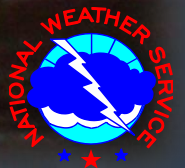


# Introduction to Storm Surge



Cody Fritz - Storm Surge Specialist







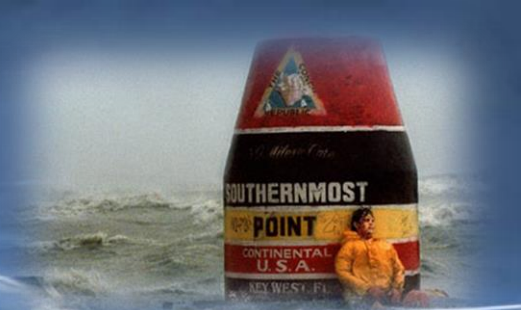
# Hurricane Ike (2008) - Bolivar Peninsula, Texas

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





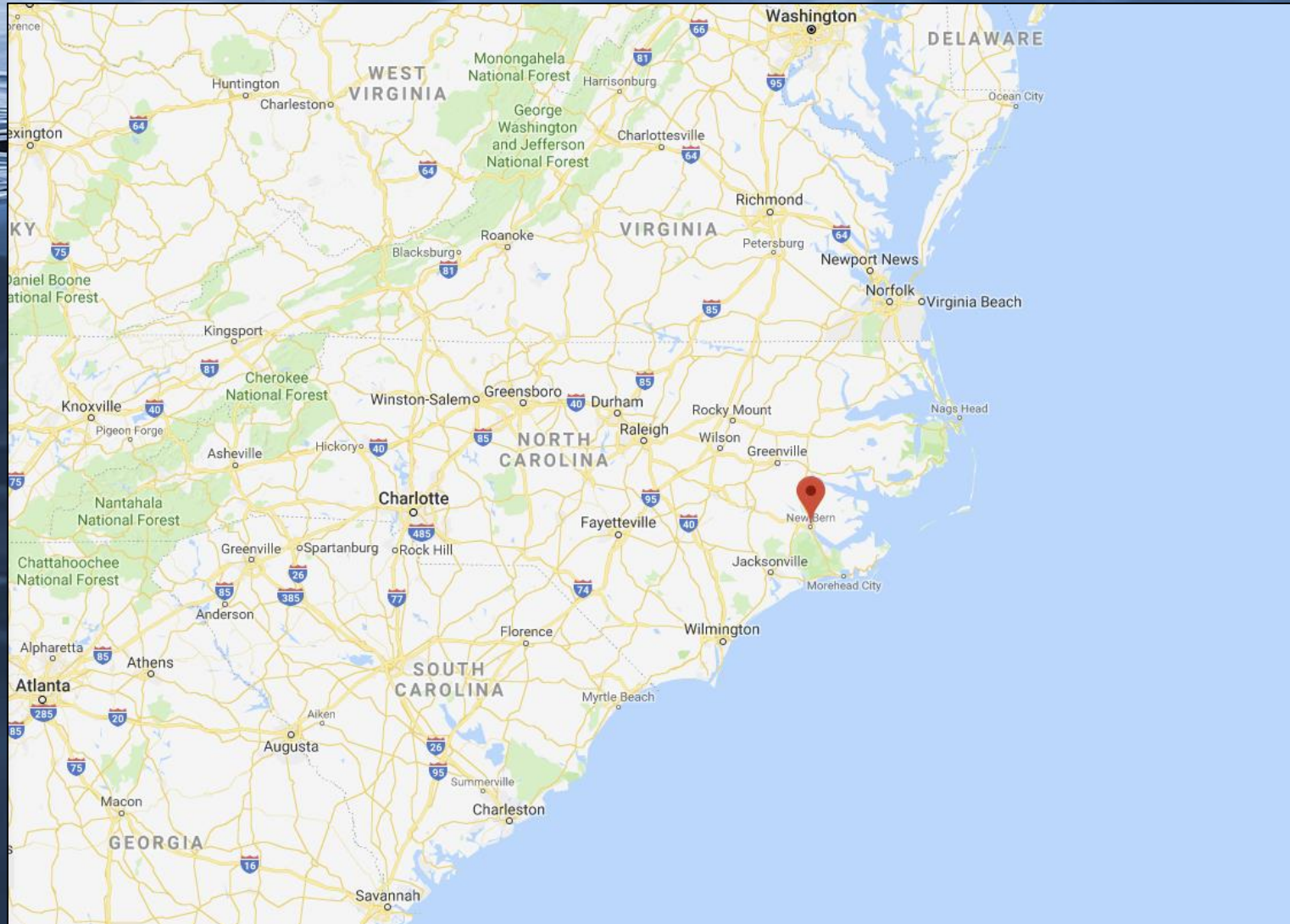
# Myth or Fact?

I live miles from the beach, so storm surge is not my problem.

