

Introduction to Storm Surge



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[The following text is a dense, continuous block of illegible characters and symbols, likely representing a corrupted or redacted document. It contains no discernible words or structure.]

Hurricane Katrina (2005) – Mississippi

1200 deaths, \$108 billion damage



Hurricane Sandy (2012) – Northeast U.S.

73 deaths, \$65 billion damage



Hurricane Ike (2008) - Bolivar Peninsula, Texas

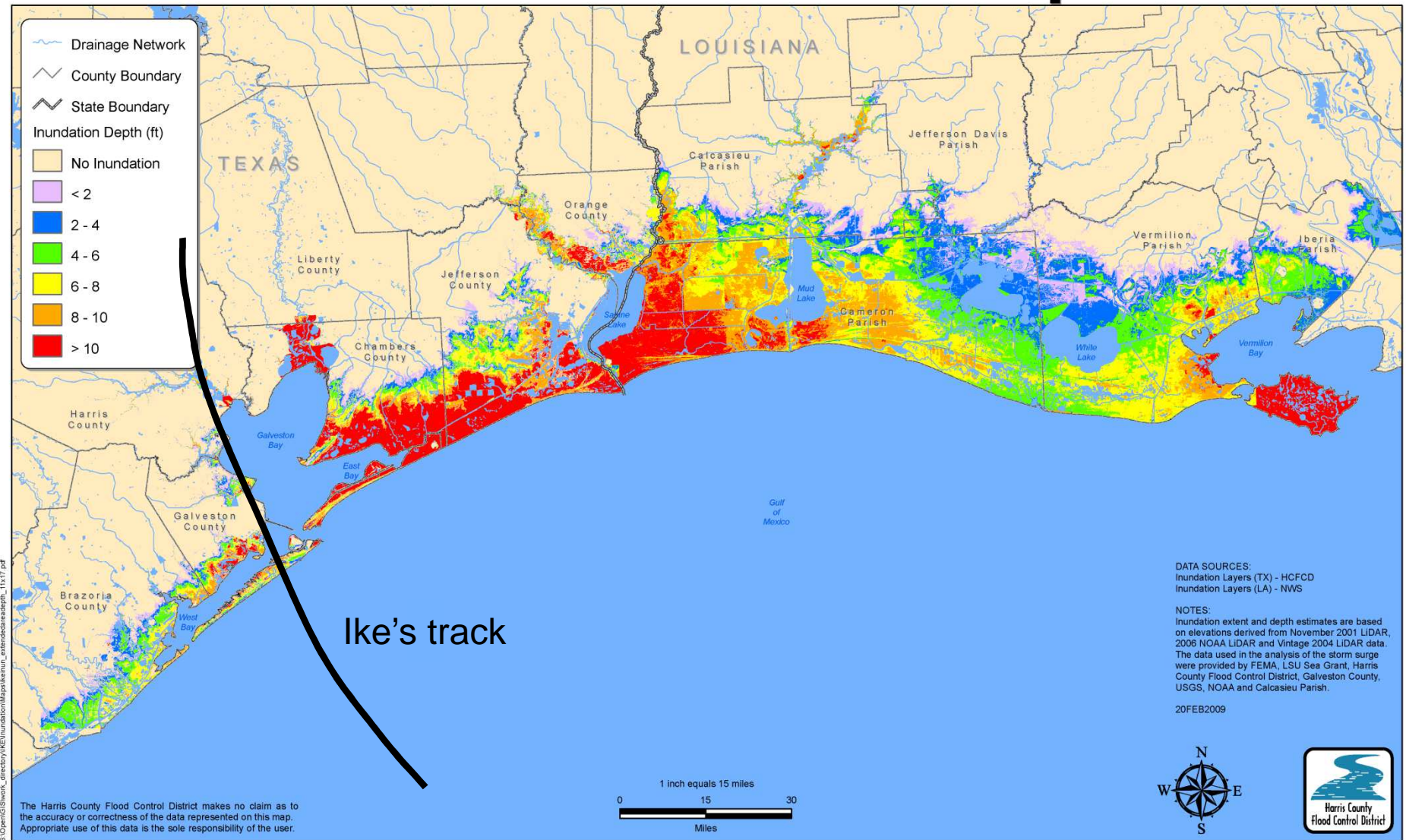
20 deaths, \$29.5 billion



Unit Outline

- Introduction to Storm Surge
 - Who is vulnerable?
 - What is Storm Surge?
 - Factors affecting Storm Surge

Hurricane Ike Inundation Depth





Dying Vegetation due to Salt Water Intrusion



The brown region along the coast indicates dying vegetation due to Salt Water burn. The brown area in the Gulf of Mexico indicates a high concentration of sediment that was taken from the coastal areas when the surge waters flowed back into the gulf. Imagery courtesy of NASA. Map made by Donovan Landreneau and Jonathan Brazzell NWS Lake Charles



House of David and Kimberly King
Waveland, Mississippi

Vulnerability



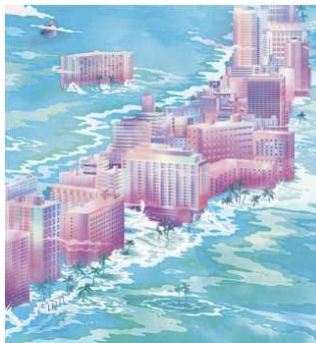
THE SIEGE OF MIAMI

As temperatures climb, so, too, will sea levels.

BY ELIZABETH KOLBERT



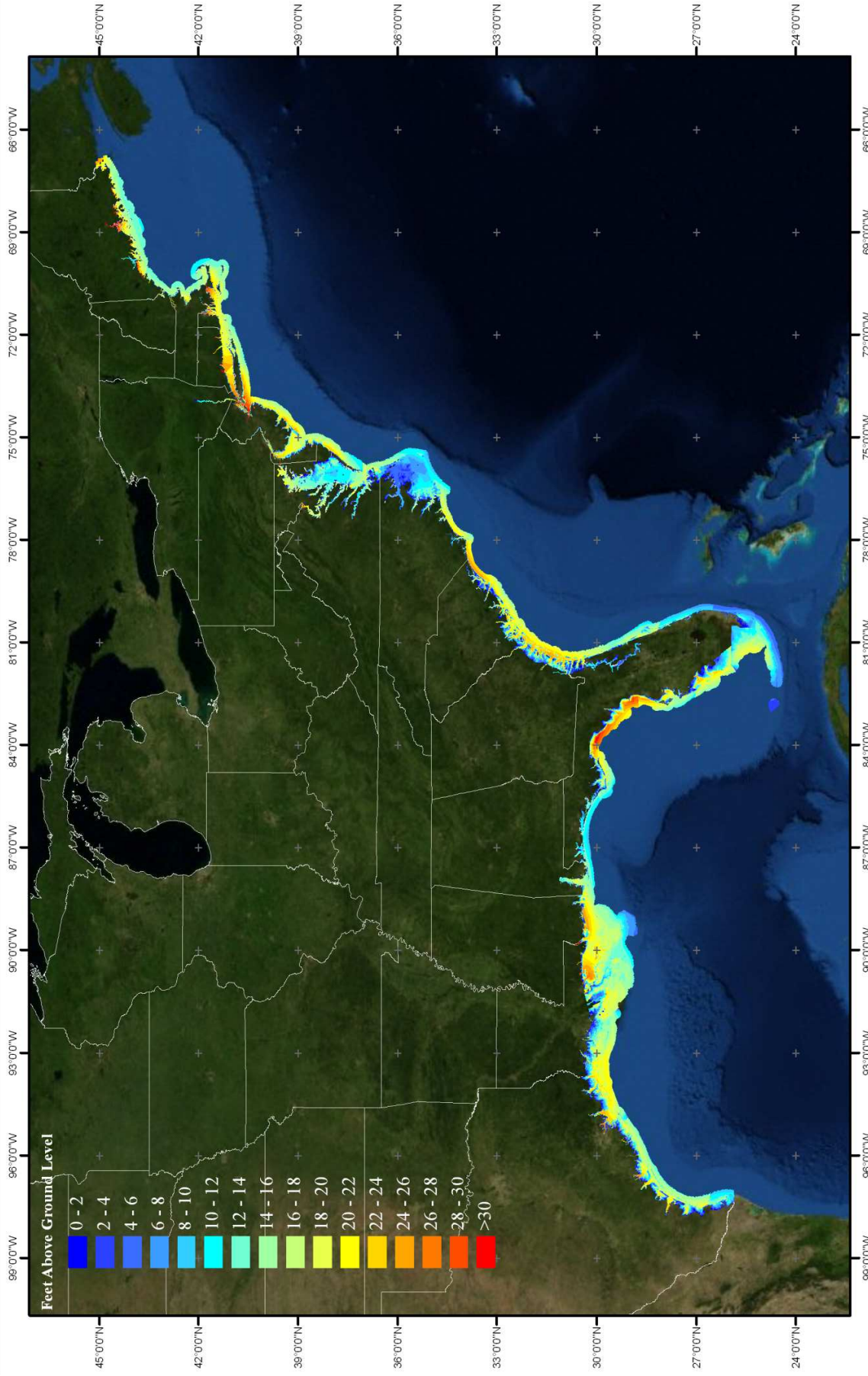
The city of Miami Beach floods on such a predictable basis that if, out of curiosity or sheer perversity, a person wants to she can plan a visit to coincide with an inundation. Knowing the tides would be high around the time of the “super blood moon,” in late September, I arranged to meet up with Hal Wanless, the chairman of the University of Miami’s geological-sciences department. Wanless, who is seventy-three, has spent nearly half a century studying how South Florida came into being. From this, he’s concluded that



In the Miami area, the daily high-water mark has been rising almost an inch a year.

