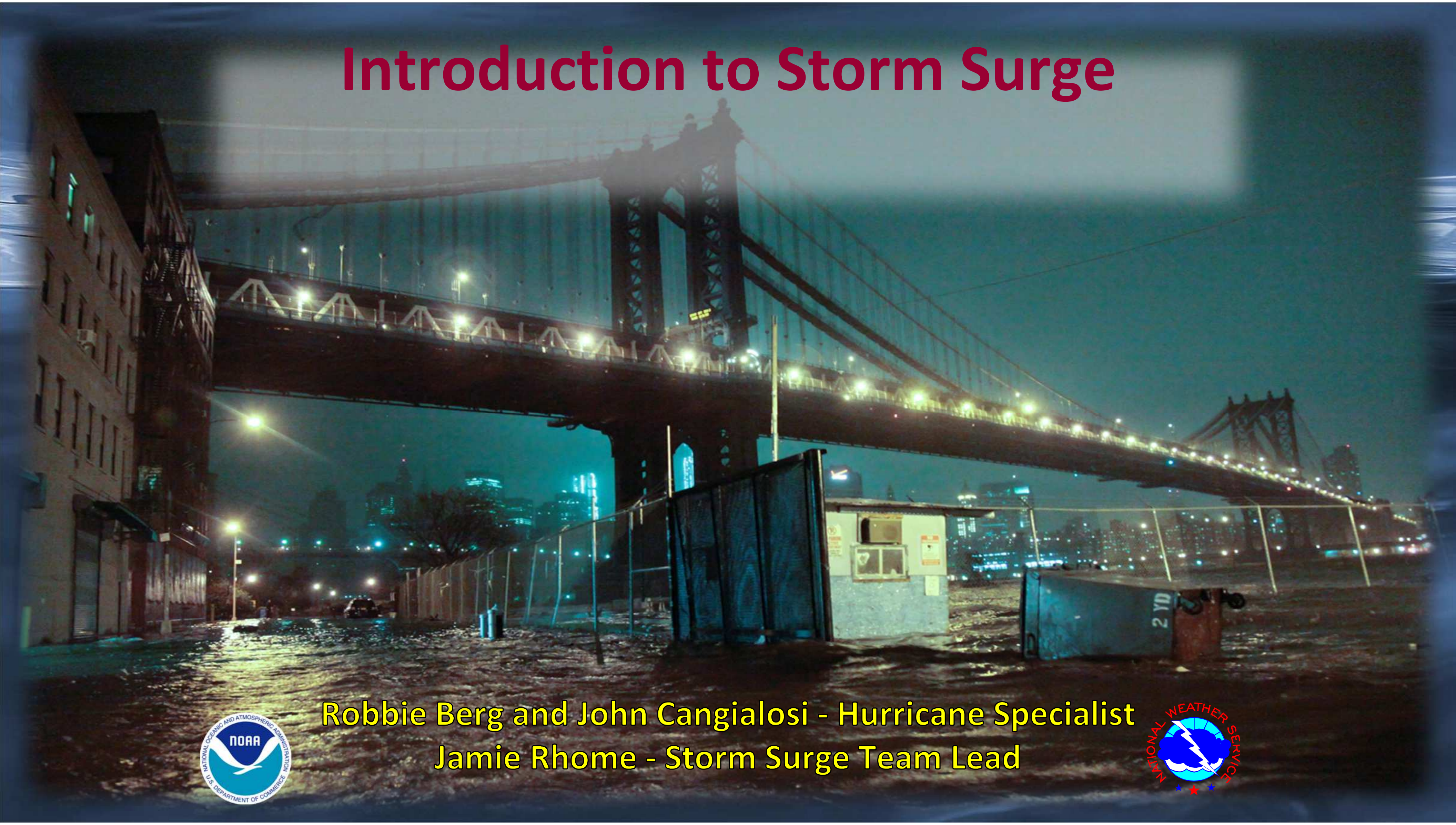
Introduction to Storm Surge



Robbie Berg and John Cangialosi - Hurricane Specialist
Jamie Rhome - Storm Surge Team Lead

Hurricane Katrina (2005) – Mississippi

1200 deaths, $108 billion damage

Hurricane Sandy (2012) – Northeast U.S.

73 deaths, $65 billion damage

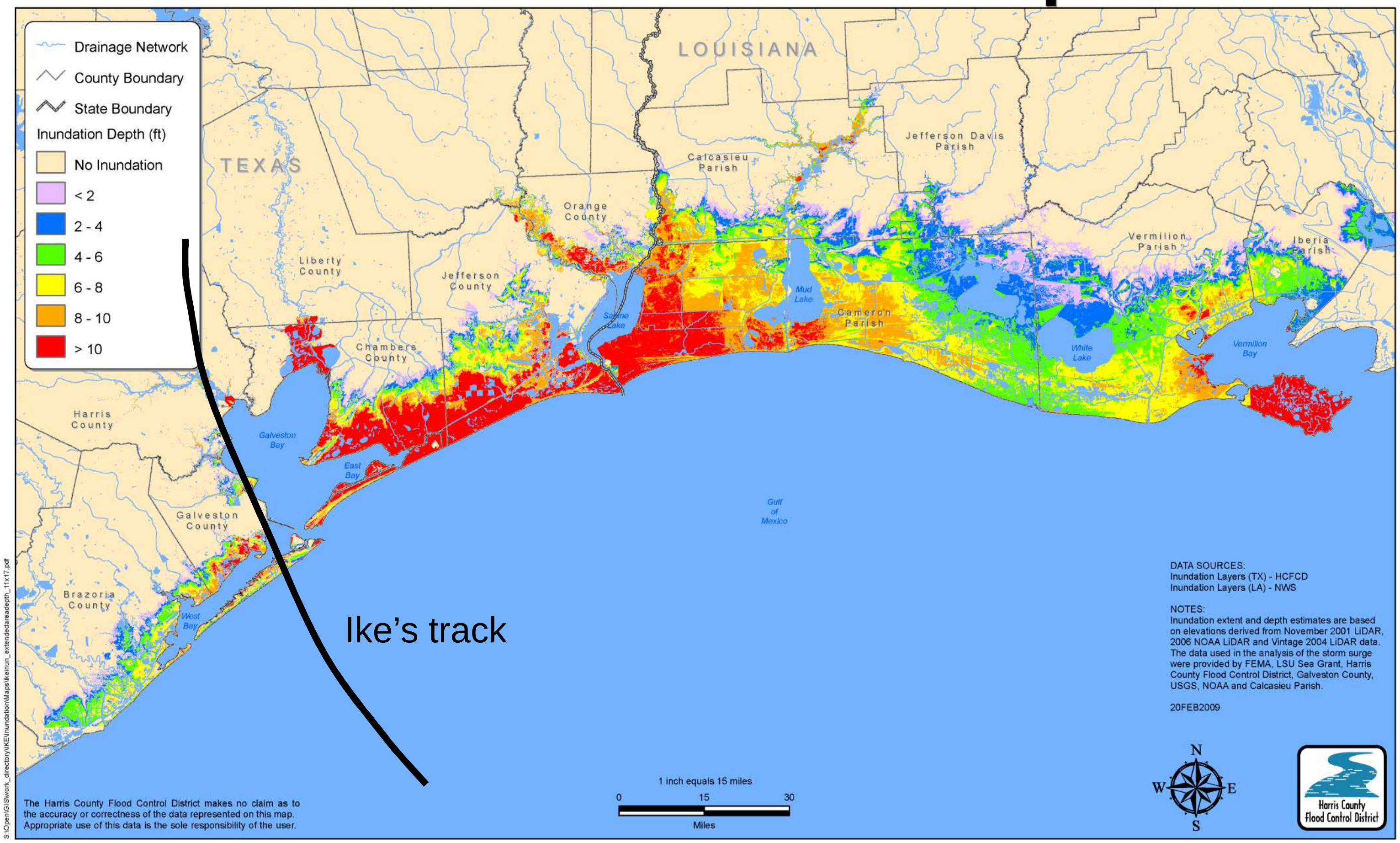
Hurricane Ike (2008) - Bolivar Peninsula, Texas

20 deaths, $29.5 billion

Unit Outline

- Introduction to Storm Surge
  - Who is vulnerable?
  - What is Storm Surge?
  - Factors affecting Storm Surge
- Measuring Storm Surge
  - Data and associated limitations

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.

