An analysis of storm surge attenuation by wetlands using USGS, FEMA, and NASA data

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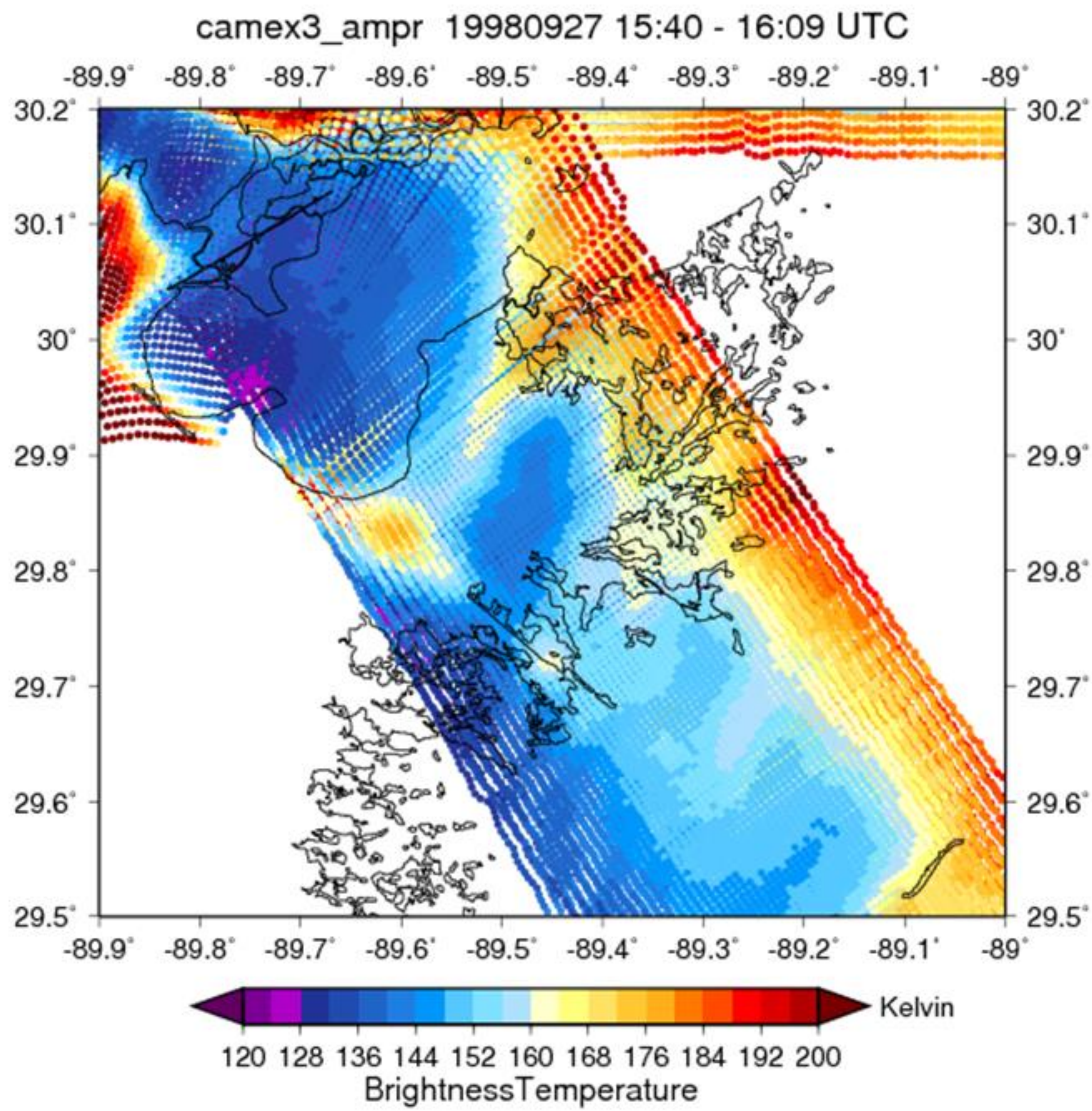
NASA Marshall

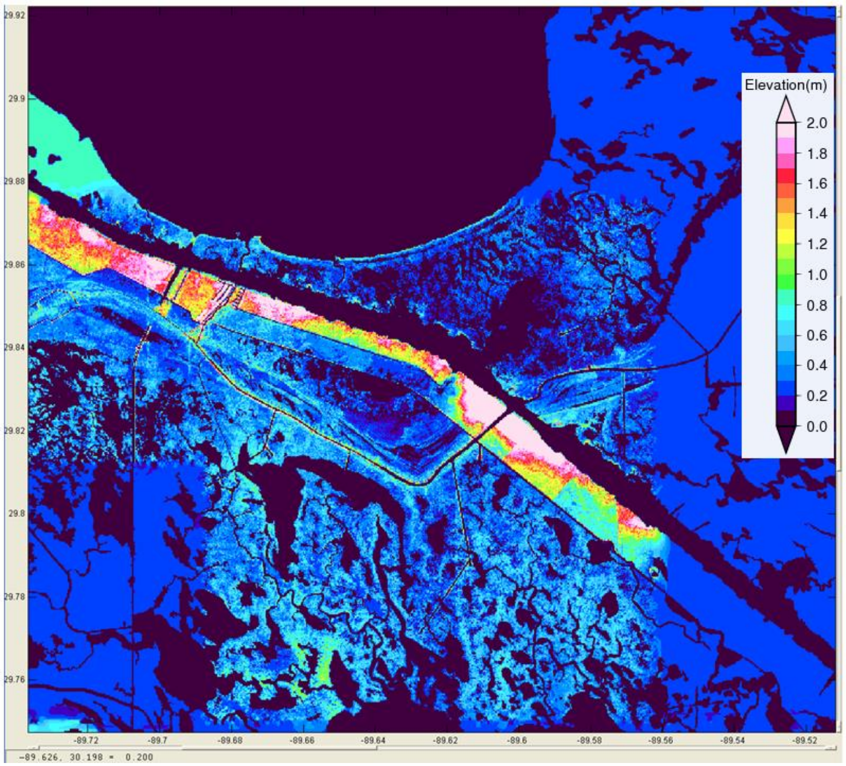
- Examination of NASA's Advanced Microwave Precipitation Radiometer (AMPR) taken during Hurricane Georges' (1998) as an aid to compliment other Louisiana storm surge analysis
- Examination of surge attenuation by wetlands during Hurricane Rita's (2005) landfall, using FEMA's high water marks and USGS data

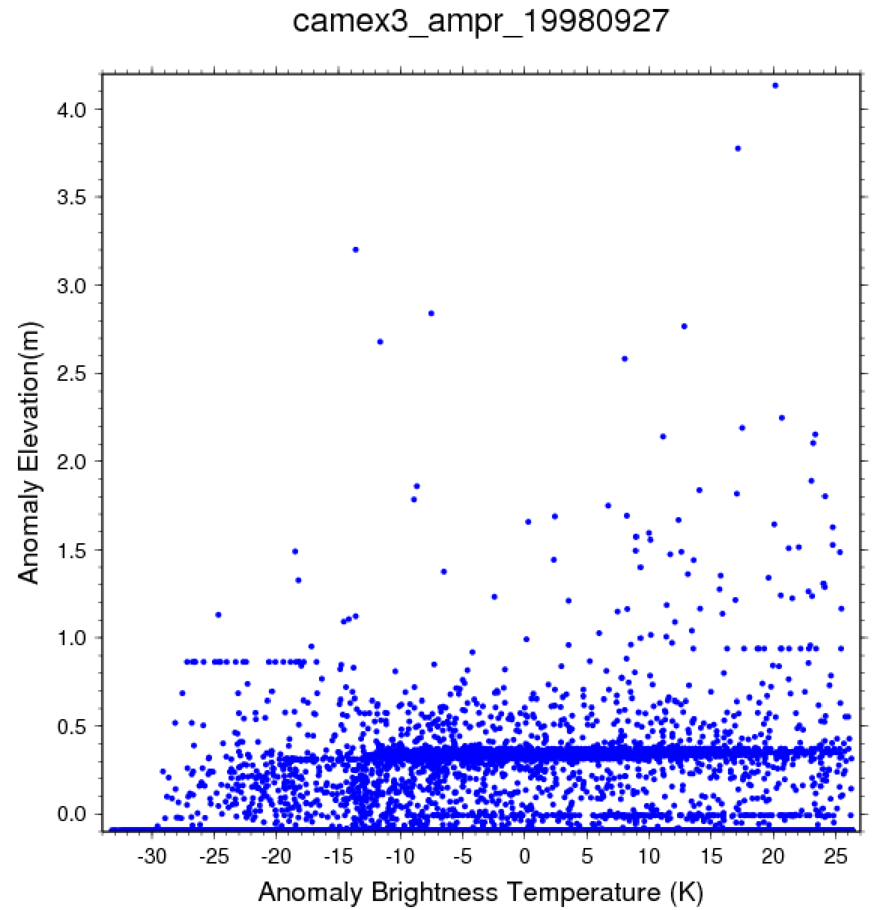
AMPR data analysis

AMPR shows spatial patterns that roughly correspond to marsh features as well
As the ridges along Bayou Loutre.

Examined radar data for heavy rain signal contamination, but most reflectivities less than 25 dBz.
The AMPR 10.7 GHz channel is relatively insensitive to light Rainfall. Could be used to detect initial surge.







We obtained topography data for this region, which combines lidar and USGS DEM data. However, the data is unrealistically flat outside lidar data region. Scatterplots of elevation Versus Tb showed no relationship, even when water regions are removed.
But elevation data is poor.

Factors impacting AMPR

- Ocean waves
- SST
- Heavy rainfall
- Land versus water (land has larger Tb)

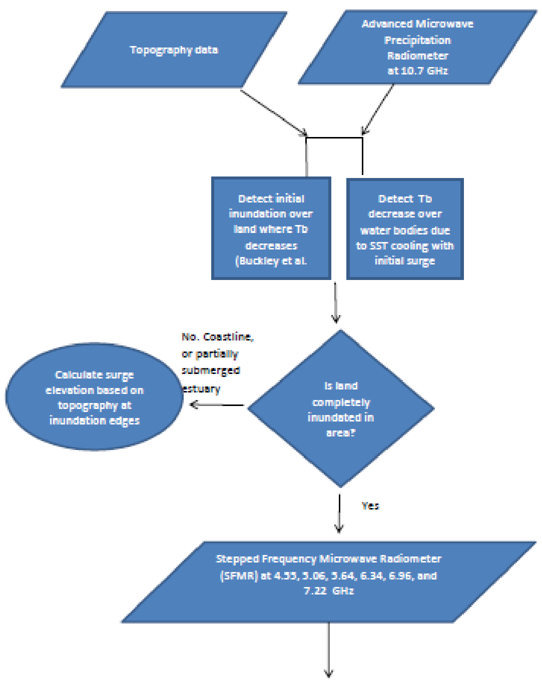
Could these combined impacts be used for surge data?

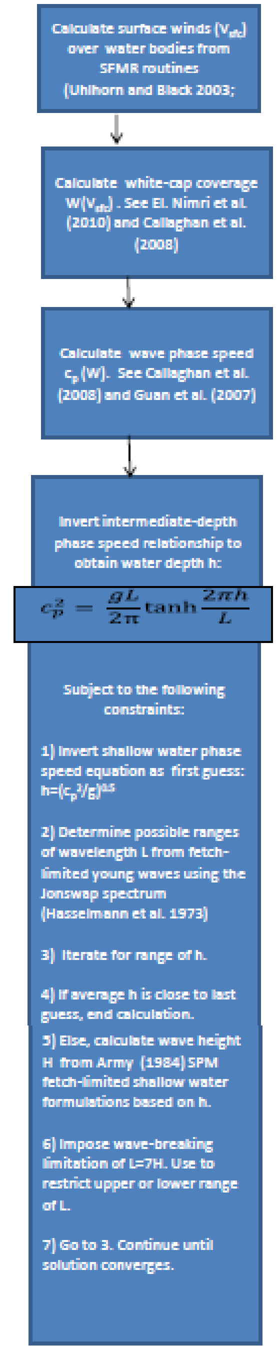
Possibly, in combination with the Stepped Frequency Microwave Radiometer, which accounts for these variations using an infrared instrument (for SST) and by measuring six frequencies (between 4.55 and 7.22 GHz), and through inverse relationships, computes surface wind speeds. The main purpose of the multiple 4.55-7.22 GHz channels is to quantify the impact of rain attenuation, although they also serve a purpose in computing surface winds due to "excess emissivity" from sea foam coverage and other variables.