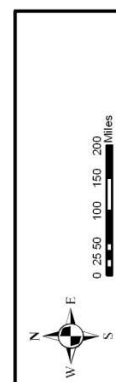
- Coastal areas are at increasing risk from sea-level rise and storm surge
 - Sea-level rise and storm surge place many U.S. coastal areas at increasing risk of erosion and flooding. Energy and transportation infrastructure and other property in coastal areas are very likely to be adversely affected (Global Climate Change Impacts in the U.S. 2009)
- Rising sea-level provides a higher “base” for future surge/inundation events thus producing an increasing threat to:
 - Coastal communities
 - Ecosystems (wetlands, critical species, habitat loss, etc)
 - Transportation systems (highway systems, ports, rail)
 - Economic viability (tourism, transport of goods, natural resources)
 - Energy

Storm Surge Vulnerability: Category 4 Hurricane



Data Source:
NWS/NHC/Storm Surge Unit

**FOR EDUCATIONAL PURPOSES ONLY
NOT TO BE USED TO MAKE LIFE OR DEATH DECISIONS**



Gulf Coast



Biloxi, Mississippi
Katrina (2005)



Key West, Florida
Georges (1998)



Laffite, Louisiana
Rita (2005)



Galveston, Texas
Ike (2008)

Southeast



Rodanthe, North Carolina
Isabel (2003)



Pawley's Island, South Carolina
Hugo (1989)



Jacksonville, Florida
Fay (2008)



North Hutchinson Island, Florida
(Jeanne 2004)


Mid-Atlantic

A street in Baltimore, Maryland, is completely flooded with murky water. Several black lampposts stand in the water. In the background, a large brick building with "FIRE DEPT" and "BALTIMORE" visible on its facade is partially submerged. A person is standing in the water, holding a camera or phone to take a picture.

Baltimore, Maryland
Isabel (2003)

A wide street in Hampton, Virginia, is flooded with water. In the background, there are trees and traffic lights. The water is calm, reflecting the overcast sky.

Hampton, Virginia
Isabel (2003)

A person wearing a life vest and a hat stands on a pile of debris on a beach in Mantoloking, New Jersey. The debris includes wooden planks, branches, and other floating items. In the background, houses are visible along the shoreline, and the ocean is calm.

Mantoloking, New Jersey
Sandy (2012)

An aerial view of a residential neighborhood in Staten Island, New York, showing significant damage from Hurricane Sandy. Many houses are destroyed, with roofs missing and structures collapsed. Debris is scattered everywhere, and the surrounding area is covered in sand.

Staten Island, New York
(Sandy 2012)

New England



Narragansett Bay, Rhode Island
Carol (1954)



Westport, Massachusetts
Irene (2011)



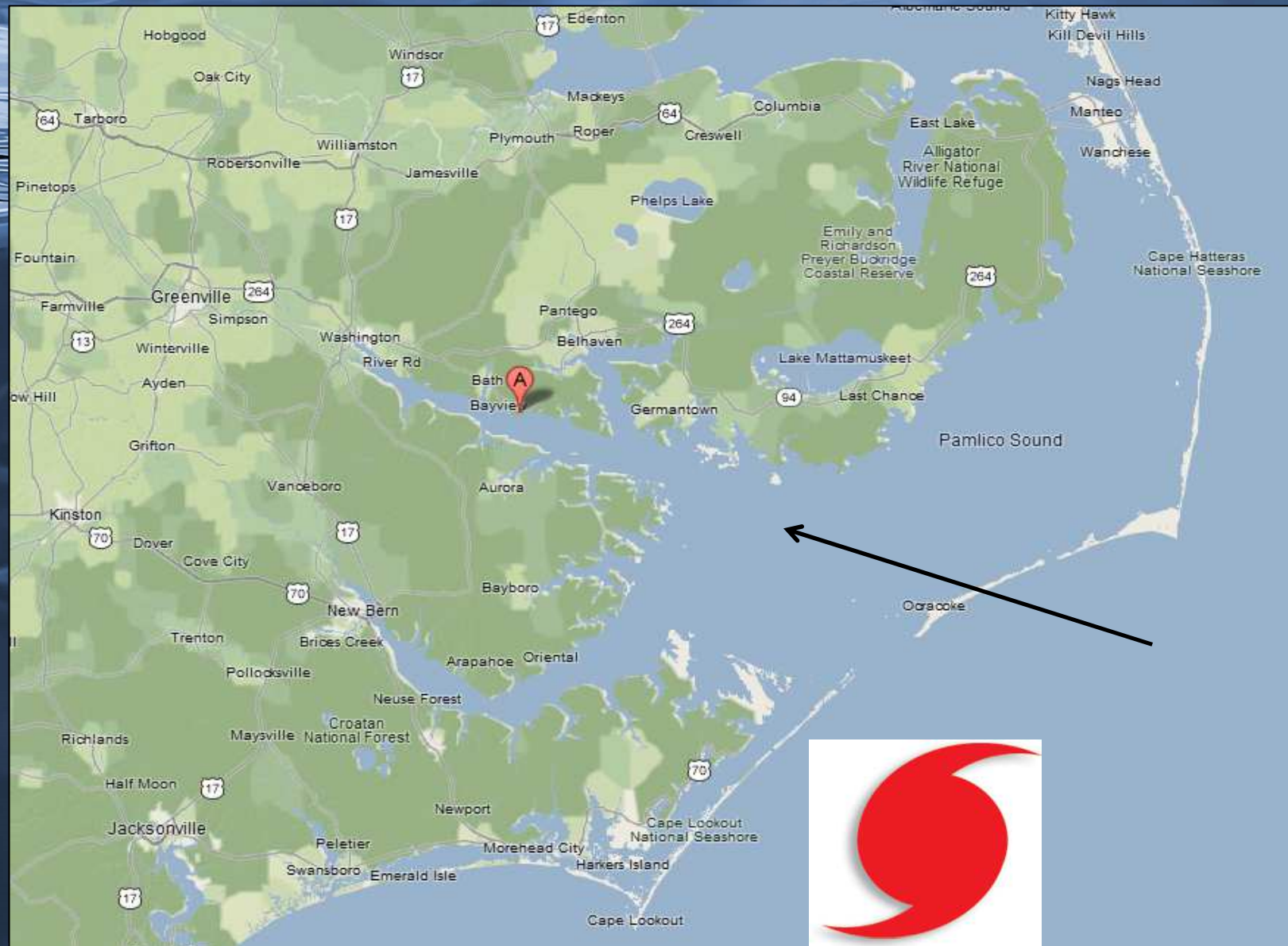
Providence, Rhode Island
1938 Hurricane



East Haven, Connecticut
Sandy (2012)

