Unit 1:
Hurricane Basics

FEMA

Unit Objectives

- **At the end of Unit 1, you should be able to:**
  - Describe the characteristics and life cycle of a tropical cyclone.
  - Describe Atlantic Hurricane Climatology.
  - Explain the hurricane hazards and how water is responsible for the vast majority of direct fatalities.

Tropical Cyclones Defined

Tropical Cyclones

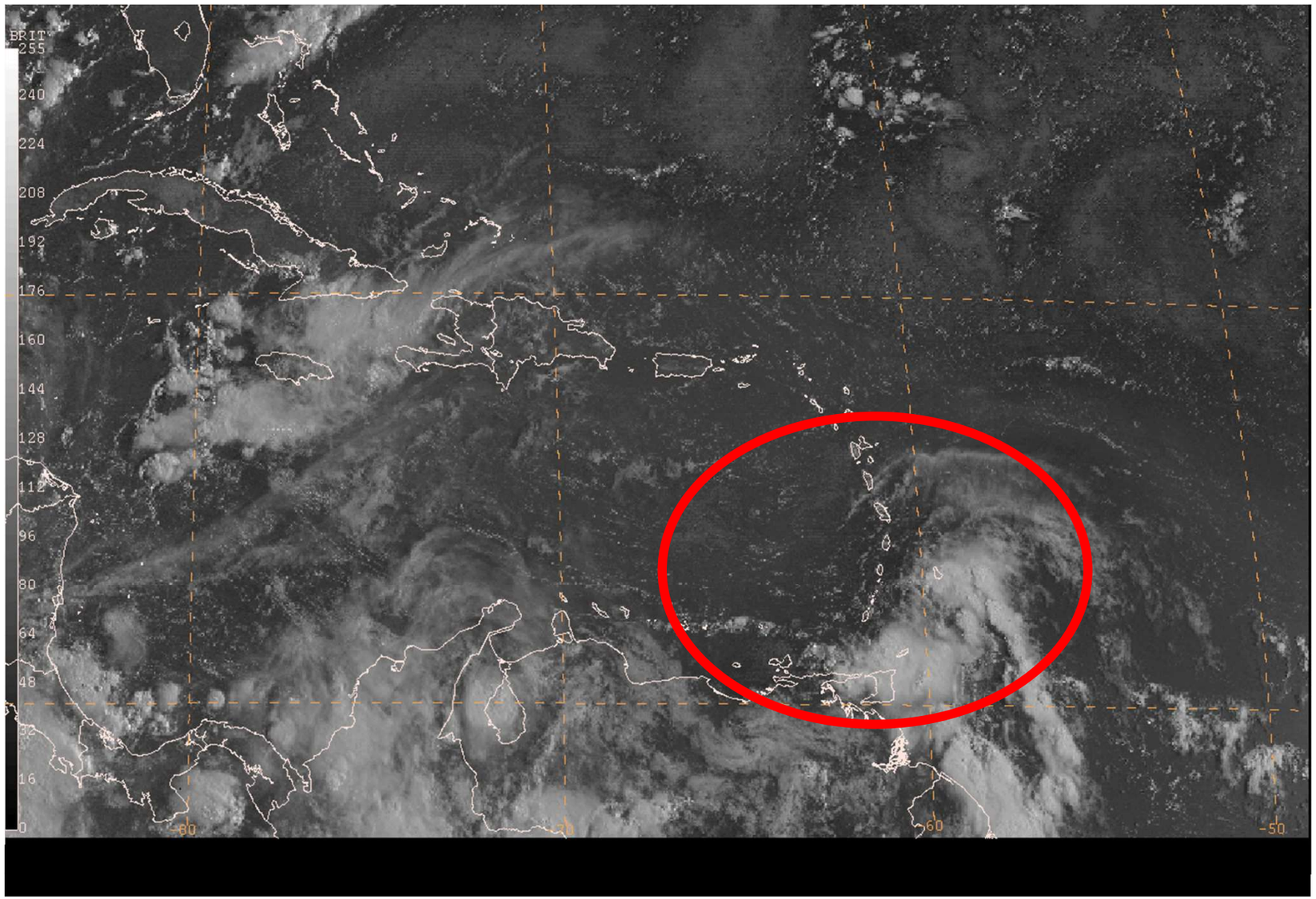
- **Large, long-lived, low-pressure system**
  (can be hundreds of miles wide, lasting for days)
- **Form over sub/tropical oceans**
- **No fronts attached**
- **Produce organized thunderstorm activity**
- **Have a closed surface wind circulation around a well-defined center**

Tropical Cyclone Classification

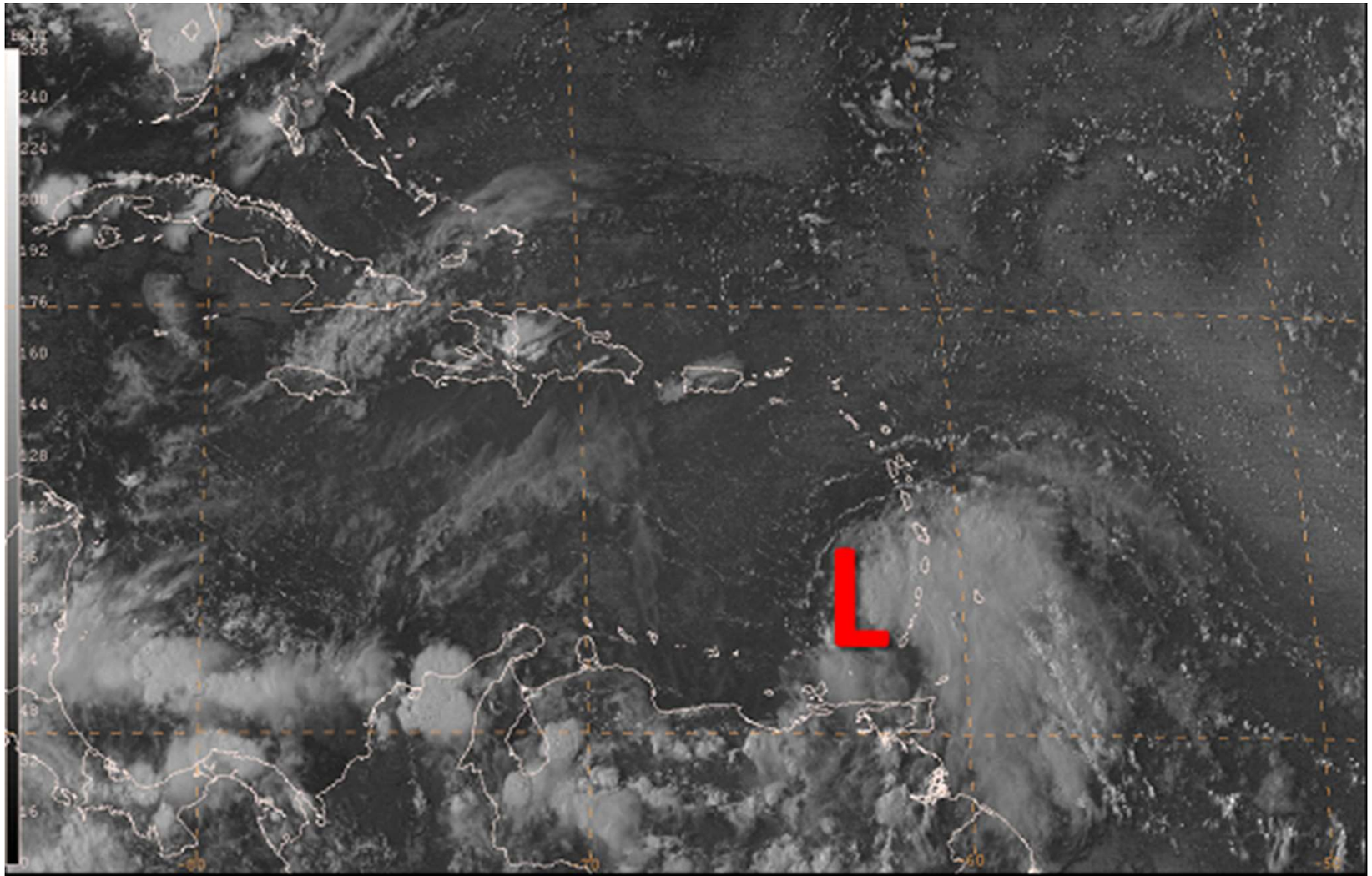
Maximum Wind Speed:

- **Tropical Depression: <39 mph**
- **Tropical Storm: 39–73 mph**
- **Hurricane: 74 mph or greater**
  - ***Major Hurricane: 111 mph or greater***

Surface Circulation? Organized?

