Storm surge fundamentals

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- Basics
- Models
- "100-year" surge events

One hundred year level of protection means reducing risk from a storm surge that has a 1% chance of being equaled or exceeded in any given year.

Based on the combined chances of a storm of a certain size and intensity following a certain track. Different combinations of size, intensity and track can result in a 100-year surge event.

Also called a 100-year return period.

Bad term, since the probability of a 100-year surge event occurring in 30 years (the lifetime of avg mortgage) is 26%

Fundamental surge components

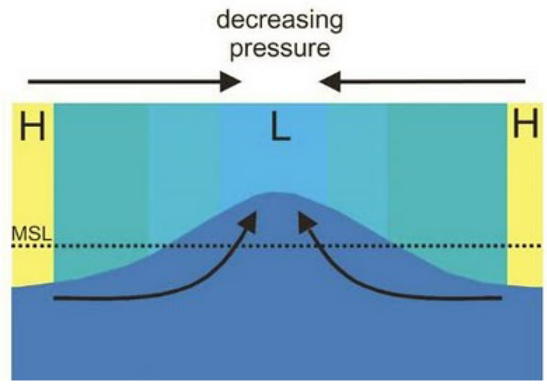
- Pressure setup - *increase in water level due to lower atmospheric pressure in storm interior.* A slight surface bulge occurs within the storm, greatest at the storm's center, decreasing at the storm's periphery. For every 10-mb pressure drop, water expands 3.9 inches.
  - *Effect is a constant*

- Wind setup - *increase in water level due to the force of the wind on the water.* As the transported water reaches shallow coastlines, bottom friction slows their motion, causing water to pile up. Further enhanced near land boundaries.
  - *Depends on bathymetry, size, and intensity. MOST IMPORTANT IN TERMS OF MAGNITUDE!*

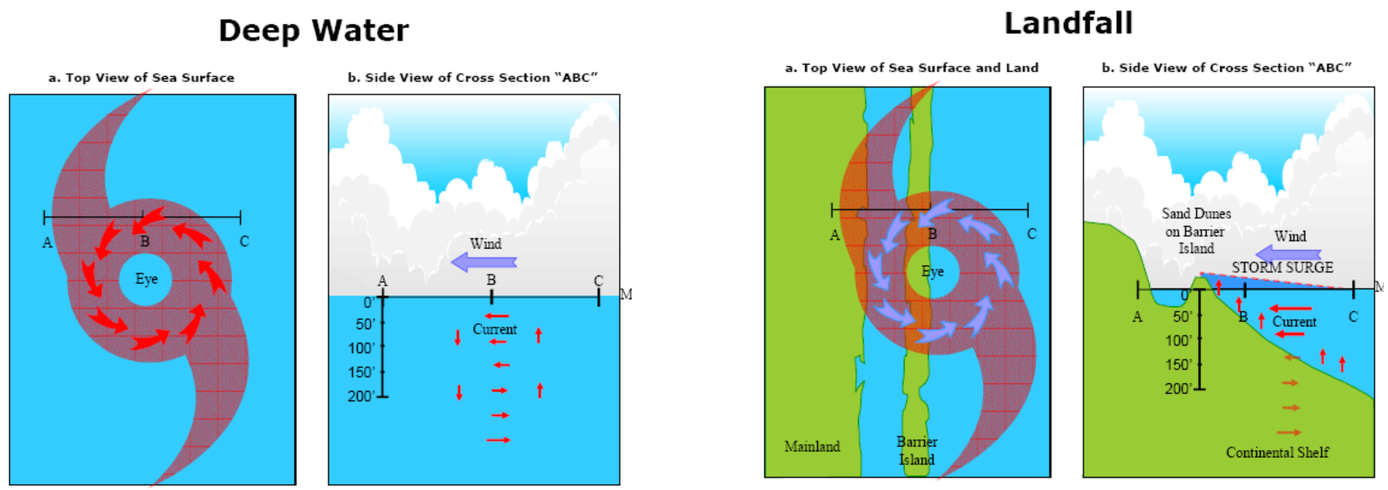
- Geostrophic adjustment – *water levels adjust to a developing longshore current.*
  - *Impact increases for slow-moving tropical cyclones*
  - *Impact increases for larger tropical cyclones*
  - *Causes a storm surge "forerunner"*

- Wave setup - *increase due to onshore waves.* Incoming water from wave breaking exceeds retreating water after wave runup.
  - *Impact minor in shallow bathymetry (0.5-1 ft); may contribute up to 3 ft surge in deep bathymetry (still the subject of debate)*