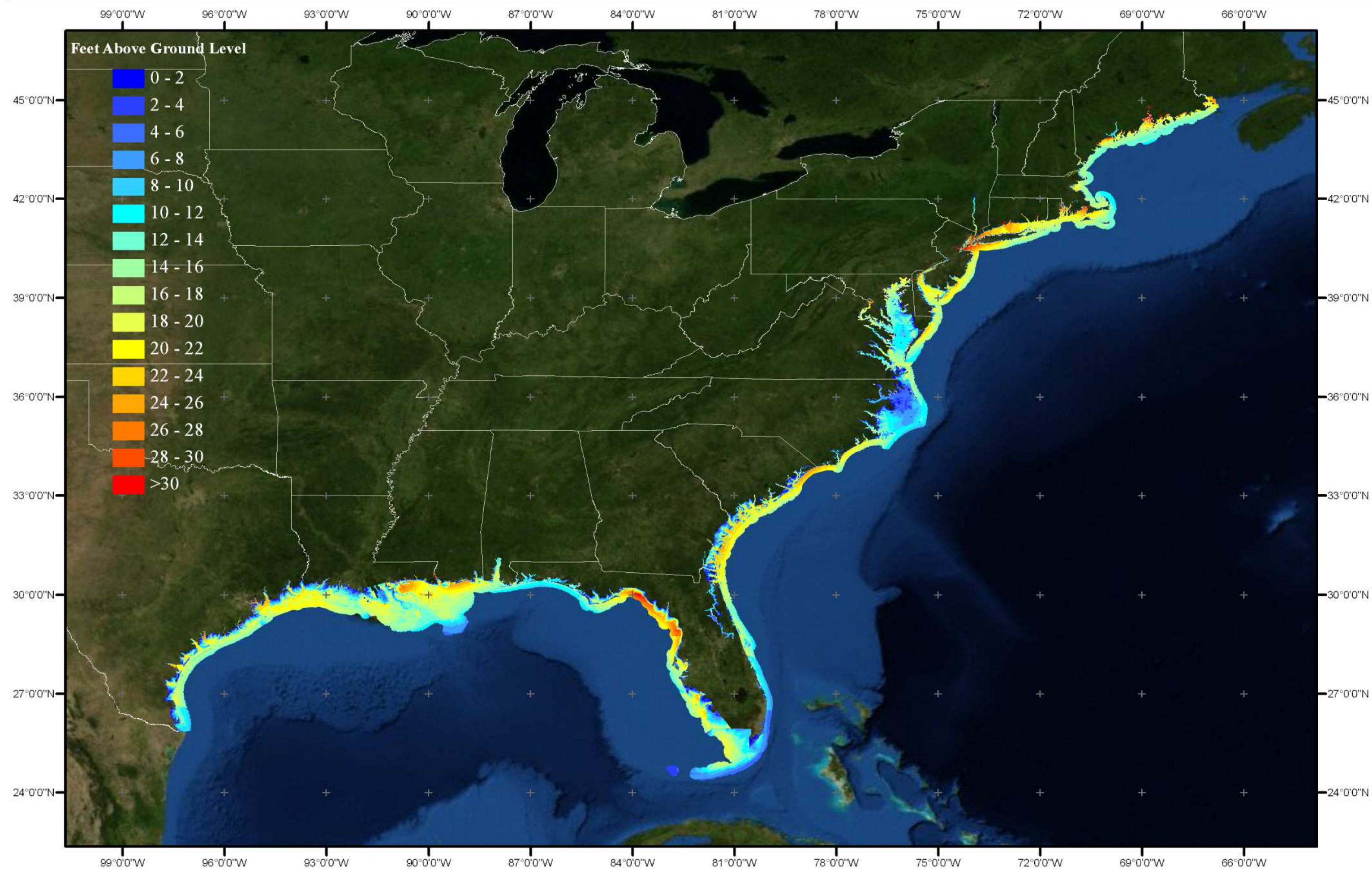
BY ELIZABETH KOLBERT

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

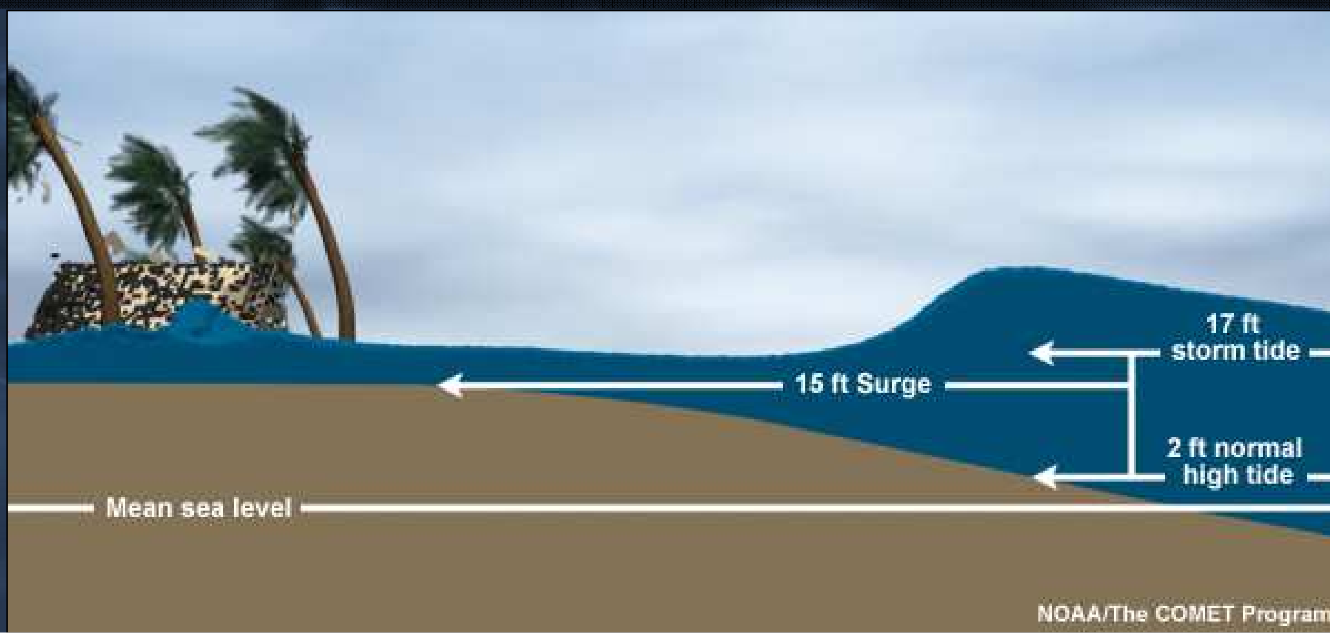
FOR EDUCATIONAL PURPOSES ONLY
NOT TO BE USED TO MAKE LIFE OR DEATH DECISIONS

N
W E
S
0 25 50 100 150 200 Miles

What is Storm Surge?

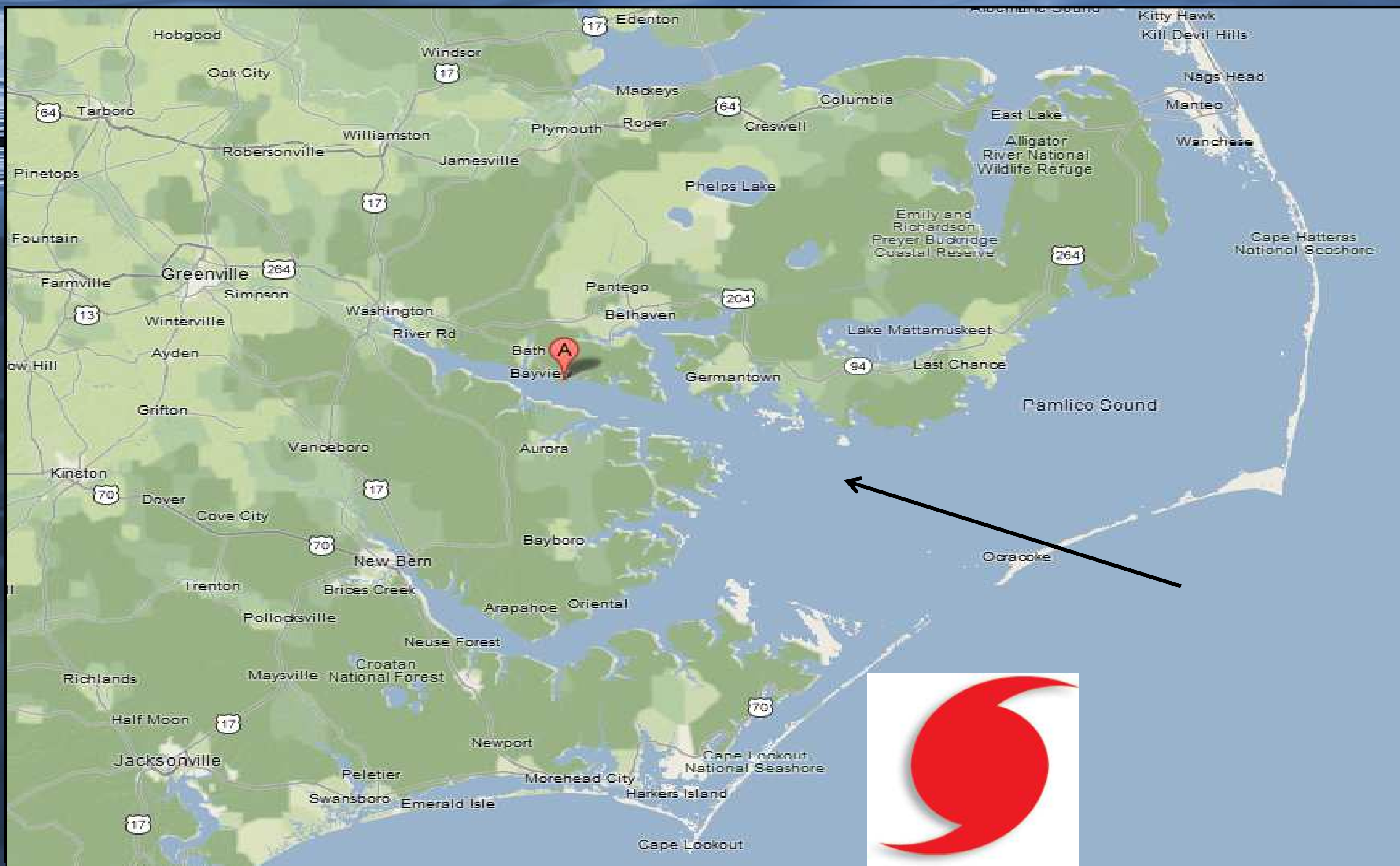
STORM SURGE is an abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