Myth



# New Bern, NC – Hurricane Florence





# New Bern, NC – Hurricane Florence

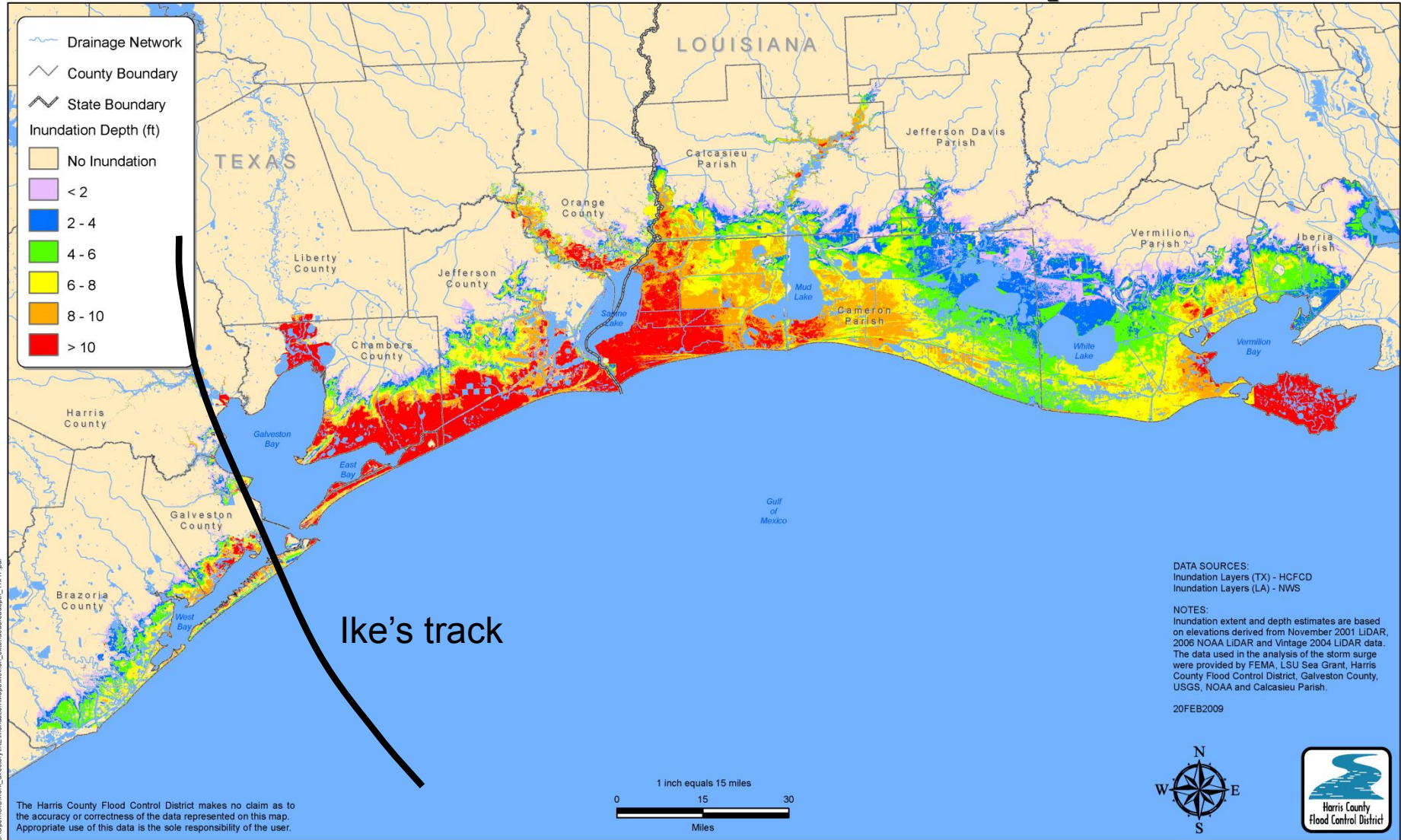


# New Bern, NC – Hurricane Florence





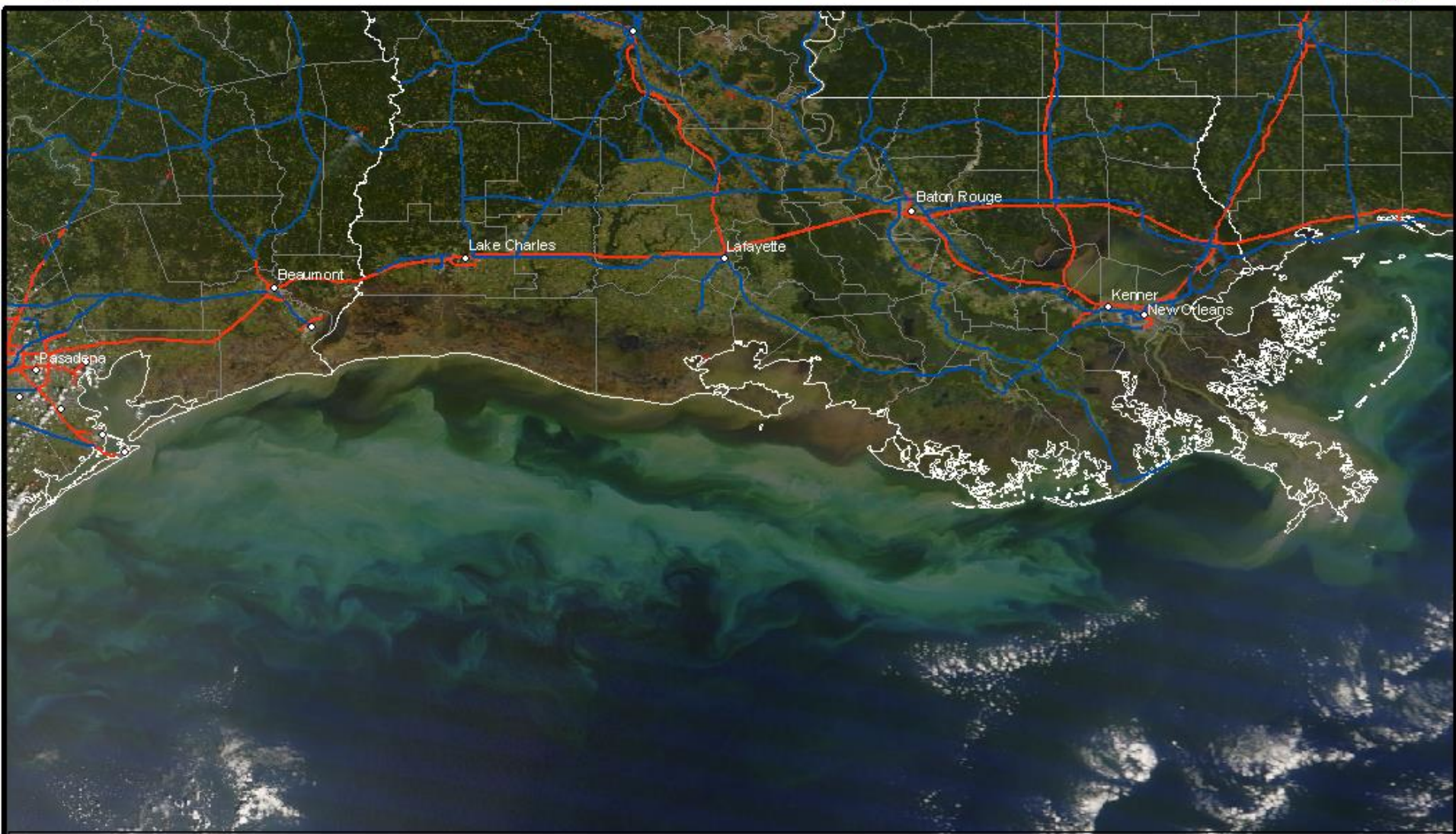
# Hurricane Ike Inundation Depth







# 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

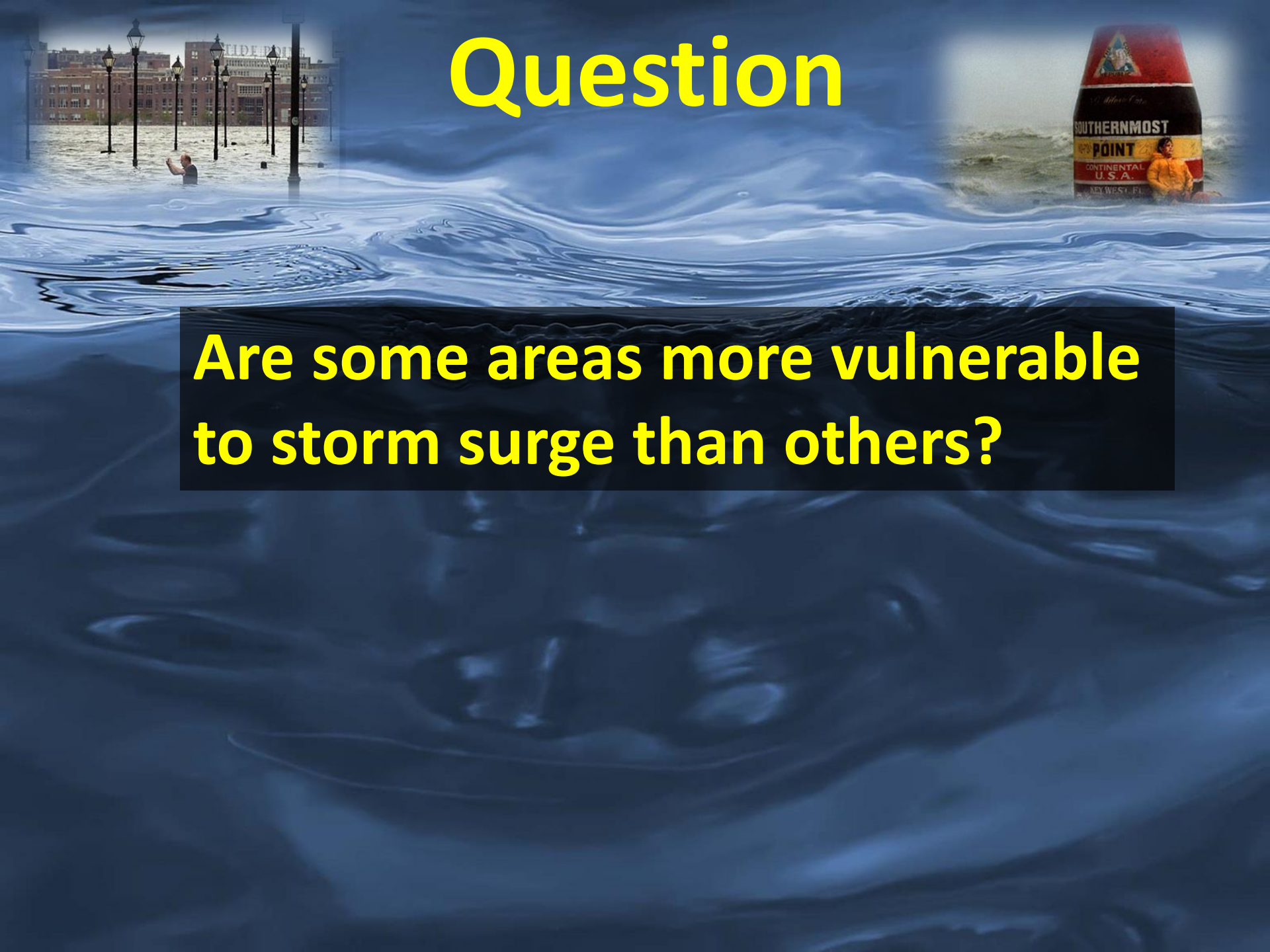




House of David and Kimberly King  
Waveland, Mississippi

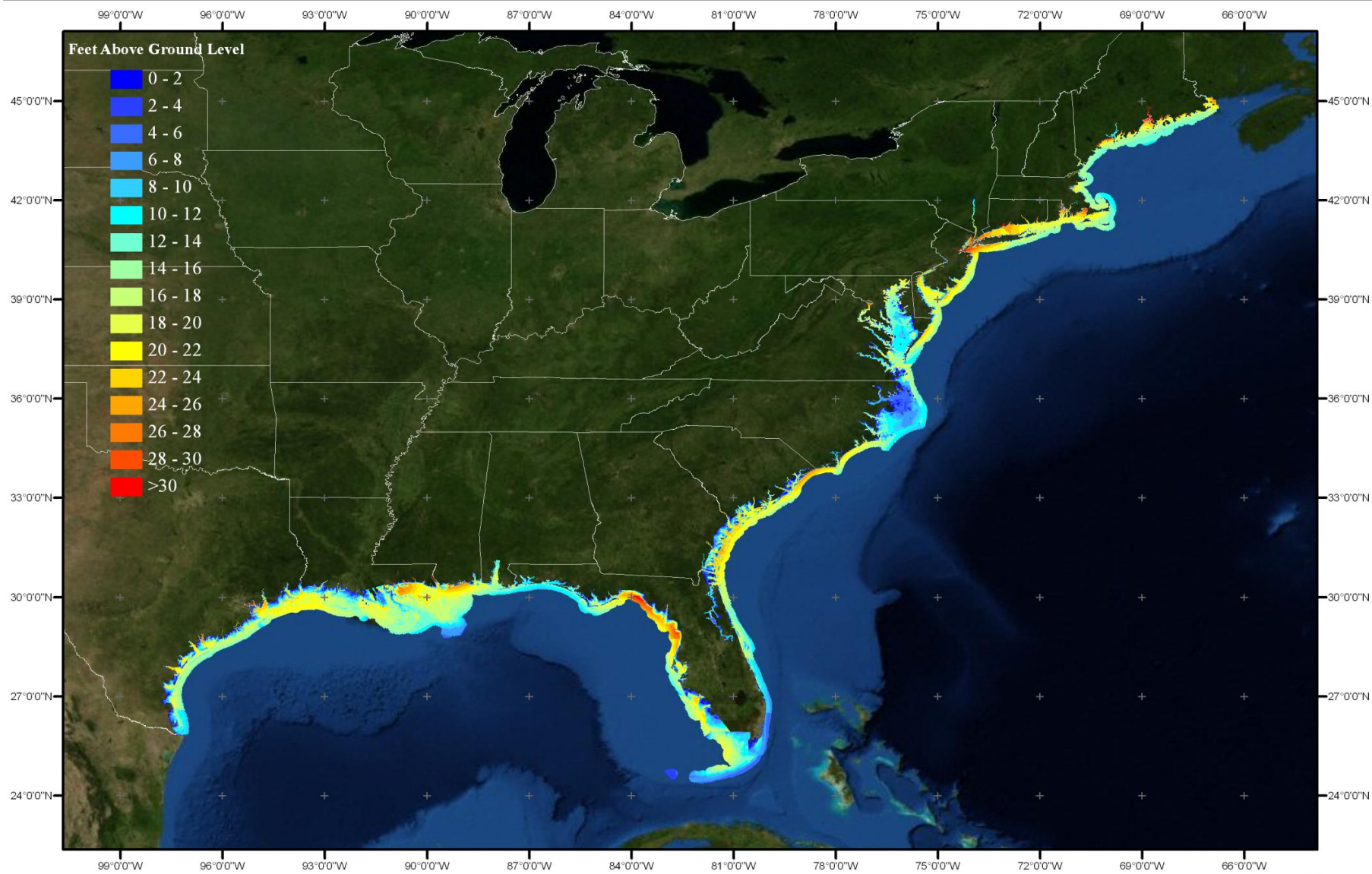
# Question

**Are some areas more vulnerable to storm surge than others?**



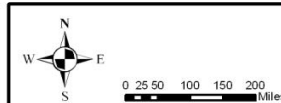


# Storm Surge Vulnerability: Category 4 Hurricane



**Data Source:**  
NWS/NHC/Storm Surge Unit

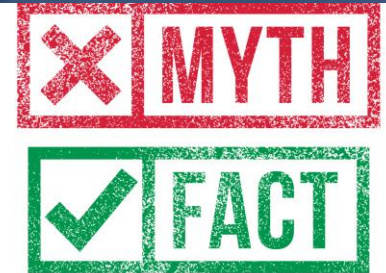
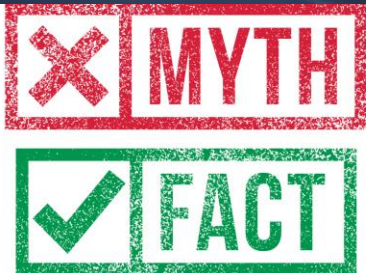
**FOR EDUCATIONAL PURPOSES ONLY  
NOT TO BE USED TO MAKE LIFE OR DEATH DECISIONS**



# Myth or Fact?

Storm surge does not affect urban areas.

