Unit 1:
Hurricane Basics

Unit 1 Objectives

At the end of this unit, you should be able to:

1. Describe the characteristics and life cycle of a tropical cyclone
2. Describe Atlantic Hurricane Climatology
3. Explain the hurricane hazards and how water is responsible for the vast majority of direct fatalities

Tropical Cyclones Defined

Tropical Cyclones

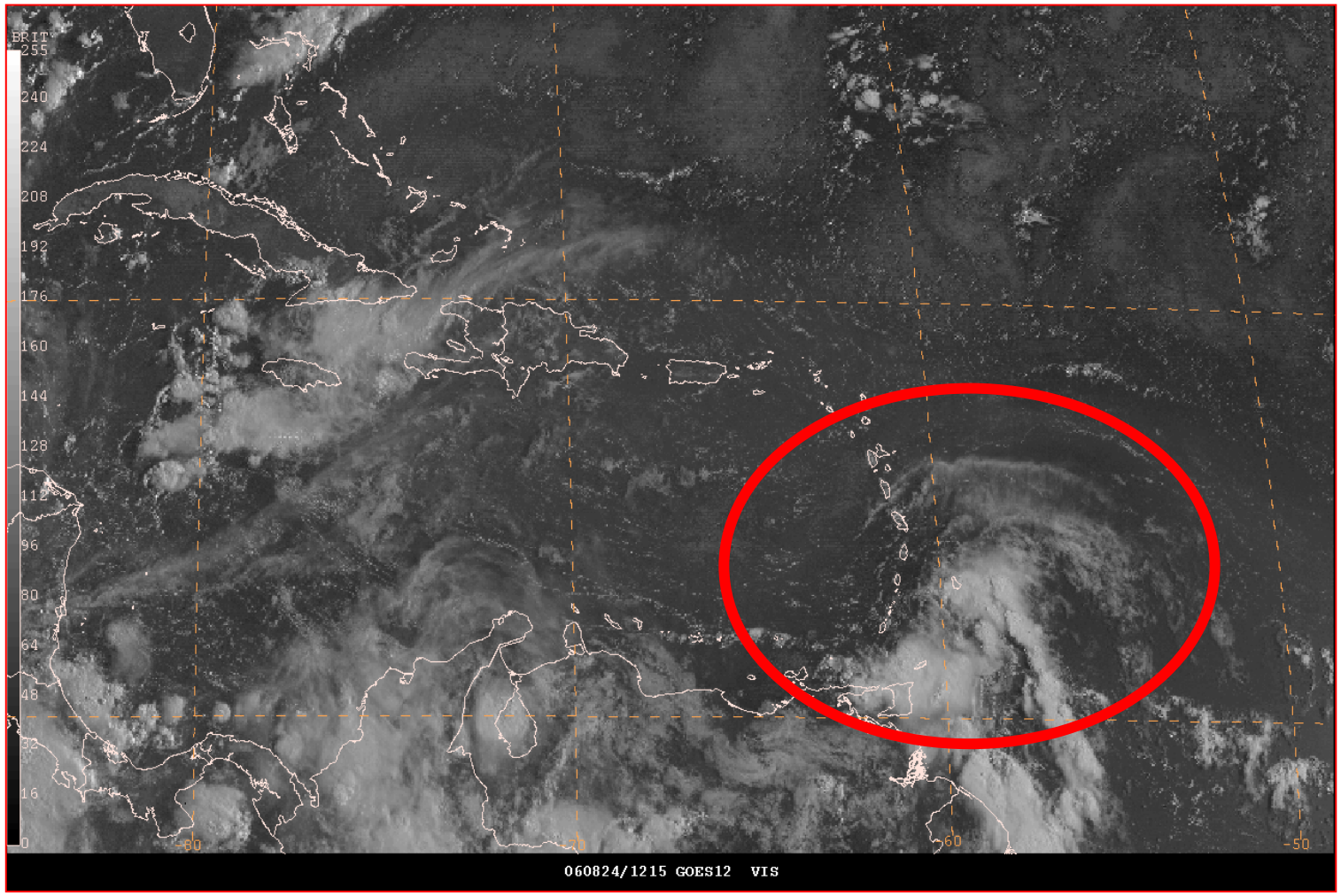
- Large, long-lived, low-pressure system
  (can be hundreds of miles wide, lasting for days)
- Form over sub/tropical oceans
- No fronts attached
- Produce organized thunderstorm activity
- Have a closed surface wind circulation around a well-defined center