It is proposed that the AMPR can be used to detect initial surge inundation, and combined with SFMR technology, surge height may be computed through inverse formulations based on ocean wave relationships and empirical sea foam formulations

DSS to compute surge from AMPR

Flowchart prototype to compute storm surge from airborne microwave radiometer





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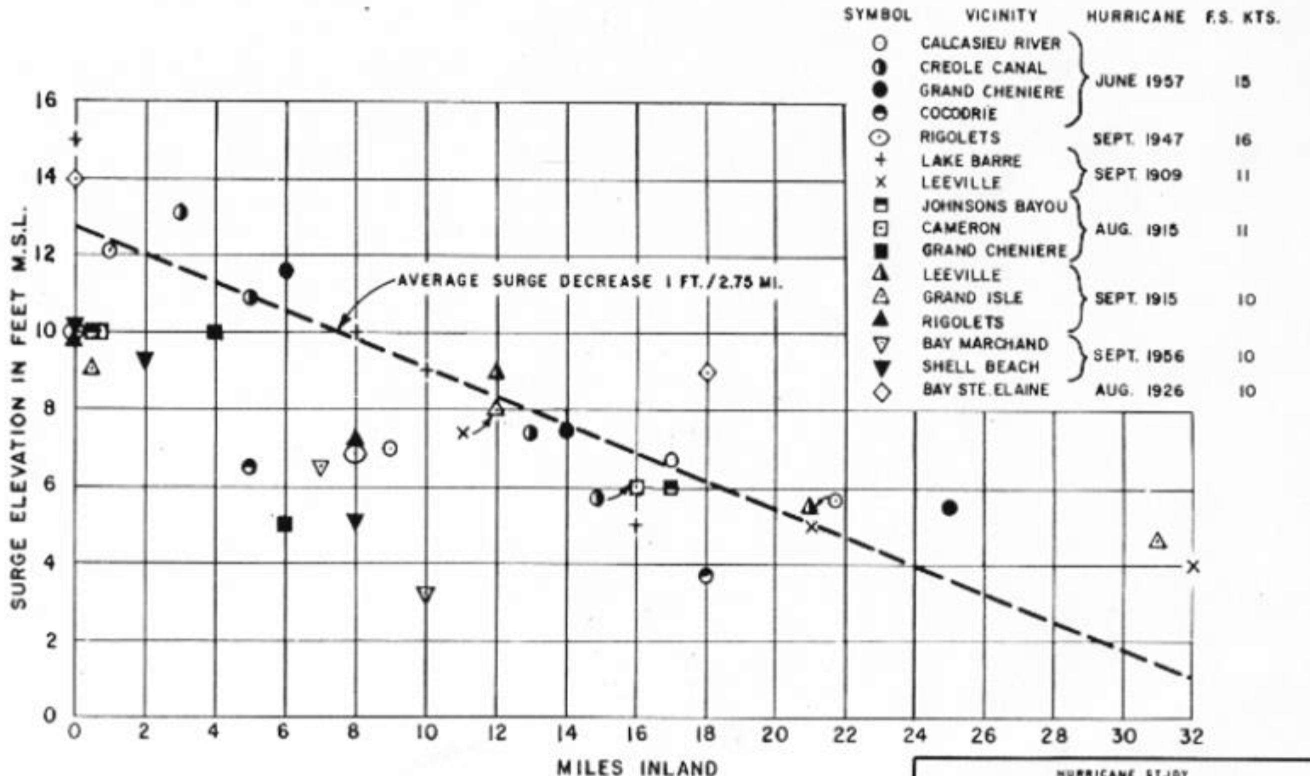
Wetland attenuation of storm surge