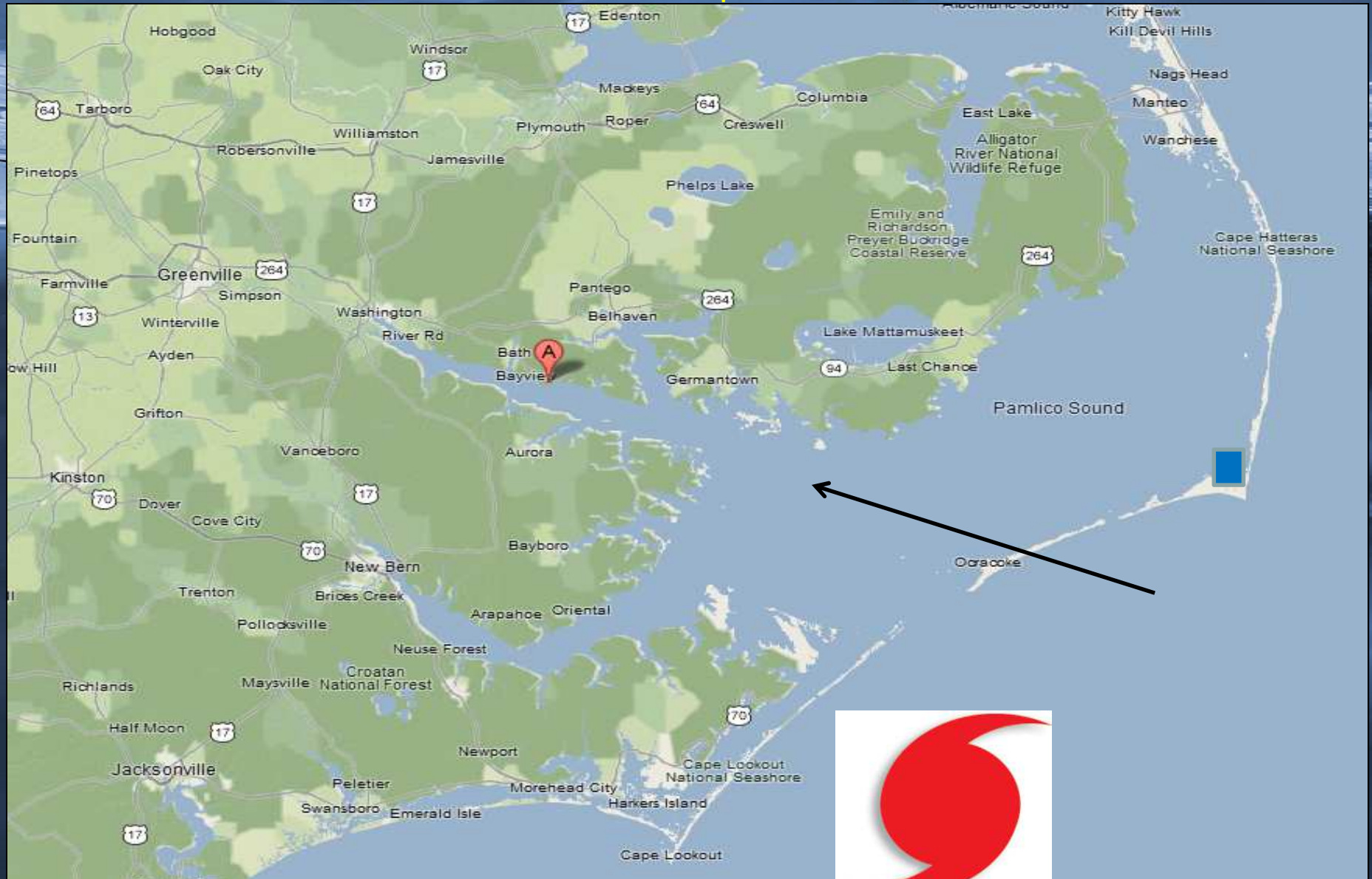
Storm Surge from Hurricane Irene

Rumley Marsh on the Pamlico River in North Carolina



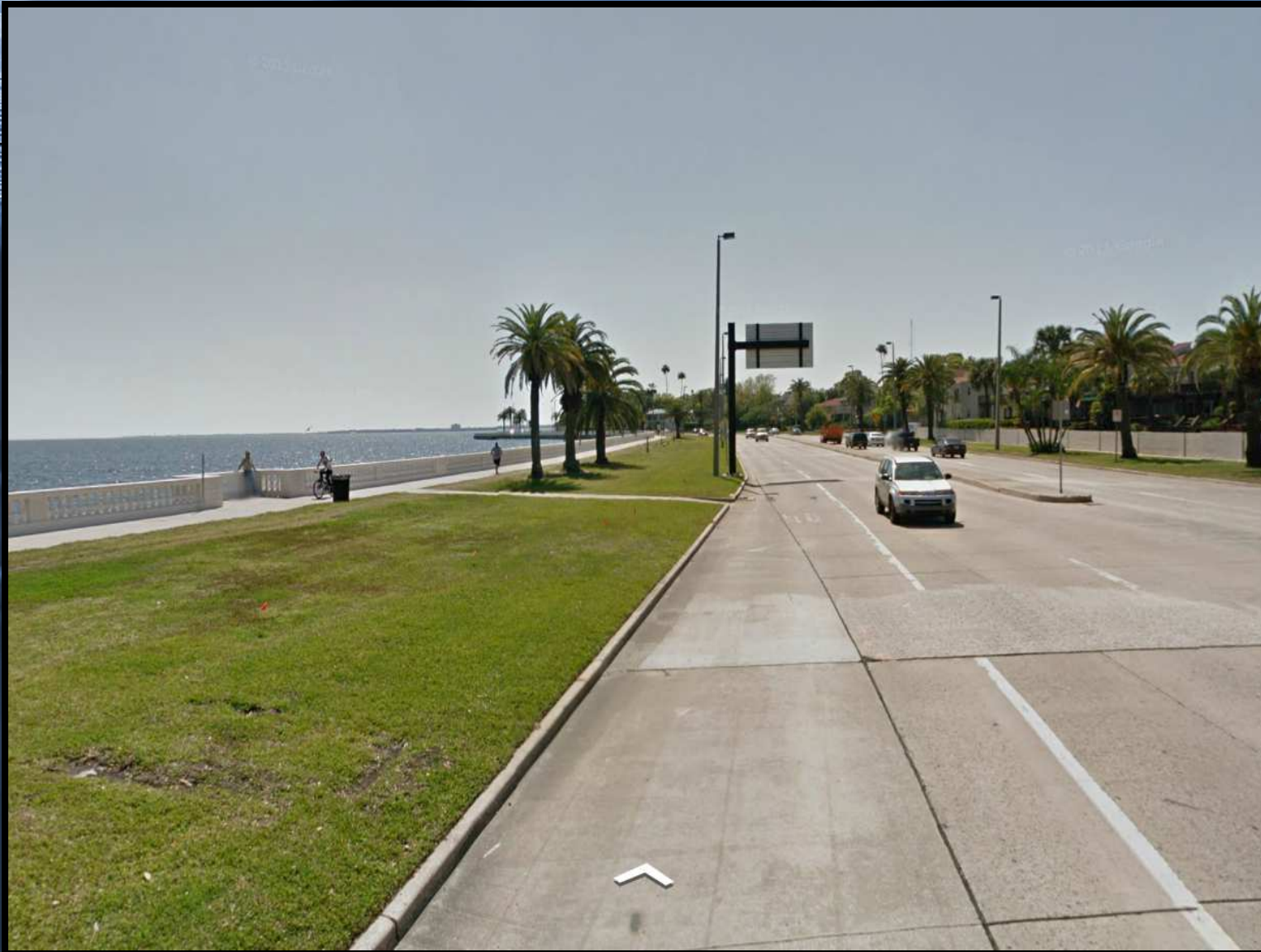
Low Water from Hurricane Irene

Pamlico Sound at Cape Hatteras, NC



Storm Surge from Tropical Storm Debby

Bayshore Blvd., Tampa, FL



Storm Surge from Hurricane Sandy

Alphabet City (East Village), Manhattan, NY

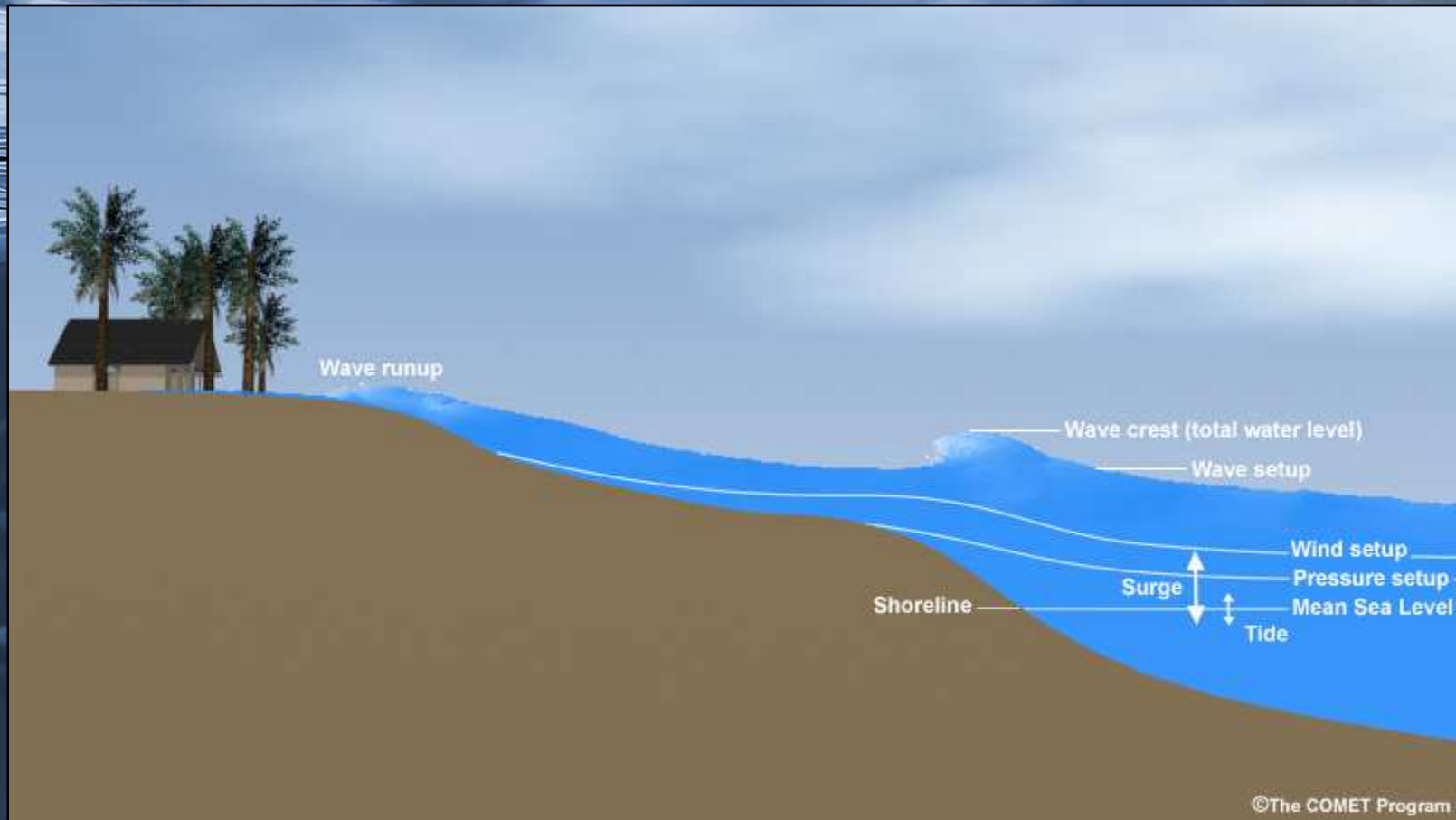


Hurricane Ike — Bolivar peninsula, TX



Courtesy of:
Mark Sudduth
Hurricanetrack.com

