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Topo-bathy LiDAR analysis of Coastline Change on the Southern Tip of Cape Cod, Massachusetts

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Abstract

Coastal erosion and morphologic changes are affecting coastlines around the globe. Coastal regions need to understand the way in which their landscapes change to prepare for floods due to sea-level rise or large scale storms. The investigation examined approximately the southern nine miles of Cape Cod for morphological changes along the coastline (Fig. 2). The area contains Monomoy Island which is home to the Monomoy National Wildlife Refuge. Monomoy refuge makes up 8 of the approximate 9-mile study area and is 7,604 acres in size. Lidar derived elevation models were created from Topo-bathy LiDAR collected by NOAA in 2007 and 2010. ArcMap 10.4.1 software was utilized to calculate elevation change between the two years. The research determined the weighted average of elevation change throughout the study area. Additionally, the research determined the percent of each elevation change in the study area. These result will help guide coastal planners to areas of concern to help develop a plan to protect or prepare for future changes along the coast line.

Introduction

The potential impacts of sea-level rise as a result of future climate change will require an immense amount of research to determine areas which will be impacted the most in order to develop adaptive mechanisms. Coastlines are affected by various erosional factors which transport sediments to various locations. Understanding where the sediments are lost and gained will provide an interpretation of the processes in effect in the study areas.

Previous research completed by Duran et Al. (2016) attempted to calculate volumes of beach sand change following severe storms through the use of LiDAR derived DSMs. The authors successfully implemented breaklines for high water marks and also utilized raster calculations to measure elevation change in their study area. Understanding these coastal changes are closely tied to climate change. More frequent large storms are occurring due to climate change. Coastal planners need to understand the impacts these storms will have on coastal communities and the landscapes.

Wang (2015) examined advances in flood predictions and impacts through advances in remote sensing technology. Wang discussed the successfulness of using remote sensing technology along with in situ rain gauge measurements to estimate flood flow in a river basin. Additionally, Wang examined the effectiveness of combining terrestrial LiDAR and Airborne LiDAR to model flooding event.

The overall objective of this research will attempt to answer the question, "How much accretion or reduction of the ground surface occurred between 2007 and 2010 along the south end of Cape Cod?"

