ANALYZING THE BEFORE AND AFTER HURRICANE BEACH PROFILES/ELEVATIONS IN SOUTH-EAST FLORIDA USING LIDAR TOPOGRAPHIC MAPS

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ABSTRACT

Coastal regions and coastal environments are one of the most important locations on the planet not just for tourism but recently these environments became home for large populations to live on coasts. Especially, in East Florida, coastal environments also been important for many other living creatures like sea turtles, and other birds. However, the coastal regions are prone to local longshore currents, change in weather, sea level changes and also hurricanes and storms periodically. Hurricanes may not affect throughout the year like longshore currents but the impact is severe at times resulting in large sediment deposition or erosion. Monitoring beaches before and after Hurricane helps to analyze the loss or gain of sediments on the coasts which further helps to provide information on coastal maintenance after the hurricane and coastal management before the hurricane. The study in the project helps to identify the elevation changes using LiDar topo maps from NOAA before (Jan 2017) and after (Oct 2017) hurricane IRMA in Jupiter North (South of the inlet). The study also includes the comparison of elevation analysis from LIDAR images to the traditional RGK beach profiles of the study area.

PROJECT OBJECTIVE:

My research work includes the study of coastal regions and the implications of changes in the beach profiles before after the nourishment as well as before and after the storm events. Further study adding up the effects of these changes on the coastal habitants like sea turtles. The main object of the project is to study and analyze the changes in the Jupiter North beach elevations before and after the hurricane Irma. The Las dataset is used to obtain the raster digital elevation model (DEM) which is used to study the changes. The second objective of the study is to analyze the changes from the obtained raster Dem. The third objective of the study is to compare the changes of the raster DEM's of pre and post Irma beach elevations to the traditional RGK total station profile measurements.

LITERATURE REVIEW

As coastal environments are increasingly threatened by climate change, hurricanes and sea level rise, there is need to efficient monitoring of these environments helps to prevent them with less or no damage. Coastal geomorphology includes beaches, dunes, and the backbarrier. Particularly in Florida, beaches are prone to erosion that can have an immense negative impact on tourism and habitants (Esteves et al. 1998). Particularly in Palm Beach County 50km of 74km are noted as critically eroded beaches (FDEP, 2014).

Beach profiles are important features to be studied as they help to obtain the whether the beaches are strong enough and withhold the erosion during storm events, how much extent that beaches can be used to habitant and recreation (Shalowitz, 1962, Shalowitz, 1964). Beach profiles are effected by many different factors. The profiles are affected by seasonal changes, like wave climatic regimes in summer and winter (Dubois et. al., 1988). The article states that there is a noticeable volume change of sediments in beaches due to seasonal changes. Beach dynamics in also said to be controlled by offshore wind and longshore directed drift (Pain et. al., 2019). The article also states that at the small spatial scale bed rock and the underlying lithology controls the morphology of beach responses to the seasonal wave and climate variations and the longshore drifts. There been considerable storm effects on the beach profile resulting in intense washover of dune and beach sediments causing elevation loss as well (Wang et al., 2006). The impact of continuous storm as storm cluster causes more erosion and change in the beach profile elevations as there is no time for the recovery of the beaches (Karunarathna et. al., 2014). However, the storms induce lot of changes in the beach profile a regular monitoring of beach elevations help to maintain and manage the beach strength. There are many methods to observe the beach profile changes.

One of those traditional method is using RGK uses a calibrated rod with prism where in the instrument notes the elevation along the profile. There are traditional methods like Emery and Stadia surveying. Many journal articles have discussed different measurement modifying the regular methods. Other methods include beach profiles measured by two people with accuracy and limited time which is modified Stadia survey, measurements based on the physical principle of communicating vessels with measurement of elevation on two calibrated rods connected by hose filled with water (Birkemeier et. al., 1981, Andrea, et. al., 2006). Besides these traditional methods there been an emergent research going on profiling and monitoring beach elevations using LIDAR topo maps.