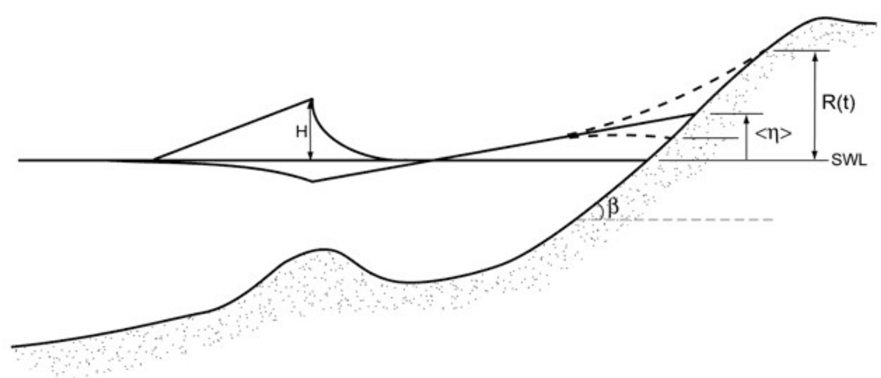
Pressure setup



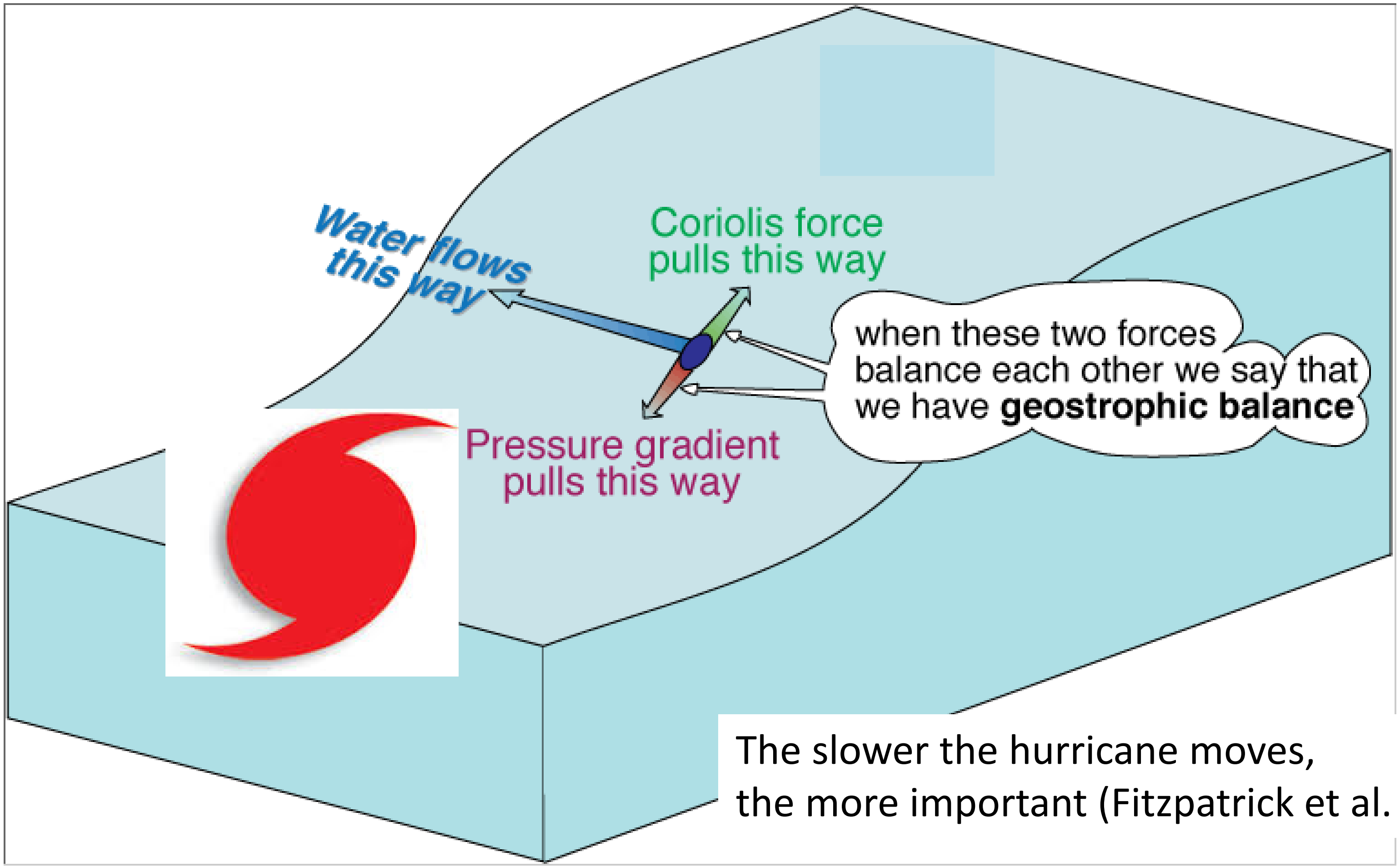
Wind setup



Wave setup



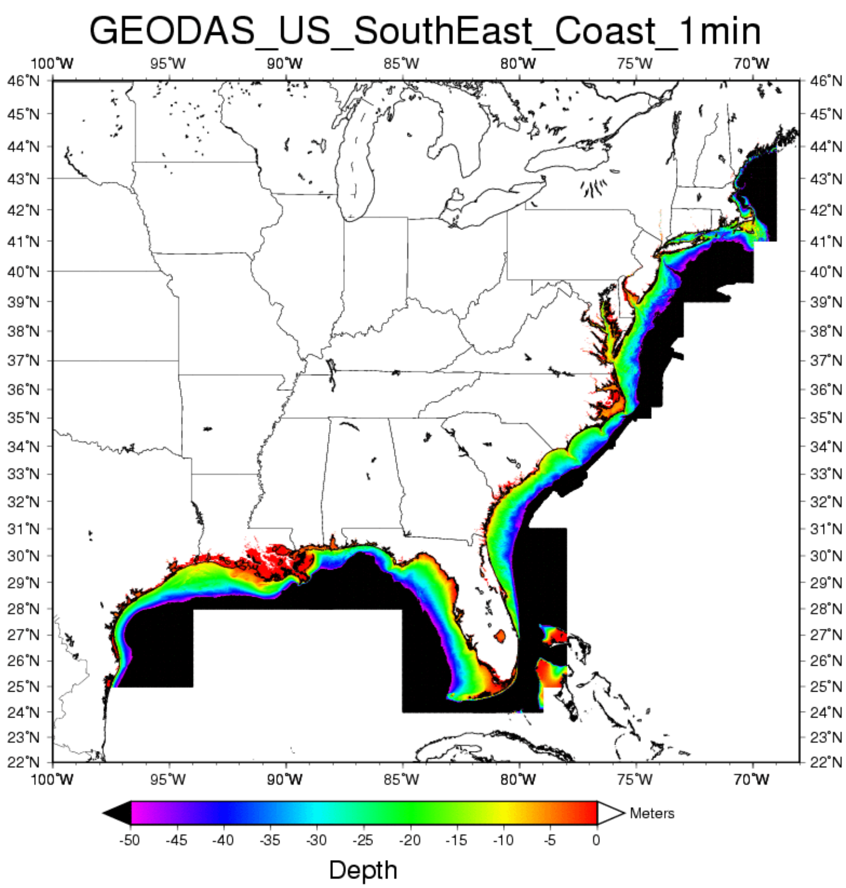
Geostrophic adjustment (creates surge "forerunner")

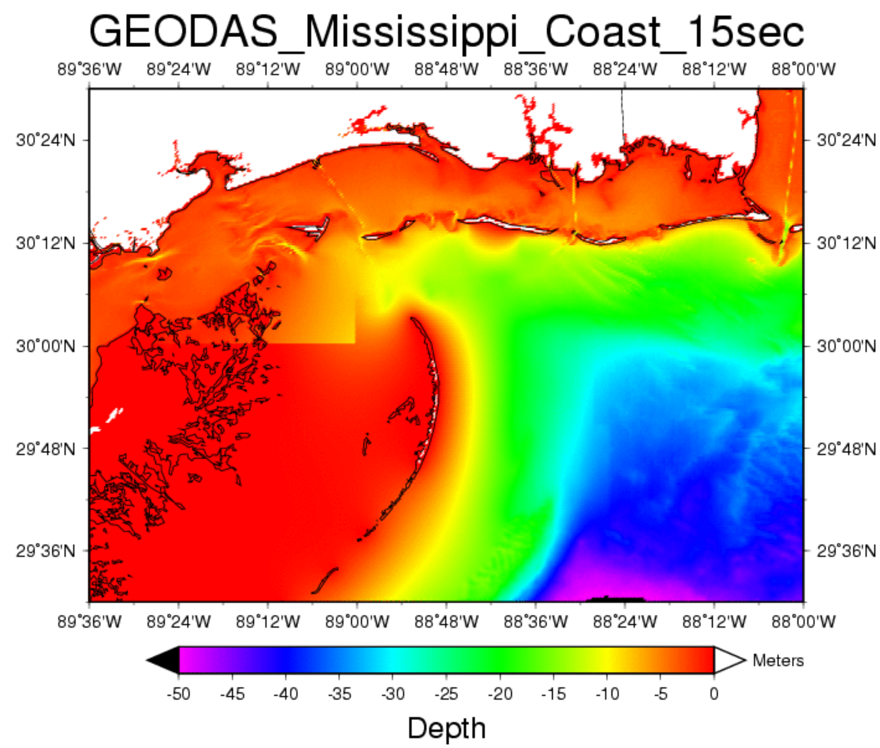


The slower the hurricane moves, the more important (Fitzpatrick et al. 2012)

