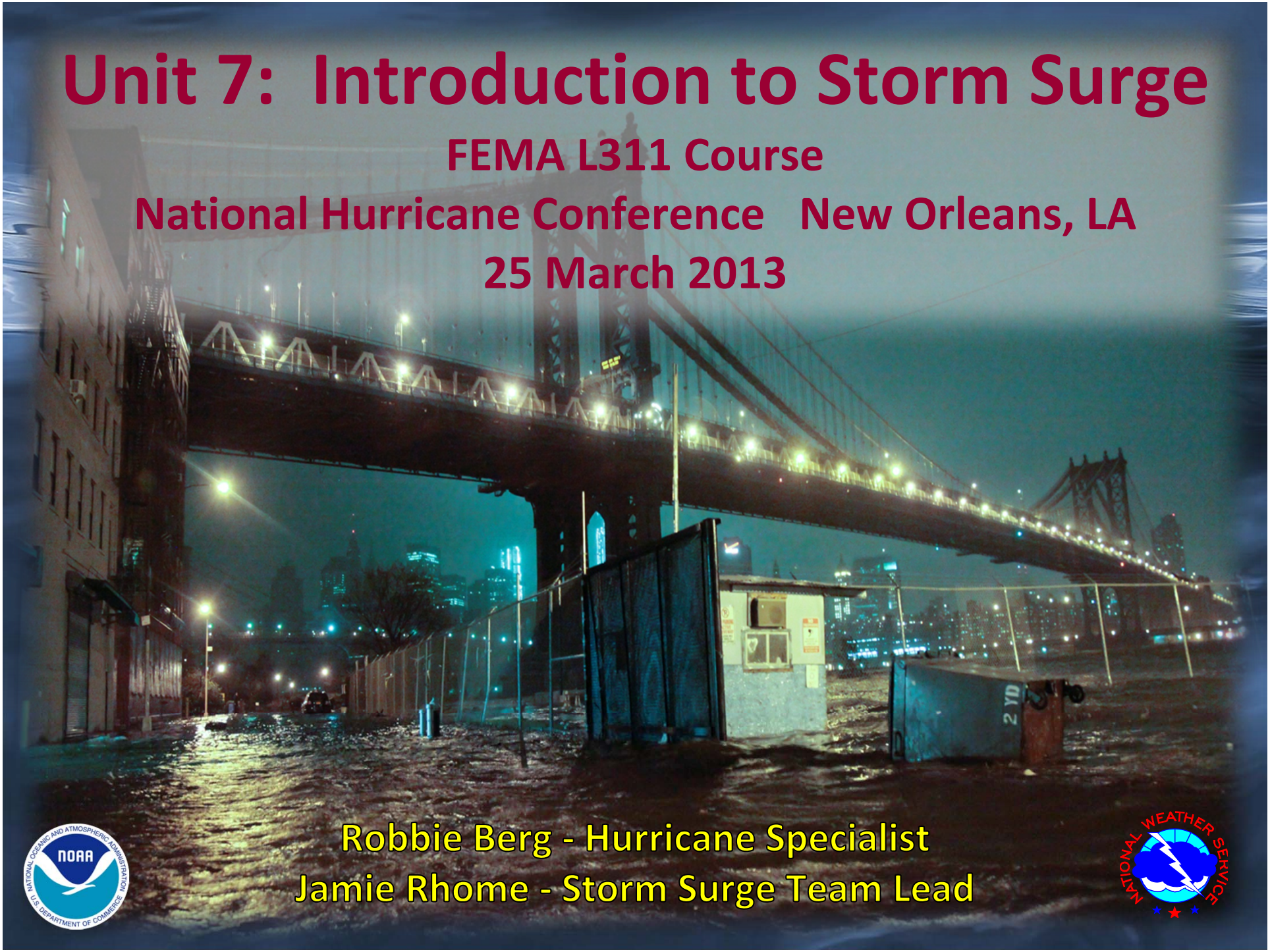
Unit 7: Introduction to Storm Surge

FEMA L311 Course

National Hurricane Conference New Orleans, LA

25 March 2013



Robbie Berg - Hurricane Specialist
Jamie Rhome - Storm Surge Team Lead

Hurricane Katrina (2005) – Mississippi

1200 deaths, $108 billion damage

Hurricane Sandy (2012) – Northeast U.S.

72 deaths, at least $50 billion (still pending)

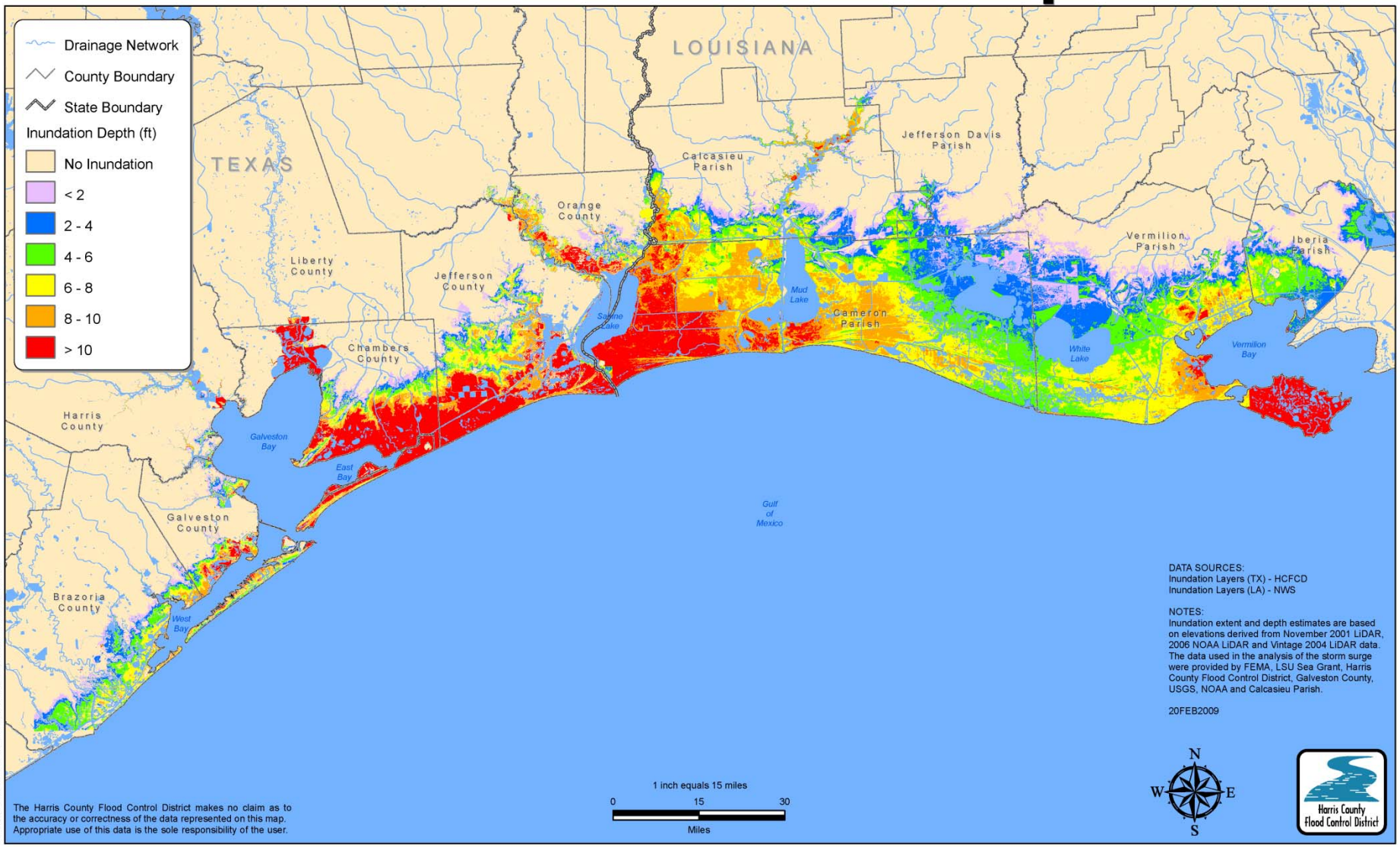
Hurricane Ike (2008) - Bolivar Peninsula, Texas