Lidar topographic maps allow to estimate over a hundreds of kilometers along the coast which will help to assess the large scale coastal behaviors. Unlike the traditional method the topo-elevation maps save tons of time and labor work of going to field. One of the studies (Stockdon et. al., 2002) shows the change in shoreline observed in NASA Airborne Topographic Mapper (ATM) and the study compared the data with the ground based GPS measurement which showed that the two methods gave close result with a root mean square difference of 2.9m. The accuracy shows that the measurements obtained from Lidar are ideal for seeing storm scale changes over the spatial scales. One of the other studies show using Lidar data to monitor the beach profiles pre and post the hurricane and see the impacts of it on sea turtle nesting success. The research found that more the alteration in beach profile less the nesting success (Long, et. al., 2011). Another article (Webster, et, al., 2014) shows the study use of high resolution Digital Elevation Model to observe the dune erosion on coastal spit which showed the large vulnerability to storm damage for the habitats on the spit. The Digital Elevation Model (DEM) was used to analyze the morphological changes in North Carolina coasts (White, et al., 2003). The study shows that the DEM data is used to examine the spatial patterns of the beach morphological changes that occurred during 1997 and 2000. Other article reviewed for the project is showing the quantification of beach changes by hurricane Floyd along Florida's Atlantic coast using Airborne Laser Surveys (Zhang. Et. al., 2005). The article shows the study of 40Km beach along the coast before and after hurricane which concluded the erosion and few depositions using the high density high density Lidar data. A study quantified the beach change created by Hurricane Floyd, in Indian River and St. Lucie Counties. The study performs aerial flyovers and obtained topographic data of the shoreline. Data was collected and analyzed to display the change in shoreline and observed the change in distance of the shores in these areas. There are different many articles which have used LIDAR topo maps and have been studying the coastal dynamic changes which shows incredible use of Lidar in coastal morphology.

DATA SOURCES AND METHODS

Study Area

Coastal areas are prone to many climatic changes like sea level rise and global warming globally but regionally many coastal locations are effected by hurricanes and diurnal waves and tides. It is always an important aspect to monitor the changes in beach profiles to see the effect of storm surges and longitudinal waves. The study area chosen for the project is Jupiter North (South of Jupiter inlet) (Figure 1). The location is found to eroded more due to the down side of the inlet which can very clearly seen in the Figure 1. The pre and post effects of Irma in the Jupiter was monitored to observe the changes in the elevation of beach profile by examining the digital elevation models obtained from the Lidar points. Considering the tourism and coastal habitant it is very important to monitor the pre and post hurricane date to implement the mitigation strategies and also to prepare for any upcoming hurricanes in the future.

Storms are considered as a major hazard in coastal regions, which effect the geomorphological changes and also damage the coastal infrastructures and human lives. Understanding coastal responses to storms and subsequent post storm recovery is an urgent issue, especially under the conditions of accelerating sea-level rise and increasing extreme-storm events (Hinkel *et al*., 2013; Ruggiero et al., 2010). Storm-induced beach/dune erosion and post storm recovery have been investigated by numerous studies (*e.g*., Coco *et al*., 2014; Finkl and Pilkey, 1991; Wang *et al.*, 2006; Wehof et al., 2014). The current understanding of coastal responses to storm impacts, however, is still limited due to the lack of quantitative measurements of beach erosion and recovery at a regional scale. Storm-induced coastal geomorphology changes can be quite site specific due to high variability in storm conditions as well as in coastal geomorphology and sedimentology characteristics. The hassle field works can now be replaced with the LIDAR point data available and with the knowledge of GIS.