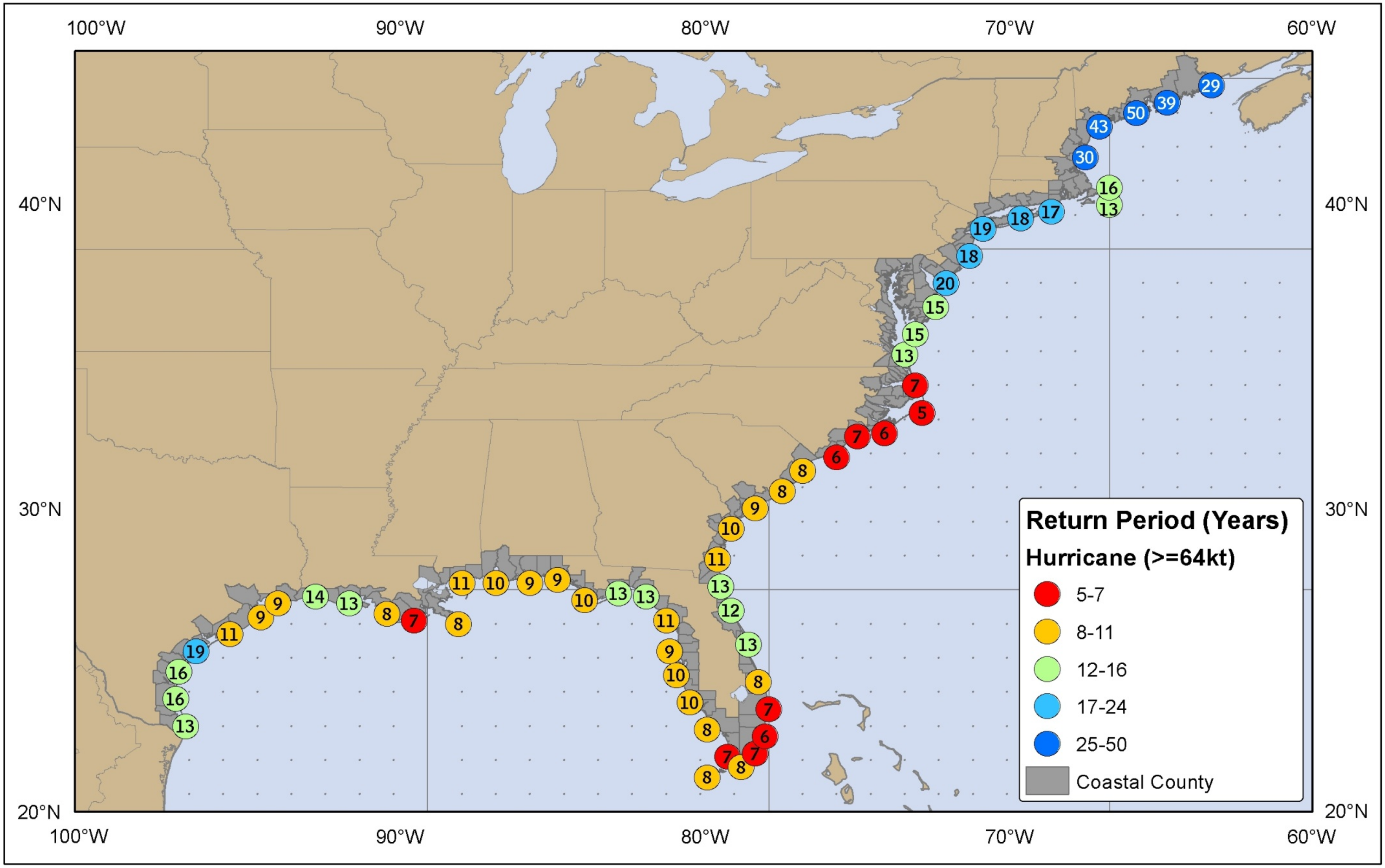
The balance between pressure gradient forces and Coriolis forces on a parcel of water is what we call geostrophic balance.

http://www.seos-project.eu/modules/oceancurrents/oceancurrents-c06-s02-p01.html


GEODAS_US_SouthEast_Coast_1min
100°W
95°W
90°W
85°W
80°W
75°W
70°W
46°N
45°N
44°N
43°N
42°N
41°N
40°N
39°N
38°N
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N
28°N
27°N
26°N
25°N
24°N
23°N
22°N
Meters
-50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0
Depth