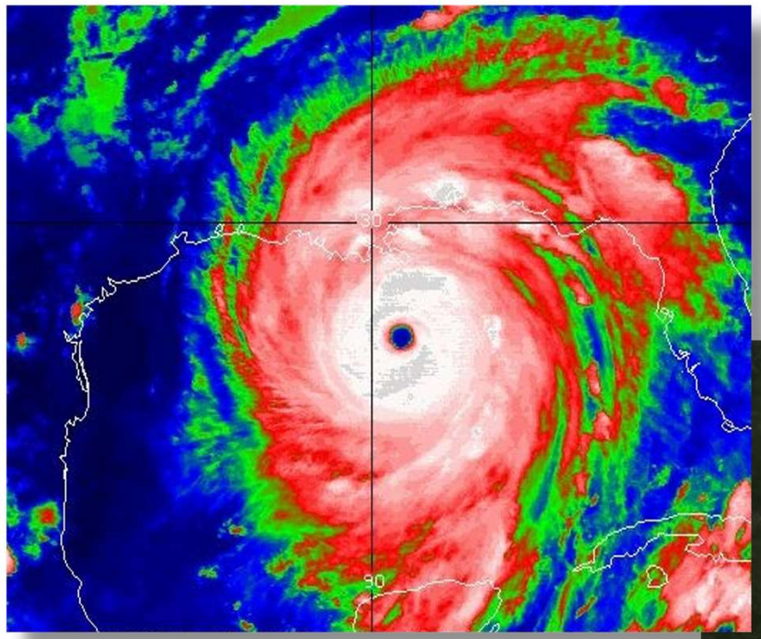


Ernesto 2006

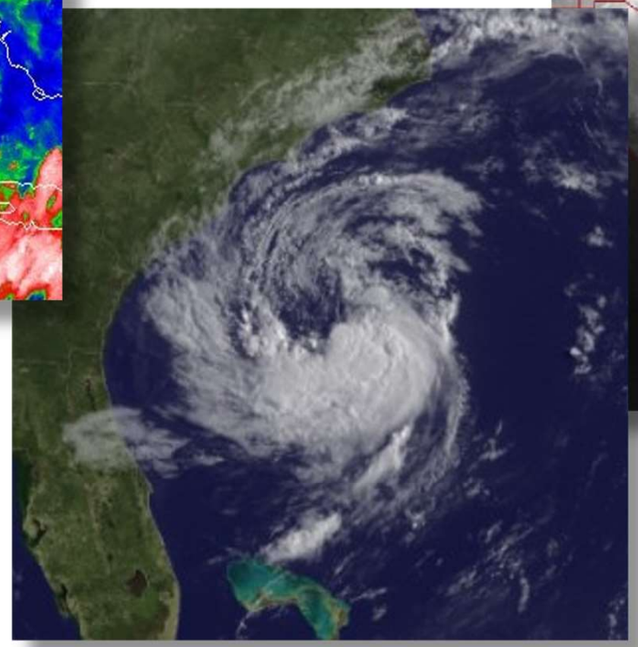


Advisory 1; issued based on aircraft data

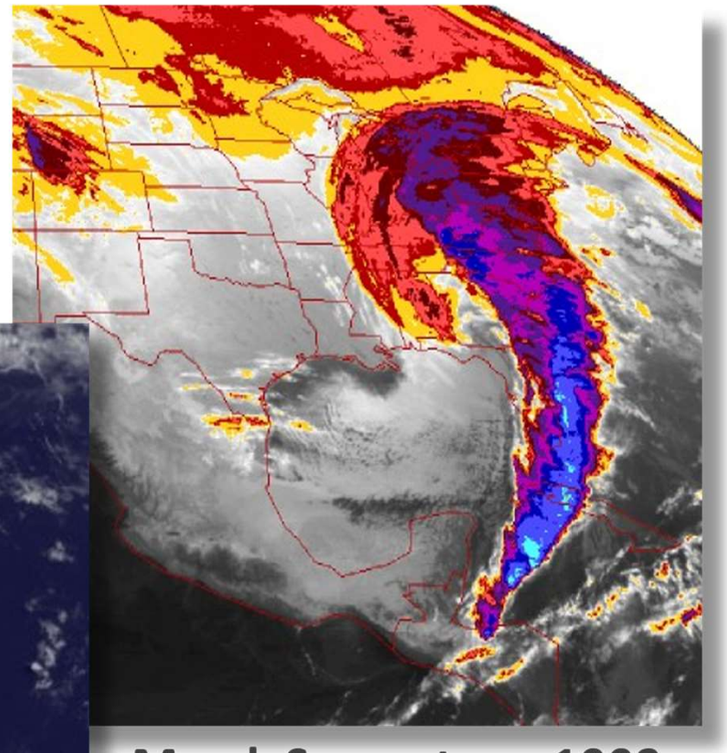
Tropical, Subtropical, & Extratropical



Hurricane Katrina 2005

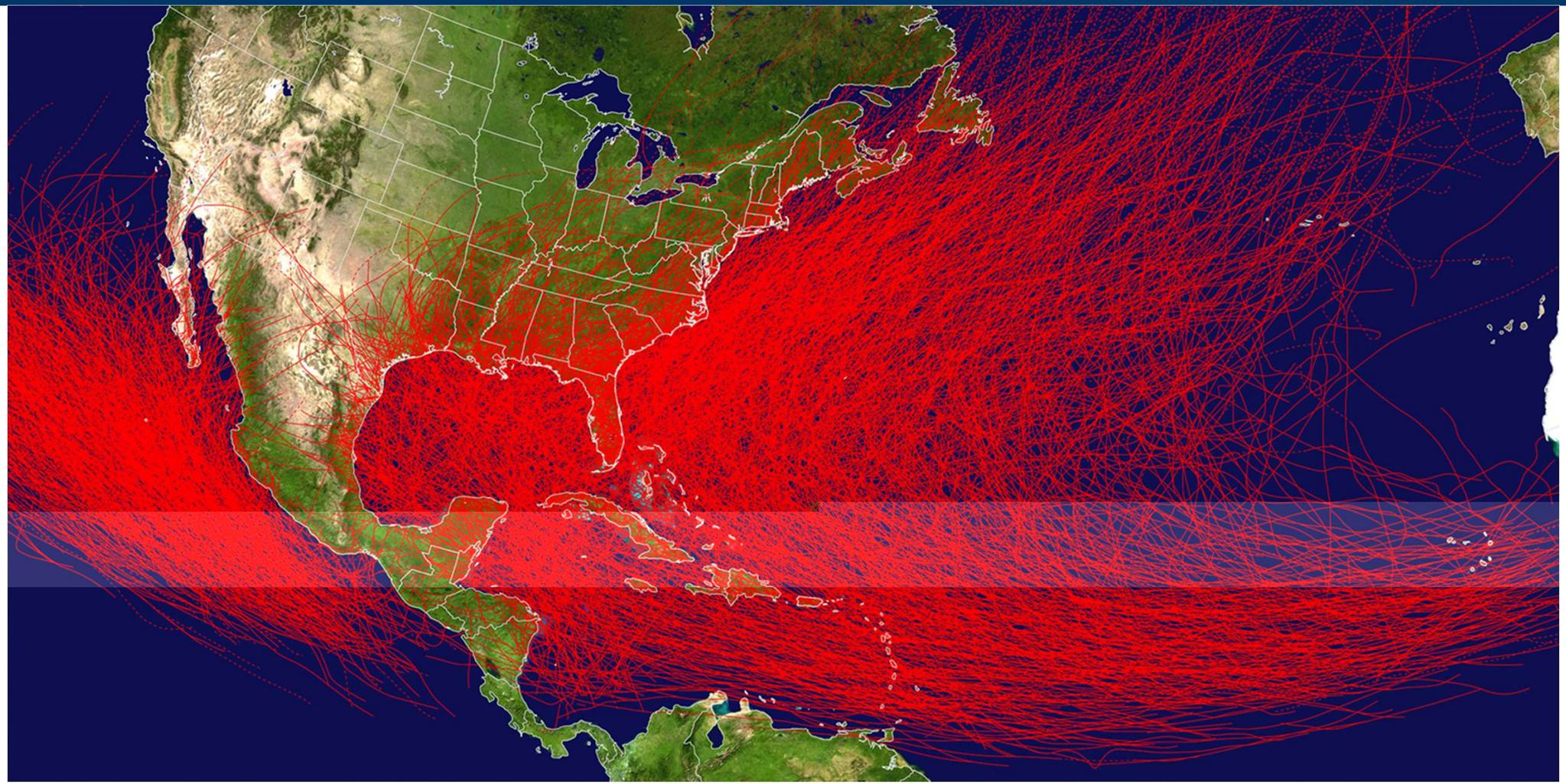


Subtropical Storm Ana 2015



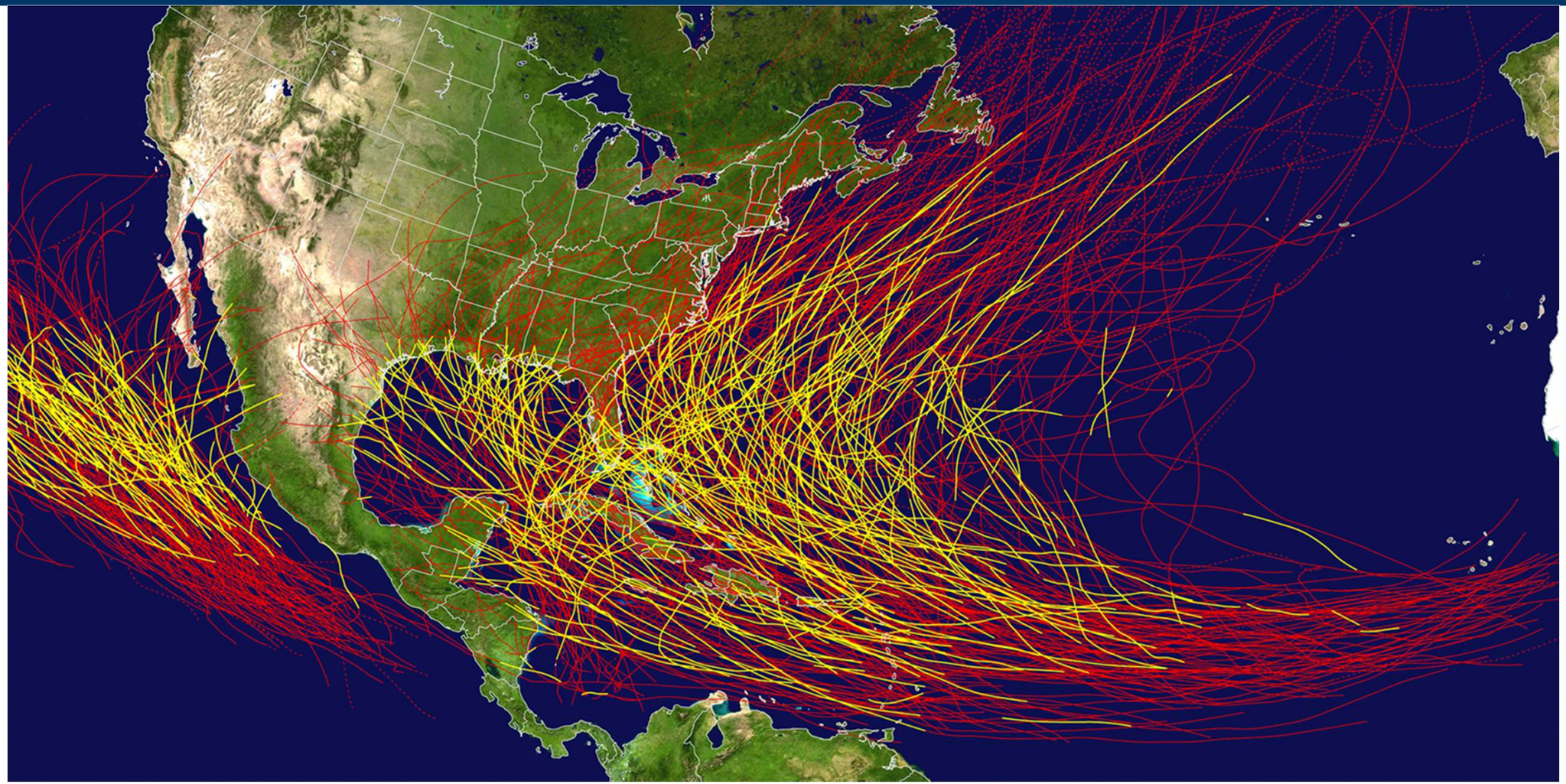
March Superstorm 1993

Tropical Cyclone History



- **Data since 1949 in Pacific, 1851 in Atlantic**

Major Hurricane History



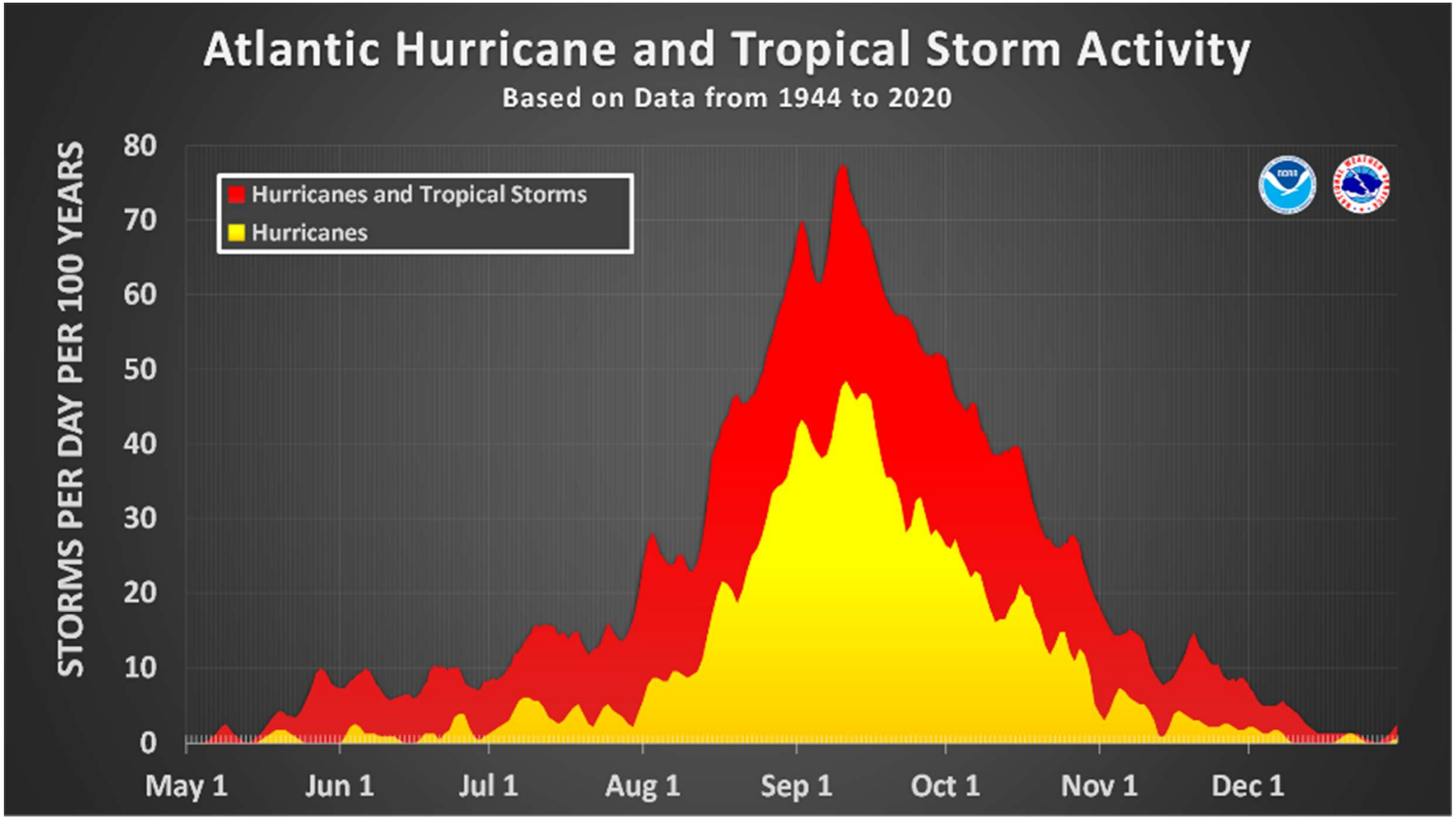
- **Data since 1949 in Pacific, 1851 in Atlantic**

Climatology – Knowledge Check

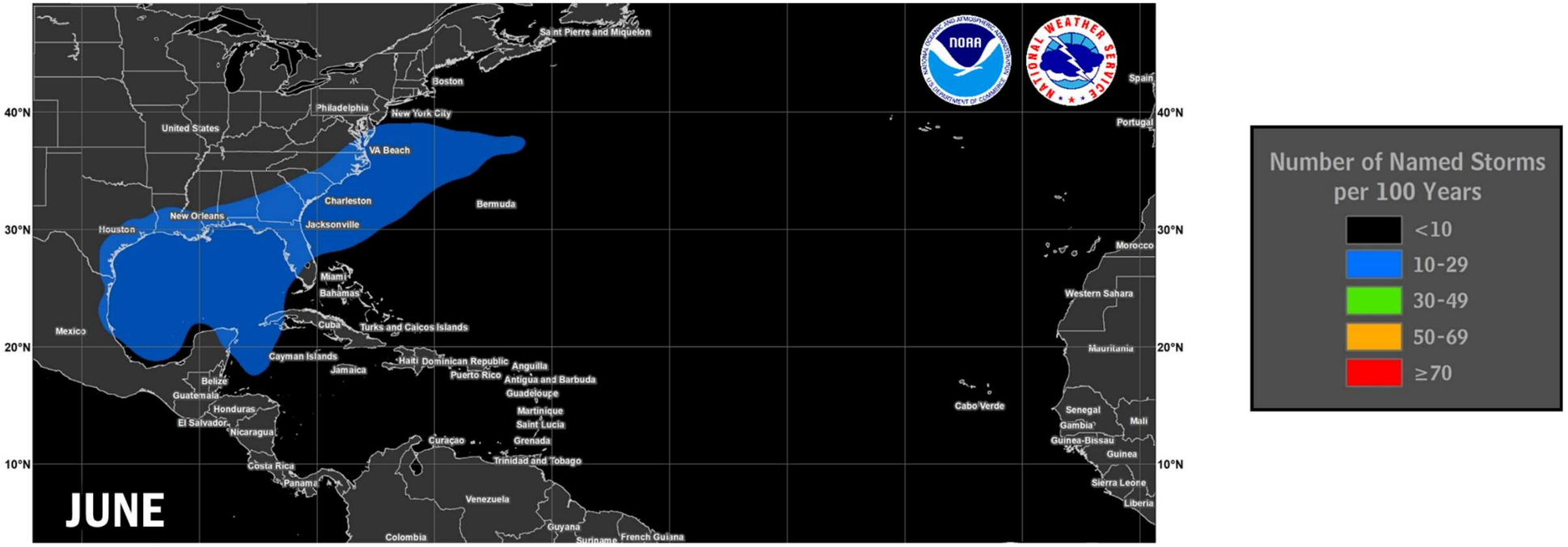
What month has the most hurricane activity in the Atlantic?

A. December
B. August
C. June
D. September

Annual Atlantic Storm Activity

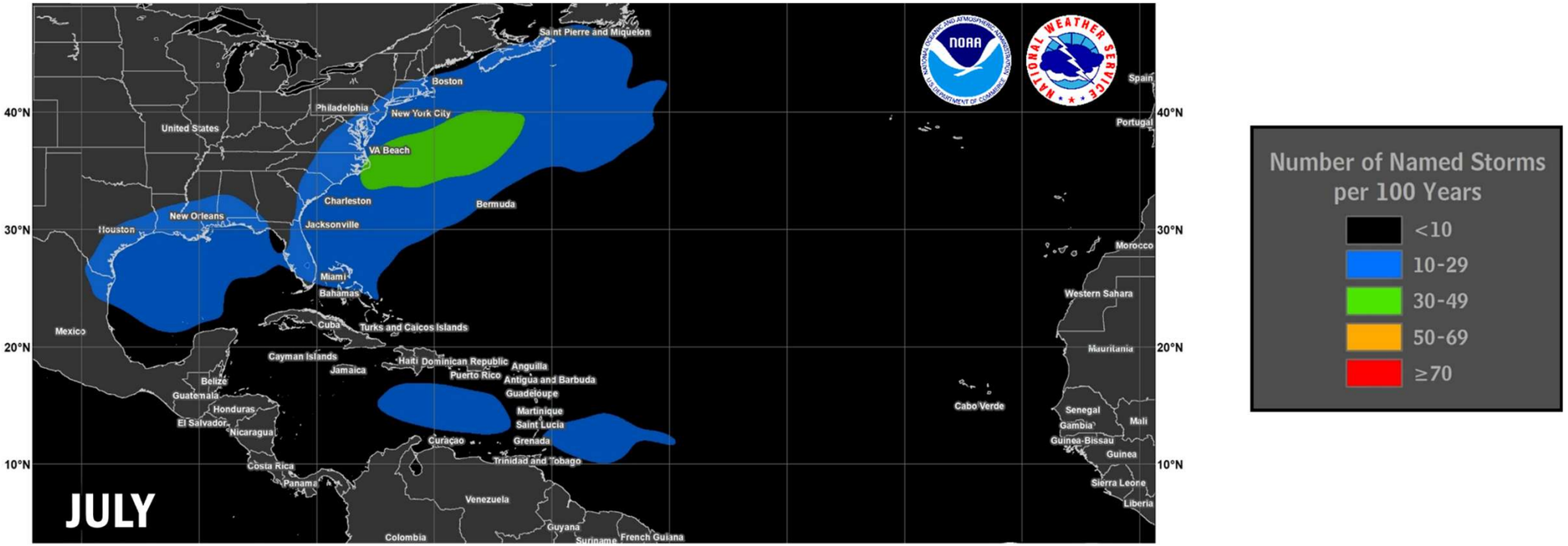


June Occurrence Areas



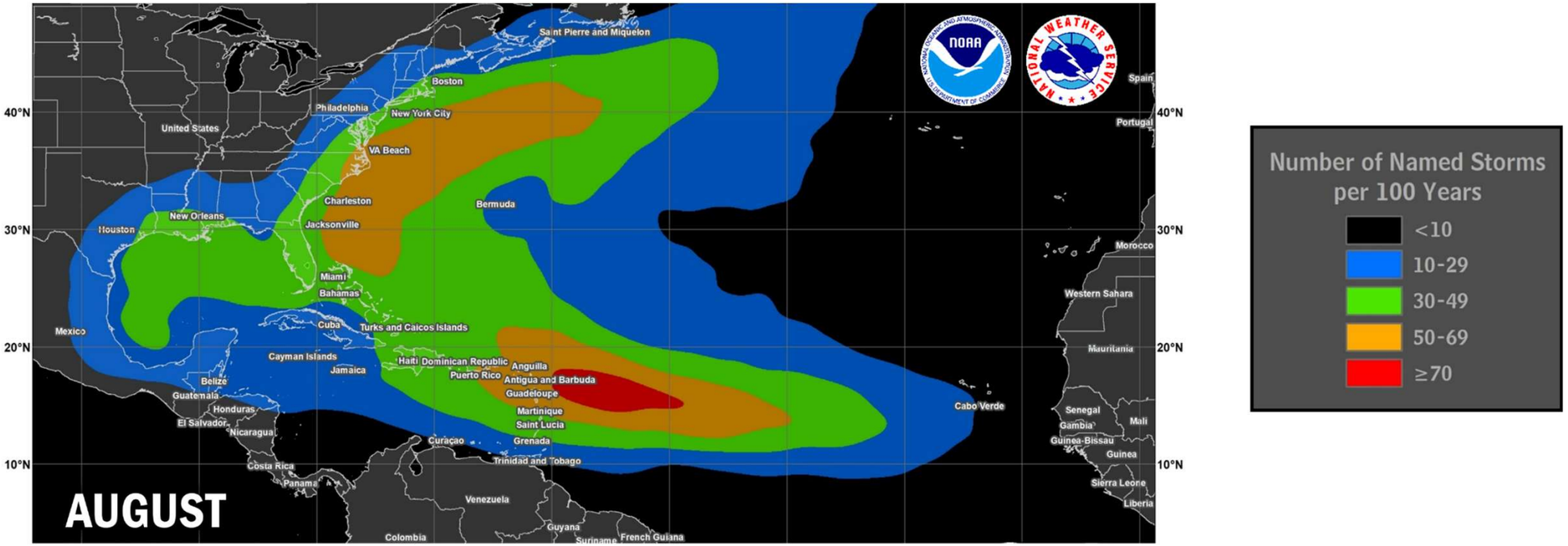
- On average, about one storm every year.
- Most June storms form in the NW Caribbean Sea or Gulf of Mexico.

July Occurrence Areas



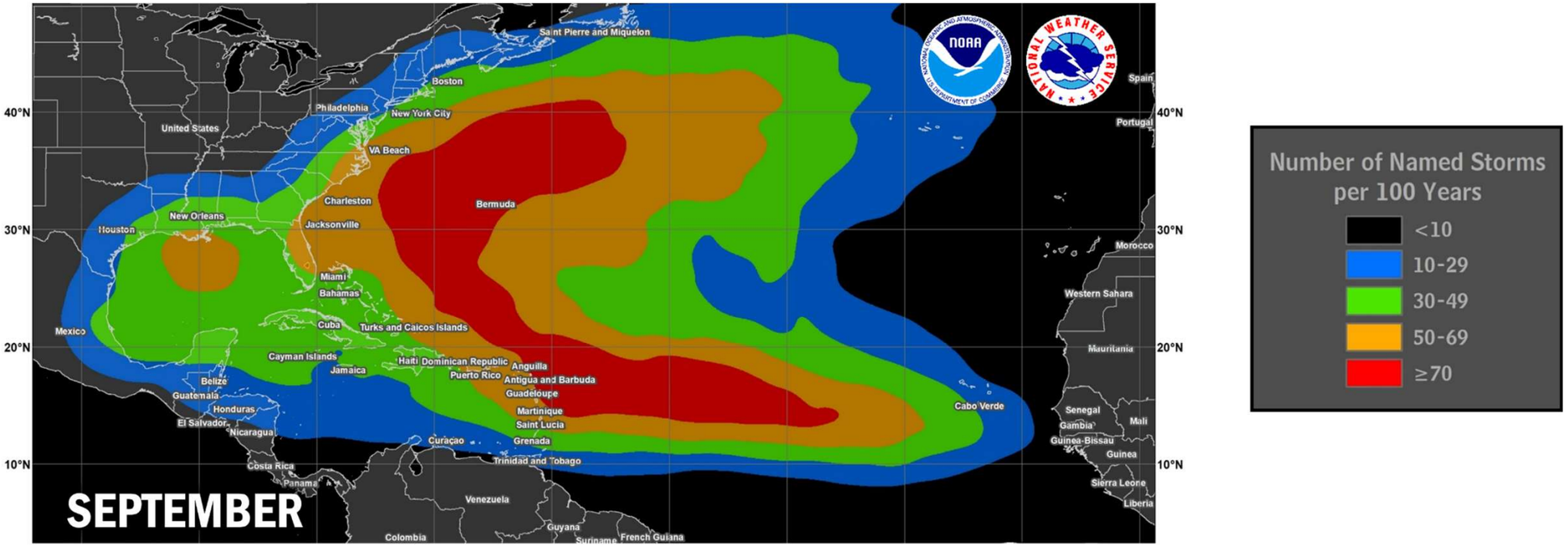
- On average, one to two named storms every year.
- July occurrence areas spread east and cover the western Atlantic, Caribbean, and Gulf of Mexico.