Total Water

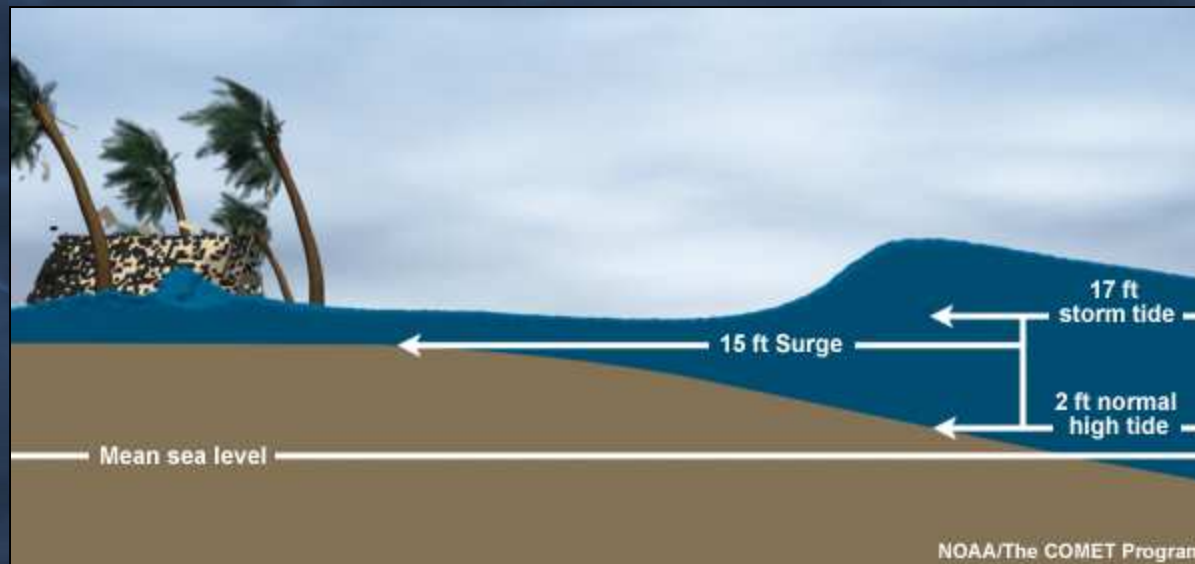


Total water level = Storm surge + Tides +
Wave setup + Freshwater

What are Storm Surge and Storm Tide?

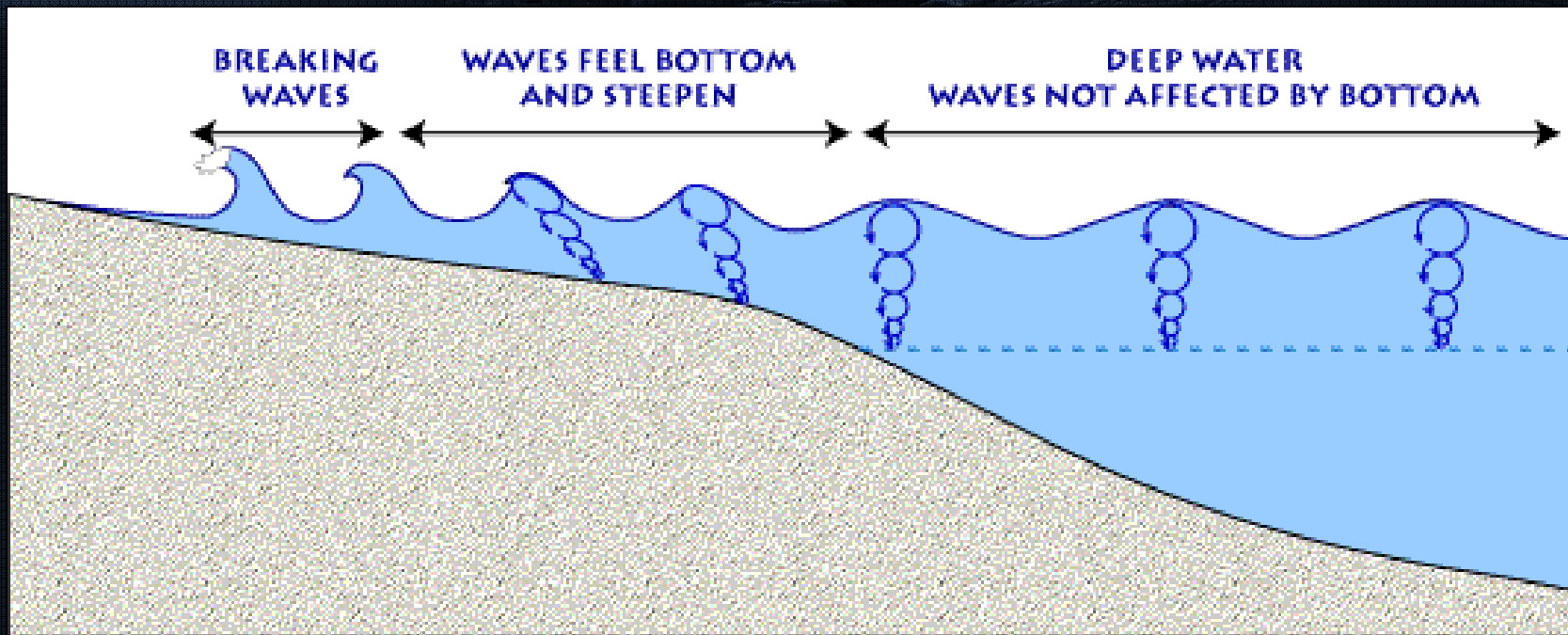
STORM SURGE is an abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

STORM TIDE is the water level rise during a storm due to the combination of storm surge and the astronomical tide



What about Waves?

- Breaking waves also contribute to the total water level through wave runup/setup