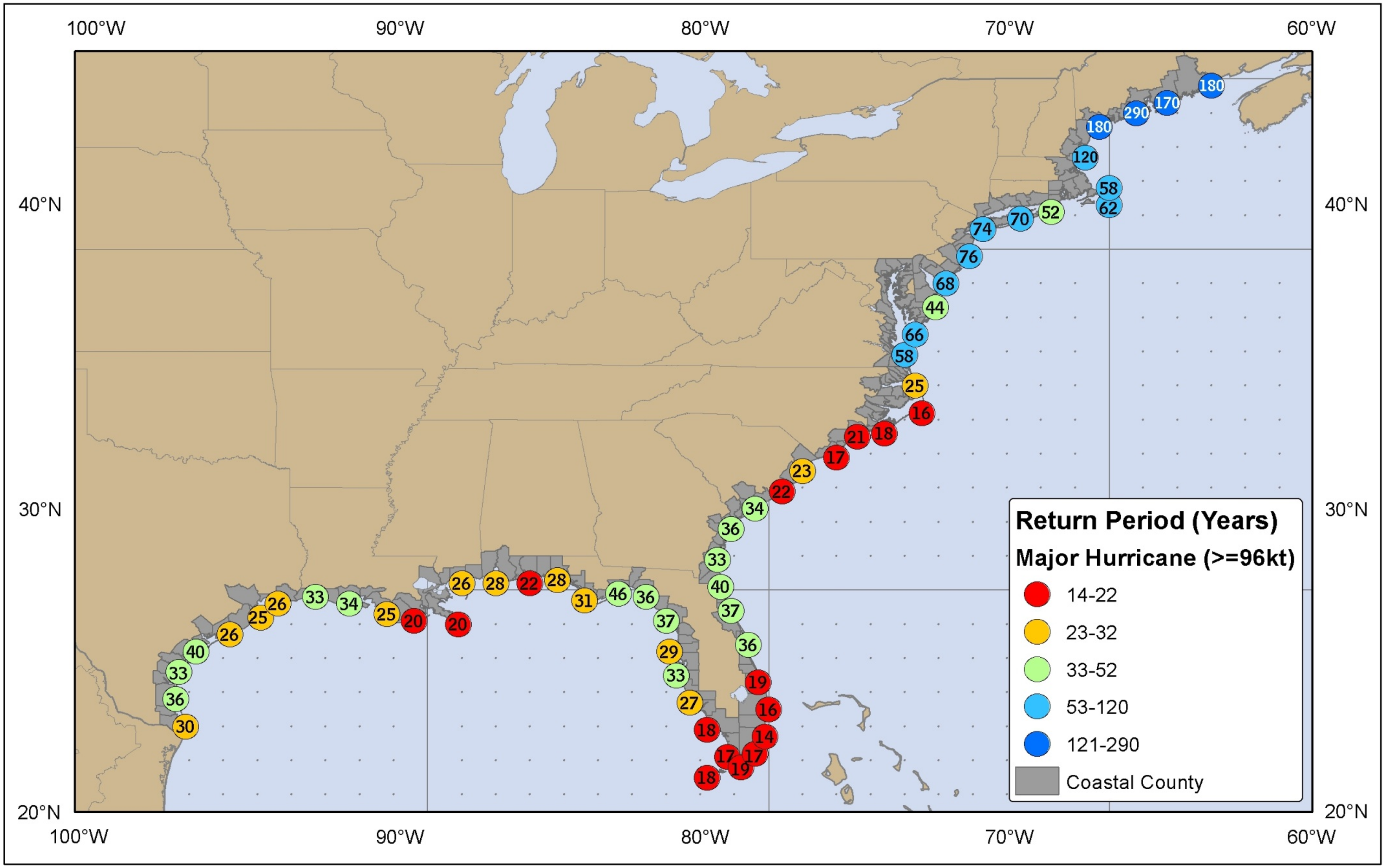

GEODAS_Mississippi_Coast_15sec
89°36'W
89°24'W
89°12'W
89°00'W
88°48'W
88°36'W
88°24'W
88°12'W
88°00'W
30°24'N
30°12'N
30°00'N
29°48'N
29°36'N
Meters
-50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0
Depth

Return periods, U.S. hurricanes



From http://www.nhc.noaa.gov/climo/, data based on 1900-2010

Return periods, U.S. major hurricanes



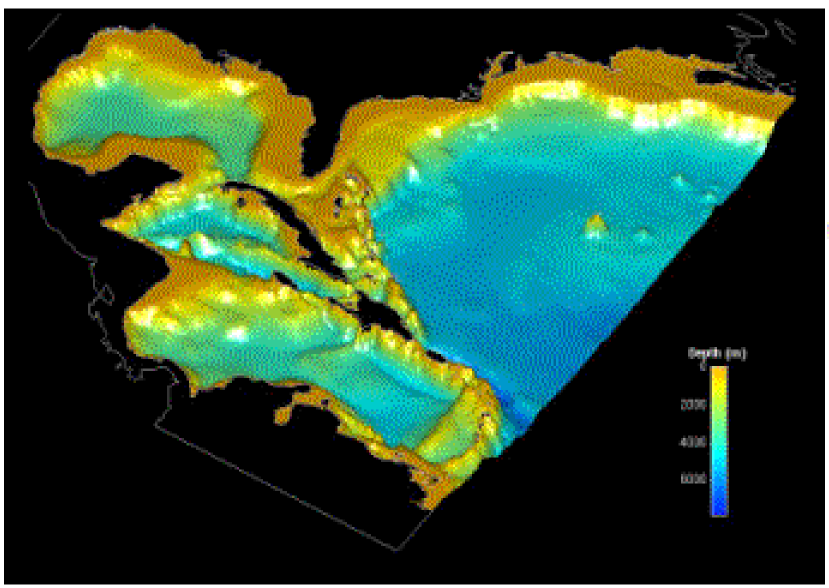
From http://www.nhc.noaa.gov/climo/, data based on 1900-2010