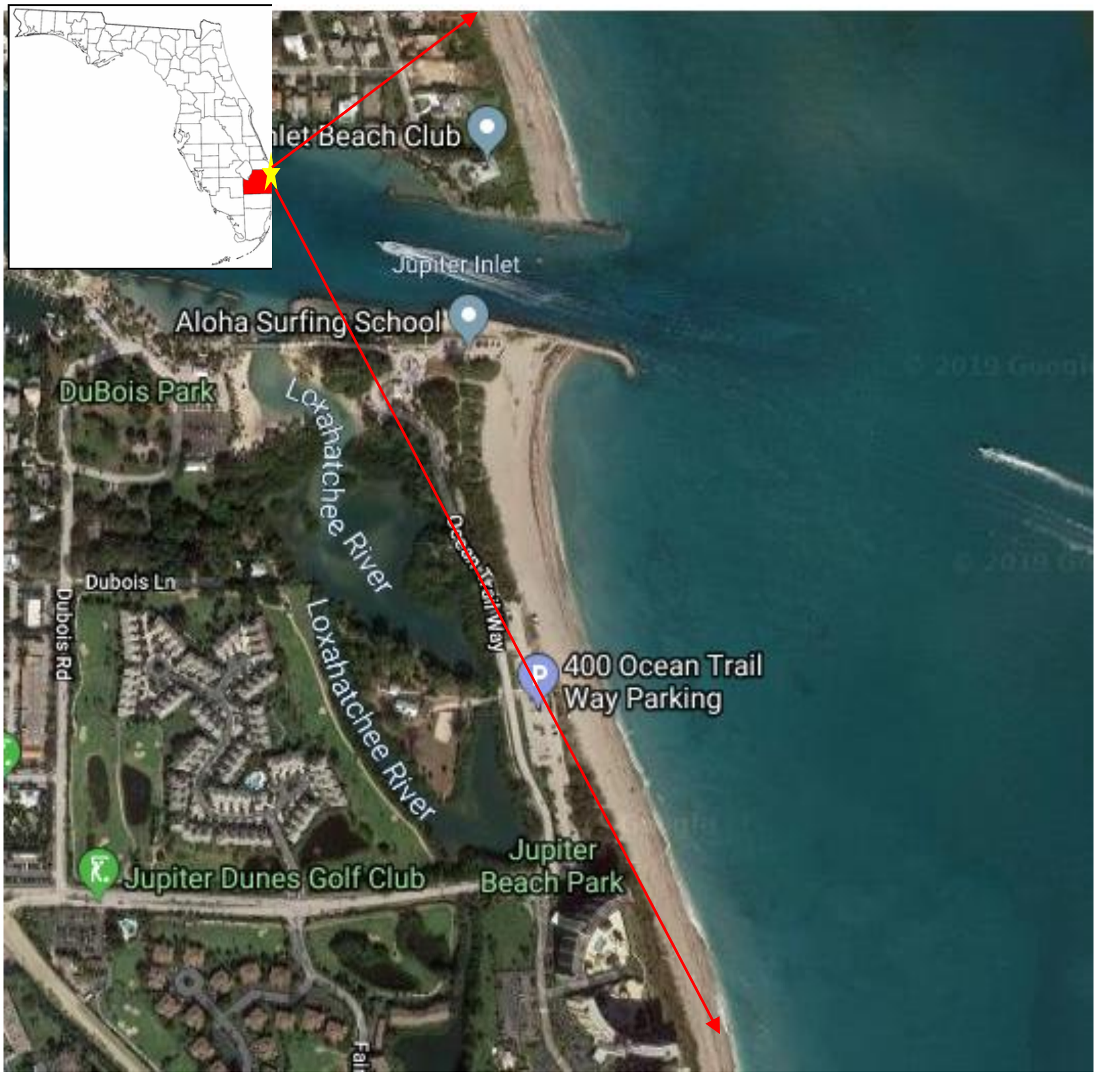

Figure 1: Study Area (Jupiter North (South of Jupiter Inlet)

DATA

The project need topo maps which give the elevation of SE Florida coast to get detailed observation of the change in coasts pre (Jan 2017) and post (Oct 2017) Hurricane Irma. For this study, data sources will be obtained from NOAA digital coast website. The dataset for the pre Irma was collected 2017 January data form the above mentioned website. The dataset is make up from USACE (U.S. Army Corps of Engineers) - FEMA (Federal Emergency Management Agency) of the Florida East coast including Florida Keys and Collier County post Irma. The vertical values in the dataset was converted to orthometric vertical North American Vertical Datum of 1988 (NAVD88) collected using Geoid12B. The data was obtained in LAZ format which was converted to LAS file by using LAS tools. Then the LAS points were converted to raster Digital Elevation Model (DEM) for further analysis.

METHODOLOGY

The method includes monitoring the change in elevations of the beach profile pre (Jan 2017) and post IRMA (Oct 2017) using the Lidar elevation maps obtained from NOAA. The LAS files were added to the Arc GIS 10.6.1 and the Las filter was set to Ground to obtain the bare earth model excluding the buildings and other artificial manmade features. The properties of the las data is set to point limit 5000000 and scale to control full resolution was checked and resolution is set to 5000 to obtain good resolution and also point density sliding bar is moved to fine. From the toolbox the conversion of LAS datasets to Raster was chosen from the conversion tools. The input file used was the las file and the output file was saved to raster format. Other fields were set as follows.