Tropical Cyclones Classification

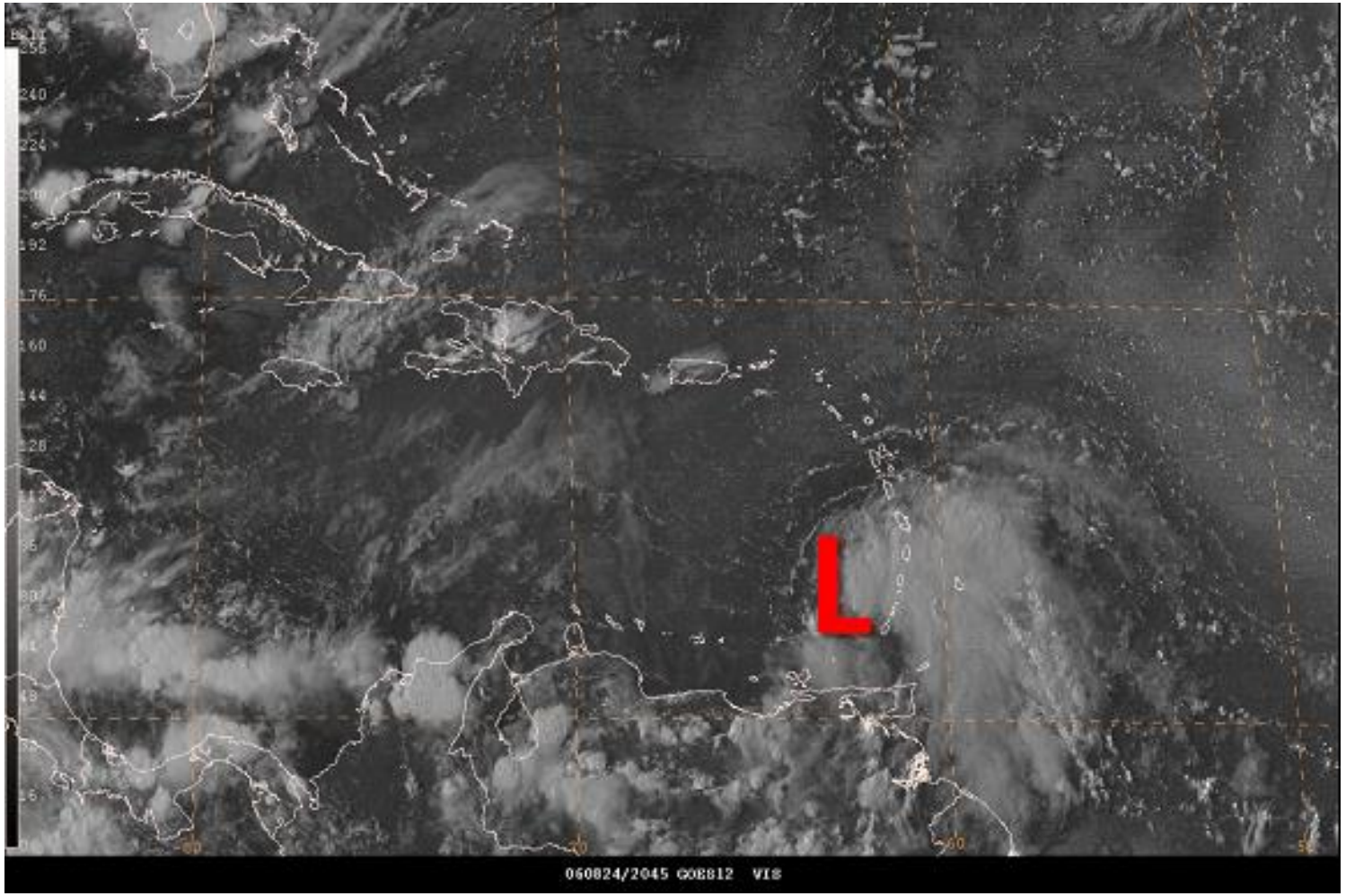
By Maximum Wind Speed:

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

Surface Circulation? Organized?

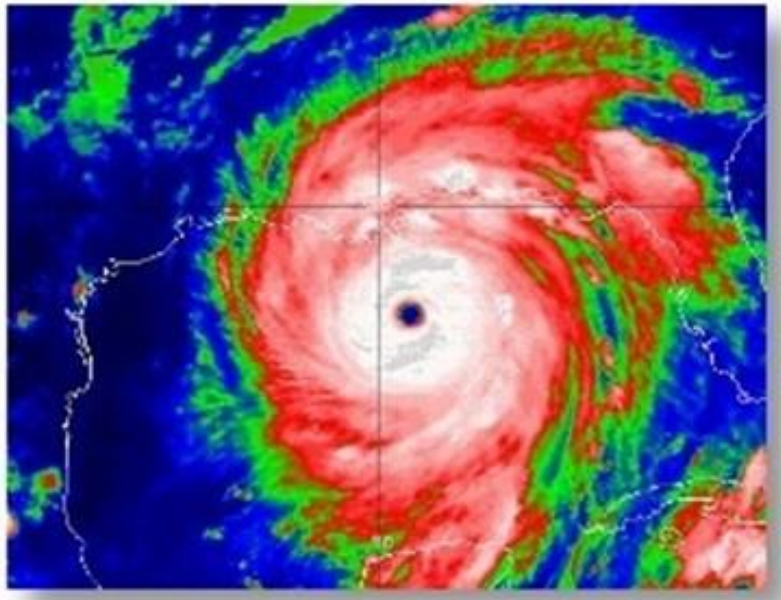


Ernesto 2006



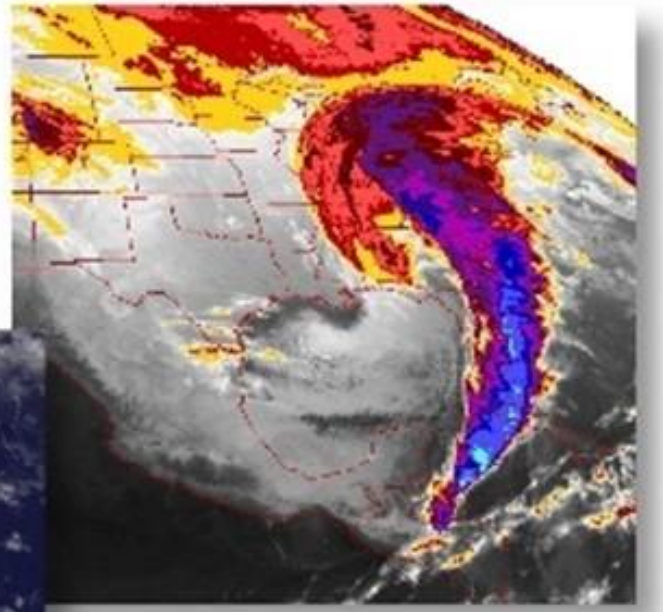
Advisory 1; issued based on aircraft data

