Fire Island National Seashore Change Analysis:

Evaluating Pre and Post Hurricane Sandy LiDAR of a breached section of the Island.

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Introduction:

Changes in a landscape can occur gradually over long periods of time or they can be sudden, caused by short-term disturbance events such as natural or man-made disasters. Changes can affect the pattern and process of the landscape and can have large impacts on ecosystem health and human interests. Identifying and quantifying these changes are important steps to help understand possible impacts to a landscape.

Fire Island National Seashore is a barrier island that lies off the southern coast of Long Island, New York. It was established as a National Seashore in the National Parks Service in 1964 and it incorporates 17 different communities that already existed on the island. According to the National Parks Service it is 10% forest, 40% wetlands, 25% open (beach, swale and fields), and 25% developed (NPS and 17 local communities). It is approximately 32 miles long and it averages less than a mile in width.(3) The landscape includes a primary dune system along the southern ocean side and areas of salt marsh and protected beaches on the northern bay side. It is home to many natural and cultural resources, and the protection and preservation of these resources of major concern to National Park Service mission and the public.

In late October of 2012 Hurricane Sandy made landfall on the Northeast Coast of the U.S. and had devastating effects to many coastal communities. Barrier islands are dynamic in nature as the shoreline is ever evolving with wave action and sediment transport, but large storm events can drastically change a barrier island and this can be seen on Fire Island where a large breach formed from the Hurricane that split the island in two. The breach is still dynamic in nature and is ever evolving as it has ranged in length and width since its formation. It started out at 908 ft. long, 276 ft. wide at the Northern end, and 108 ft. wide at the Southern end in November of 2012 and most recently measured in October of 2013 it is 1,302 ft. long, 699 ft. wide at the Northern end, and 2,087 ft. wide at the Southern end. This breach in the island became a major management issue with NPS staff and the local communities as many wanted the new inlet filled and closed and others fought for it to remain open. The breach has remained open and NPS has no plans to fill it in as of the winter of 2013.

Objective:

The goal of this study was to classify the changes to Fire Island National Seashore in the area of the breach on a landscape level from the effects of Hurricane Sandy. To analyze these changes LiDAR data that was collected pre and post storm were evaluated to determine elevation and slope changes to the island. LiDAR or Light Detection and Ranging is a remote sensing technology that collects 3-dimentional point clouds of the Earth's surface. This data contains x, y, and z information as longitude, latitude, and elevation and it generally has a sub meter accuracy on elevation. This type of data is essential for understanding elevation differences and effects on a landscape. Changes in elevation and slope can lead to drastic changes in habitat type, vegetation regimes, and species dispersal. Coastal habitats such as barrier islands and salt marshes are fragile ecosystems and even subtle changes in elevation or slope can drastically change the landscape. This study attempts to quantify the changes in elevation and slope to the breached area of Fire Island National Seashore.

Methods:

LiDAR data was obtained from sources involved with the National Park Service and the Fire Island National Seashore. The Pre-Hurricane Sandy LiDAR, from May 2012, was produced by the USGS and the Post-Hurricane Sandy LiDAR, from November 2012, was produced for the National Park Service. Both LiDAR data sets had a spatial resolution of 0.5-meters. This equates to 4 elevation points per square meter. The data was delivered as LAS files and zipped LAS files, which are the raw data that is produced by LiDAR. The zipped LAS files had to be specially processed using LAS Tool Software to extract the LAS files into a format that could be used in ArcGIS. The LAS files were then processed in ArcGIS to view and analyze the LiDAR data and to detect and quantify changes between the datasets. The LAS files were also viewed in a 3-D viewer and the elevation was extruded to help visualize the changes to the island.

The LAS files were converted to a raster format with a cell size of 1-meter. Since the spatial resolution of the LiDAR data was 0.5-meter this had a slight smoothing effect on the data as it grouped points together. While a little detail was lost in this process, the 1-meter cell size was very representative of the landscape and was a good size to work with and analyze.