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



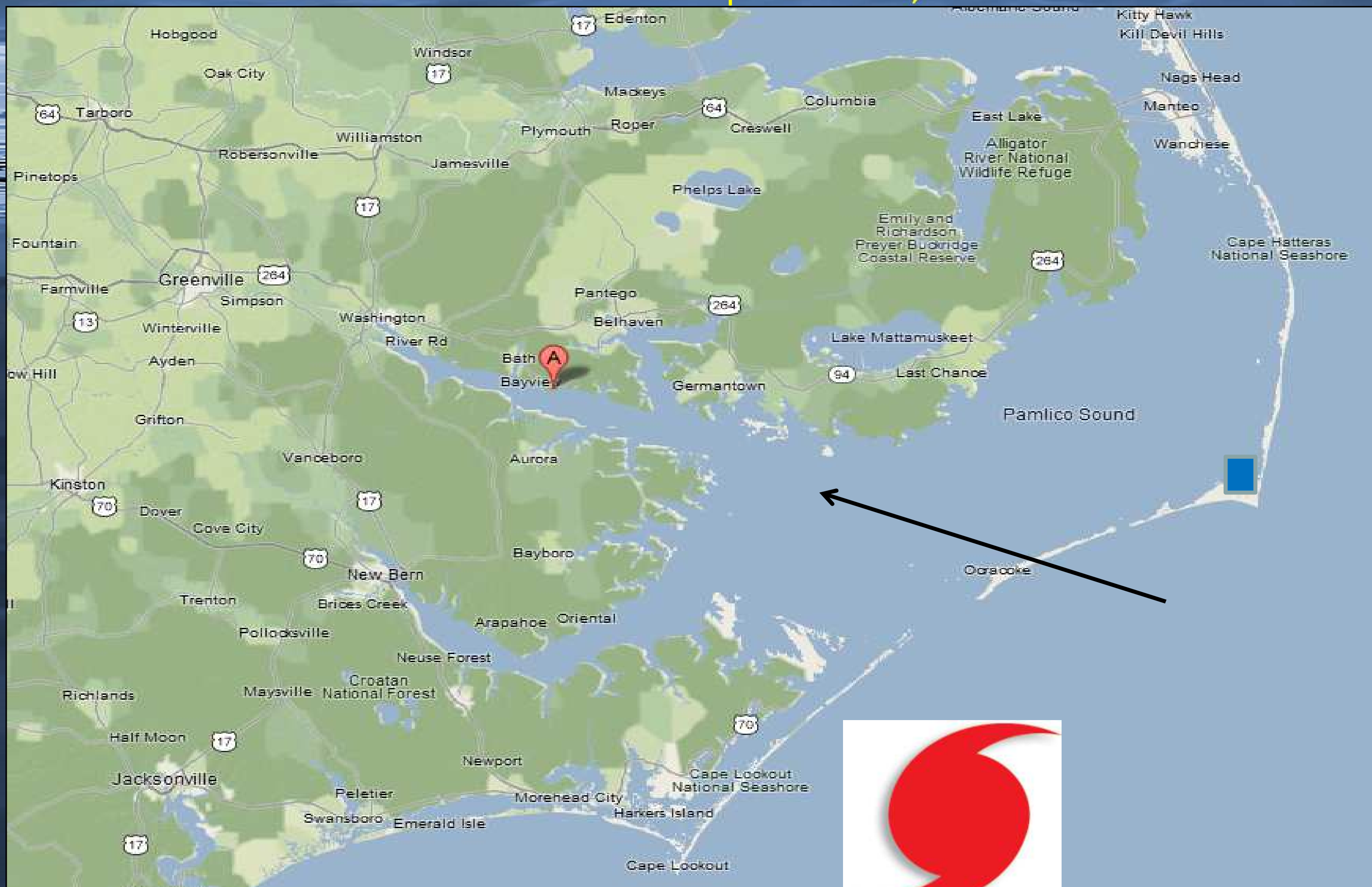
Storm Surge from Hurricane Irene

Rumley Marsh on the Pamlico River in North Carolina



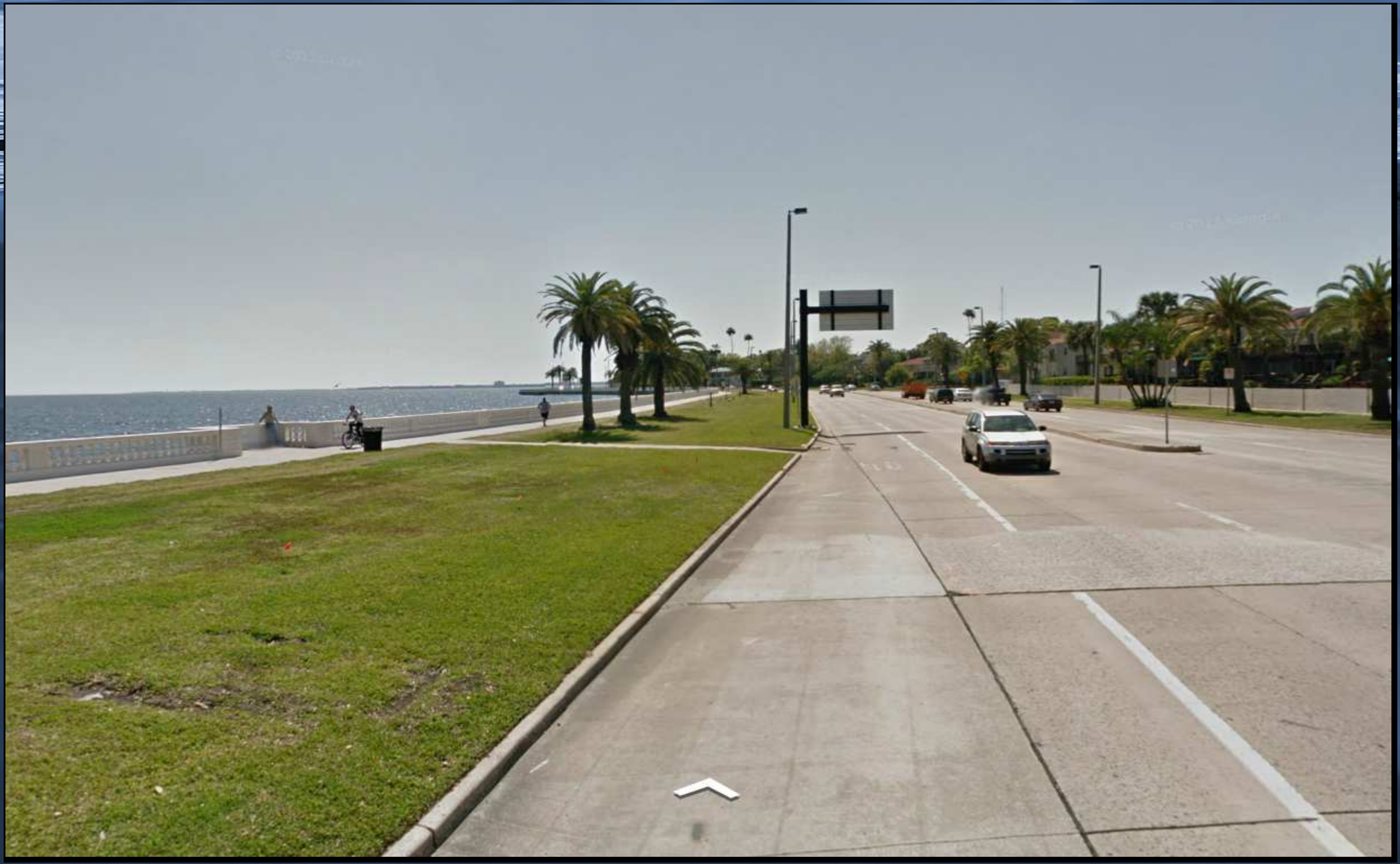
Low Water from Hurricane Irene

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

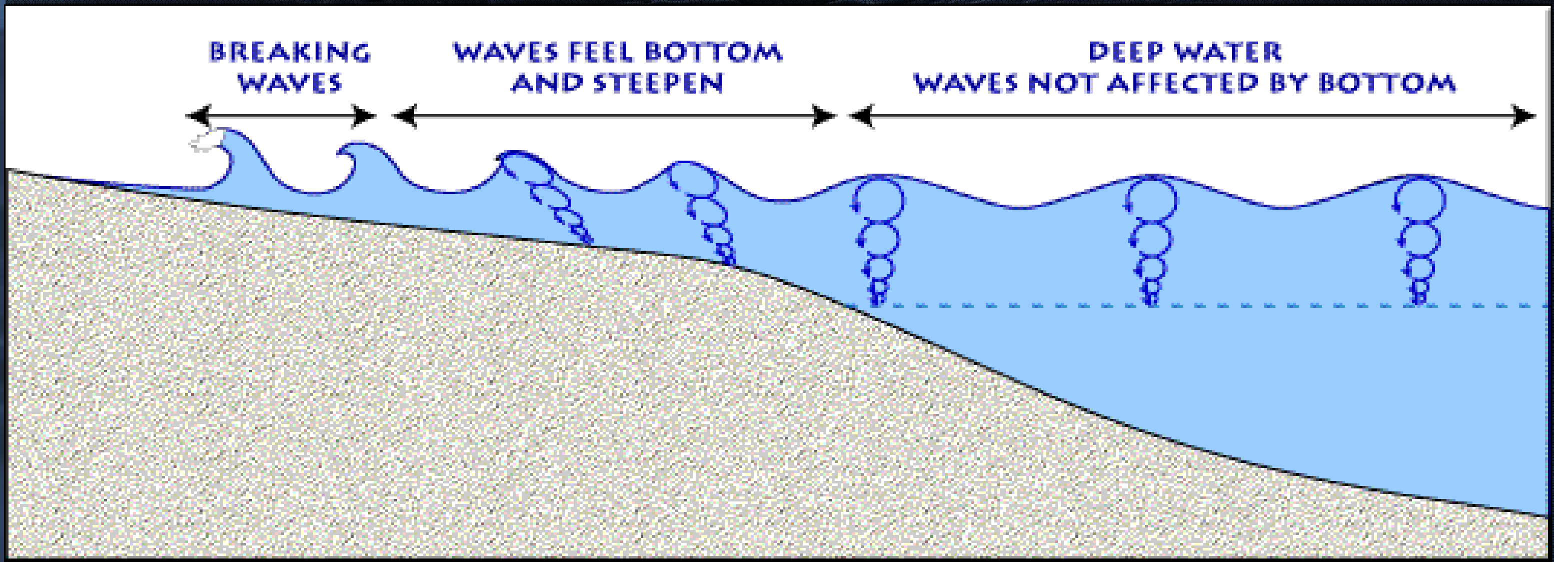
8th St./Ave. C, Manhattan, NY
(YouTube/Kevin Barnett)

Hurricane Ike – Bolivar peninsula, TX

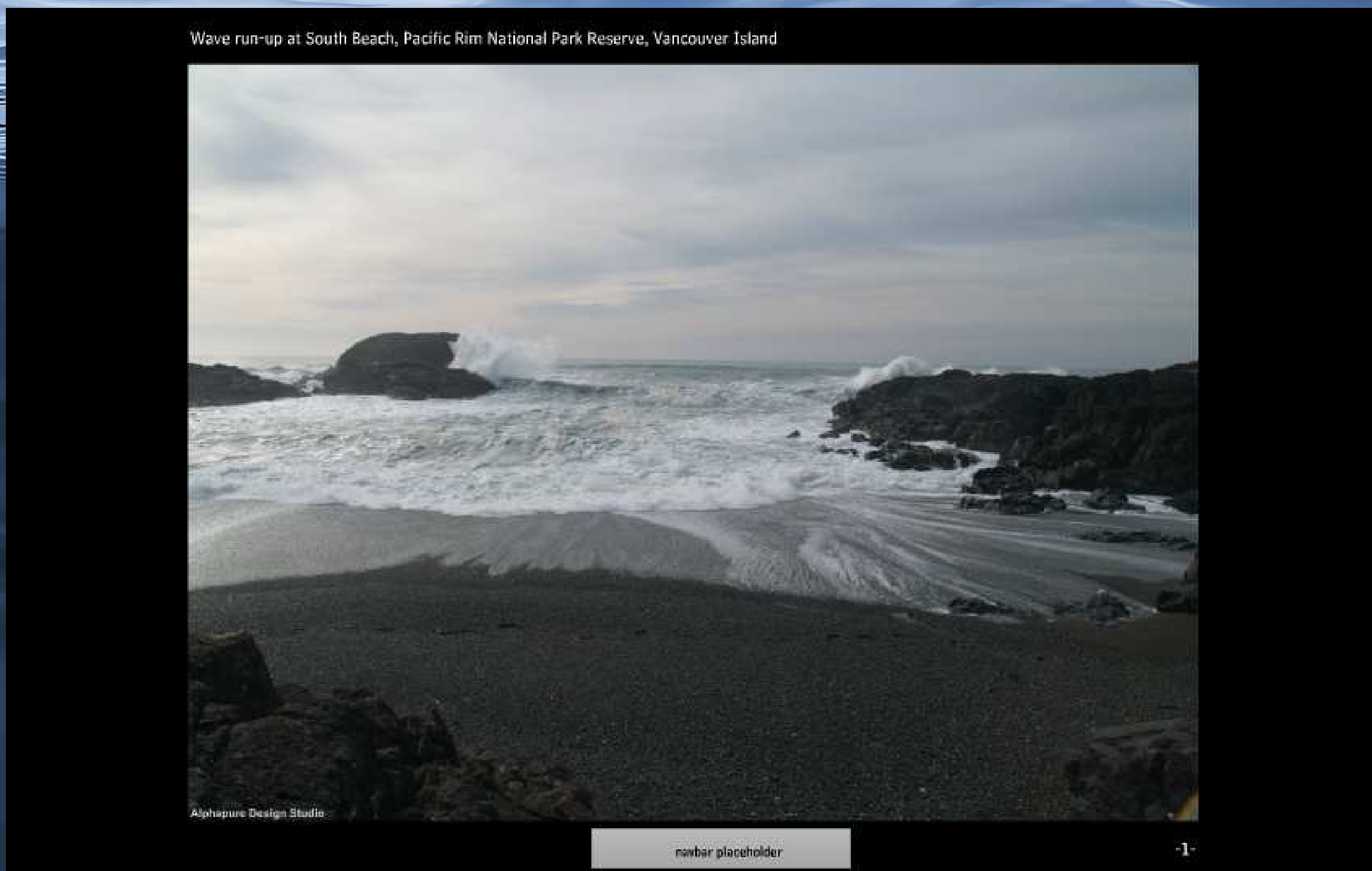
Courtesy of:
Mark Sudduth
Hurricanetrack.com

What about Waves?

