Identifying Overwash Layers in Marsh Sediment

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Introduction

Hurricanes have become a point of interest for research over the years due to the economic costs of their damage and their correlation with climate change. To find new methods of hurricane mitigation and prediction, a record of storms must be created. Most written records are incomplete or inaccurate due to the temporal resolution of the record or the limitations of technology at the time. These records also do not have enough information to confirm or deny current theories on hurricanes and climate change. However, there is a record of past hurricanes that can be on the geologic timescale within the sediments themselves. Through extracting and examining these sediments, known as grain size analysis, this record can be created and give a further understanding of both the history and the future of hurricanes.

Paleotempestology, the study of historic storms, has varying methods of study across literature. All reviewed literature that collected field data used some method of radiometric dating to develop a chronology of events, usually using radiocarbon dating, however methods of 210Pb dating can be used for shallower layers of sediment (Wallace et al, 2021). Grain size analysis was the most popular method for directly determining storm layers, however multiple different systems were used to gather the grain size data. The Loss-on-Ignition method, where subsections of the cores were dried and then burned, and then put through a 63 µm to determine the percentage of organics and sand within the layer, was used in multiple sources to determine the grain size. Lane et al. used ground penetrating sonar and then correlated the reflection of the sediment layers at each depth as a less invasive method of grain size analysis. Denommee et al used a method of counting varves, an alternating set of silt and sand layers, to correlate a near-annual record of events (2014). Although regionally different, the results of each location are consistent with each other. Denommee et al (2014), Ercolani et al (2015), Lane et al (2011), and Rodysill et al (2020) show that there was an increase in significant tropical storm landfalls in the Caribbean and the Gulf of Mexico between the years of ~600 CE and ~1200 CE. However even though this establishes a historical record, this does not address either an increase in rate of hurricane landfalls over this timeframe. To remedy this, statistical analyses have been done on these records to determine an increase in rate or frequency. Emanuel and Vecchi et al took this data using landfall data from NOAA and CERA databases by downscaling and reanalyzing the frequency of these landfalls. Both these analyses show that even with possible increase in frequency of hurricane landfalls, attributing them completely to anthropogenic climate change is not a valid explanation (2021). Most show that climate variability, specifically regional climate variability, is the main culprit for these increases in landfalls. The intensity of the landfalls however, are the most likely factor effected by anthropogenic climate change.

This study aims to add to that record of hurricanes in the Gulf of Mexico using the methods of grain size analysis, loss on ignition, and radiocarbon dating to create a geological profile. Adding to this geological record of hurricanes also gives further insight into the future of hurricane intensity and frequency within this region.

Objectives

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Methods

Field Methods

Upon arrival at St. Vincent Island, FL, a location to take a piston core of the sediment was scouted using a hand auger and was chosen based on the depth and makeup of the sediment for radiocarbon dating. A piston core was taken. The elevation of the core was also taken using an optical leveling technique.

Lab Methods

Once the core was transported to the laboratory, the core was split into a working core and an archive core. The working core was then sub-sectioned into equal 0.5 cm sections up until the barrier sand boundary located at the 110 cm mark. A sample from each subsection was taken for grain size analysis. The samples were placed into beakers and then had 3 ml of 30% hydrogen peroxide solution added to eradicate organics in the sediment and left to rest overnight. The next day, samples were boiled to kill of any other organics and had Calgon, a suspension agent, added. Once fully prepped, each sample was put through the Cilas 1180 Laser Particle Analyzer, which gave both direct and histogram data for each sample. For Loss on ignition data, samples were taken at every centimeter. these samples would go into crucibles and then be weighed for initial wet weight. After the sample would be put in a drying kiln set at 100°C overnight, to be weighed for their dry weight the next day. These dry samples were then put into a furnace for 4 hours at 450°C, and the ashes were then weighed.

Data Analysis

Data analysis for this was done in MATLAB r2022a. To remove the trend from the laser particle analysis data, a linear regression was done on each section of the data, separating the data at the transition boundaries. Once this was done the residuals were added to the grain size to adjust for trends such as sea level rise.