A project area was designed based upon knowledge of the breach that occurred in the barrier island. The raster data sets were then clipped to this area to focus the study and to create smaller data sets that could be easily worked with. Visual analysis and a statistical analysis were then done for the two digital elevation models that were generated

A change detection process was done using "Raster Calculator" in ArcGIS to produce an "elevation change map". In this process the post-storm raster was subtracted from the pre-storm raster to show areas where large elevation differences occurred due to the storm. In the resulting "elevation change map" positive numbers represent areas where elevation loss occurred and a zero value represents no elevation change between the data sets. To further the analysis 0.5-meter contour maps were developed from both data sets as a visual tool to identify the differences in elevation. Contour lines are great ways to visualize the difference in elevation in a landscape by visualizing the number, frequency, and closeness of the lines. Finally slope maps were generated from the LiDAR rasters to show differences in slope pre and post storm.

A statistical analysis was done on the elevation maps and the slope maps to quantify the differences in the data pre and post storm. This was done by looking at the Cell Statistics for each of the maps created in ArcGIS.

Discussion:

Overall through visual and statistical analysis there was a significant elevation loss in this section of Fire Island due to Hurricane Sandy and also a decrease in slope. As Hurricane Sandy hit the island strong waves, heavy rains, and a severe storm surge powered by high winds pushed sediment across the island and cut out the breached area. The mean elevation of the study area pre-storm was 1.14 meters and it decreased to 0.95 meters post-storm. Data from the "elevation change map" shows that there was a

maximum elevation difference of 6.06 meters where the breach occurred and a mean value of 0.19 meters for the whole study area. The large amount of this elevation change definitely came from the breached area but there is still an apparent elevation loss throughout the rest of the island, which can be seen in the elevation change map. Along with this change the mean slope of the area decreased from 2.91 degrees pre-storm to 1.89 degrees post-storm which shows a "flattening" effect as severe waves and storm surge over-washed the island and pushed sediment across it. The maximum slope value was actually higher in the post-storm data set as high dunes were undercut and it caused a very sharp slope similar to a bluff. These changes will no-doubtedly have impacts on things like habitat type, vegetation, wildlife, and natural processes of the island. The breach will also change tidal dynamics as the new inlet allows water to drain in and out of the bay.

Conclusion:

Elevation and slope changes to a fragile landscape can have drastic impacts and can threaten many important features of the landscape. The mission of the National Park Service is to protect and preserve the cultural and natural resources of the Parks. To accomplish this goal the use of remotely sensed data such as LiDAR is a vital part to understanding changes and analyzing effects of disturbance events such as Hurricane Sandy. Having pre and post storm data sets is essential in this analysis and for long term monitoring.

Further analysis on the impacts of Hurricane Sandy to Fire Island National Seashore could involve classifying the habitat change or vegetation change due to the storm. It is believed that the over-washing and flattening of the island has actually increased the amount of Piping Plover habitat. The Piping Plover is a species of particular concern and the changes to the island from the storm could have large impacts on this species as well as others.

It is important to understand landscape change and the causes and the impacts from change. Using change analysis techniques and harnessing remotely sensed data is a very valuable tool in this process. With the possibility of more frequent and more intense storm systems due to climate change, our coastal landscapes need extra attention and analysis. Acquiring and analyzing remotely sensed data for both pre and post storm is a priority for the future.

References:

1. Claudino-Sales, Vanda, Wang, Ping, Horwitz, Mark H. **Effect of Hurricane Ivan on Coastal Dunes of Santa Rosa Barrier Island, Florida: Characterized on the Basis of Pre- and Poststorm LIDAR Surveys**. 2010. Journal of Coastal Research, Number 263: 470-484. http://www.bioone.org/doi/full/10.2112/08-1105.1
2. Stoker, Jason M., Tyler, Dean J., Turnipseed, D. Phil, Van Wilson Jr., K, Oimoen, Michael J. **Integrating Disparate Lidar Datasets for a Regional Storm Tide Inundation Analysis of Hurricane Katrina.** 2009. Journal of Coastal Research. Number 10053: 66-72. http://www.bioone.org/doi/full/10.2112/SI53-008.1
3. National Park Service website. http://www.nps.gov/fiis/index.htm

Appendices:

Figure 1. LAS files showing elevation of a section of Fire Island National Seashore largely effected by Hurricane Sandy. The upper image is Pre (May 2012) Hurricane Sandy and the lower image is Post (November 2012) Hurricane Sandy.