Study Area

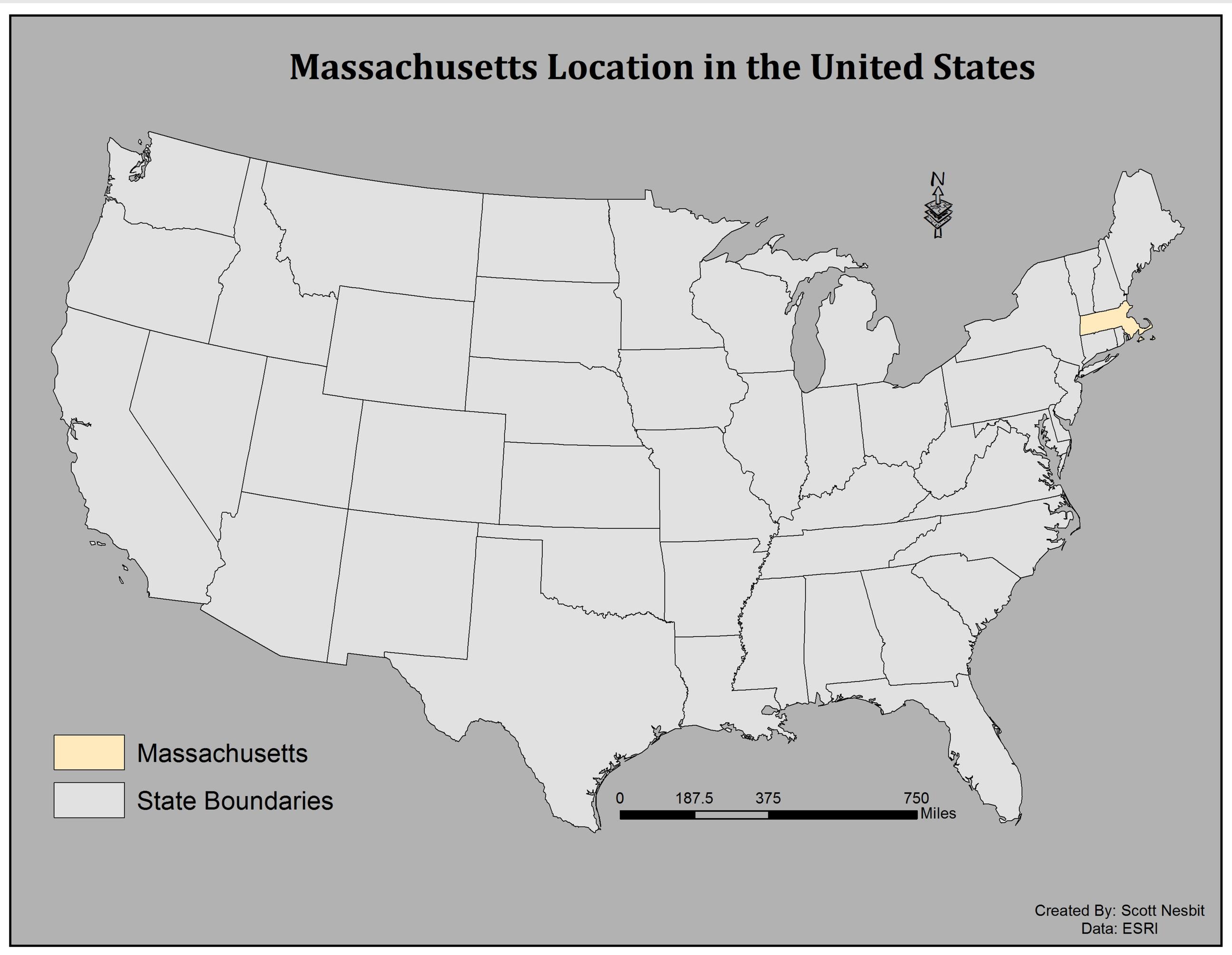


Fig. 1. Massachusetts location in the Contiguous United States.