Wave Runup



Wave run-up at South Beach, Pacific Rim National Park Reserve, Vancouver Island



Alphapure Design Studio

navbar placeholder

-1-

Wave Runup and Setup



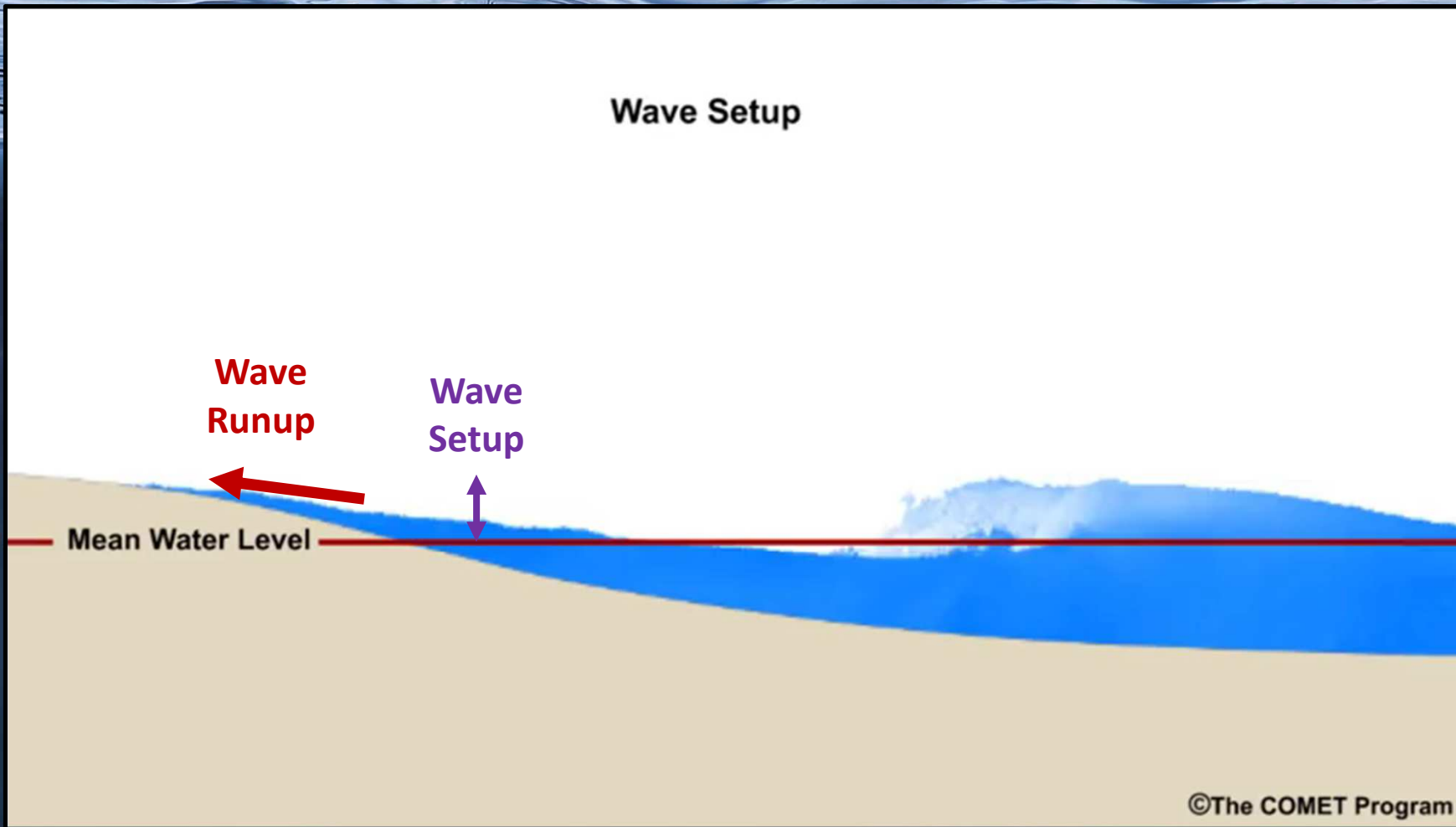
Wave Setup

Wave
Runup

Wave
Setup

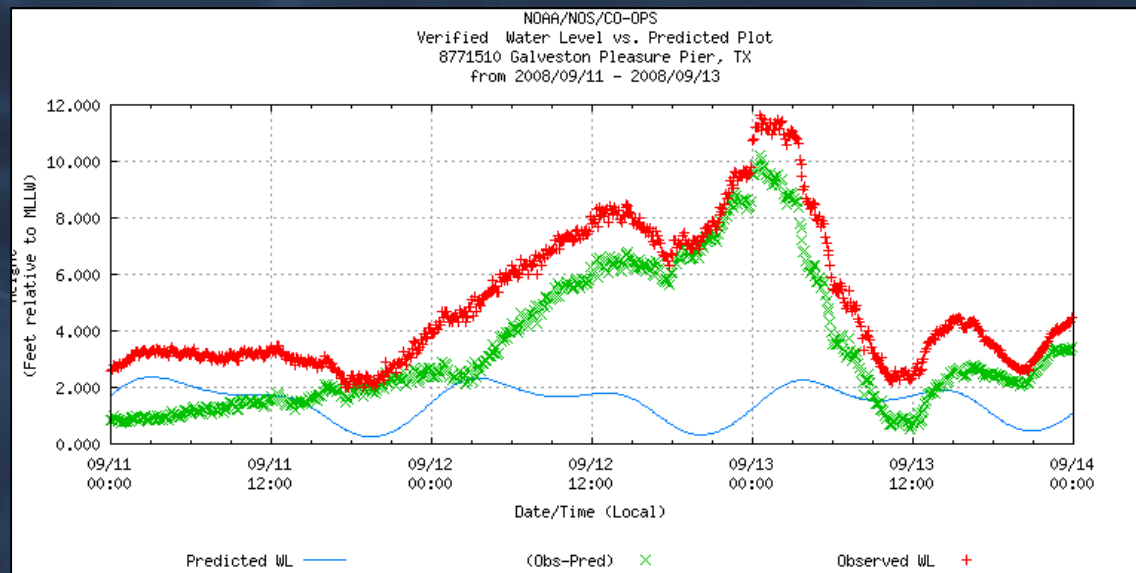
Mean Water Level

©The COMET Program



Galveston

Day before Ike arrived



Freshwater Input



- River input, esp. into bays and sounds
 - Mississippi River discharges 200,000 – 700,000 cubic feet per second
- Rainfall



No More Surge in the Saffir-Simpson Scale!

(it fits like a square peg in a round hole)



Category	Central Pressure		Winds (mph)	Surge	Damage
	Millibars	Inches			
5	< 920	< 27.17	>155	>18'	Catastrophic
4	944-920	27.88-27.17	131-155	13'-18'	Extreme
3	964-945	28.47-27.91	111-130	9'-12'	Extensive
2	979-965	27.91-28.50	96-110	6'-8'	Moderate
1	≤ 980	≤ 28.94	74-95	4'-5'	Minimal

← **KATRINA (3)**

← **IKE (2)**

← **SANDY (1)**

ISAAC (1)

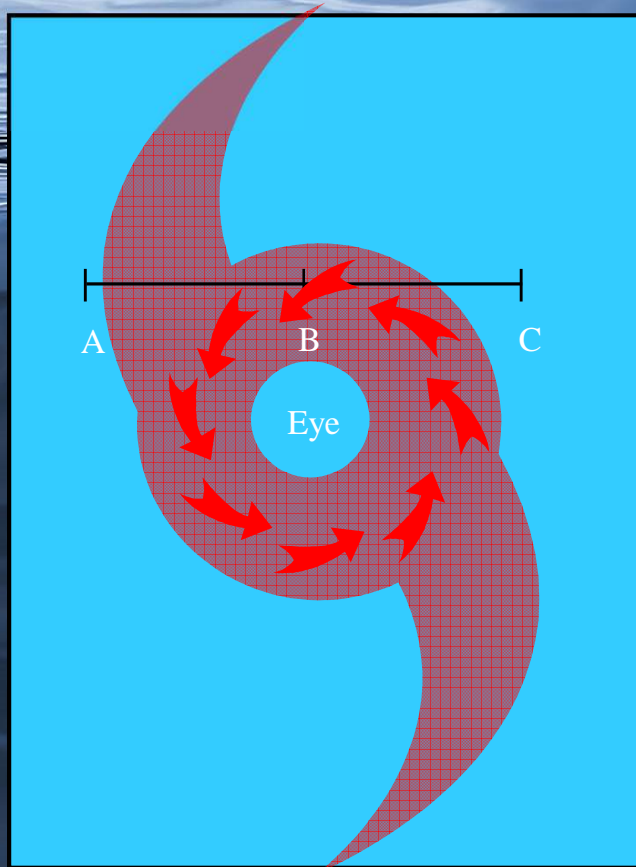
← **CHARLEY (4)**

No Such Thing as “Just a Tropical Storm”

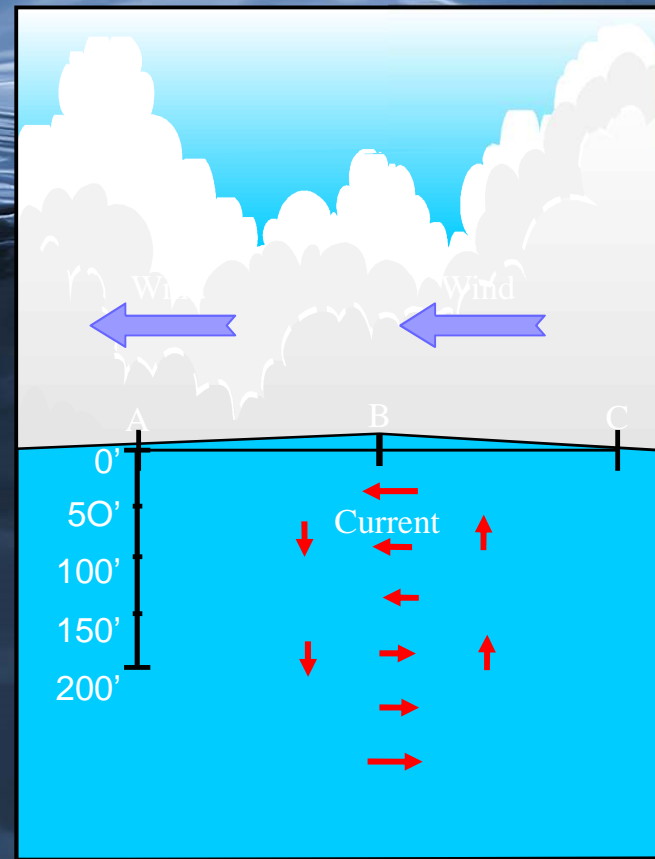


**Louisiana State Rd. 23 near Myrtle Grove
Tropical Storm Lee (2011)**

Deep Water



a. Top view of Sea Surface

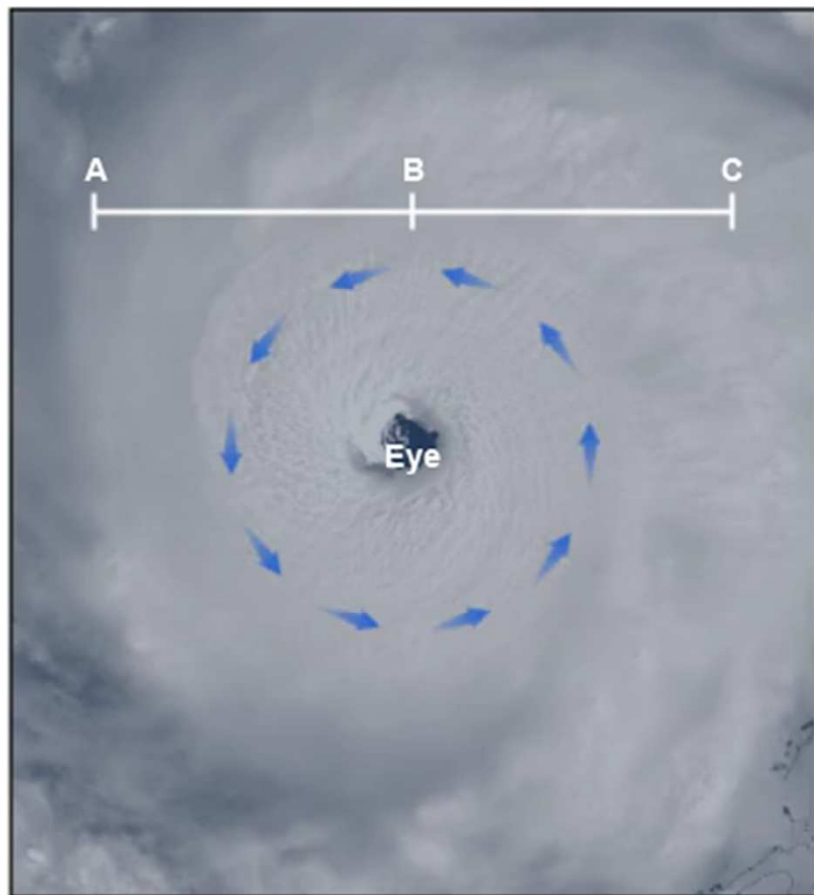


b. Side view of Cross Section "ABC"