Tropical, Subtropical, & Extratropical



Hurricane Katrina
2005

Subtropical Storm Ana
2015

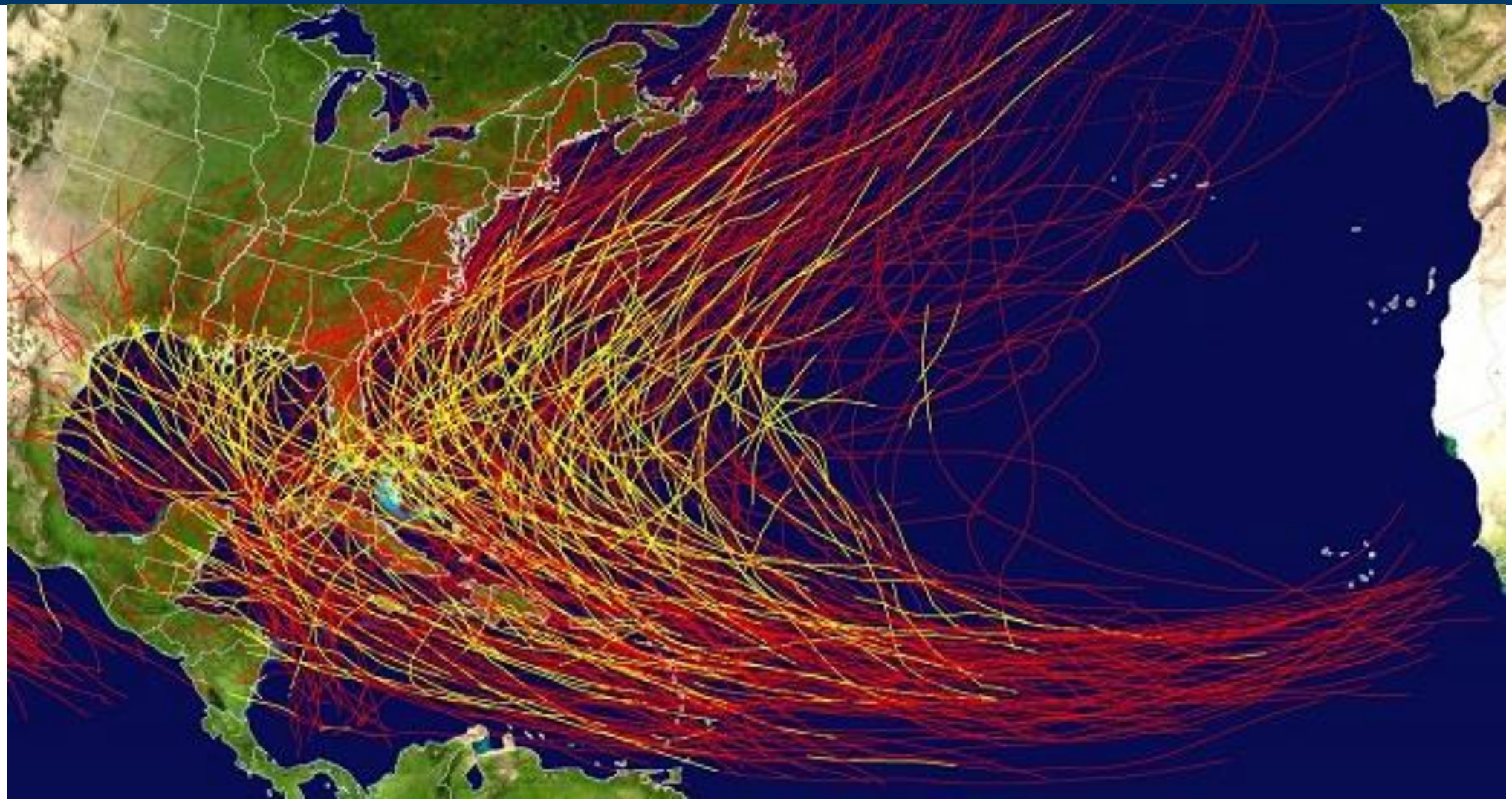


March Superstorm
1993

Tropical Cyclone History

Data since 1949 in Pacific, 1851 in Atlantic

Major Hurricane History



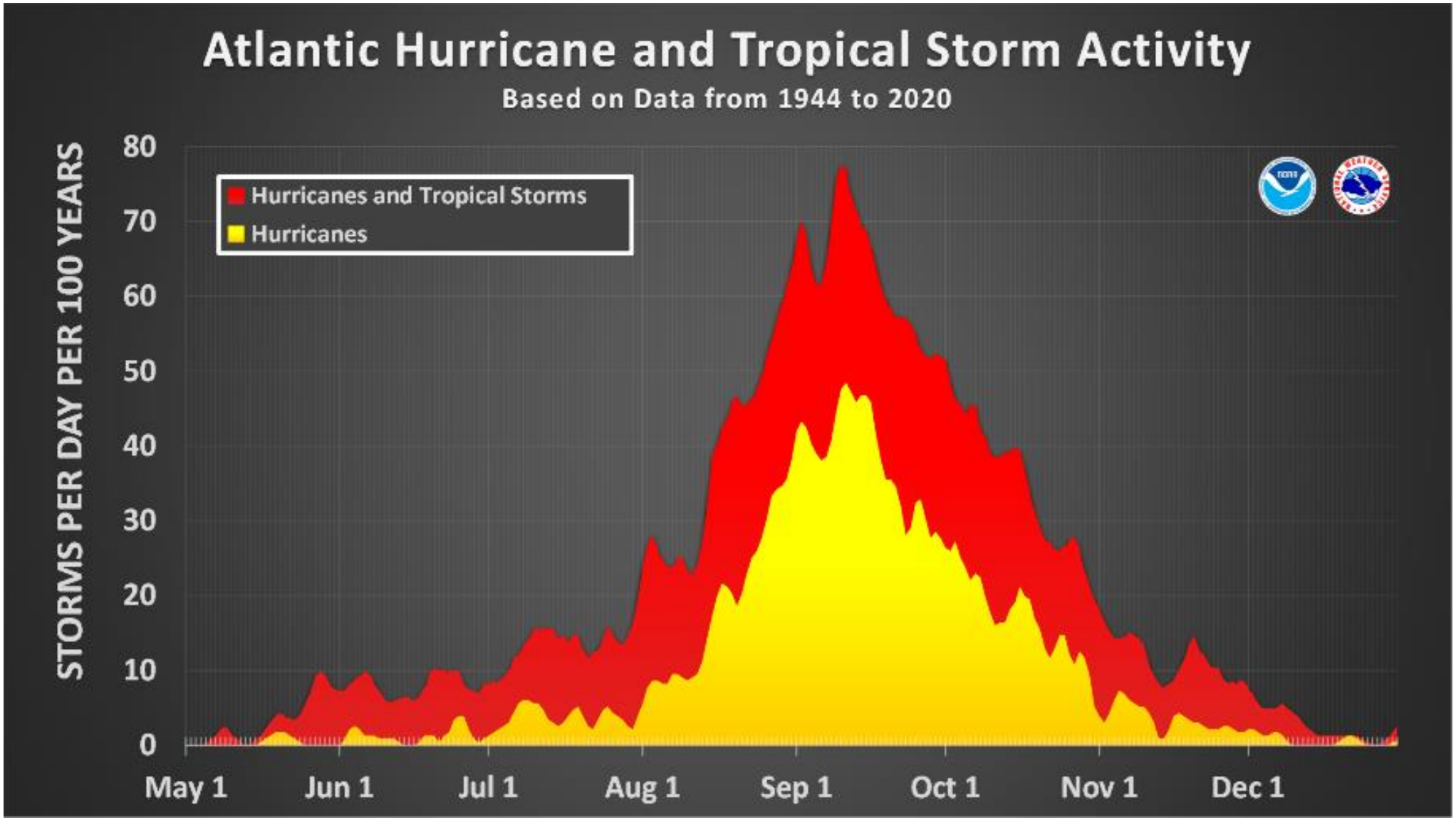
Data since 1949 in Pacific, 1851 in Atlantic