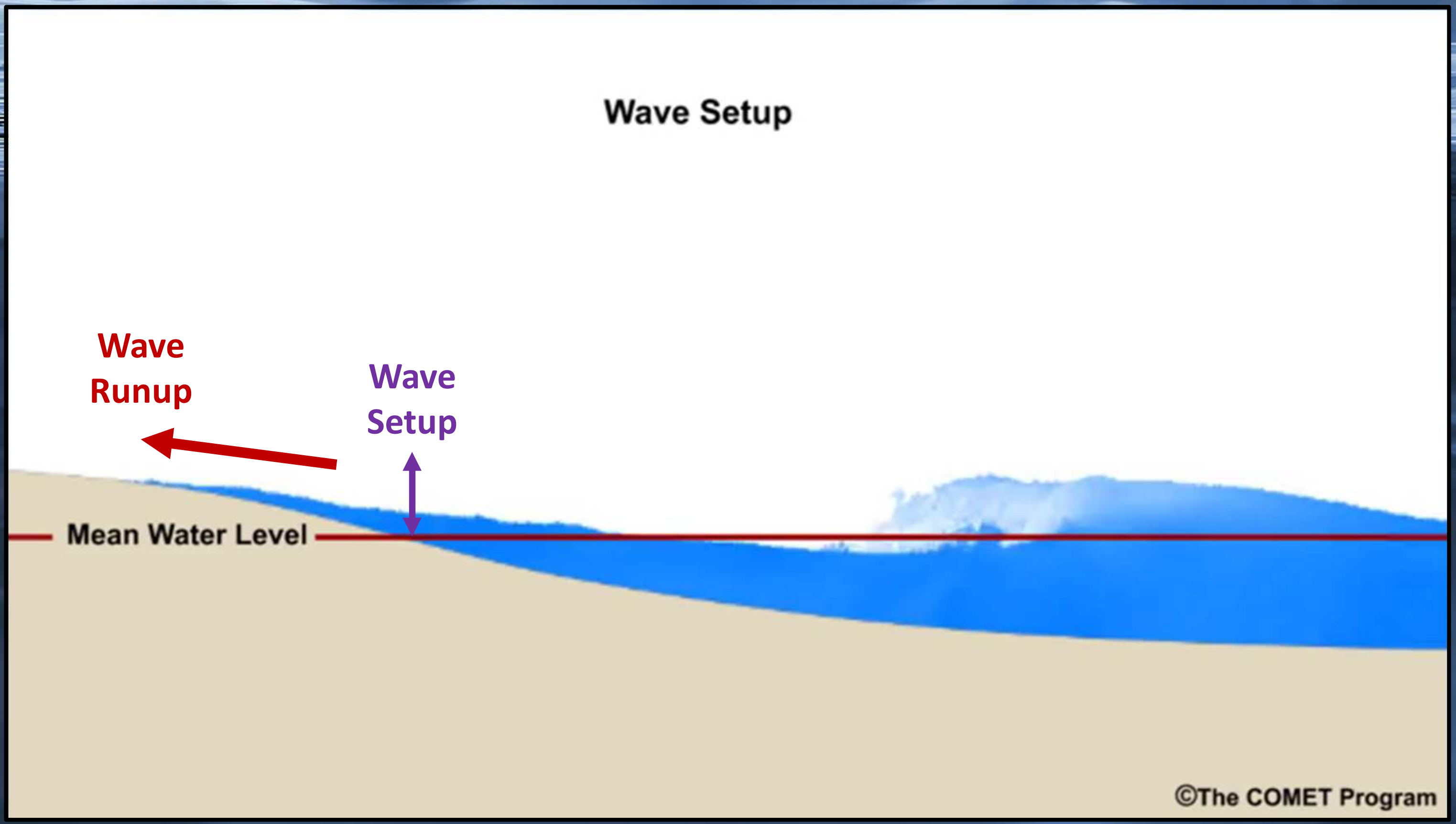
- Breaking waves also contribute to the total water level through wave runup/setup



Wave Runup


Wave run-up at South Beach, Pacific Rim National Park Reserve, Vancouver Island
Alphapure Design Studio
navbar placeholder
-1-

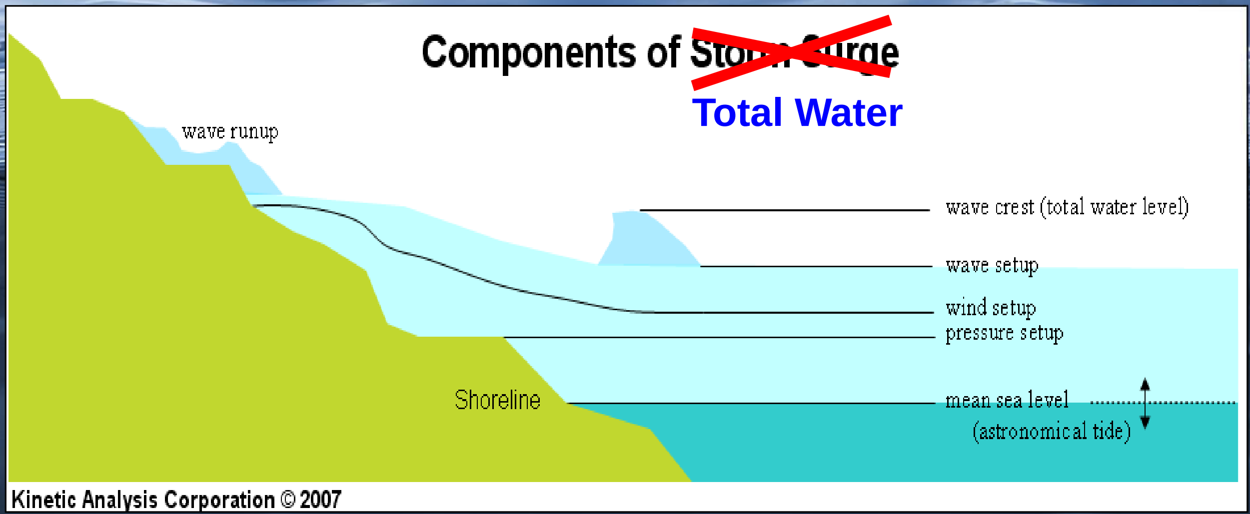
Wave Runup and Setup



Freshwater Input

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

Total Water



Total water level =

Storm surge +

Tides +

Wave setup +

Freshwater

No More Surge in the Saffir-Simpson Scale!

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

Category	Central Pressure: Millibars	Central Pressure: Inches	Winds (mph)	Surge	Damage
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)

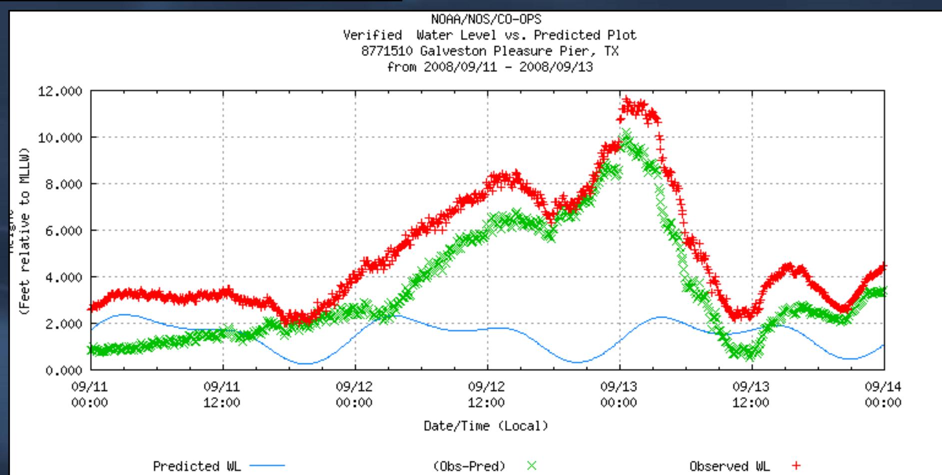
CHARLEY (4)

No Such Thing as
"Just a Tropical Storm"

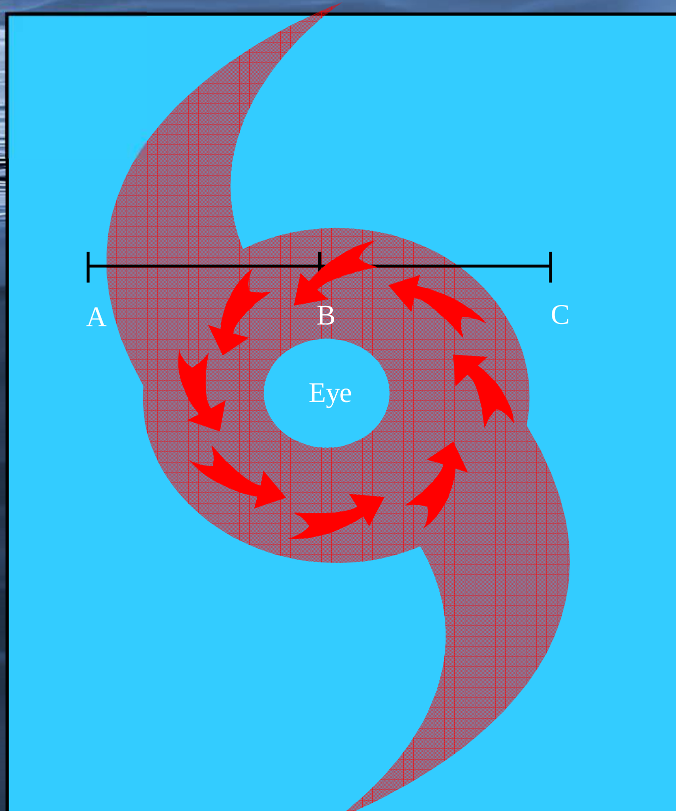
Louisiana State Rd. 23 near Myrtle Grove
Tropical Storm Lee (2011)

