Wetland loss associated with hurricane storm surge near the Caernarvon freshwater diversion

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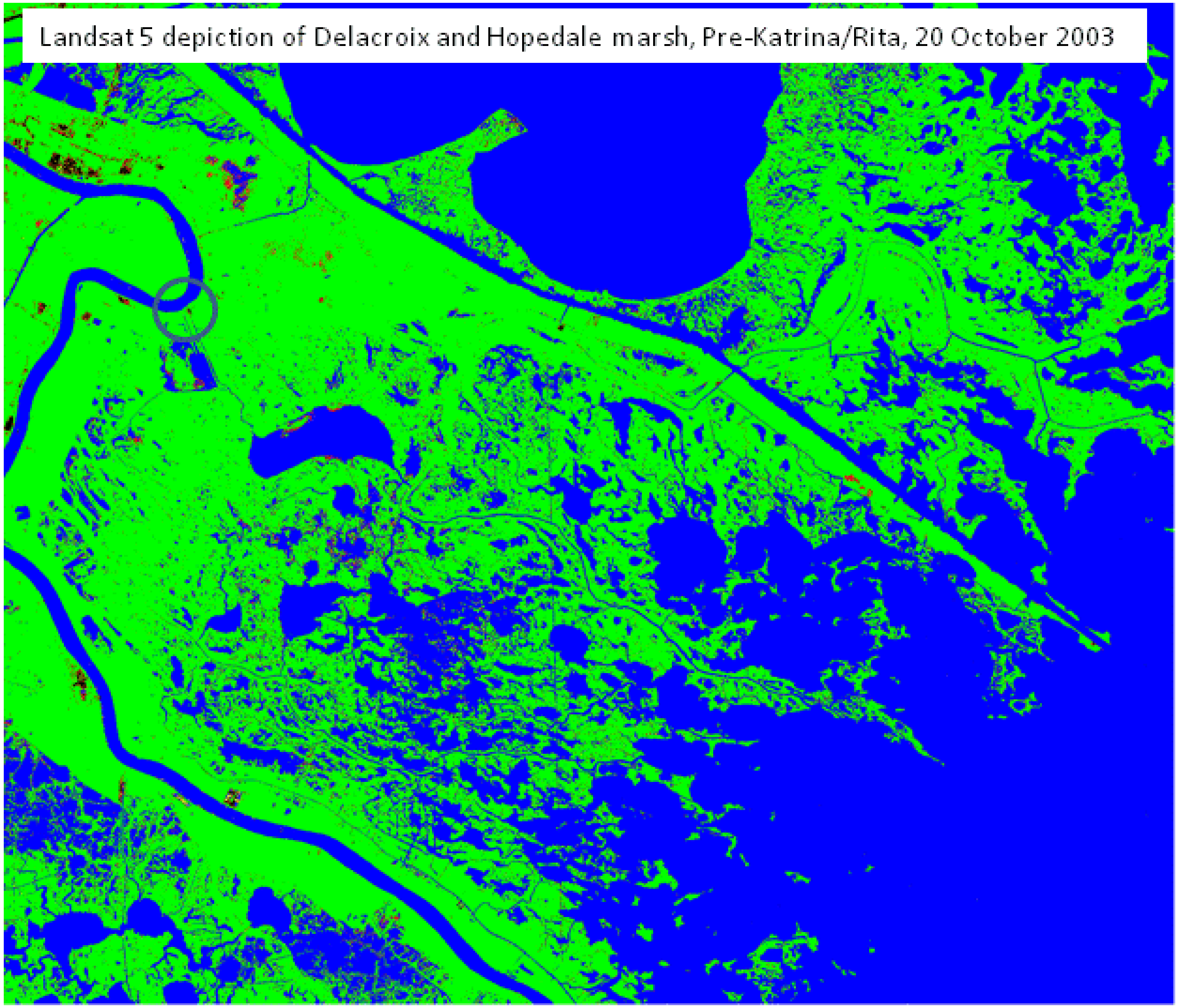
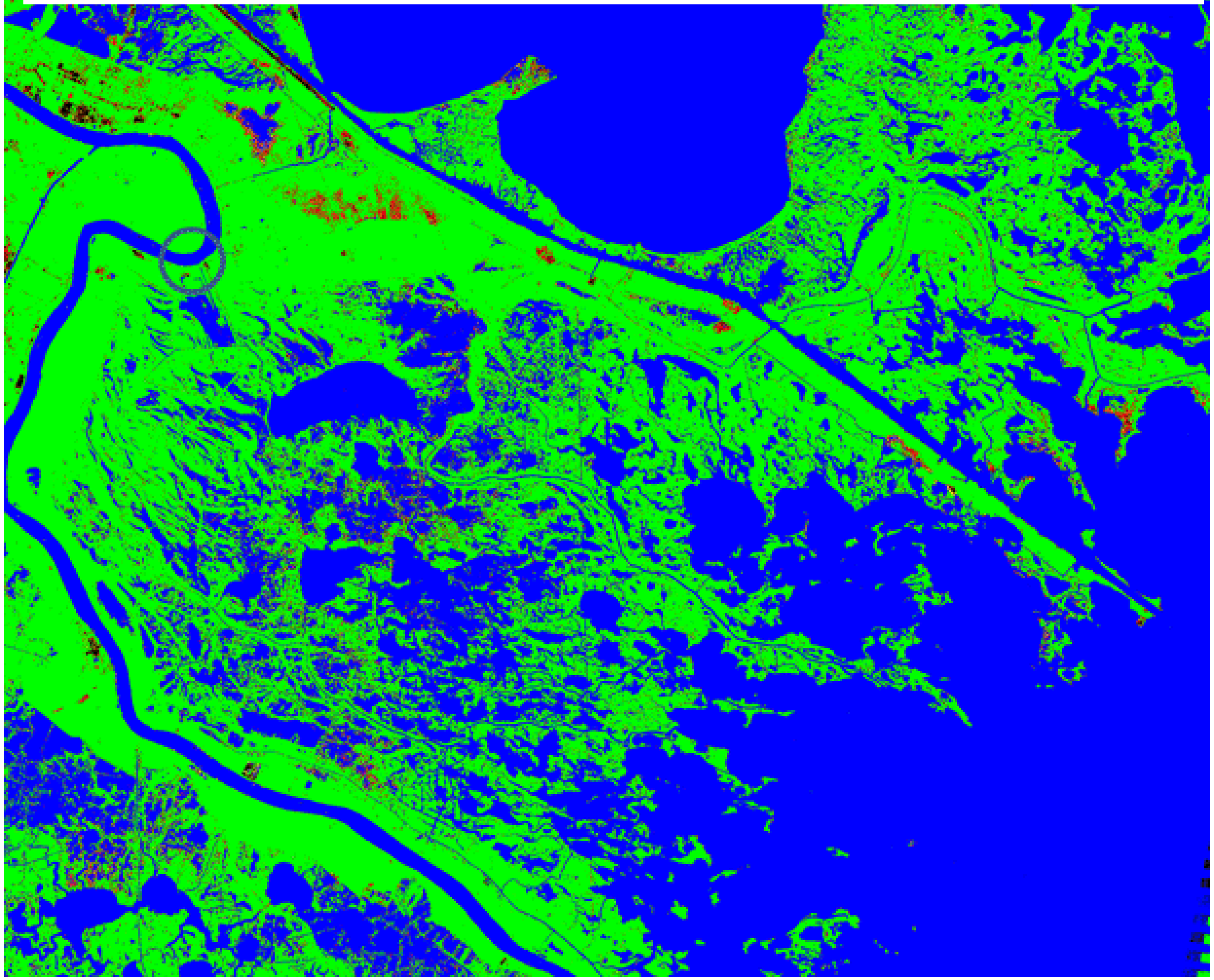
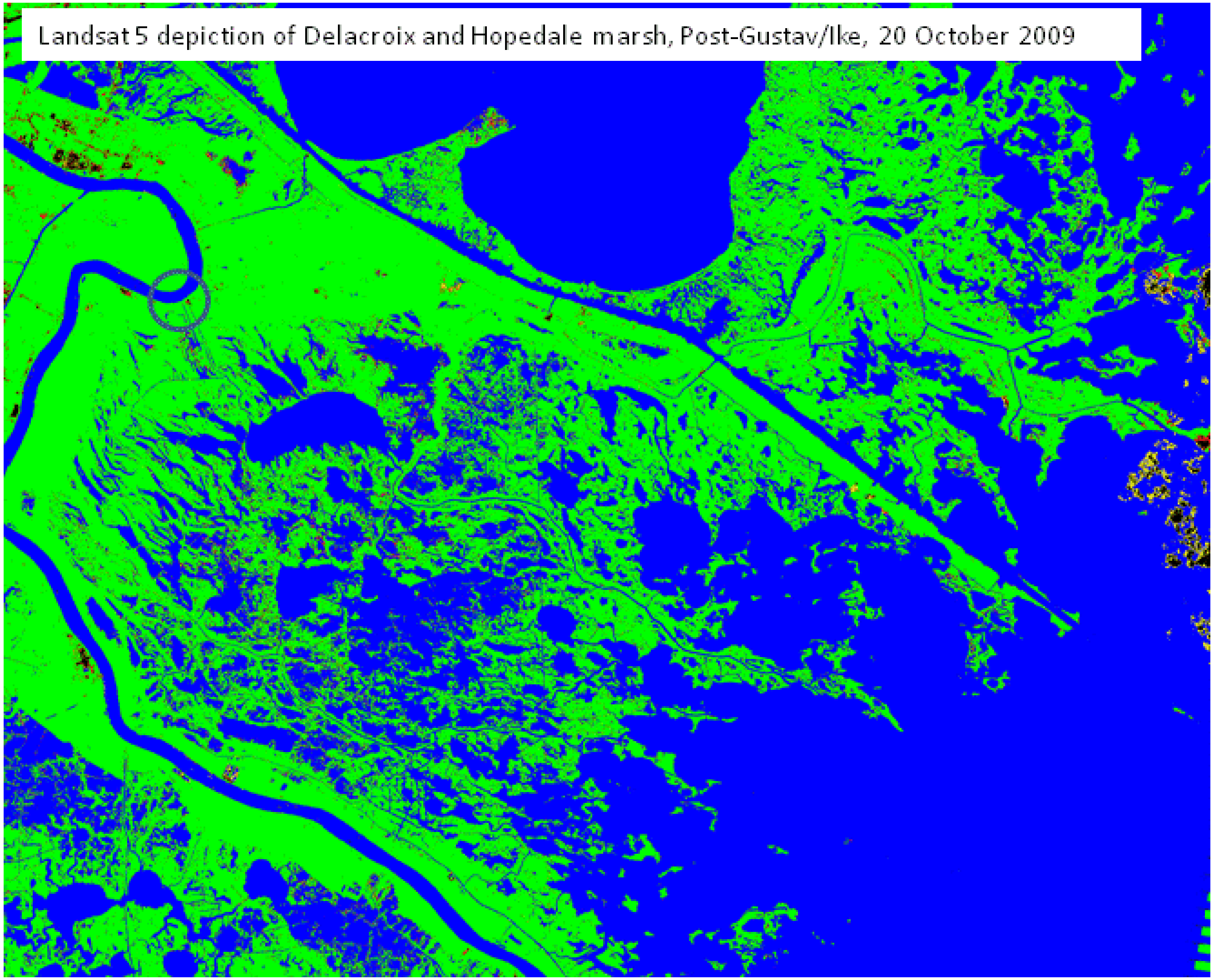