Myth





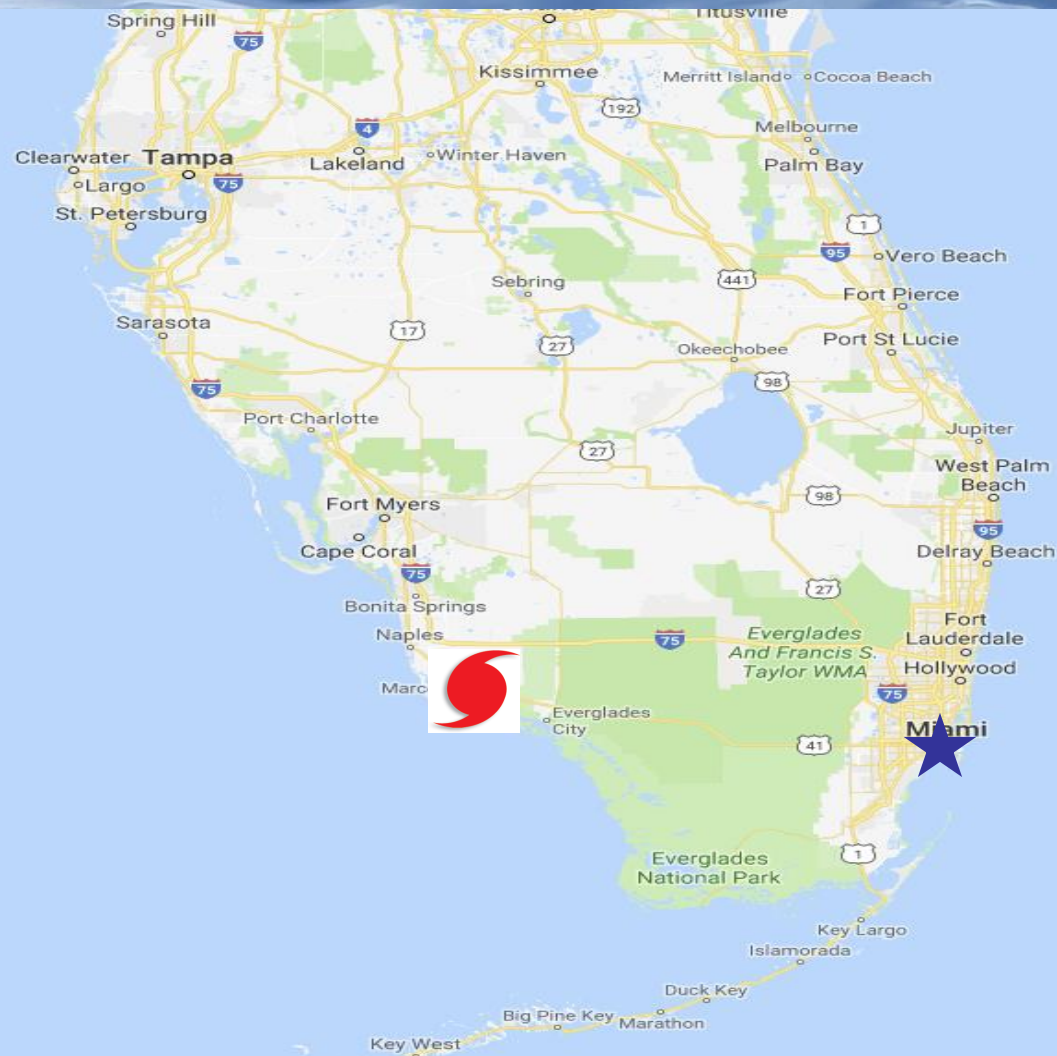
# Storm Surge from Hurricane Sandy

## Alphabet City (East Village), Manhattan, NY



# Storm Surge from Hurricane Irma

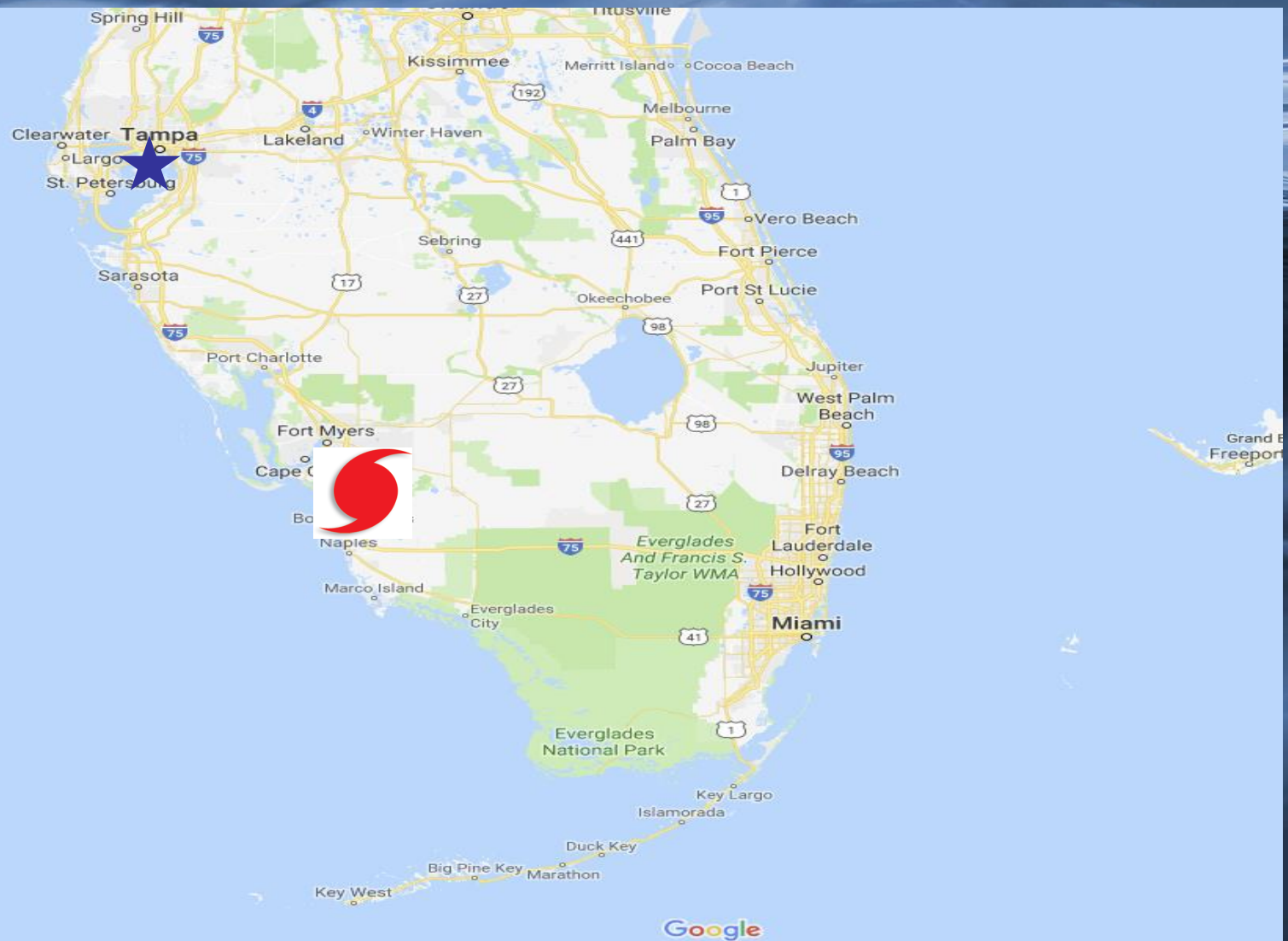
## Downtown Miami

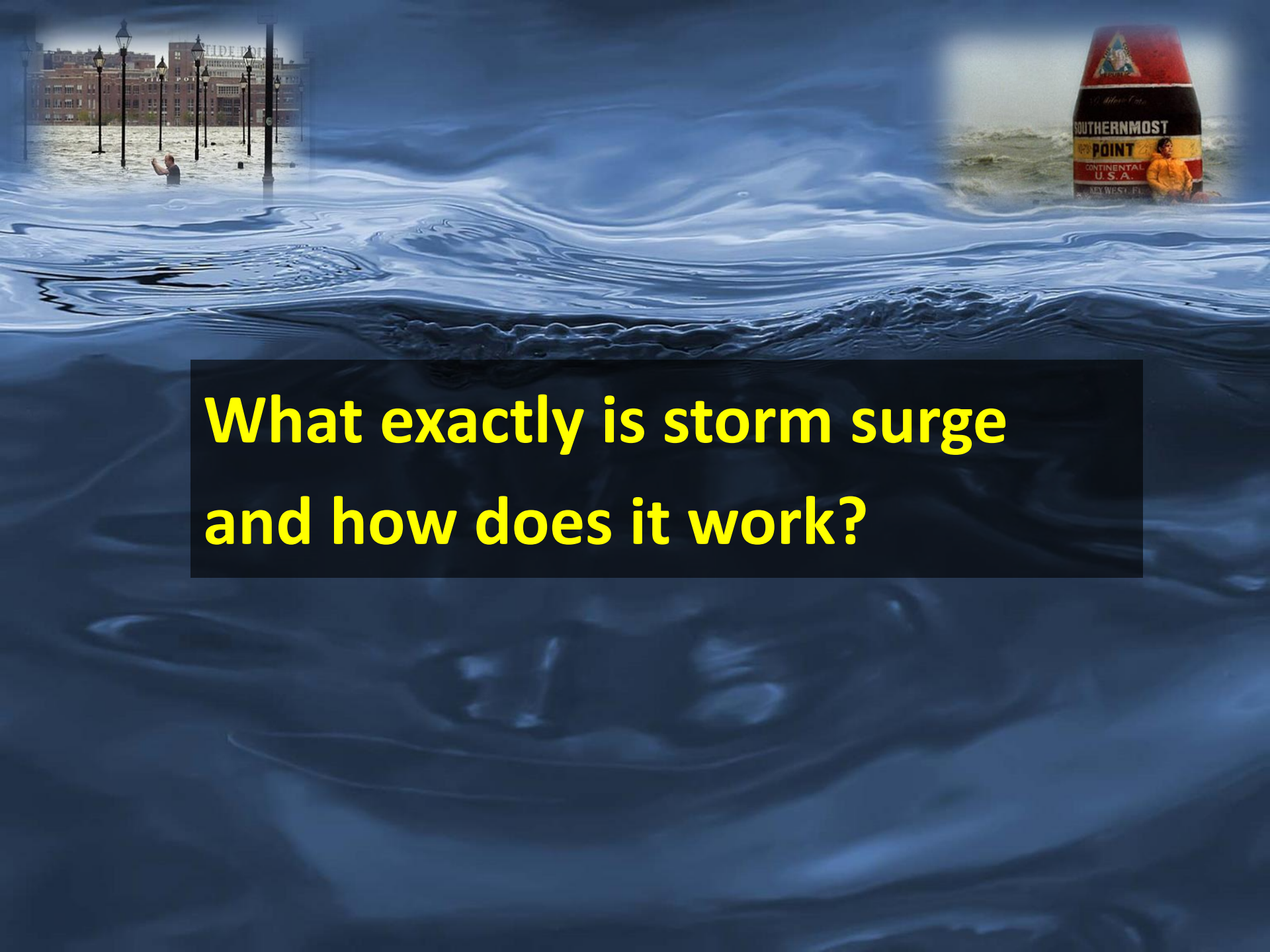




# Hurricane Irma

Tampa Bay, FL

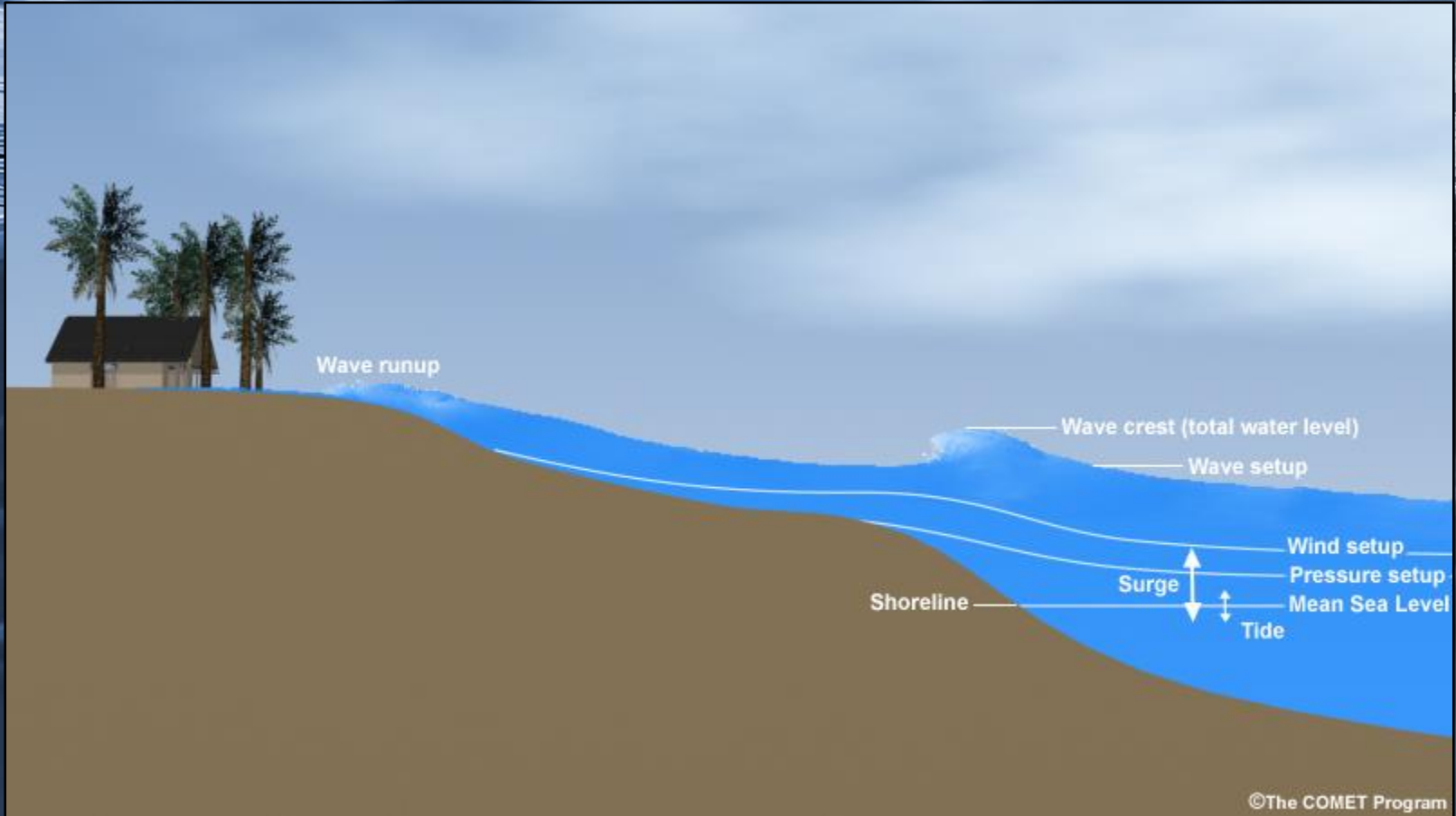