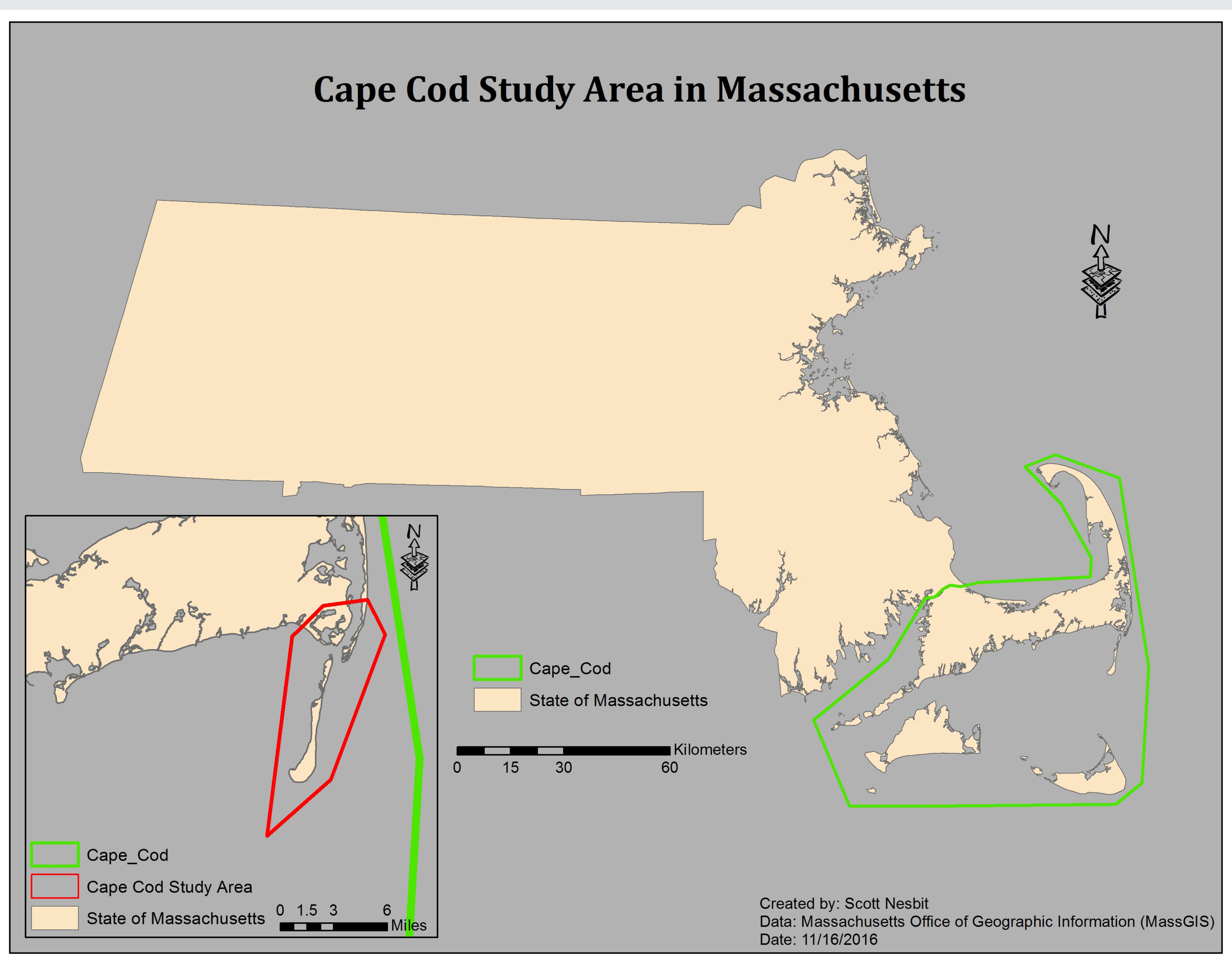


Fig. 2. Study area on the southern tip of Cape Cod highlighted by the red polygon in the left subset of the image.

Data

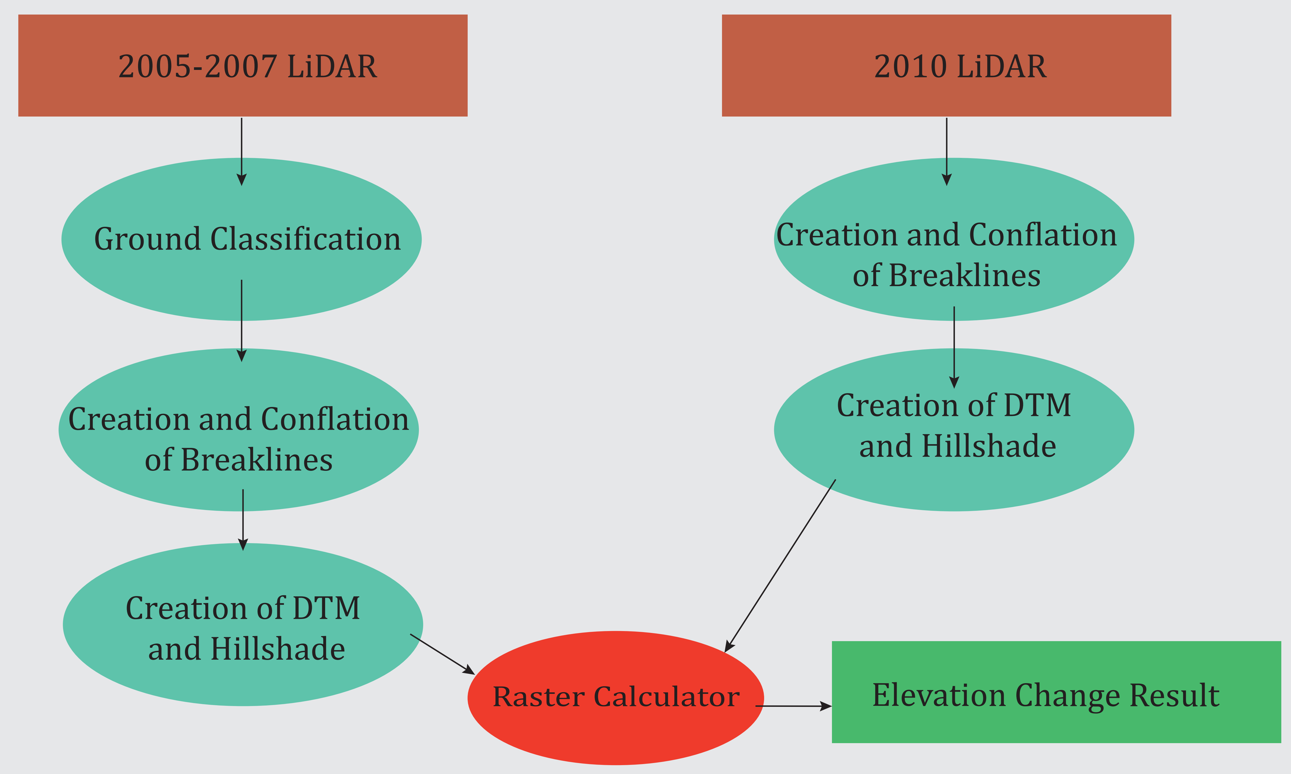
I acquired the following data from the National Oceanic and Atmospheric Administration (NOAA) via their Data Access Viewer:

***2005 - 2007 US Army Corps of Engineers (USACE) Topo/Bathy Lidar: Maine, Massachusetts, and Rhode Island**

***2010 US Army Corps of Engineers (USACE) Joint Airborne Lidar Bathymetry Technical Center of eXpertise (JALBTCX) Topobathy Lidar: Northeast (MA, ME, NH, RI)**

The 2007 data had a horizontal accuracy of +/- 3 meters (2 sigma) and a vertical accuracy of +/- 30 centimeter (2 sigma). The metadata stated the Position Dilution of Precision (PDOP) was always greater than 3.0. A Kinematic GPS (KGPS) solution was utilized to correct for positional error. The data was collected with the SHOALS-1000T. The 2010 data had a fundamental vertical accuracy of .172 meters at a 95% confidence level in open terrain. The horizontal accuracy was stated at .50 root-mean-square error (RMSE).

Methods



The 2007 data was not classified from NOAA so I utilized the Adaptive TIN Ground Filter in LP360 to classify the ground points. The 2010 data was classified from NOAA though there were variation between my classification and NOAA's (Fig. 4 &5). Next I employed a process I have coined The 'Sawall Solution' to create breaklines for the shoreline for both years of data in ArcMap (Fig. 3). Conflation of the breaklines was completed in LP360 using Summarize Z to convert the 2-dimensional breaklines to 3-dimensional. A Triangulation method was utilized in LP360 to export a Digital Terrain Model (DTM) for both years. Both DTM's were brought into ArcMap and the Raster Calculator was used to subtract the 2010 DTM from the 2007 DTM. Finally, I used the calculated values of elevation change to determine the weighted average of elevation change for both areas which gained elevation and decreased in elevation in the study area. Additionally, I calculated the percentage of each value of elevation change for both the areas which gained elevation and decreased in elevation.

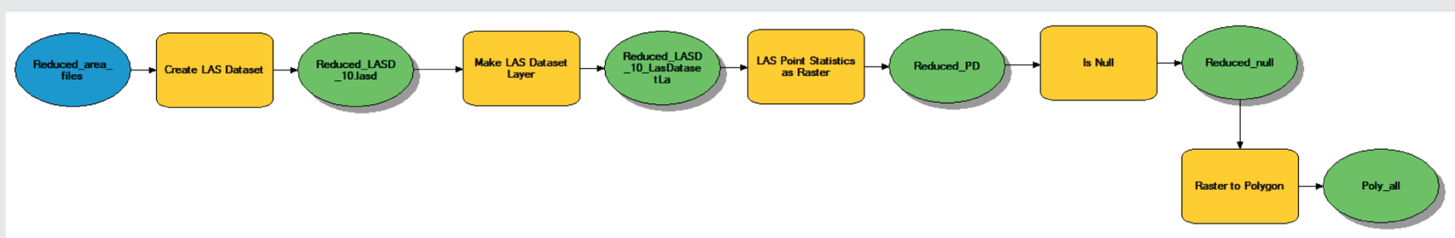


Fig. 3. Workflow model creating the breakline features using the Sawall Solution.