1) Value filed: The value field is the field that generates the raster from Lidar points according the need for the project. As I was looking at the elevation data it was set to elevation.
2) Interpolation type: The interpolation technique helps to determine the cell values of the output.
    a) Binning technique was chosen as the interpolation method over the triangulation method as this approach provides a Cell Assignment Method for determining each output cell using the points that fall within its extent, along with a Void Fill Method to determine the value of cells that do not contain any LAS points.

b) Cell Assignment was set to maximum as it assigns the maximum value found in the points within the cell. Natural neighbor method was used to void fill which uses natural neighbor to interpolate the void cell value.

3) Output data type: The output data raster is set to integer which uses the appropriate integer bit depth. Which will round Z-values to the nearest whole number and write an integer to each raster cell value.

4) Sampling type: The sampling type is set to cell size which defines the cells size of the output raster.

5) Sampling Value: sampling value is set to 6 which specifies the value used in conjunction with the Sampling Type to define the resolution of the output raster. Finally, the Z factor was set to default.

Above parameters were used to convert the las data to raster digital elevation model. Both the datasets were processed with the same parameters as mentioned above to convert the lidar points to raster.

Traditional beach profile measurements

The data of traditional method of beach profiling was obtained from the Dr. Briggs lab data. The dates the data collected were not matching to the Lidar data obtained but the closest dates were picked to the comparison. The tradition field method include the elevation data obtained from the RGK total station which includes the surveying of beach profile as shown in the figure 4.

Figure 2 Beach profile measurements using the RGK total station (traditional method)(Picture captured: during the field survey 2016 June)

This method involves the field survey of beach profile at the monumental locations given by the County. The survey is done by using the Total station and one holding the measuring pole. The elevation is calculated automatically from the back shooting know elevation and obtain the unknown elevation. The laser light shoots the prism on top of the pole and directly records the elevation measurement. The data from the total station is extracted once we are back from the field and used for the further analysis. The data used for the comparison include 4th May 2017 for the pre Irma and 28th November 2017 for the post Irma.

RESULTS

The study conducted provides the elevation changes before and after the hurricane IRMA in Jupiter beach. The color topo maps showing digital elevation model obtained from the raster is used to compare the beach profile change pre post the hurricane, the results are expected to have lower elevations in beach profile post the hurricane in Oct 2017 compared the pre Irma which is in Jan 2017.

The conversion of las data to raster DEM shown in the Figure 2 for the pre Irma data. The top image in Figure 2 shows the las dataset obtained from the NOAA digital coast as a laz file and later converted to LAS file. The top image shows the ground filtered las data set showing the bare earth elevations. The highest elevation shown in the red color in the image which is the property on the beach. The yellow color on the beach area indicates the dune high on the beach. The image below in the figure 2 indicates the raster image of all the ground points excluding the artificial and manmade constructions. The coastal waters shown as the lowest elevation and the beach is shown the elevation ranging from 3ft (light yellow to 4ft (orange) to 2 ft (pale green) and negatives in the waters as moved from the dune high to the shoreline.