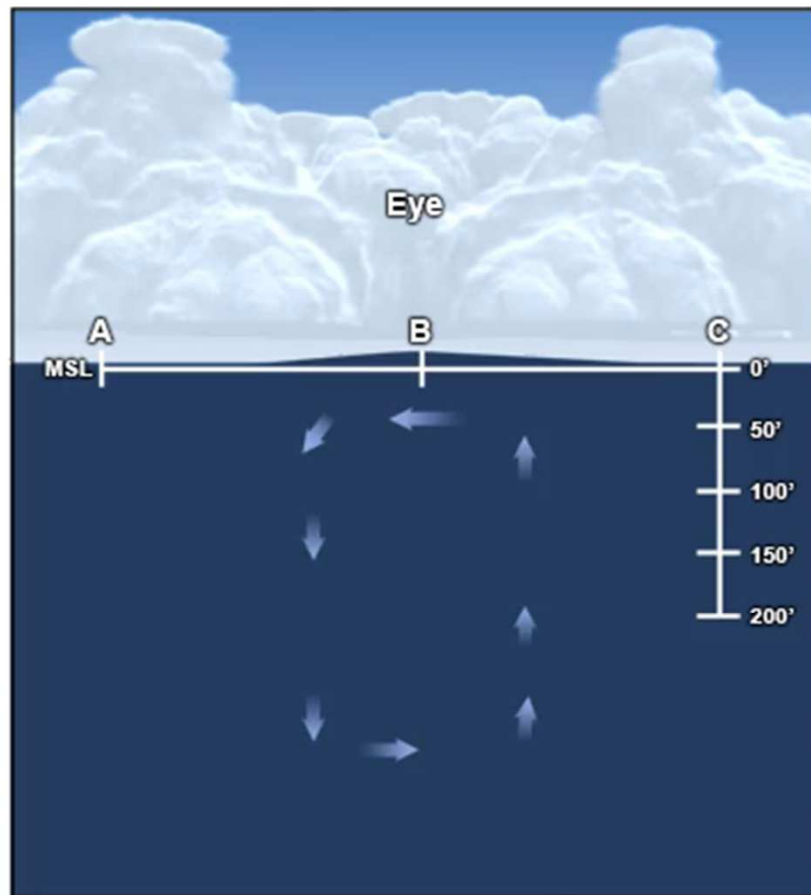
From Deep Water to Shallow Water



Top View of Sea Surface

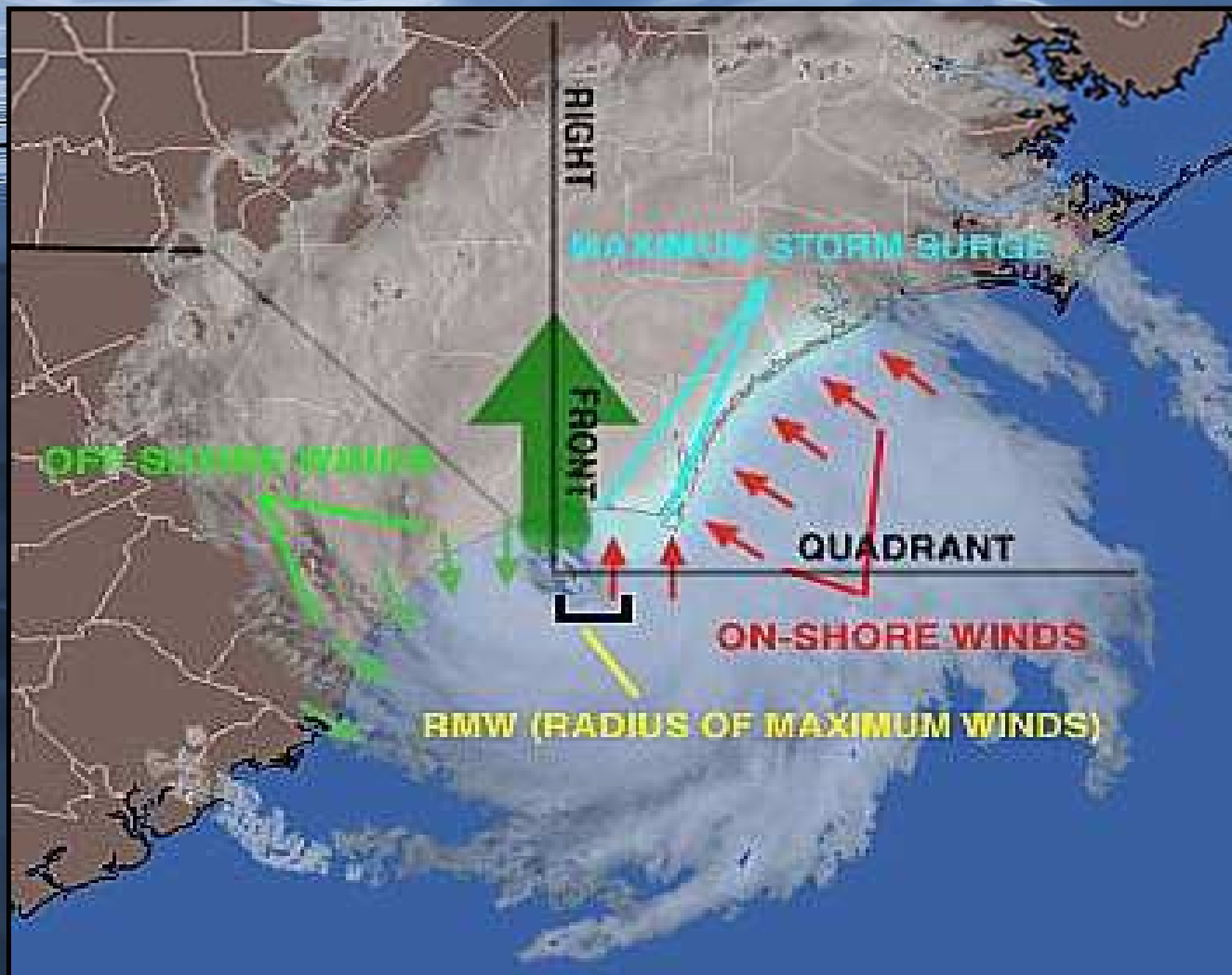


Side View of Cross Section "ABC"



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Understanding Surge



Factors Affecting Storm Surge

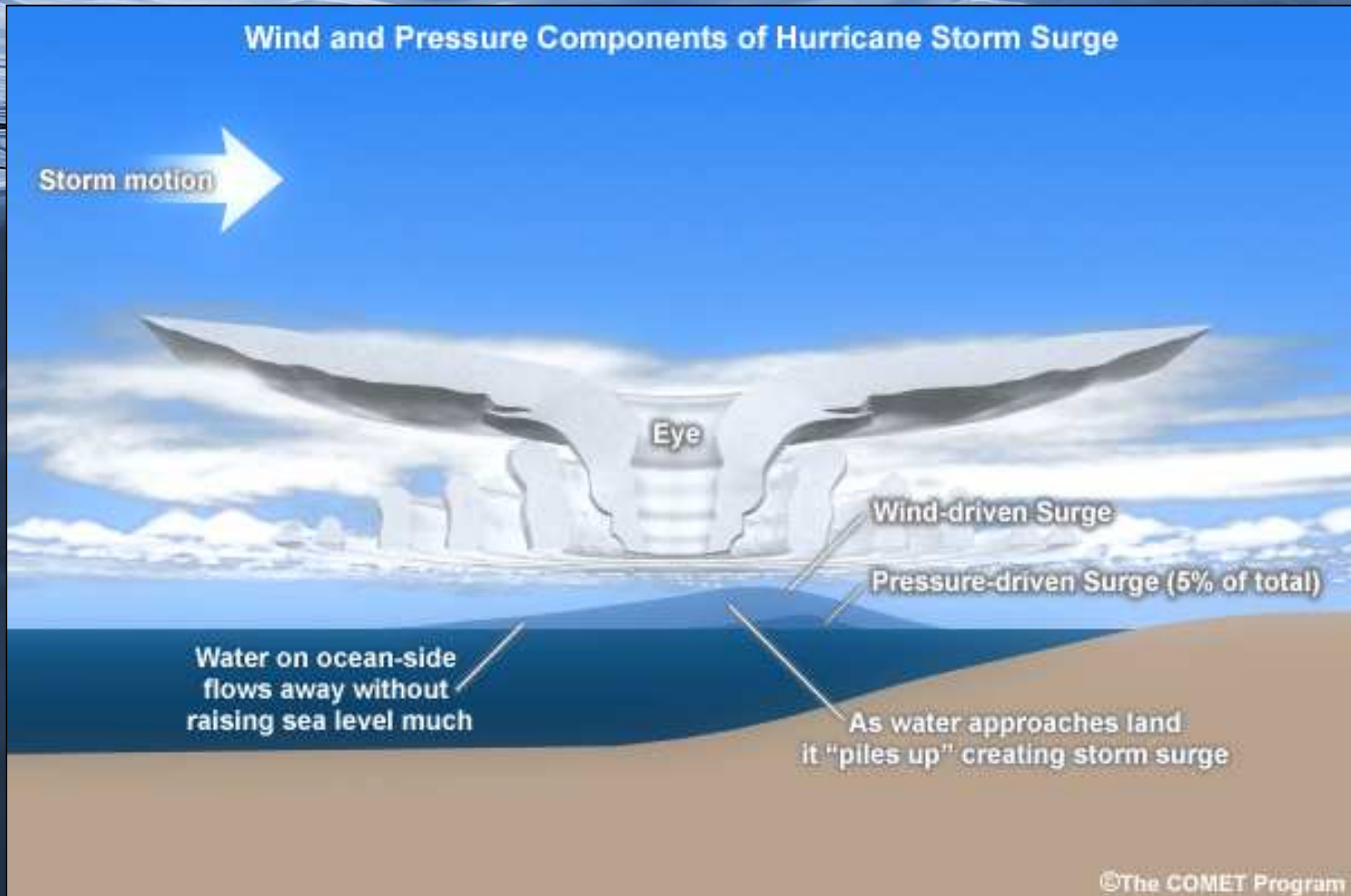
- Central Pressure
- Intensity (wind speed)
- Forward Speed
- Size
 - Radius of Maximum Winds (RMW)
- Angle of Approach
- Width and Slope of Shelf
- Local features – concavity of coastlines, bays, rivers, headlands, or islands