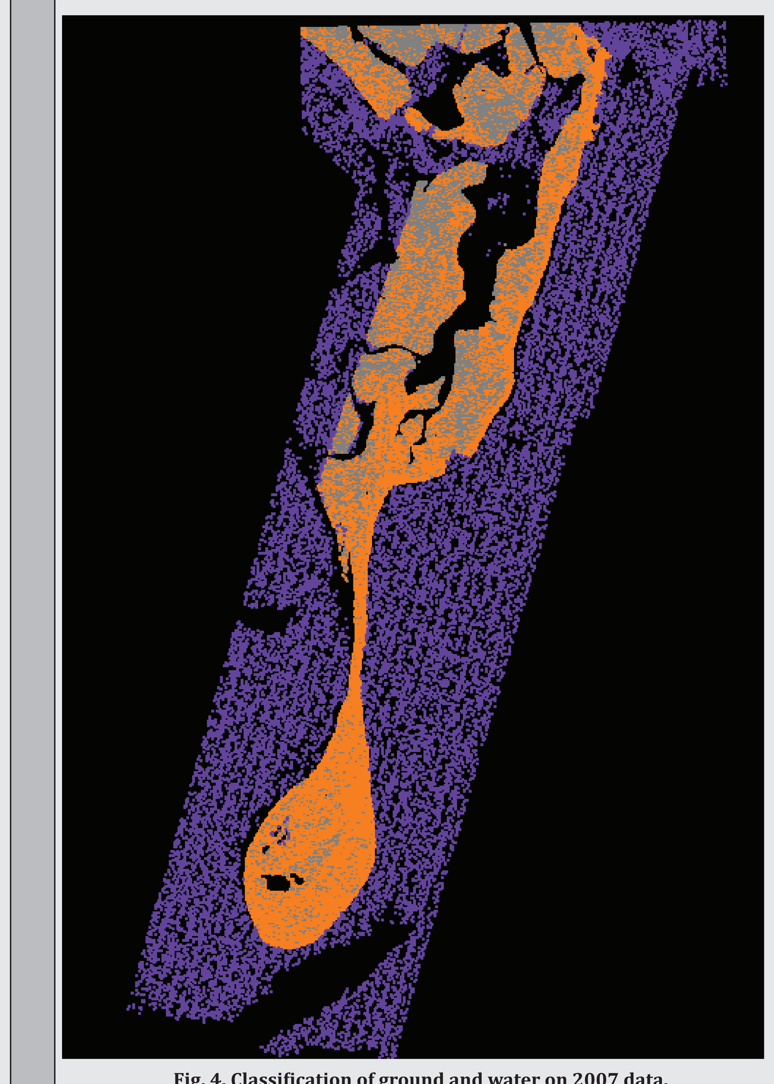


Fig. 4. Classification of ground and water on 2007 data.