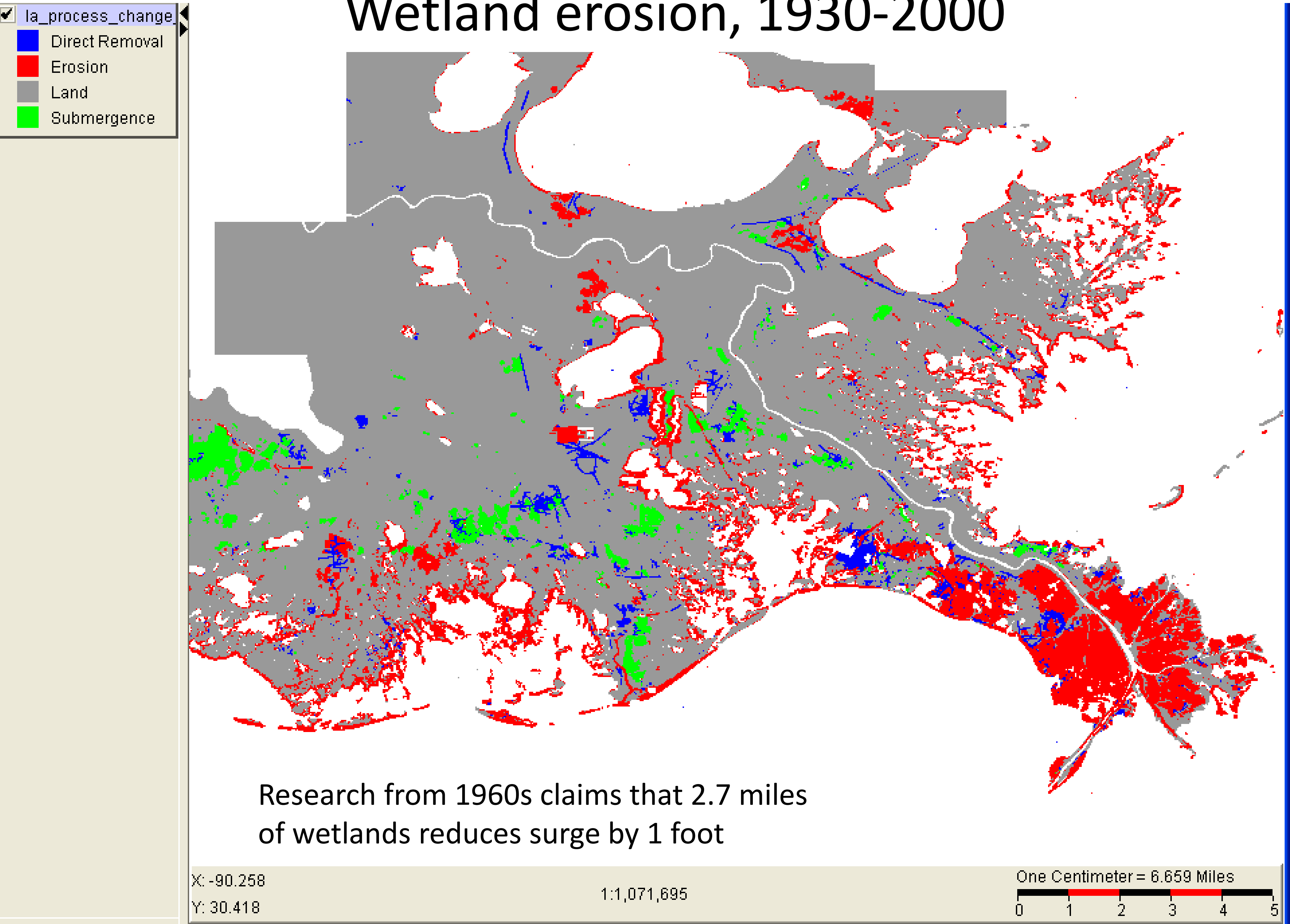
HURRICANE STUDY
INTERLYING AREA ALONG COASTAL LA.
IN THE VICINITY OF HOUMA

OVERLAND SURGE ELEVATIONS
COASTAL LOUISIANA

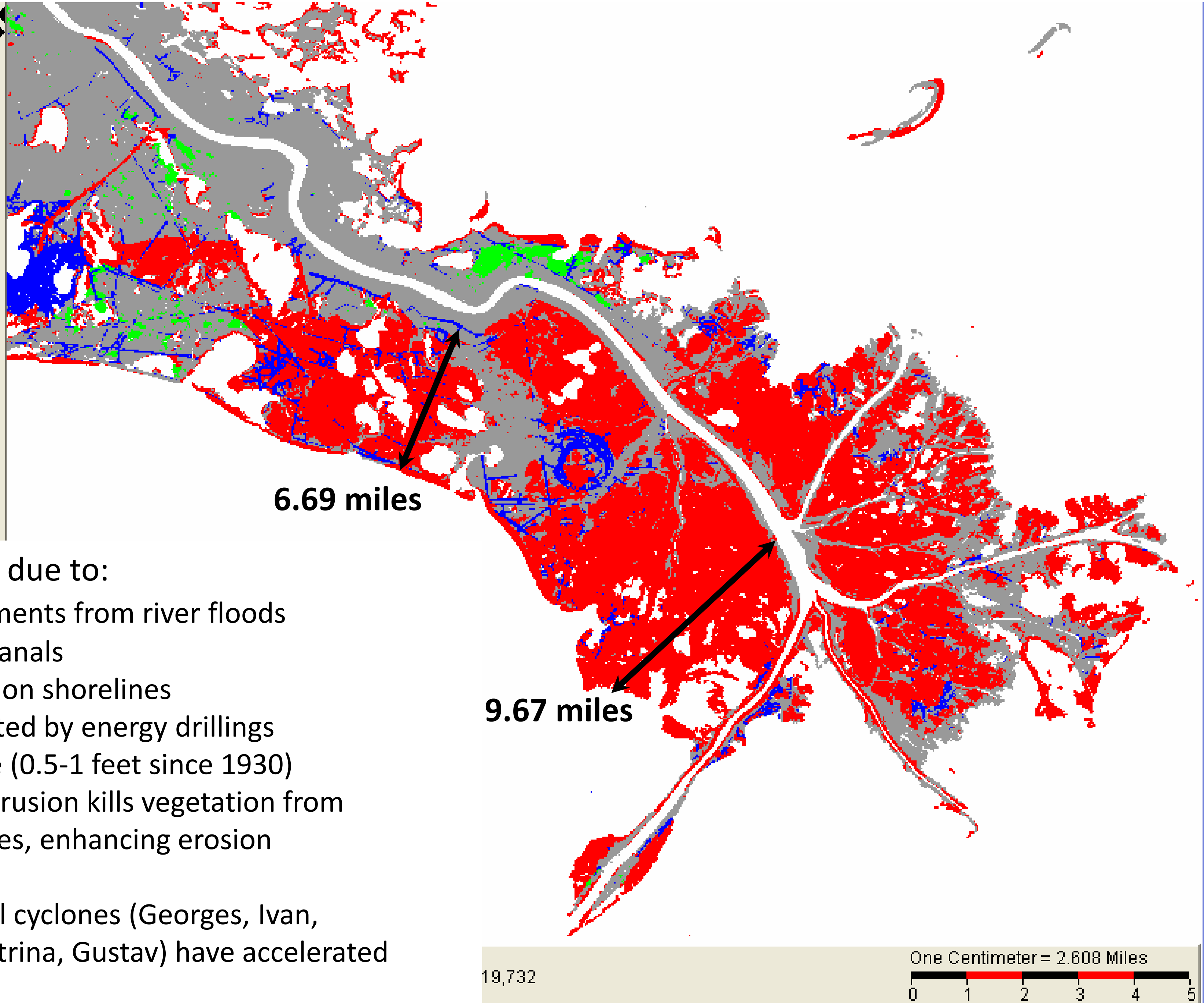
U.S. ARMY ENGINEER DISTRICT, NEW ORLEANS
CORPS OF ENGINEERS

OCTOBER 1963 FILE NO. H-2-22823

Wetland erosion, 1930-2000



Research from 1960s claims that 2.7 miles of wetlands reduces surge by 1 foot



LA coast has 3 feet ***relative*** sea level rise per century

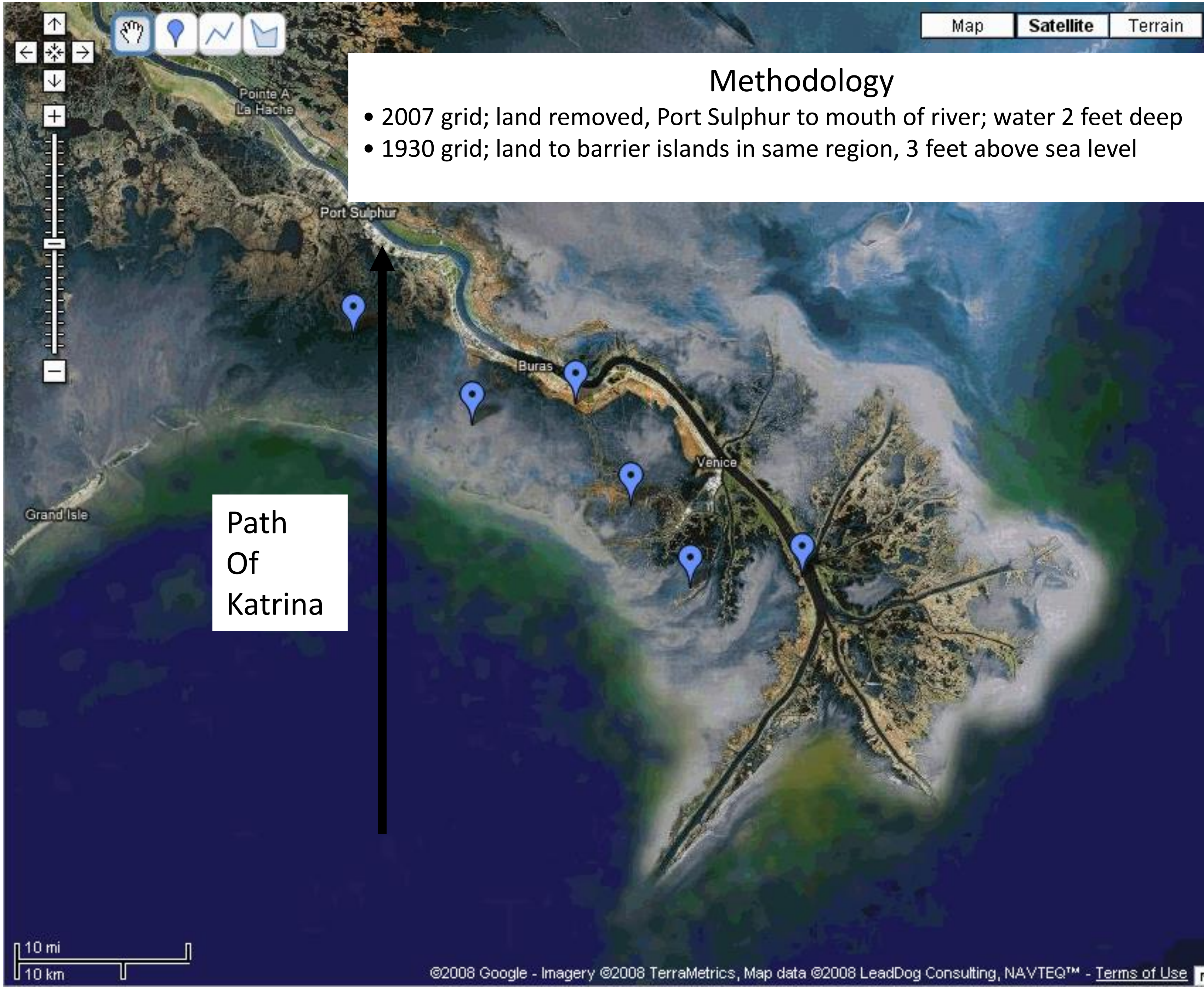
Wetland loss due to:

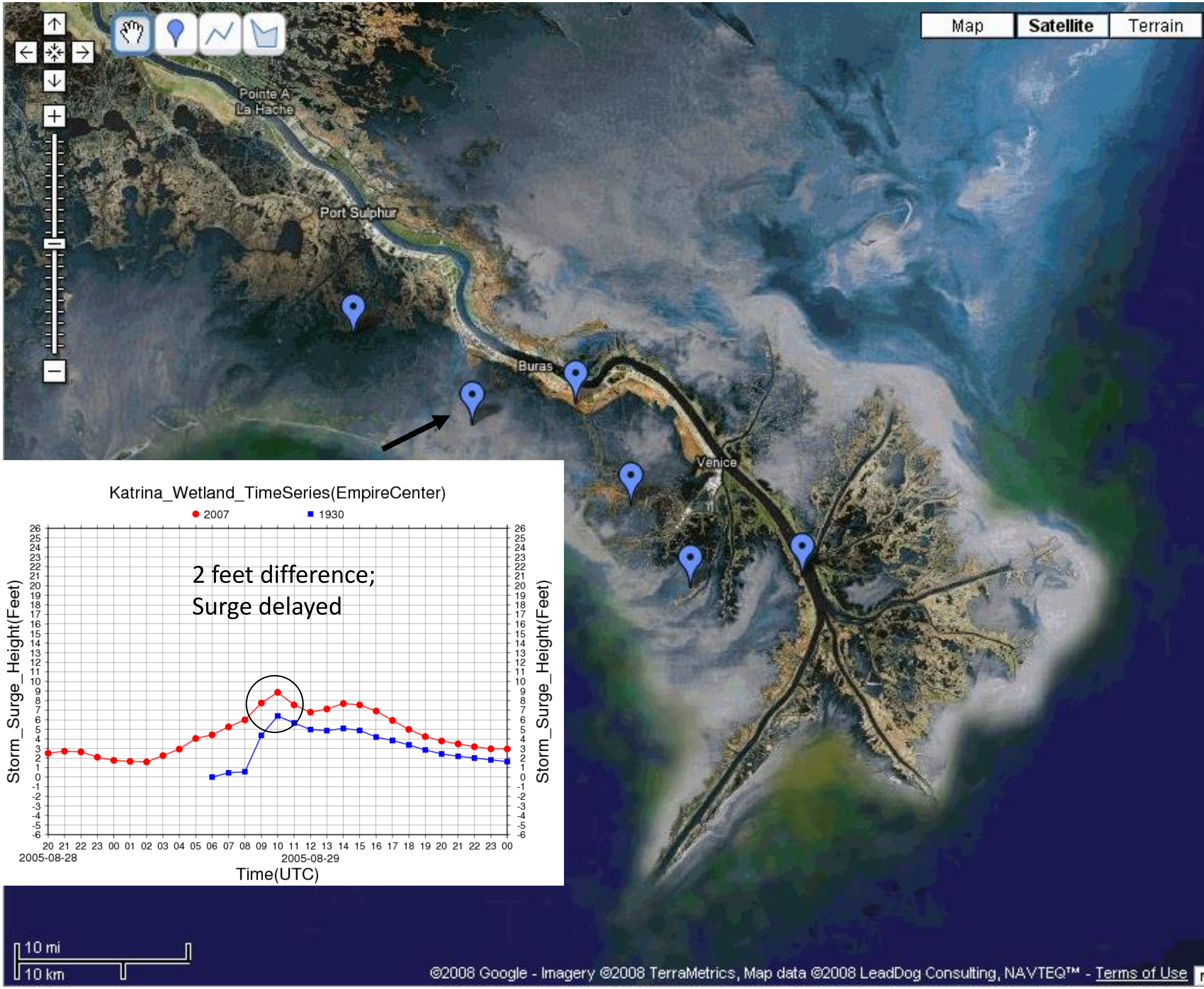
- Loss of sediments from river floods
- Man-made canals
- Wave action on shorelines
- Faults activated by energy drillings
- Sea level rise (0.5-1 feet since 1930)
- Saltwater intrusion kills vegetation from above processes, enhancing erosion

Recent tropical cyclones (Georges, Ivan, Isidore, Lili, Katrina, Gustav) have accelerated erosion

Methodology

- 2007 grid; land removed, Port Sulphur to mouth of river; water 2 feet deep
- 1930 grid; land to barrier islands in same region, 3 feet above sea level





Map
Satellite
Terrain
Pointe A La Hache
Port Sulphur
Buras
Venice
Katrina_Wetland_TimeSeries(EmpireCenter)
2007
1930
2 feet difference;
Surge delayed
Storm_Surge_Height(Feet)
Time(UTC)
2005-08-28
2005-08-29
10 mi
10 km
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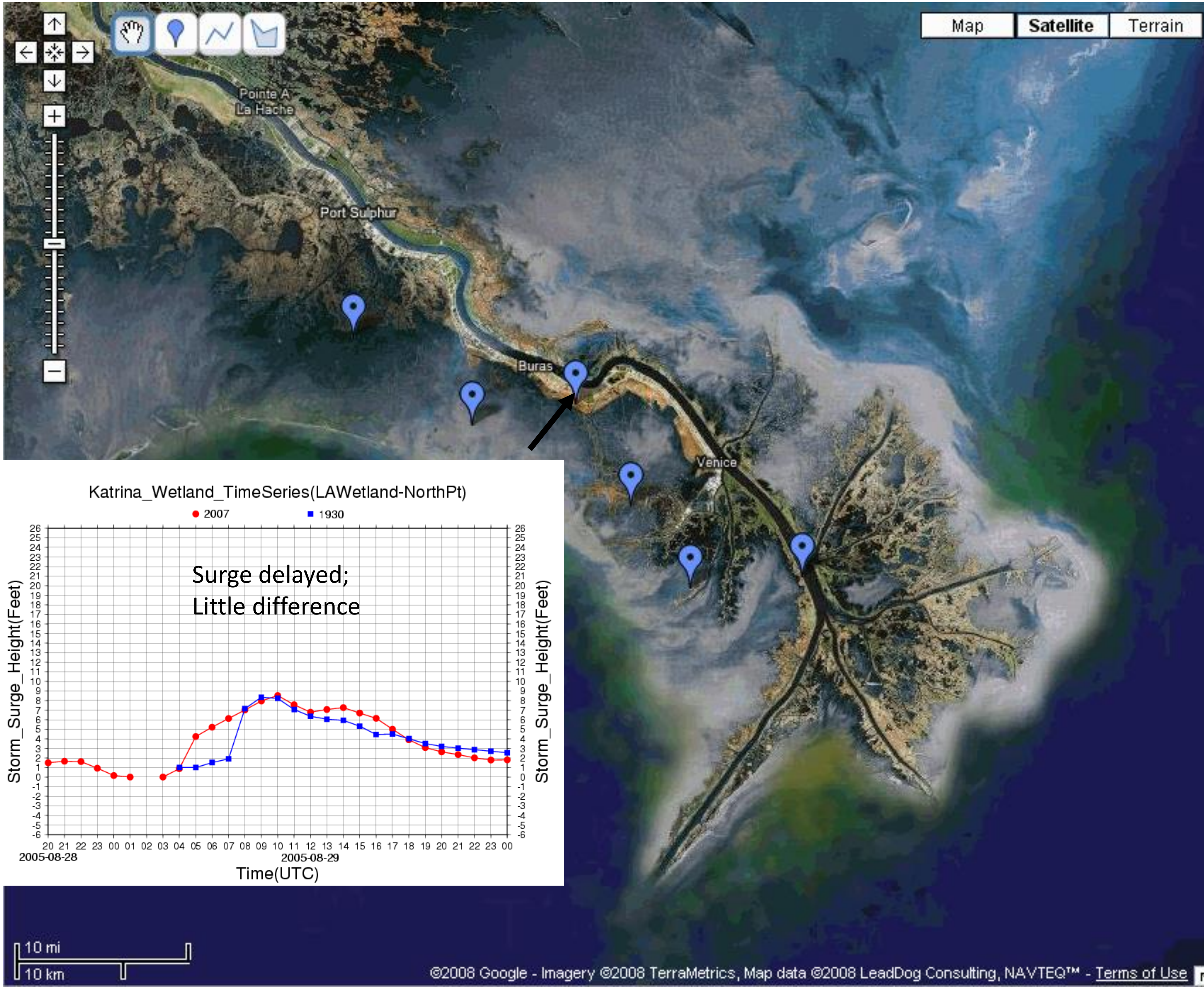