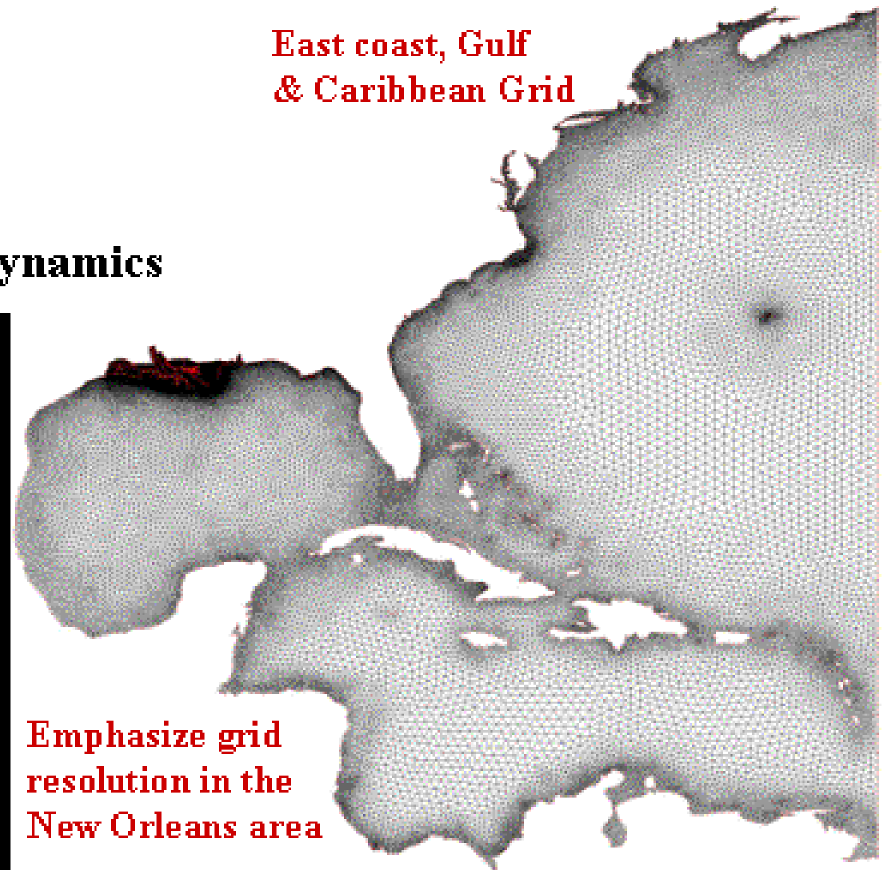
ADCIRC Storm Surge Implementation

Simulation of coastal regions – **Large Domain Strategy**

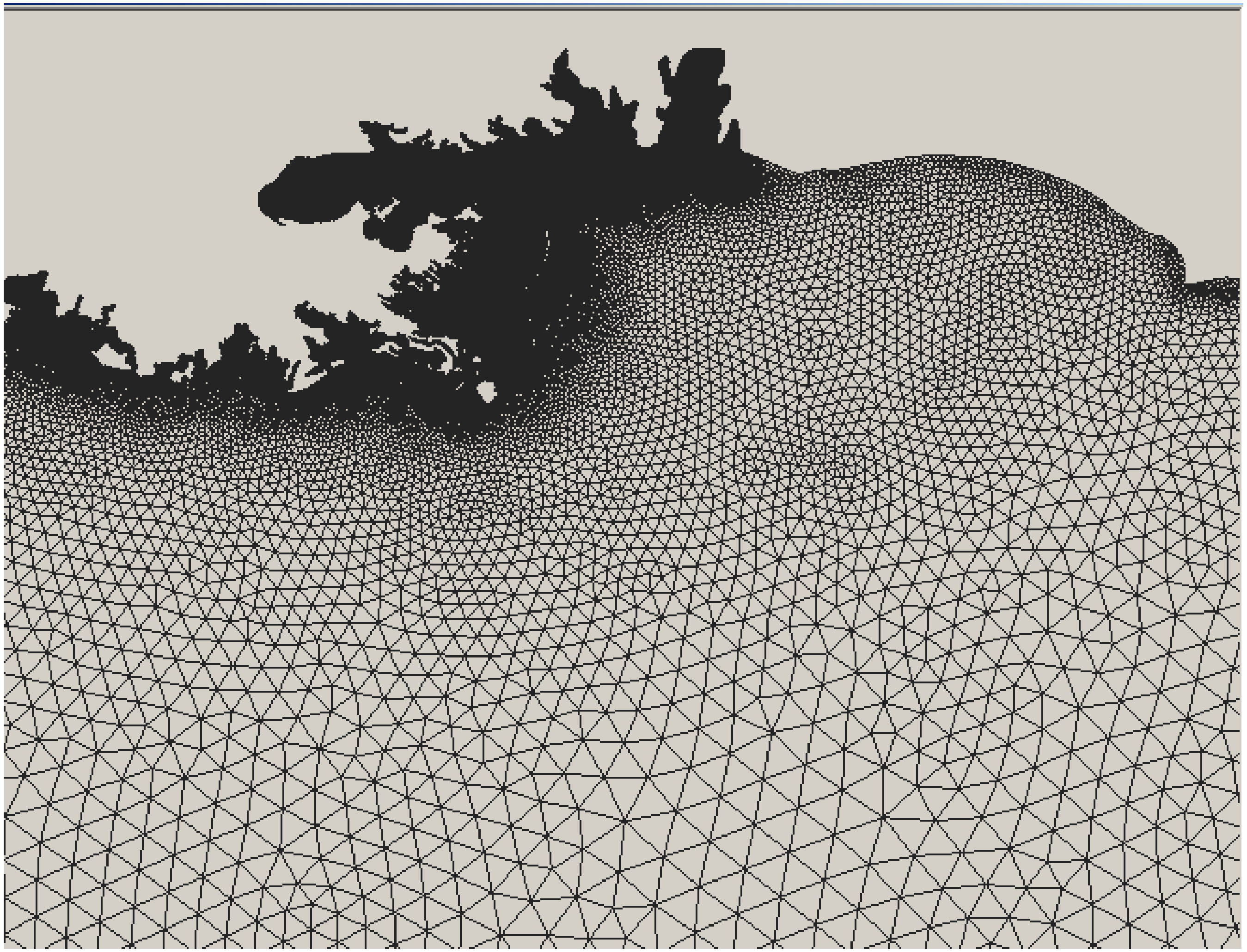
Correctly capture

- **Basin to basin interactions**
- **Basin to shelf dynamics**
- **Shelf to adjacent coast/land dynamics**



