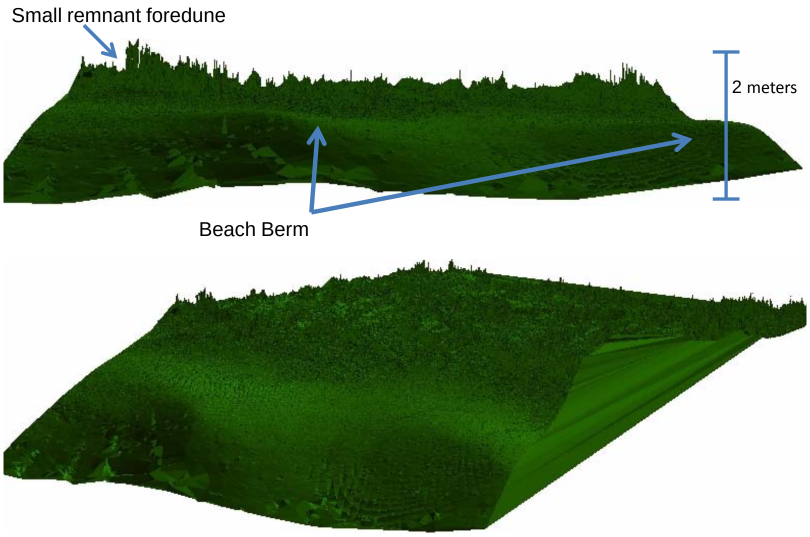

Figure 4. Arcscene overwash flat survey at 5 times vertical exaggeration

Methods

Data Acquisition

Two surveys were conducted with a Lecia Scan Station 2 Terrestrial Laser Scanner (Fig. 5): November, 2007 for baseline conditions, and Feburary, 2010 after complete over wash events occurred and multiple storm systems moved through the area. Although technically only three are needed, four control points (Leica Geosystems High Definition Survey targets) were established on the overwashed area for redundancy and to add mobility of scanning locations (targets add the ability of multiple scans from different locations to be merged as a contagious dataset). Each Survey required 7 separate scanning locations. The number of scan locations is a function of: size of the basin, complexity of topography, study site relief and resolution of final product. Mean absolute errors for x, y, and z for both surveys were less than or equal to +/- 3mm.

Figure 5. TLS setup. Landward extent of the overwash, February 2010.

Figure 6. RTK-GPS Base Station setup.

In a typical surveyed area, monuments are established below each of the control points so that repeat scans can be referenced against the other, and change can be detected between surveys. In a costal setting, where the beach is an active surface, monuments are not a solution, especially over longer time spans, where erosion or deposition may cover or remove built monuments. A proposed solution is to RTK-GPS points at each of the target locations (Fig. 6), allowing for the geo-referencing of multiple scans. This solution has two issues. First, it adds a level complexity to the survey with additional time in the field, datasets and steps for post processing. Second, it adds error to the survey. RTK-GPS has an accuracy of +/- 2 centimeters, well above the +/- 3 millimeters of the Lecia Scan Station 2. Because of these drawbacks, reliance upon comparative measures of beach and dune topography are used to draw conclusions regarding change on the overwashed area of beach.

A problem unique to TLS surveying is laser attenuation. In a costal setting, relief is minimal, especially on overwash fans and beaches. When shooting across the fan from the ground, point spacing becomes greater as the laser moves further away from the scanner. If not compensated for this will produce large data voids and exaggerated shadowing, both of which are unacceptable for accurate data analysis at

>1m resolutions. Increasing the surveyed resolution and scanning from multiple locations can lessen the attenuation, although the best way to remove attenuation is to increase the TLS height above surface.

GIS Processing

Both surveyed TLS point clouds were exported from Cyclone (native Leica TLS software) as a database file (xyz) and imported into ArcMap, where they were converted into feature (point), TIN, and 0.05 meter raster Digital Elevation Model (DEM). The Raster DTM's were used for quantitative analysis in ArcMap, while the TIN DTM's were used for qualitative analysis and visualization in ArcScene.

From both 5 centimeter raster DTM, 5 profiles were made using EZ profiler 9.1 perpendicular to the beach.

Figure 7. Baseline scan raster DTM and shoreline perpendicular profile locations.

Figure 8. Overwash flat survey raster DTM and shoreline perpendicular profile locations.

Results

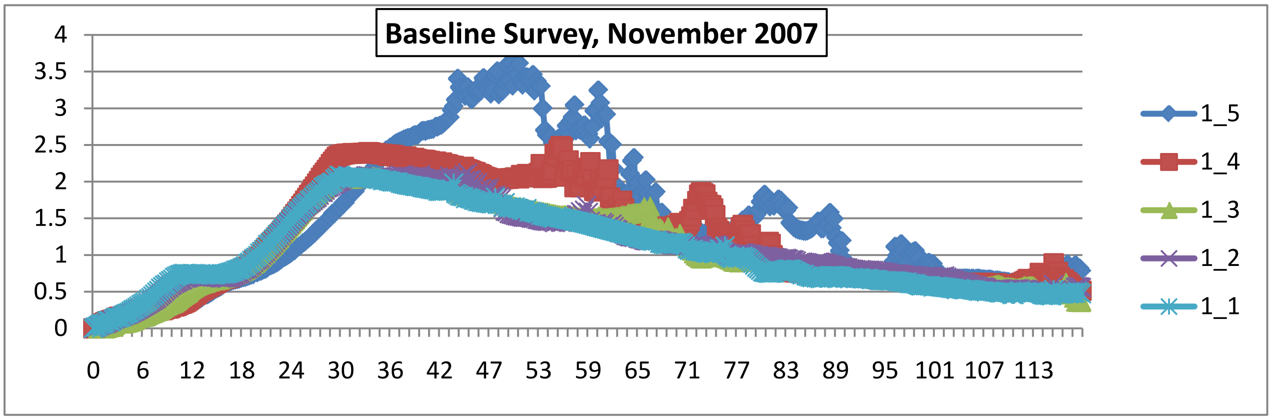

Figure 9.