Landsat 5 depiction of Delacroix and Hopedale marsh, Pre-Katrina/Rita, 20 October 2003

Landsat 5 depiction of Delacroix and Hopedale marsh, Post-Katrina/Rita, 28 October 2006



Landsat 5 depiction of Delacroix and Hopedale marsh, Post-Gustav/Ike, 20 October 2009



Where did land go? West towards MS River

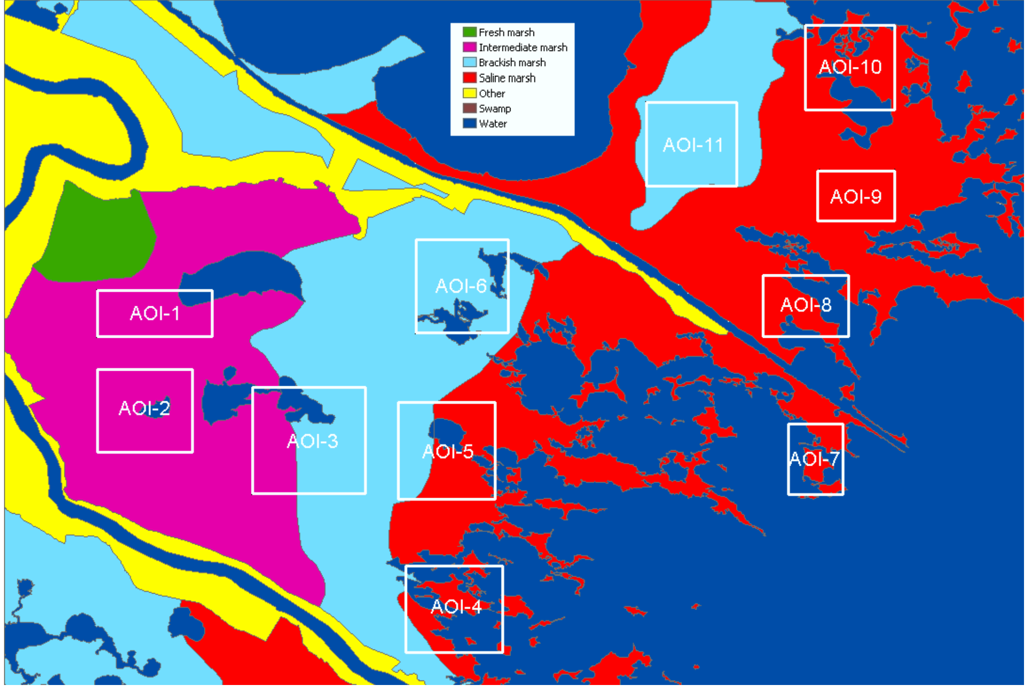
Video documentary from interviews

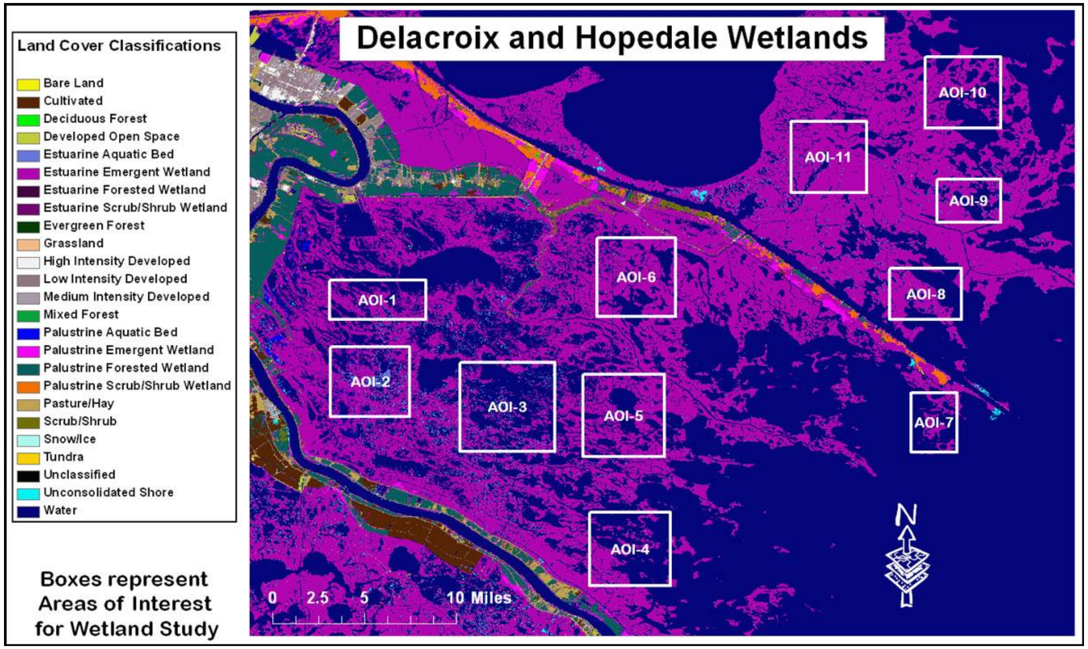
Research goal

- Quantify the land loss in the Hopedale and Delacroix regions after the 2005 and 2008 hurricanes
  - north of the MRGO
  - saline outer marsh of Delacroix
  - interior freshwater marsh
- Implications

Methodology

- Process C-CAP (Coastal Change Analysis Program) land cover data pre- and post-2005 hurricanes
- Develop pre-2005, post-2005, and post-2008 datasets;
  - MSU dataset based on Landsat 5 TM
  - Relatively cloud free
  - Land and water delineated using Normalized Difference Water Index (NDWI) and Normalized Difference Vegetation Index (NDVI) scheme
- Computed mean water coverage in eleven Areas Of Interest (AOI) for both datasets
- Perform significance tests using Wilcoxon rank-sum test
  - $0.15 > p \geq 0.05$, suggestive but inconclusive
  - $0.05 > p \geq 0.01$, moderately convincing
  - $0.01 > p \geq 0.001$, convincing
  - $p < 0.001$, very convincing


Fresh marsh
Intermediate marsh
Brackish marsh
Saline marsh
Other
Swamp
Water
AOI-1
AOI-2
AOI-3
AOI-4
AOI-5
AOI-6
AOI-7
AOI-8
AOI-9
AOI-10
AOI-11