20 deaths, $29.5 billion

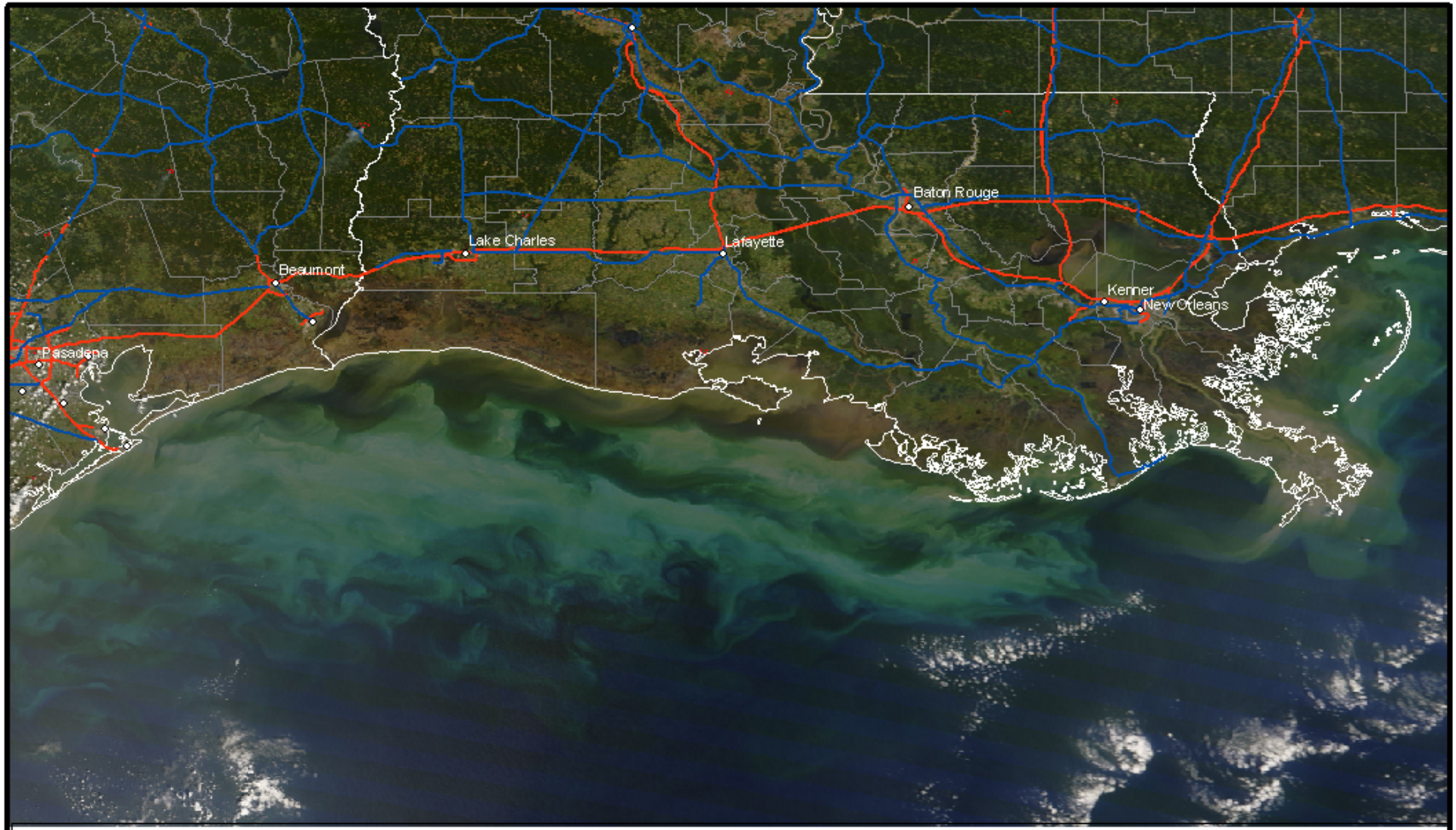
Unit Outline

- 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



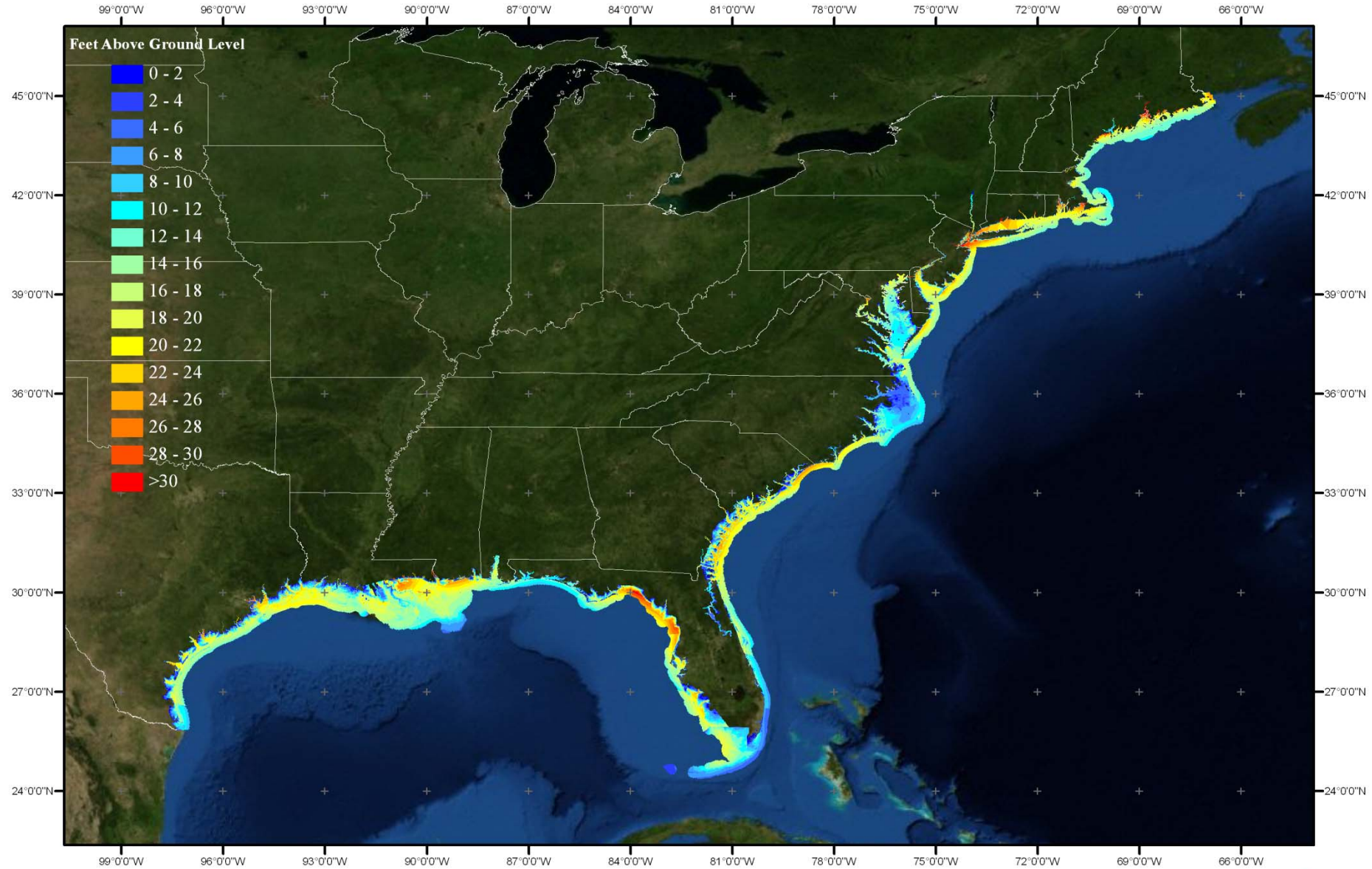
The brown region along the coast indicates dying vegetation due to Salt Water burn. The brown area in the Gulf of Mexico indicates a high concentration of sediment that was taken from the coastal areas when the surge waters flowed back into the gulf. Imagery courtesy of NASA. Map made by Donovan Landreneau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

House of David and Kimberly King
Waveland, Mississippi

Vulnerability

- 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

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

Baltimore, Maryland
Isabel (2003)

Hampton, Virginia
Isabel (2003)

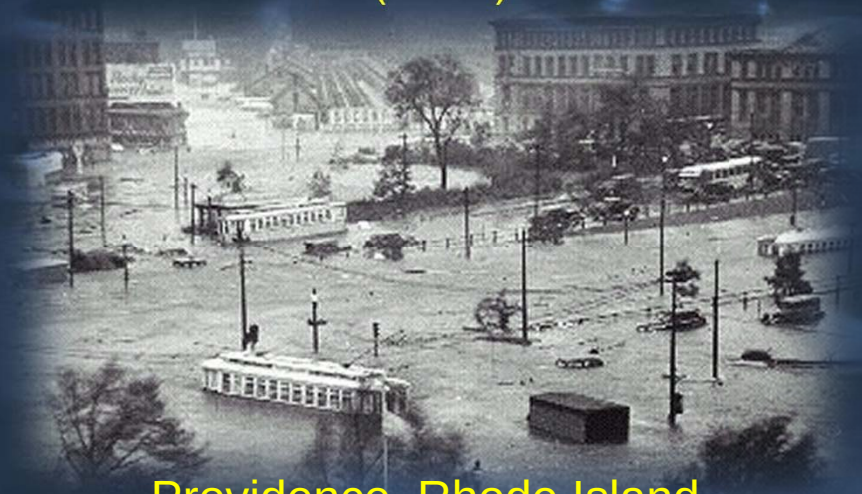
Mantoloking, New Jersey
Sandy (2012)

Staten Island, New York
(Sandy 2012)

New England

Narragansett Bay, Rhode Island
Carol (1954)

Westport, Massachusetts
Irene (2011)



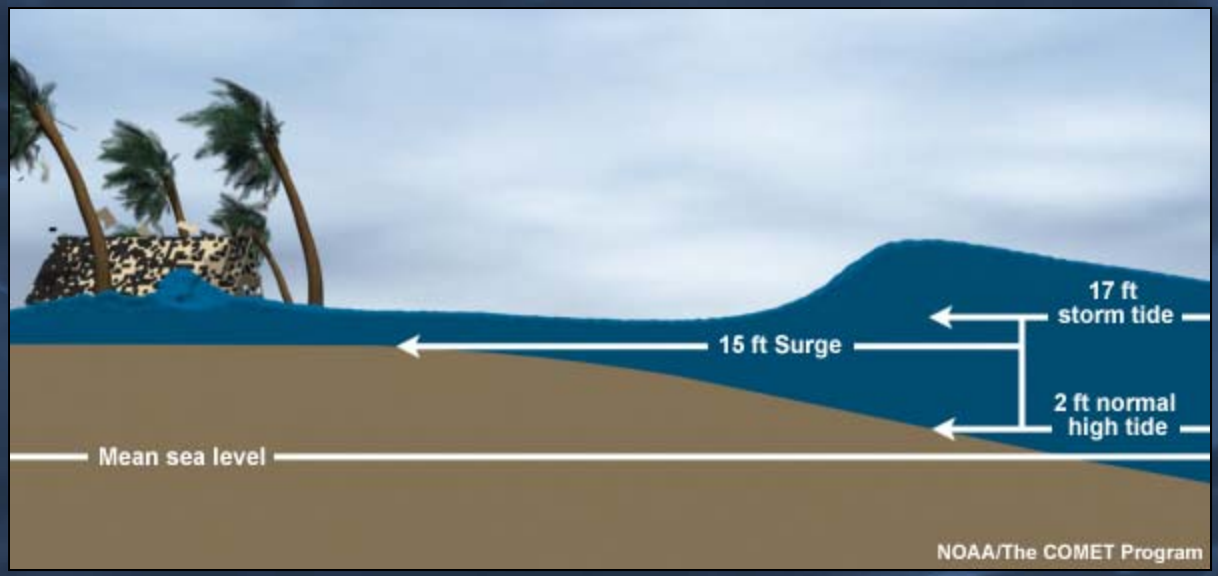
Providence, Rhode Island
1938 Hurricane

East Haven, Connecticut
Sandy (2012)

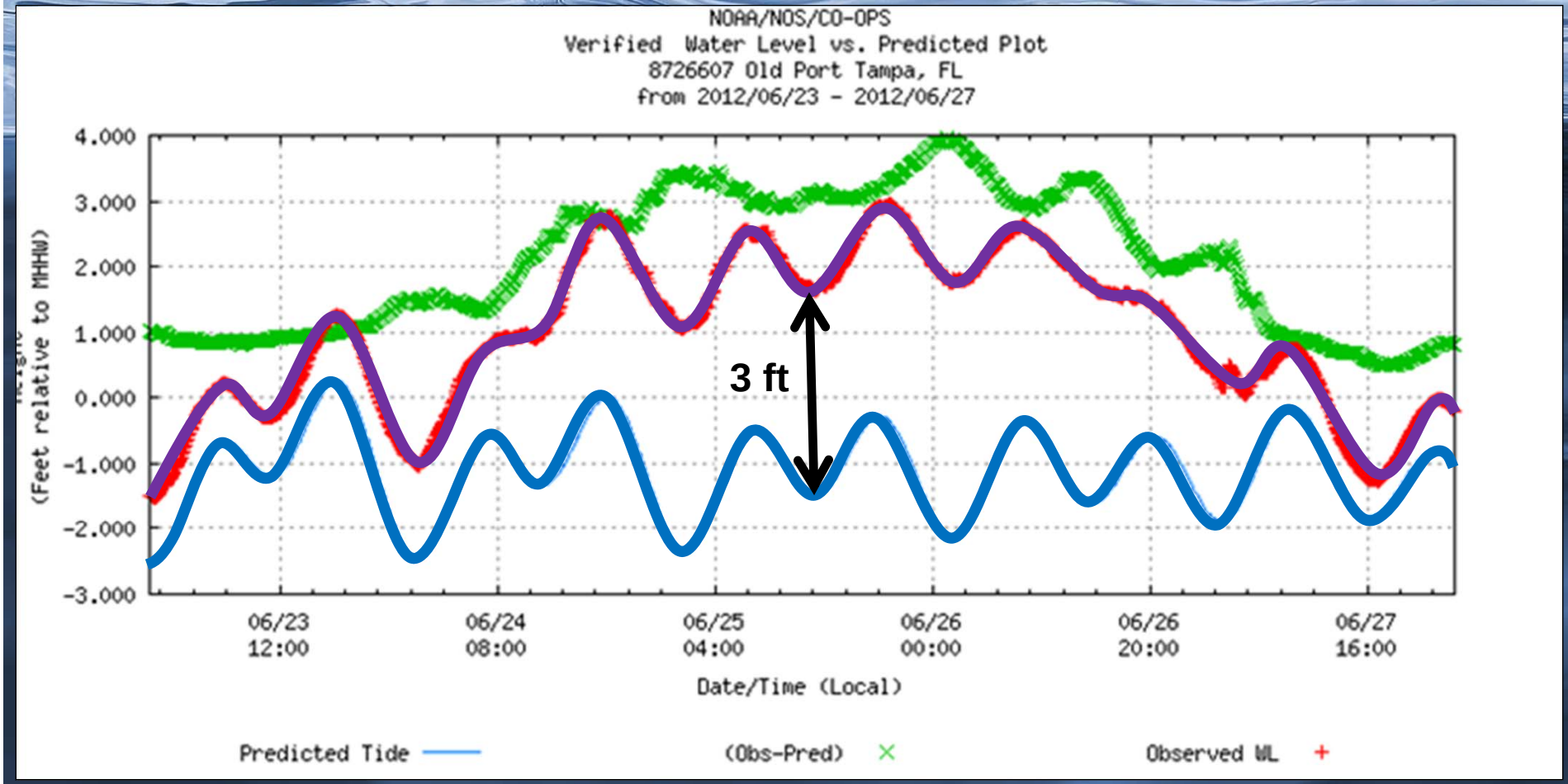
What is Storm Surge?