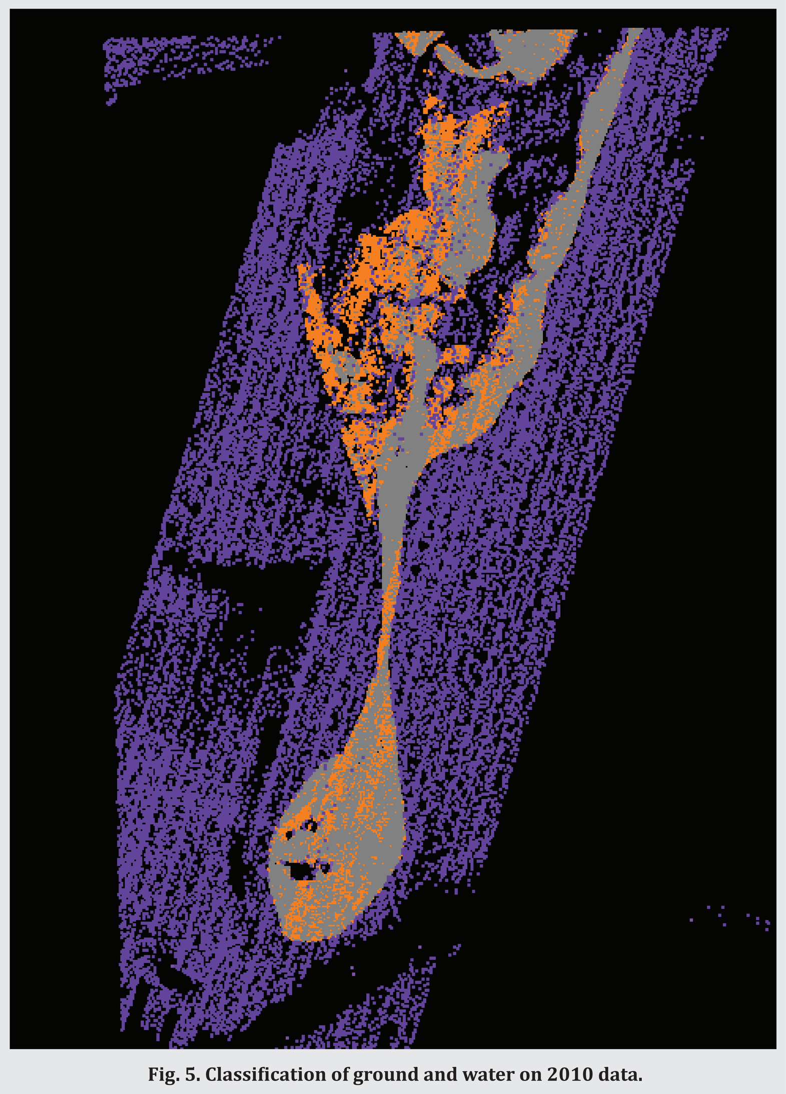


Fig. 5. Classification of ground and water on 2010 data.