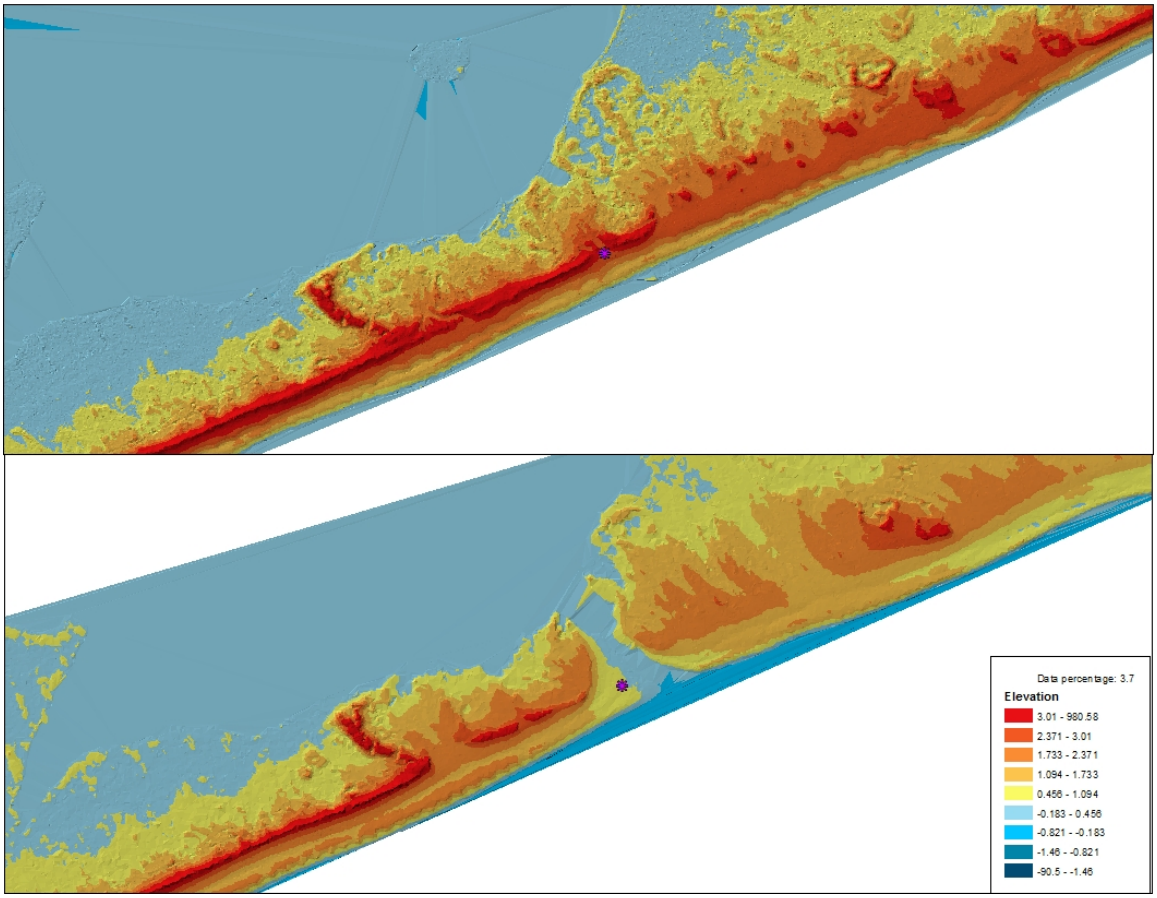

Figure 2. Pre (left image) and Post (right image) Hurricane Sandy LAS files shown in a 3-D viewer with a z factor extrusion of 20x.