August Occurrence Areas



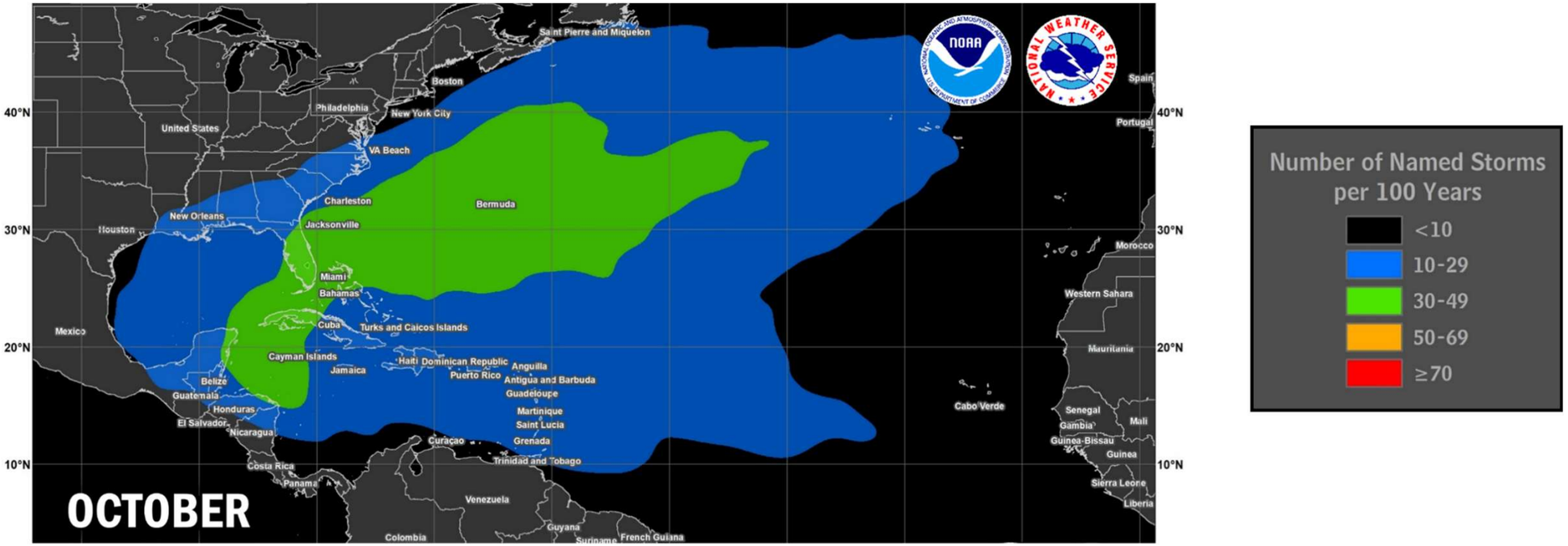
- On average, about three to four storms form each year.
- The Cape Verde season usually begins in August.

September Occurrence Areas



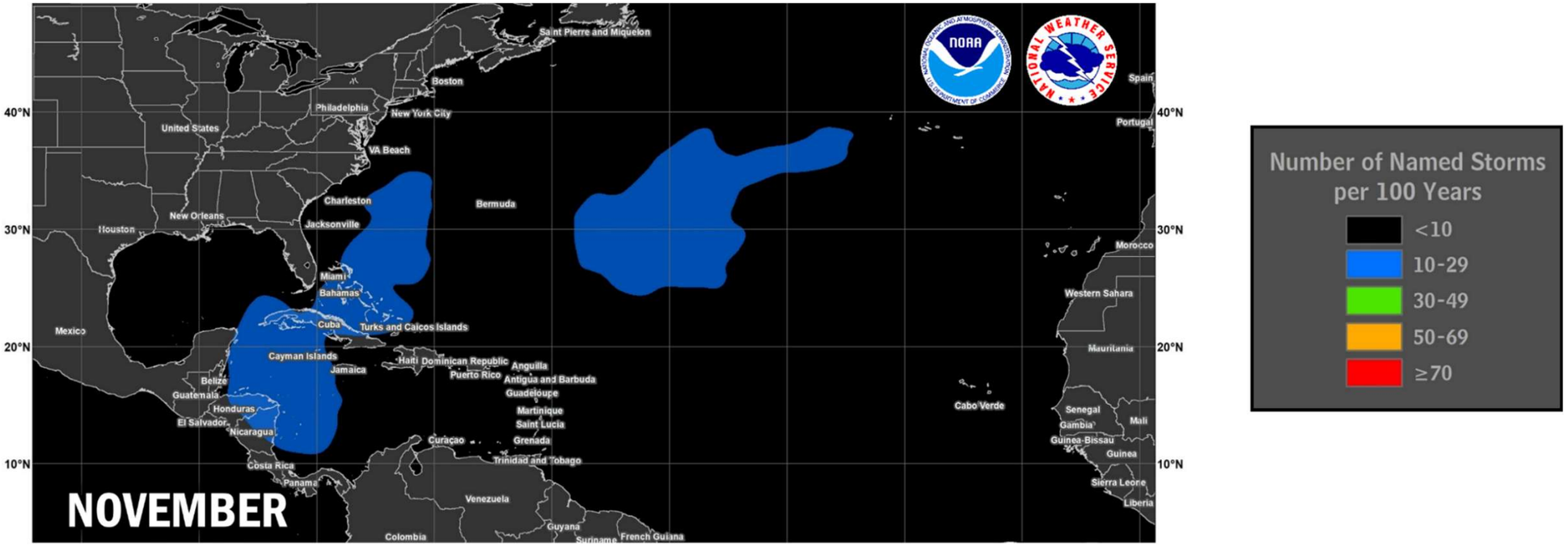
- Climatological peak of the season; on average, four to five storms every year.
- Storms can form nearly anywhere in the basin; long-track Cape Verde storms are more likely.

October Occurrence Areas



- On average, two to three storms every year.
- Cape Verde season ends, and activity shifts to the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean.

November Occurrence Areas



- On average, about one storm every other year.
- Storms typically occur in the western Caribbean Sea or western and central Atlantic Ocean.

Cape Verde Hurricane Lifecycle

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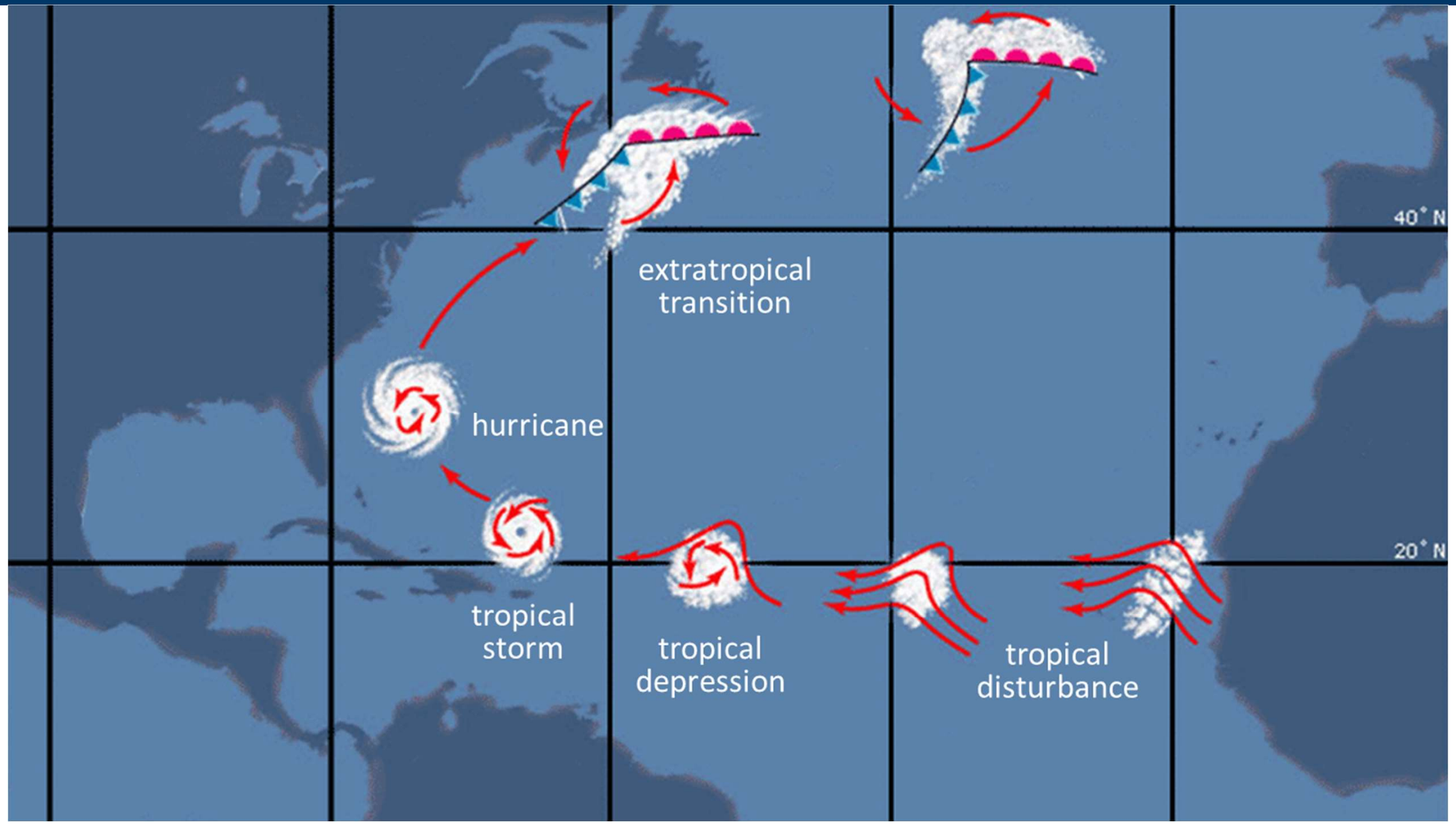
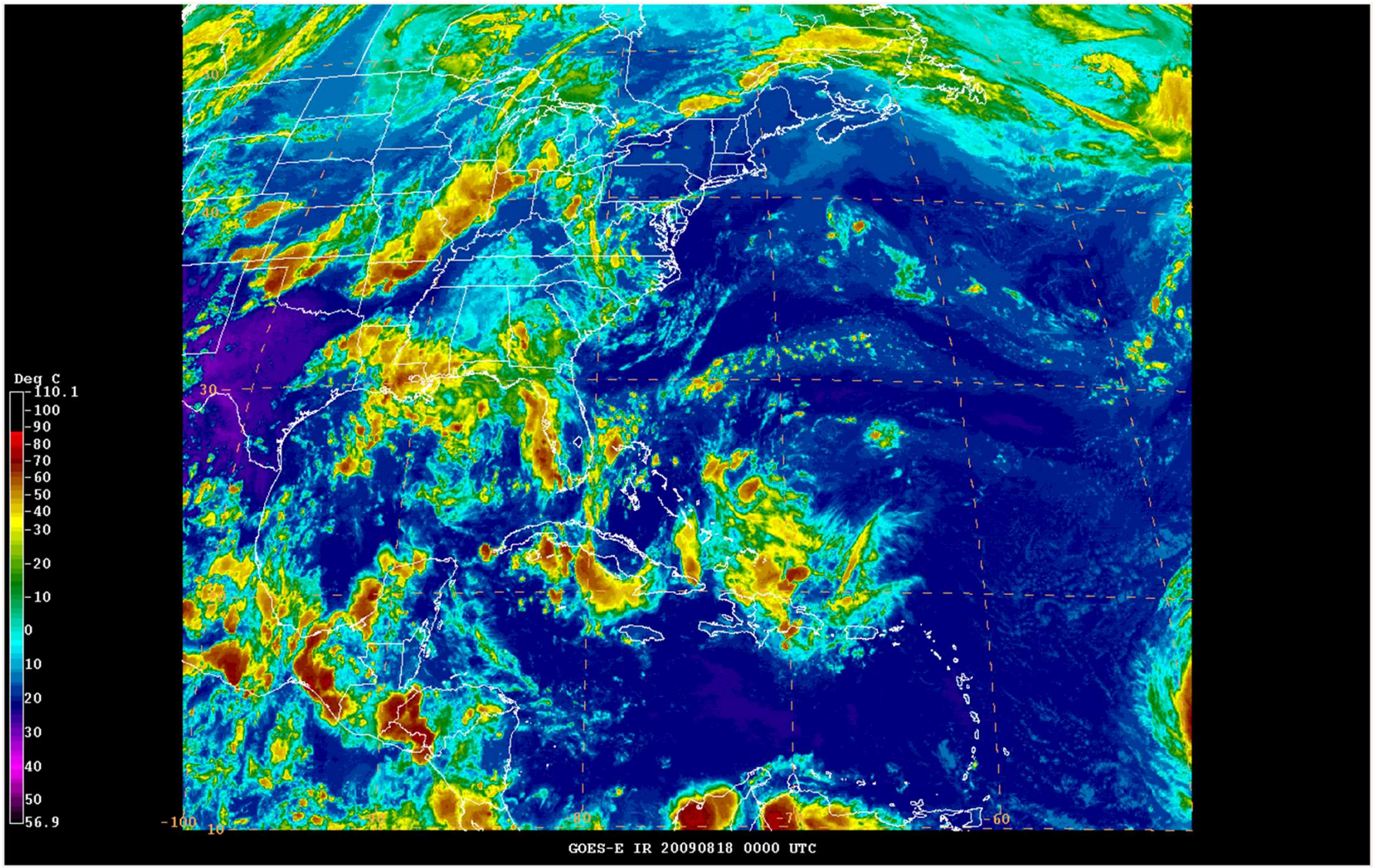


Hurricane Bill (2009)



Forecasting – Knowledge Check

Which of the following are ingredients for hurricane development?

A. Warm Water
B. Cold Air
C. Lots of Moisture
D. Strong Winds Aloft
E. Icebergs

Ingredients for a Tropical Cyclone

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Building Blocks	Fuel
1) A pre-existing disturbance (vorticity or spin) 	4) Warm sea-surface temperatures (usually at least 80°F) 
2) Location several degrees north of the equator 	5) Unstable atmosphere (temperature goes down as you go up) 
3) Little change in wind speed and/or direction with height (vertical wind shear) 	6) High atmospheric moisture content (relative humidity) 

Pre-existing Disturbances

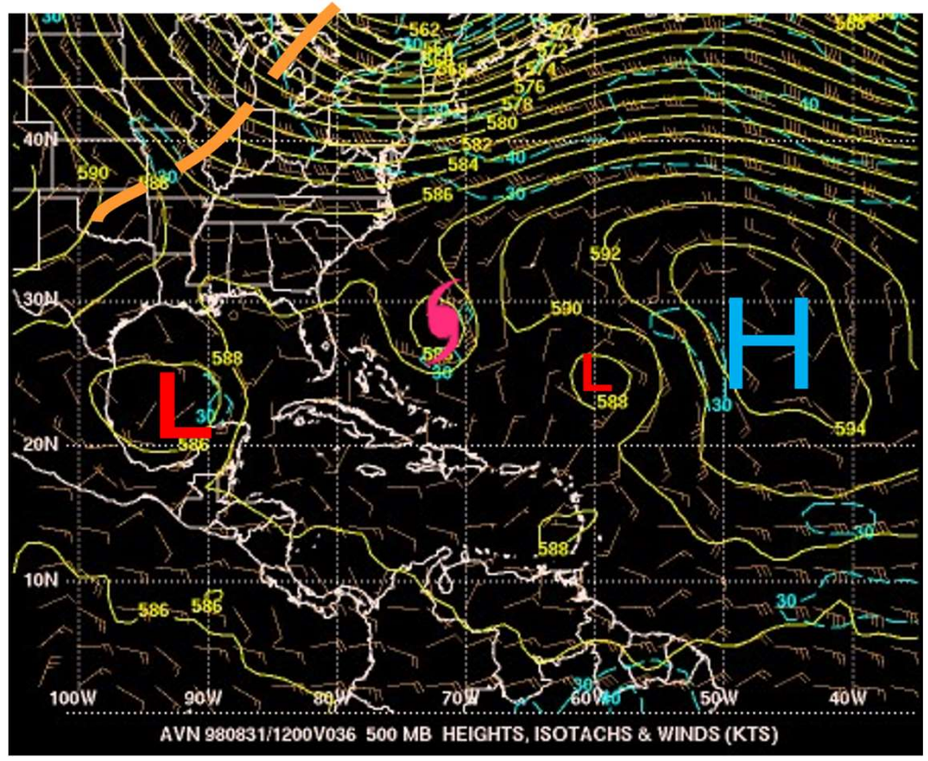
Disturbances

- **Tropical Waves**
  - About 70% of all Atlantic-basin formations
  - Most major hurricanes
- **Decaying cold fronts**
  - Formation often near Gulf of Mexico and SE United States
  - Typically early or late-season storms
- **Non-tropical lows and thunderstorm complexes**
  - Often subtropical systems

Storm Motion and Track

Forecasting

- **Track forecast is usually controlled by large-scale weather features.**
  - "Cork-in-a-stream" analogy
- **Numerical computer models forecast track quite well.**
  - Constantly upgrading model physics and resolution
  - Long ago surpassed statistical models in accuracy