Galveston

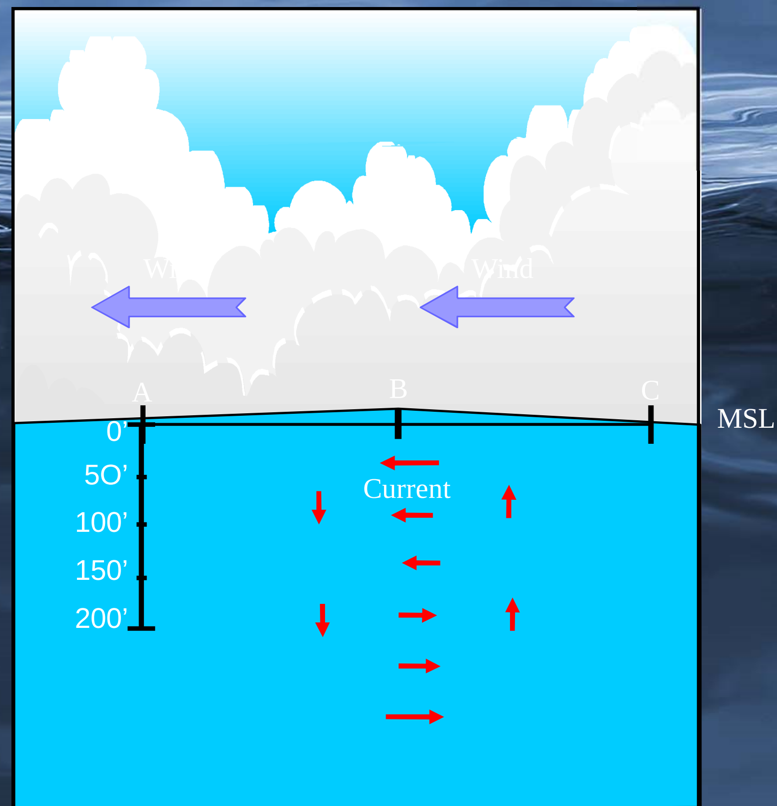
Day before Ike arrived



Deep Water

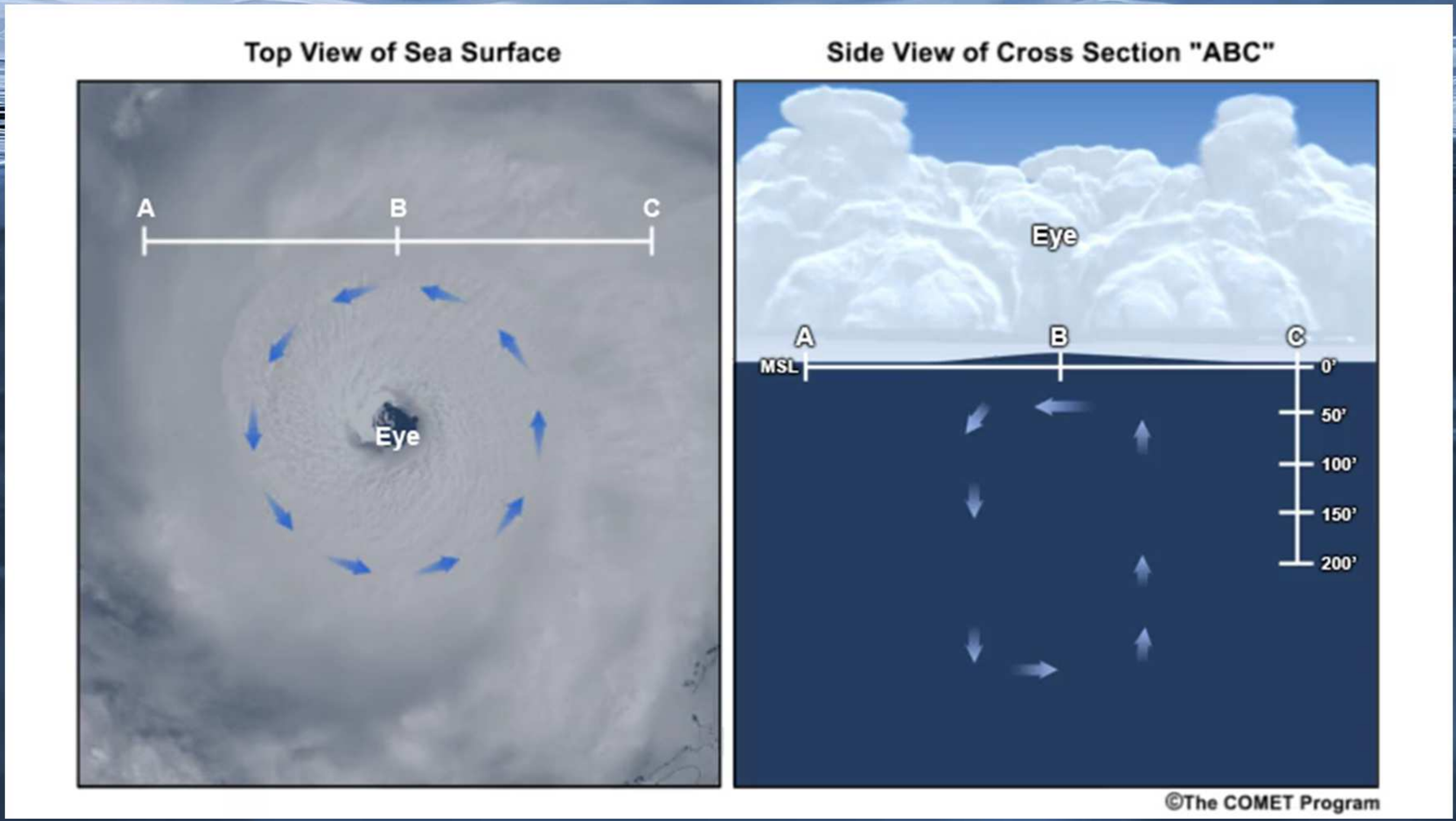


a. Top view of Sea Surface

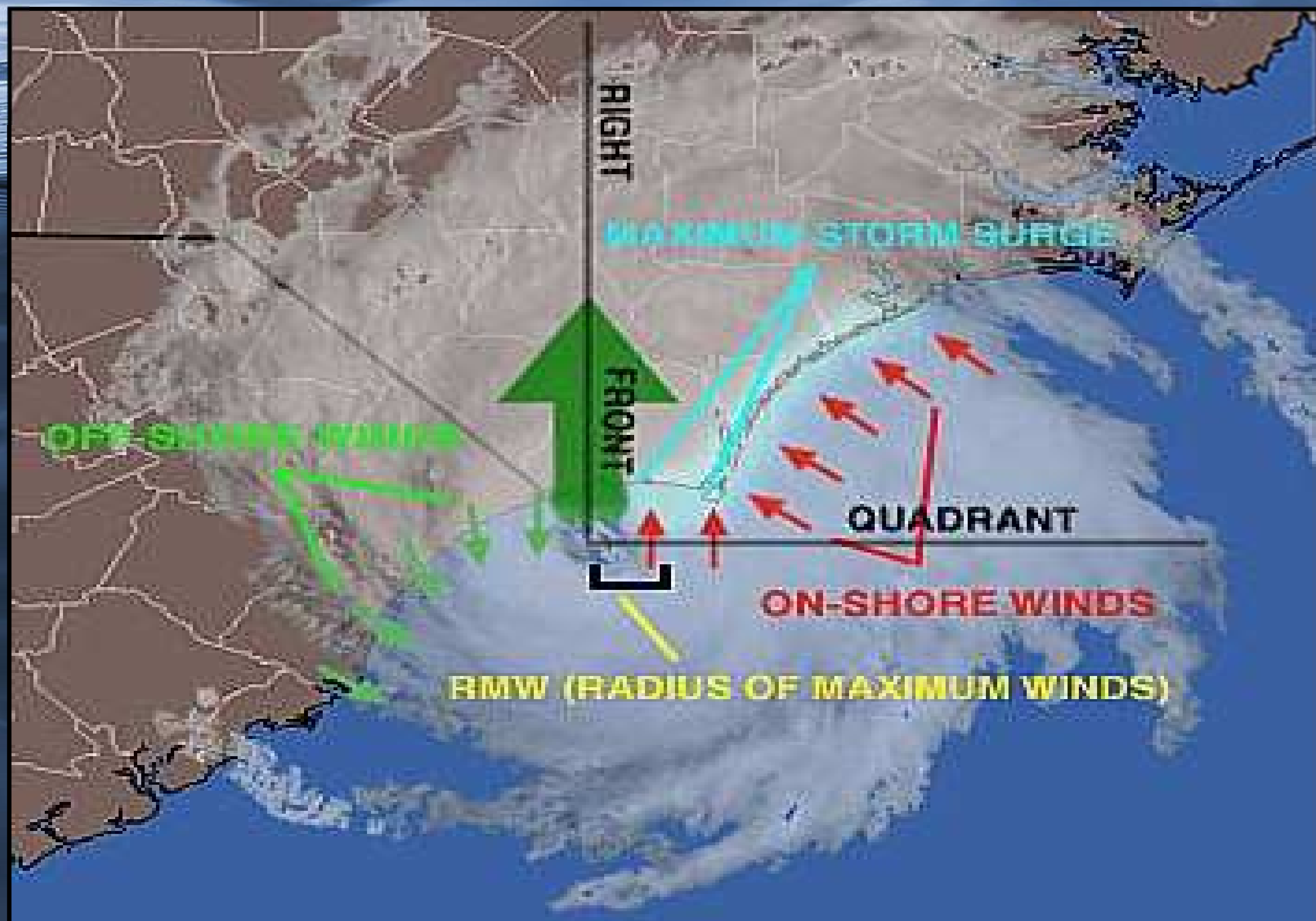


b. Side view of Cross Section "ABC"