Effects of Low Pressure

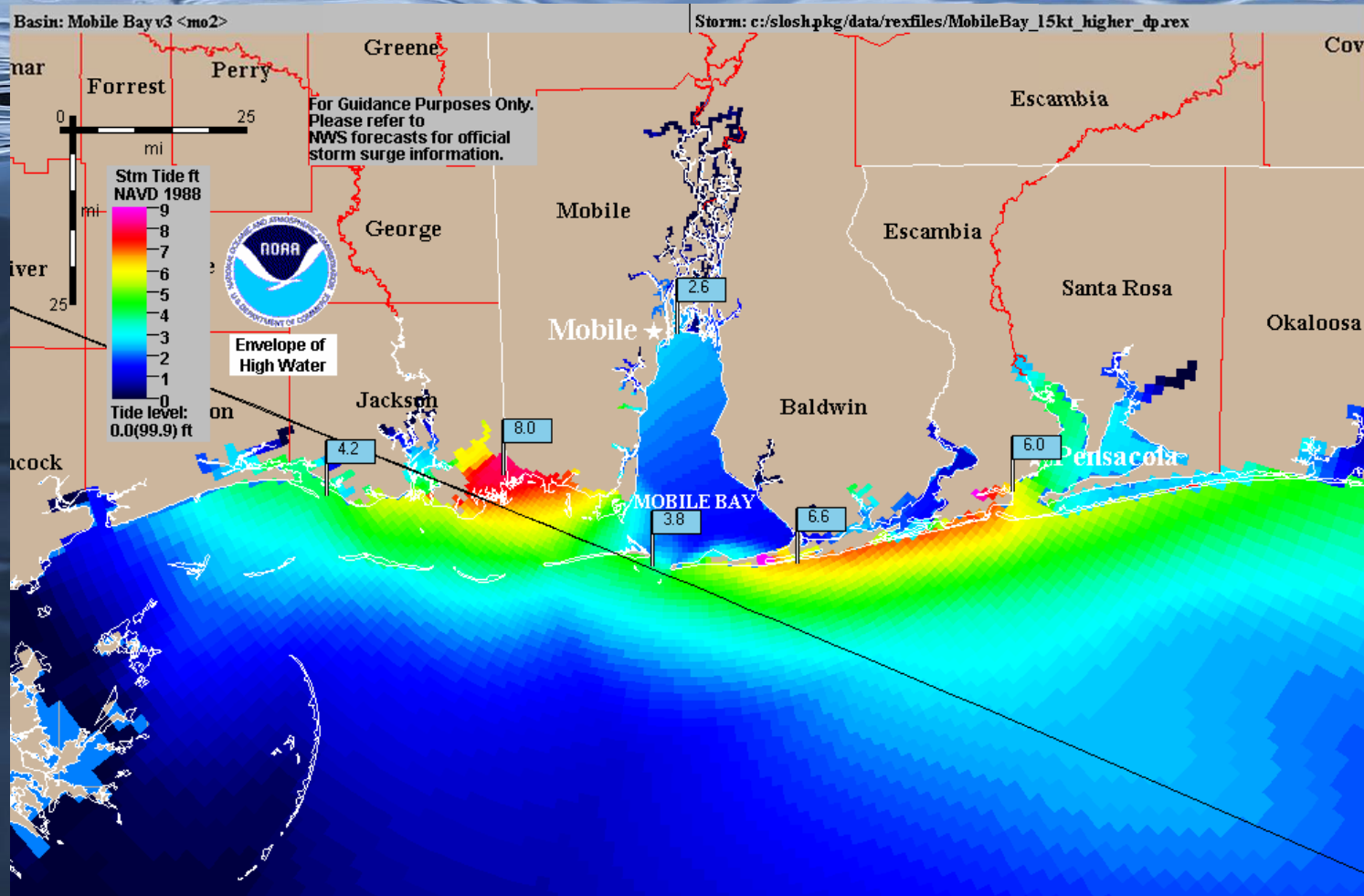


Wind and Pressure Components of Hurricane Storm Surge



Intensity (Wind Speed)

15 mph stronger



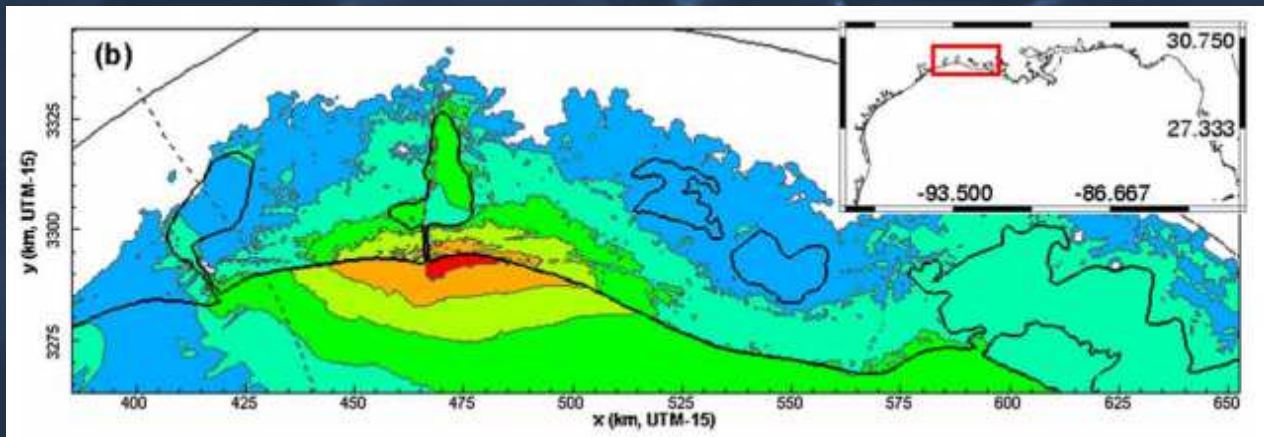
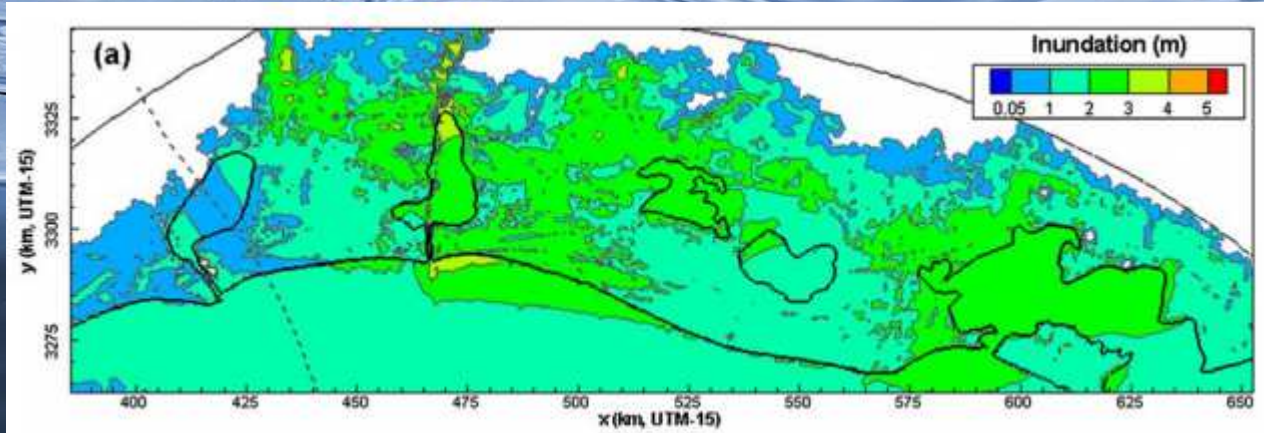
Forward Speed

Slow Speed (5 mph)

- More inland penetration

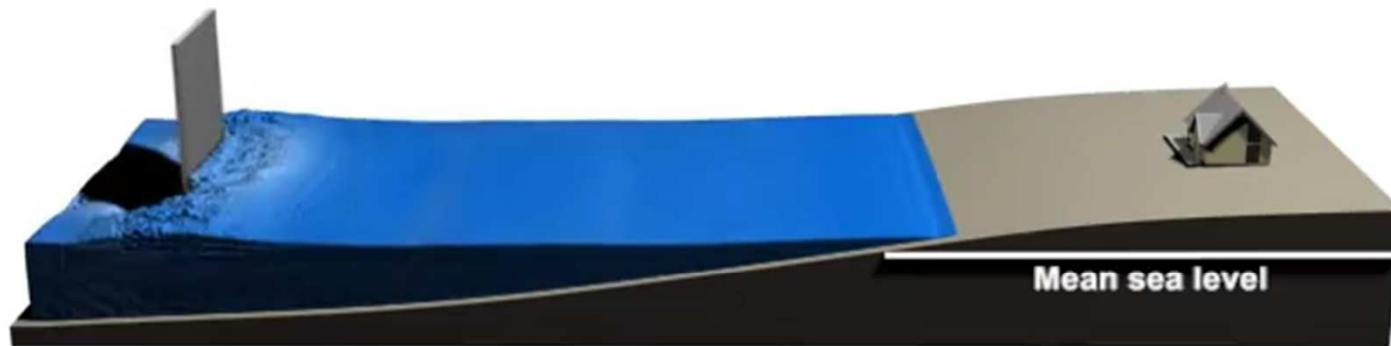
Fast Speed (25 mph)