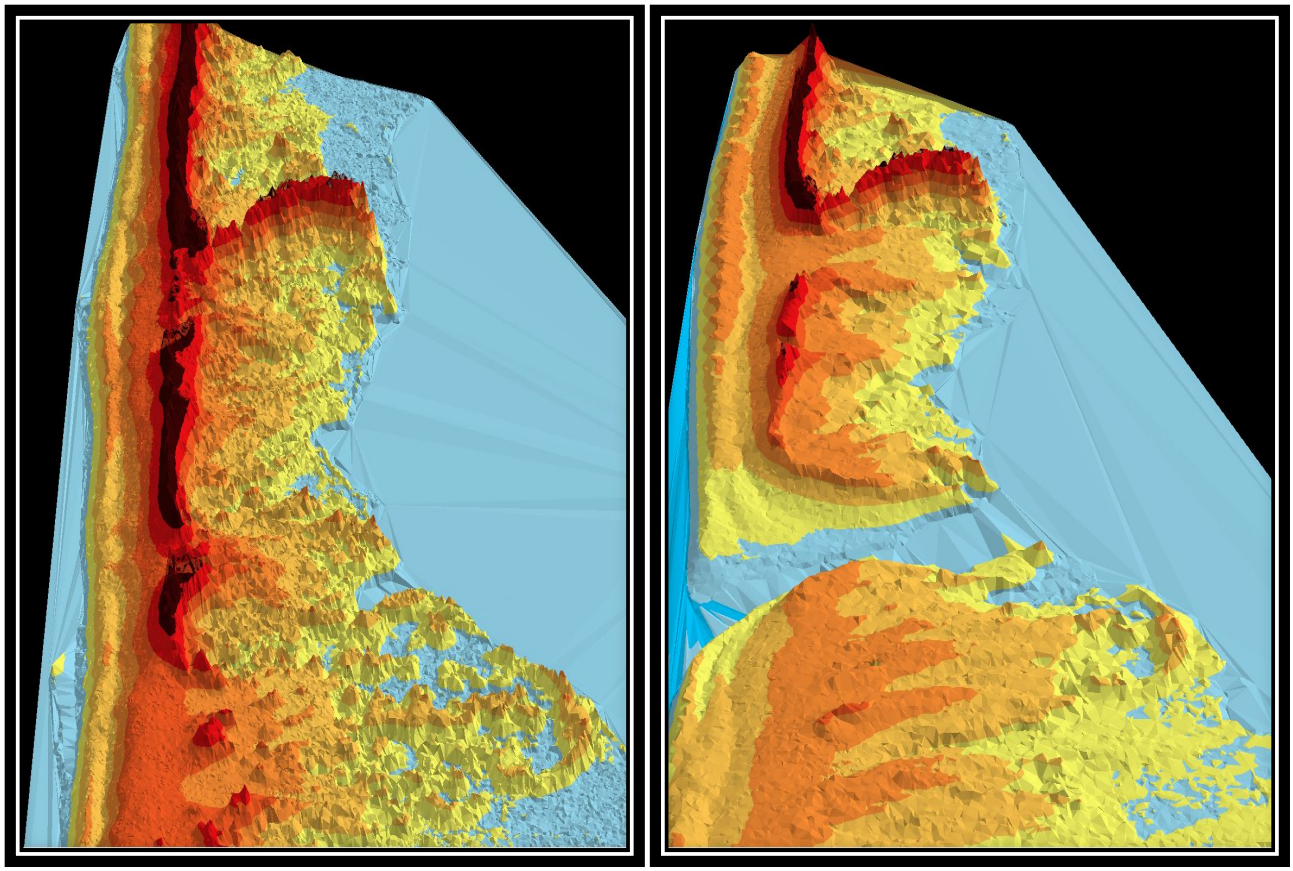

Figure 3. Raster images derived from the LiDAR data show elevation of the study area Pre (top image) and Post (bottom image) Hurricane Sandy.