Map
Satellite
Terrain
Pointe A La Hache
Port Sulphur
Buras
Venice
Katrina_Wetland_TimeSeries(LAWetland-NorthPt)
2007
1930
Surge delayed;
Little difference
Storm_Surge_Height(Feet)
2005-08-28
2005-08-29
Time(UTC)
10 mi
10 km
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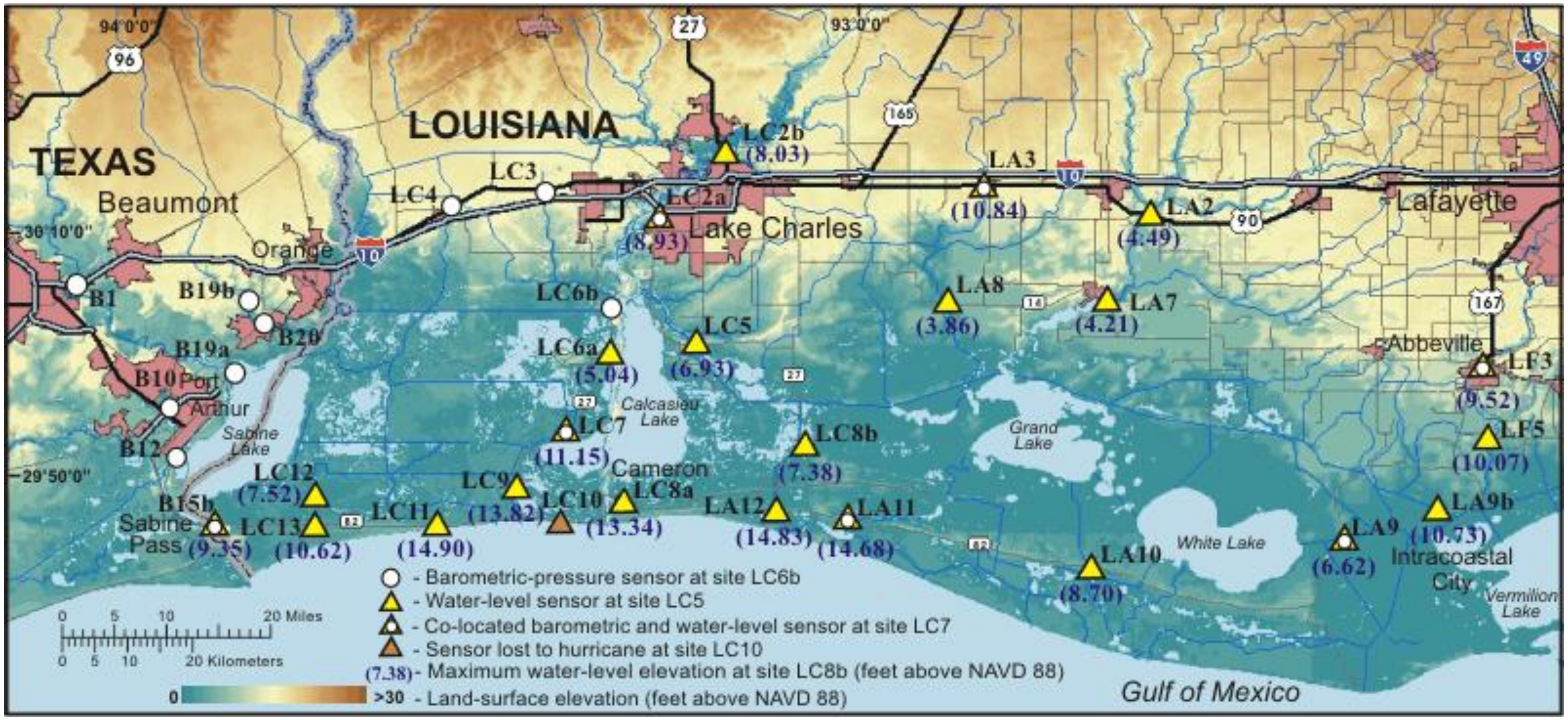
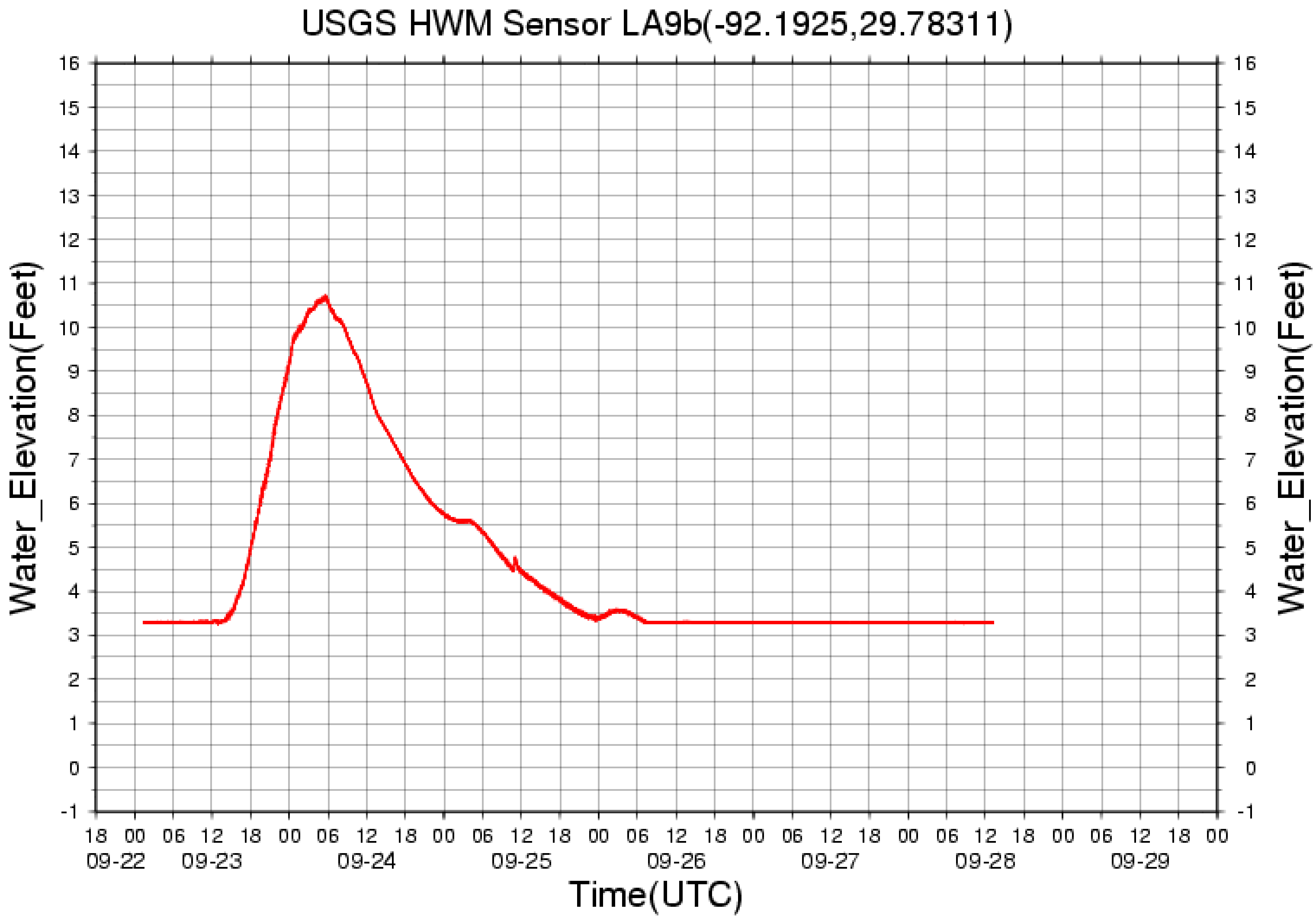
What do observations show about wetland attenuation?

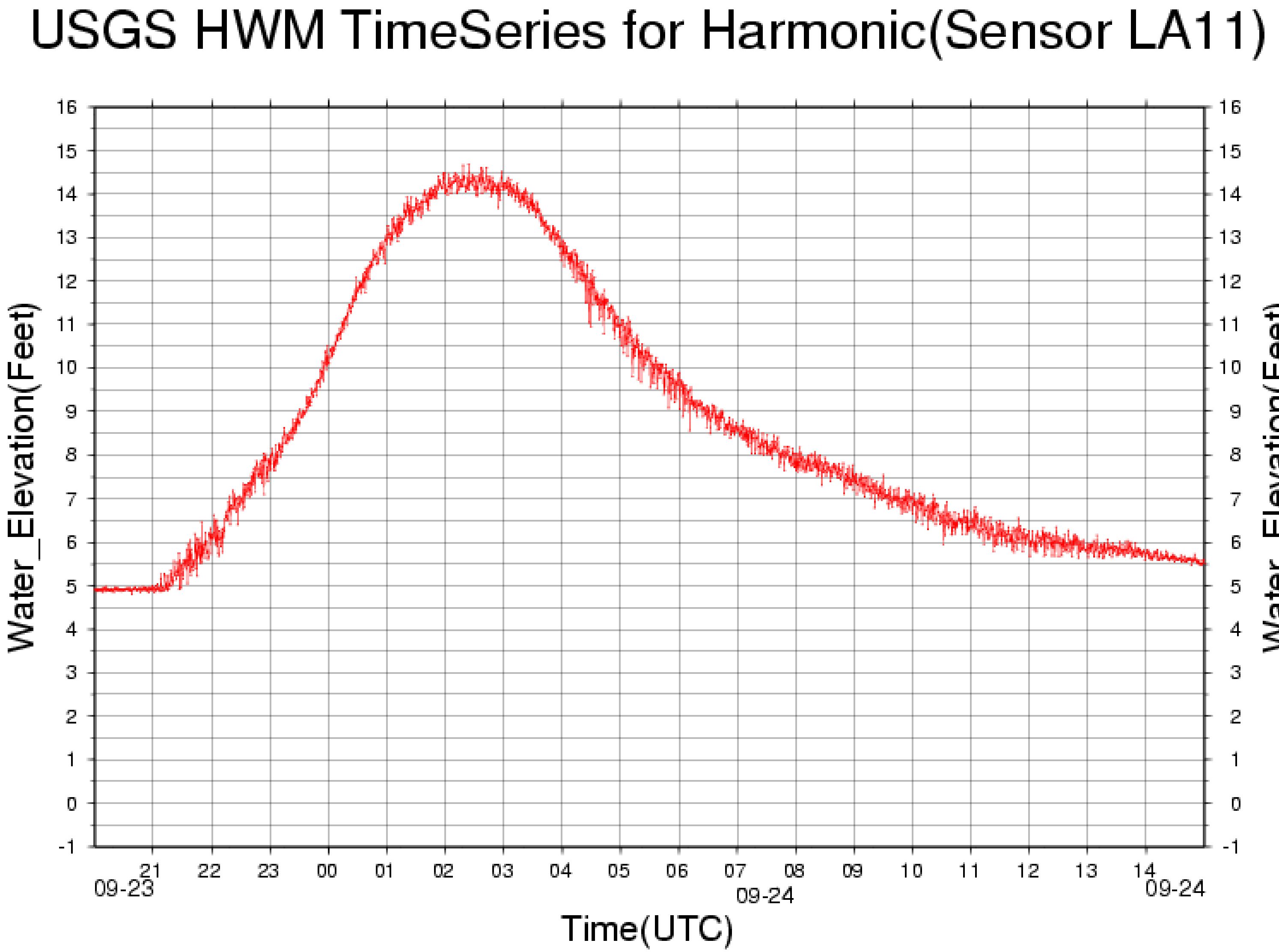


TEXAS
LOUISIANA
Beaumont
Orange
Port Arthur
Sabine Lake
Sabine Pass
Lake Charles
Calcasieu Lake
Cameron
Grand Lake
White Lake
Abbeville
Lafayette
Intracoastal City
Vermilion Lake
Gulf of Mexico
94°0'0"
93°0'0"
30°10'0"
29°50'0"
B1
B19b
B20
B19a
B10
B12
B15b (9.35)
LC2b (8.03)
LC2a (8.93)
LC3
LC4
LC5 (6.93)
LC6a (5.04)
LC6b
LC7 (11.15)
LC8a (13.34)
LC8b (7.38)
LC9 (13.82)
LC10
LC11 (14.90)
LC12 (7.52)
LC13 (10.62)
LA2 (4.49)
LA3 (10.84)
LA7 (4.21)
LA8 (3.86)
LA9 (6.62)
LA9b (10.73)
LA10 (8.70)
LA11 (14.68)
LA12 (14.83)
LF3 (9.52)
LF5 (10.07)
- Barometric-pressure sensor at site LC6b
- Water-level sensor at site LC5
- Co-located barometric and water-level sensor at site LC7
- Sensor lost to hurricane at site LC10
(7.38) - Maximum water-level elevation at site LC8b (feet above NAVD 88)
0 >30 - Land-surface elevation (feet above NAVD 88)
0 5 10 20 Miles
0 5 10 20 Kilometers

Pressure sensor strapped to a power pole at site LC4 near Vinton, La.