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

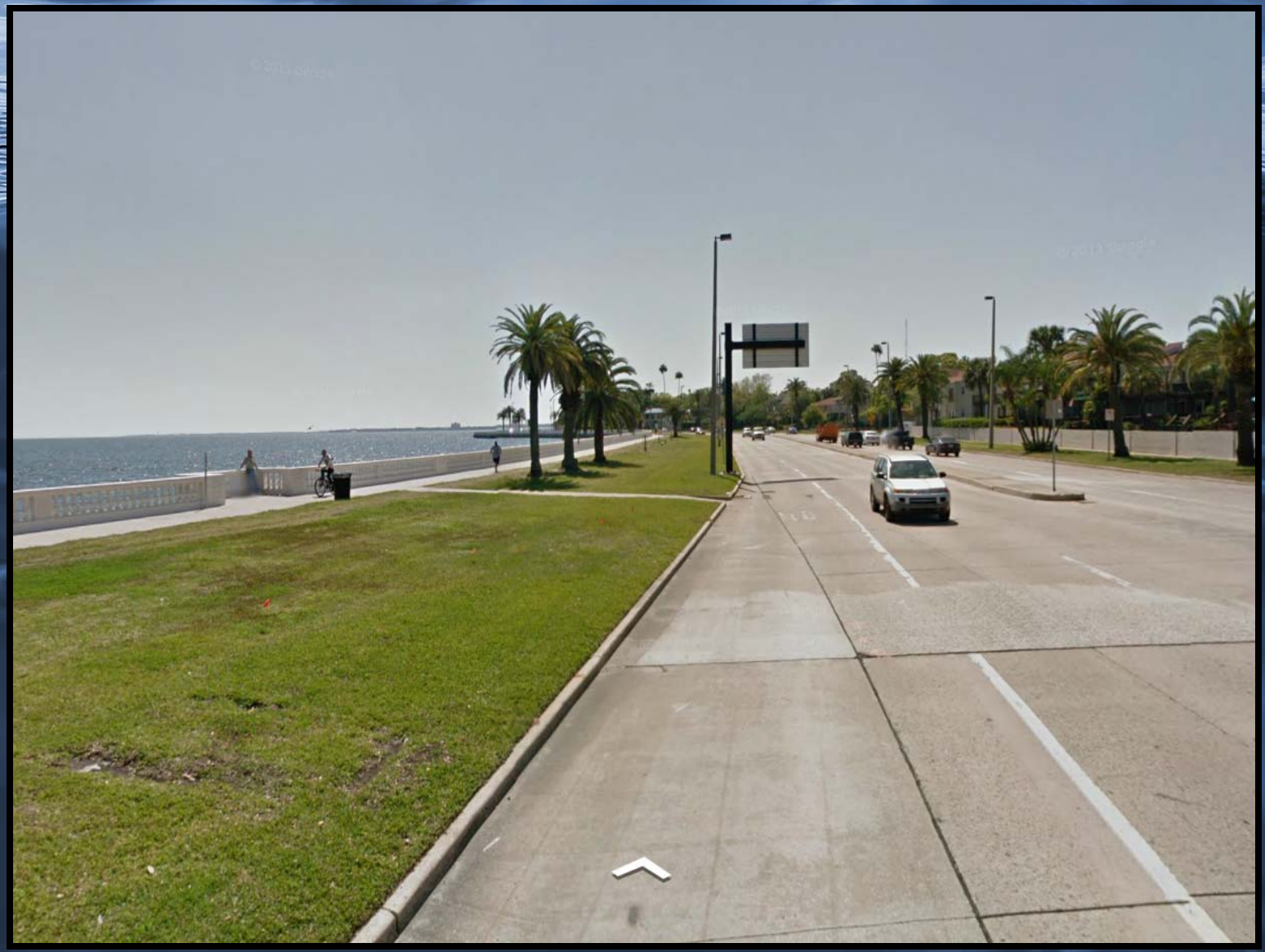


Storm Surge / Storm Tide



Storm Surge from Tropical Storm Debby

Bayshore Blvd., Tampa, FL



Storm Surge from Hurricane Isaac

Pontchartrain Drive, Slidell, LA

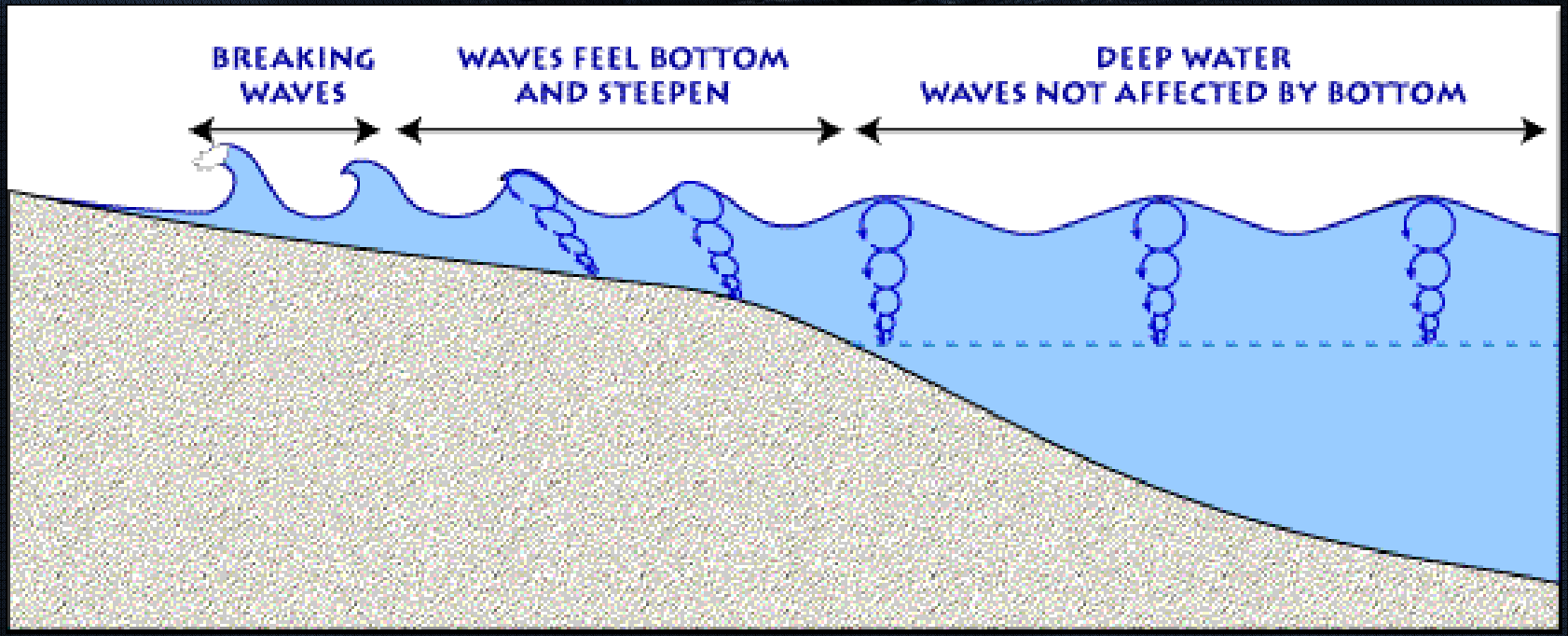
Storm Surge from Hurricane Sandy

Alphabet City (East Village), Manhattan, NY

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

What about Waves?

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



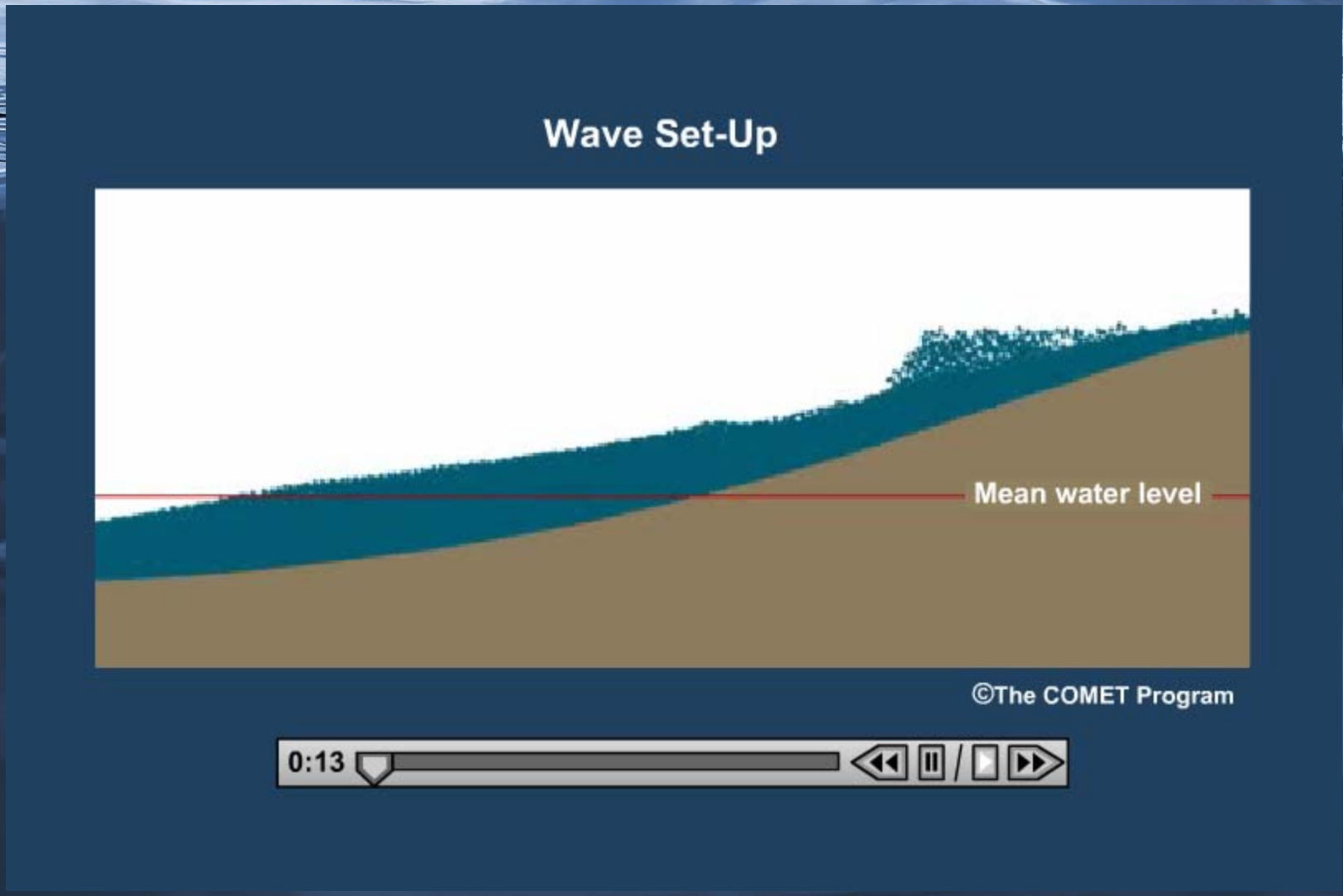
Wave Runup

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

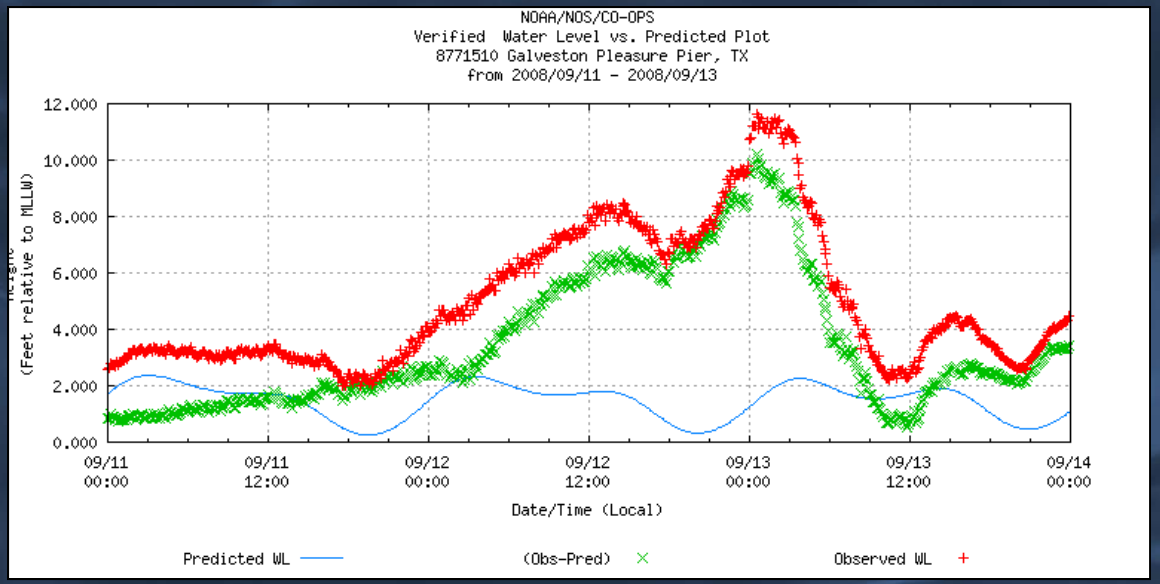
navbar placeholder

Wave Setup


SOUTHERNMOST
POINT
CONTINENTAL
U.S.A.