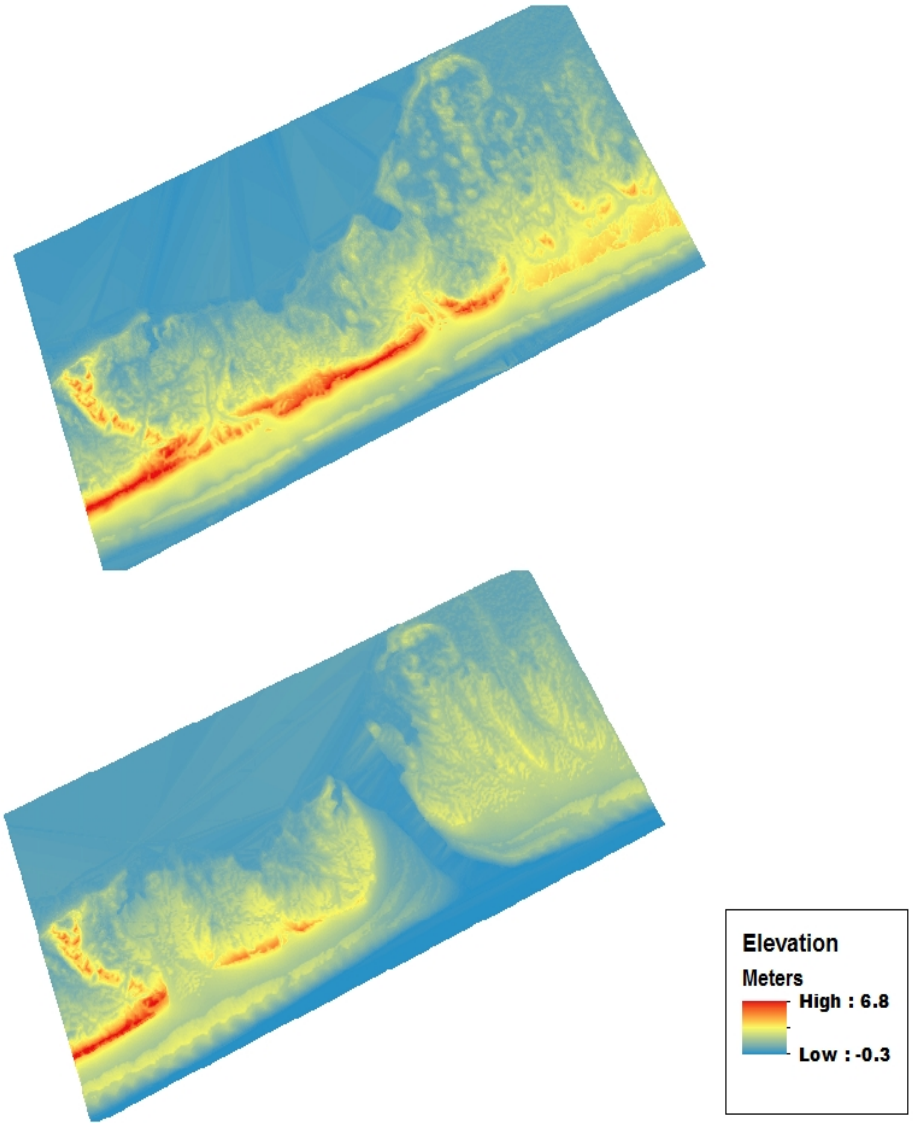

Figure 4. An elevation change map showing the difference in elevation between the Pre and Post Storm LiDAR. Values from the Post Hurricane Sandy LiDAR were subtracted from the values of the Pre Hurricane Sandy to generate this map in ArcGIS.