Climatology – Knowledge Check

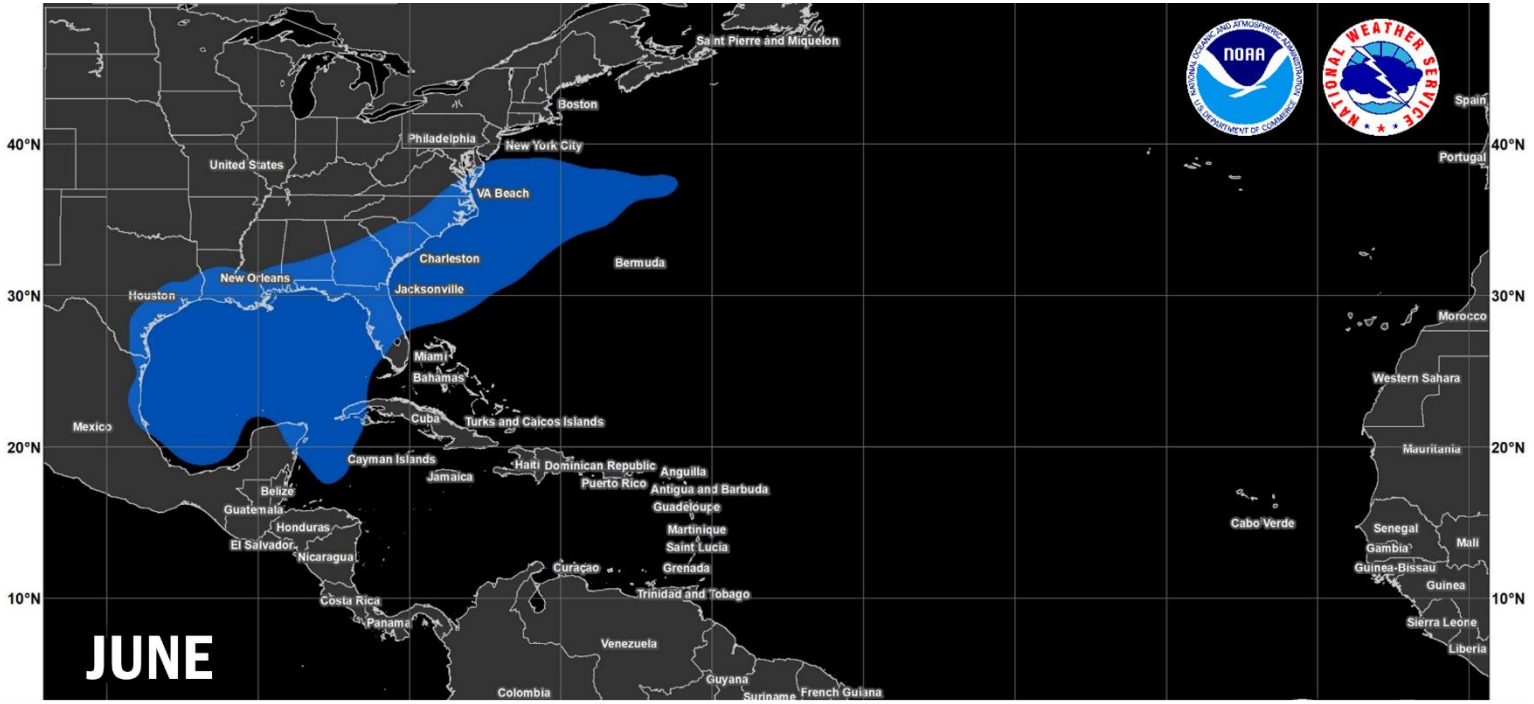
What month has the most hurricane activity in the Atlantic?

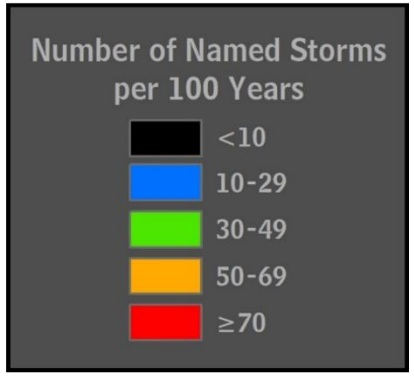
A. December
B. August
C. June
D. September