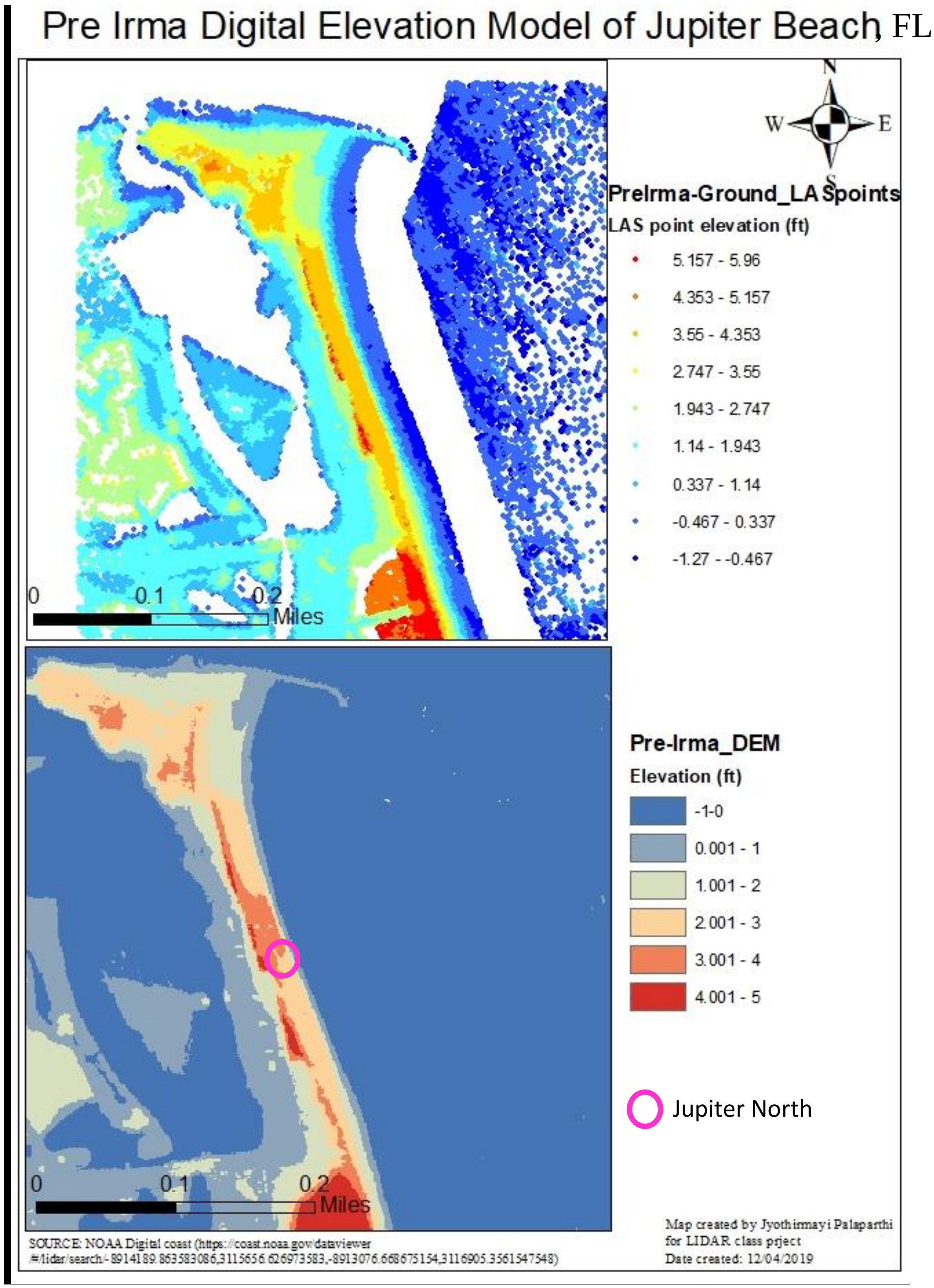

Figure 3: Pre Irma Jupiter beach DEM (Top figure shows the Las file/point data of the Jupiter beach obtained from the NOAA Digital coast, bottom image shows the Raster DEM.)

The conversion of las data to raster DEM shown in the Figure 3 for the post Irma data. The image on the left of figure 3 shows the las data obtained from the NOAA digital coast website showing ground points on the beach and adjacent locations. Post Irma las points show the increase in elevation. The image on the right of the figure 3 shows the raster image converted from the las points as mentioned in the methods section. The image shows the decrease in the elevation of beach profile compared to the pre Irma beach profile. The elevation data shows in the image indicates the range of 3ft to 4ft.