- Higher maximum



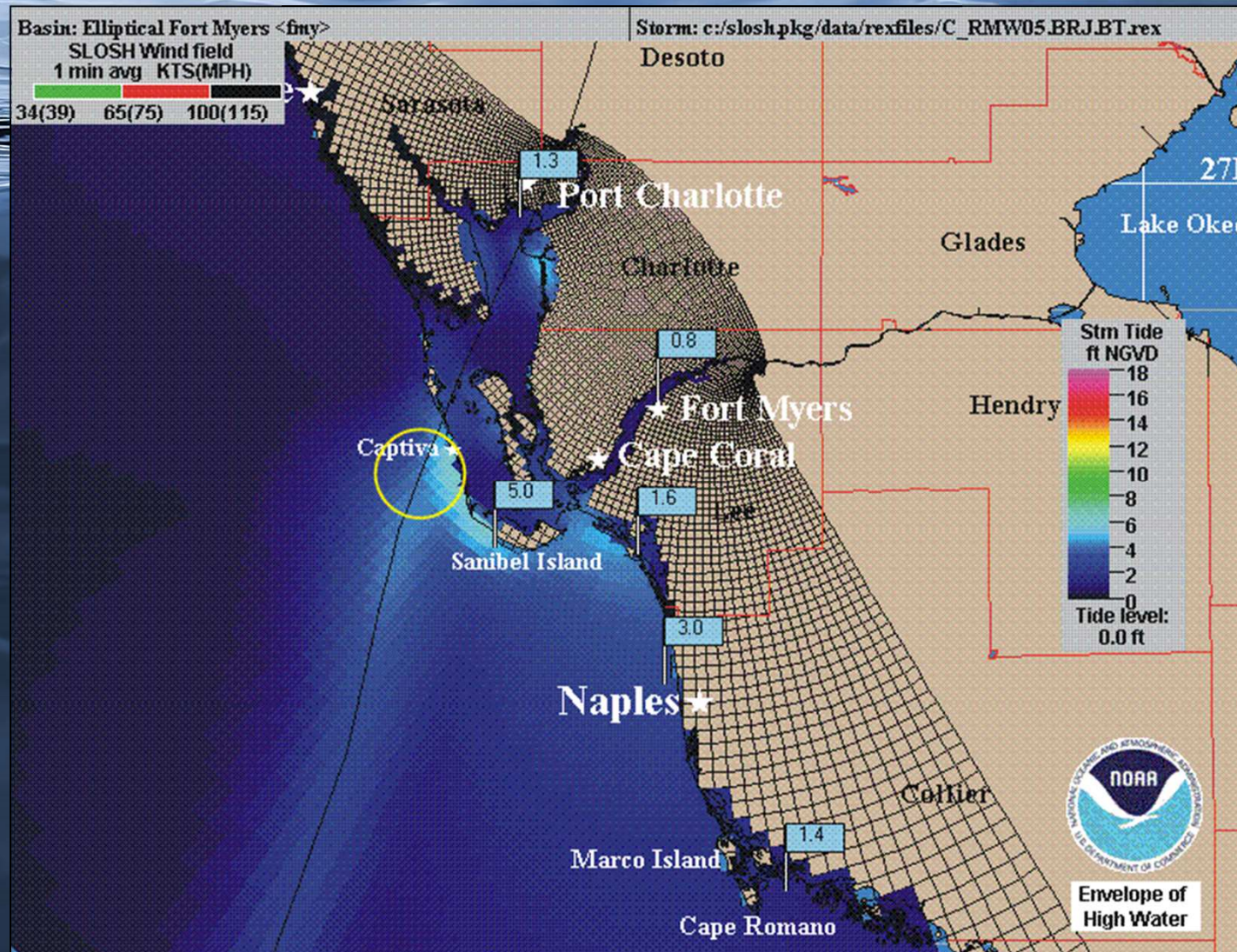
Rego, J. L., and C. Li (2009). Forward speed of a hurricane. *Geophysical Research Letters*, 36.

Size (Radius of Max Winds)



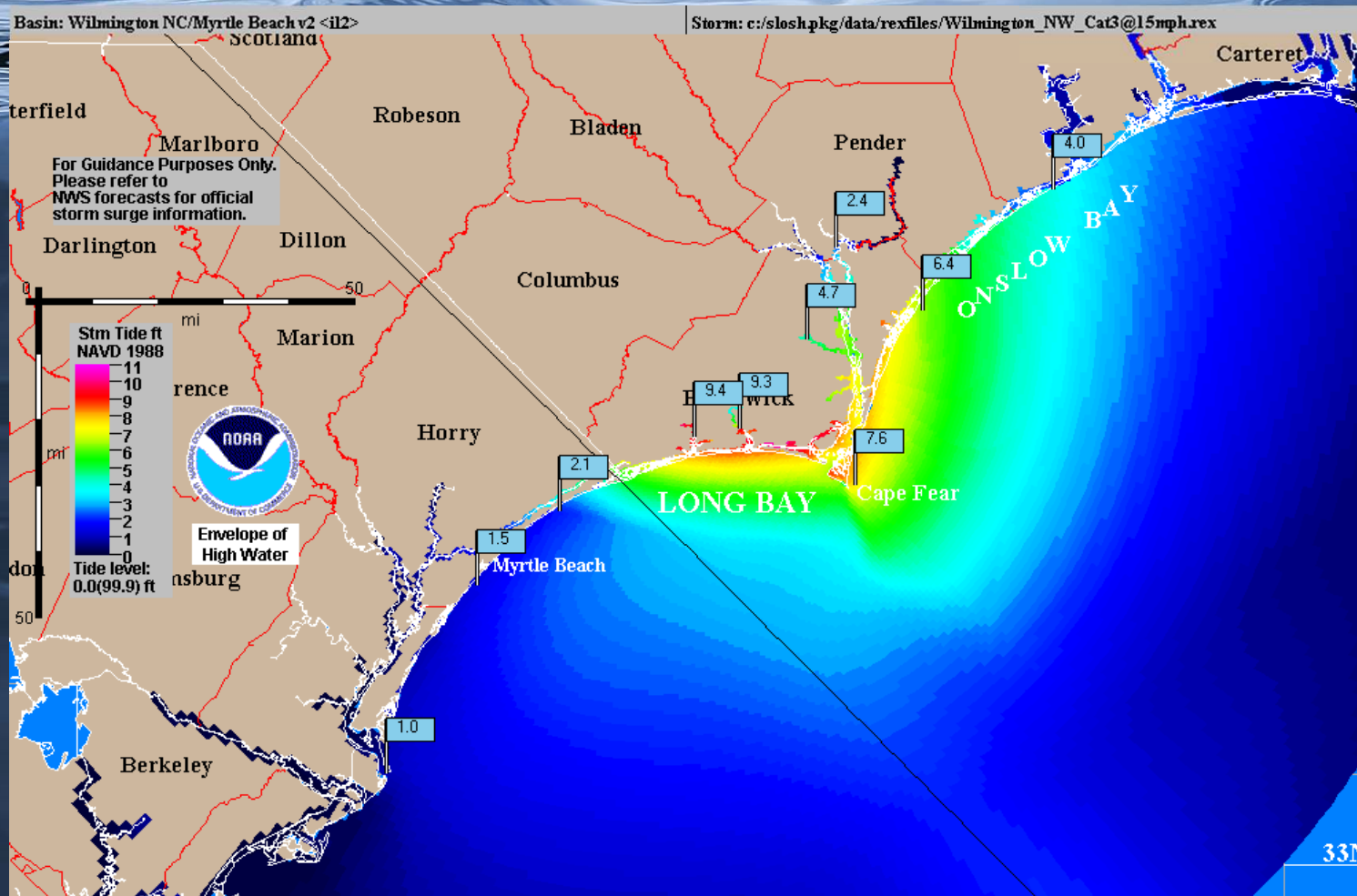
Size

(Radius of Max Winds)



Angle of Approach

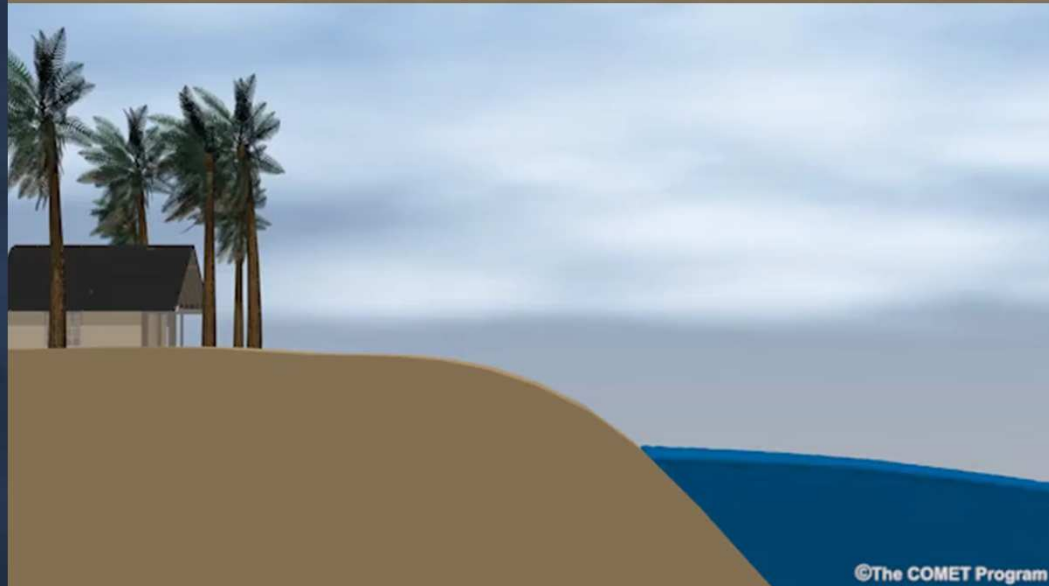
NNW Motion



Width and Slope of Shelf



Wide shelf/
gentle slope



Narrow
shelf/ sharp
slope

Local Features