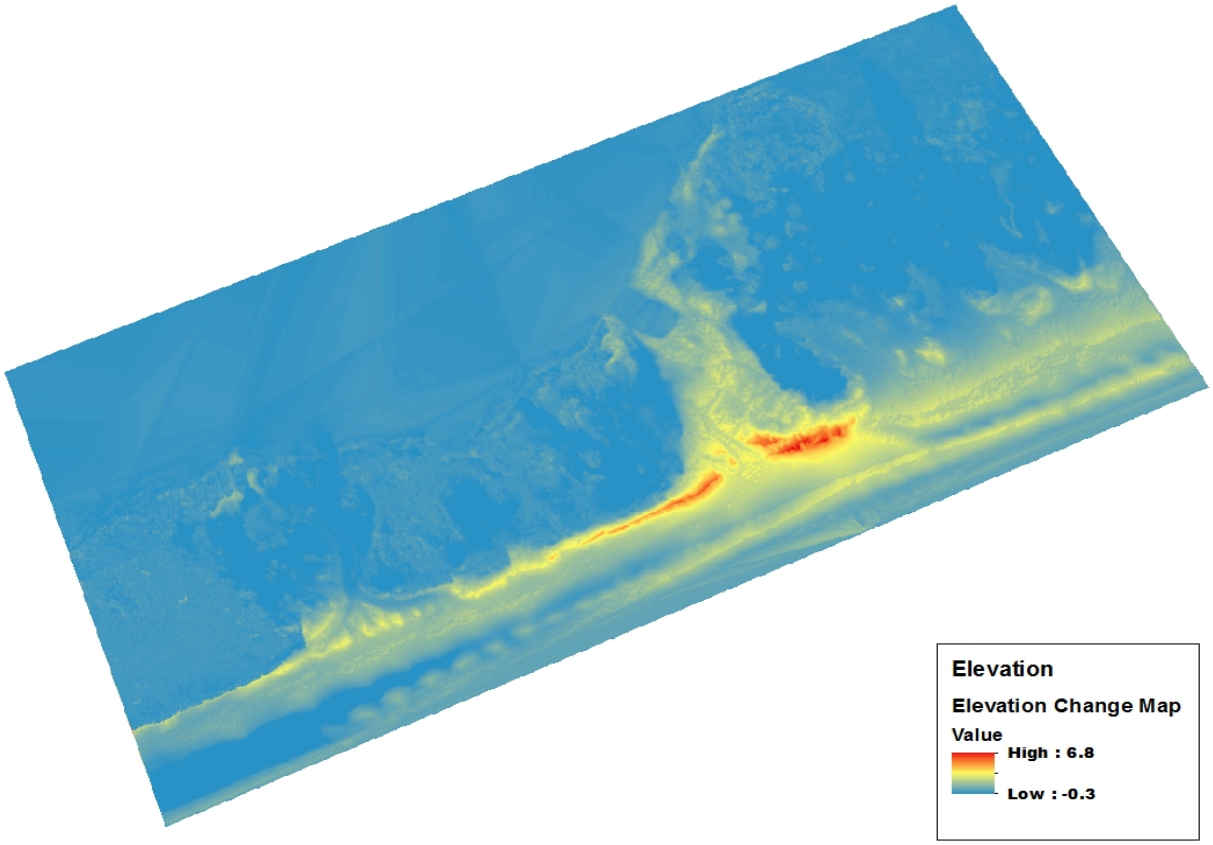

Figure 5. Contour maps of 0.5 meters were generated from the Pre (top image) and Post (bottom image) storm LiDAR to represent the elevation loss from the over-wash that occurred on the island.