**What exactly is storm surge  
and how does it work?**



# Total Water

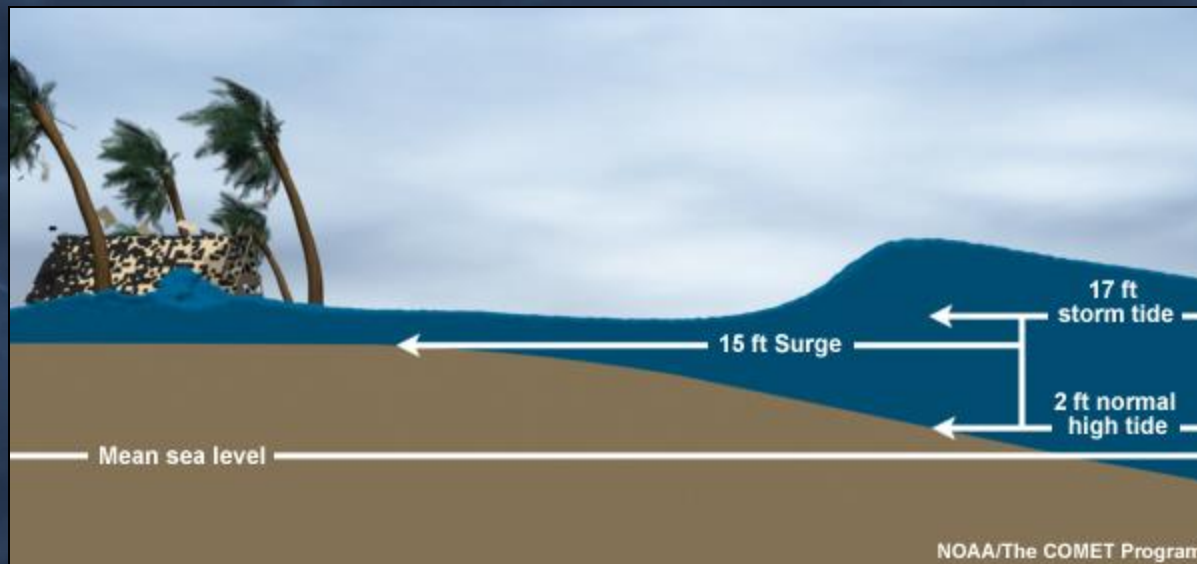


Total water level = Storm surge + Tides +  
Wave setup + Freshwater

# 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.

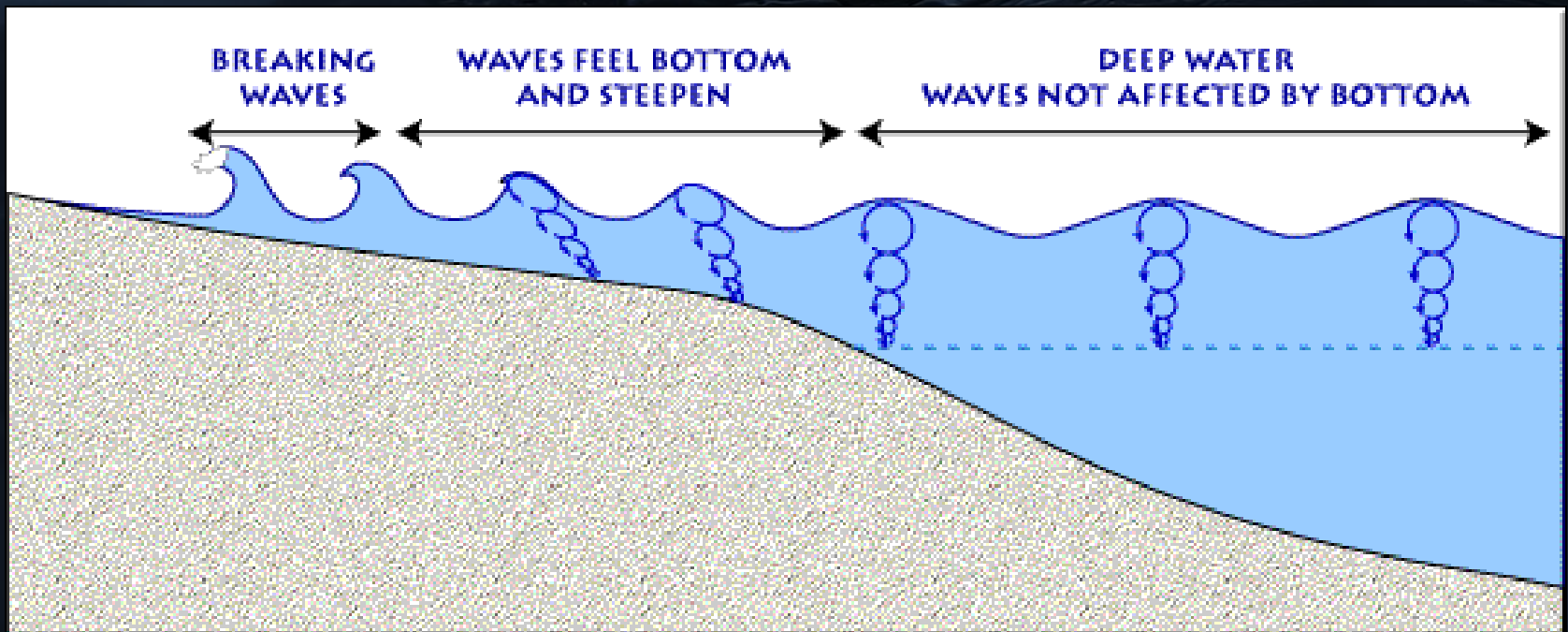
**STORM TIDE** is the water level rise during a storm due to the combination of storm surge and the astronomical tide





