An investigation of event driven sedimentation along the southwest shore of Lake Pontchartrain, Frenier, Louisiana

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Abstact:

Hurricanes have a great impact on the residents of south Louisiana. Each storm brings a unique combination of storm surge, fresh-water flooding, and wind damage. On August 28th, 2012, persistent east winds from Hurricane Isaac caused an unexpected amount of storm surge in and around LaPlace Louisiana. The resulting flood deposited sediment from Lake Pontchartrain in the adjacent wetland. Analysis of this storm event layer via loss-on-ignition, grain-size calculation, and radiochemical analysis has provided a lens through which to view the history of sedimentation in the wetlands around Frenier, Louisiana. Two additional layers with similar sedimentary characteristics are strong evidence for the prominence of event driven sedimentation. Radiochemistry helps to constrain the timing of these events to the last 60 years. The coincidence of larger than normal grained sediment (very fine sand) with equal levels of radioactive decay of ^{210}Pb support the idea of rapid sediment deposition during intense flooding, such as during Hurricane Isaac.

Introduction

Hurricane Isaac was a less intense storm and caused less economic damage than Hurricane Katrina, but Isaac resulted in major impacts to several coastal communities. Hurricane Isaac struck south Louisiana between the evening of August 28th 2012 and the morning of the 29th, 7 years after the Gulf Coast was devastated by Hurricane Katrina. Katrina was the costliest storm in United States history, causing an estimated 81 billion dollars worth of damage, most of which occurred in New Orleans. New Orleans was spared the same destruction by category 1 Isaac; however, the surrounding communities of LaPlace and Plaquemines Parish received over three meters of storm surge that temporarily displaced over 65,000 residents.

Storm surge inundation and associated sedimentation is an important control on coastal geomorphology, and provides markers in sediment cores for the study of the historical occurrences of hurricanes. A storm layer from Hurricane Rita has been documented on the Chenier Plains of southwest Louisiana (Williams, 2009). The storm deposit left by Hurricane Katrina has been identified in 17 cores from the Pearl River Marsh (Reese et al, 2008). Studying sediment overwash layers deposited by modern hurricanes in coastal lakes, marshes, and lagoons has proven to be an accurate analog for investigating the impact of paleo-hurricanes (Liu, 2004).

Paleotempestology is a recent field that uses a variety of historic and geologic proxies to provide a more complete picture of hurricane impacts than is available in modern government records. Use of the modern analog has provided a 7,000-year hurricane activity record from Belize, and 5,000 year record from Puerto Rico

(McCloskey, 2013; Donnelly, 2007). To date, no paleotempestology findings about the Lake Pontchartrain basin have been published.

Hurricane Isaac had a definite impact in the coastal marshes, swamps, and communities surrounding Lake Pontchartrain in 2012. Many of the communities in and around LaPlace Louisiana had never previously been submerged by storm surge. In order to understand the complete record of sedimentary markers in the local record, the differences between paleo-hurricanes and other event layers such as crevasse-splay deposits must be understood. Determining a return period for flooding caused by hurricanes depends on an accurate study of the marker bed deposited by Hurricane Isaac.

Methods

Sediments were collected on the west shores of Lake Pontchartrain near Frenier, Louisiana, which is located just north of LaPlace (Figure 1). Coring took place within one kilometer of the lakeshore. All cores were collected in aluminum irrigation tubing, some driven and retrieved by hand, while two cores were drive with a vibracore rig. The vibracores were driven into the sediments using a motorized vibrator, and extracted using a ten-foot tripod and wenches.

Loss-on-ignition (LOI) was performed on all cores collected to determine water content and organic matter content in the cores. Cores that displayed clear trends were selected for grain size analysis. Samples selected for grain size analysis were passed through a 250 micron wet sieve to remove large organic material. Two cores from different locations were prepared for ^{210}PB and ^{137}Cs analysis by dividing cores into 2 cm intervals, dehydrating then powdering the sediment, then sealing the powder inside 1.5 inch petri dishes.

Results

Loss on ignition (LOI) results showed trends in organic matter content across all cores analyzed. At least three layers of relative depletion in organic content were found in all cores used in this study (FRE-4, FRE-5, LAP-Film-3, and LAP-Film-5)(Figure 2). The depleted layers differ from core to core with respect to depth of occurrence and thickness of the layers.