Annual Atlantic Storm Activity



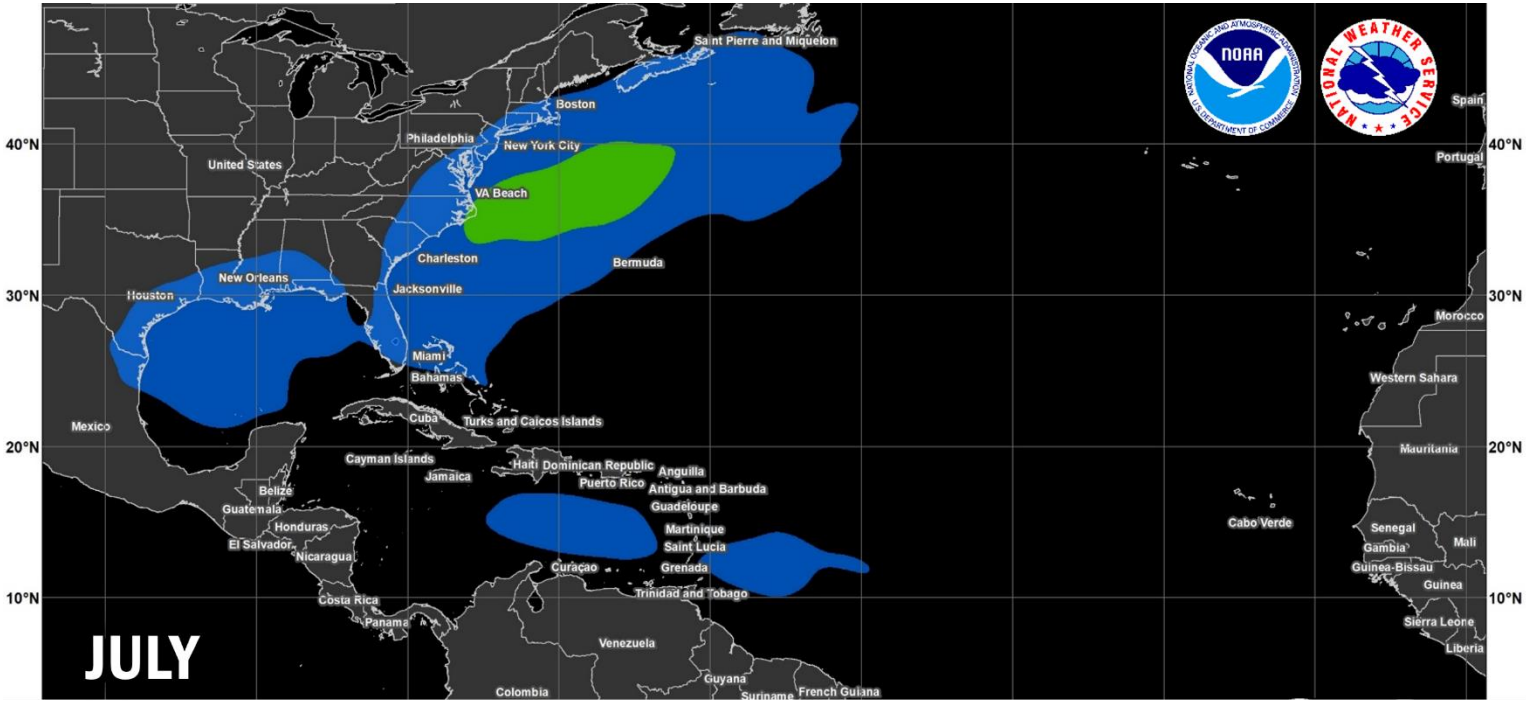
June Areas of Occurrence

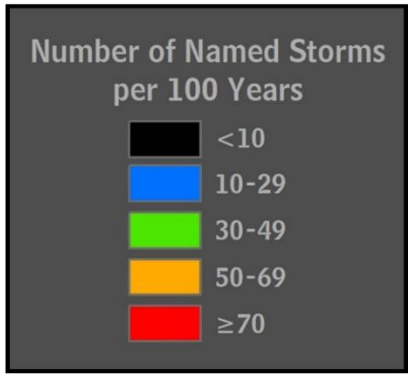




- On average about one storm every year
- Most June storms form in the NW Caribbean Sea or Gulf of Mexico