# 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



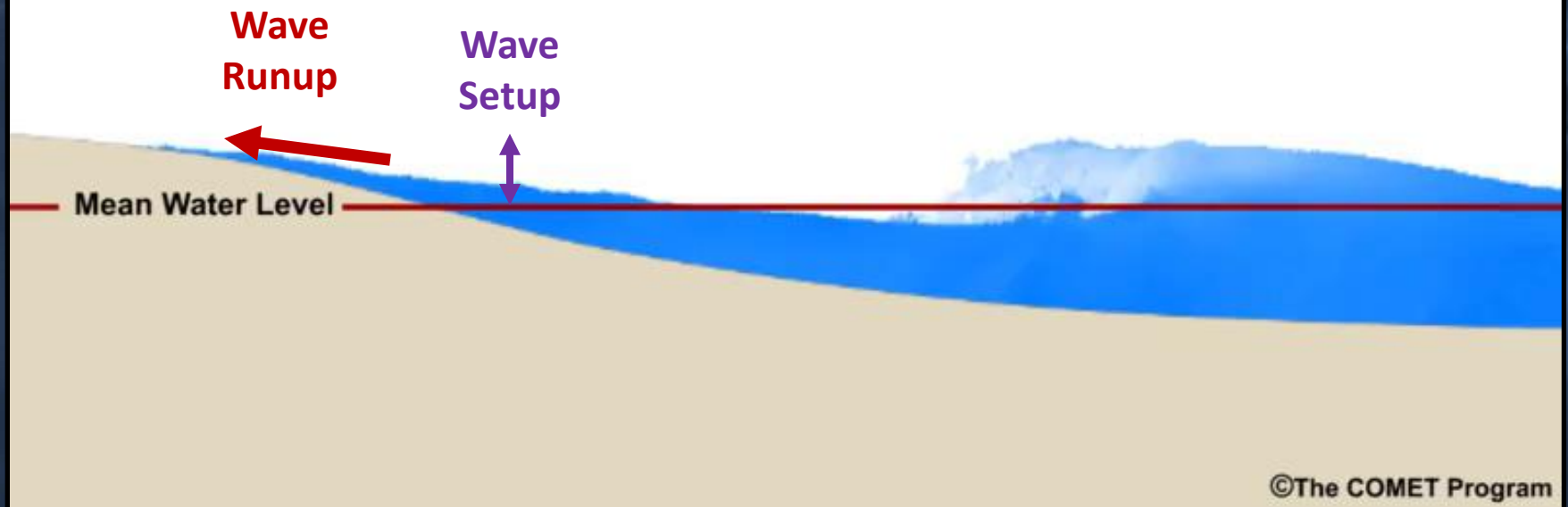
Alphapure Design Studio



# Wave Runup and Setup



## Wave Setup



# Freshwater Input



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

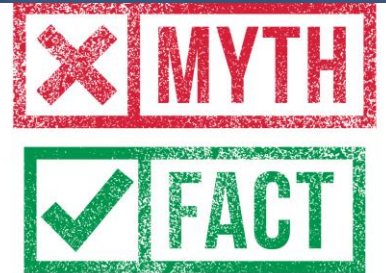


# Myth or Fact?



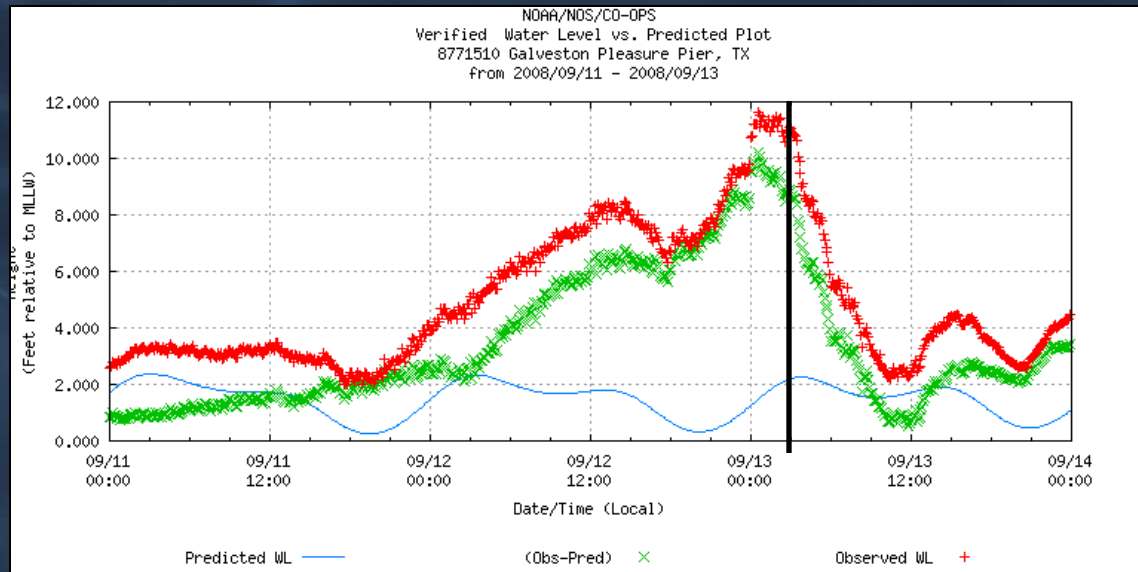
Water levels can increase long before the wind and rain hazards begin.

Fact



# Galveston

## Day before Ike arrived



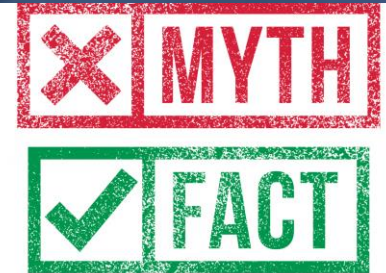


# Myth or Fact?



Category 4 hurricanes always produce more storm surge than Category 1 hurricanes.

Myth



# 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)**

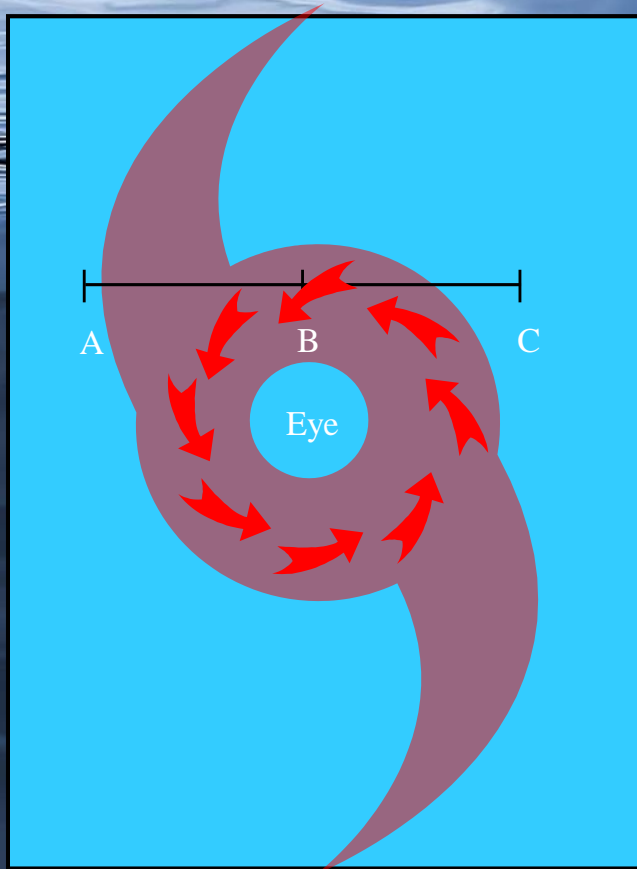


# No Such Thing as “Just a Tropical Storm”

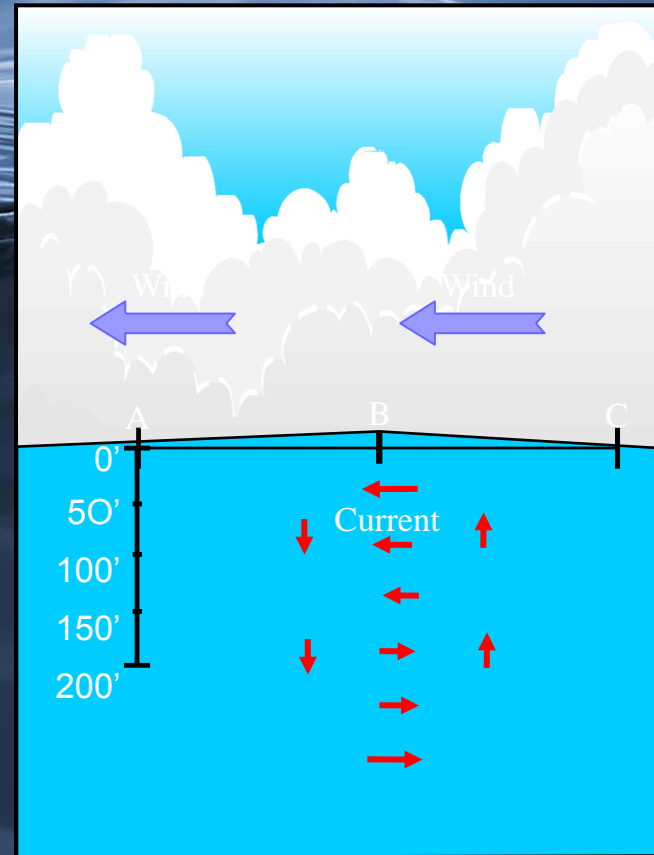


Louisiana State Rd. 23 near Myrtle Grove  
Tropical Storm Lee (2011)

# Deep Water



a. Top view of Sea Surface



b. Side view of Cross Section "ABC"