The first depleted layer occurs at depths 0-3 cm, and is 2-3 cm thick. In cores FRE-4 and FRE-5 (collected February 2013) the first layer begins at the surface. In cores LAP-Film 3 and LAP-Film 5 (collected July 2013), the first layer is found beneath 3 cm of sediment average organic content. It is likely that this layer is the deposit of hurricane Isaac. One explanation of the average organic content at the top of the LAP cores is that their later collected date means that they are also recording the colonization of the area by post-disturbance flora. Large amounts of ragweed were noted on the July trip that was not present in February.

The second and third layers with depleted organic content vary in thickness and depth more than the uppermost layer. The second layer is 4 cm think in cores FRE-4 and FRE-5, 3 cm thick in LAP-Film 3, and 2 cm thick in LAP-Film 5. In FRE-4, the second layer begins at 12 cm, while it begins at 7 cm in FRE-4. The difference in depth is less pronounced in the two LAP-Film cores, occurring at 10 cm in core 3 and 9 cm in core 5. The third depleted layer is 3 cm thick in FRE-4, FRE-5, and LAP-Film 3, while it is 4 cm thick in LAP-Film 5. As with the second layer, the difference in depth of the third layer is more pronounced in the FRE series than the LAP-Film series. The third layer begins at 21 cm in FRE-4, while it occurs at 17 cm in FRE-5, 15 cm in LAP-Film 3, and 17 cm in LAP-Film 5.

Grain size analysis of FRE-4 also shows multiple anomalous layers. FRE-4 contains three layers where the mean grain size is considerably larger than the surrounding sediment. Mean sizes associated with each sample are presented in table 1. The first layer with large grain size coincides with the first layer of depleted organic material (0-3cm). The first three samples (at half centimeter resolution) have mean grain sizes in the very fine sand range (84.7, 106.7, 77.8 microns). The next three samples from depths 1.5-3 cm have smaller mean grain sizes in the coarse silt range (55.8, 47.8, 52.8 microns), however they are larger than much of the underlying sediment. Samples 8-9cm and 10-11cm have mean grain sizes in the very fine sand range (77.6 and 74.6 microns), while sample 9-10cm falls in the coarse silt range (46.06 microns). The third zone of elevated grain size in FRE-4 is from 16-26cm. Of the 11 samples in this range, 8 have mean grain sizes in the very fine sand range. The largest mean size in this zone is 94.6 microns (23-24cm).

Radiochemistry analysis of FRE-4 shows five distinct units in the core (Figure 3). The first unit is from 0-4cm, where ^{210}Pb values are similar. The second unit, also displaying similar ^{210}Pb activity, is from 4-10 cm. The third unit (10-16 cm) shows a trend of increasing ^{210}Pb activity up the core. The fourth unit is another zone of equal activity from 16-26 cm. The final unit is another sequence of increasing ^{210}Pb activity up the core. The first ^{137}Cs is detected in the 30-32 cm sample. ^{137}Cs levels peak at 26-28 cm, and decrease up through 4-6 cm, before becoming undetectable in the top 4 cm of the core.

Discussion

The compilation of LOI, grain size, and radiochemistry datasets suggests that three event layers are present in FRE-4. The presence of physically stratified sediment between 0-3cm is suggested to be the deposit of Hurricane Isaac. The larger sediment size and lower organic content than surrounding sediment indicate a period of rapid sediment deposition, consistent with bedload transport of Lake Pontchartrain sediment by Hurricane Isaac's storm surge. The second proposed event layer is 4-11 cm. The radiochemistry dataset reveals similar ^{210}Pb activity between 4-12 cm. When sediment is deposited the source of ^{210}Pb is removed and it begins to decay to the stable ^{206}Pb configuration. Similar activity levels suggest that the source of ^{210}Pb for the sediment deposited between 4 and 12 cm was deposited around the same time. The presence of very fine sand at the base of this unit (8-9 and 10-11 cm) suggests faster fluid movement was required to transport this sediment. Finer grain sizes at the top of this unit may correspond to deposition during the waning stages of the flood event, or the settling of suspended load from standing water. The third proposed event layer is 16-27 cm. This is another zone with similar ^{210}Pb decay rates. Of the 11 grain size samples in this section of the core, 8 have a mean grain size of very fine sand. The coincidence of elevated grain size with similar levels of ^{210}Pb decay point toward rapid, event driven sedimentation.