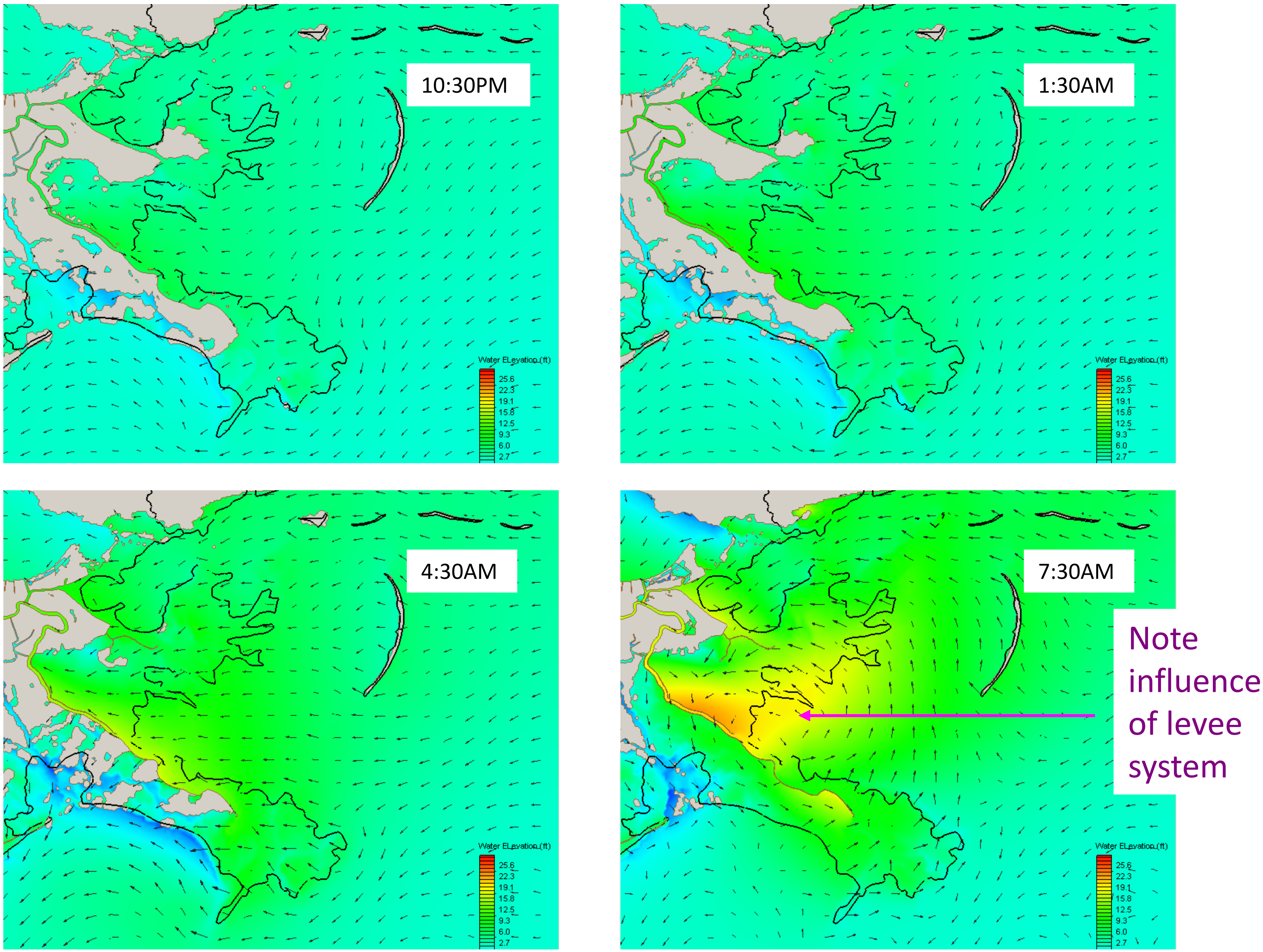


ADCIRC grid – zoom in of North Gulf Coast

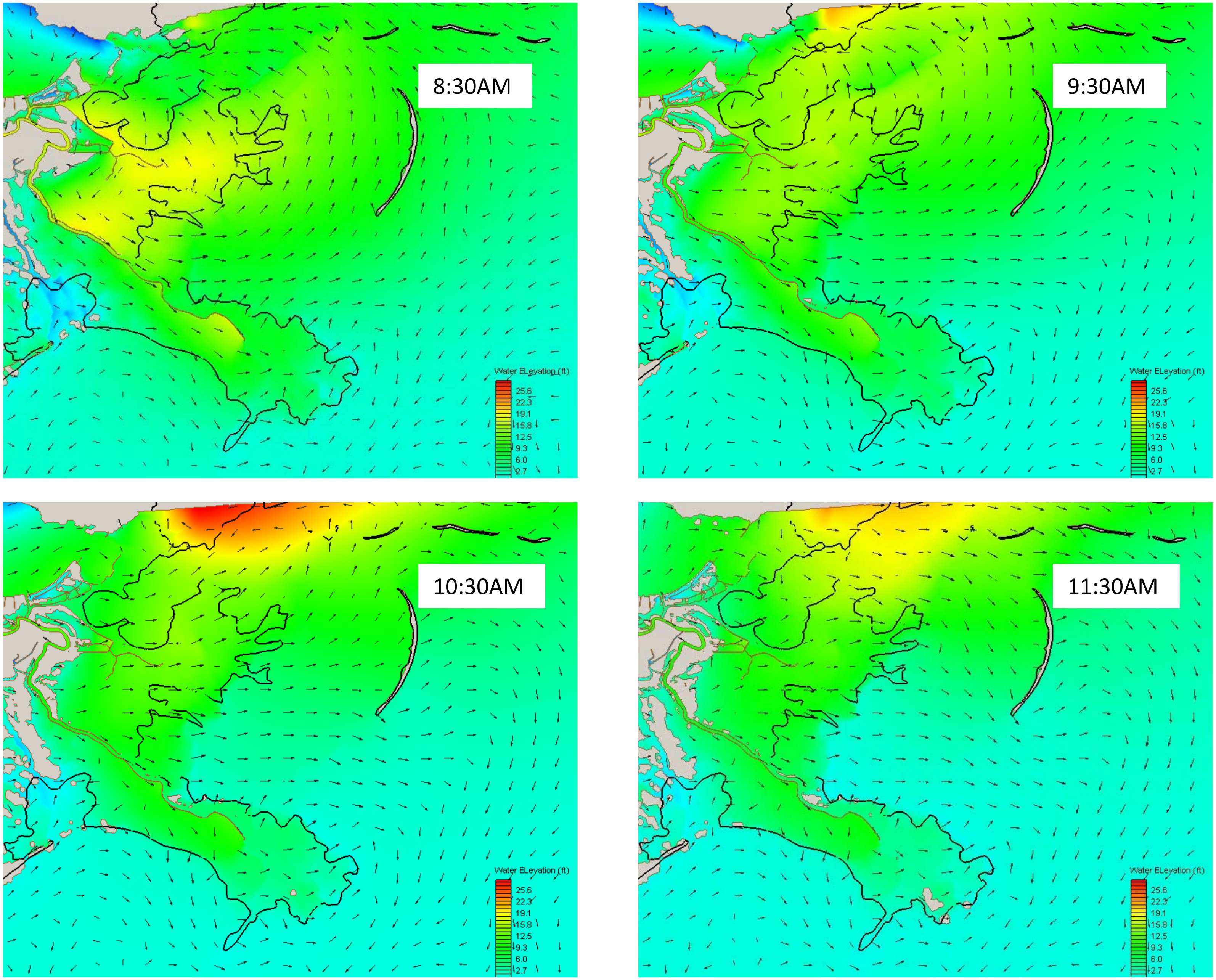


Calculations done at each point. Higher resolution done along shoreline, bays, and bayous to accurately simulation storm surge.

Computer simulation of Katrina storm surge in Louisiana marsh



Computer simulation of Katrina storm surge in Louisiana marsh



Surge very sensitive to track and intensity in SE Louisiana

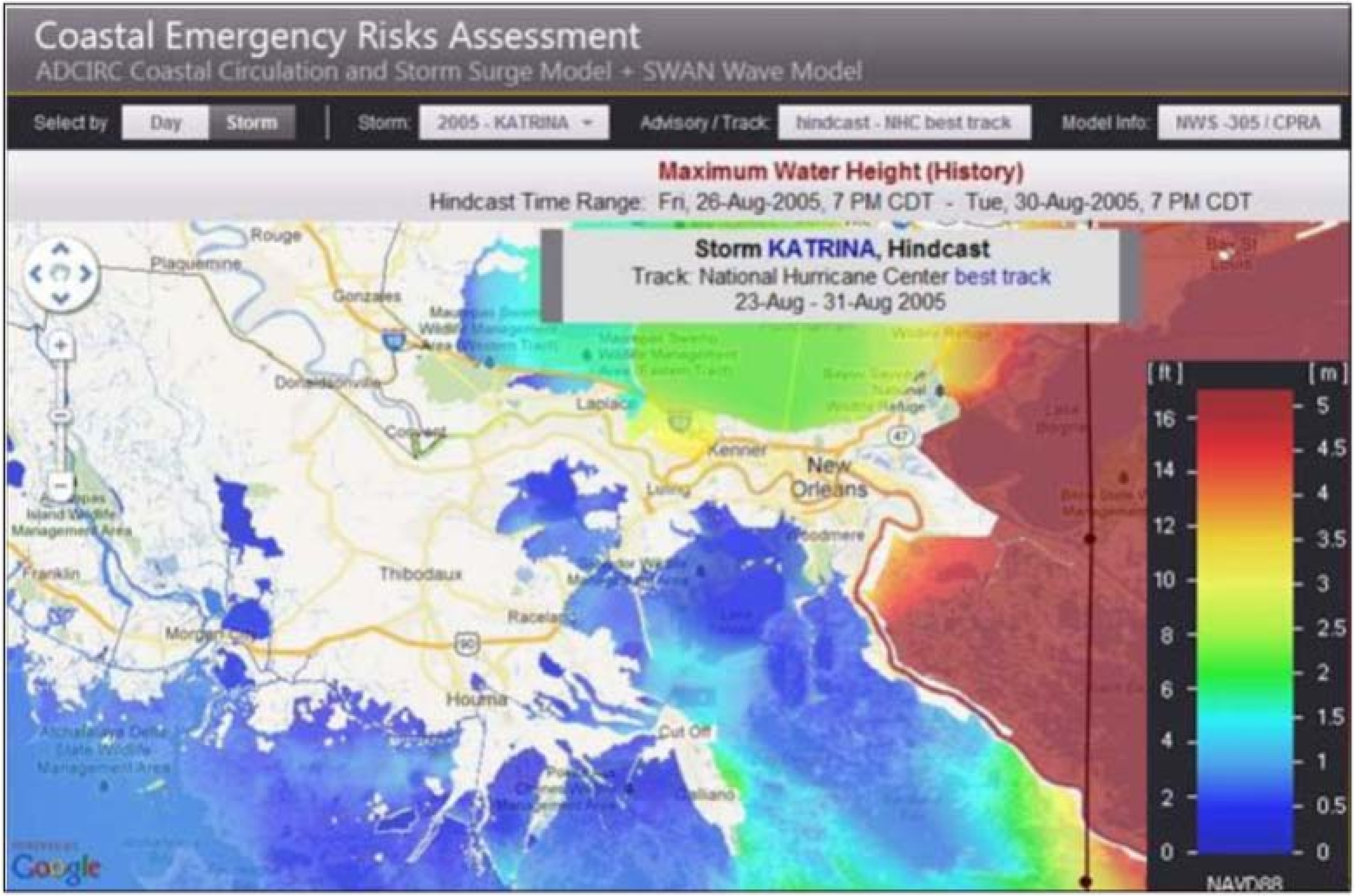


Figure 3.29 Map of the estimated maximum storm surge during Hurricane Katrina.