Wave Set-Up
Mean water level
©The COMET Program
0:13

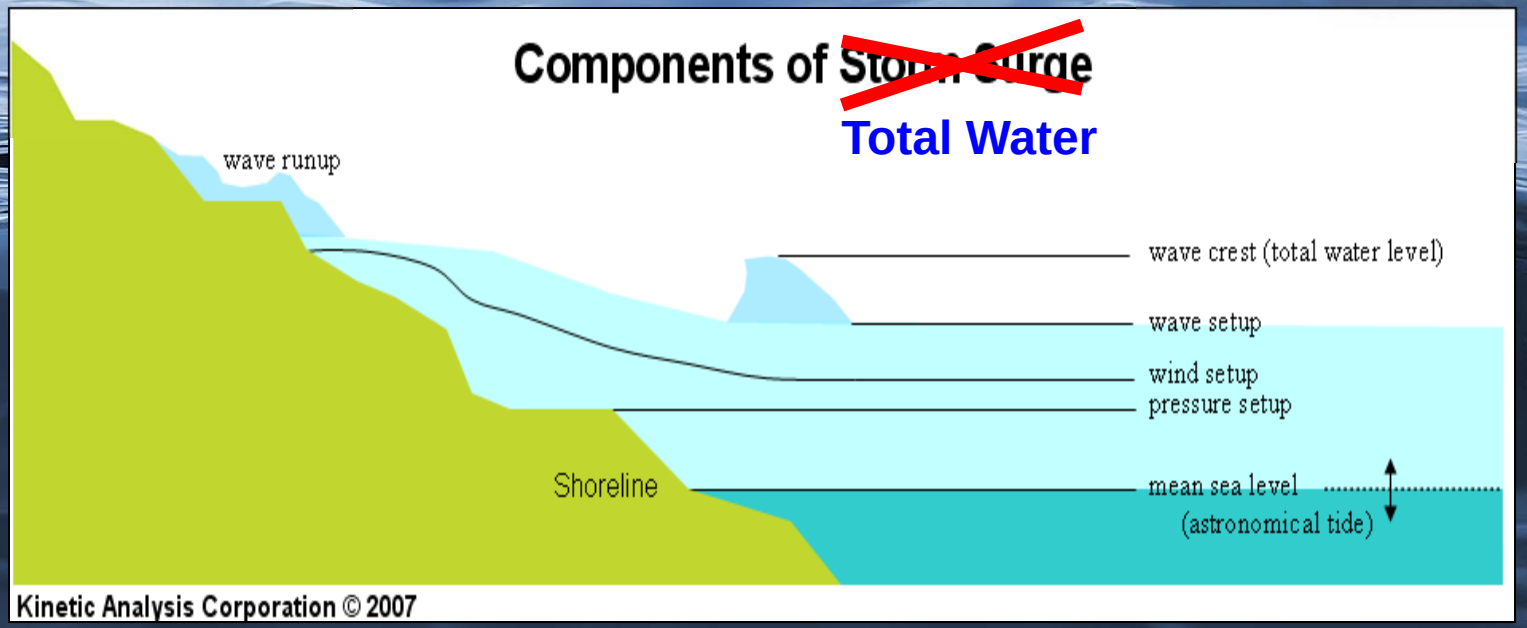
Galveston
Day before Ike arrived



Freshwater Input

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

Total Water



Total water level =

Storm surge +

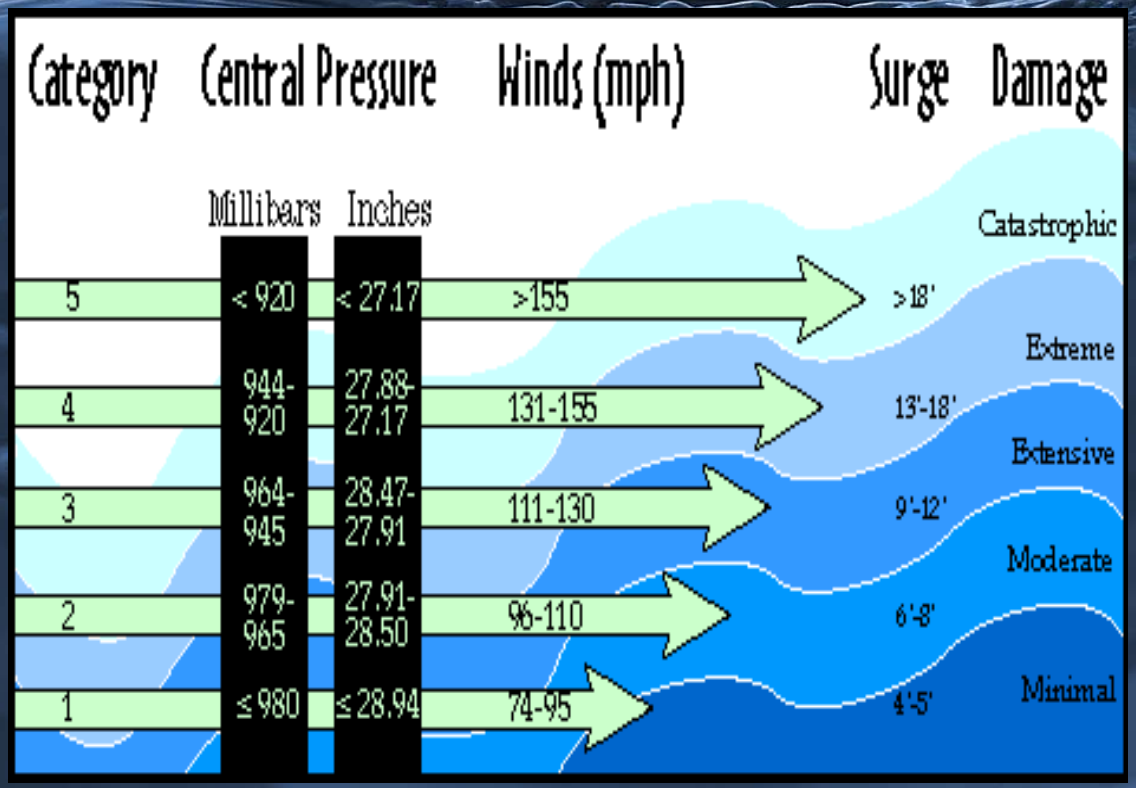
Tides +

Wave setup +

Freshwater

No More Surge in the Saffir-Simpson Scale!

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



KATRINA (3)

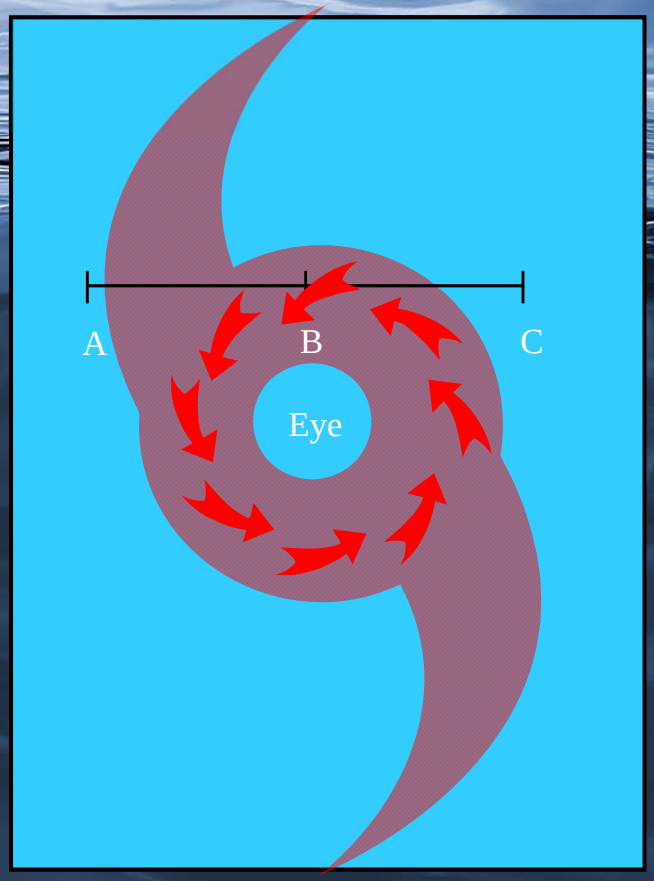
IKE (2)

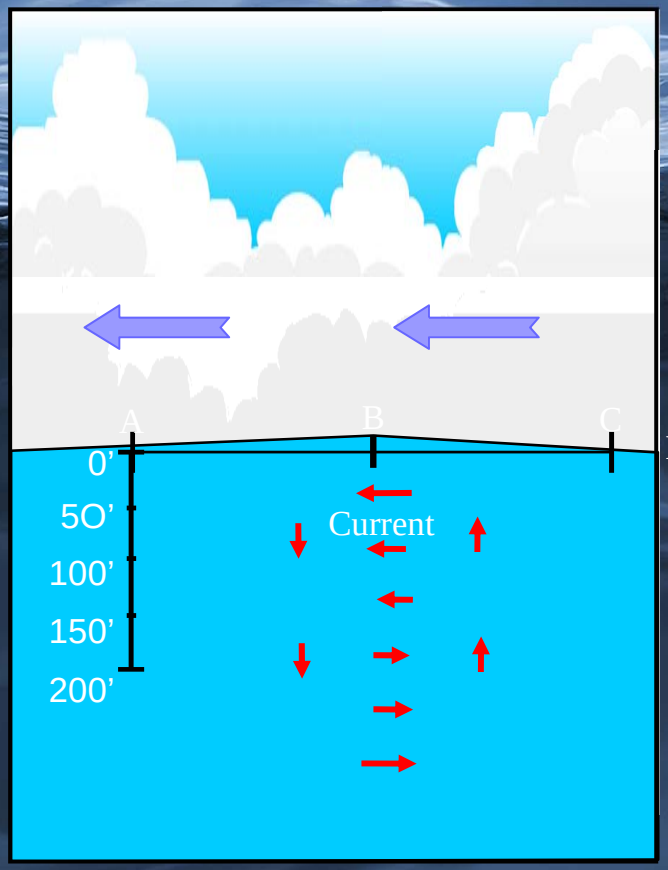
CHARLEY (4)

No Such Thing as "Just a Tropical Storm"

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

Deep Water

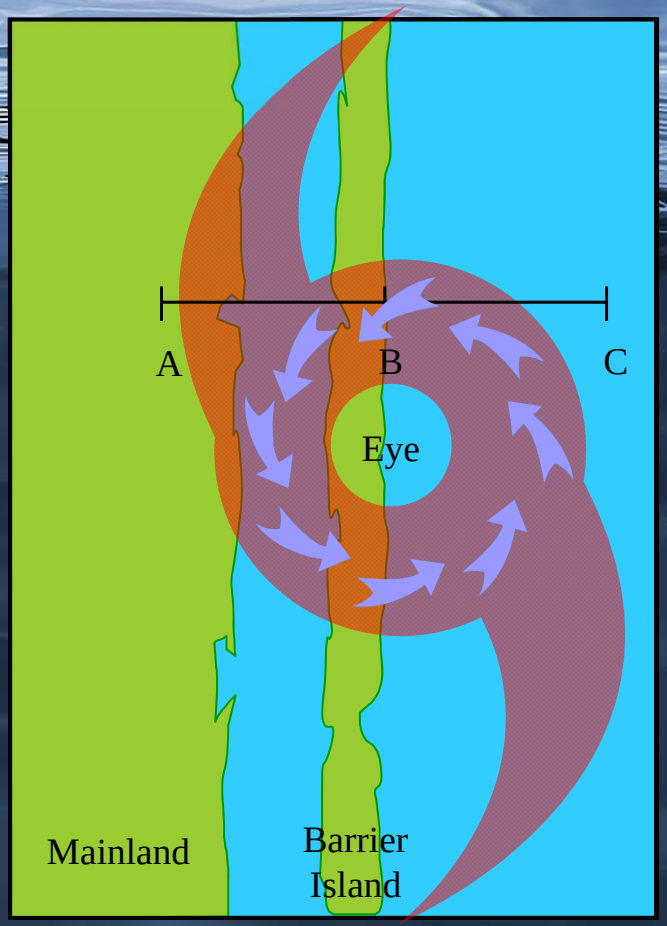




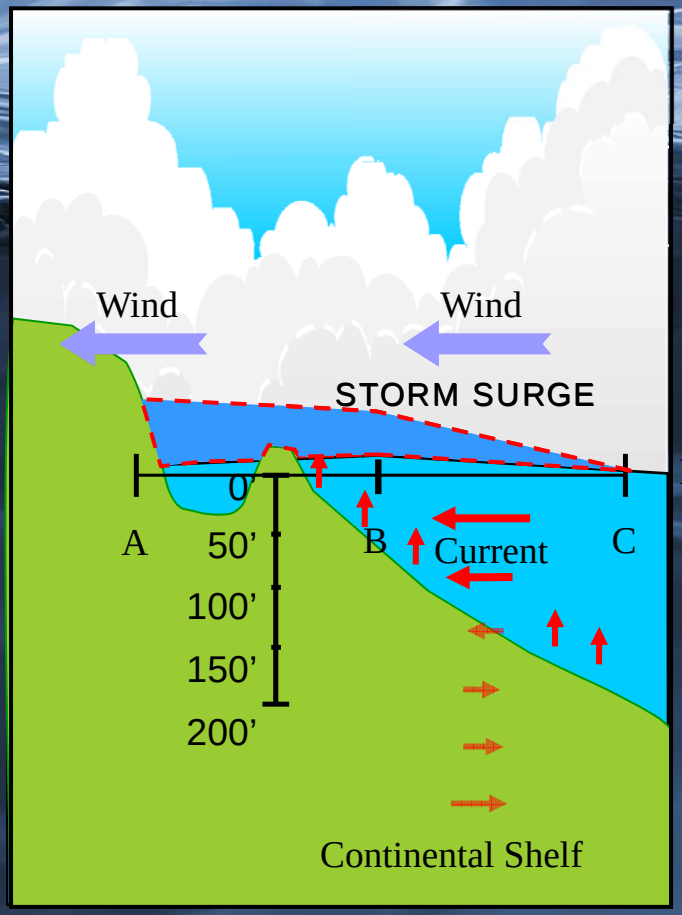
a. Top view of Sea Surface

b. Side view of Cross Section "ABC"