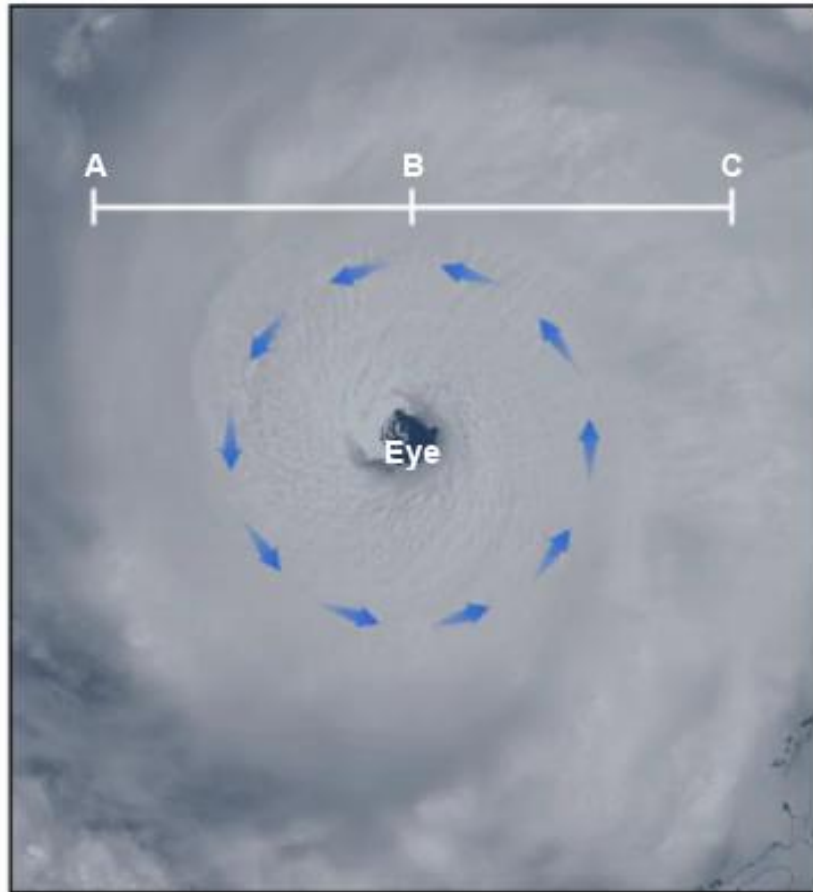




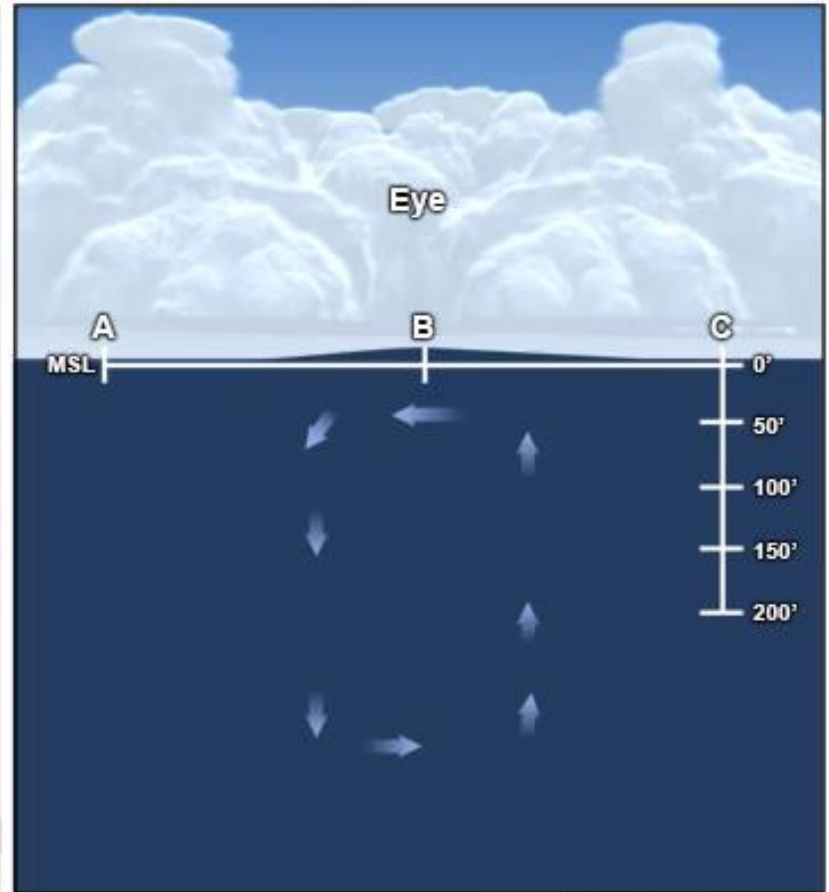
# From Deep Water to Shallow Water



Top View of Sea Surface

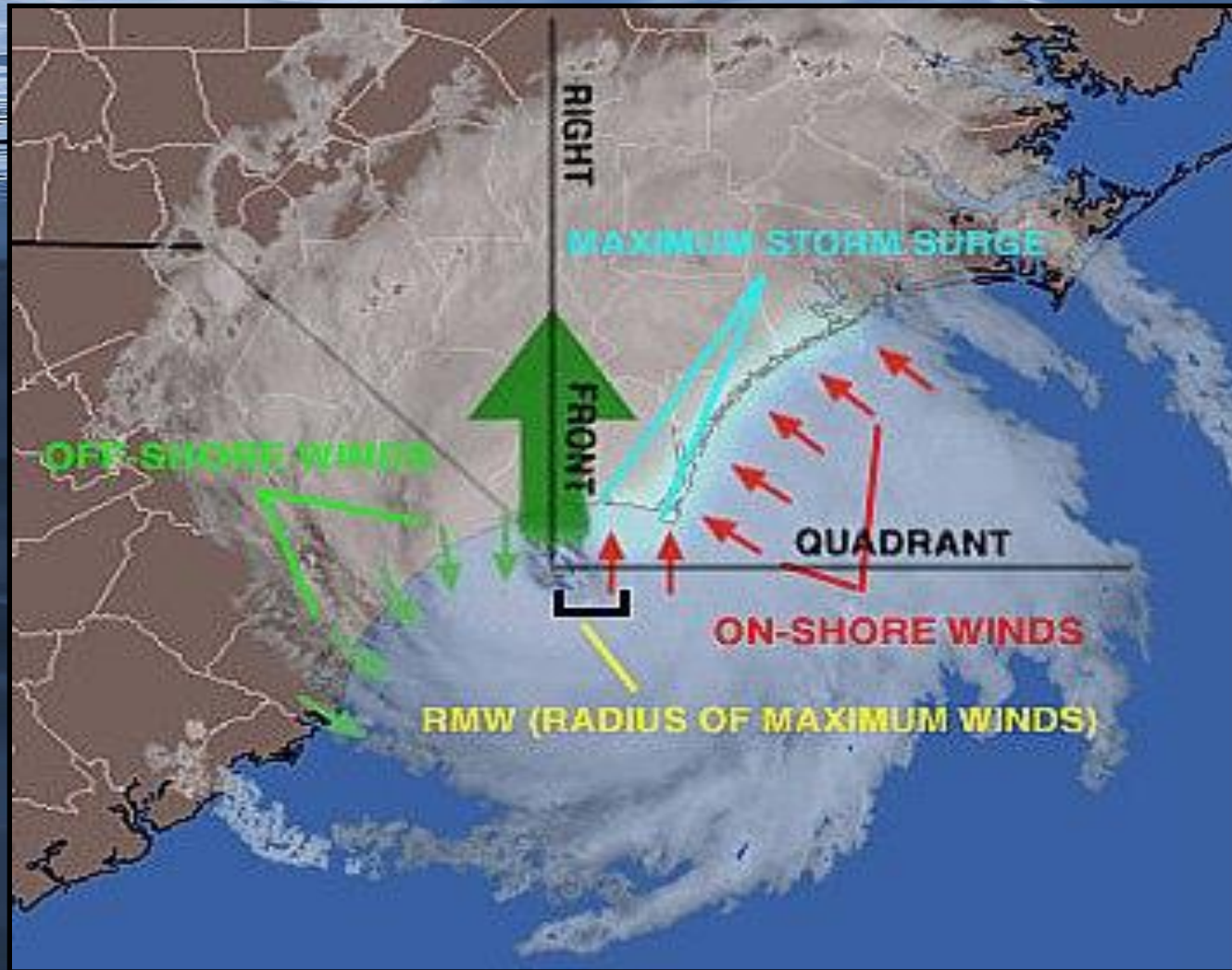


Side View of Cross Section "ABC"