Results

The results of the grains size analysis through a laser particle analyzer show consistent data between each other. The percent sand data, laser particle size data, and trend-removed laser particle size data show about 3 major peaks of grain size and 2 minor peaks with a large grouping of high grain size below 84.5 cm (Figures 2,3, & 4). The major peaks of this data are at 0-5 cm,46-51cm,and 70-76 cm depths. The minor peaks of the data are at 13-14cm and 30cm depths. The percent organics data shows an almost inverse effect where at points of peaks in the grain size data, the organics show a drop relative to the area around it (Figure 1). The 14C age in years was 2242 at 92 cm depth, and ages of each subsection were assigned ages based on a linear model of the age.

Figures

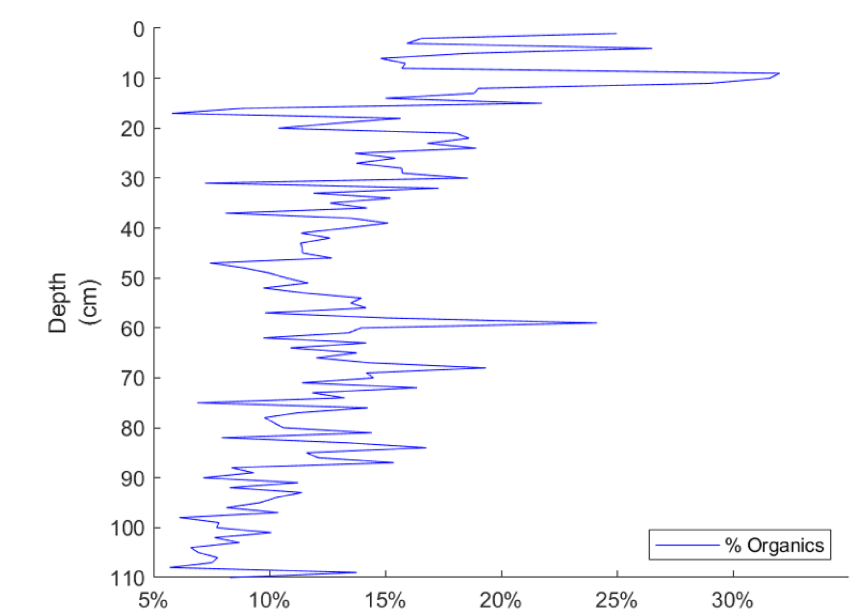

Figure 1: Percent organics data from loss-on-ignition data from St. Vincent Island, FL on March 11th, 2022.

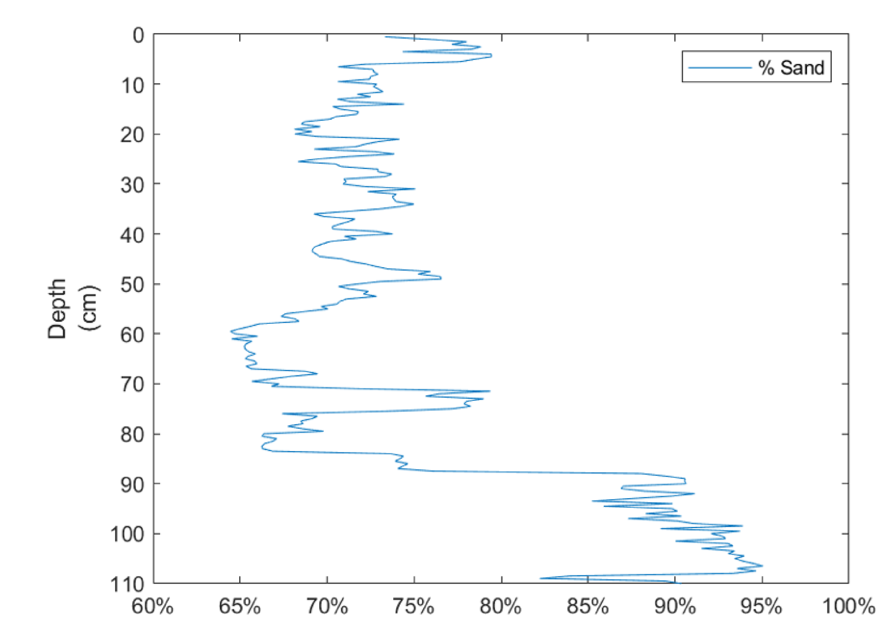

Figure 2: Percent sand data from a CILAS laser particle analyzer at St. Vincent Island, FL on March 11th, 2022.