Cesium and Lead activity measured in FRE-4 gives valuable information on sedimentation rates and the timing of the events. ^{137}Cs is a by-product of atmospheric testing of hydrogen bombs. The lowermost sample (32-35 cm) of FRE-4 contains no ^{137}Cs, indicating that it was deposited before the first hydrogen bomb test in 1953. Peak ^{137}Cs activity occurs in the 26-28 cm sample which is taken to coincide with the ban of open air testing of hydrogen bombs in 1963. The long-term sedimentation rate using the first occurrence of ^{137}Cs at 31 ± 1 cm as 1953 is 0.517 ± 0.017cm. Sedimentation rates corresponding to the non-event layers were calculated from the changes in ^{210}Pb activity. The sediment accumulation rate between 26-35 cm is 0.1 cm/y, and the rate between 10-16 cm is 0.2 cm/y. Radiochemisty profiles cannot be used to pinpoint events to precise years; however the technique does show the presence of three rapid sedimentation events in the last 60 years.

Loss on ignition data must be interpreted with caution for these cores. The Hurricane Isaac storm layer in FRE-4 and FRE-5 is characterized by less organic material than underlying sediment, as a result of rapid deposition preventing the incorporation of organic debris. The storm layer associated with Hurricane Isaac from LAP-Film 3 and 5 is characterized by above average organic content. The FRE core series was collected in February 2013, before warmer spring temperatures led to a post-disturbance vegetation bloom. The LAP-Film core series was collected in July 2013. There was extensive ground coverage of ragweed during this trip, which commonly thrives in the aftermath of disturbances to tree canopies. The shallow roots and litter generated by ragweed may have led to elevated organic content in the Isaac layer in the cores collected longer after the storm passed. This phenomenon may also explain the increased organic content at the base of the proposed event layers in FRE-4.

Changes to the shoreline of Lake Pontchartrain affect the recording sensitivity of inland sites. Local landowners in Frenier were allowed to extend their lakefront property to the location of the shoreline in a 1927 survey. Analysis of aerial photography show that in some places the shoreline had receded up to 100 meters between 1927 and 1998 (1927 shoreline inferred from 2013 imagery, after landfilling reached the 1927 survey line). The shoreline transgressed an average of 1.41 meters/year over that time. A shoreline shift of 100 meters would mean that the location of the cores collected may have been too far inland to record the signatures of tropical cyclones of moderate/low intensity during the past. In addition to affecting the sensitivity of inland sites, sites able to record events of greater age have been eroded.

Conclusion

A multi-proxy approach is required to interpret the depositional history along Lake Pontchartrain's southwest shoreline. The combination of grain-size analysis and radiochemistry provide the strongest arguments for periodic, event-driven, rapid sedimentation, followed by periods of slow accumulation. The eroding shorelines of Lake Pontchartrain make it difficult to detect events before the 1950's. The sedimentation events are shown to occur on average every 20 years since 1953.