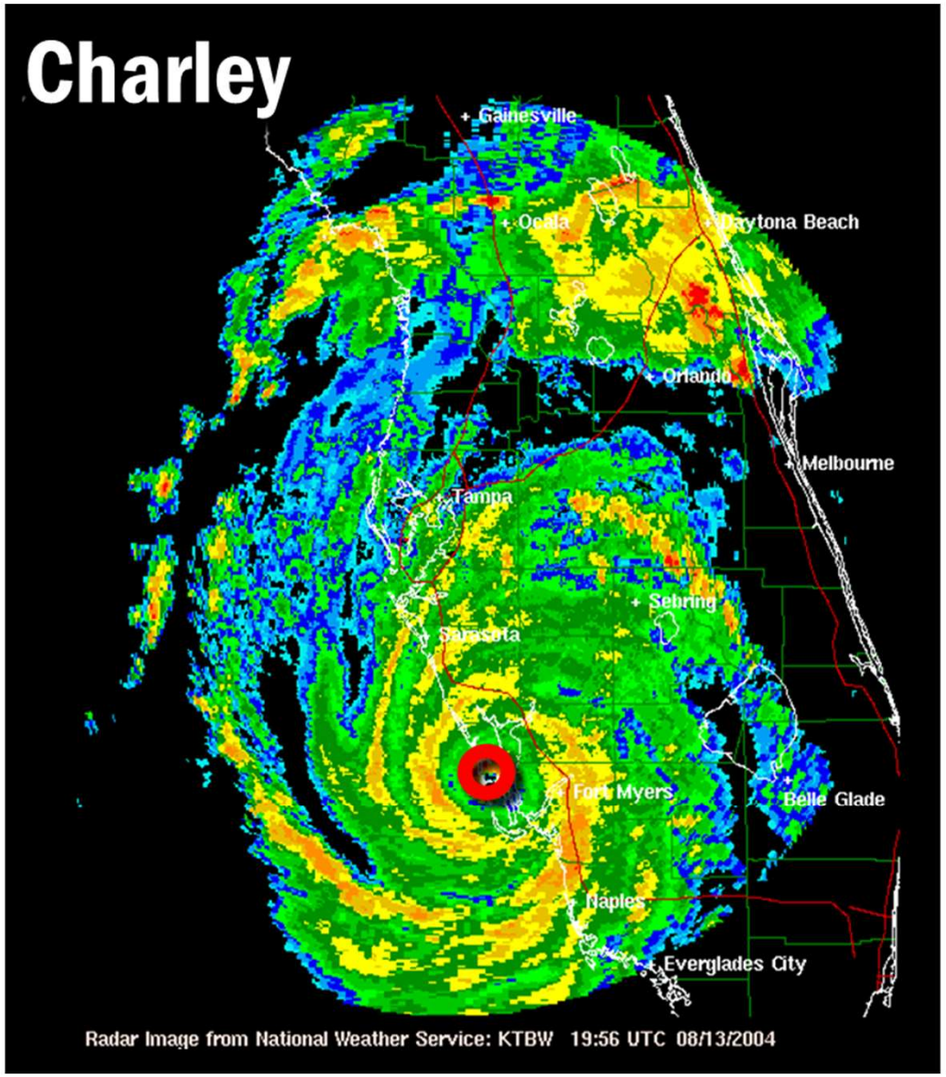


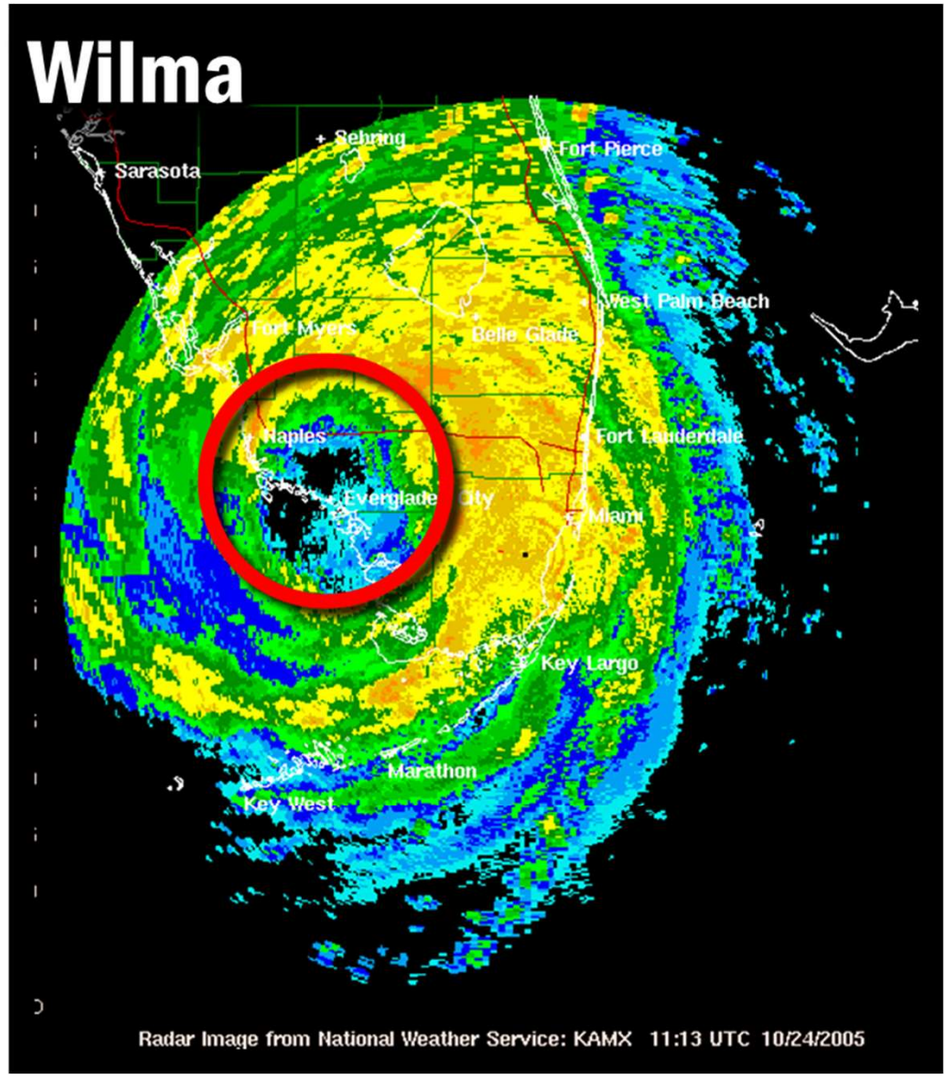
Factors Affecting Intensity

Intensity Factors

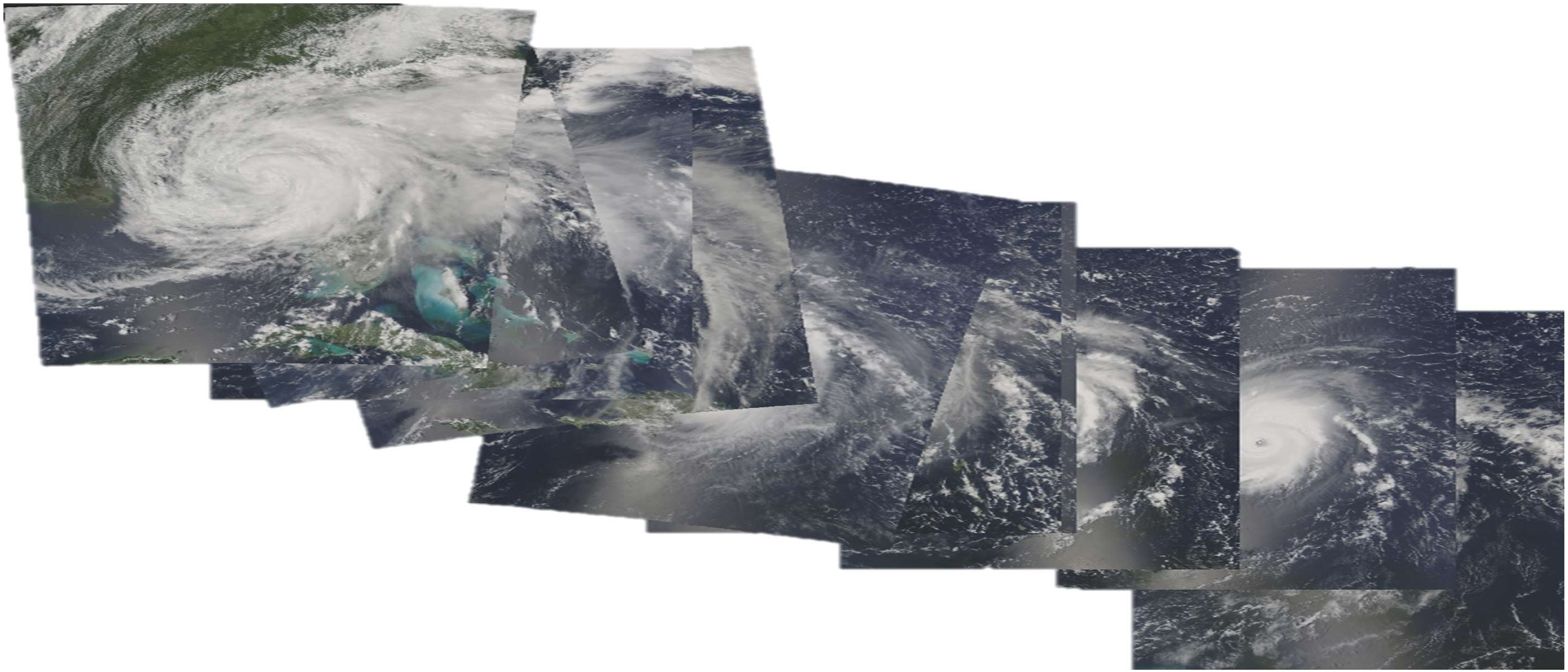
- **Upper-Ocean Temperatures**
  More heat favors a stronger storm
- **Interaction with Land/Topography**
  More land increases weakening
- **Vertical Wind Shear**
  Shear limits strengthening
- **Moisture in Storm Environment**
  Dry air can limit strengthening
- **Structural Changes, Eyewall Replacement**
  Difficult to forecast and not straightforward
- **Interactions with Other Weather Systems**

Tropical Cyclones Come in All Sizes





Questions?



Hazards – Knowledge Check

Which hazard has the greatest potential for large loss of life?

A. Wind

B. Rain-induced flooding

C. Tornadoes

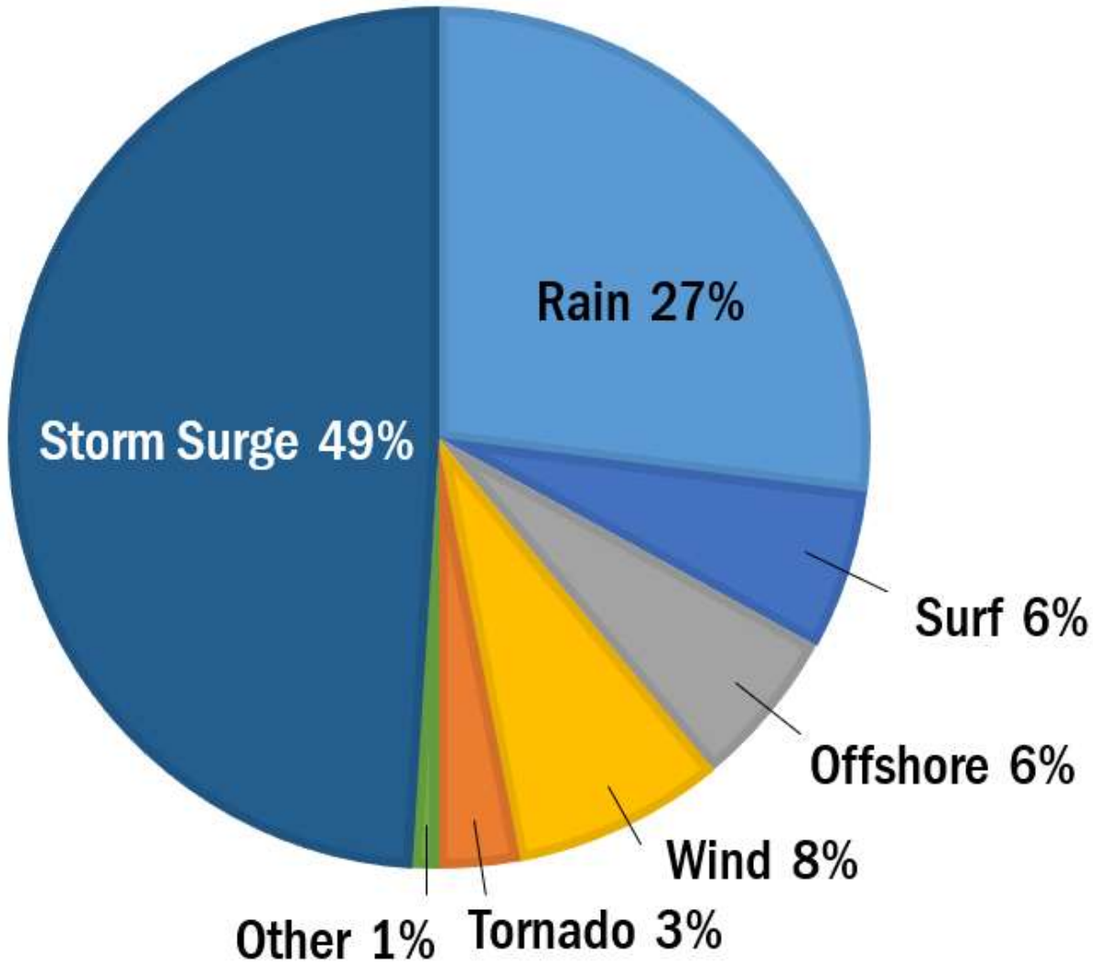
D. Storm Surge

Atlantic Tropical Cyclone Deaths

Direct Fatalities

U.S. Tropical Cyclone Direct Fatalities

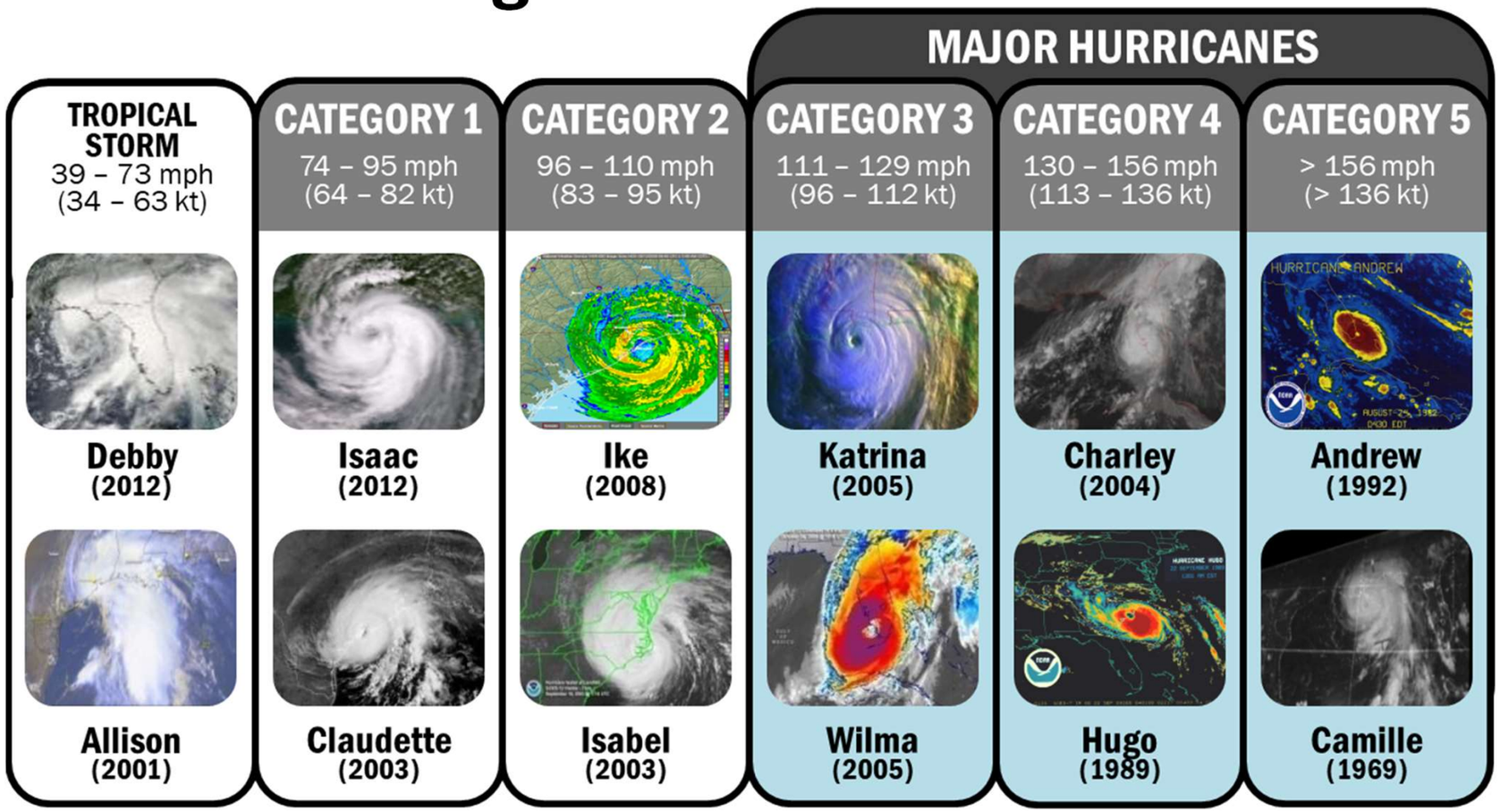
– from 1963 to 2012



Hurricane Hazards

Saffir-Simpson Scale

- **Estimates Wind Damage**



Category 1 (74–95 mph)


Humberto (2007) Southeast TX


Isaias (2020) Oak Island, NC

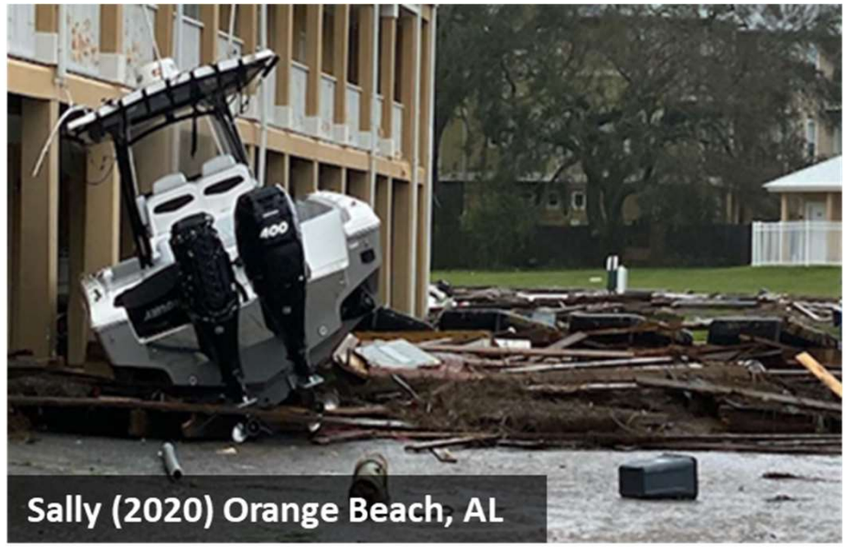

Lili (2002) Louisiana

Category 1

- **Some Damage**
  - Well-constructed frame homes could have roof damage.
  - Large tree branches will snap; shallow-rooted trees may topple.
  - Damage to power lines and poles; outages could last several days.