USGS HWM Sensor LA9b(-92.1925,29.78311)
Water_Elevation(Feet)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00
09-22
09-23
09-24
09-25
09-26
09-27
09-28
09-29
Time(UTC)



USGS HWM TimeSeries for Harmonic(Sensor LA11)
Water_Elevation(Feet)
Time(UTC)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
21
22
23
00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
09-23
09-24
09-24

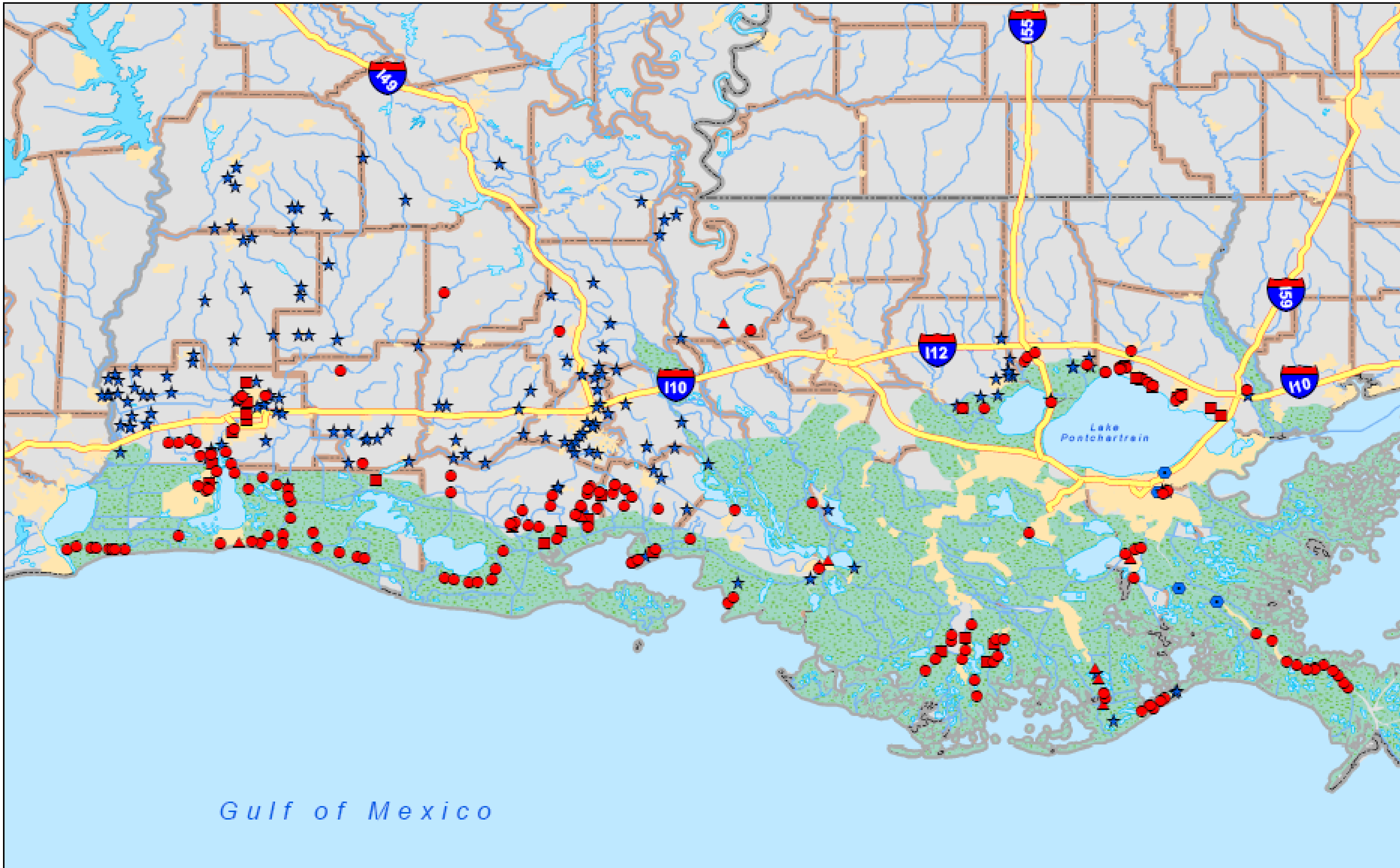
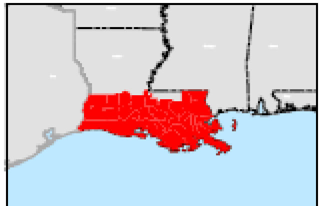


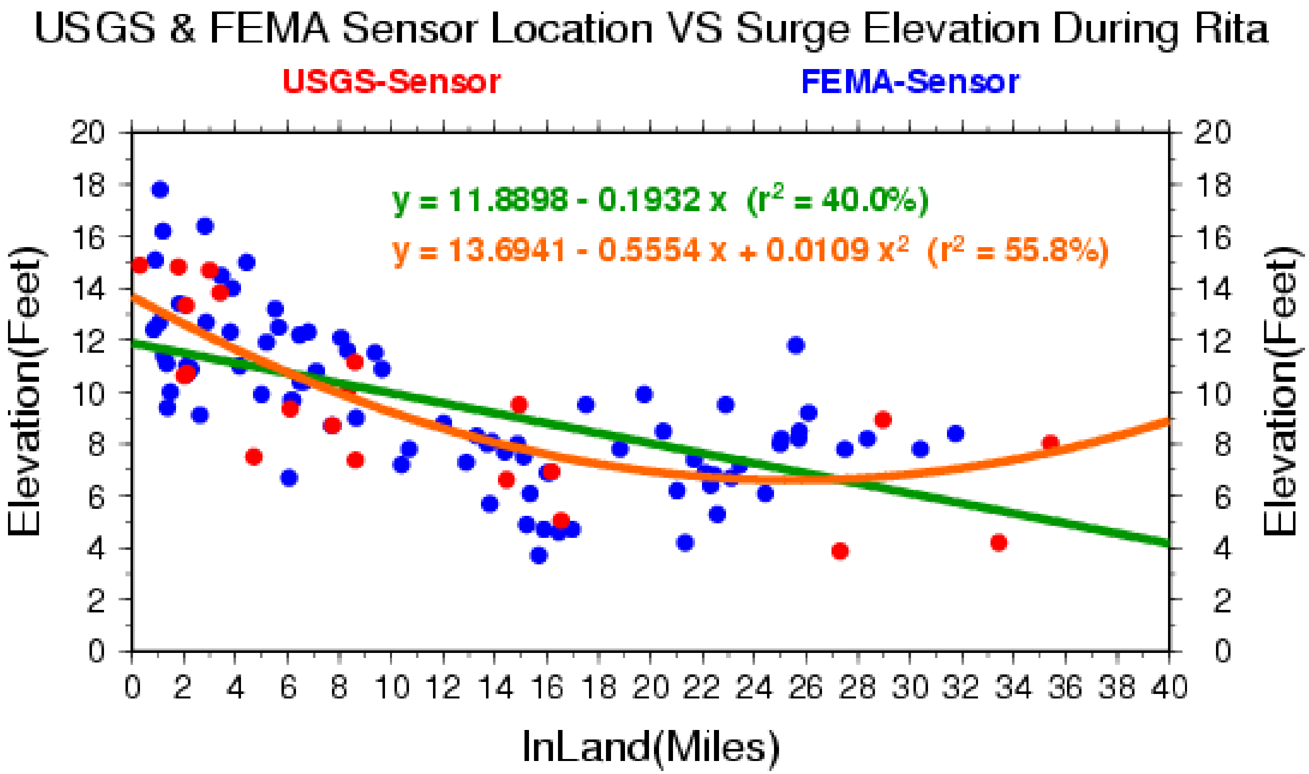
Figure 4 : Hurricane Rita, Louisiana
Surveyed Locations of High Water Mark Elevations



FEMA

Coastal- Surge Only
Coastal- Wave Height
Riverine
Inset
Municipalities
Water Body
Hydrology
Road Classification
Limited Access

0 3.5 7 14 21 28
Miles



1 foot reduction every 2 miles seven miles inland (1.4 ft per 2.75 miles)

0.5-0.8 foot reduction every 2 miles afterwards

Multiple regression results: R^2=59.5%

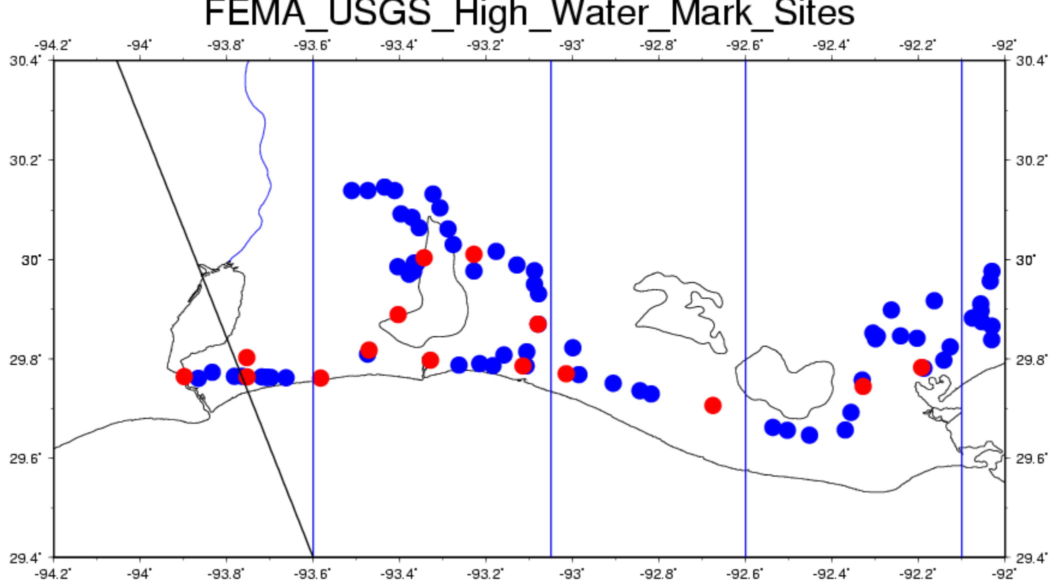
Variable	Normalized coefficient	P value
Distance	-1.43	0.0000
Surge-elevation	0.26	0.0023
Distance squared	1.00	0.0000

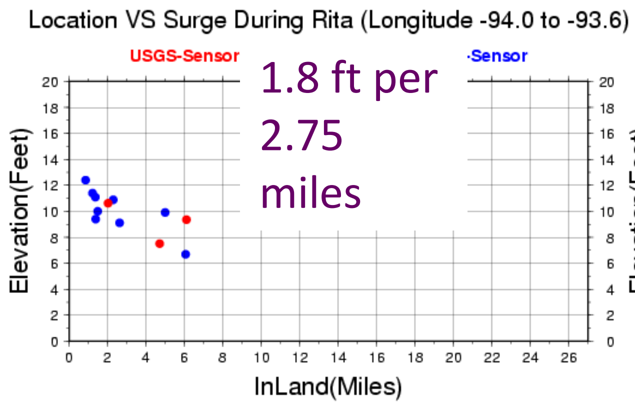
r for distance and distance squared is 0.95. Highly correlated, but necessary to make the regression residuals normally distributed.

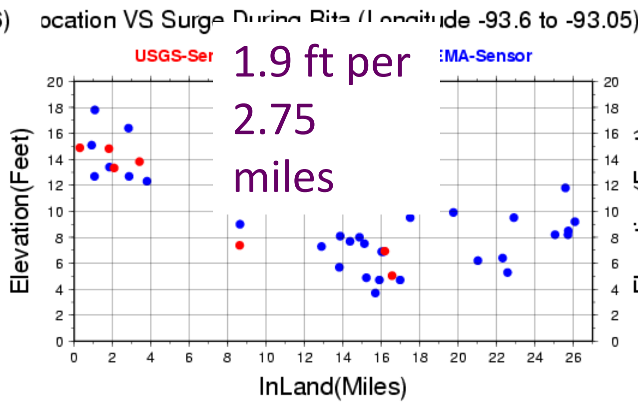
This means the distance normalized coefficient is actually -0.43 (-1.43 + 1.00). This represents the influence of the dissipative effects of the wetlands.

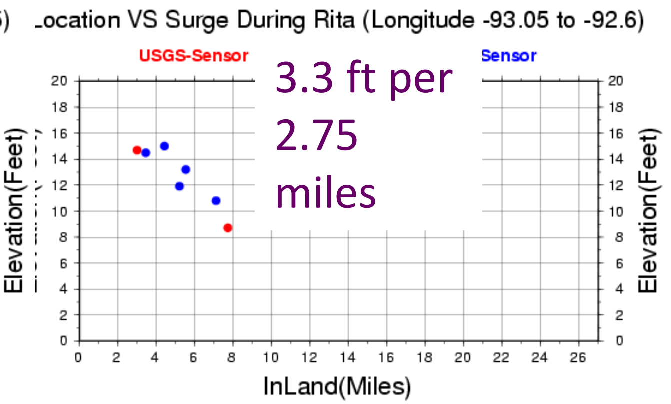
The elevation is 40% less influential than dissipative effects with a normalized coefficient of 0.26. This indicates the impact of subsidence.

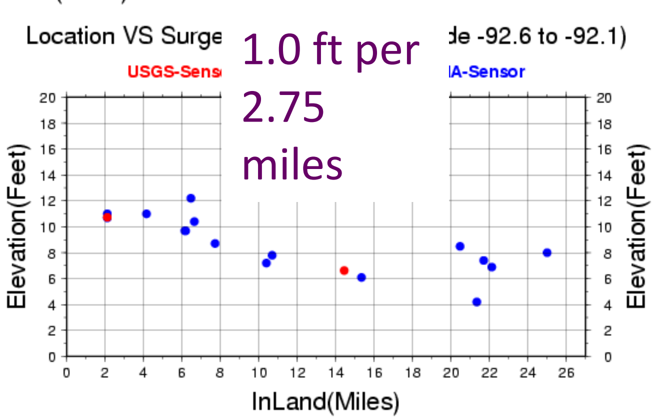
Nonlinear multiple regression was also tried with a variety of function types, but the explained variance did not increase.