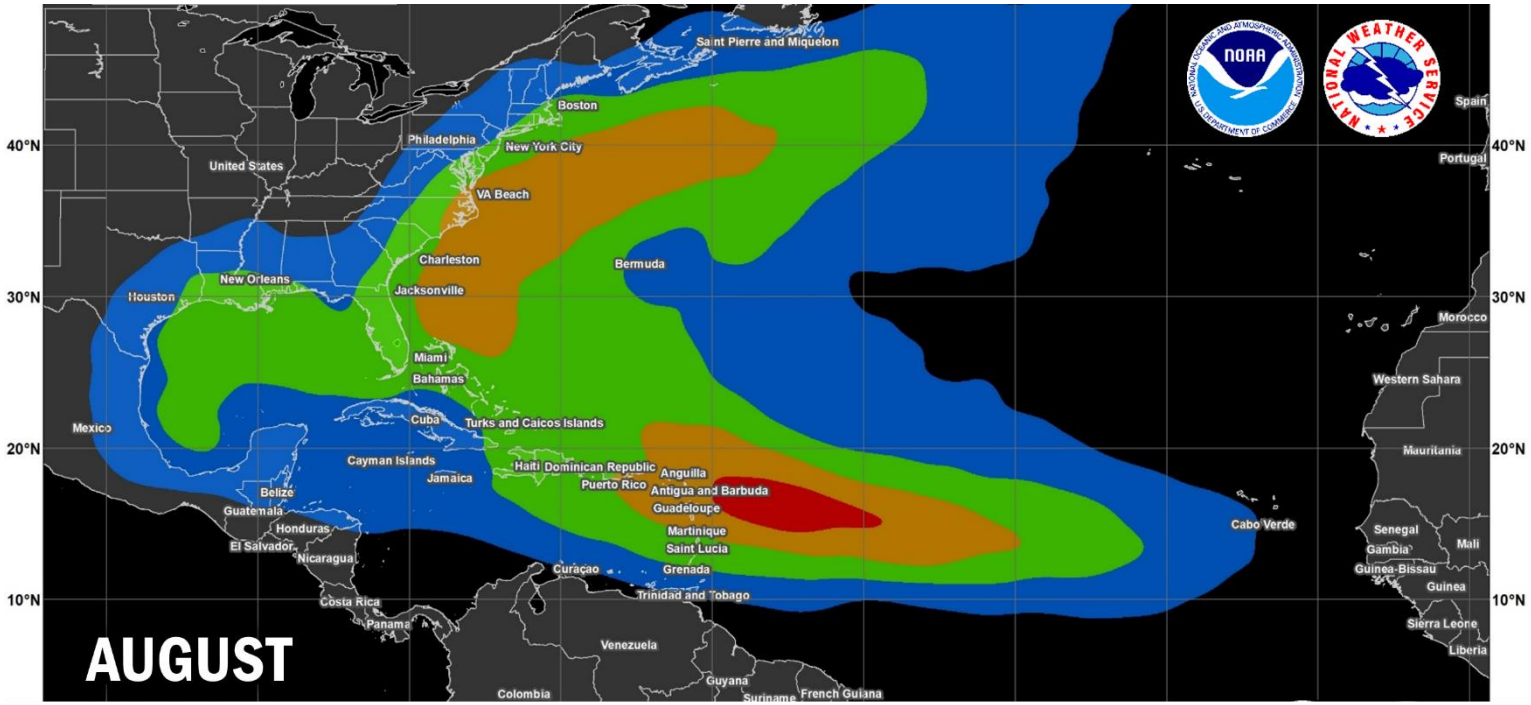
July Areas of Occurrence

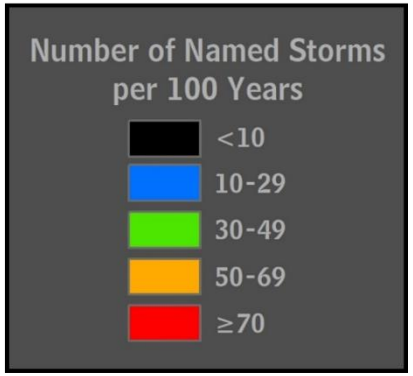




- On average 1-2 named storms every year
- July occurrence areas spread east and cover the western Atlantic, Caribbean, and Gulf of Mexico

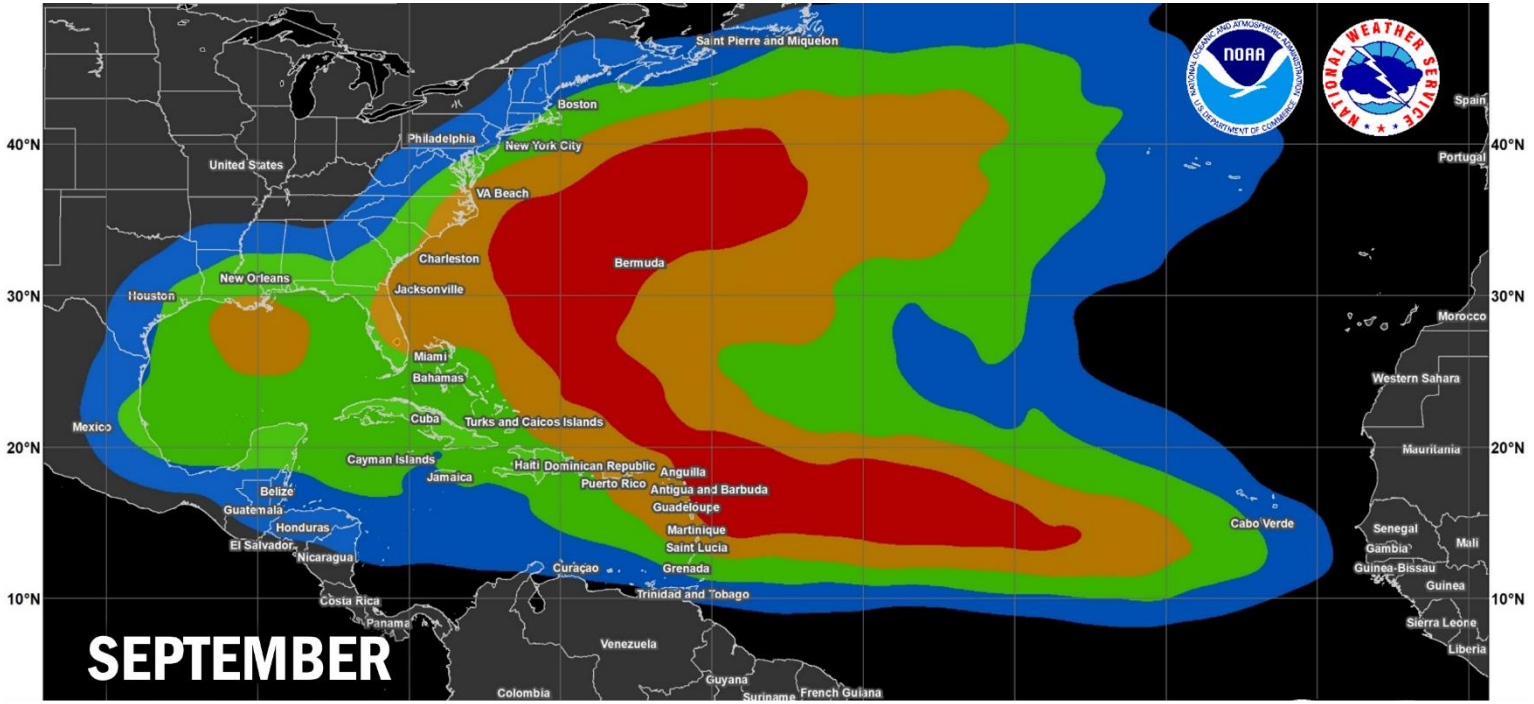
August Areas of Occurrence

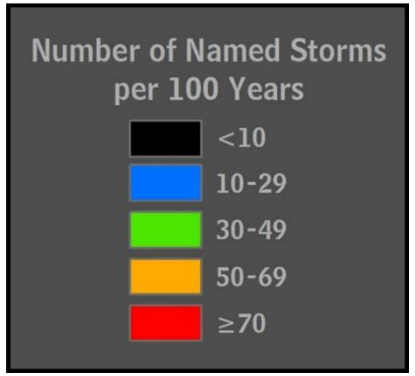




- On average about 3-4 storms form each year
- The Cape Verde season usually begins in August