Category 2 (96–110 mph)


Ike (2008) Houston, TX


Sally (2020) Orange Beach, AL


Wilma (2005) SE Florida

Category 2

- **Extensive Damage**
  - Well-constructed frame homes could sustain major roof damage.
  - Many shallow-rooted trees will be snapped or uprooted.
  - Near total power loss is expected that could last several days.

Category 3 (111–129 mph)

Category 3

- **Devastating Damage**
  - Well-constructed frame homes may incur major damage.
  - Many trees will be snapped or uprooted.
  - Electricity and water will be unavailable for several days to weeks.

Category 4 (130–156 mph)


Charley (2004) Punta Gorda, FL


Maria (2017) Puerto Rico


Laura (2020) Lake Charles, LA

Category 4

- **Catastrophic Damage**
  - Well-constructed frame homes may sustain severe damage.
  - Most trees will be snapped or uprooted; power poles downed.
  - Power outages will last weeks to possibly months.

Category 5 (>156 mph)


Michael (2018) Florida– Getty Images


Felix (2007) Nicaragua


Andrew (1992) South Dade, FL

Category 5

- **Catastrophic Damage**
  - A high percentage of framed homes will be destroyed.
  - Fallen trees and power poles will isolate residential areas.
  - Power outages will last weeks to possibly months.

Category 5 Landfalls – 5 Days Out

Cat 5 Landfalls

- Labor Day (1935)
- Camille (1969)
- Andrew (1992)
- Michael (2018)

Where were these hurricanes **5 days** before landfall?

Category 5 Landfalls – 3 Days Out

Cat 5 Landfalls

- Labor Day (1935)
- Camille (1969)
- Andrew (1992)
- Michael (2018)

Where were these hurricanes **3 days** before landfall?

Storm Surge

Hurricane Sandy (2012)

72 deaths
$86 billion damage (2023 USD)

Hurricane Katrina (2005)

520 deaths
$195 billion damage (2023 USD)

Hurricane Ian (2022)

66 deaths
$115 billion damage (2023 USD)

Storm Surge Definitions

Storm Surge

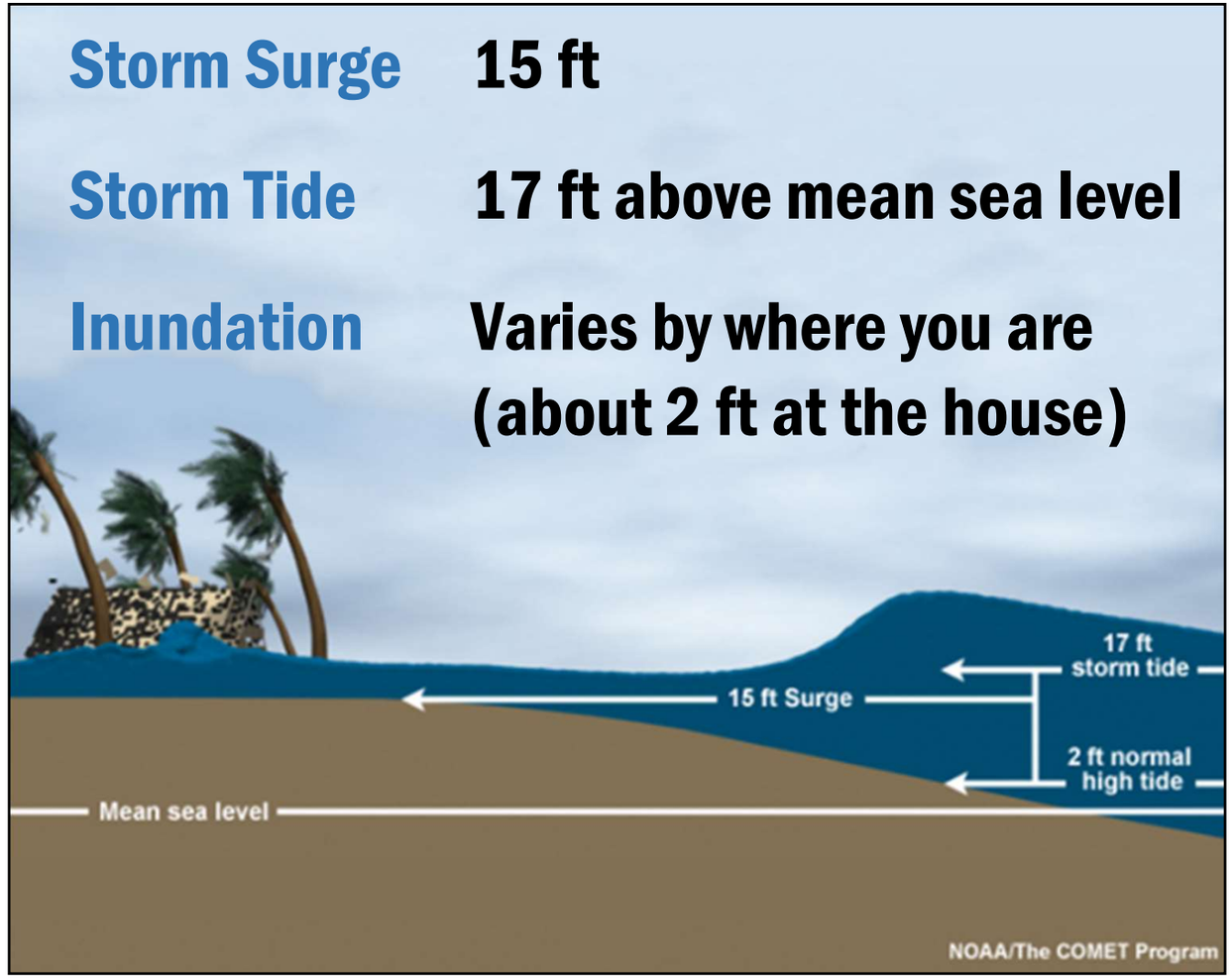
An abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

Storm Tide

Water level due to the combination of storm surge and the astronomical tide.

Inundation

The flooding of normally dry land, resulting from storm tide and possibly other factors.



Storm Surge: Katrina 2005

Waveland,
Mississippi

Storm Surge: Ian 2022

Storm Surge: Gulf Coast

Storm Surge: Southeast

Storm Surge: Mid-Atlantic

Storm Surge: New England

Where Does Storm Surge Occur?

Storm Surge – Knowledge Check

Which are important factors in determining how much storm surge could occur for a storm?

A. Size of the storm
B. Forward speed of the storm
C. Intensity
D. All of the above

Factors Affecting Storm Surge

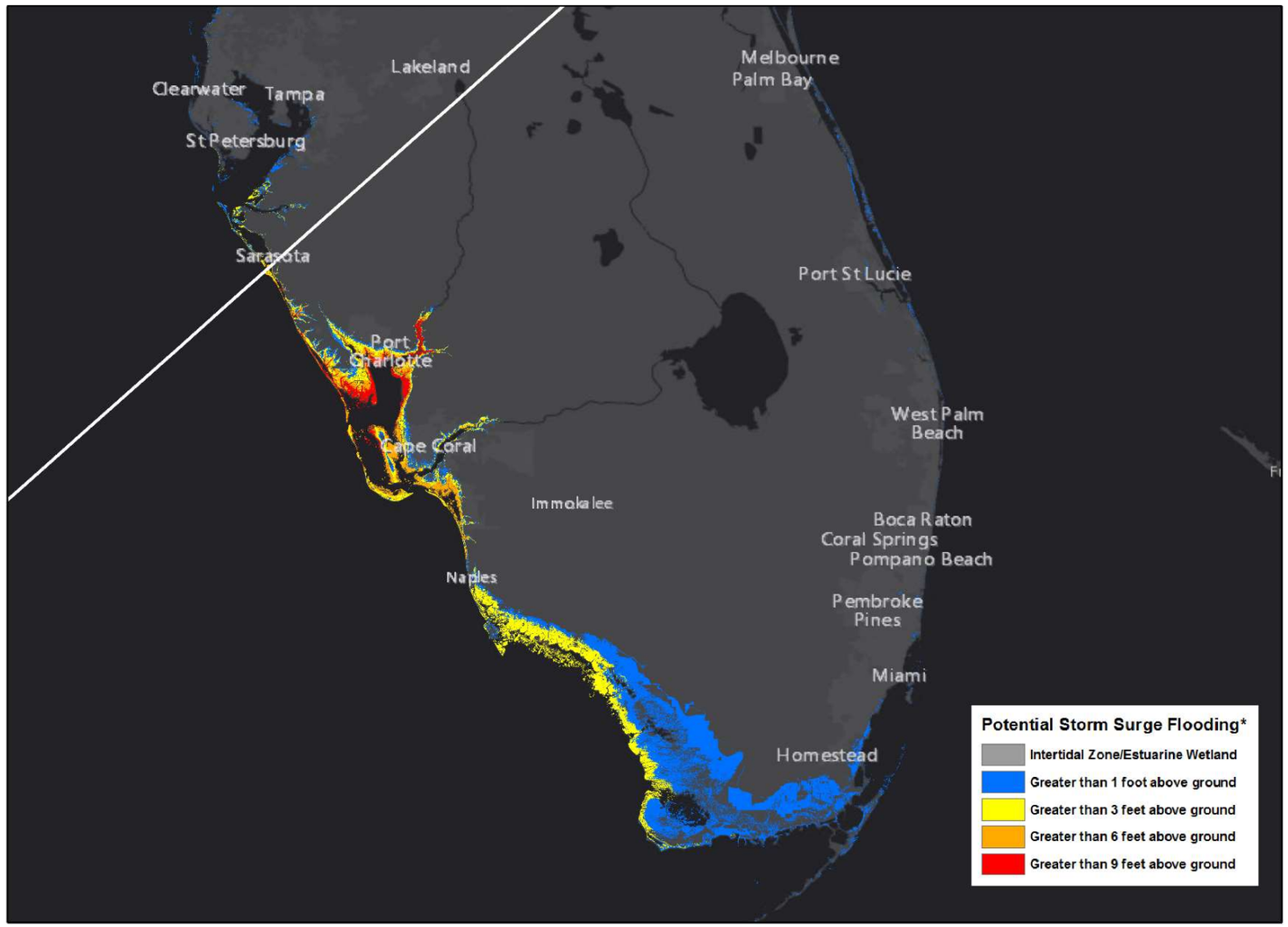
Storm Surge Factors

- **Intensity**
  Stronger storm = More storm surge
- **Size (Radius of Maximum Winds)**
  Larger storm = More storm surge
- **Forward Speed**
  Slower storm = Storm surge farther inland
- **Angle of Approach**
  Alters focus of storm surge
- **Width and Slope of Shelf (Bathymetry)**
  Gradual shelf = More storm surge

Effect of Storm intensity

Storm Intensity

- **Category 3**



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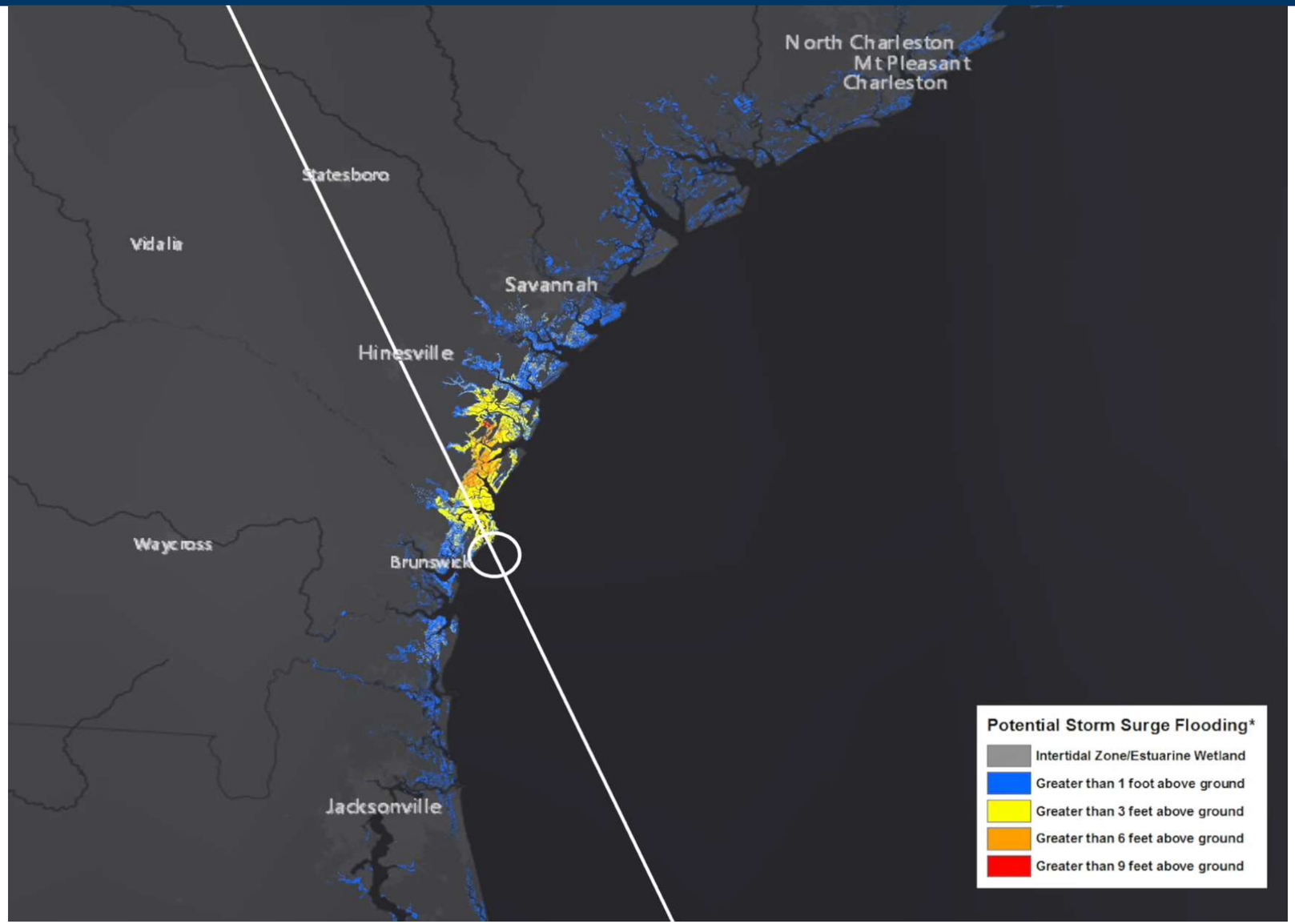
Effect of Storm Size

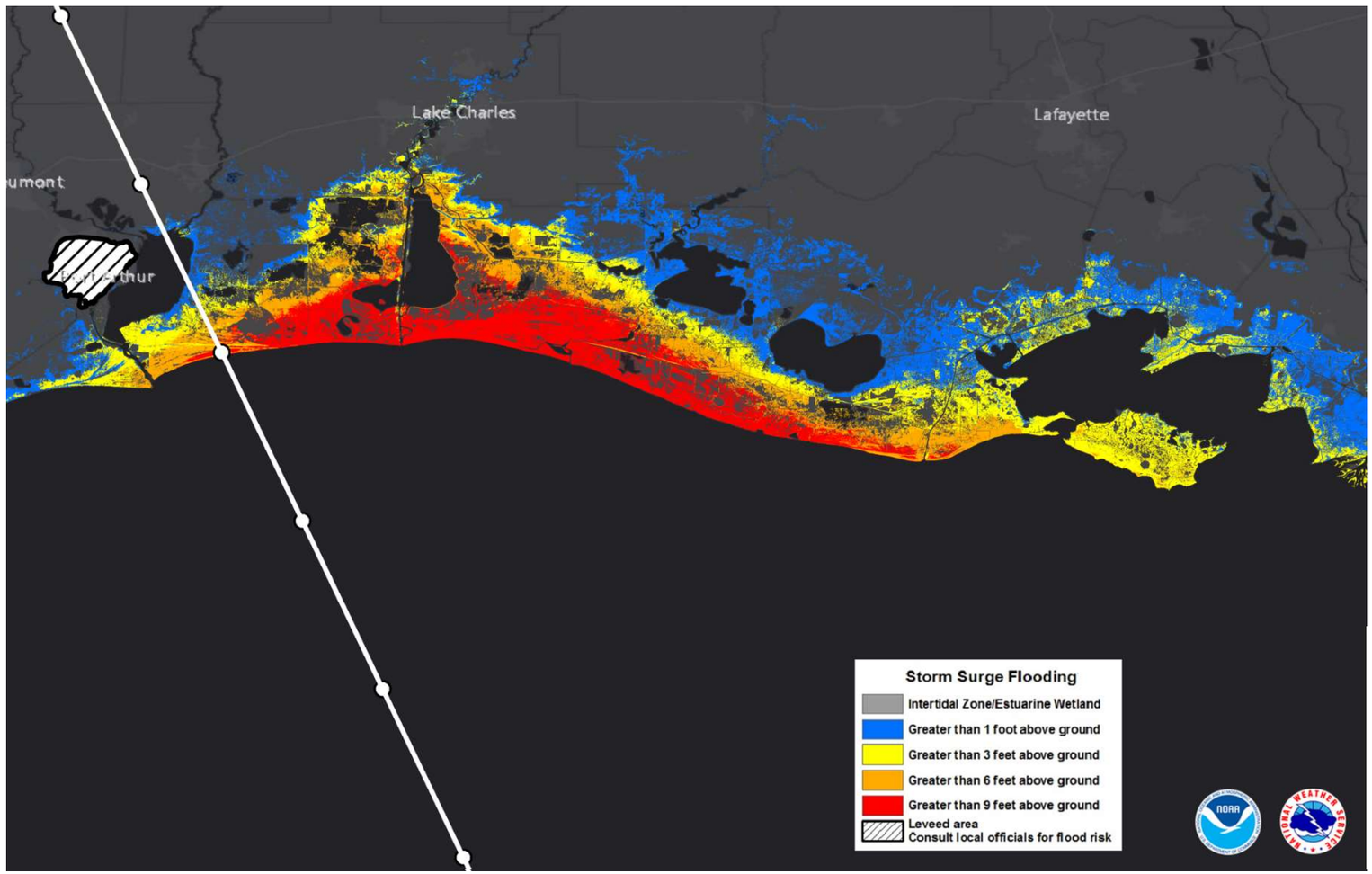


Effect of Forward Speed

Forward Speed

- **5 mph**
  (Slower Storm)