Landfall

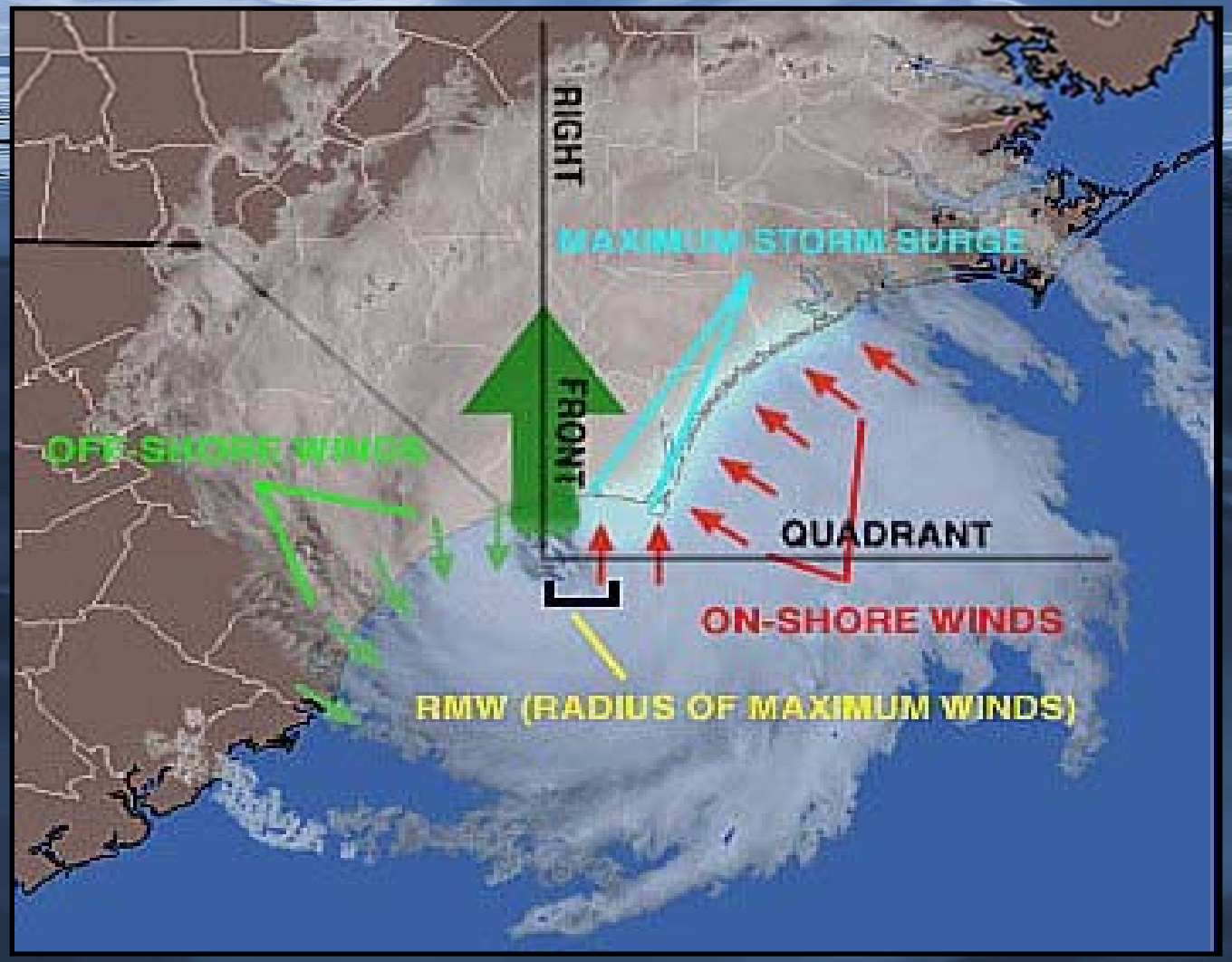


a. Top view of sea surface and land



b. Side view of Cross Section "ABC"

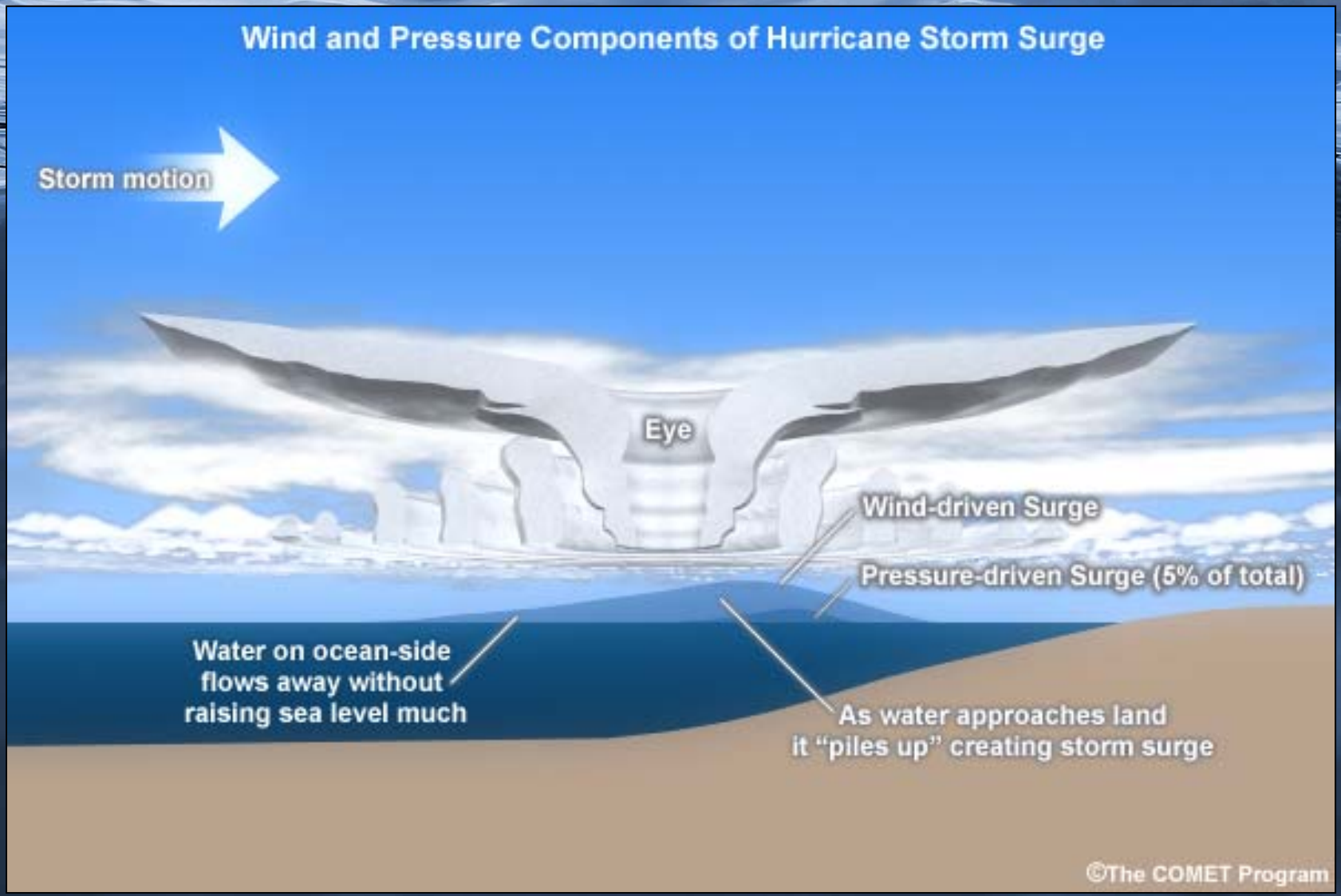
Understanding Surge



Factors Affecting Storm Surge

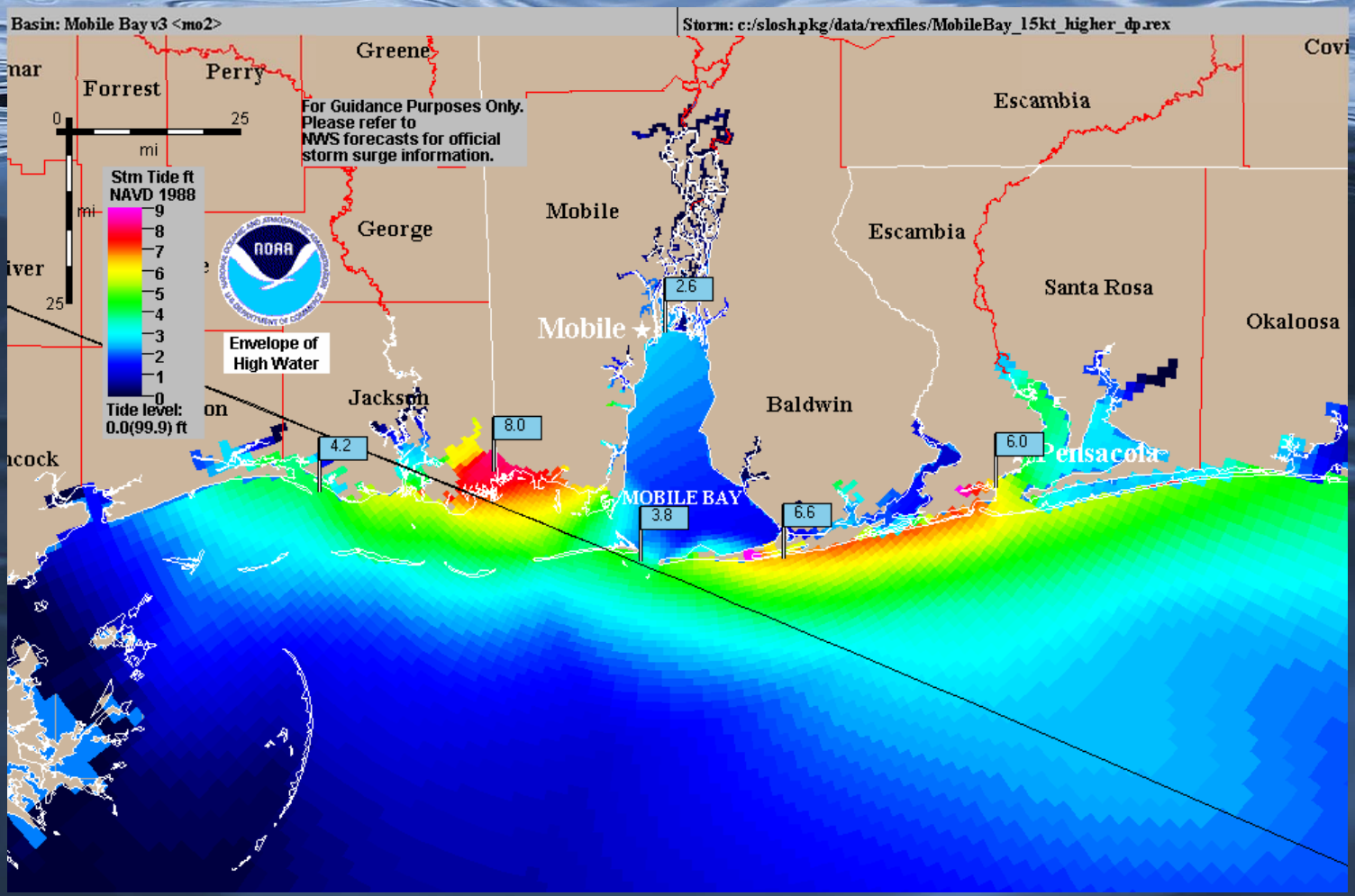
- **Central Pressure**
- **Intensity (wind speed)**
- **Forward Speed**
- **Size**
  - **Radius of Maximum Winds (RMW)**
- **Angle of Approach**
- **Width and Slope of Shelf**
- **Local features** – concavity of coastlines, bays, rivers, headlands, or islands

Effects of Low Pressure



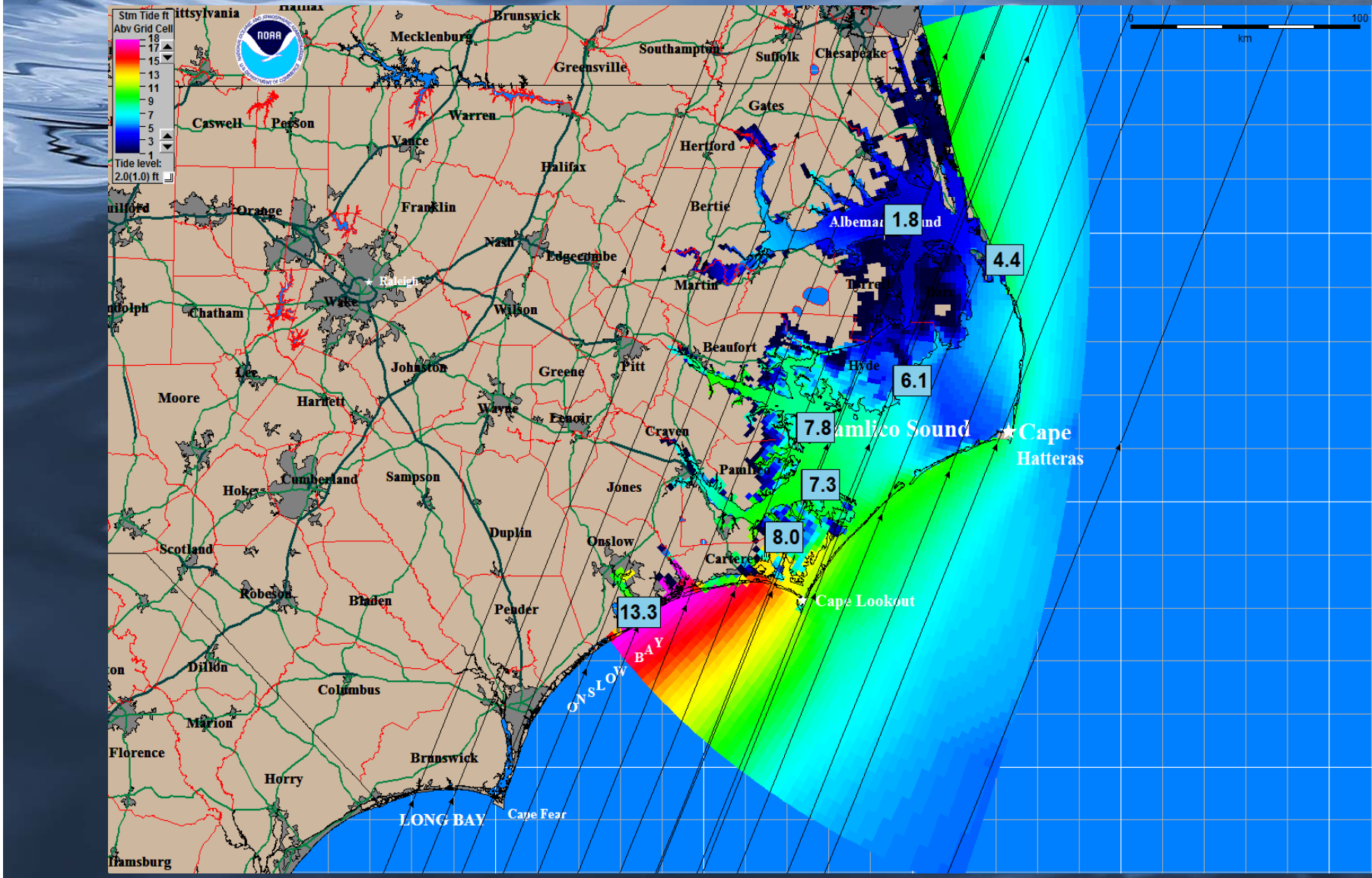
Intensity (Wind Speed)