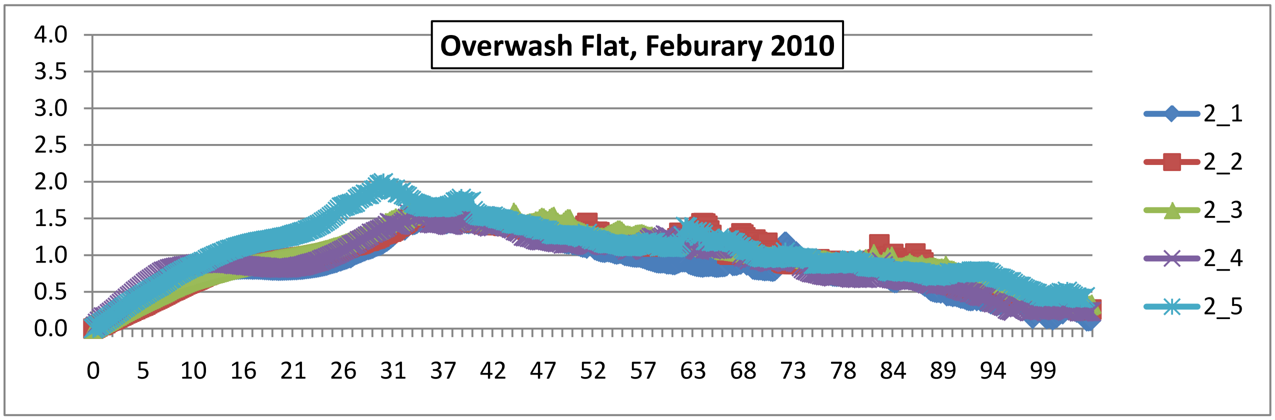

Figure 10.

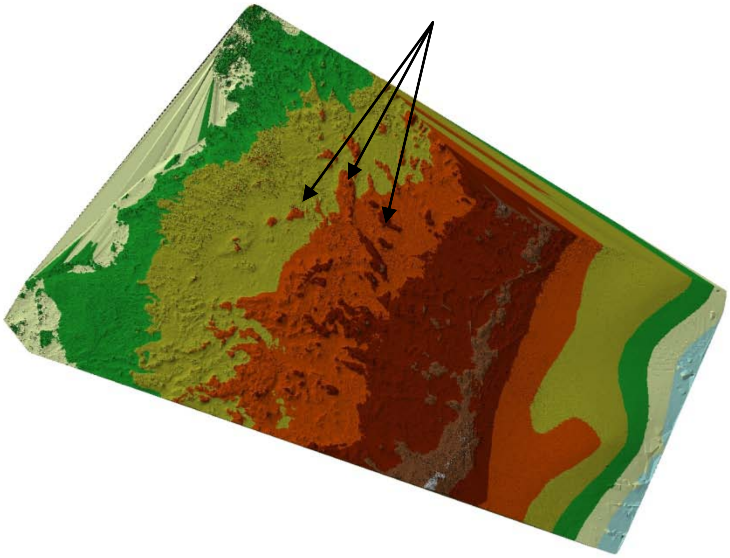

Figure 11. TIN showing Embryonic dunes (Hummocked Topography) on overwash flat

	Beachberm horizontal location (m)	Beachberm height (m)	Beach Slope	Foredune Height (m)	Beach Width(m)
Baseline	13	0.60	0.08	3.2	32
Overwash Flat/terrace	13	0.75	0.06	2	32

Table 1.

Discussion

Across both surveys, both large (foredune, beach berms) and small >1m (beach hummocks, debris) features can be seen. The beach berms, located oceanward of the foredune ridge, are located in similar horizontal positions in both surveys but the overwash flat profiles show the berm to be slightly higher in 2010 than in 2007 (Fig. 9,10 Table 1). Beach slope changed significantly between scans. Baseline scans revealed a beach slope of .08, while the overwash terrace/flat revealed a slope of .06. Not suprisingly, foredune height measured 1.2 meters lower on the overwash flat than on the dune terraced survey. Beach width remained constant across both scans.

Conclusions

The first survey made in 2007 is characterized by a steep beach with a small beach berm. The foredune ridge is still intact in sections with two large overwash inlets penetrating the ridge. The second survey made in 2010 is characterized by a markedly shallower beach face large beach berm and non-existent foredune where overwash receives little or no resistance moving landward. As drawn and researched by Hoiser and Cleary (1977) and Ritchie and Penland (1987), these two surveys are a straightforward representation of the last stages of barrier island overwash processes (dune terracing and overwash flat) before the redevelopment of a foredune ridge.

For future costal overwash fan TLS, a method of referencing the scans is needed for conclusive quantitative data to be established from these surveys. Changes are too subtle across the overwash fan to locate any areas of deposition landward of the foredune ridge. Although GPS-RTK dataset integration is beyond the scope of this research, it was a significant setback and should be an integral part of any future coastal beach scanning.

Although it is difficult to fully understand sediment distribution within the overwash fan without differencing the surfaces, features within the overwash fan can be captured, captured more efficiently and at higher resolutions compared with GPS-RTK surveying.

Future TLS surveying of overwash fans should incorporate some form of platform (vehicle or tower) to raise the scanner off the surface of the overwash fan. Laser attenuation was an issue during the survey, and although it can be somewhat compensated by making more scans at higher resolutions, increasing scanner height would enable the scanner to capture smaller features more accurately in a more efficient manner.

References

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