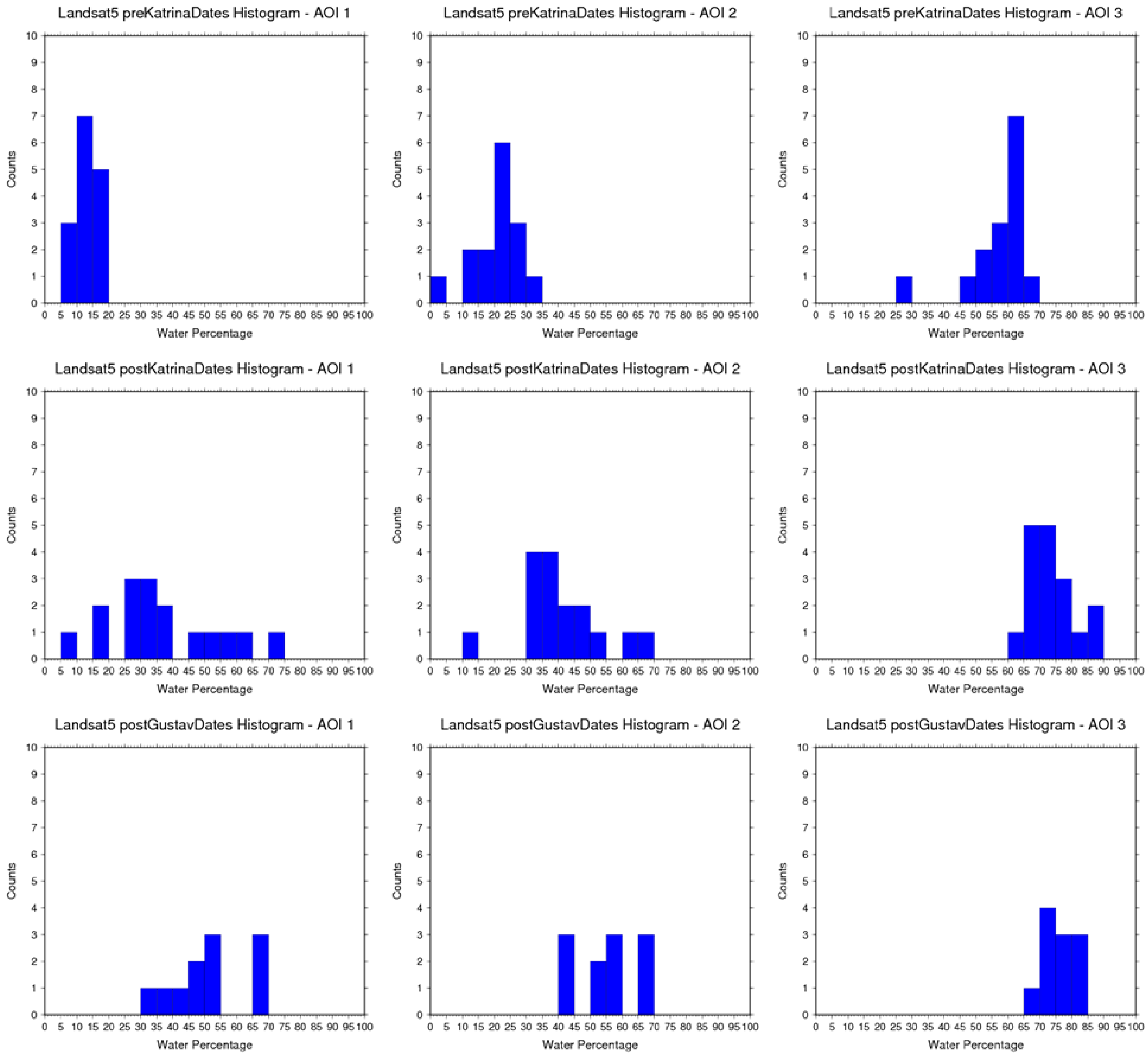

Delacroix and Hopedale Wetlands
Land Cover Classifications
Bare Land
Cultivated
Deciduous Forest
Developed Open Space
Estuarine Aquatic Bed
Estuarine Emergent Wetland
Estuarine Forested Wetland
Estuarine Scrub/Shrub Wetland
Evergreen Forest
Grassland
High Intensity Developed
Low Intensity Developed
Medium Intensity Developed
Mixed Forest
Palustrine Aquatic Bed
Palustrine Emergent Wetland
Palustrine Forested Wetland
Palustrine Scrub/Shrub Wetland
Pasture/Hay
Scrub/Shrub
Snow/Ice
Tundra
Unclassified
Unconsolidated Shore
Water
Boxes represent Areas of Interest for Wetland Study
AOI-1
AOI-2
AOI-3
AOI-4
AOI-5
AOI-6
AOI-7
AOI-8
AOI-9
AOI-10
AOI-11
0 2.5 5 10 Miles
N

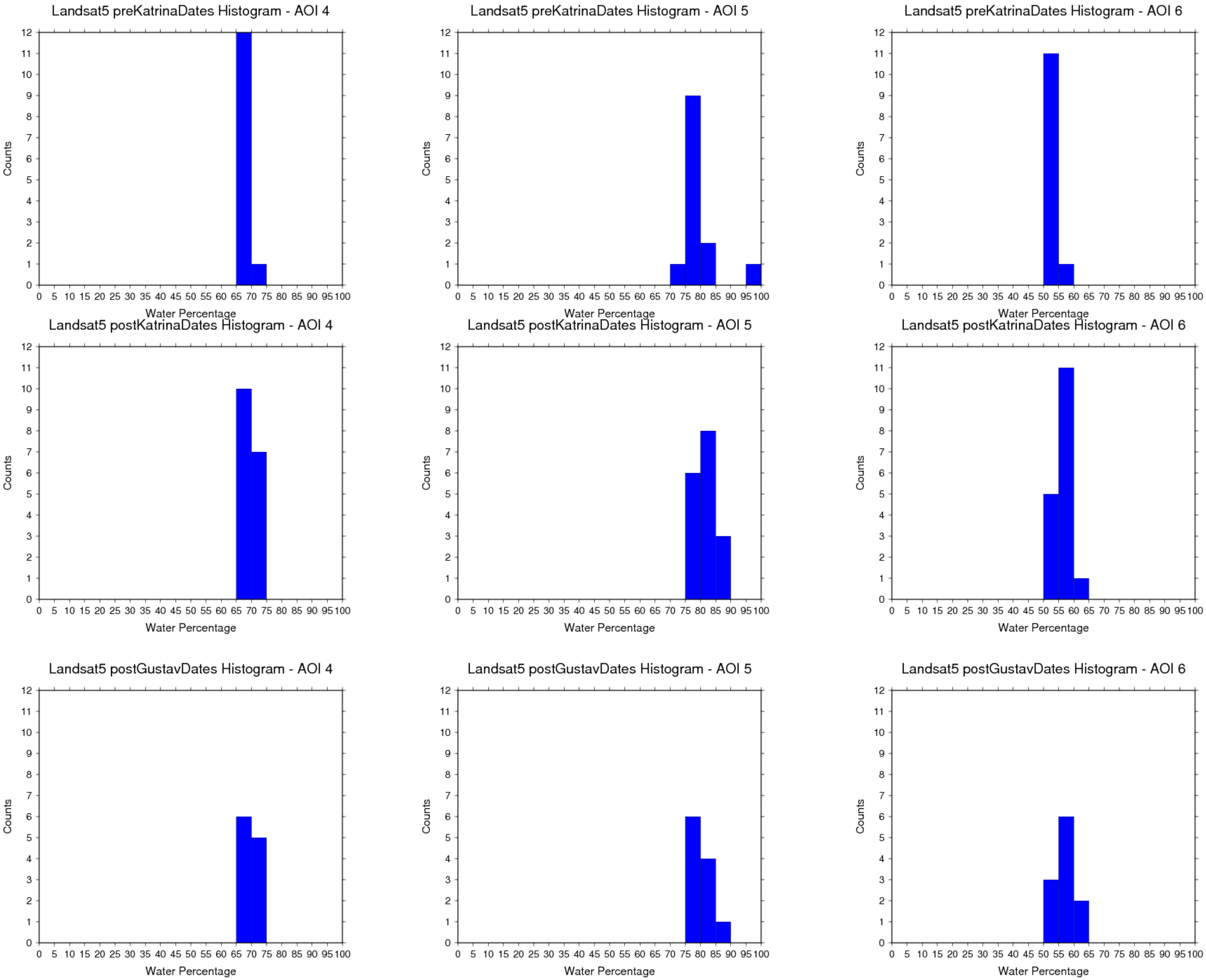
Area Of Interest (AOI)	Distance from Caernarvon diversion (km)	Salinity	North or south of BTAB	North or south of MRGO	C-CAP Percentage water 1996	Pre-Katrina/Rita (August 2005)	Post-Katrina/Rita
1	9.5	Low	S	S	11.7	13.5	52.5
2	16.1	Low	S	S	11.6	14.0	37.7
3	22.1	Low	S	S	54.1	56.1	68.4
4	38.5	High	S	S	66.5	67.1	69.1
5	28.4	High	S	S	37.1	38.1	41.8
6	21.5	High	N	S	29.7	30.9	34.1
7	48.2	High	N	S	72.6	72.9	75.3
8	44.9	High	N	N	49.6	49.6	51.1
9	46.2	High	N	N	38.4	38.5	40.1
10	46.9	High	N	N	48.8	49.0	50.9
11	34.5	High	N	N	12.0	13.0	14.5