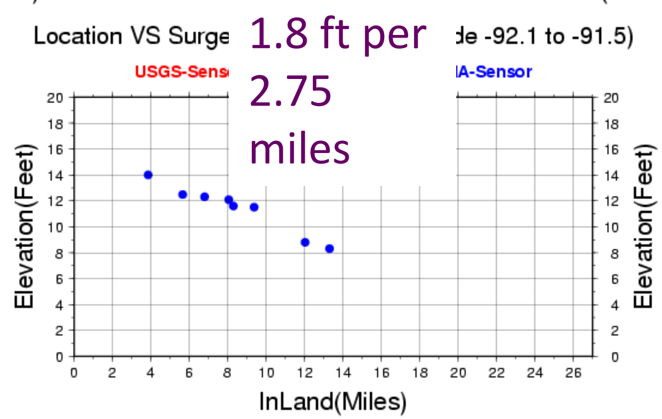

FEMA_USGS_High_Water_Mark_Sites


Location VS Surge During Rita (Longitude -94.0 to -93.6)
USGS-Sensor
Sensor
1.8 ft per
2.75
miles
Elevation(Feet)
InLand(Miles)

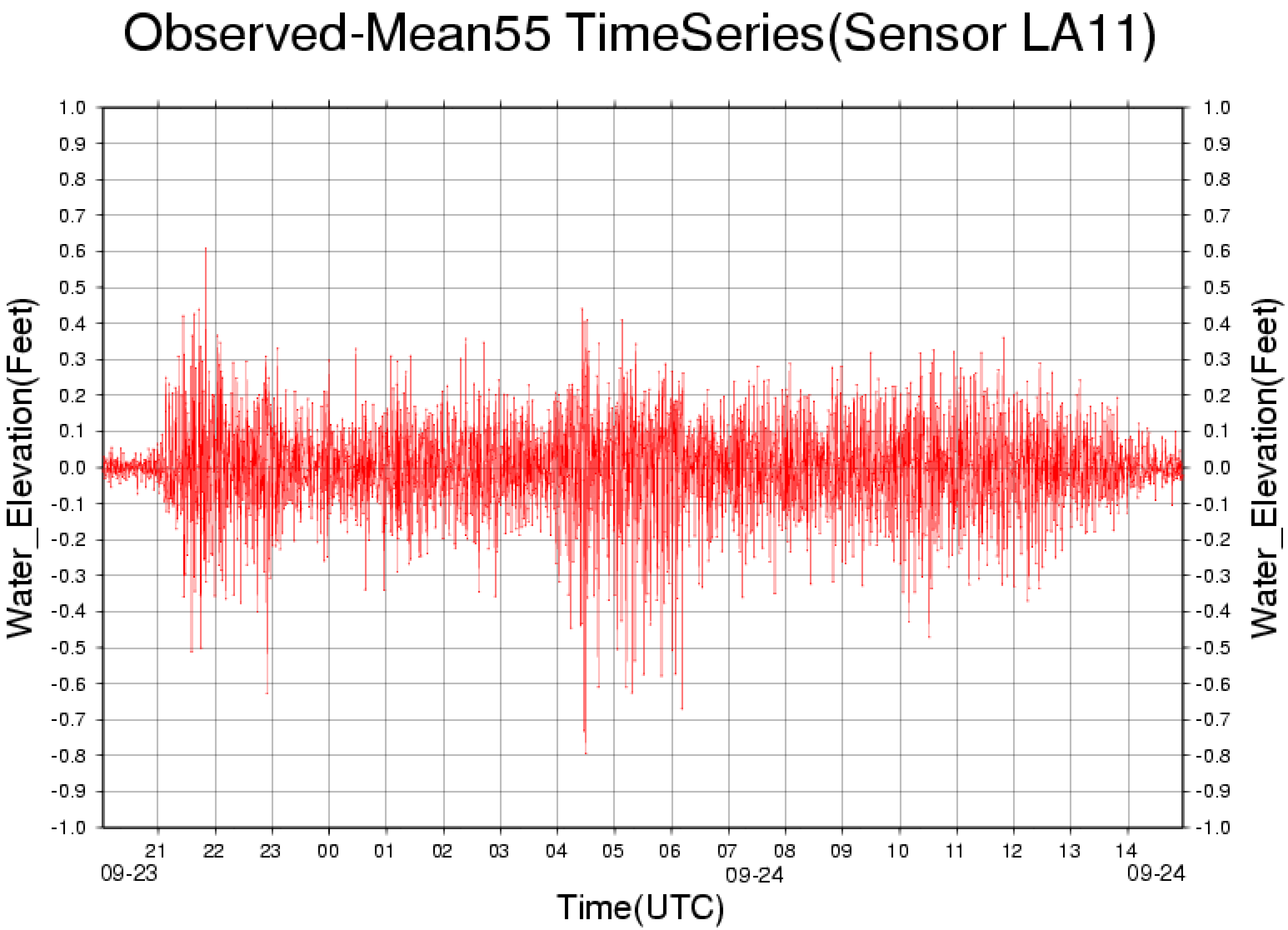

USGS-Ser
1.9 ft per
2.75
miles
EMA-Sensor
Elevation(Feet)
InLand(Miles)


USGS-Sensor
3.3 ft per
2.75
miles
Sensor
Elevation(Feet)
InLand(Miles)

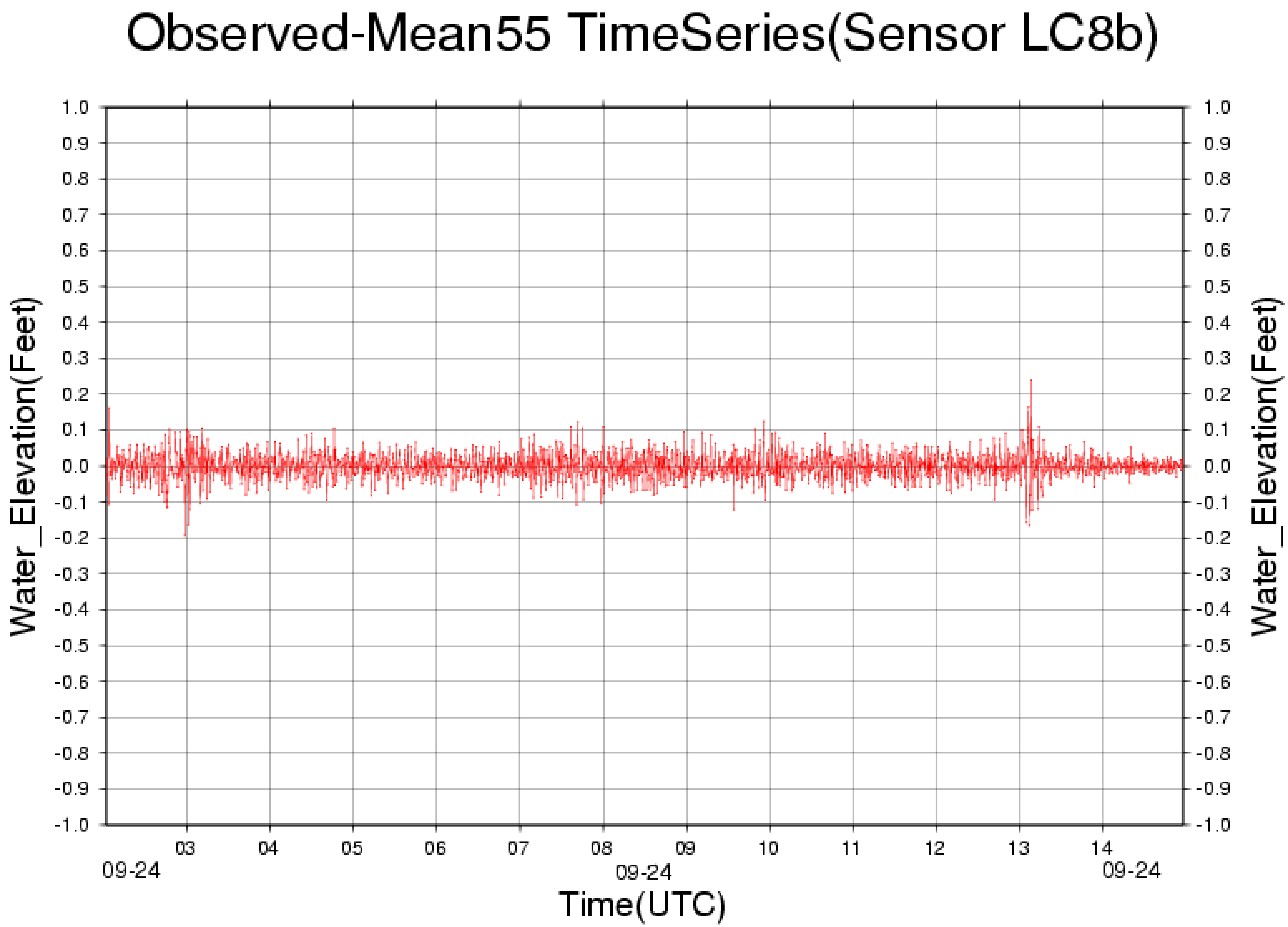

Location VS Surge
1.0 ft per
2.75
miles
de -92.6 to -92.1)
USGS-Sens
IA-Sensor
Elevation(Feet)
InLand(Miles)


Location VS Surge
1.8 ft per
2.75
miles
de -92.1 to -91.5)
USGS-Sens
IA-Sensor
Elevation(Feet)
InLand(Miles)

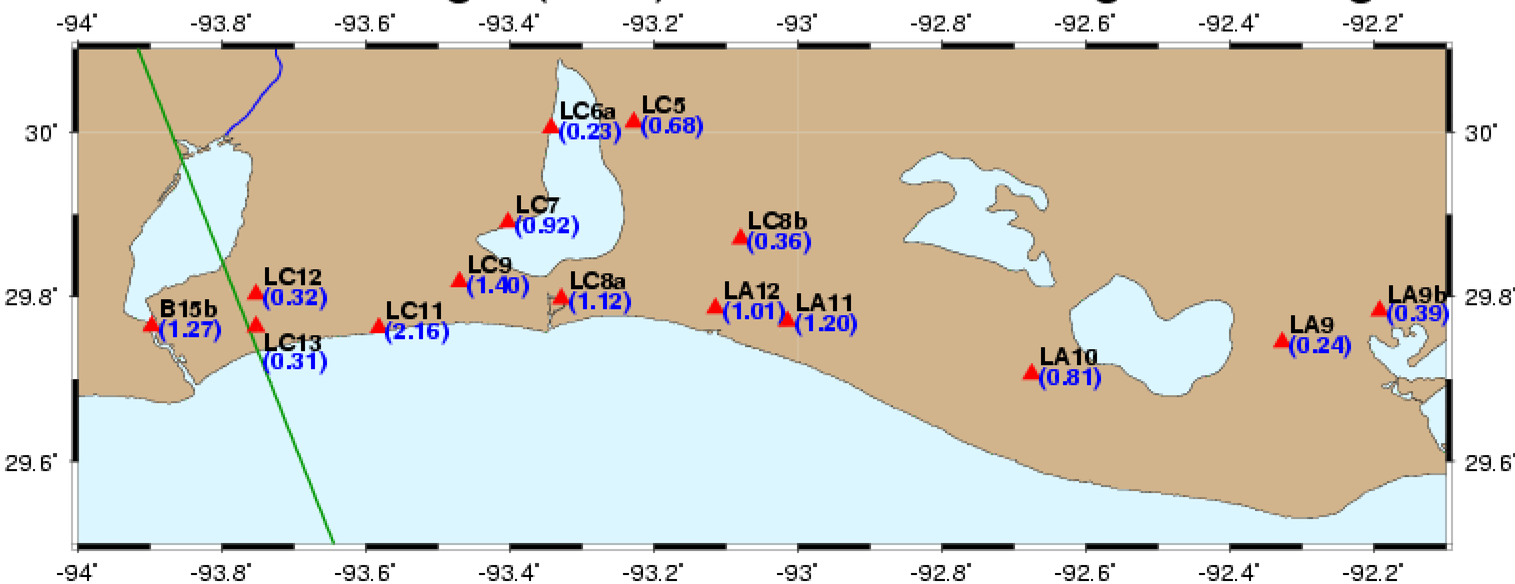
Reduction of waves on storm surge by wetlands