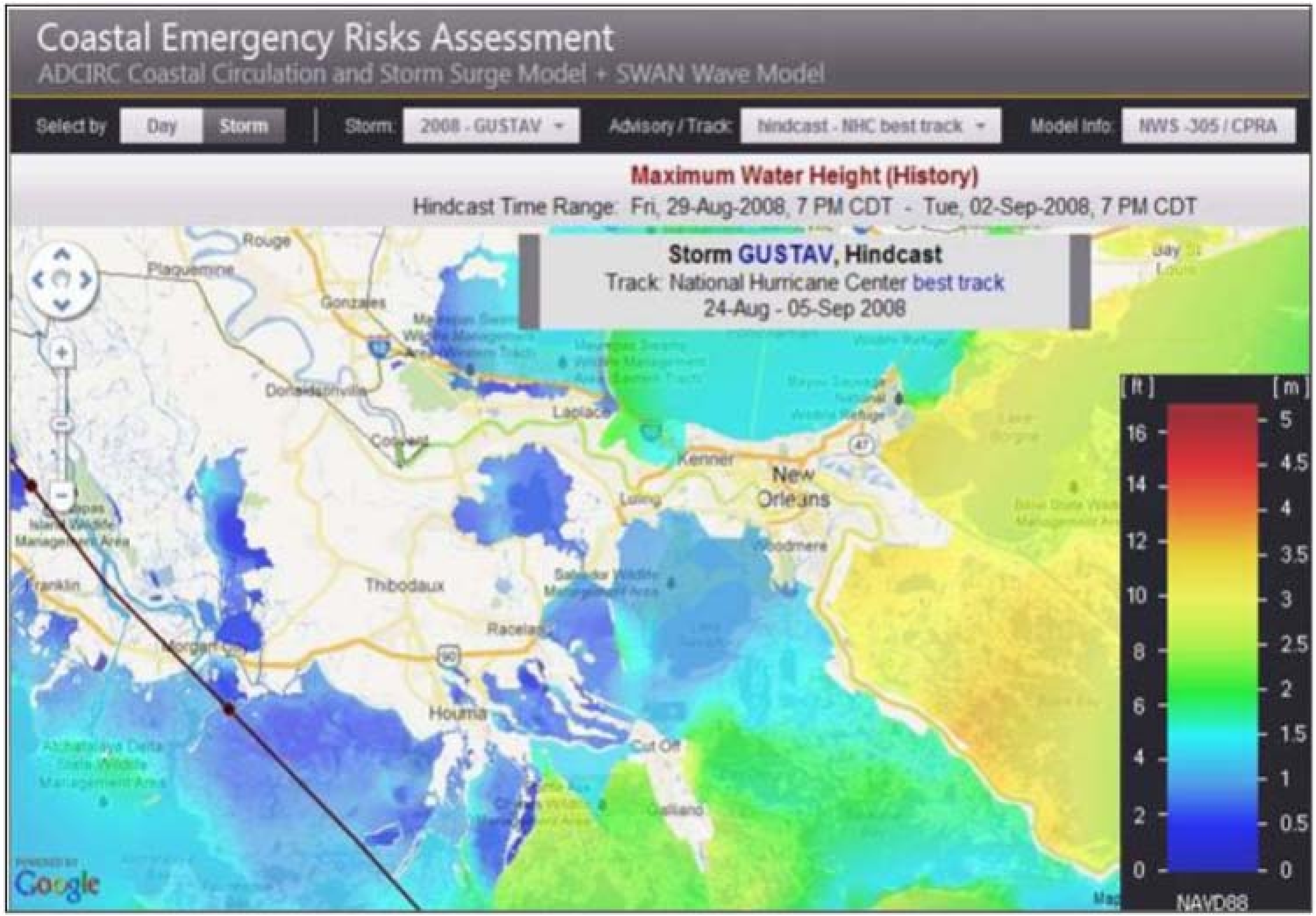


Figure 3.28 Map of the estimated maximum storm surge during Hurricane Gustav.

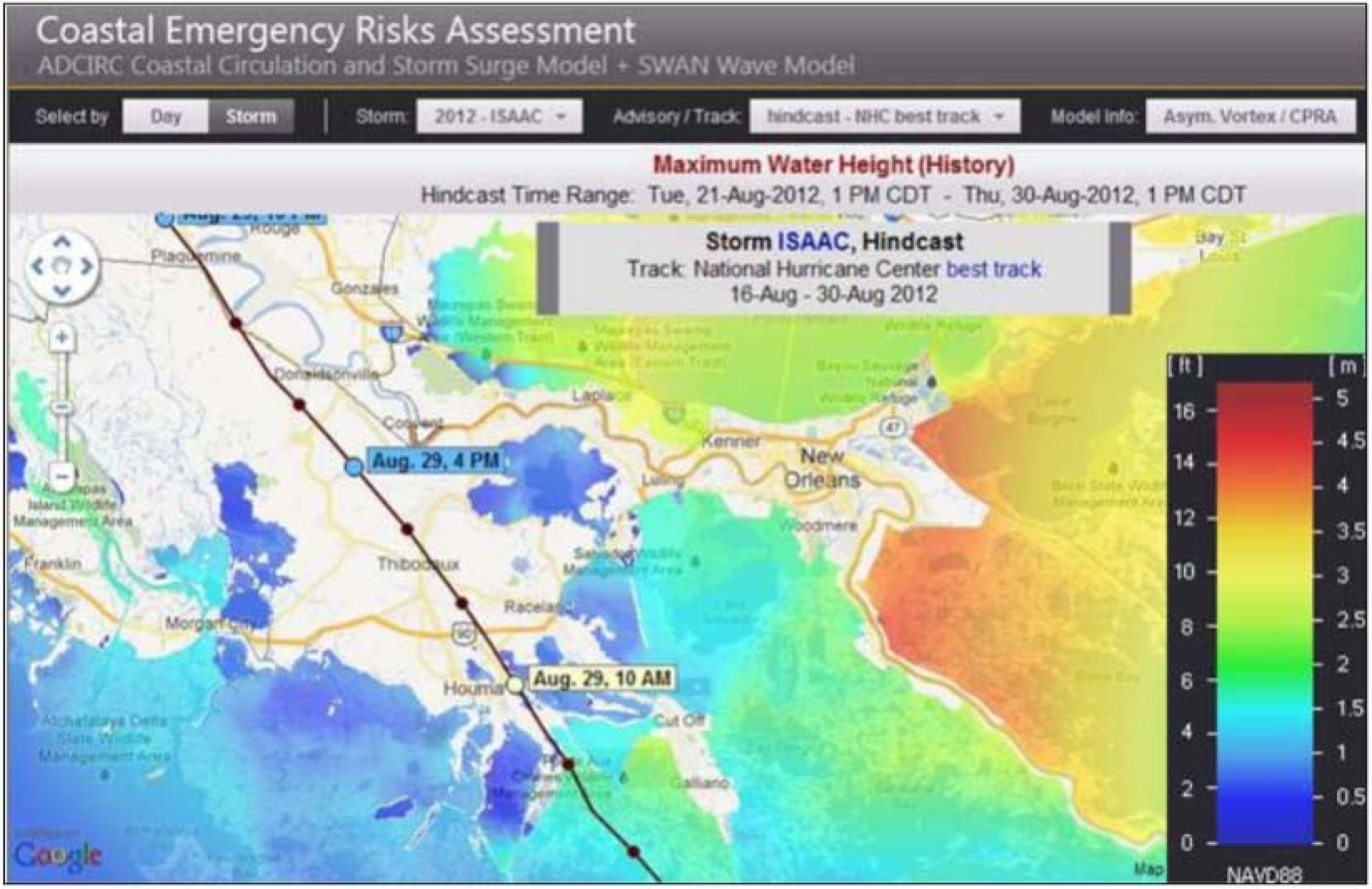


Figure 3.27 Map of the estimated maximum storm surge during Hurricane Isaac.