From Deep Water to Shallow Water



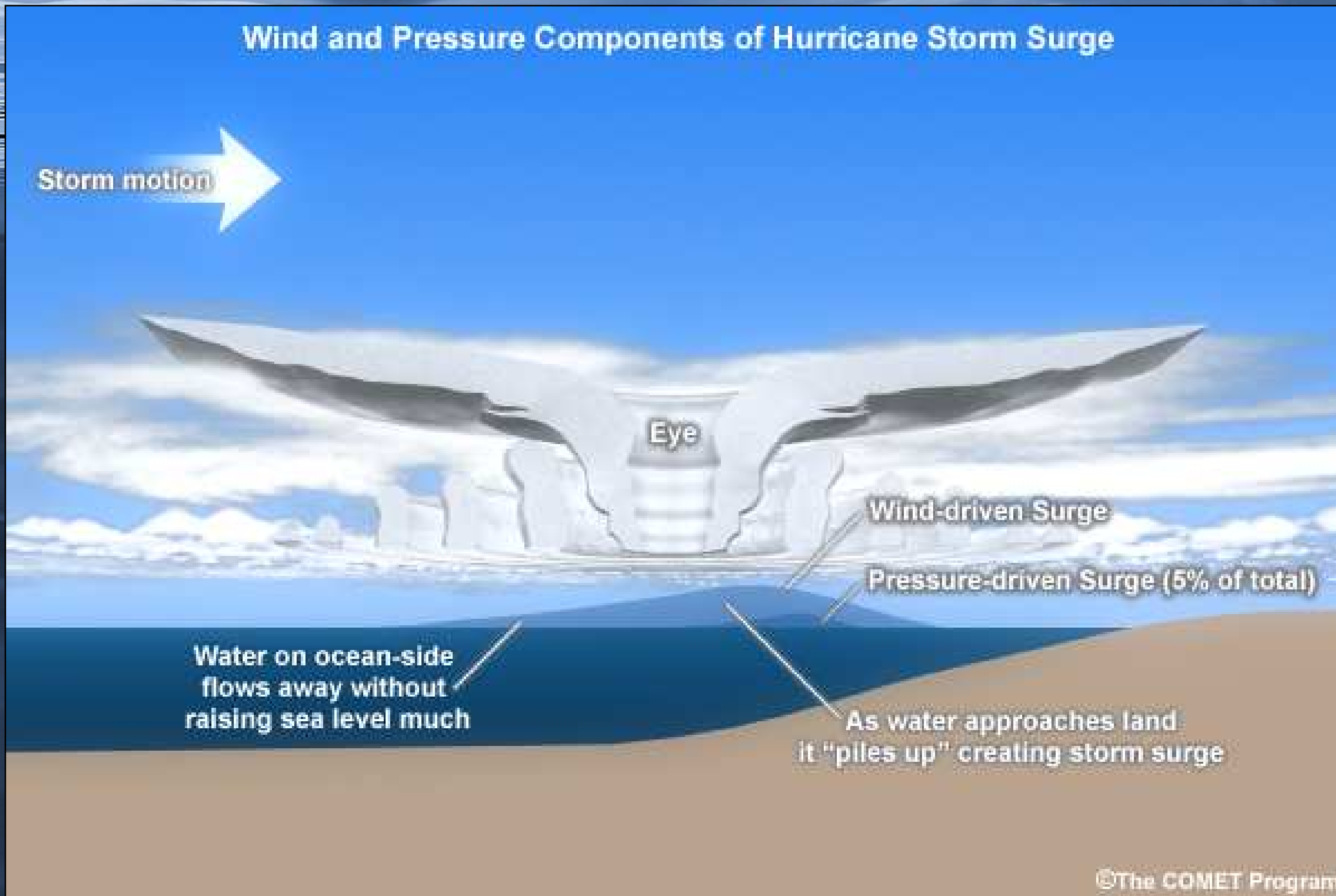
Understanding Surge



Factors Affecting Storm Surge

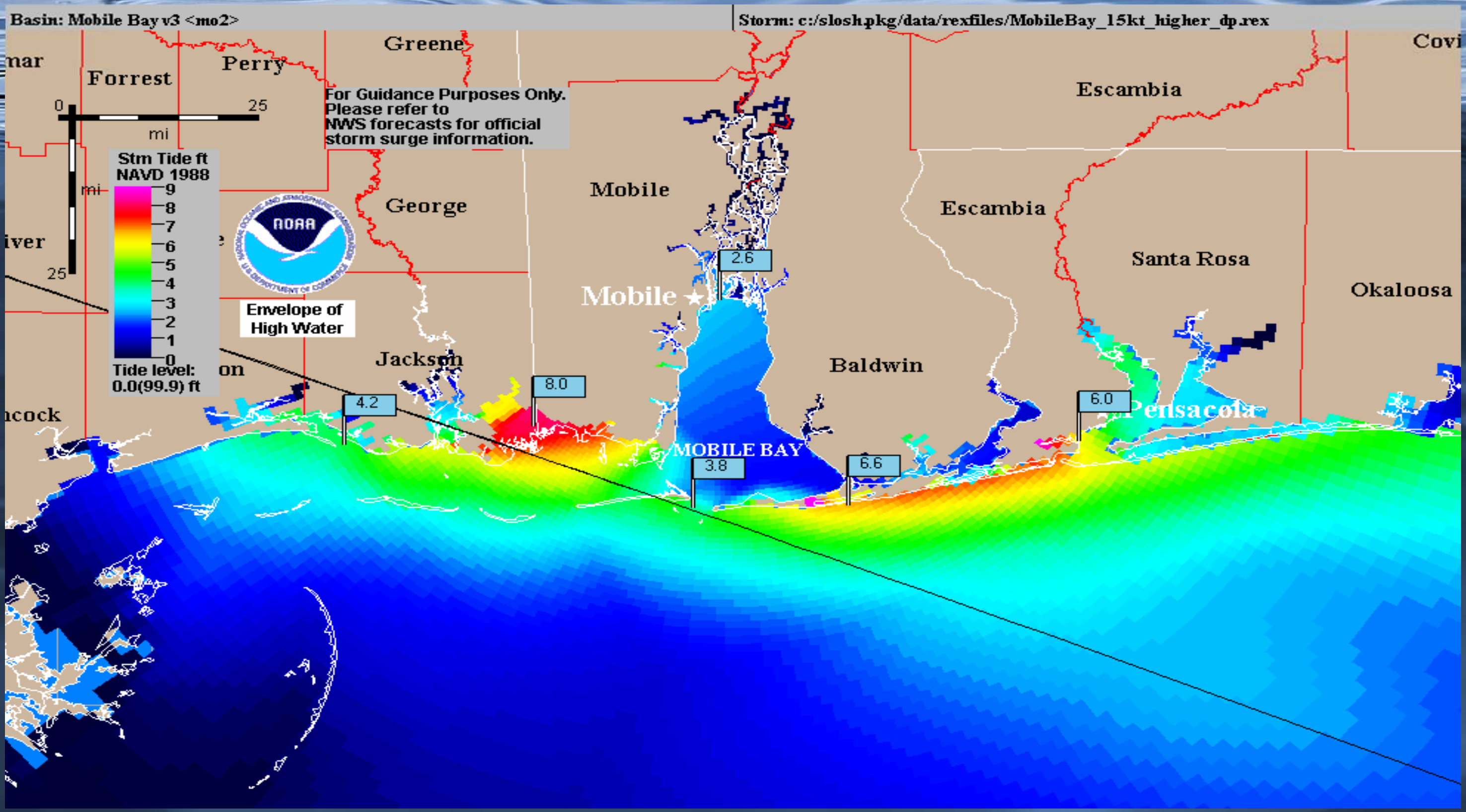
- **Central Pressure**
- **Intensity (wind speed)**
- **Forward Speed**
- **Size**
  - **Radius of Maximum Winds (RMW)**
- **Angle of Approach**
- **Width and Slope of Shelf**
- **Local features** – concavity of coastlines, bays, rivers, headlands, or islands

Effects of Low Pressure

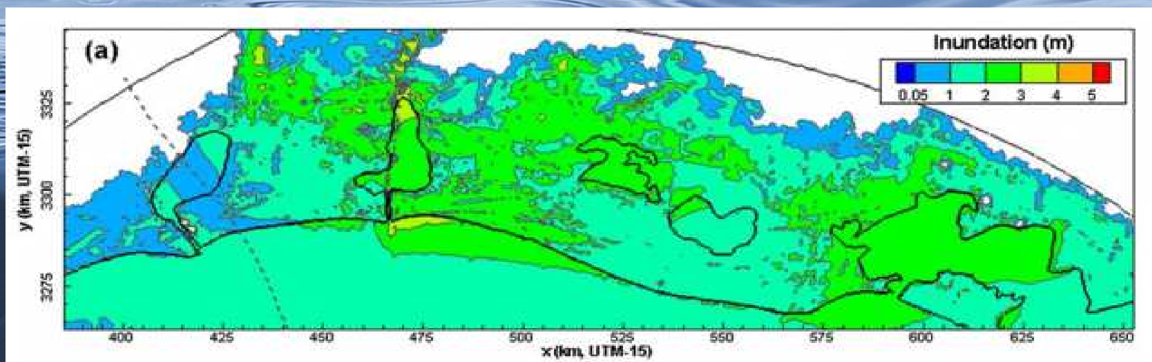


Intensity (Wind Speed)

15 mph stronger

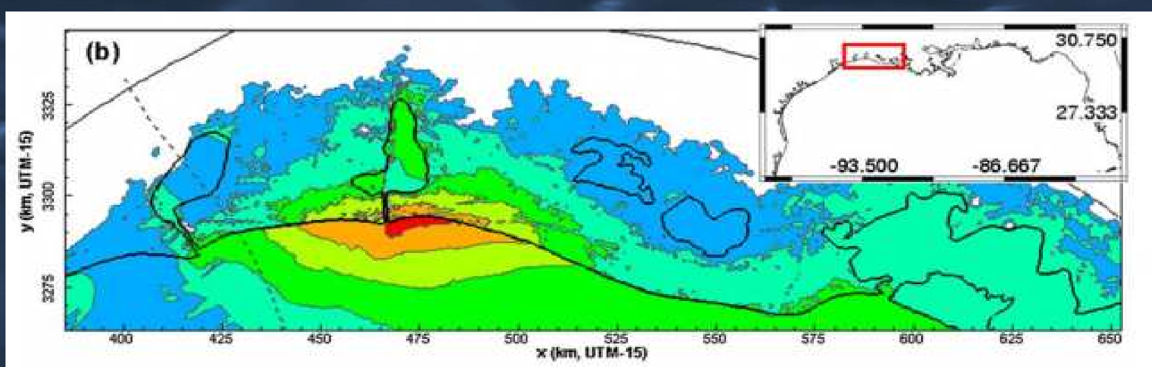


Forward Speed



Slow Speed (5 mph)

- More inland penetration



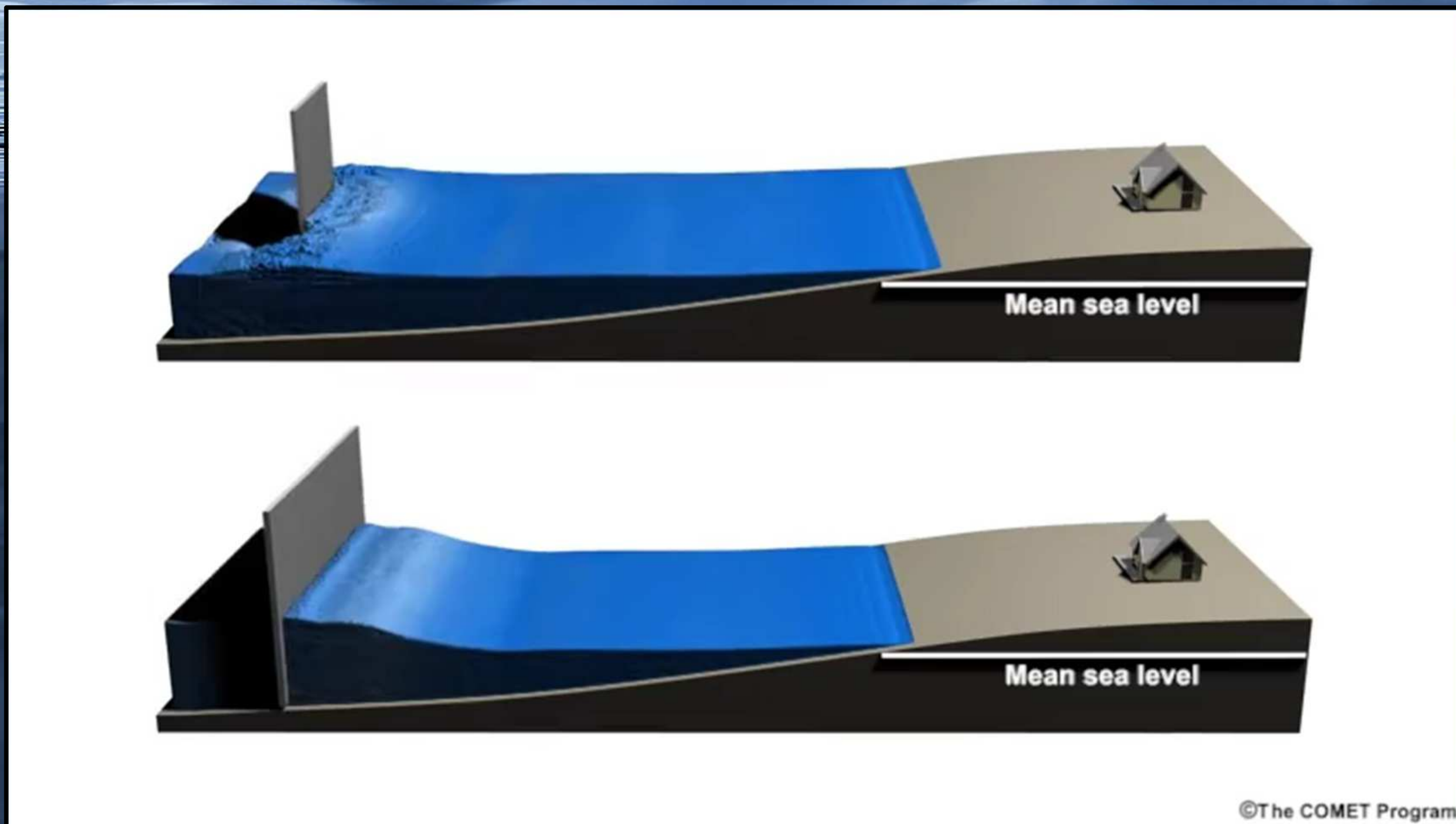
Fast Speed (25 mph)