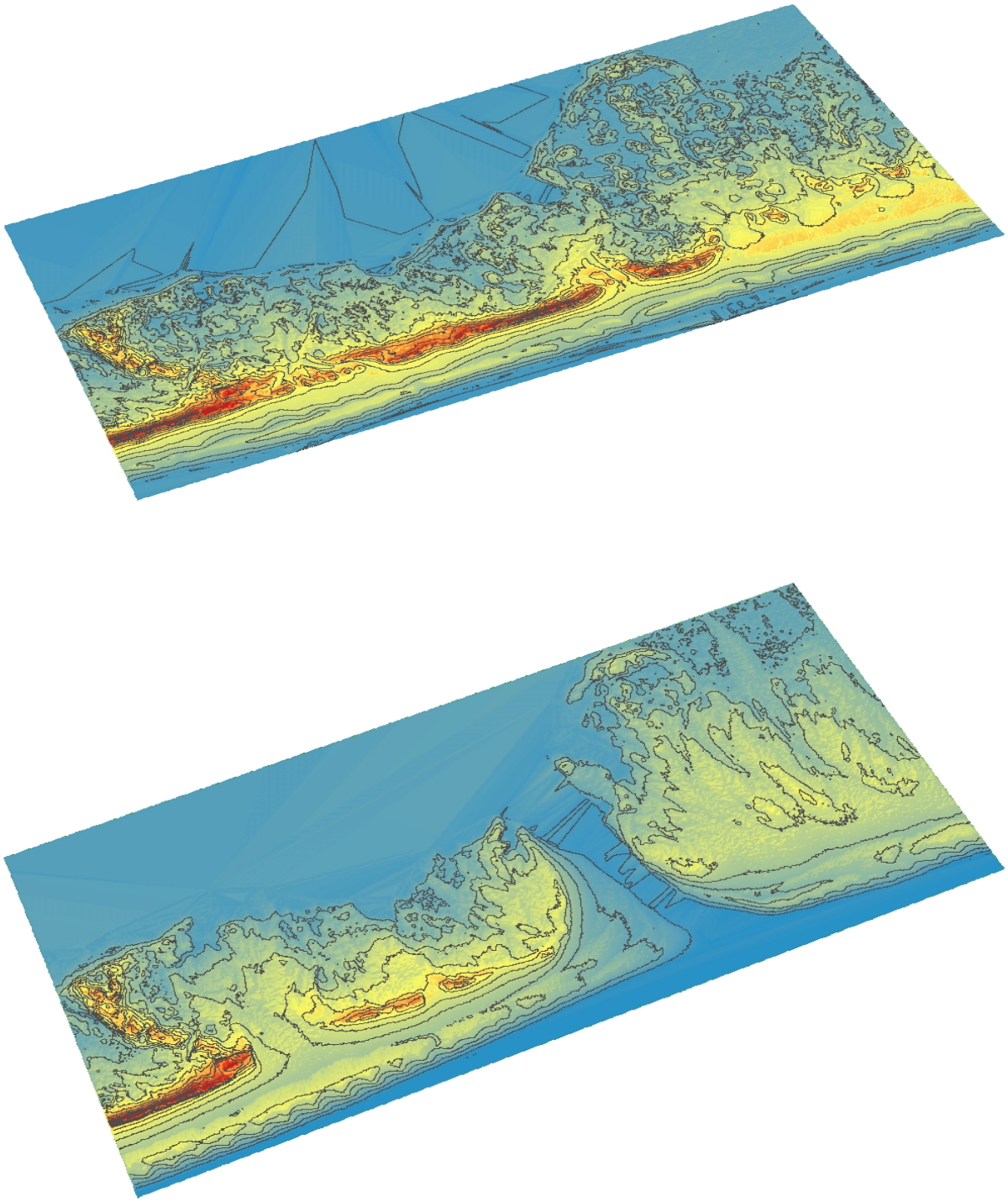

Figure 6. Slope maps generated from the LiDAR data show the difference in slopes between the Pre (top image) and Post (bottom image) Storm landscape.