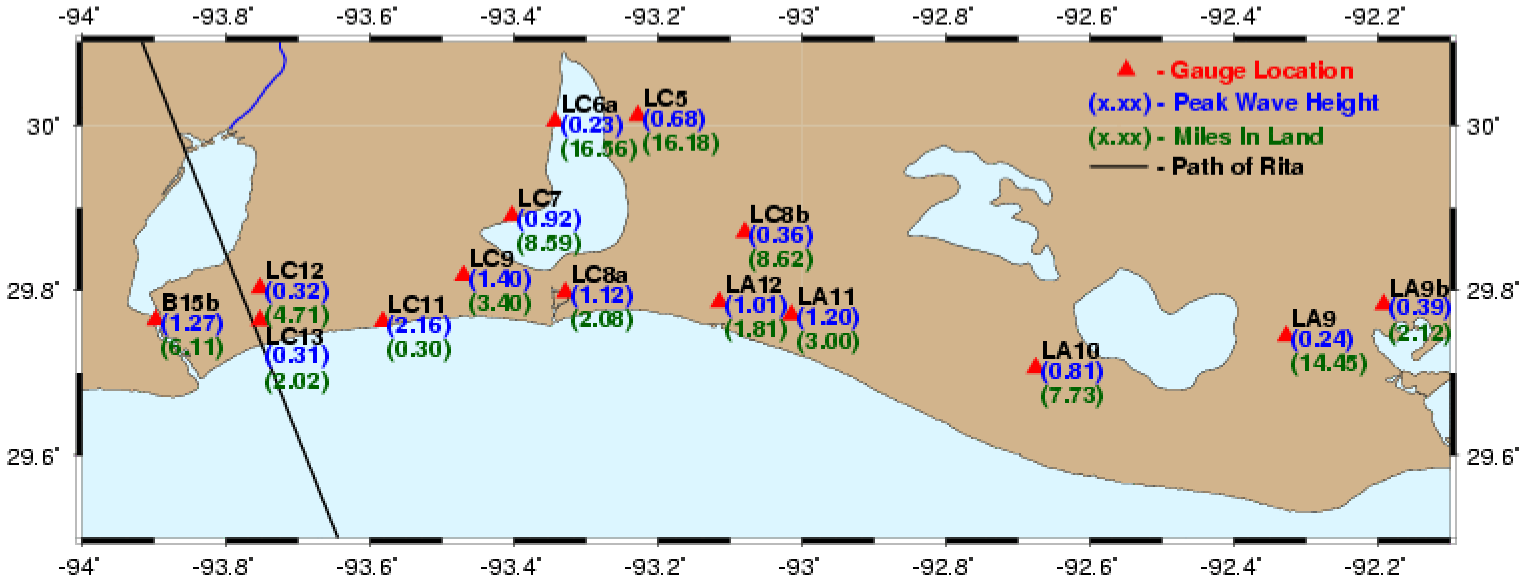
Observed-Mean55 TimeSeries(Sensor LA11)
Water_Elevation(Feet)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
21 22 23 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
09-23
09-24
09-24
Time(UTC)

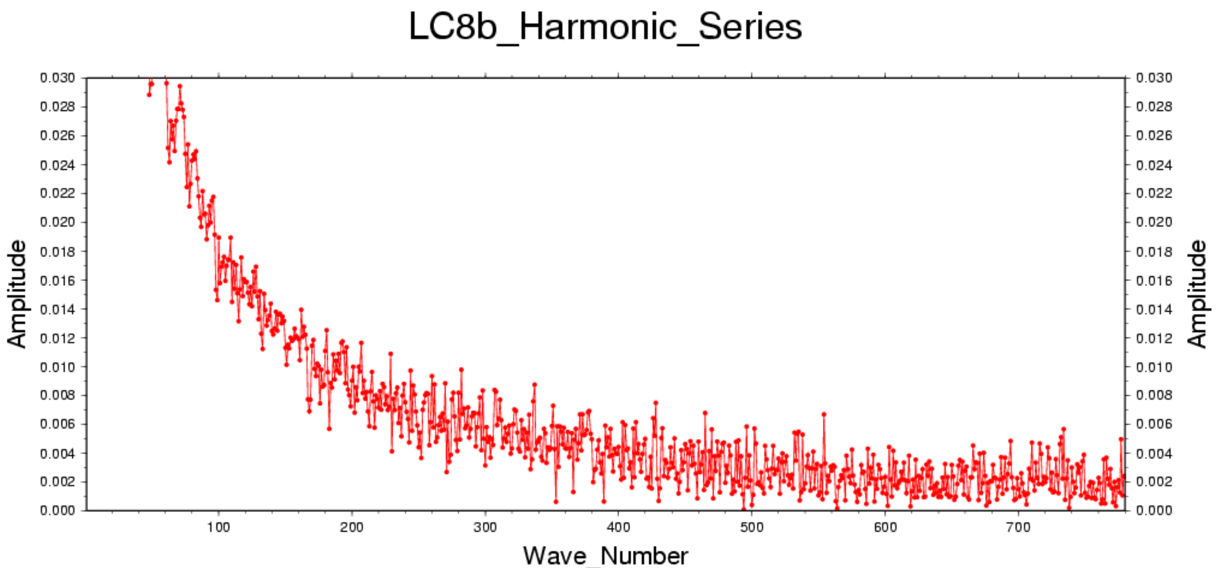

Observed-Mean55 TimeSeries(Sensor LC8b)
Water_Elevation(Feet)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
03
04
05
06
07
08
09
10
11
12
13
14
09-24
09-24
09-24
Time(UTC)

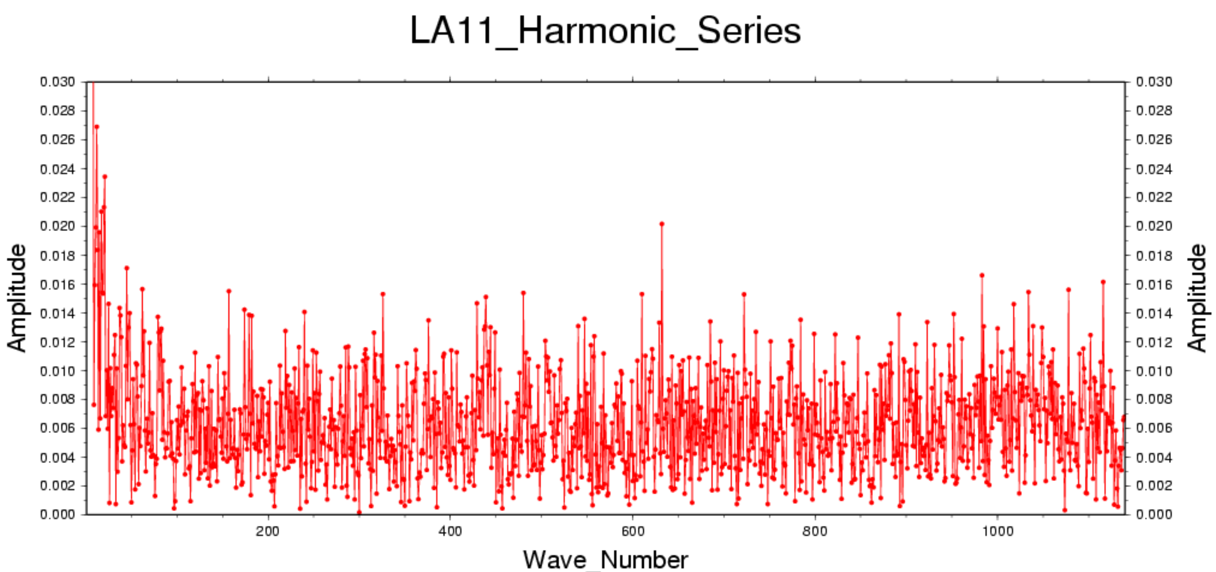
Peak Wave Height(feet) for USGS Gauges during Rita



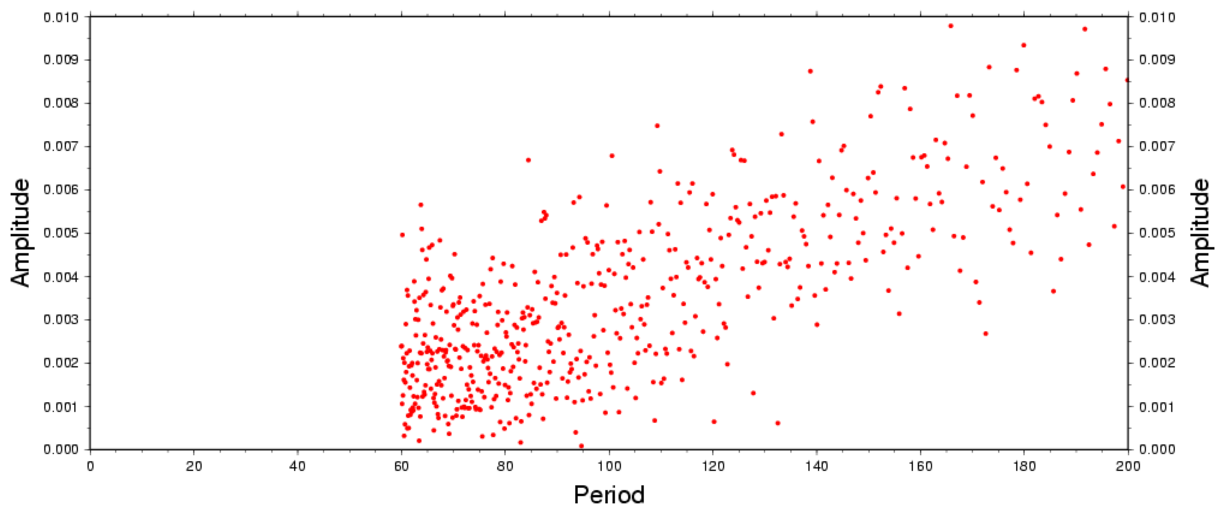
USGS HWM Gauges during Rita



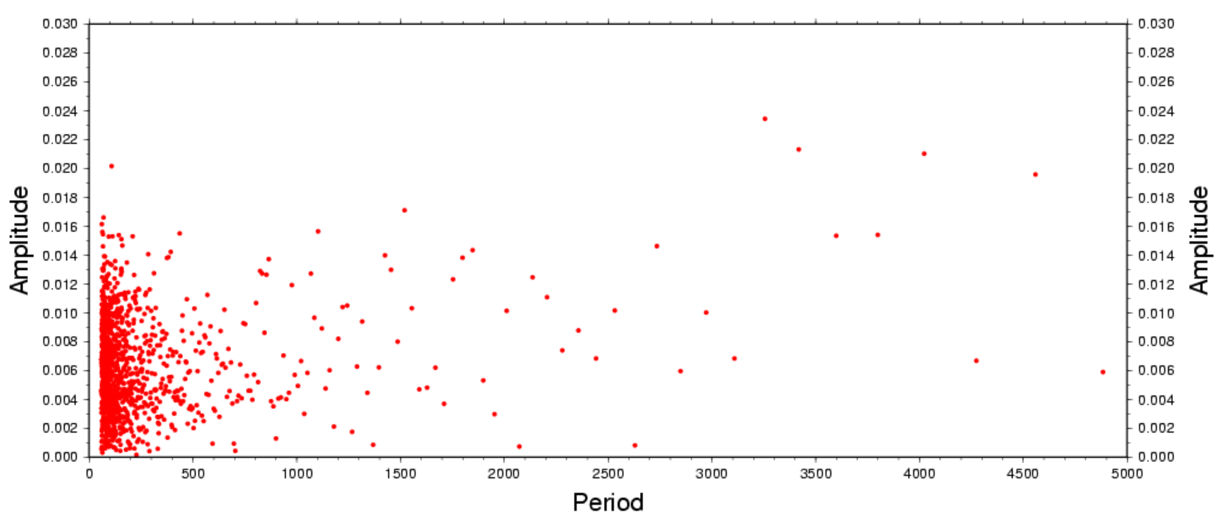

LC8b_Harmonic_Series
Amplitude
Wave_Number
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
100
200
300
400
500
600
700

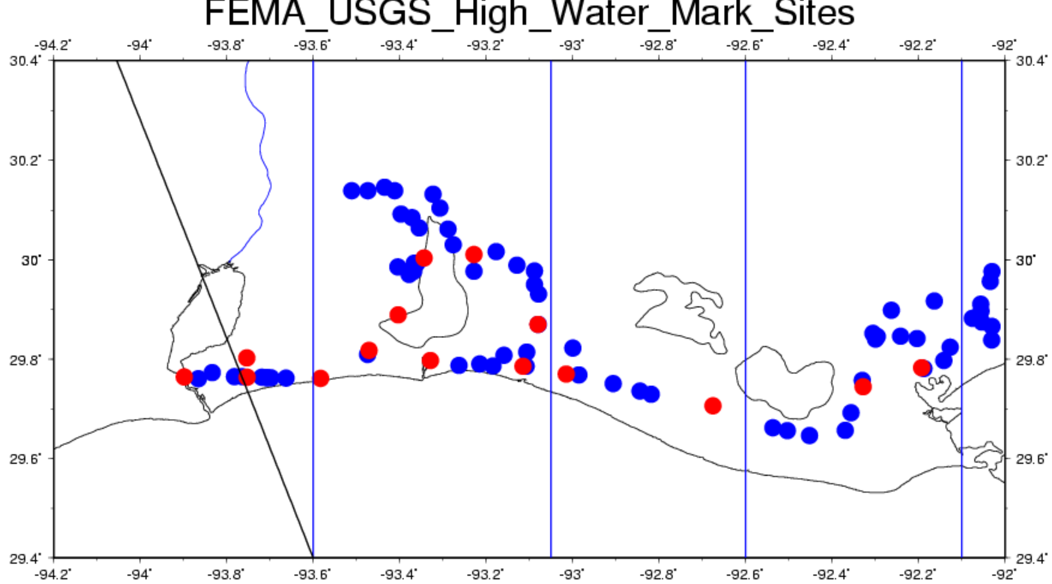

LA11_Harmonic_Series
Amplitude
Wave_Number
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
200
400
600
800
1000