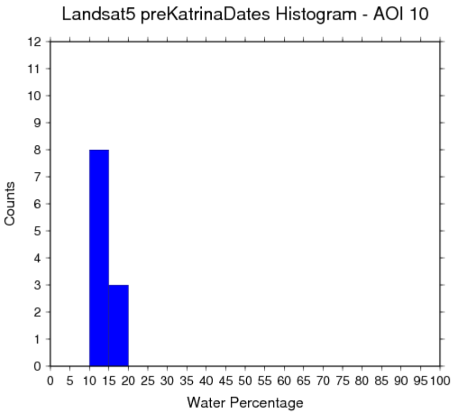
Landsat 5 Mean Percentage Water Pre-Katrina/Rita (n=15)	Post-Katrina/Rita (n=19)	Post-Gustav/Ike (n=11)
12.8	36.8	51.5
20.8	40.8	54.3
57.5	73.5	80.0
68.0	69.6	69.6
38.0	43.2	43.1
29.4	35.2	37.2
79.8	81.3	80.5
53.5	56.5	56.4
43.3	45.5	46.3
51.1	52.7	53.3
14.0	15.6	15.7

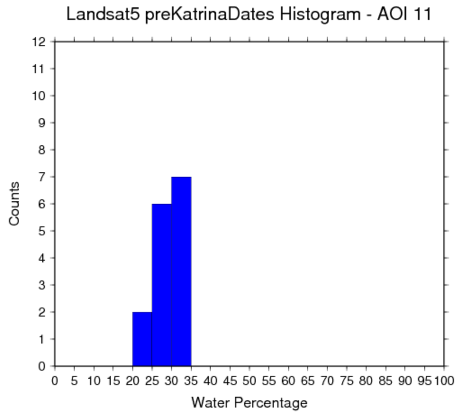
Table 3. Statistical significance results using Wilcoxon Rank-Sum test between Landsat 5 AOIs water coverage before and after Katrina/Rita and Gustav/Ike. ^ denotes $0.15 > p \geq 0.05$, * denotes $0.05 > p \geq 0.01$, ** denotes $0.01 > p \geq 0.001$, and *** denotes $p < 0.001$.

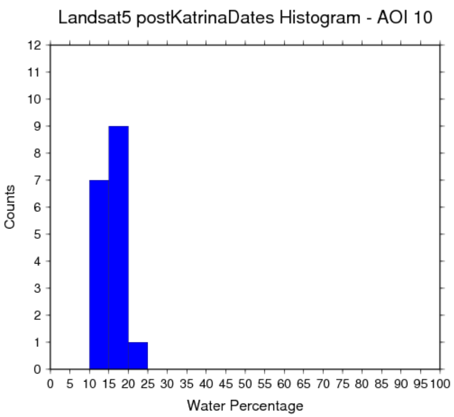
Area Of Interest (AOI)	Wilcoxon Rank-Sum Significance Test Difference in Water Coverage: Pre-Katrina/Rita vs. Post-Katrina/Rita	Post-Katrina/Rita vs. Post-Gustav/Ike
1	***	*
2	***	**
3	***	
4	**	
5	***	
6	***	^
7	*	
8	***	
9	**	
10	***	^
11	*	

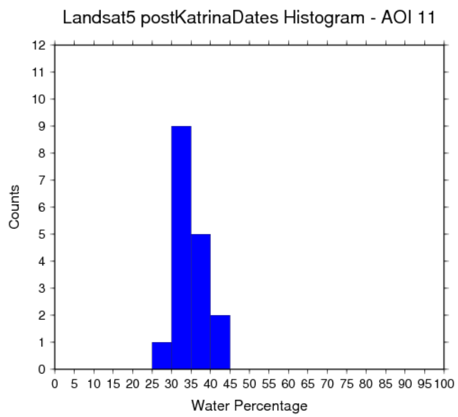

Landsat5 preKatrinaDates Histogram - AOI 1
Landsat5 preKatrinaDates Histogram - AOI 2
Landsat5 preKatrinaDates Histogram - AOI 3
Landsat5 postKatrinaDates Histogram - AOI 1
Landsat5 postKatrinaDates Histogram - AOI 2
Landsat5 postKatrinaDates Histogram - AOI 3
Landsat5 postGustavDates Histogram - AOI 1
Landsat5 postGustavDates Histogram - AOI 2
Landsat5 postGustavDates Histogram - AOI 3
Counts
Water Percentage