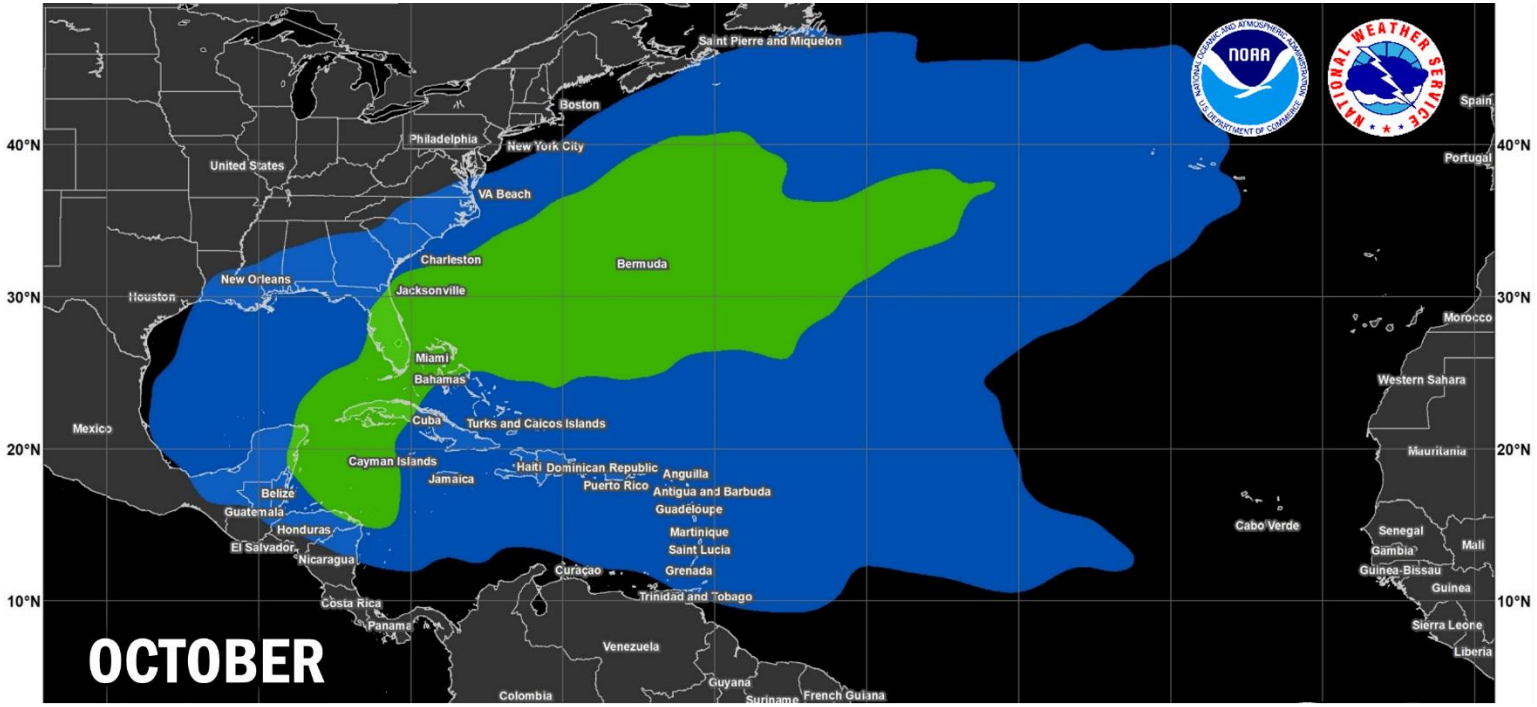
September Areas of Occurrence

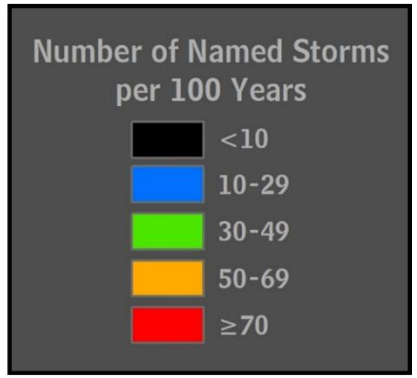




- Climatological peak of the season; on average 4-5 storms every year
- Storms can form nearly anywhere in the basin;
  Long-track Cape Verde storms are more likely