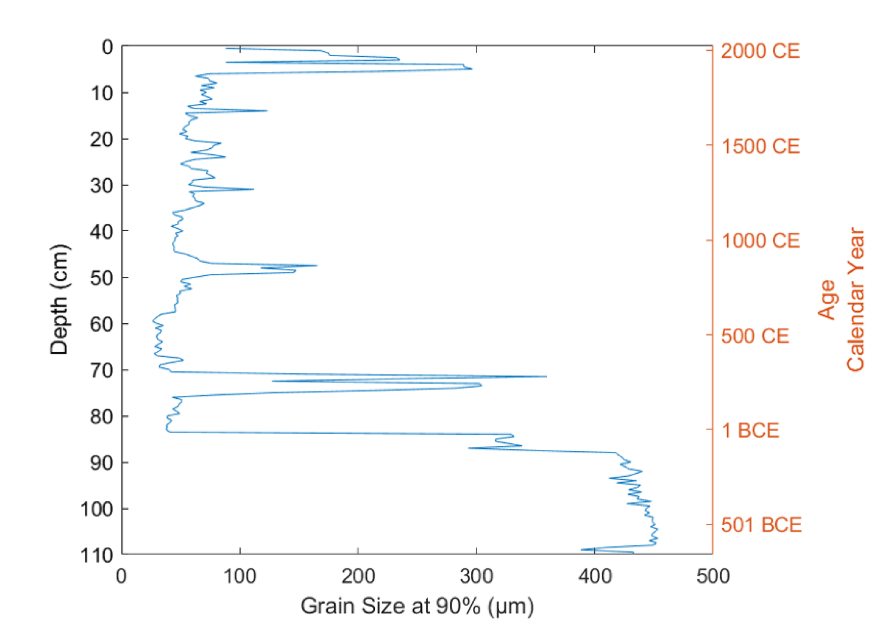

Figure 3: Grain size at 90% from a CILAS laser particle analyzer in microns with calendar year age from St. Vincent Island, FL on March 11th, 2022.

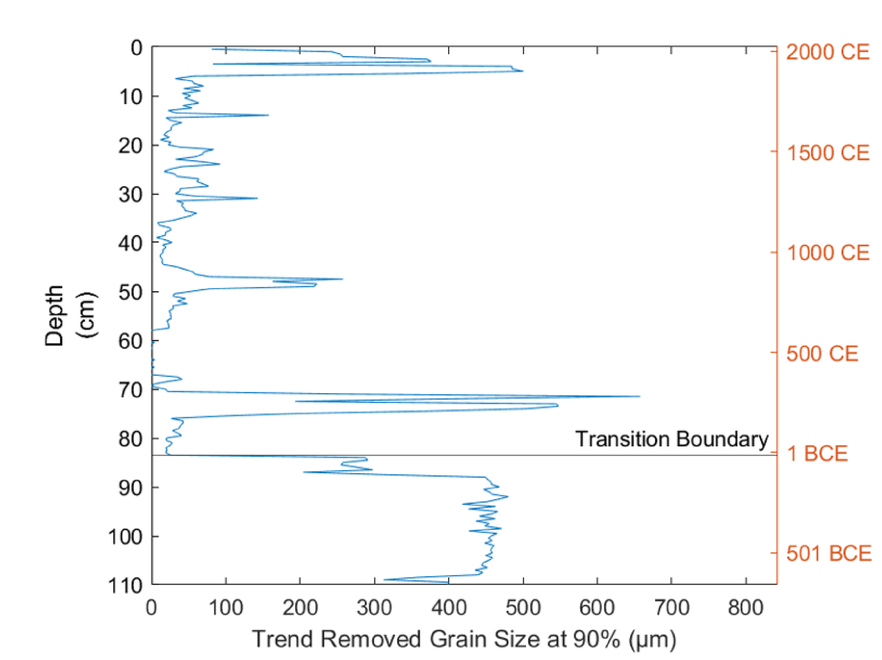

Figure 4: Trend-Removed Grain Size at 90% from a CILAS laser particle analyzer with calendar year age from St. Vincent Island, FL on March 11th, 2022.