15 mph stronger

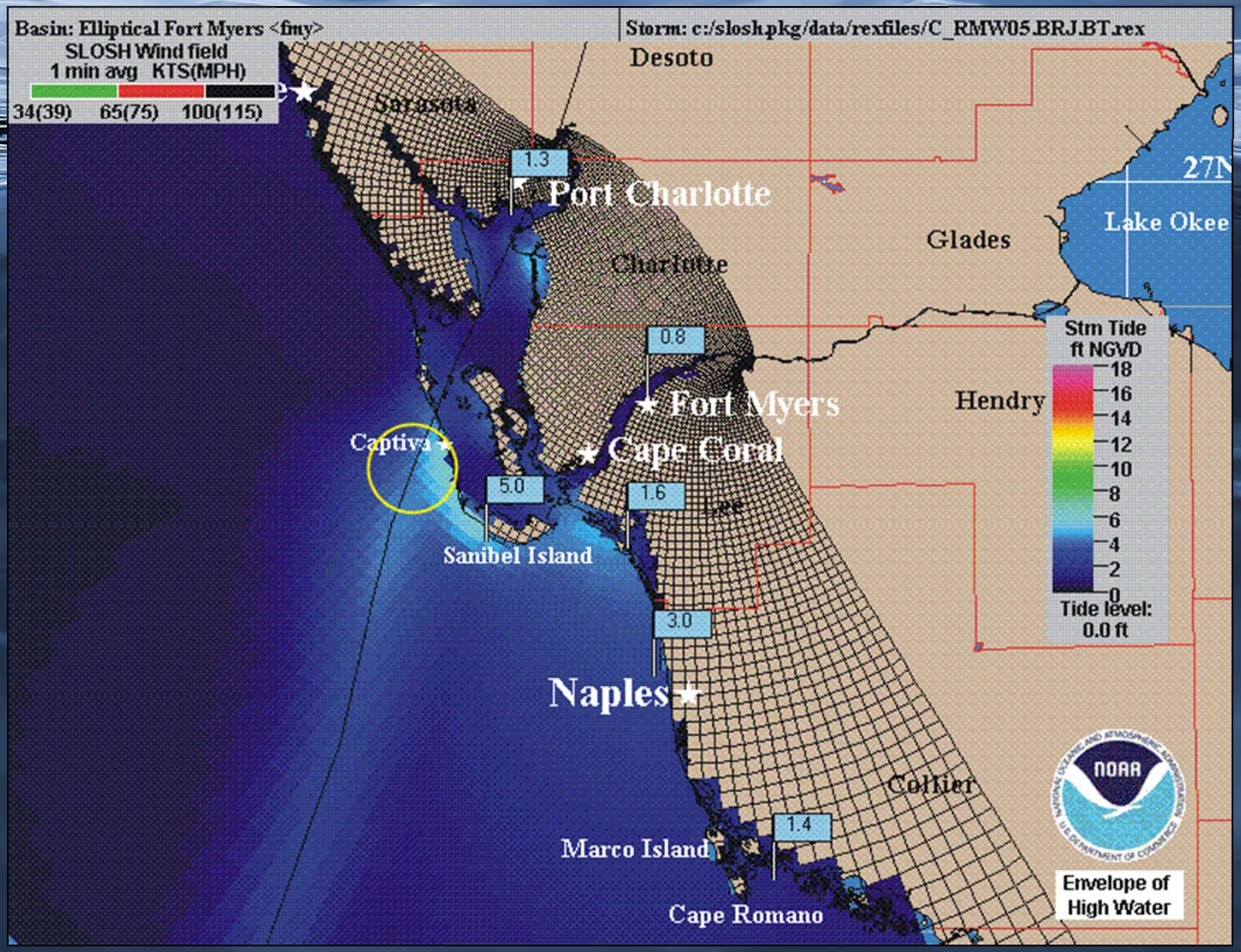


Forward Speed

25 mph

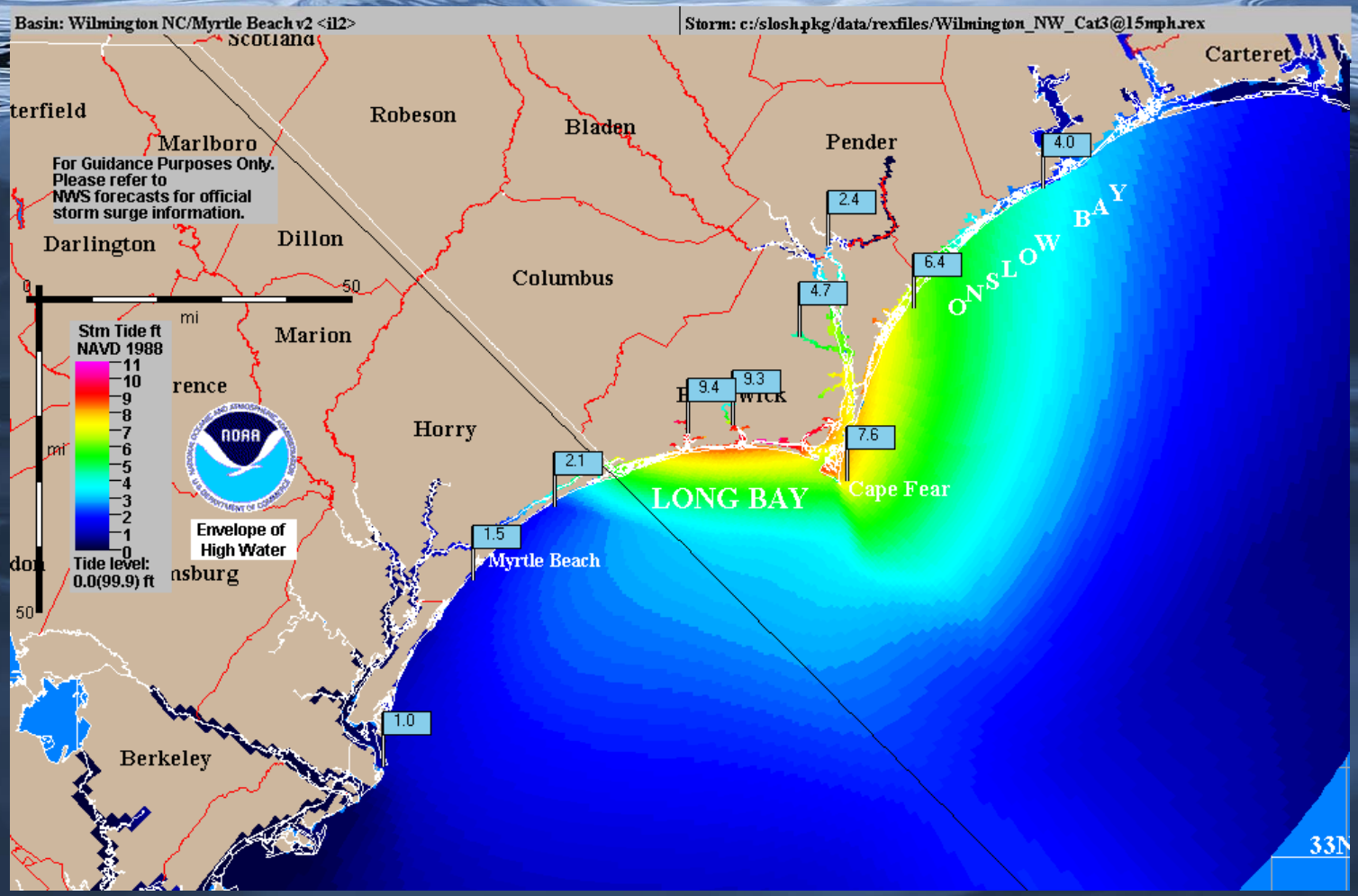


Size
(Radius of Max Winds)