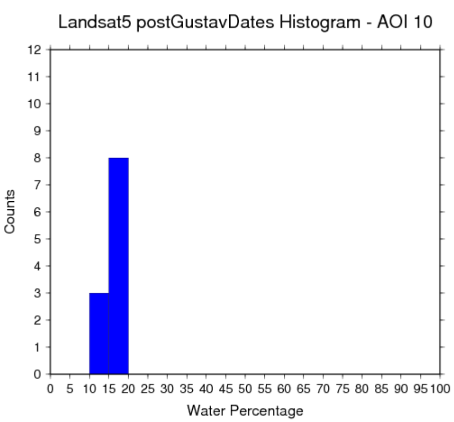

Landsat5 preKatrinaDates Histogram - AOI 4
Landsat5 preKatrinaDates Histogram - AOI 5
Landsat5 preKatrinaDates Histogram - AOI 6
Landsat5 postKatrinaDates Histogram - AOI 4
Landsat5 postKatrinaDates Histogram - AOI 5
Landsat5 postKatrinaDates Histogram - AOI 6
Landsat5 postGustavDates Histogram - AOI 4
Landsat5 postGustavDates Histogram - AOI 5
Landsat5 postGustavDates Histogram - AOI 6
Counts
Water Percentage

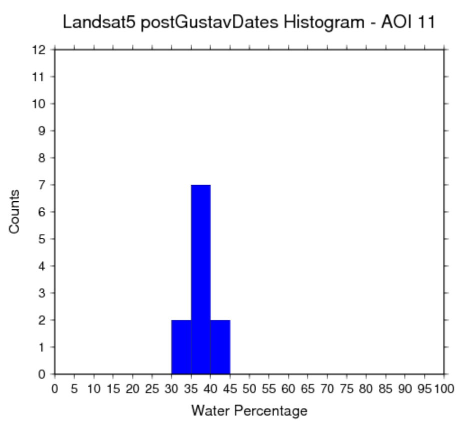

Landsat5 preKatrinaDates Histogram - AOI 10
Counts
Water Percentage


Landsat5 preKatrinaDates Histogram - AOI 11
Counts
Water Percentage

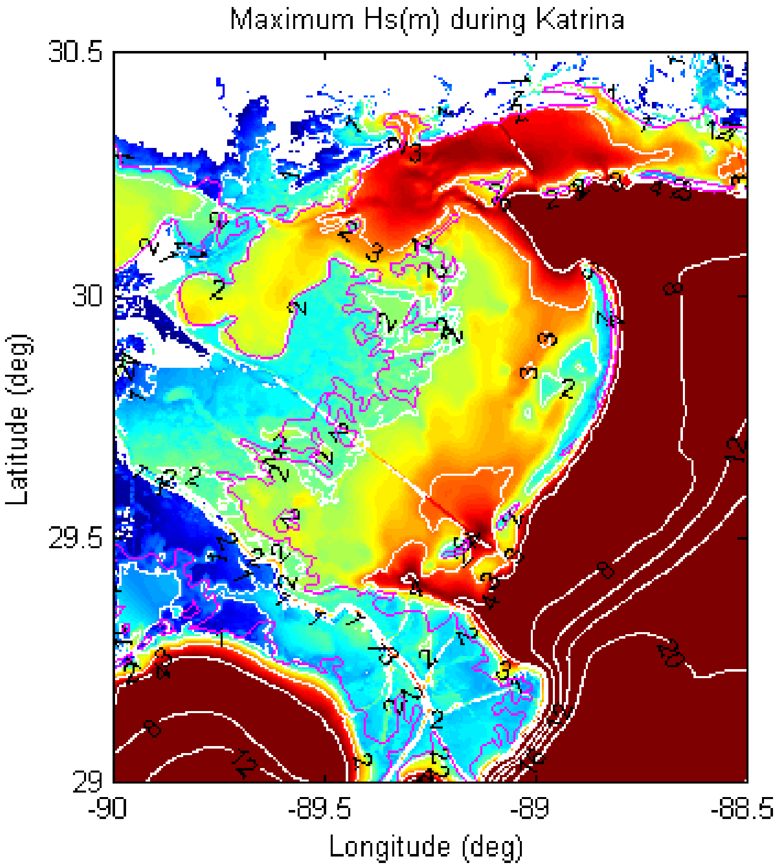

Landsat5 postKatrinaDates Histogram - AOI 10
Counts