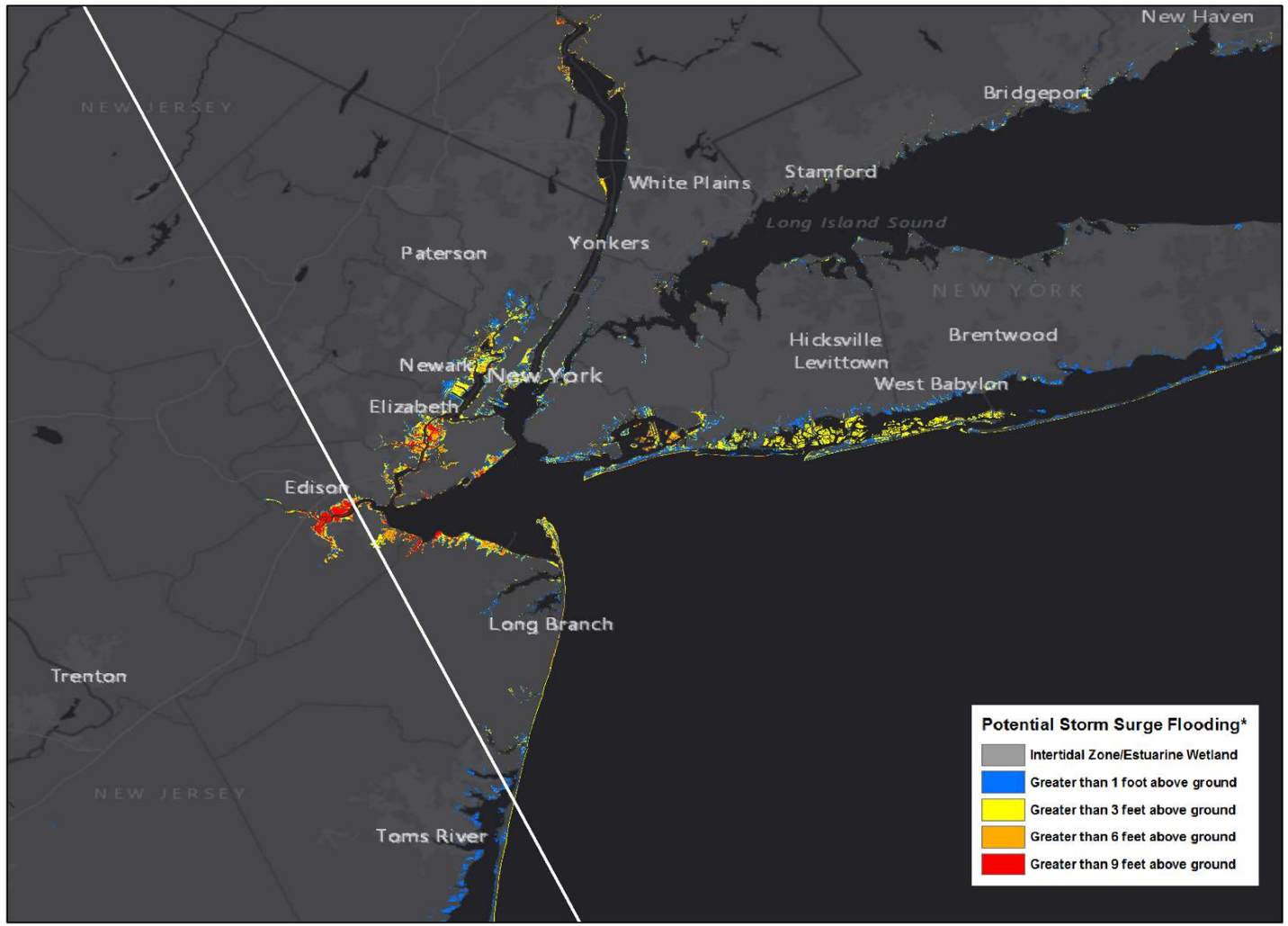
- **Slower Storms**
  Farther inland penetration



Effect of Angle of Approach

Angle of Approach

- **NNW**



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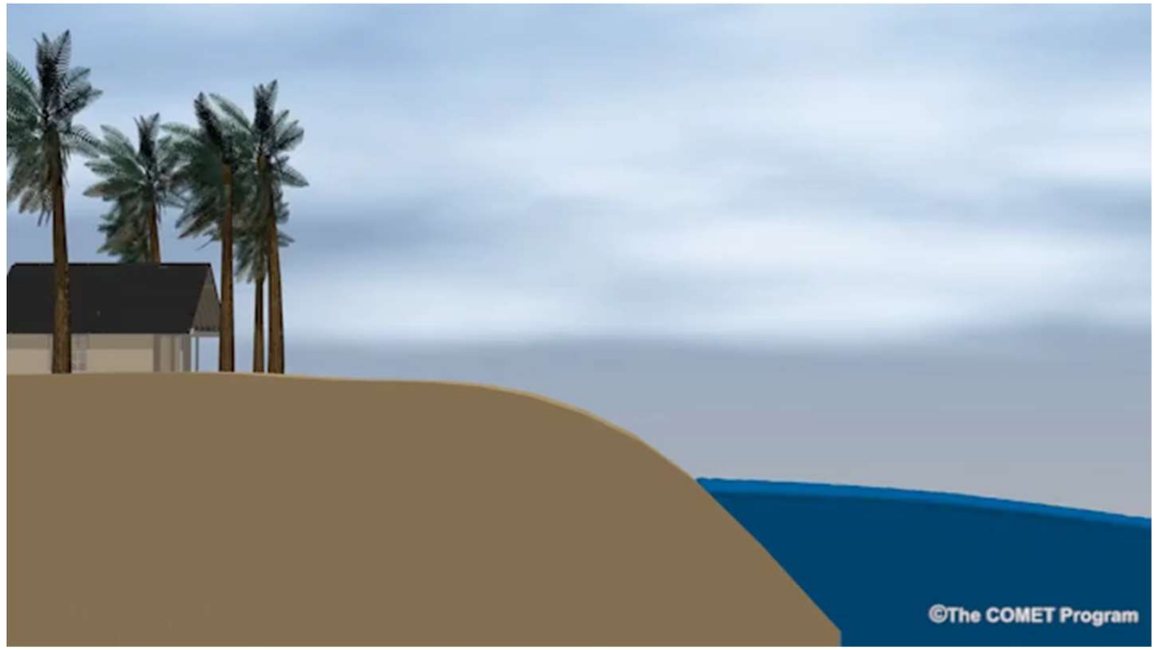
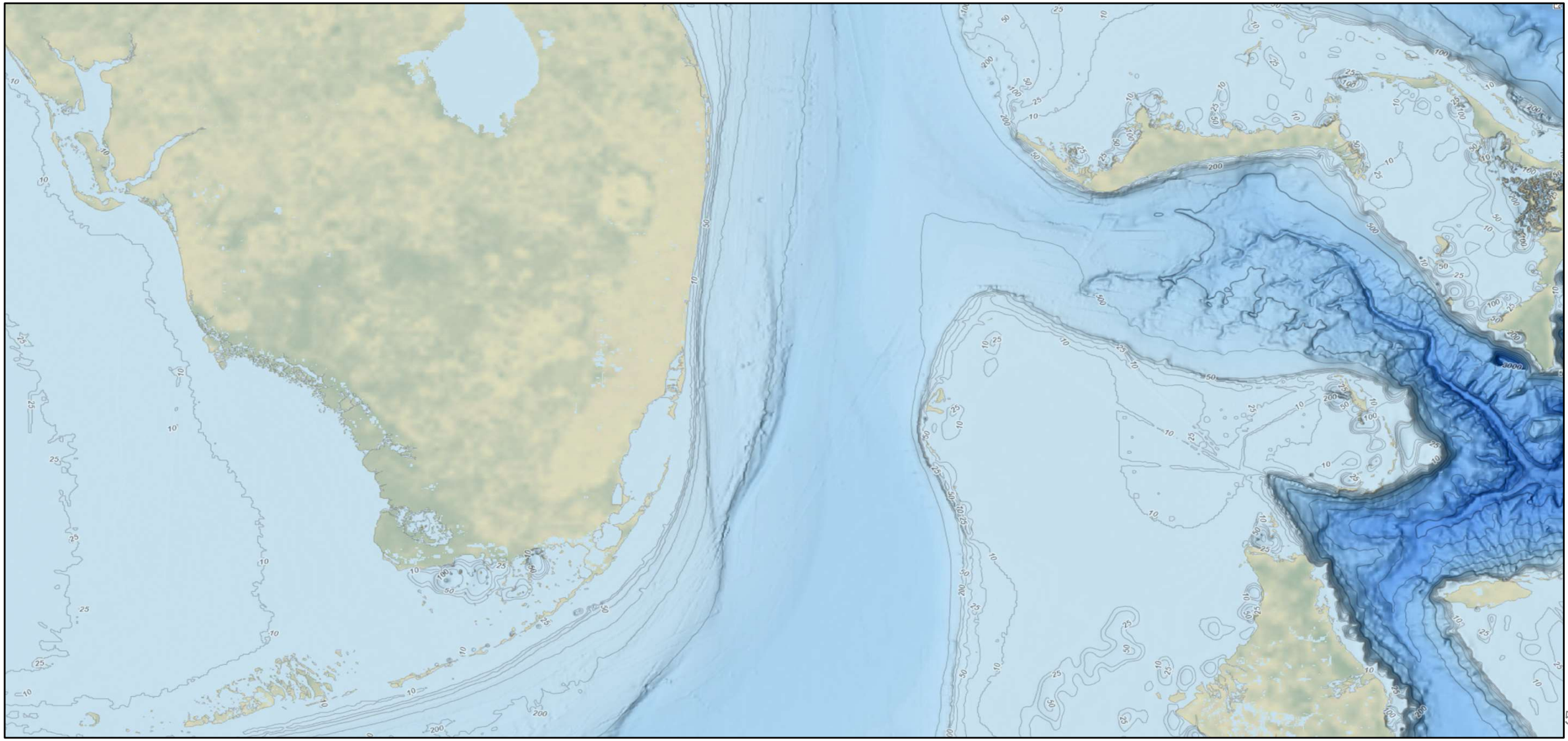
Effect of Width/Slope of Shelf

Wide shelf – Gentle slope

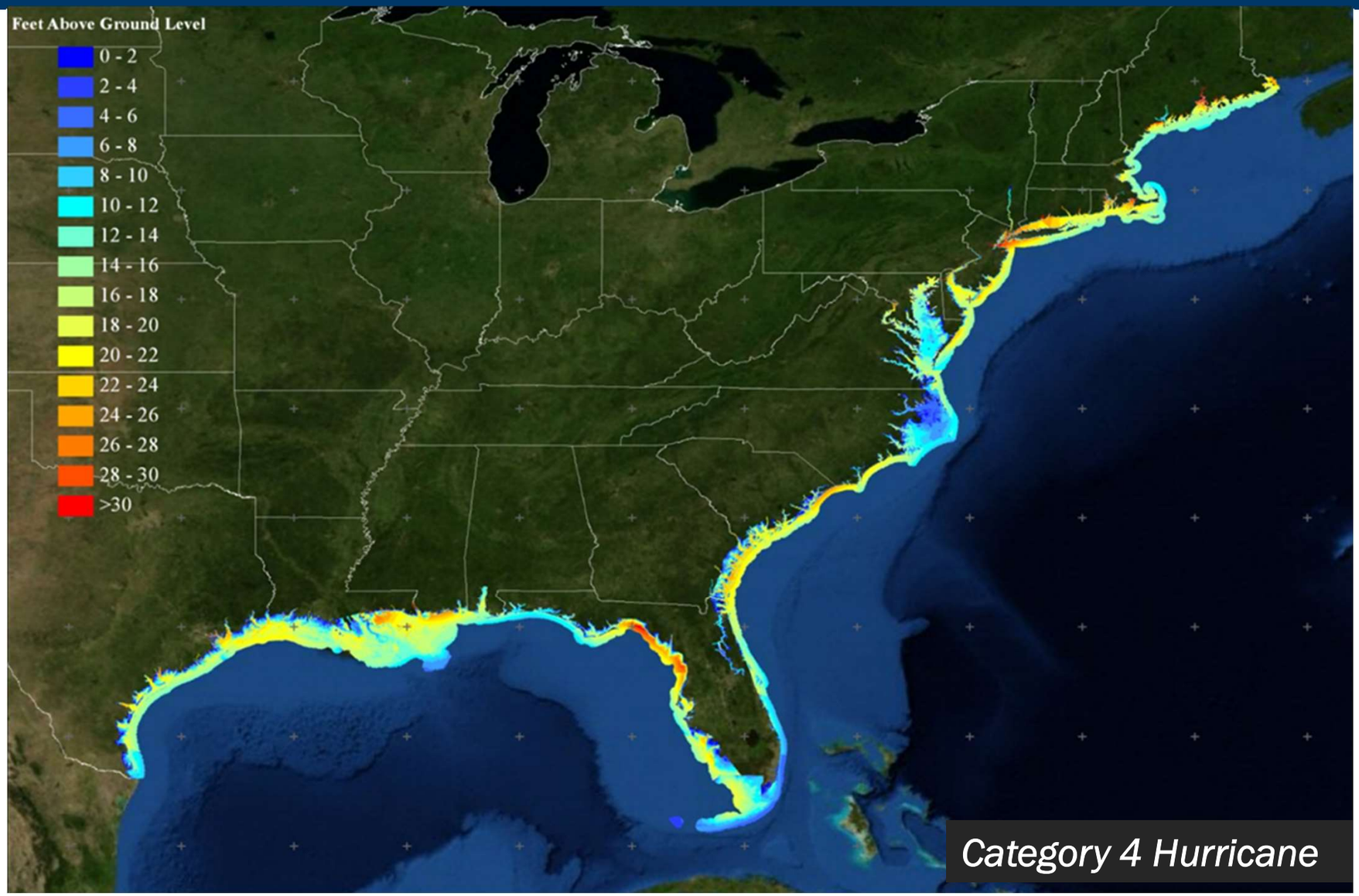


Narrow shelf – Sharp slope

Effect of Width/Slope of Shelf – FL

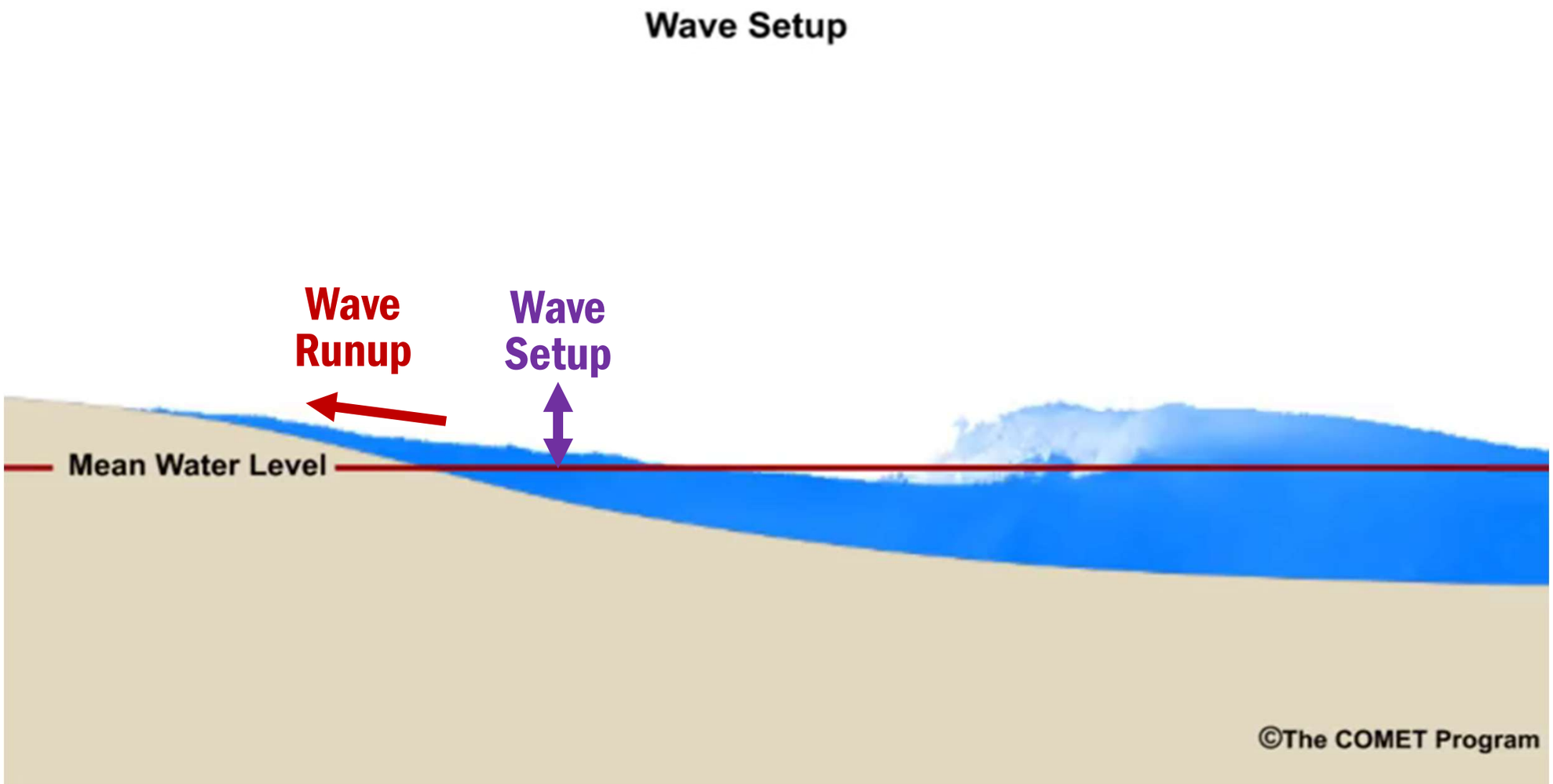


Location, Location, Location.