Results

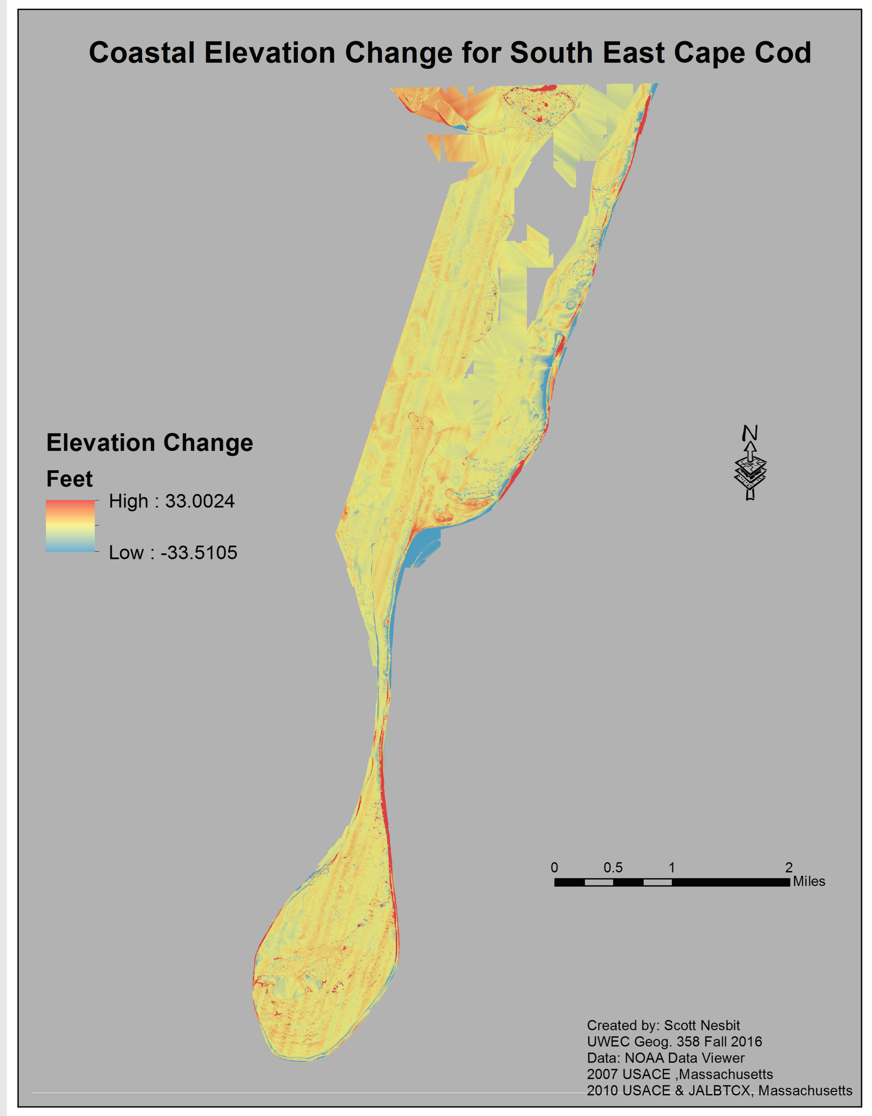


Fig. 6. Results displaying elevation change for the study area.

Examining the data without the water features you can easily decipher where the shoreline lost and gained sediment. In Fig. 6 you can see numerous area which are in deep red color. These areas have gain significant amounts of elevation between the two years. The areas in blue are areas which have lost significant amounts of elevation between the two years. Throughout the majority of the study area you can see a minimal amount of elevation change.

76% of the accretion areas gain 1 foot of elevation. Likewise, 76% of the area which eroded lost 1 foot. The weighted average was -1.63 feet for the areas which lost elevation and 1.60 feet for the areas which gained elevation. When all the values are calculated together the erosion and accretion of 1-foot total 38% of the elevation change respectively. This suggest that approximately 76% of the area only varied 1 foot in either direction. The weighted average for all of the values was -.04026.

Examining the spatial trends or patterns along specific areas of coastlines will be one of many useful derivatives from the research. The results from my analysis accurately demonstrate the elevation change in the study area. There are a few anomalies in the elevation change caused by the absences of ground points, breakline enforcement, and TIN creation in LP360. Additionally, there was an error within a flight line of the 2010 data contained within the water points (Fig. 4). The flight line error caused an erroneous elevation range. I created the DTM without the shoreface/water features for purpose of eliminating the error and displaying a more accurate elevation change range (Fig. 6).

Discussion & Conclusion

The calculations from the raster image show a good balance of loss and gain. Natural longshore drift is the likely cause of these changes. Had I been able to examine the entire coastline I would have been able to better display and analyze if longshore drift was in fact the cause. The weighted average for the entire study area displays a slight loss in elevation on average over the entire study area. Which would make sense as the land feature ends and if the longshore drift is going south, there is no more land to catch traveling sediments. The resulting maps reveal that most of the accretion or erosion happens along the shoreline and not on the inland features which would follow the longshore drift hypothesis (Fig. 6). This research will be able to provide information to the coastal communities to properly prepare and manage their lands for various impacts such as sea-level rise or impending storms and flooding.

The methods employed in the study were successful in determining the morphological change in the study area along the coastline. The inland features leave a lot to be desired as the breakline was not properly enforced. The enforcement issues are very likely tied to a lack of ground points in those areas to properly create an accurate elevation during the conflation. Additionally, in the north most portion of the study area there is vegetation which was not classified but is providing a high elevation change. Further examination of the region and possibly reclassification will be needed to correct the errors.

The classification of the 2007 dataset will need to be further examined for accuracy concerns to utilize the information further. The topography and land cover makes it difficult to differentiate between elevation change and vegetation.

Overall, improvements need to be made in the steps prior to calculating the DTM for a more accurate and acceptable result. Limitations of processing capability and time have limited the precise outcome I was hoping for on this project. Nonetheless, this project was able to show how LiDAR data can be used to estimate elevation loss and gain in coastal areas.

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