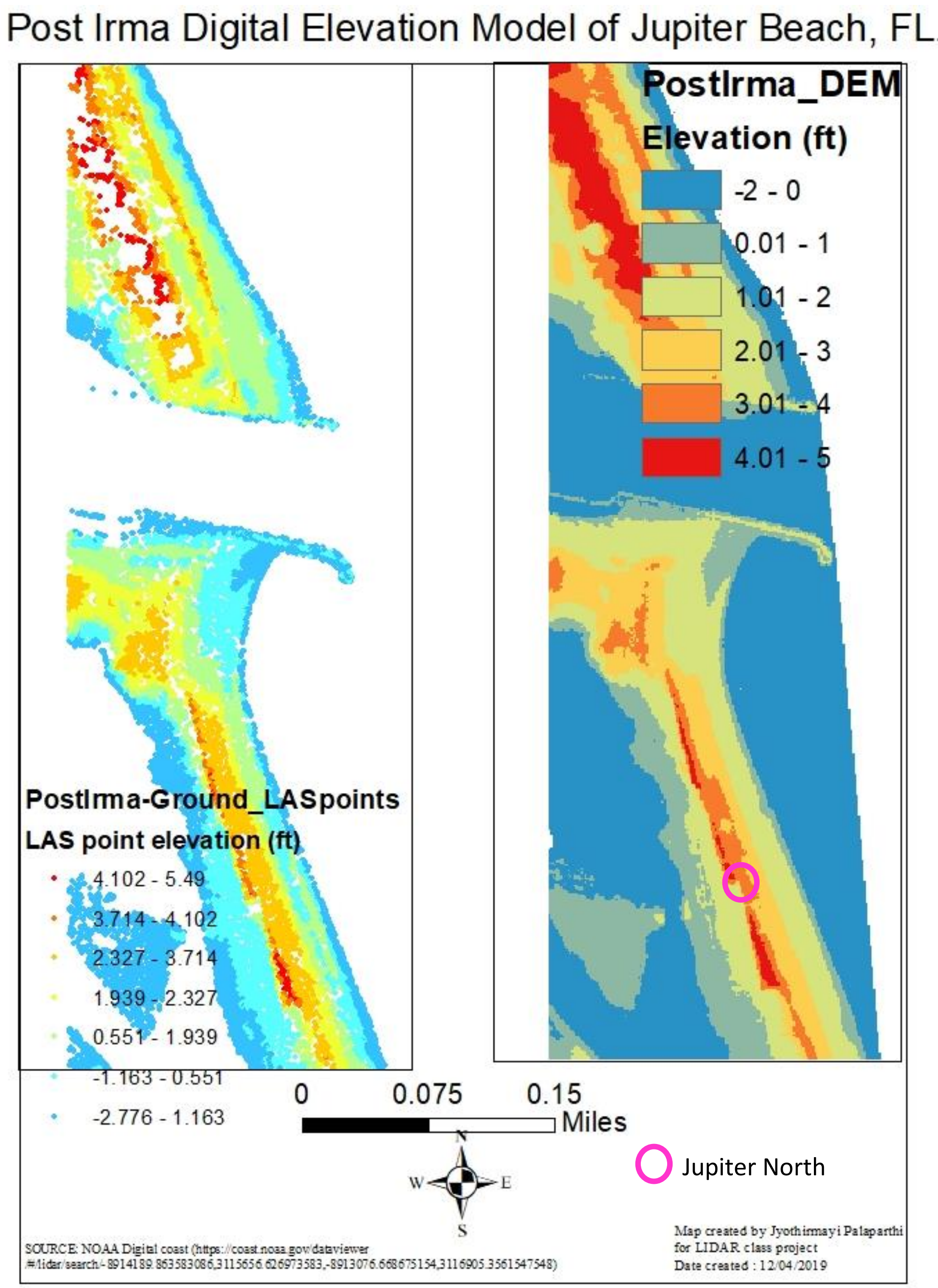

Figure 4: Post Irma Jupiter beach DEM (Left figure shows the Las file/point data of the Jupiter beach obtained from the NOAA Digital coast, right image shows the Raster DEM)

Traditional beach profile results

The beach profile data obtained from the traditional RGK measurements are shown in Table 1 for the Jupiter North location.

Table 1: Beach elevation data measured using RGK total station.

Name	Easting	Northing	Elevation (ft) (Post Irma)	Elevation (ft) (Pre Irma)
1	292183.9	289228.5	4.261	4.261
2	292180.1	289227.6	4.649	4.773
3	292190.4	289230	4.418	4.601
4	292199.3	289232.1	4.098	4.331
5	292205.2	289233.7	3.509	3.016
6	292211.3	289235.4	2.82	1.558
7	292218.5	289237	2.537	1.943
8	292219.7	289237.5	2.225	1.162
9	292220.8	289237.8	1.725	0.051
10	292222.4	289238.1	1.476	-0.525
11	292224.6	289238.7	0.992	-0.835
12	292227.9	289239.5	0.422	-1.175
13	292233.6	289241	-0.112	-1.329
14	292238.6	289242.2	-0.579	-0.984
15	292242.9	289243.2	-0.393	-0.794
16	292303.2	289242.9		-0.962
17	292314.7	289244.5		-1.472
18	292320.5	289245.3		-1.996

The data from the above table was used to obtain the beach profiles. The graph in the Figure 5 shows the elevation changes obtained before and after hurricane Irma. The profiles show that there been the volume difference indication the increase in sand volume at mid beach after the hurricane.