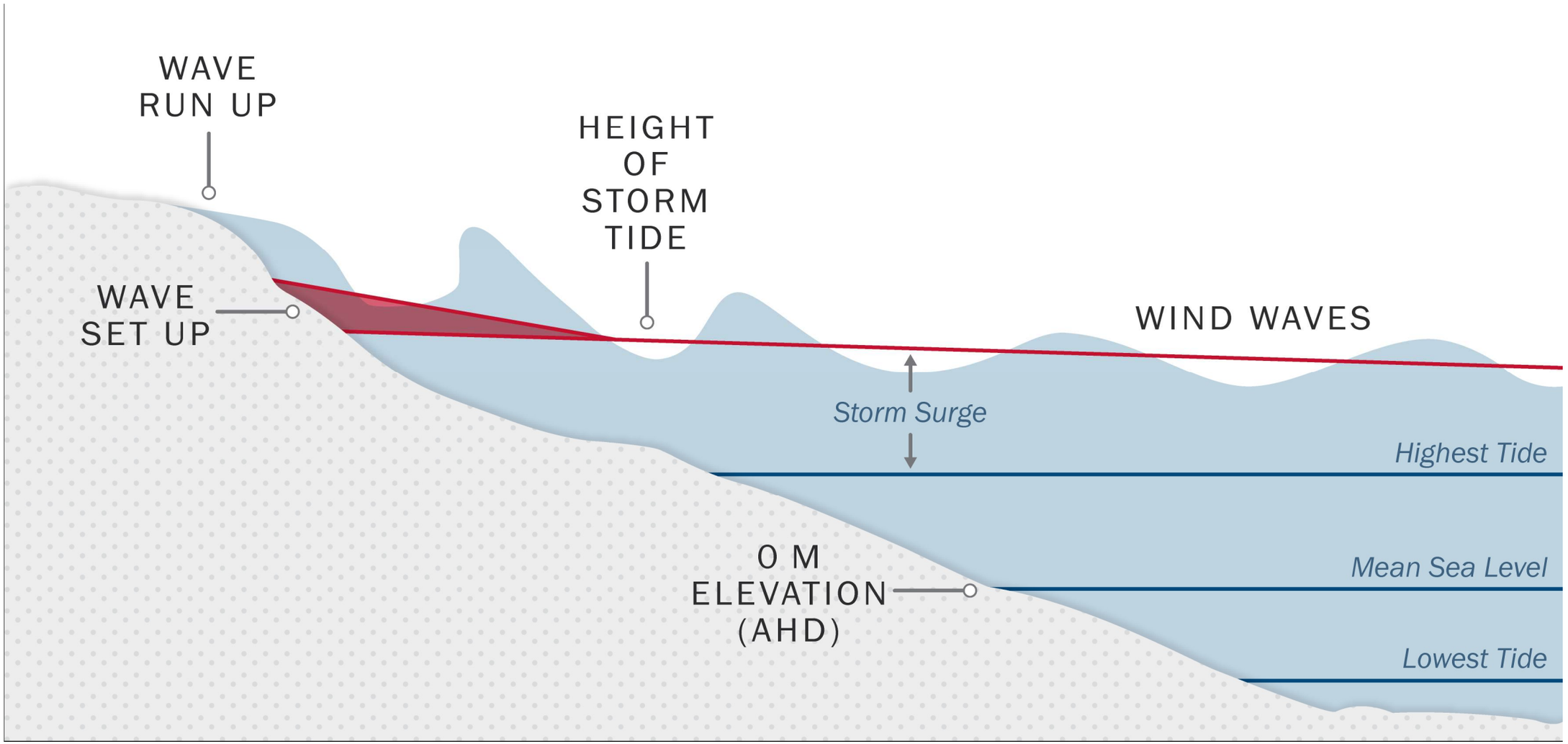
Category 4 Hurricane

Wave Setup


Wave Setup
Wave Runup
Wave Setup
Mean Water Level
©The COMET Program

Components of Total Water Level

Total Water = Storm Surge + Tides + Wave Setup + Freshwater

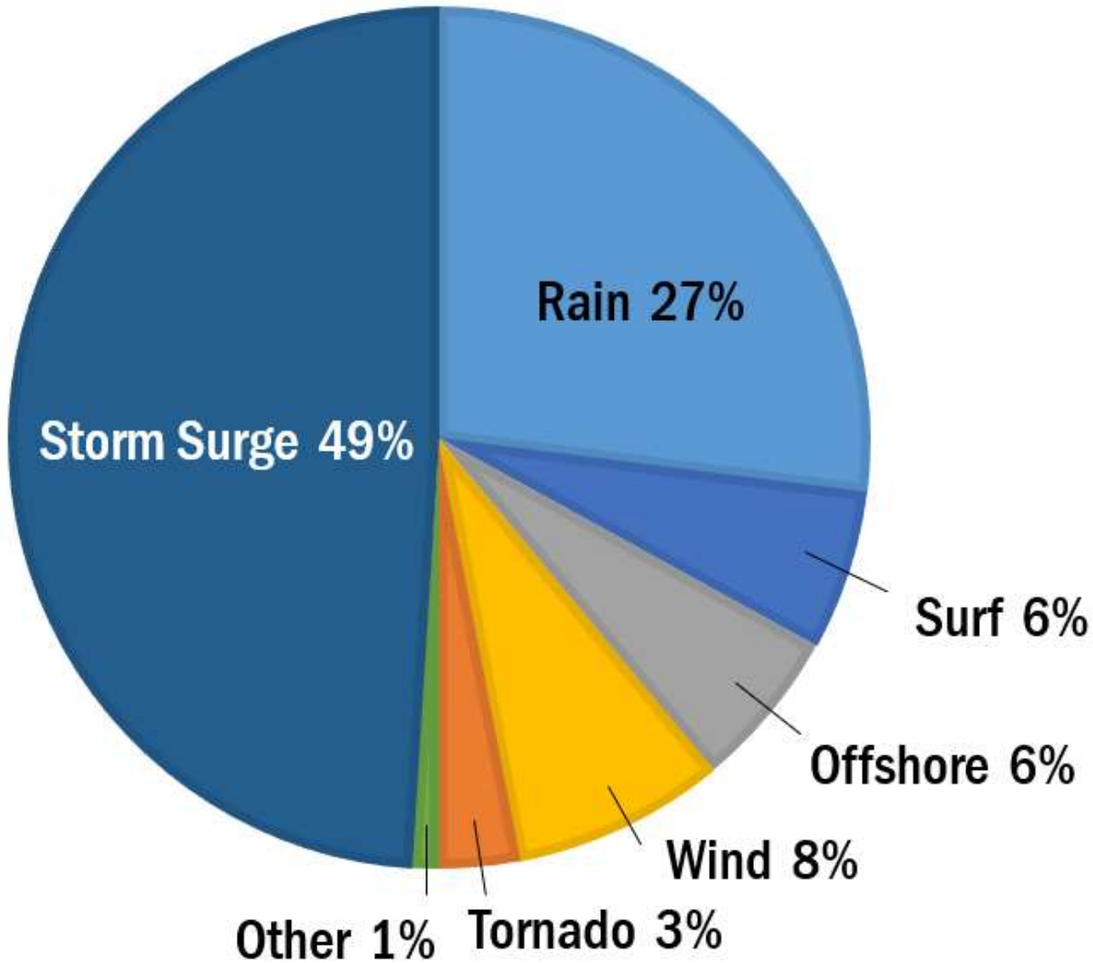


Atlantic Tropical Cyclone Deaths 2

Direct Fatalities

U.S. Tropical Cyclone Direct Fatalities

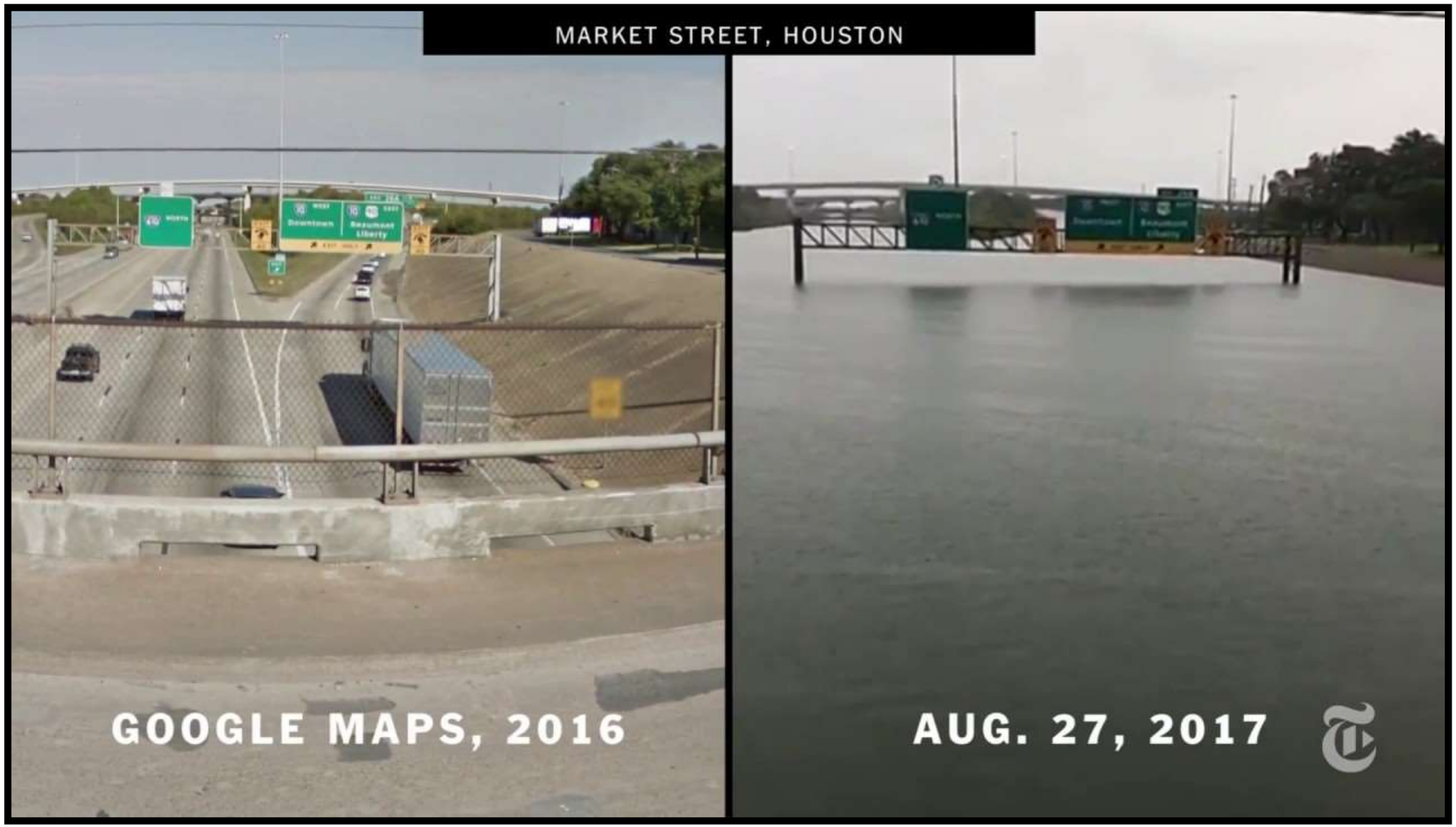
– from 1963 to 2012



Flash Floods. Riverine Flooding.

Tropical Storm Allison (2001) I-10

Hurricane Harvey (2017) Flooding 1



Hurricane Harvey (2017) Flooding 2

Hurricane Irene (2011) Flooding 1

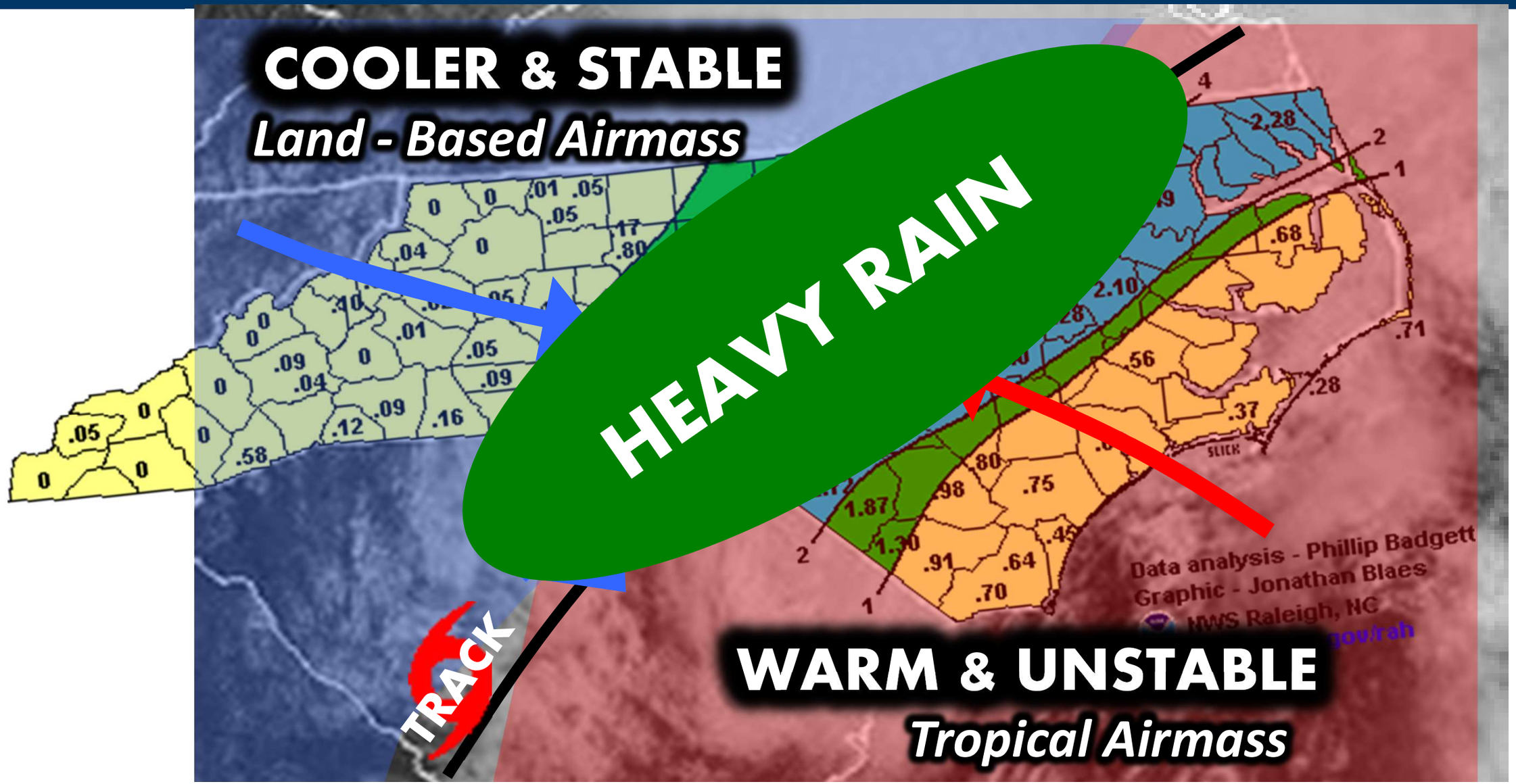
Hurricane Irene (2011) Flooding 2

Tropical Cyclone Rainfall Factors

Rainfall Factors

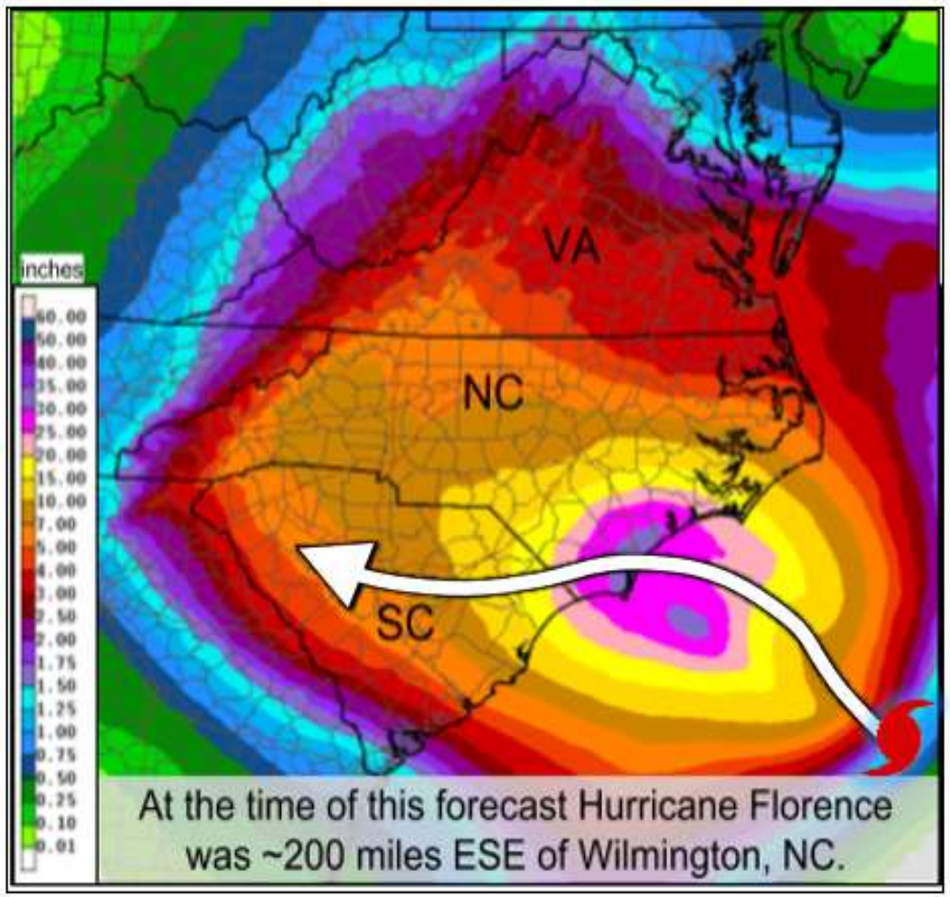
- **Forward Speed**
  Slower storm = More rainfall
- **Size**
  Larger storm = More rainfall
- **Topography / Mountains**
  More rain on windward side
- **Fronts / Upper-level troughs**
  Enhance rainfall
- **Storm Track**
  Alters geographic focus of rainfall