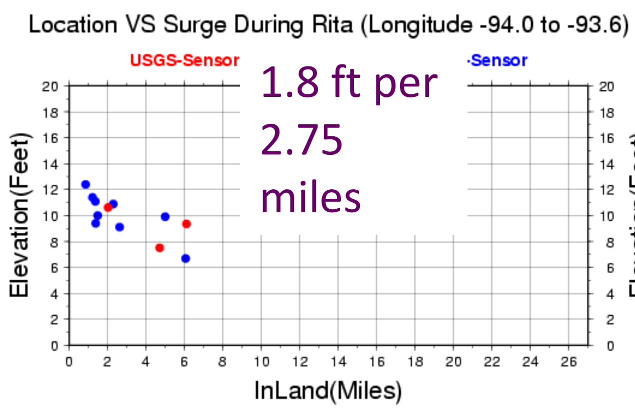
LC8b_Harmonic_Series

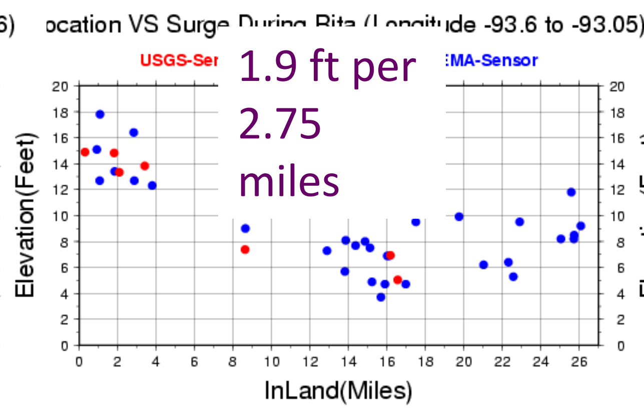


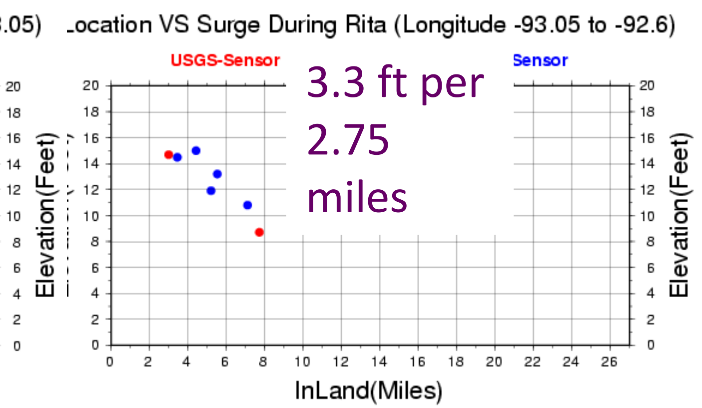
LA11_Harmonic_Series

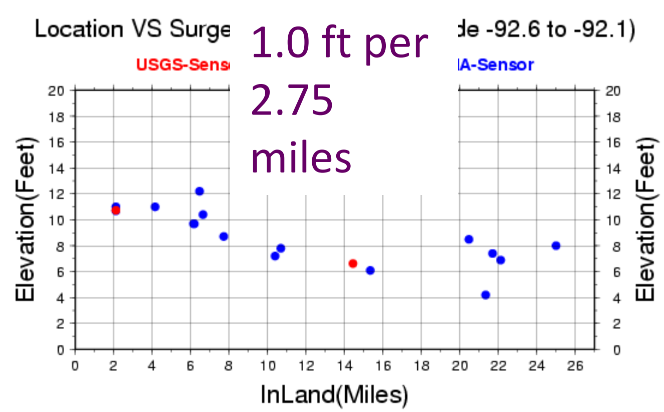


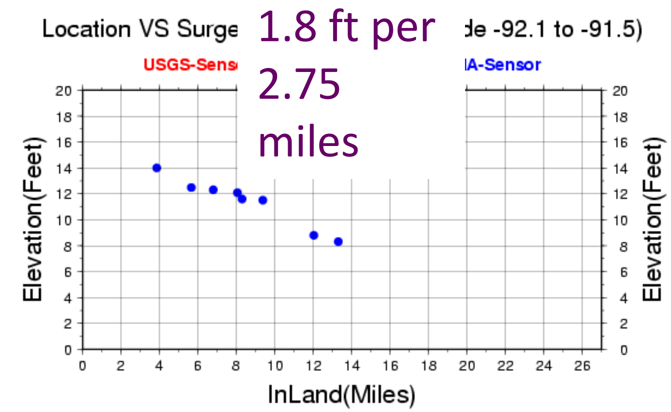

FEMA_USGS_High_Water_Mark_Sites
-94.2˚ -94˚ -93.8˚ -93.6˚ -93.4˚ -93.2˚ -93˚ -92.8˚ -92.6˚ -92.4˚ -92.2˚ -92˚
30.4˚ 30.2˚ 30˚ 29.8˚ 29.6˚ 29.4˚


Location VS Surge During Rita (Longitude -94.0 to -93.6)
USGS-Sensor
-Sensor
1.8 ft per
2.75
miles
Elevation(Feet)
InLand(Miles)

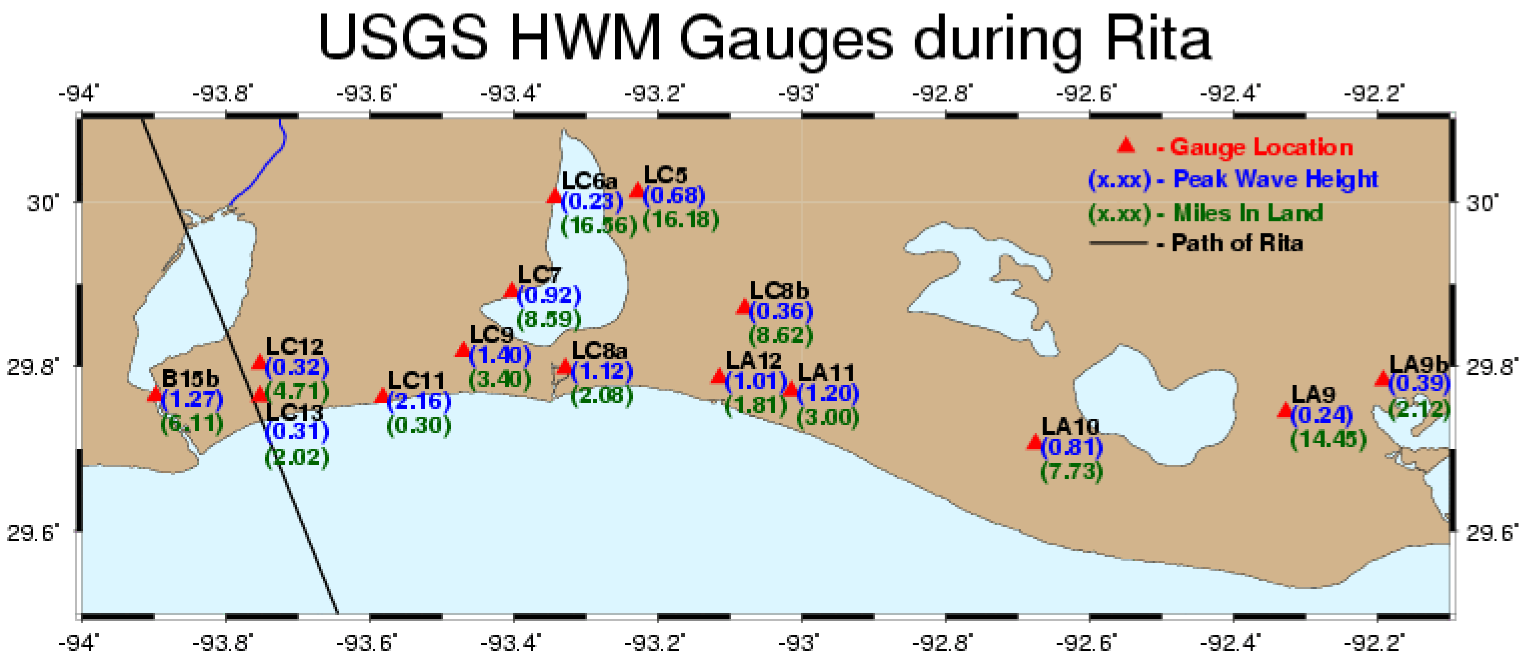

ocation VS Surge During Rita (Longitude -93.6 to -93.05)
USGS-Ser
EMA-Sensor
1.9 ft per
2.75
miles
Elevation(Feet)
InLand(Miles)


ocation VS Surge During Rita (Longitude -93.05 to -92.6)
USGS-Sensor
Sensor
3.3 ft per
2.75
miles
Elevation(Feet)
InLand(Miles)


Location VS Surge
de -92.6 to -92.1)
USGS-Sens
A-Sensor
1.0 ft per
2.75
miles
Elevation(Feet)
InLand(Miles)


Location VS Surge
de -92.1 to -91.5)
USGS-Sens
A-Sensor
1.8 ft per
2.75
miles
Elevation(Feet)
InLand(Miles)

Wave height reduction significant, though



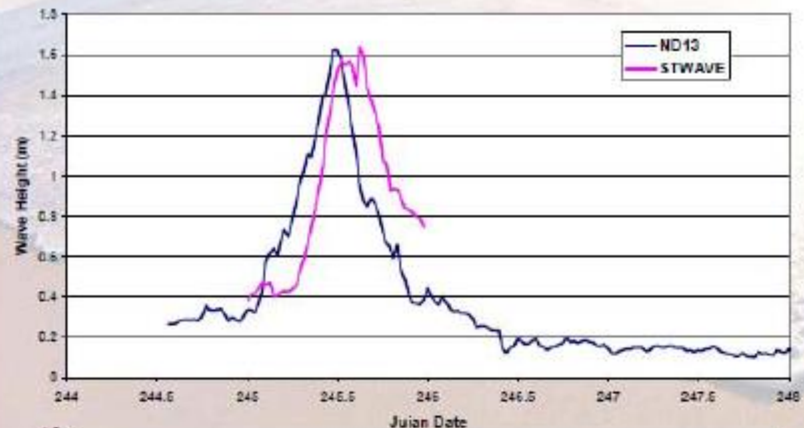
LC8b reduced 64-70% 5.5-6.8 miles inland (compared to LA12 and LA11)
LC8a reduced 48% 1.8 miles inland (compared to LC11)
LC9 reduced 36% 3.1 miles inland (compared to LC11)

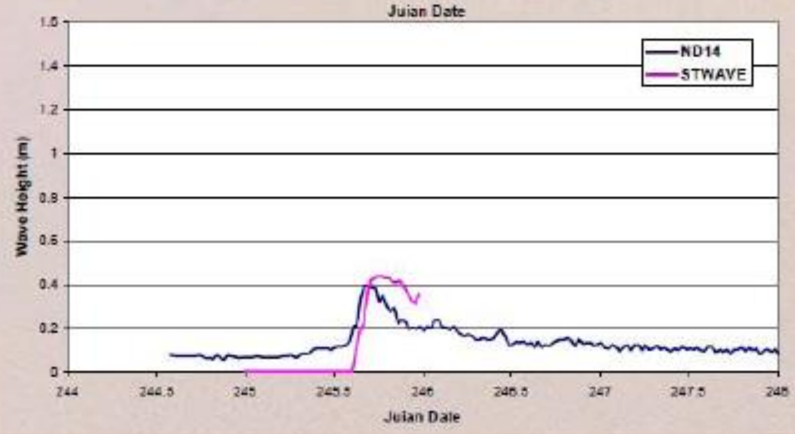
System Validation - Waves

Gustav

STWAVE Results: Comparison to Data; UND

Caernarvon Marsh





Outer Caernarvon Marsh

Hmax = 1.5 m (4.9 ft)

Note: Based on preliminary wind fields

Inner Caernarvon Marsh

Hmax = 0.4 m (1.3 ft)

Slide provided by Chris Bender