©The COMET Program

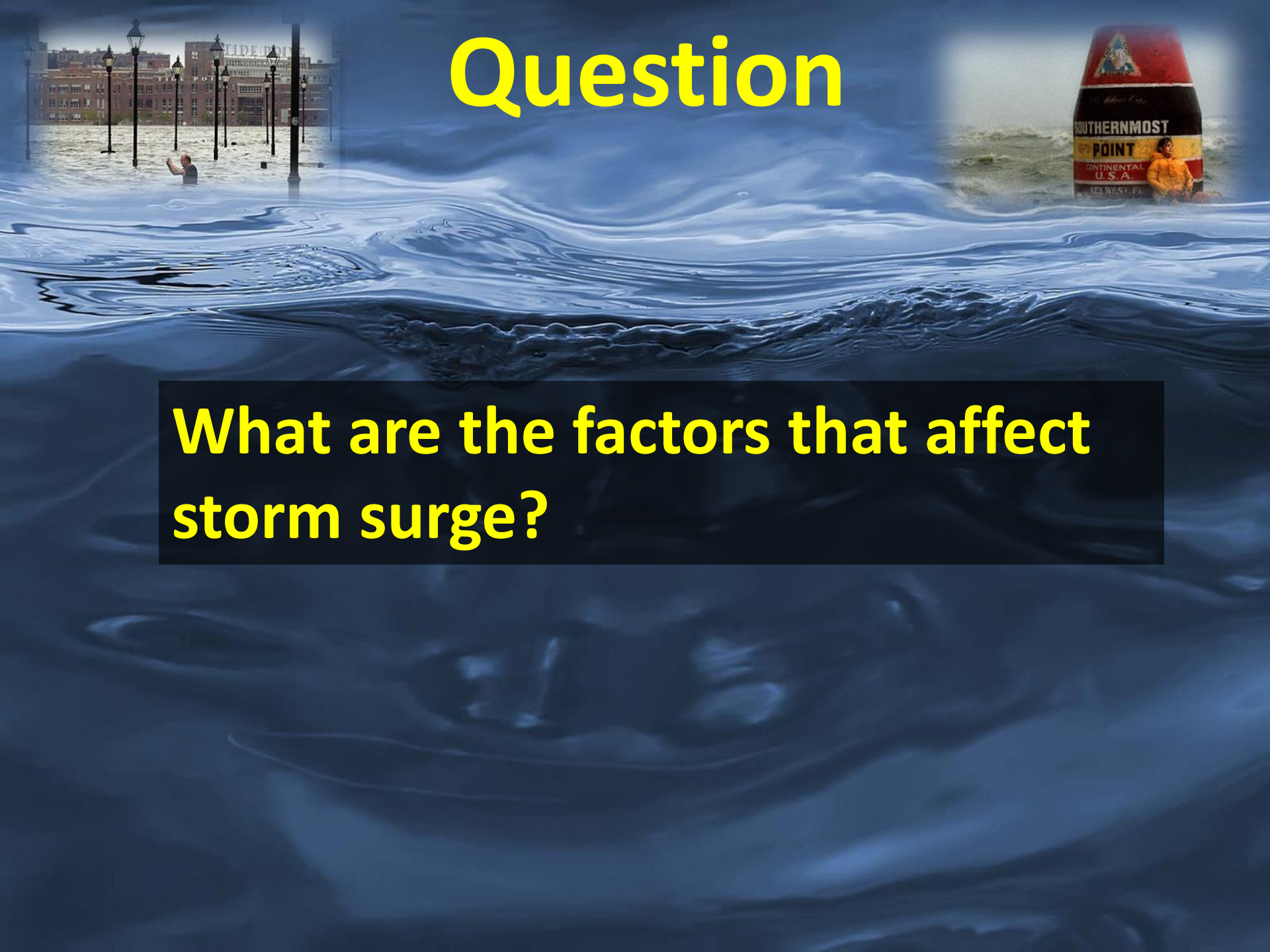
# Understanding Surge





# Question

**What are the factors that affect storm 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

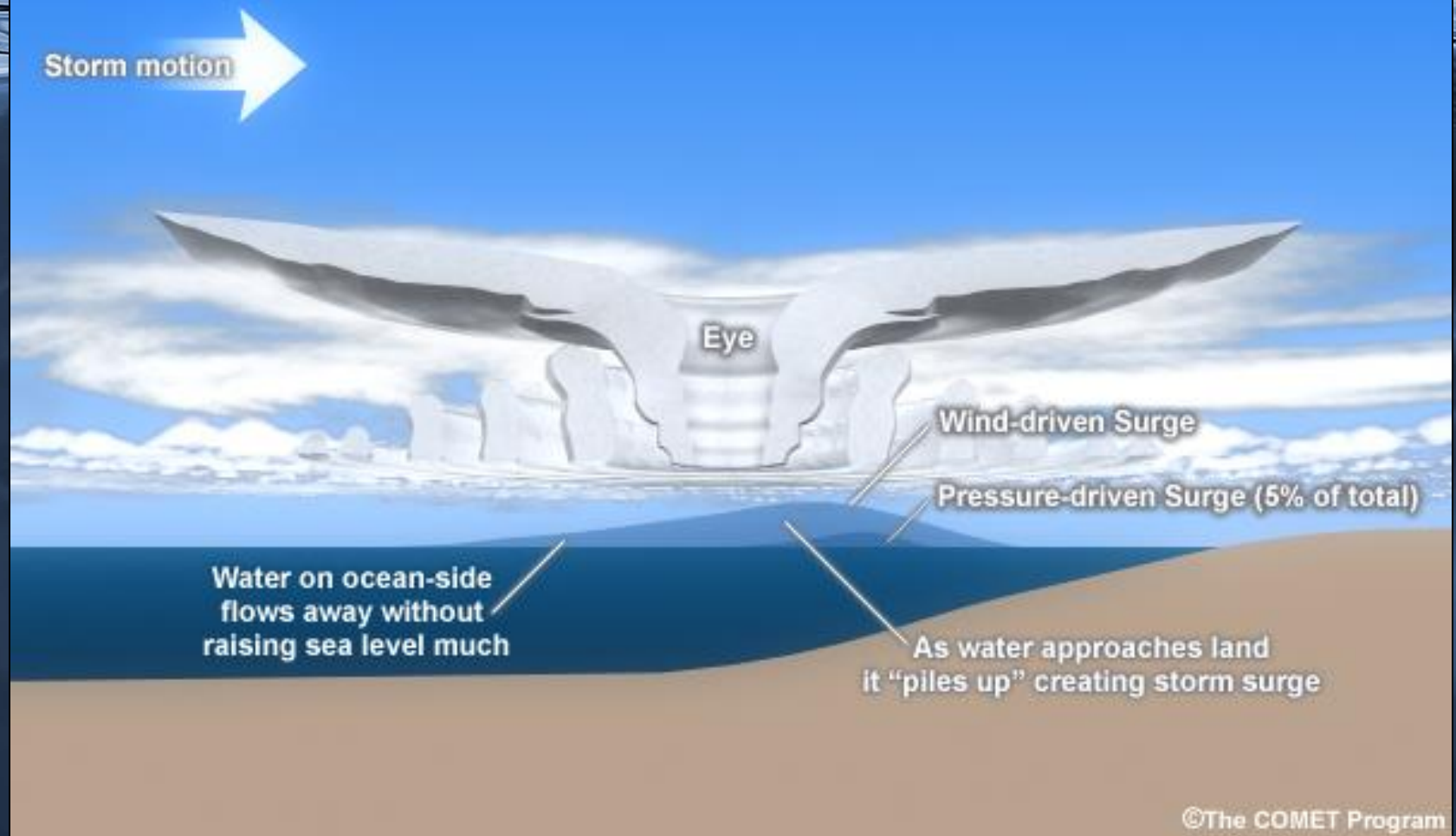




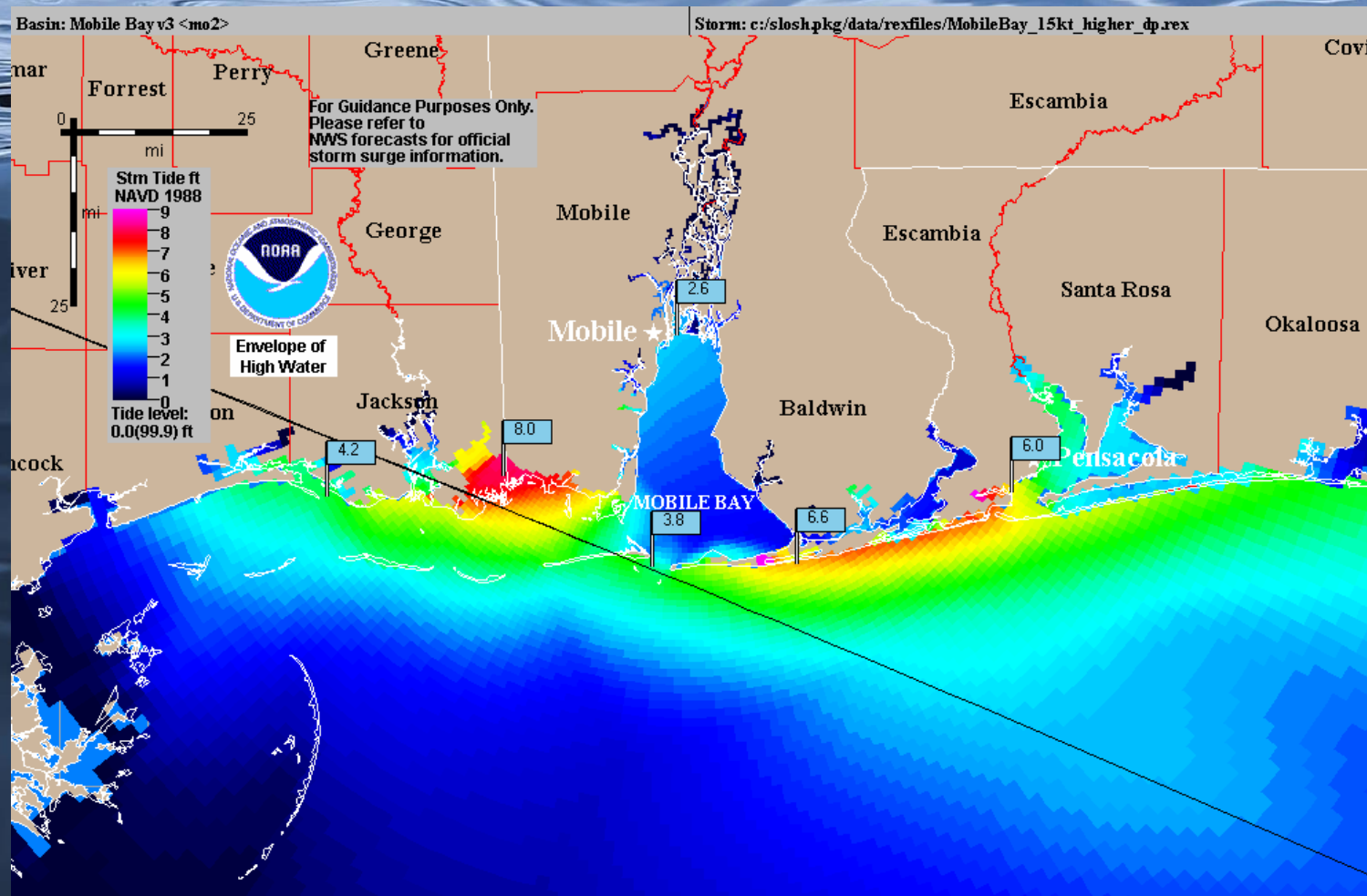
# Effects of Low Pressure



## Wind and Pressure Components of Hurricane Storm Surge

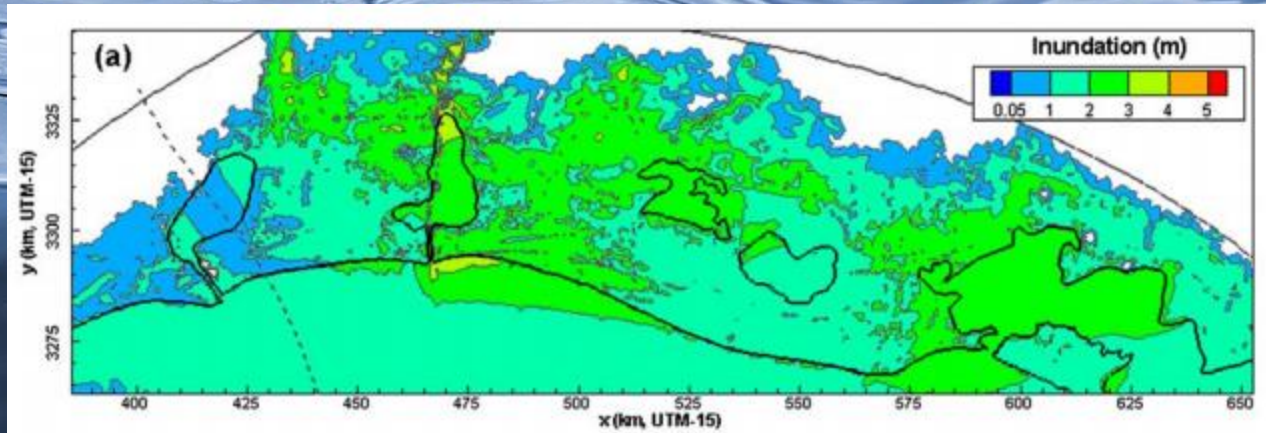


## A photograph showing a flooded street in New York City. Several black lampposts are partially submerged in the water. In the background, a large brick building with the words "HIDE OUT" visible on its facade stands behind a row of trees. A person is wading through the water in the foreground.



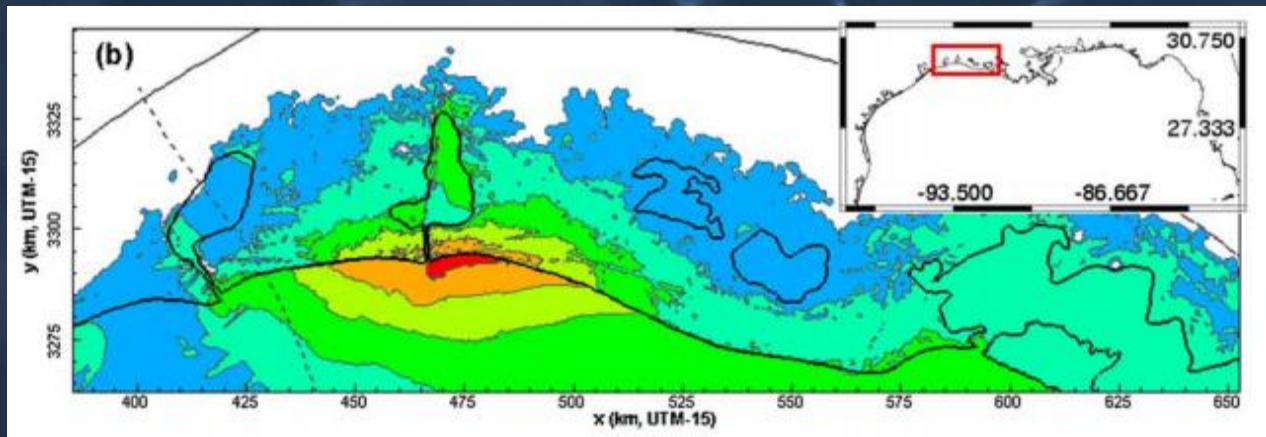


# Forward Speed



Slow Speed (5 mph)

- More inland penetration

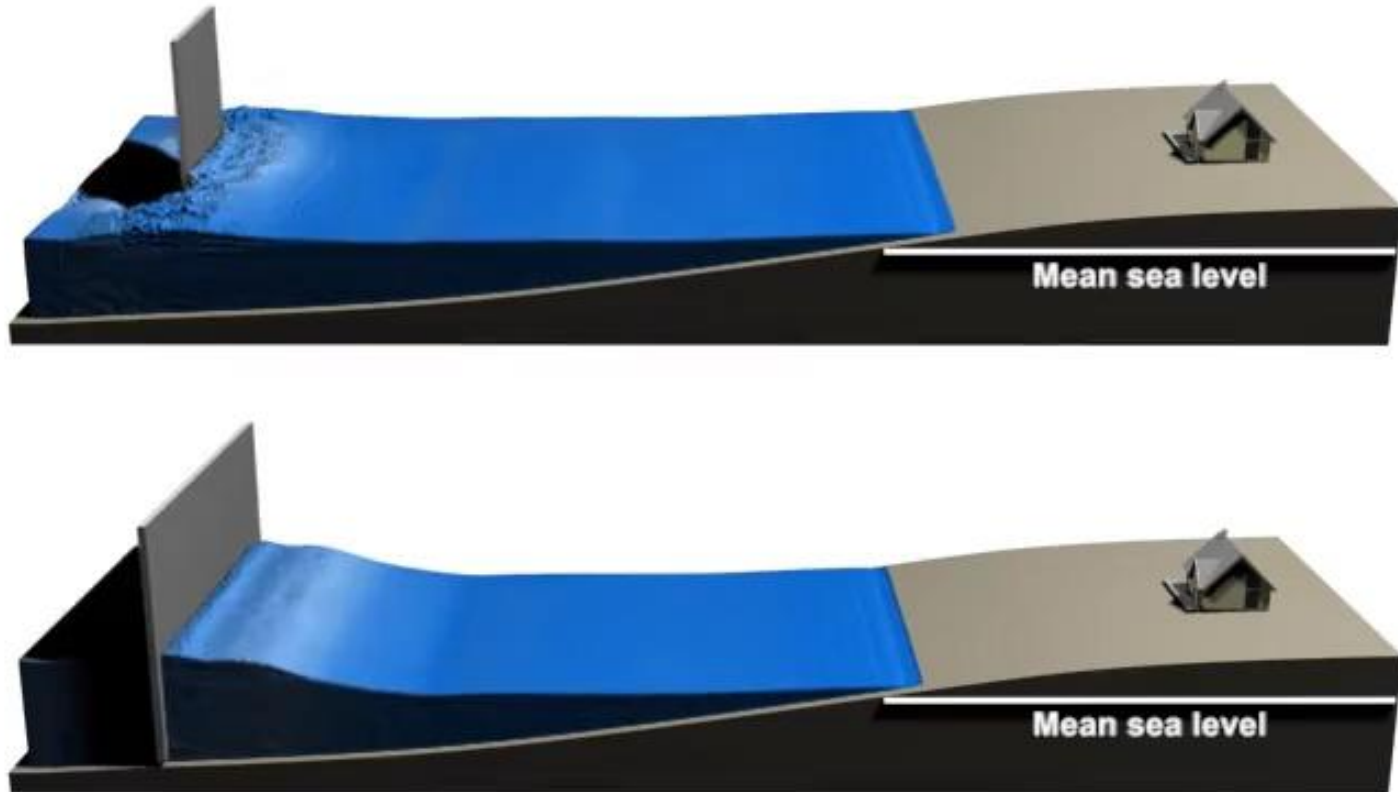


Fast Speed (25 mph)