- Higher maximum

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

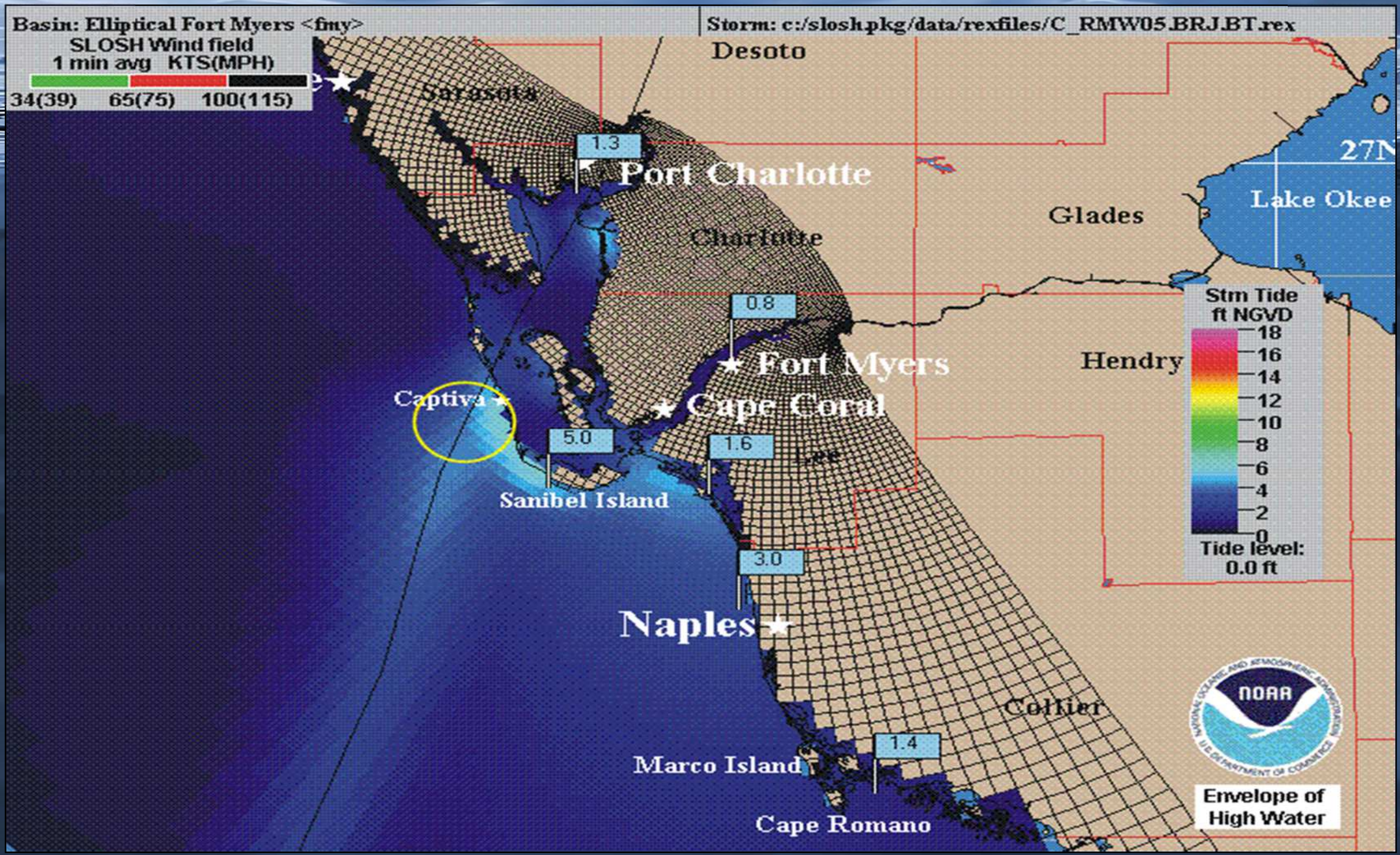
Size

(Radius of Max Winds)



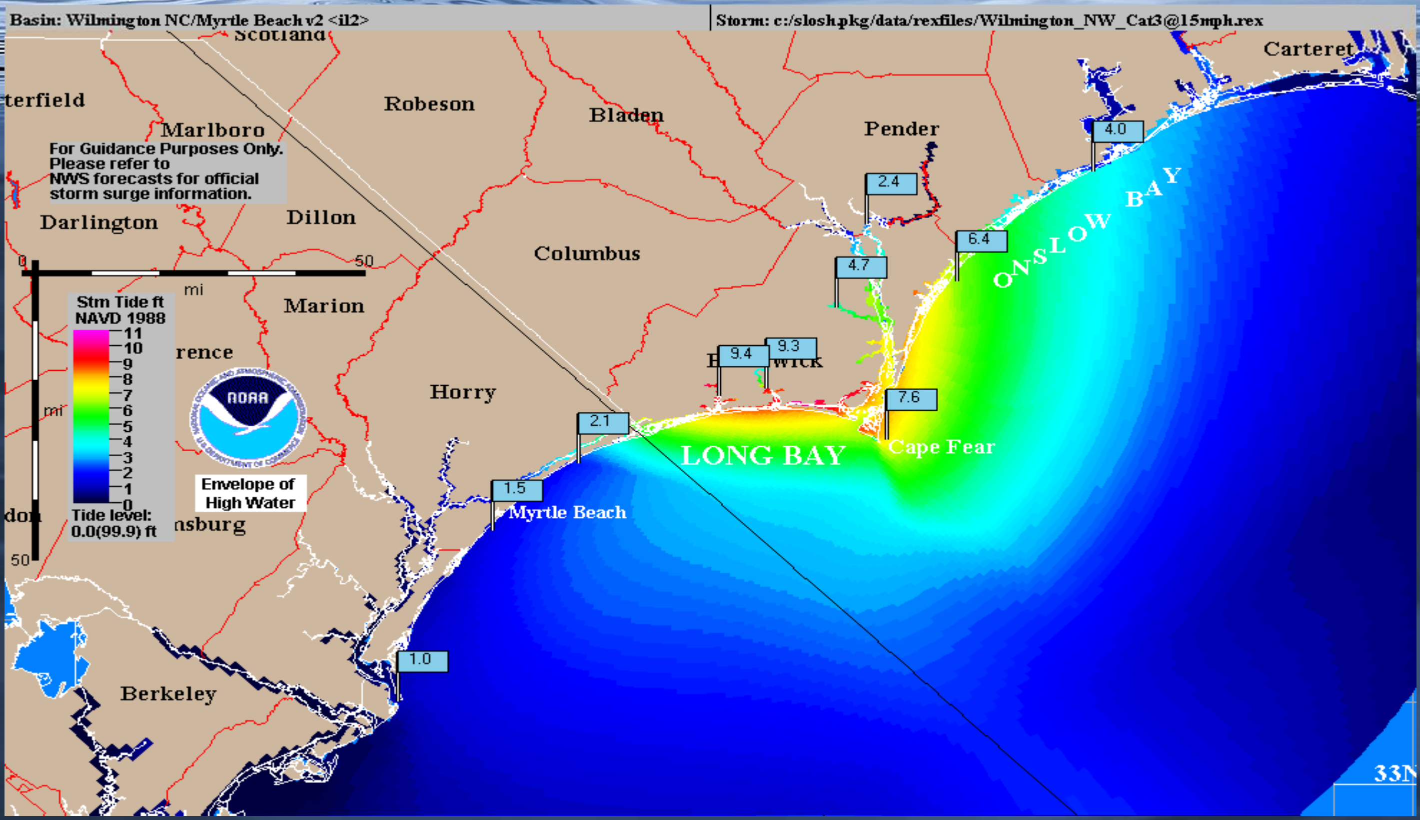
Size

(Radius of Max Winds)