Tropical Storm Alberto (2006)

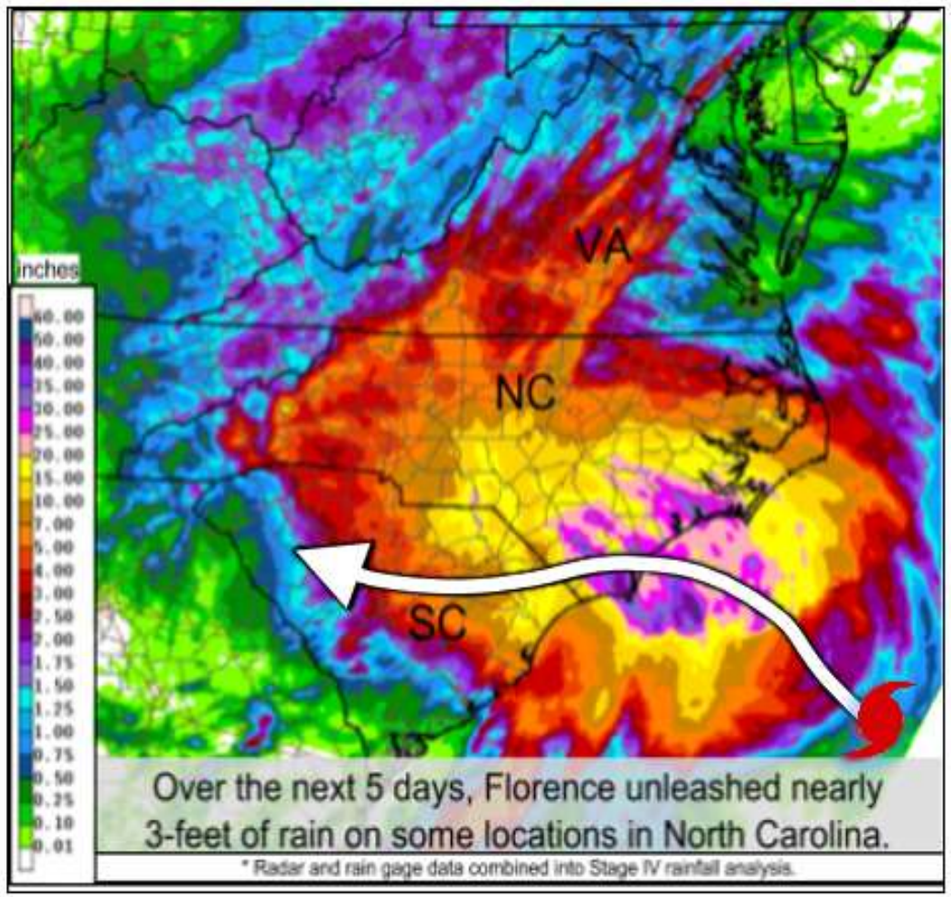


Hurricane Florence (2018)

5-Day Forecast vs. Observed Rainfall

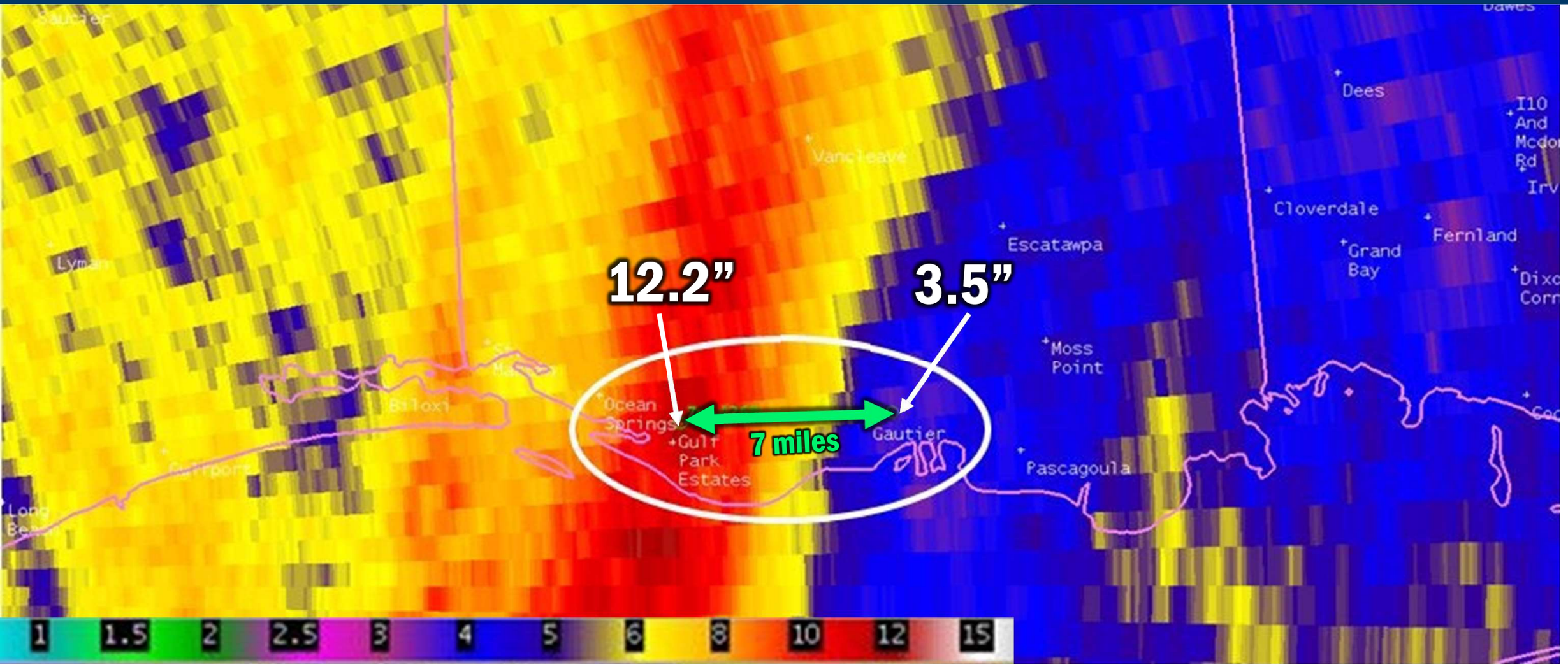


5-day Rainfall Forecast – Issued Sep 13, 2018

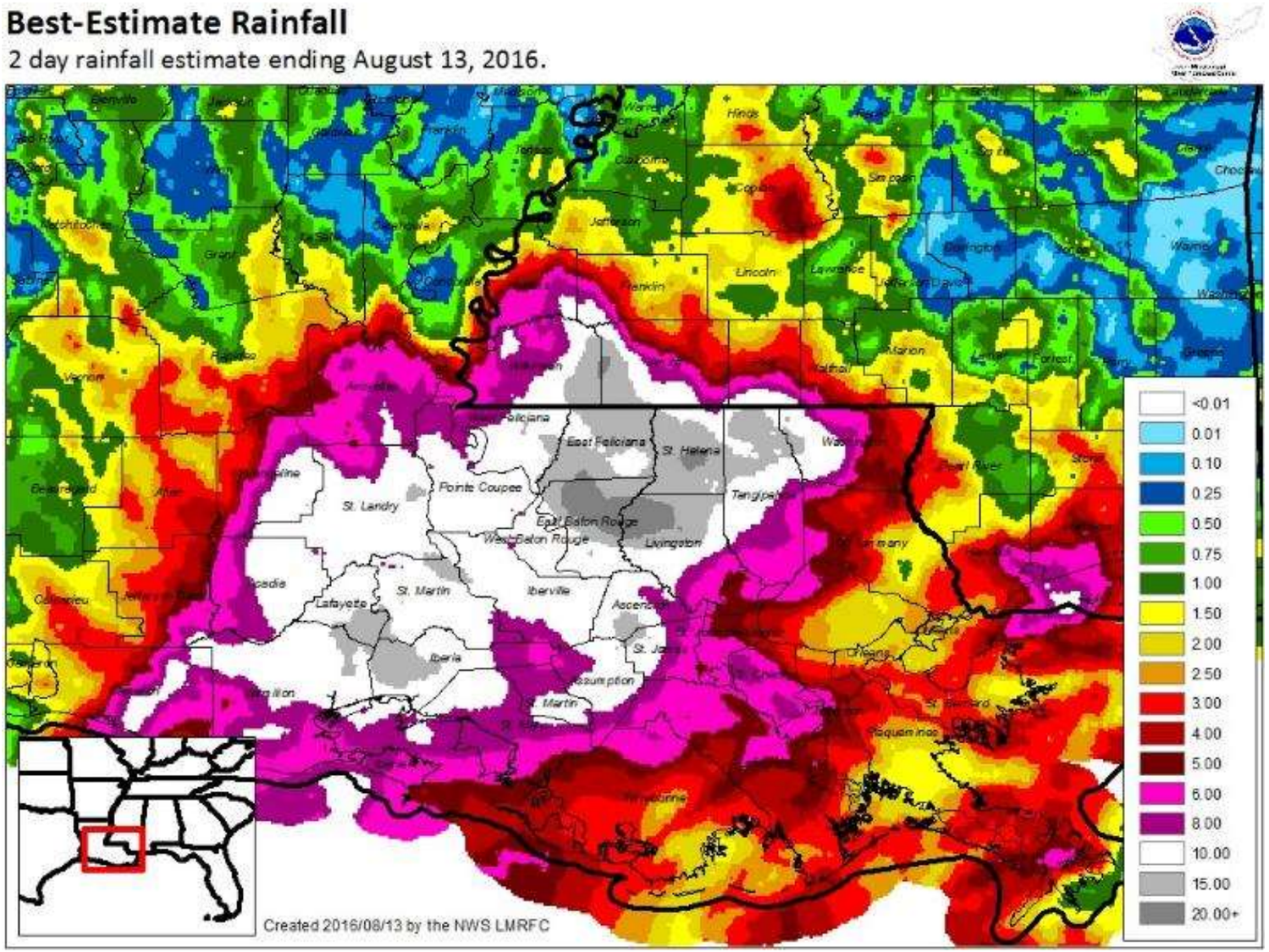


5-day Rainfall – Sep 13-18, 2018

Tropical Storm Cindy (2017)



Unnamed Low (2016)



Tornadoes

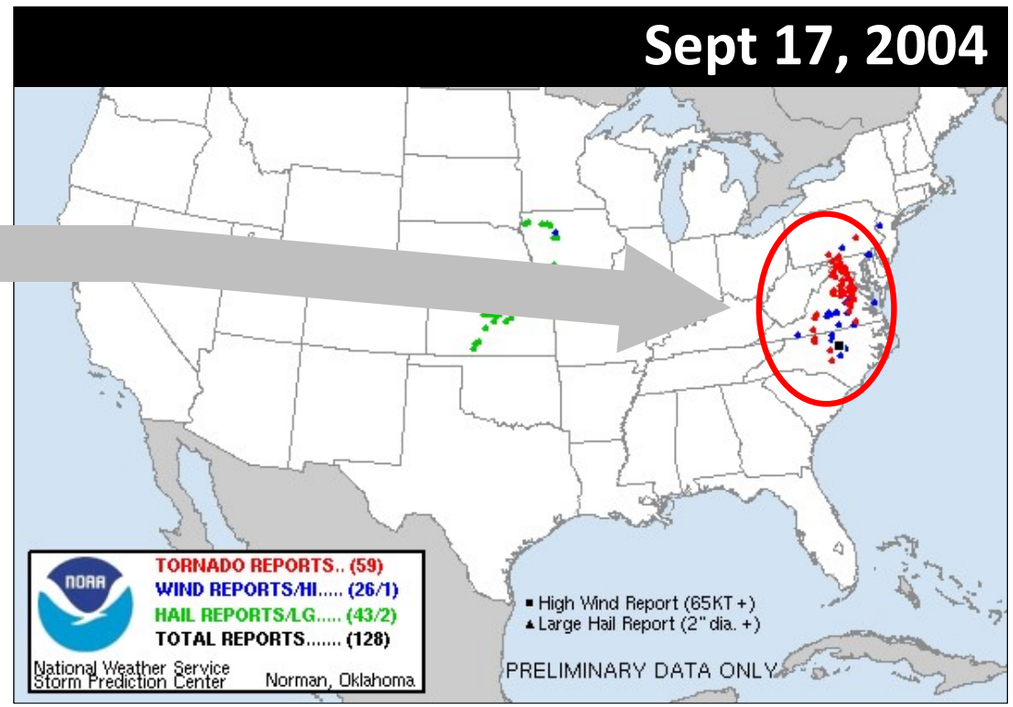
Landfalling Hurricanes

- **70% produce at least one tornado.**
- **40% produce more than three.**

Tornado "outbreak"

Hurricane Ivan (2004)

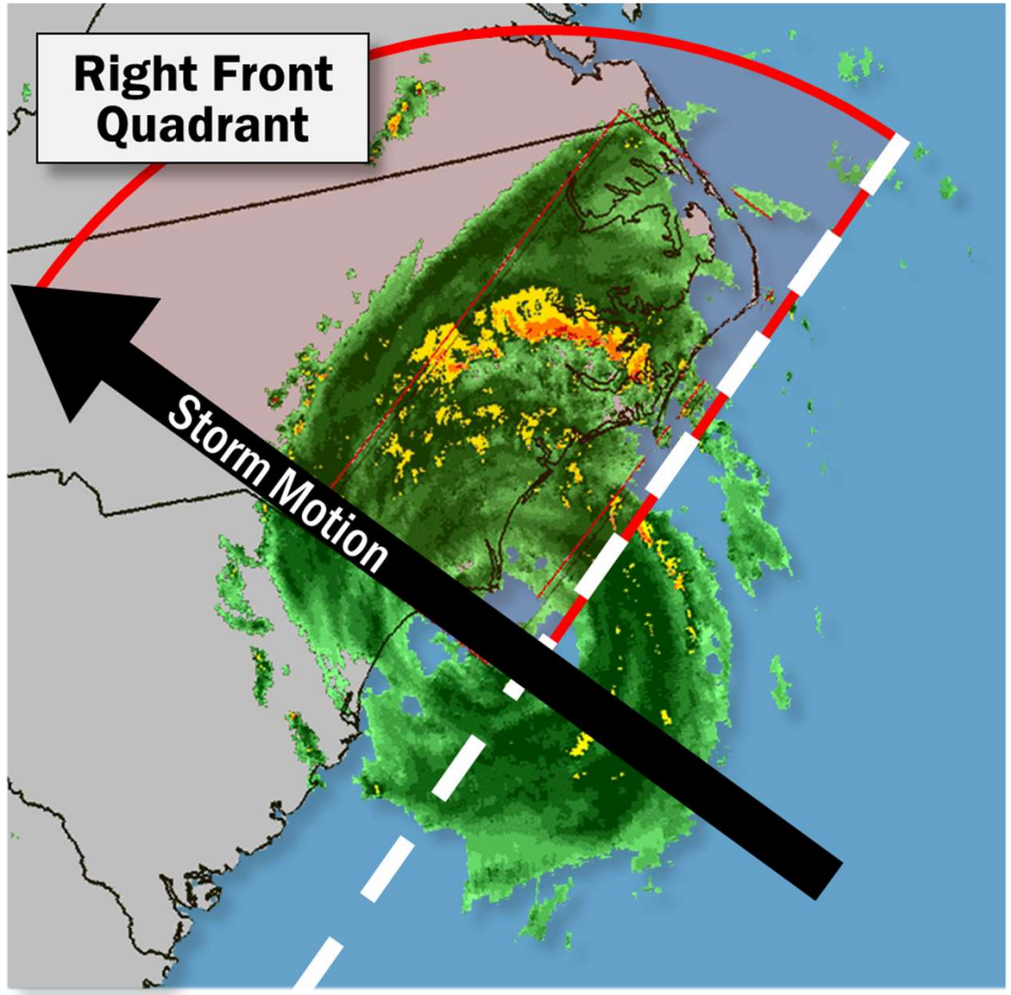
– 117 Tornadoes



Where Do Tornadoes Form?

Tornadoes in Hurricanes

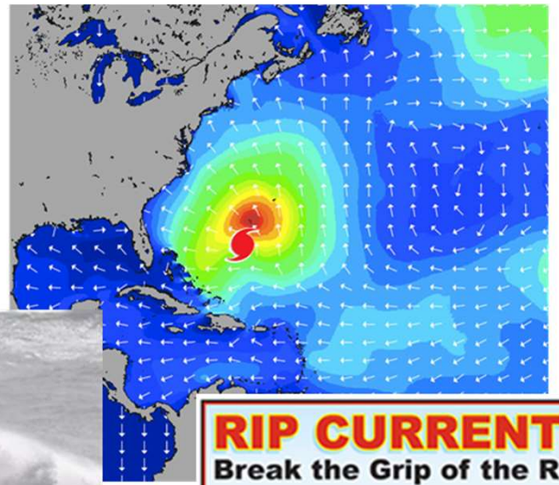
- **Right-front quadrant**
  Friction over land creates favorable conditions.
- **Outer rainbands**
  Generally, form farther from the center – and the tornado potential continues after landfall.
- **Smaller and short-lived**
  Tend to be less intense than those that occur in the Great Plains; however, some large or strong tornadoes have occurred.



FEMA

Waves and Rip Currents

- **Swells from a large hurricane can affect beaches of the entire western Atlantic.**
- **Hurricane Lorenzo (2019)**
  - 8 people drowned along the U.S. East Coast in rip currents and hazardous surf.
- **Hurricane Delta (2020)**
  - 2 people drowned along the NW Florida coast.



Questions/Comments?