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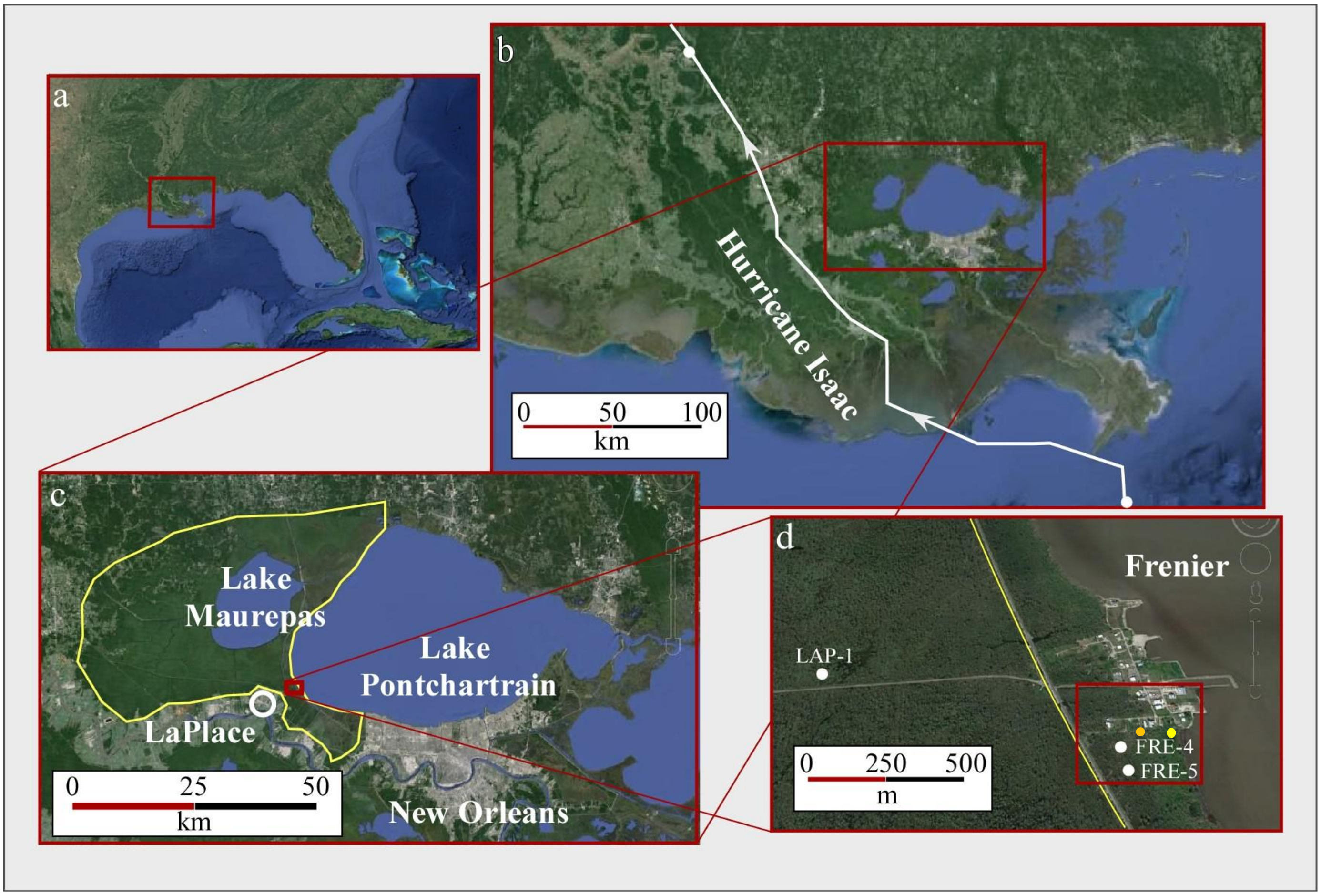


Figure 1: Location of study area. The orange dot corresponds to LAP-Film 3, the yellow dot corresponds to LAP-Film 5. (After Liu et al, 2014)