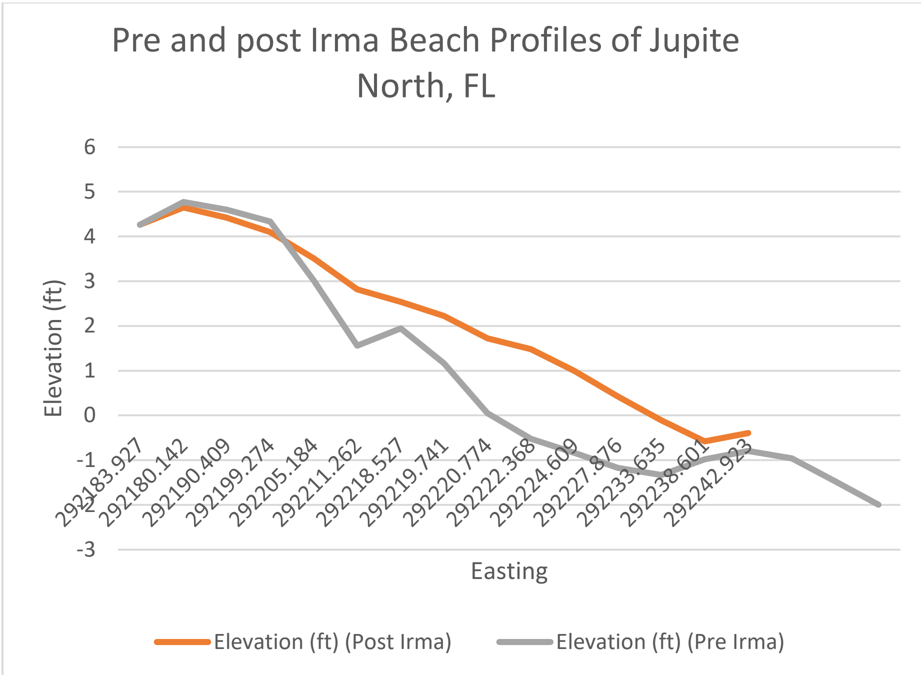

Figure 5 Beach profile comparison of pre and post Irma at Jupiter Beach, FL

DISCUSSION

The raster Digital Elevation Model (DEM)/ bare earth model shows that the change of elevation pre and post the Irma. The images in Figure 3 and 4 show the changes in the beach elevation indicating slight increase in the elevation at Jupiter North as it can clearly see more orange red area indicates high elevation at the mid beach in the post Irma raster DEM (Figure 4). Also when compared with the traditional RGK the results shown in Figure 5 indicated the increase in the volume of the sediment after the hurricane showing up to an increase form 2 ft to 3 ft. The data obtained for the Lidar points show that the increase in elevation ranging from 2 to 3 ft in pre Irma DEM to 3 to 4 ft in the post Irma DEM. The little difference in the elevation change for the traditional method and the remote sensing data may be due to the difference in the data collected date. The post hurricane DEM was collected close after the hurricane Irma (October 2017) whereas the RGK measurements were collected in September 2017. The sediments might be getting back to state how it was before the hurricane. Moth the methods show a good correlation and help to study the beach changes before and after the hurricane.

CONCLUSION

The study obtains the raster Digital Elevation Model images form the las point data using the raster conversion tool. The images obtained were analyzed to see the changes in the beach elevation before and after the hurricane Irma. The resulting DEM how that there is change in the beach profile elevation indicating the increase in the elevation post the hurricane Irma. The study also compared the raster DEM to the traditional beach profile data obtained from the total station. Result from both the methods show that increase in the elevation of beach profile post the hurricane. The reason for the increase may be because of the storm drawn sediments to the coast after the hurricane. The beach profile after three months of the post hurricane from the traditional method shows that the beach is regaining back to the native state as it was before the hurricane by the waves. The data difference would be minimal or zero if it is compared to the data collected on the same day for both the methods. LiDAR data is easy and more robust way collecting the data not just for the single region as show in the study but can obtain large area datasets in limited a time. Processing the data gives great understanding of the different aspects based on the requirements of the study. Whereas, the traditional RGK total station surveying includes the labor and takes too much time to collect the data and can only obtain the limited data (like one survey line but not the entire stretch of the beach). However, the Lidar dataset need at least one survey line measurement for each location to compare with, to gain more robust analysis. Definitely the Lidar dataset is already in boom for many analyses like tree height canopy, vegetation maps, Digital Elevation Models (ground points/bare earth without the artificial and manmade structures), Digital Surface Models (non-ground points/buildings, trees and other structures) and Digital Terrain Models and many other uses. As a coastal geologist the study of the large coasts with the available LIDAR data is very helpful and definitely make easier in gathering of the data.

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