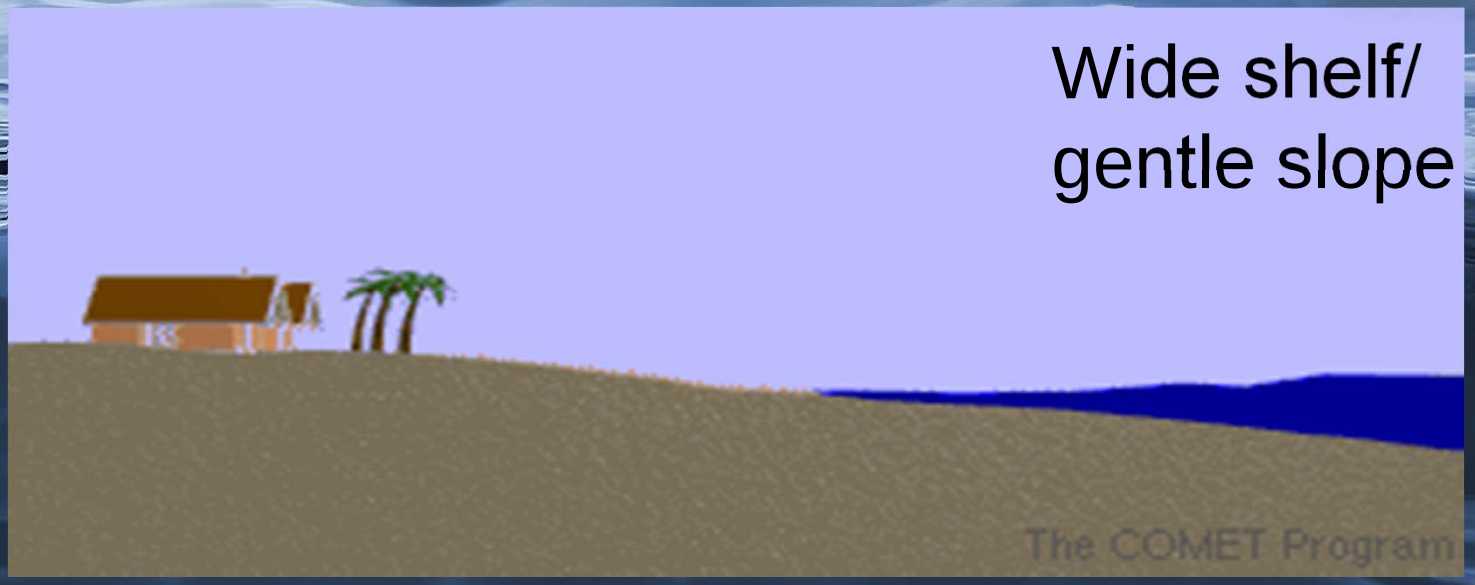


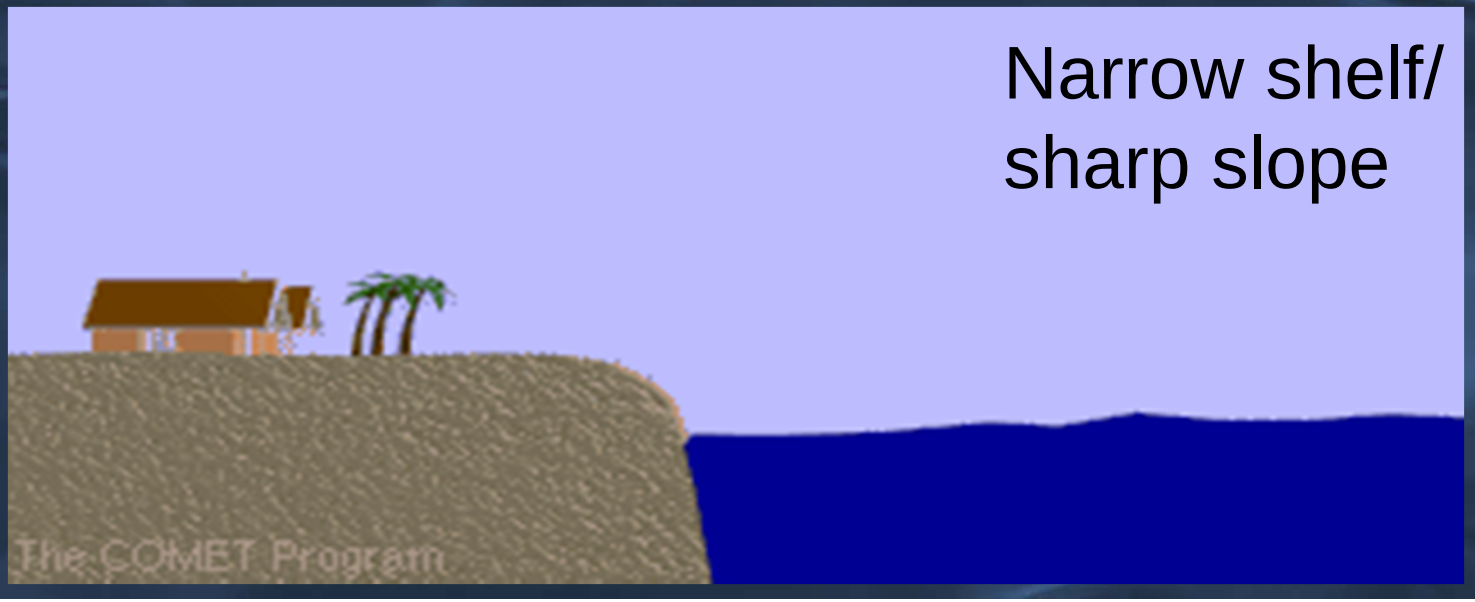
Angle of Approach

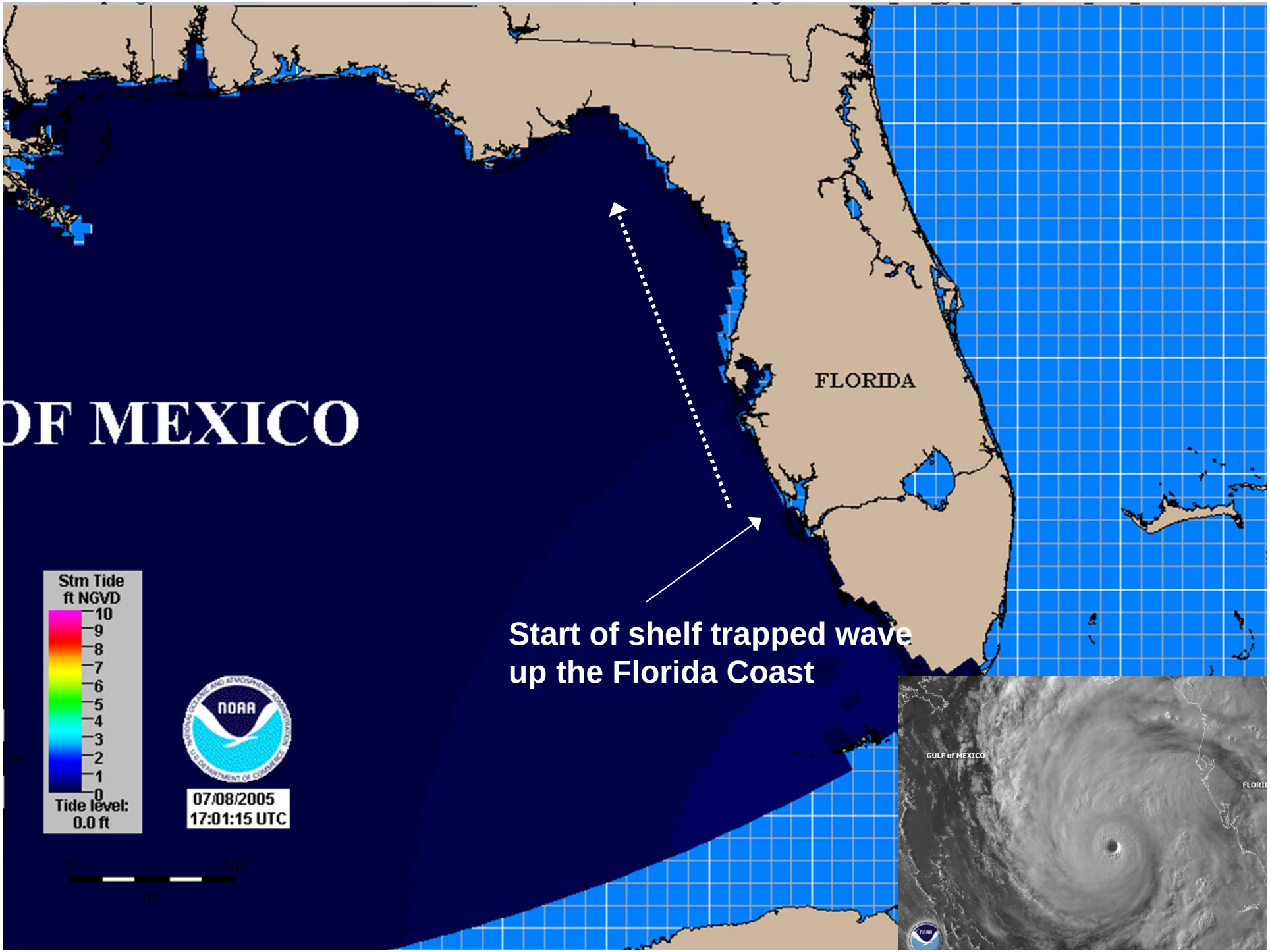
NNW Motion

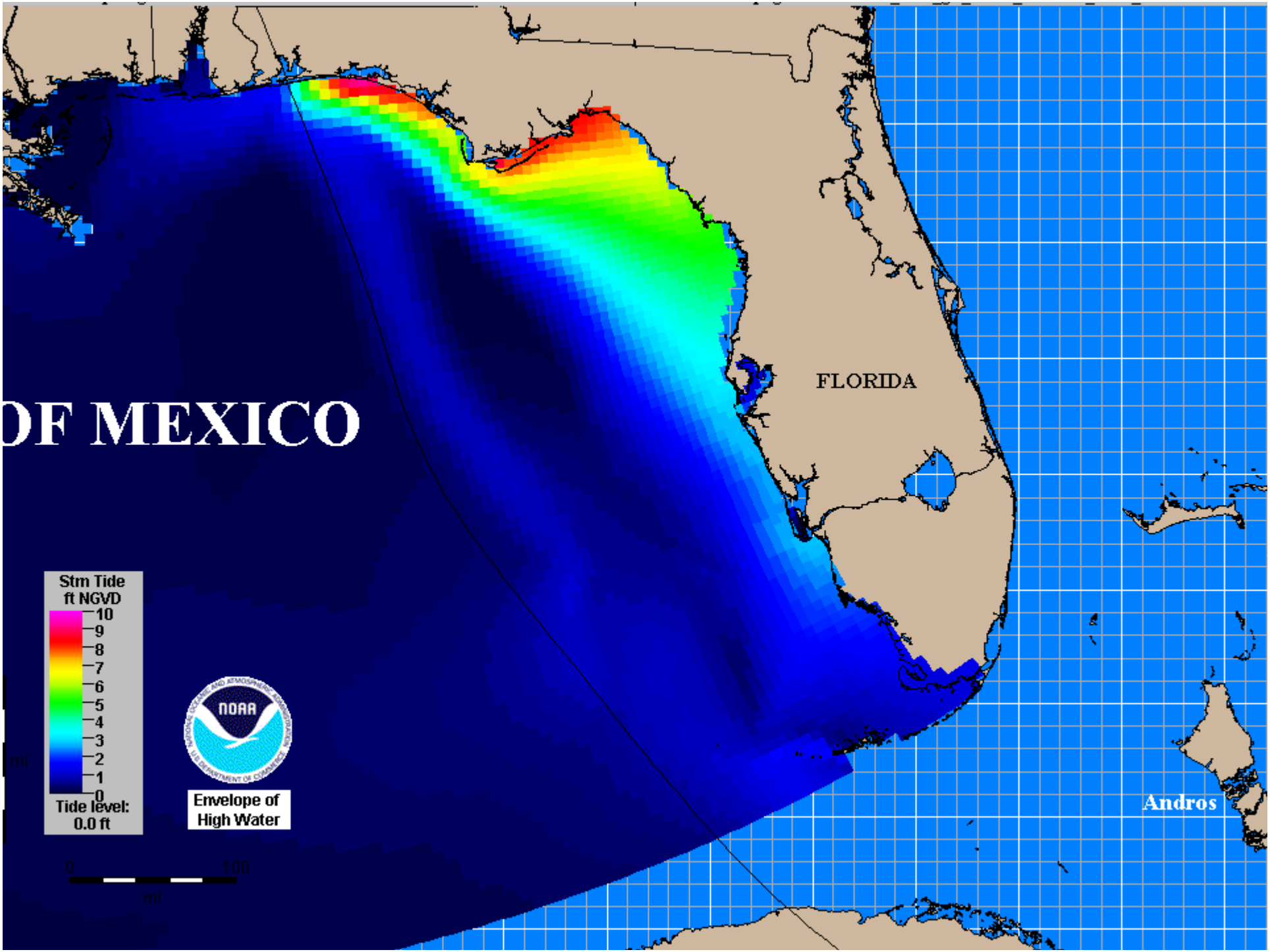


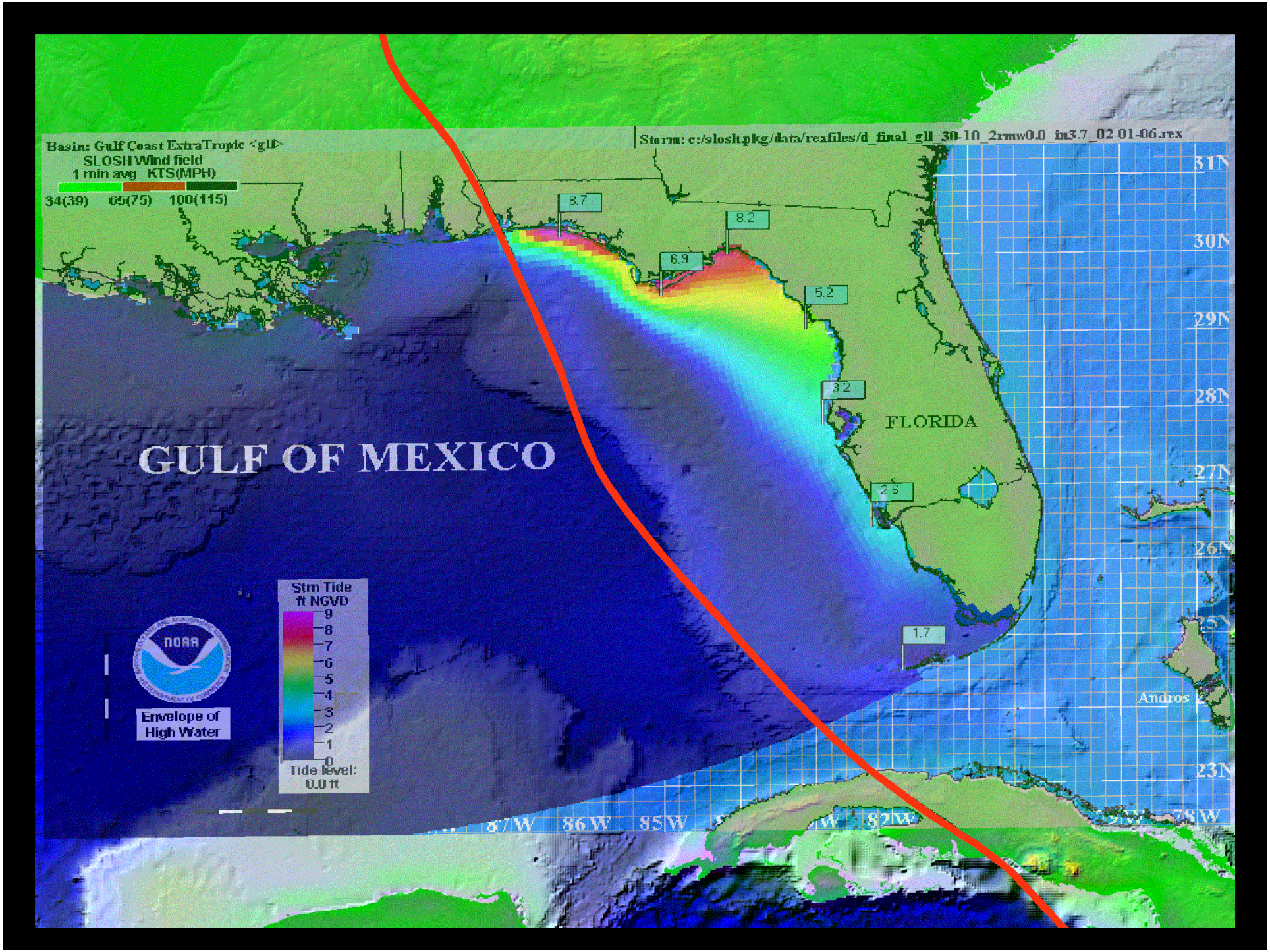
Width and Slope of Shelf



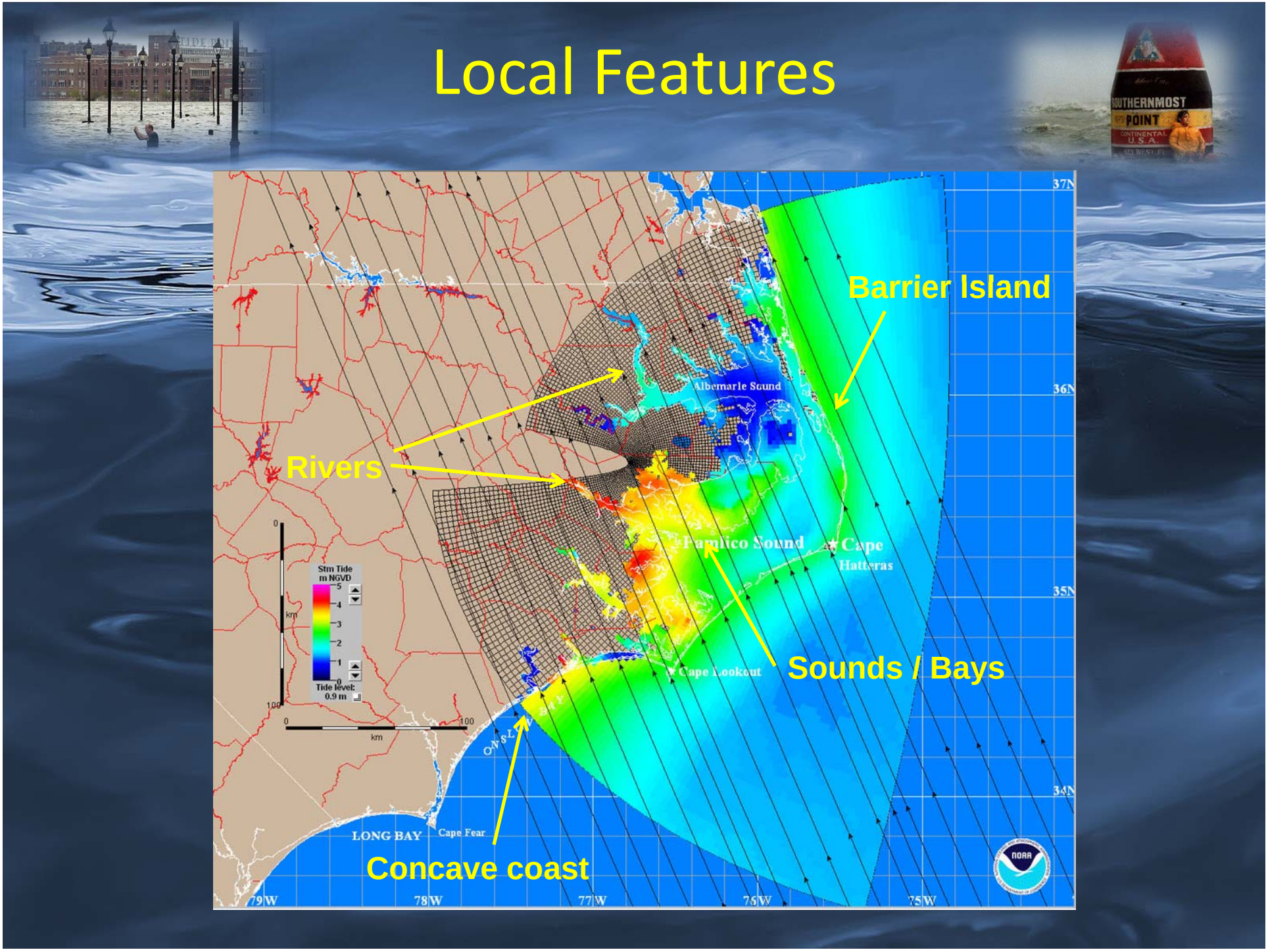



OF MEXICO
FLORIDA
Stm Tide
ft NGVD
10
9
8
7
6
5
4
3
2
1
0
Tide level:
0.0 ft
NOAA
07/08/2005
17:01:15 UTC
Start of shelf trapped wave
up the Florida Coast
GULF of MEXICO


OF MEXICO
FLORIDA
Andros
Stm Tide
ft NGVD
10
9
8
7
6
5
4
3
2
1
0
Tide level:
0.0 ft
NOAA
Envelope of
High Water
0
100
mi
mi


Basin: Gulf Coast ExtraTropic <gll>
SLOSH Wind field
1 min avg KTS(MPH)
34(39) 65(75) 100(115)
Storm: c:/slosh.pkg/data/rexfiles/d_final_gll_30-10_2rmw0.0_in3.7_02-01-06.rex
8.7
8.2
6.9
5.2
3.2
2.6
1.7
GULF OF MEXICO
FLORIDA
Andros
Stm Tide
ft NGVD
9
8
7
6
5
4
3
2
1
0
Tide level:
0.0 ft
NOAA
Envelope of
High Water
31N
30N
29N
28N
27N
26N
25N
23N
87W
86W
85W
82W