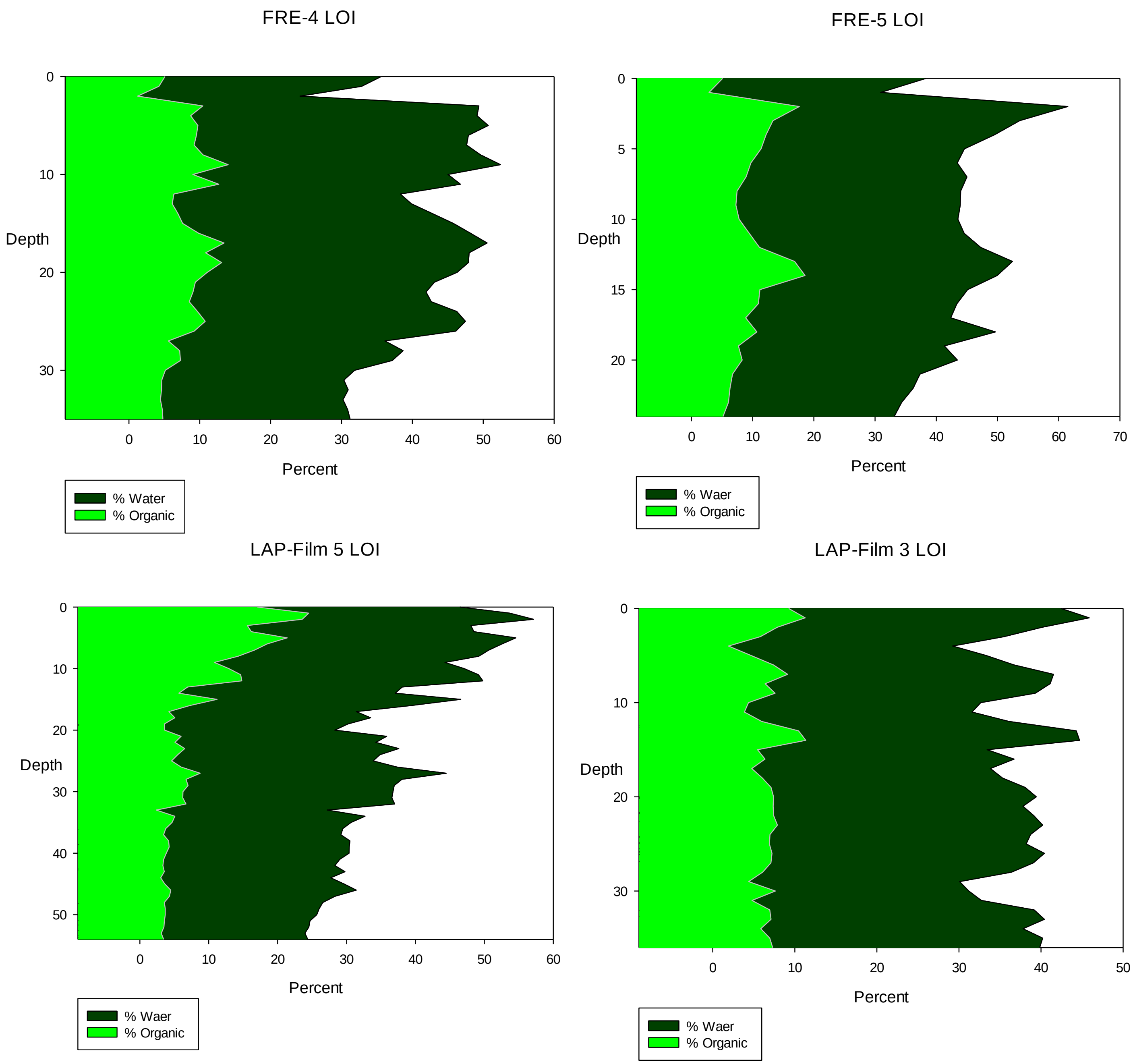
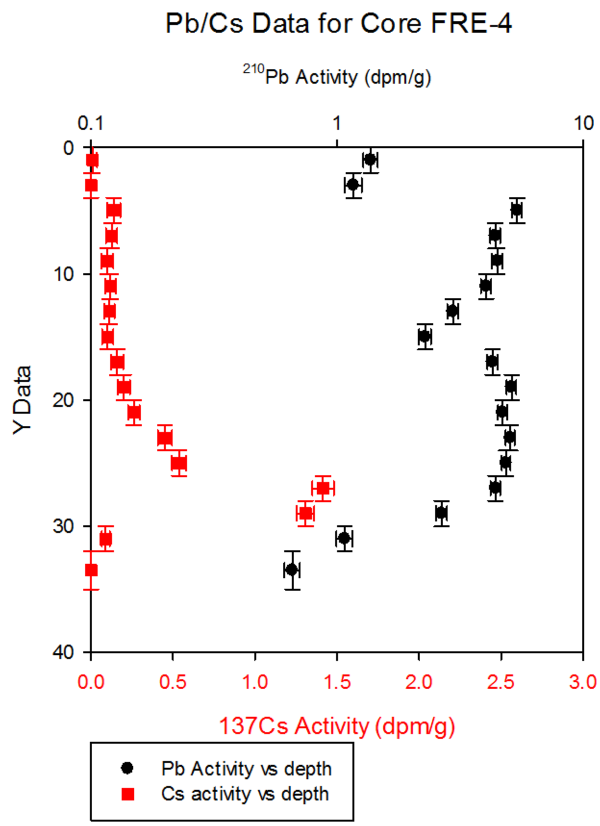


Figure 2: LOI for cores FRE-4, FRE-5, LAP-Film 3, and LAP-Film 5



Above: Figure 3: ^{137}Cs and ^{210}Pb activity values for FRE-4

Right: Table 1: Mean grain sizes for FRE-4.Values reported in red correspond to the very fine sand grain size.

Sample Depth (cm)	Mean Grain Size (microns)
0.0-0.5	84.0008
0.5-1	106.696
1-1.5	77.758
1.5-2	55.8172
2-2.5	47.822
2.5-3	52.7912
3-4	48.0292
4-5	51.1687
5-6	38.7164
6-7	35.8092
7-8	44.6217
8-9	77.5709
9-10	46.096
10-11	74.5855
11-12	36.5851
12-13	36.9701
13-14	36.9269
14-15	51.4092
15-16	63.3462
16-17	44.7025
17-18	68.0088
18-19	65.1422
19-20	68.9613
20-21	76.3336
21-22	33.7832
22-23	94.585
23-24	47.6972
24-25	74.1523
25-26	75.4167
26-27	26.6842
27-28	45.5281
28-29	33.4541
29-30	29.6368
30-31	31.465
31-32	30.1441
32-33	*sample lost
33-34	26.3744
34-35	26.3767
35-36	24.0522