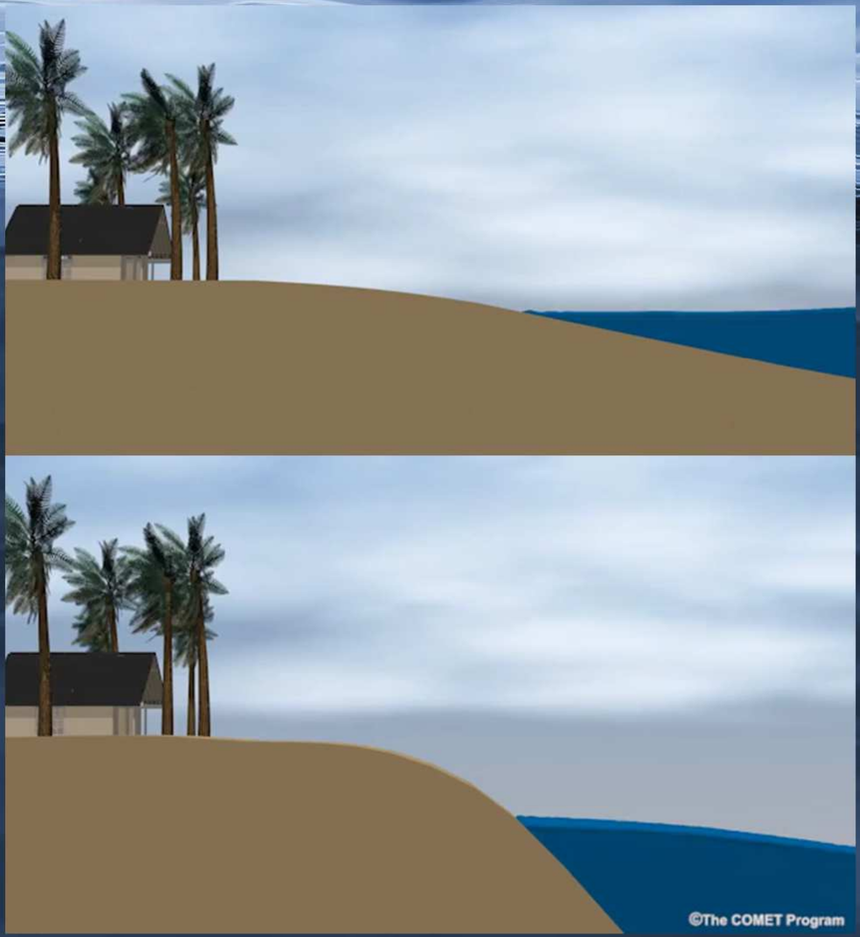


Angle of Approach

NNW Motion



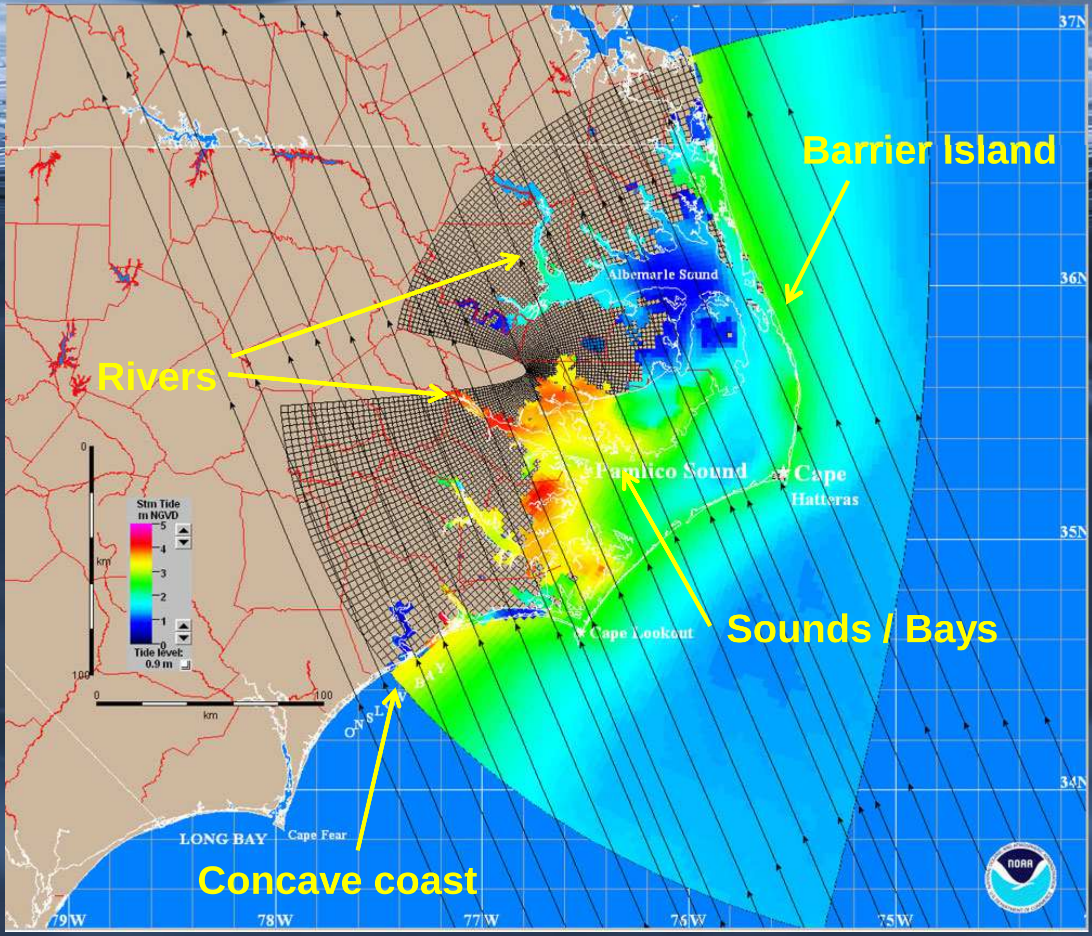
Width and Slope of Shelf

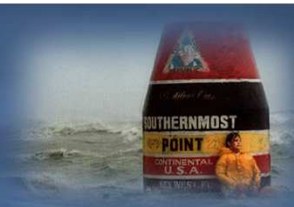


Wide shelf/
gentle slope

Narrow shelf/
sharp slope

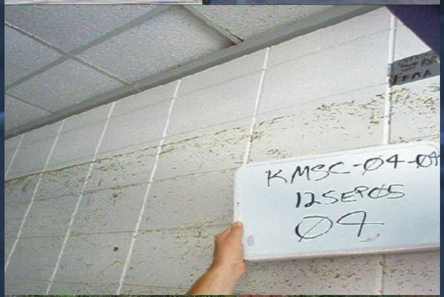
Local Features

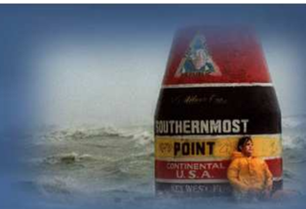




Observing and Measuring Storm Surge

- Tide stations (NOAA)
  - Still water
  - Traditionally most reliable
  - Limited stations
  - Stations often fail at height of event
- High water marks (FEMA/USGS)
  - Perishable
  - Traditionally best method for capturing highest surge
  - Subjective and often include impacts of wave runup/setup
- Pressure Sensors (USGS)
  - Relatively new method
  - Deployed in advance of storm at expected location of highest surge
  - Can contain effects of waves



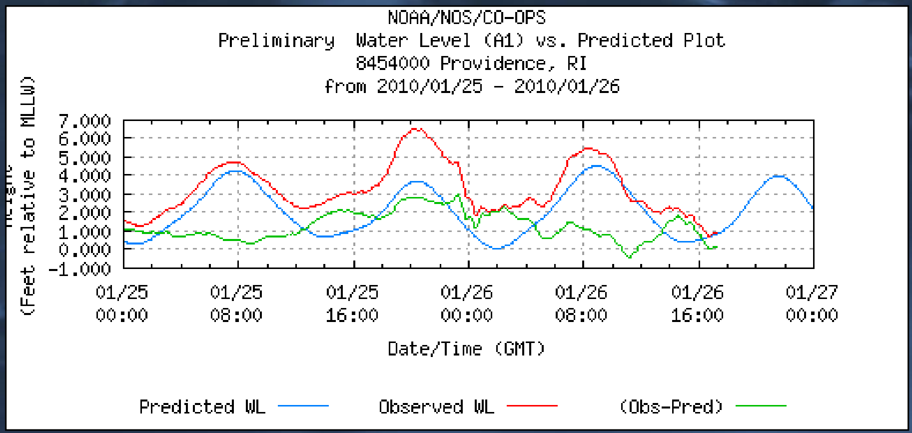


NOS Water Level Stations

- A network of long-term, continuously operating water-level stations throughout the U.S.
- Expanded over time in response to increasing national and local needs.
- Serve as foundation for NOAA's tide prediction products

NOS Water Level Stations

- http://tidesonline.nos.noaa.gov
- http://tidesandcurrents.noaa.gov

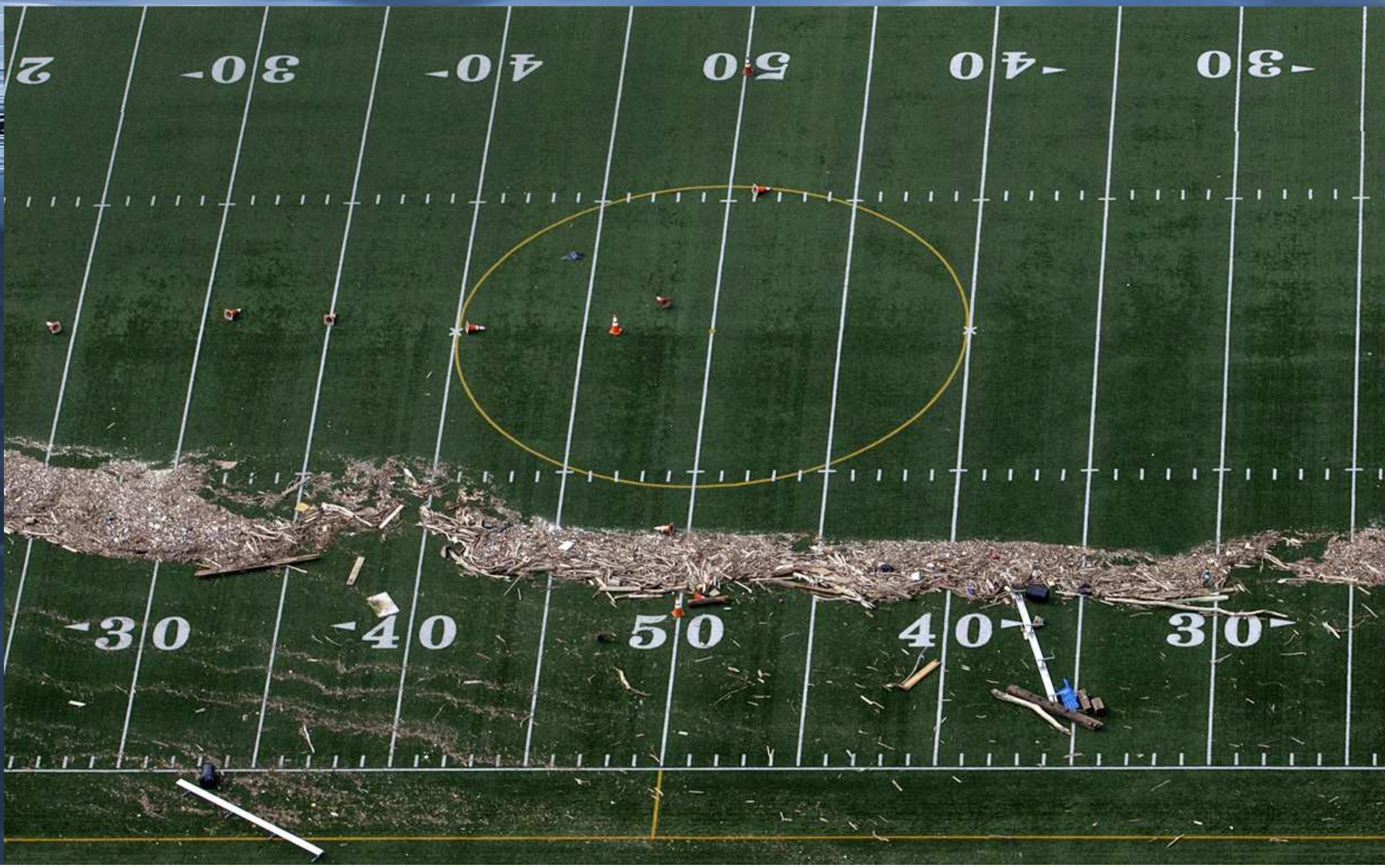


High Water Marks

- Lines found marking the highest elevation (peak) of the water surface for a flood event
- Two types:
  - Lines found on trees and structures
  - Foam, seed, debris lines marking furthest extent
- Survey crews deployed after storm to locate and record reliable HWMs
- Generally include effects of wave action/wave runup and only a small percentage of HWMs represent still water (storm surge)

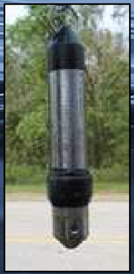
High Water Mark

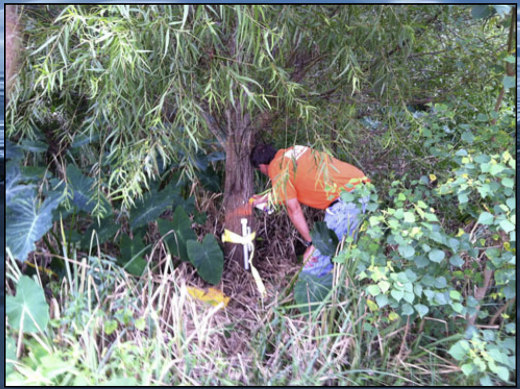
Hoboken, New Jersey (Sandy)

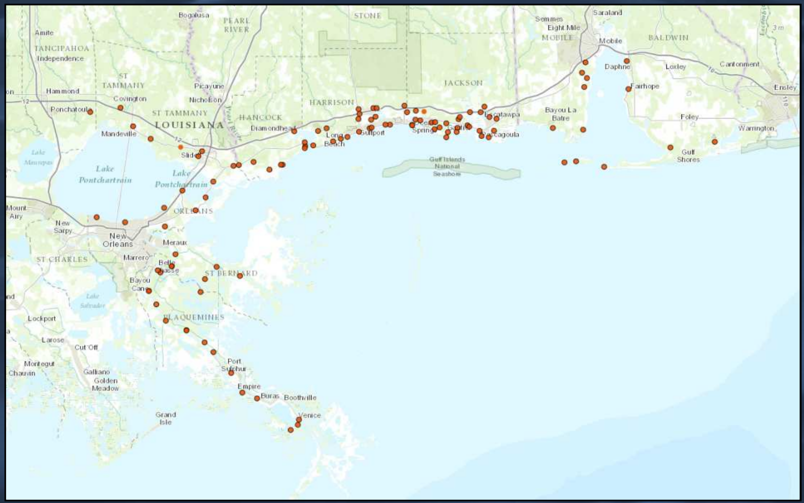


USGS Pressure Sensors

- Temporary water-level and barometric-pressure sensors
- Installed right before cyclone landfall
- Provide information about storm surge duration, times of surge arrival and retreat, and maximum depths







Surge Data Issues

- Instrument failures during event
  - Incomplete data or data does not capture height of event
- Different reference levels (what the heck is the difference between sea level, MLLW, NGVD29, NAVD88, etc.?)
  - Complicated conversion methods
- Different or even unknown error characteristics
  - Incompatible data sources
- Data measuring different things
  - Stillwater versus wave runup