Water Percentage

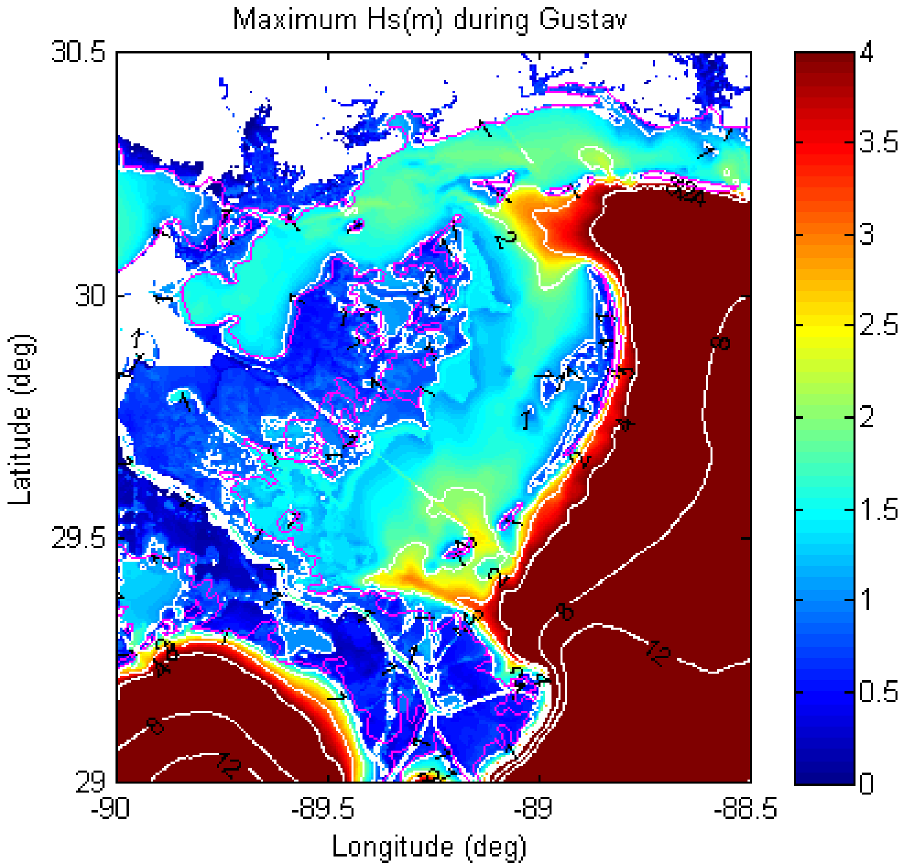

Landsat5 postKatrinaDates Histogram - AOI 11
Counts
Water Percentage


Landsat5 postGustavDates Histogram - AOI 10
Counts
Water Percentage

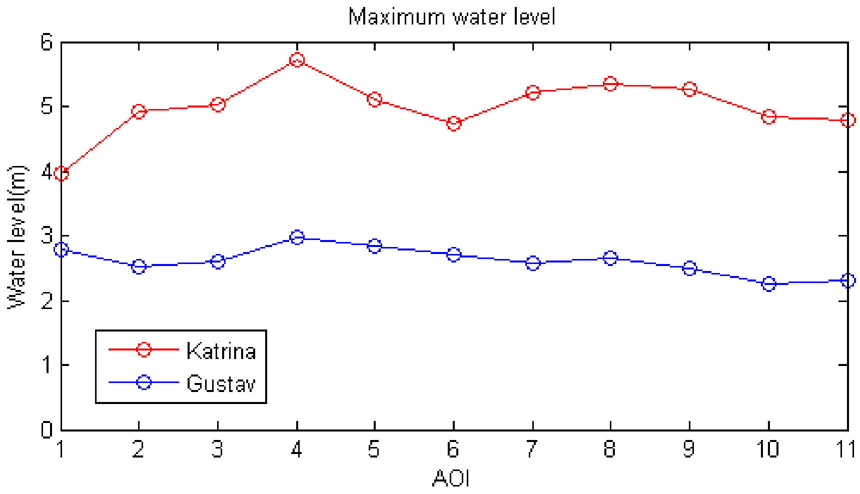

Landsat5 postGustavDates Histogram - AOI 11
Counts
Water Percentage

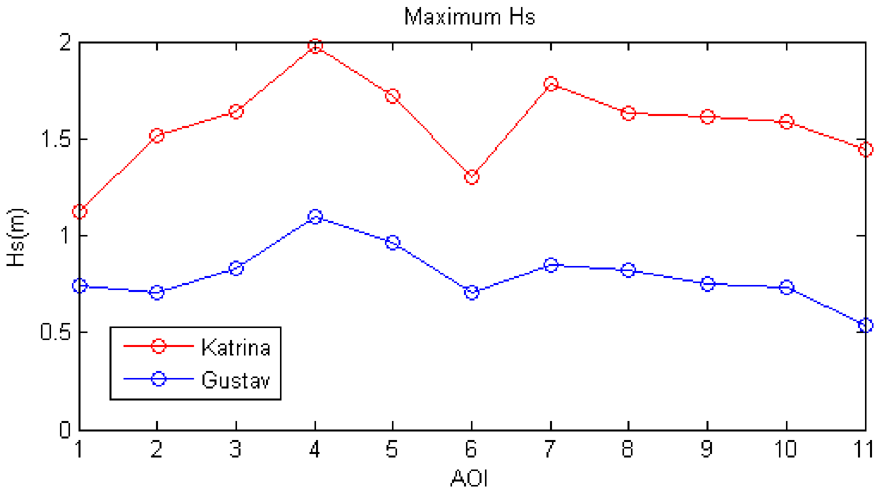
Are wave heights enhanced near diversion during hurricane surge events?



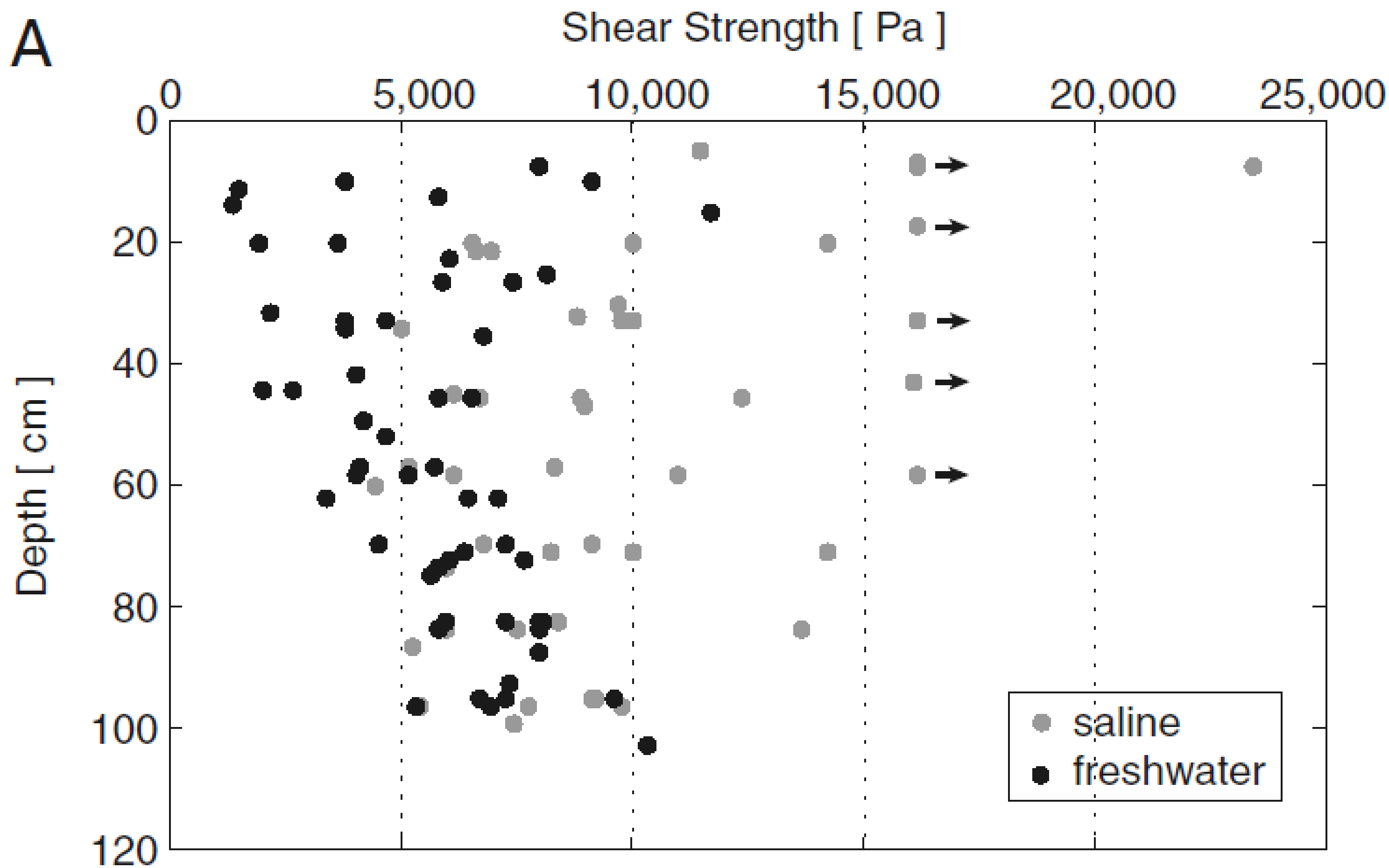


Peak surge and wave heights for eleven AOIs





From Howes et al. 2010



Reference: Howes et al., 2010, Hurricane-induced failure of low salinity wetlands, *Proceedings of the National Academy of the United States of America*, **107(32)**, pp. 14014–14019.