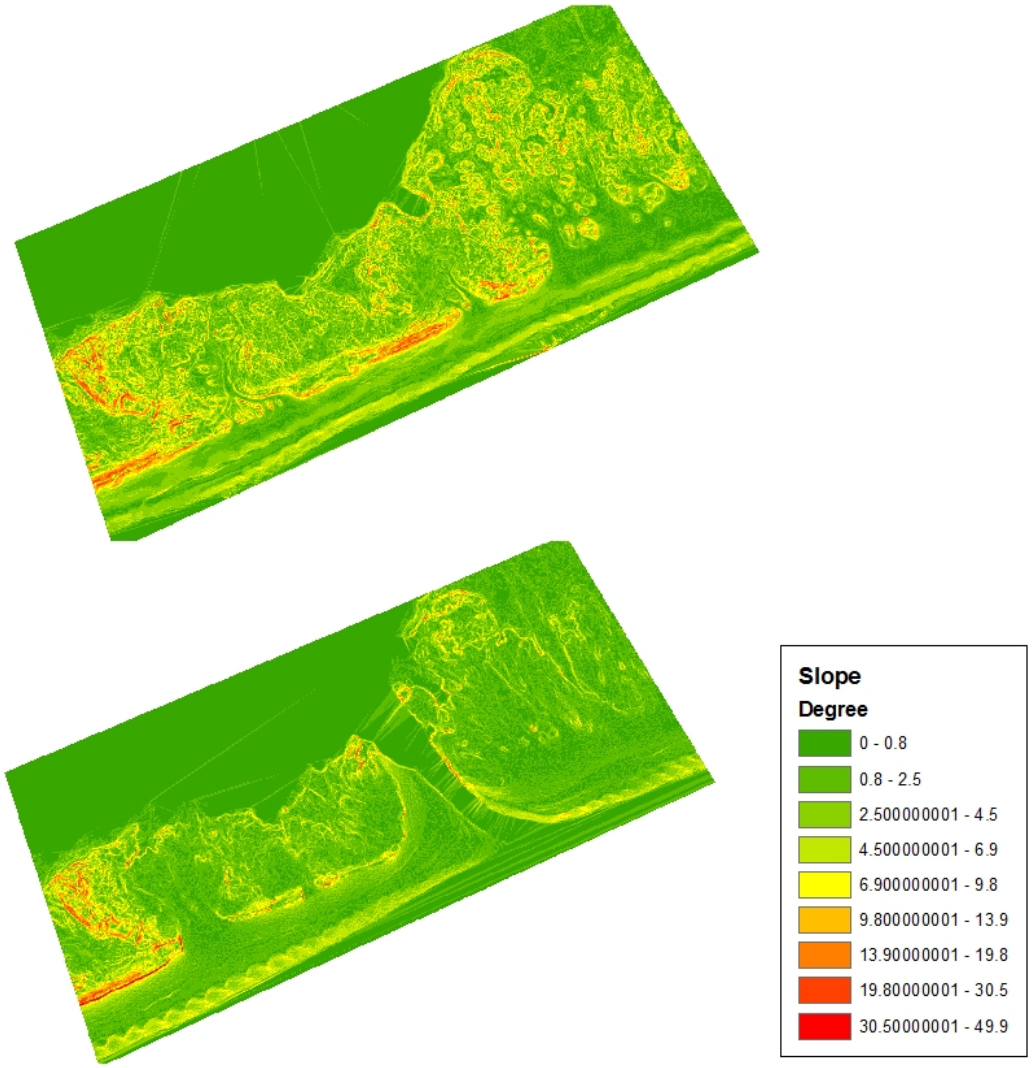

Figure 7. Table showing the differences in elevation and slope between the Pre and Post Storm data sets.

Field	Pre-Sandy Value	Post Sandy Value
Elevation Min (m)	**-0.29**	**-0.56**
Elevation Max (m)	**6.74**	**6.85**
Elevation Mean (m)	**1.14**	**0.95**
Slope Min (degrees)	**3.02**	**0**
Slope Max (degrees)	**34.94**	**49.93**
Slope Mean (degrees)	**2.91**	**1.89**