- Higher maximum

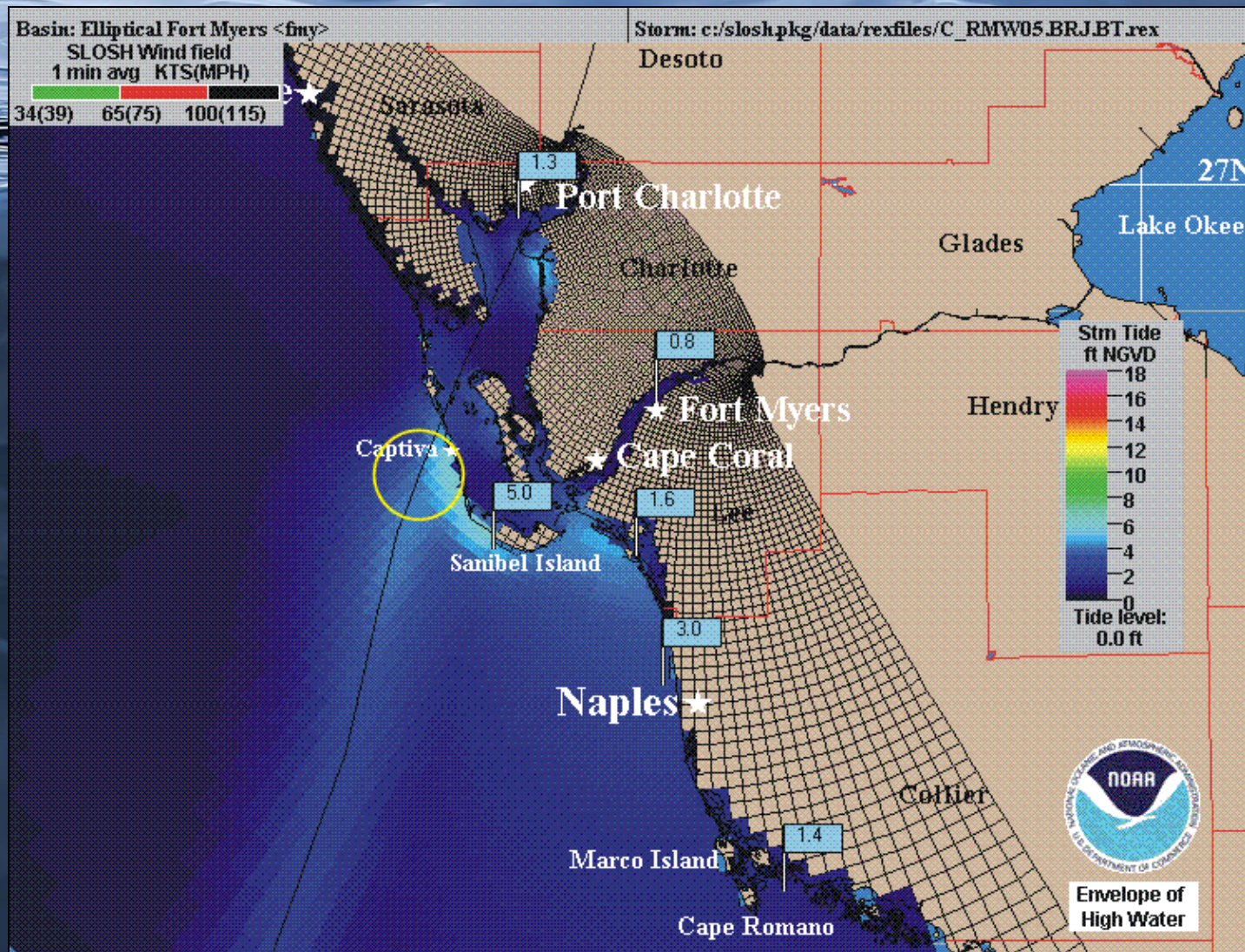
Rego, J. L., and C. Li (2009). Forward speed of a hurricane. *Geophysical Research Letters*, 36.

# Size (Radius of Max Winds)





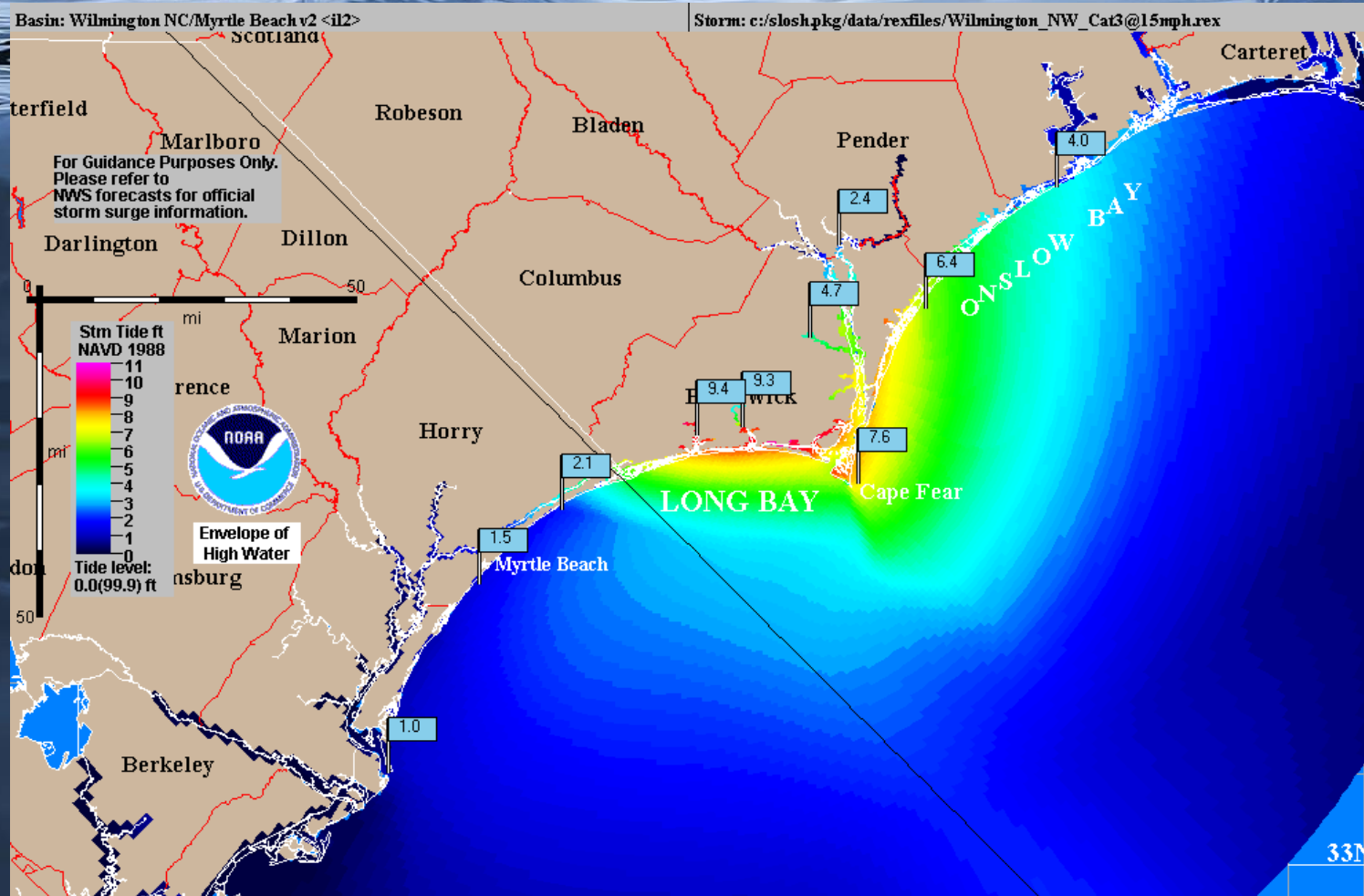
# Size (Radius of Max Winds)





# Angle of Approach

## NNW Motion

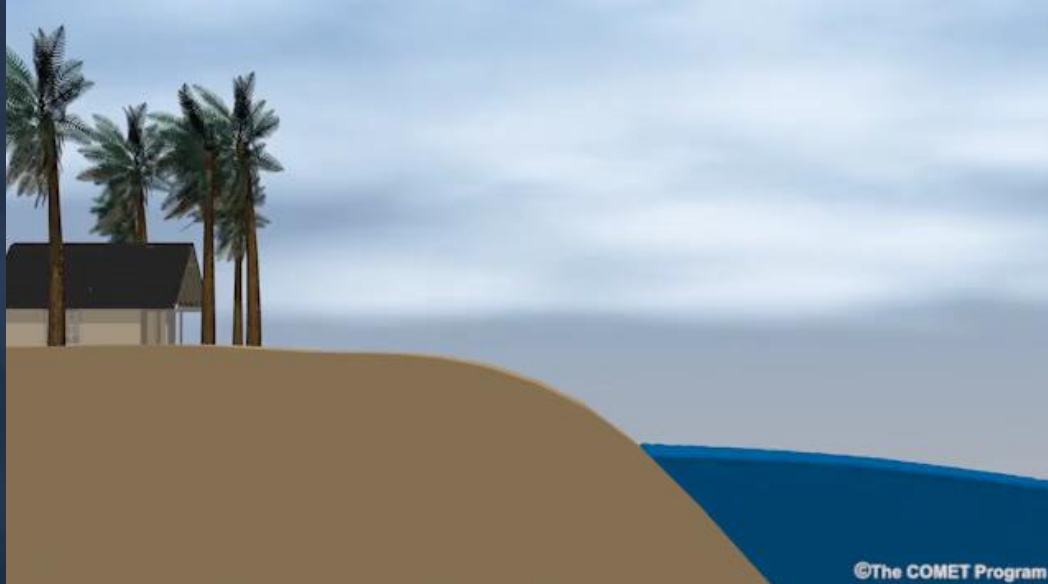




# Width and Slope of Shelf



Wide shelf/  
gentle slope



Narrow  
shelf/ sharp  
slope



# Local Features