From Howes et al. 2010

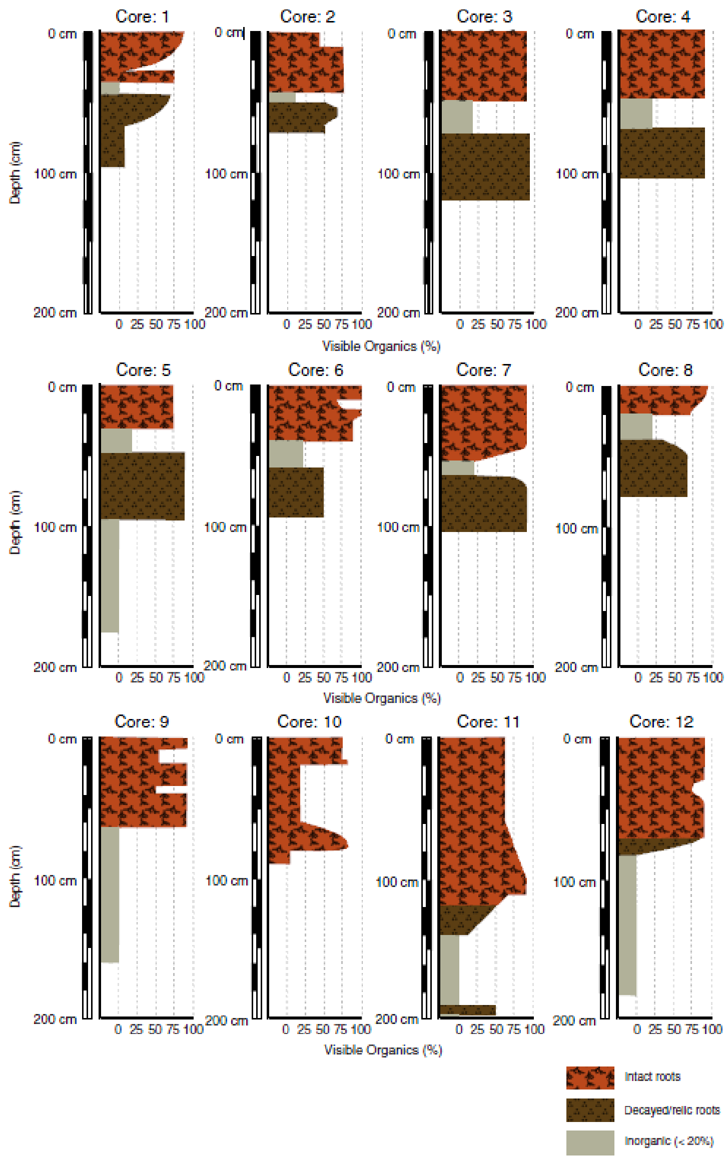


Fig. S2. Stratigraphy of the short cores. Cores 1–9 were taken in the low salinity wetland, while cores 10–12 were taken in high salinity wetlands. Intact rooting in the low salinity cores extends to average depth of 42 cm (range 31–67), below which an inorganic layer separates the live rooting from an older decomposing root horizon. In the high salinity region, roots extend to an average depth of 92 cm (range 74–112) and intact rooting is seen within relatively inorganic layers.

Implications

- Results support a growing body of evidence (Mort and Barras 2011; Howes et al. 2010) that the Caernarvon wetlands, while promoting biodiversity through salinity control, lack hurricane resilience.

- More info - Fitzpatrick, P. J., S. Bhate, Y. Lau, V. Anantharaj, S. Shean, Q. Chen, and K. Hu, 2012: Wetland loss associated with tropical cyclone storm surge near the Caernarvon freshwater diversion. Submitted to *International Journal of Remote Sensing*.

- Controversial issues related to floatants and shallow rooting being susceptible to storm surge. The return period for tropical events is 3-7 years, so this is a recurring issue that must be addressed.

- Caernarvon has successfully restored salinity balances. How can storm surge vulnerability be addressed?

Critical comments

Howes et al. 2010 (*Proc. Nat. Academy of Sci.*)

- "Vegetation in low salinity marshes is subject to shallower rooting"
- "Hurricane Katrina (waves) produced shear stresses …..sufficient to cause widespread erosion of low salinity wetlands"

Eugene Turner, LSU (from *Responses of LA Marsh Soil and Vegetation to Freshwater Diversions Workshop*, 23 February 2011)

- "Nutrient enrichment (from the diversion) leads to lower root and Rhizome biomass, below ground production, organic accumulation, and soil strength"
- "Sustaining and restoring coastal marshes is more likely if they receive a lower, not a higher, nutrient load."
- "Large river diversions into organic soils, an unproven restoration approach, may be causing wetland loss, not restoring them."

Andy Nyman, LSU (from *Responses of LA Marsh Soil and Vegetation to Freshwater Diversions Workshop*, 23 February 2011)

- "Bulk density is positively related to plant biomass; thus mineral sedimentation ….is indirectly important to accretion via vegetation growth.
- "….Bulk density of fresh marsh (0.07 g cm^{-3}) is much less than …..saline marsh (0.24 g cm^{-3})

Supporters of status quo of Caernarvon

Richard Raynie, OCPR LA Applied Coastal Engineering & Science Division (from *Responses of LA Marsh Soil and Vegetation to Freshwater Diversions Workshop*, 23 February 2011)

- Betsy caused similar erosion; system recovered

R. D. DeLaune, A. Jugsujinda, and G. W. Peterson, LSU (from *Responses of LA Marsh Soil and Vegetation to Freshwater Diversions Workshop*, 23 February 2011)

- "Using ^{137}Cs dating and artificial marker horizons, increases in the rate of….accretion were measured….along….diversion"
- "Diversion….will enhance marsh accretion and stability…..slowing or reversing the wetland loss."