Discussion

The grain size and sand percentage data peaks correlate with increased energy of the environment, this however cannot determine an overwash layer by itself as transitioning from a beach environment to a marsh environment can also influence the grain size. This transition can be shown at the area below 84.5 cm, where the grain size jumps from under 50 µm to over 200 µm. this is the point of transition from a marsh to beach environment (Figure 3 & 4).

The grain size peaks after the transition boundary at approximately 5 BCE represent overwash events, the largest of which occurs at 70-76 cm or approximately 300 CE. These events cannot be linked directly to specific events such as hurricanes, as the resolution of the core is too large to evaluate these events. However, these can show trends of the area where over decades of time when large amounts of storm events have occurred. This shows that between 650 CE and about 1400 CE there was an increase in storms, shown by having 3 out of the 5 grain size peaks. Rodysill et al concludes however, that the period of increased storm landfalls is between 650 CE and 1250 CE (2020). This leaves a discrepancy between the upper limit of about 150 years. This however is accounted for, as the margin of error for the radiocarbon dating is about 100 years, and the other 50 years can be a product of compaction of the core (Figure 4).

There is a period between 50 cm and 70 cm where there seems to be a very small grain size compared to the rest of the core. This indicates a lower energy environment. this low energy environment could be a drowned marsh area, which is indicated by the percent organics data. At moments of low energy environments in the grain size, the organics show an increase in percentage of weight, showing that these sections are located in a drowned marsh environment (Figure 1).

Even with this defined chronology of events in the region, this still does not further an understanding of the future of hurricane landfalls in this region. Based on this historical record, modern intensity of hurricane landfalls is not unprecedented, at 350 CE there is about the same size peak in grain size as around the year 1900 CE till present day. However, this is concerning as hurricane intensity is only set to increase with climate change, as the threshold for hurricane cyclogenesis increases. This could mean that the next set of hurricane intensity could become unprecedented in this location, but further research into that would be necessary to conclude this for certain.

References

Denommee, K. C., Bentley, S. J., & Droxler, A. W. (2014). Climatic controls on hurricane patterns: a 1200-y near-annual record from Lighthouse Reef, Belize. Scientific Reports, 4(1). doi:10.1038/srep03876

Emanuel, K. (2021). Atlantic tropical cyclones downscaled from climate reanalyses show increasing activity over past 150 years. Nature Communications, 12(1). doi:10.1038/s41467-021-27364-8

Ercolani, C., Muller, J., Collins, J., Savarese, M., & Squiccimara, L. (2015). Intense Southwest Florida hurricane landfalls over the past 1000 years. Quaternary Science Reviews, 126, 17–25. doi:10.1016/j.quascirev.2015.08.008

Lane, P., Donnelly, J. P., Woodruff, J. D., & Hawkes, A. D. (2011). A decadally-resolved paleohurricane record archived in the late Holocene sediments of a Florida sinkhole. Marine Geology, 287(1–4), 14–30. doi:10.1016/j.margeo.2011.07.001

Rodysill, J. R., Donnelly, J. P., Sullivan, R., Lane, P. D., Toomey, M., Woodruff, J. D., … van Hengstum, P. J. (2020). Historically unprecedented Northern Gulf of Mexico hurricane activity from 650 to 1250 CE. Scientific Reports, 10(1). doi:10.1038/s41598-020-75874-0

Vecchi, G., Landsea, C., Zhang, W., Villarini, G., & Knutson, T. (2021). Changes in Atlantic major hurricane frequency since the late-19th century. doi:10.21203/rs.3.rs-153527/v1

Wallace, E., Donnelly, J., van Hengstum, P., Winkler, T., Dizon, C., LaBella, A., … Maio, C. (2021). Regional shifts in paleohurricane activity over the last 1500 years derived from blue hole sediments offshore of Middle Caicos Island. Quaternary Science Reviews, 268(107126), 107126. doi:10.1016/j.quascirev.2021.107126