Local Features



Observing and Measuring Storm Surge

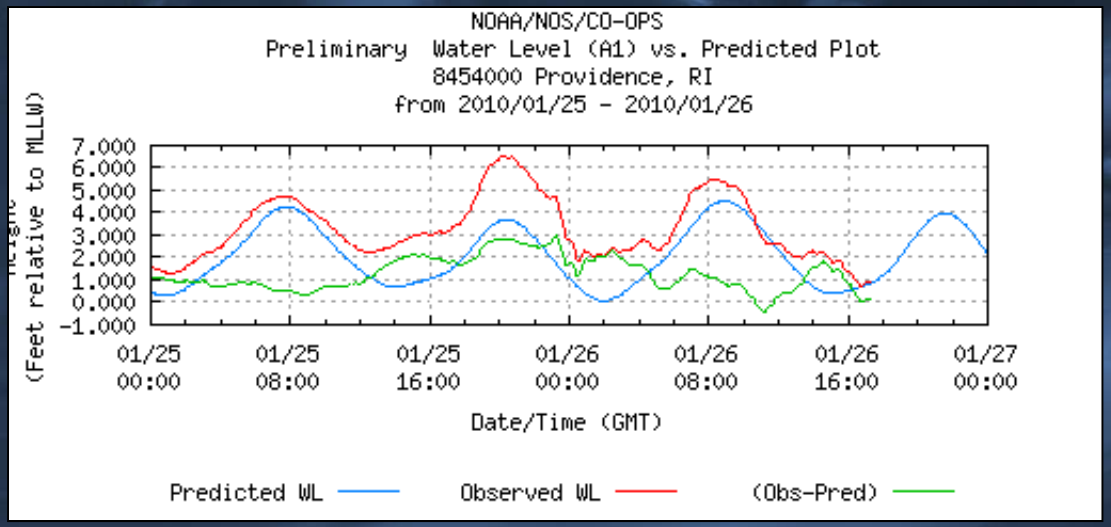
- Tide stations (NOAA)
  - Still water
  - Traditionally most reliable
  - Limited stations
  - Stations often fail at height of event
- High water marks (FEMA/USGS)
  - Perishable
  - Traditionally best method for capturing highest surge
  - Subjective and often include impacts of wave runup/setup
- 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 175 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

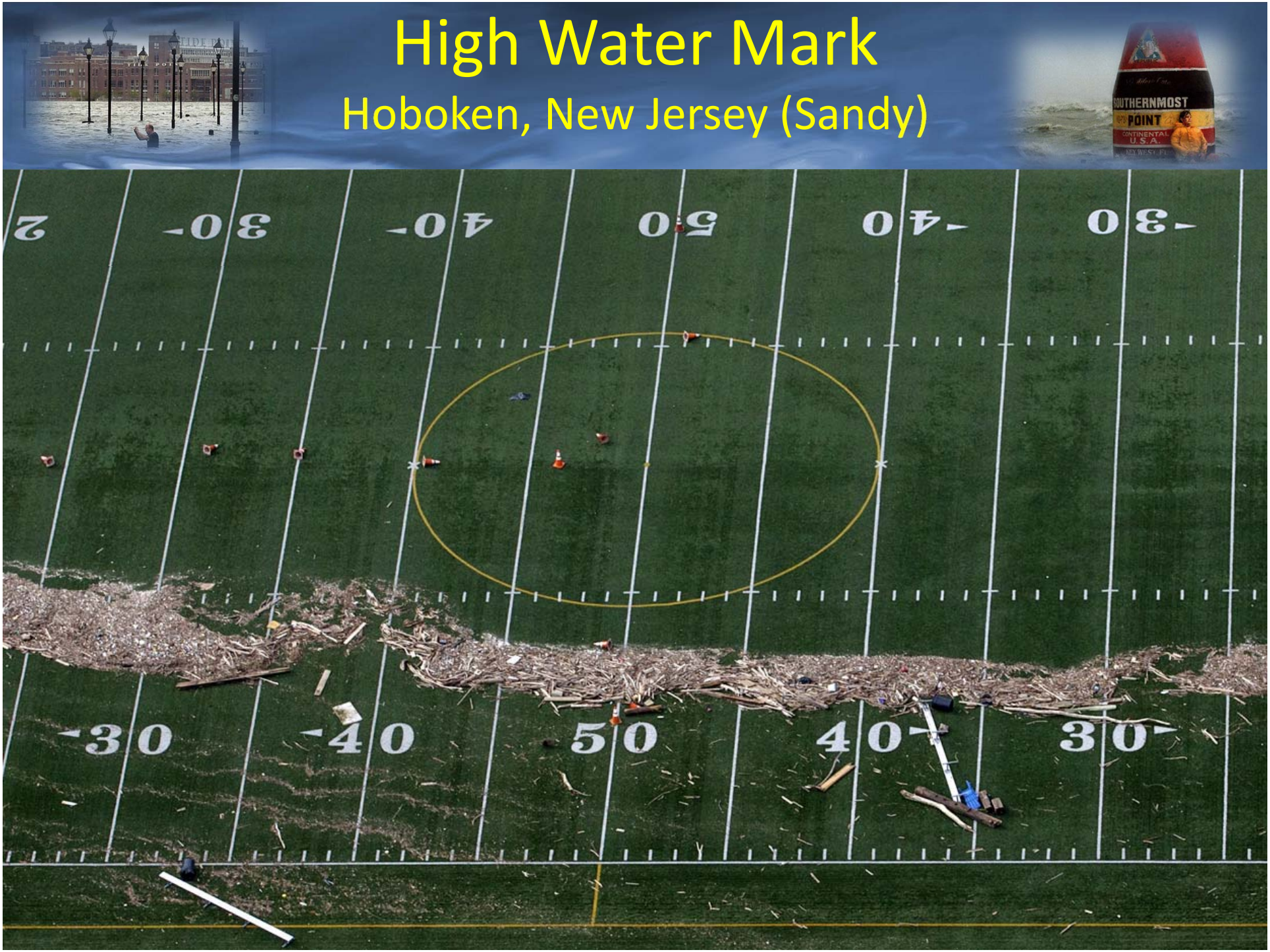


High Water Marks

- 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)

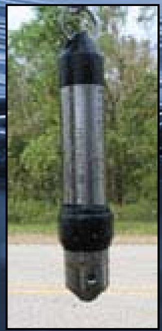
High Water Mark

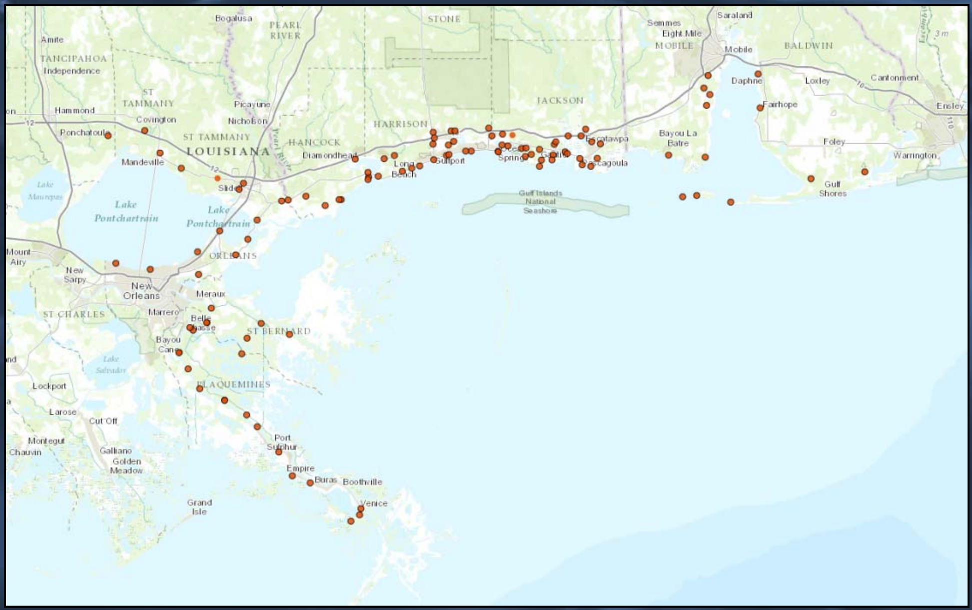
Hoboken, New Jersey (Sandy)



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

Next…

- What is a vertical datum and why should I care?
- What is the SLOSH model?
- What kind of storm surge products are available?
- How does NHC forecast storm surge?