How “100-year” surge event is determined

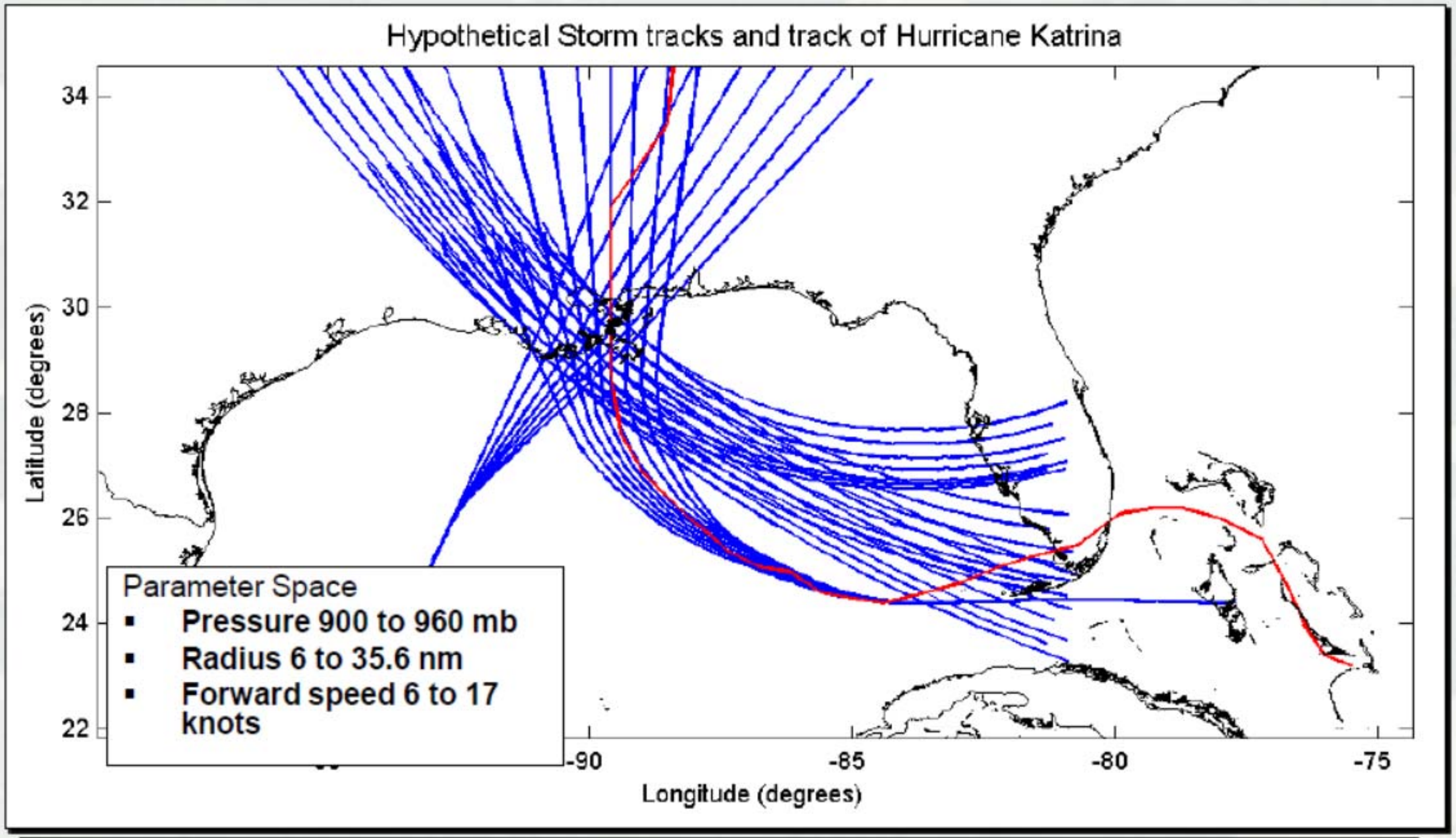
- Develop probability distributions for each storm parameter (size, intensity, etc.) from observations
- Establish rate of storm occurrence in space and time
- Construct hypothetical storm tracks
- Conduct storm surge simulations
- Determine rate of occurrence for each storm
- Compute highest surge for locations of interest, tag it with rate of occurrence
- Construct a histogram of rate versus surge height
- Find the 1% surge elevation for each location

Summary: All possible storms are considered, weighted to appropriate rate of occurrence, and a probability distribution is derived from the sample

Table 1. Summary of the 152 HSDRRS JPM-OS hurricane tracks, stratified by central pressure, radius of maximum winds, translation speed, track direction, primary and secondary plus intensity (Saffir-Simpson scale), and number of storms in each group. From Jacobsen (2013).

GoM CP mb	GoM R_{max} miles	Landfall V_f mph	θ direction from	Track Set (Number)
960	40.9	12.7	Central	P (5)
	28.3	12.7	SE	P (4)
			SW	P (4)
	24.2	12.7	Central	P (5)
	20.9	12.7	SE	P (4)
			SW	P (4)
	20.4	12.7	Central	S (4)
			SE	S (3)
			SW	S (3)
		6.9	Central	P (5)
				S (4)
	12.7	12.7	Central	P (5)
930	29.7	12.7	Central	P (5)
	20.4	19.6	Central	P (5)
				S (4)
			SE	P (4)
				S (3)
			SW	P (4)
				S (3)
		12.7	Central	P (5)
		6.9	SE	P (4)
				S (3)
			SW	P (4)
				S (3)
	9.2	12.7	Central	P (5)
900	25.1	12.7	Central	P (5)
	21.2	12.7	SE	P (4)
			SW	P (4)
	20.4	12.7	Central	S (4)
			SE	S (3)
			SW	S (3)
		6.9	Central	P (5)
				S (4)
	17.1	12.7	Central	P (5)
	14.4	12.7	SE	P (4)
			SW	P (4)
	6.9	12.7	Central	P (5)
3 CP	**15 CP-R_{max}**	**19 CP-R_{max}-V_f**	**30 CPD-R_{max}-V_f-θ**	**152 Storms**

Selection of Synthetic Storms



Example 100-year surge curves for southshore