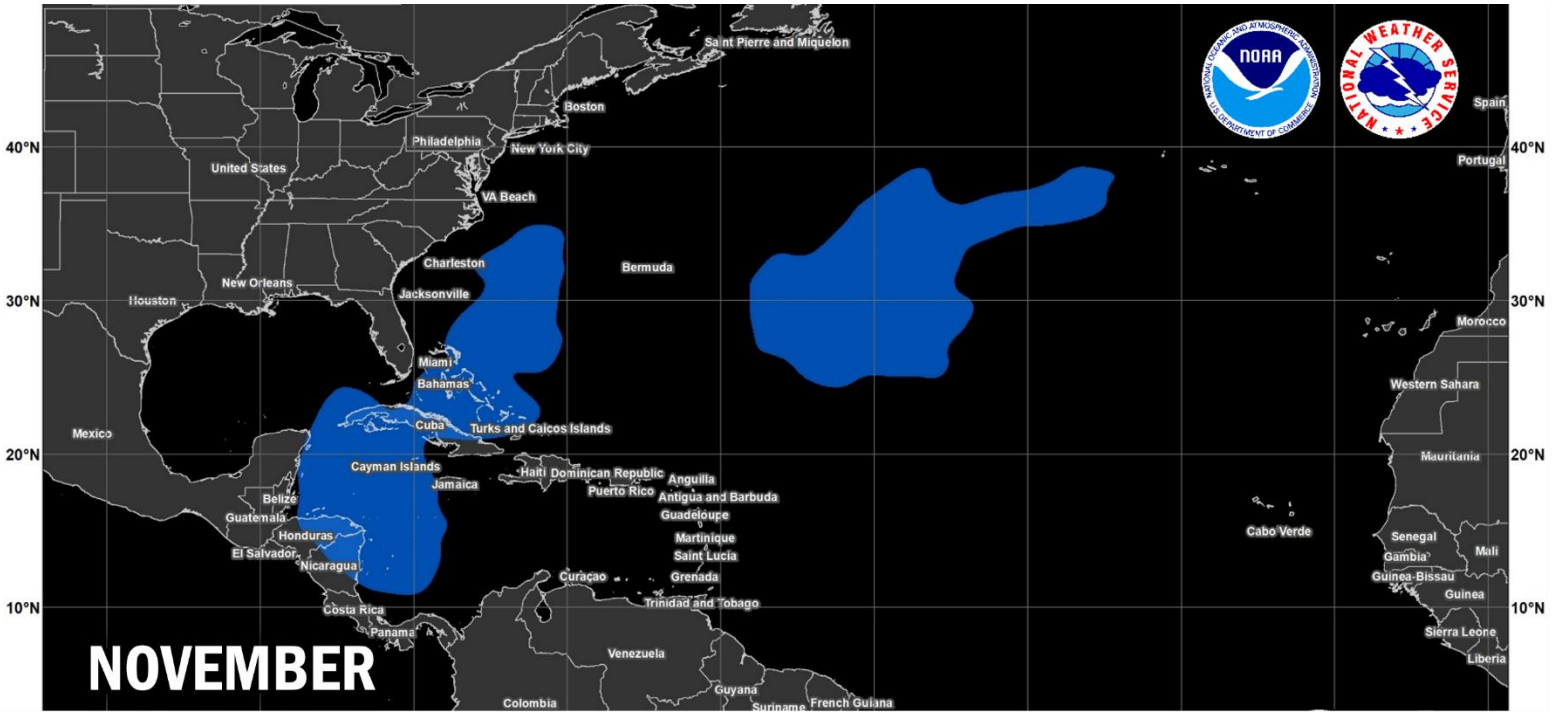
October Areas of Occurrence

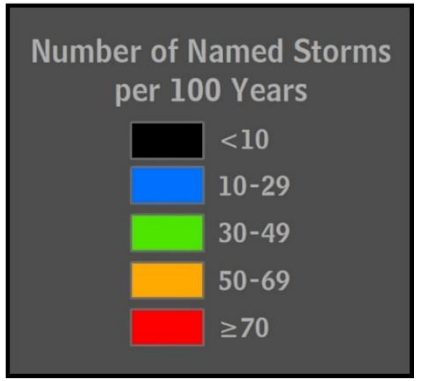




- On average 2-3 storms every year
- Cape Verde season ends and activity shifts to the Gulf of Mexico, Caribbean Sea, and western Atlantic Ocean

November Areas of Occurrence





- On average about 1 storm every other year
- Storms typically occur in the western Caribbean Sea or western and central Atlantic Ocean

Hurricane Lifecycle – Cape Verde Hurricanes 1

Hurricane Lifecycle – Cape Verde Hurricanes 2

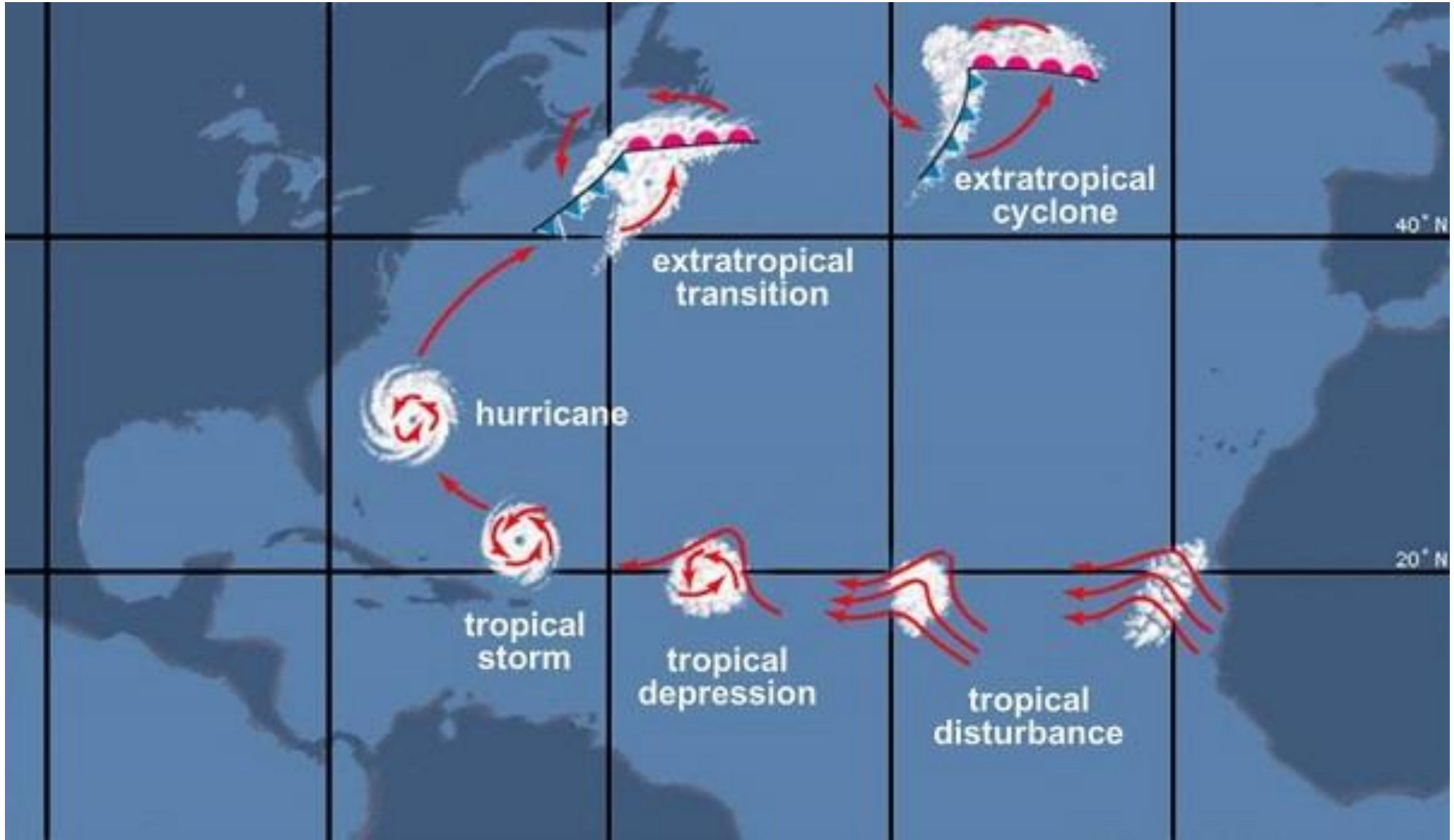
Hurricane Lifecycle – Cape Verde Hurricanes 3

Hurricane Lifecycle – Cape Verde Hurricanes 4

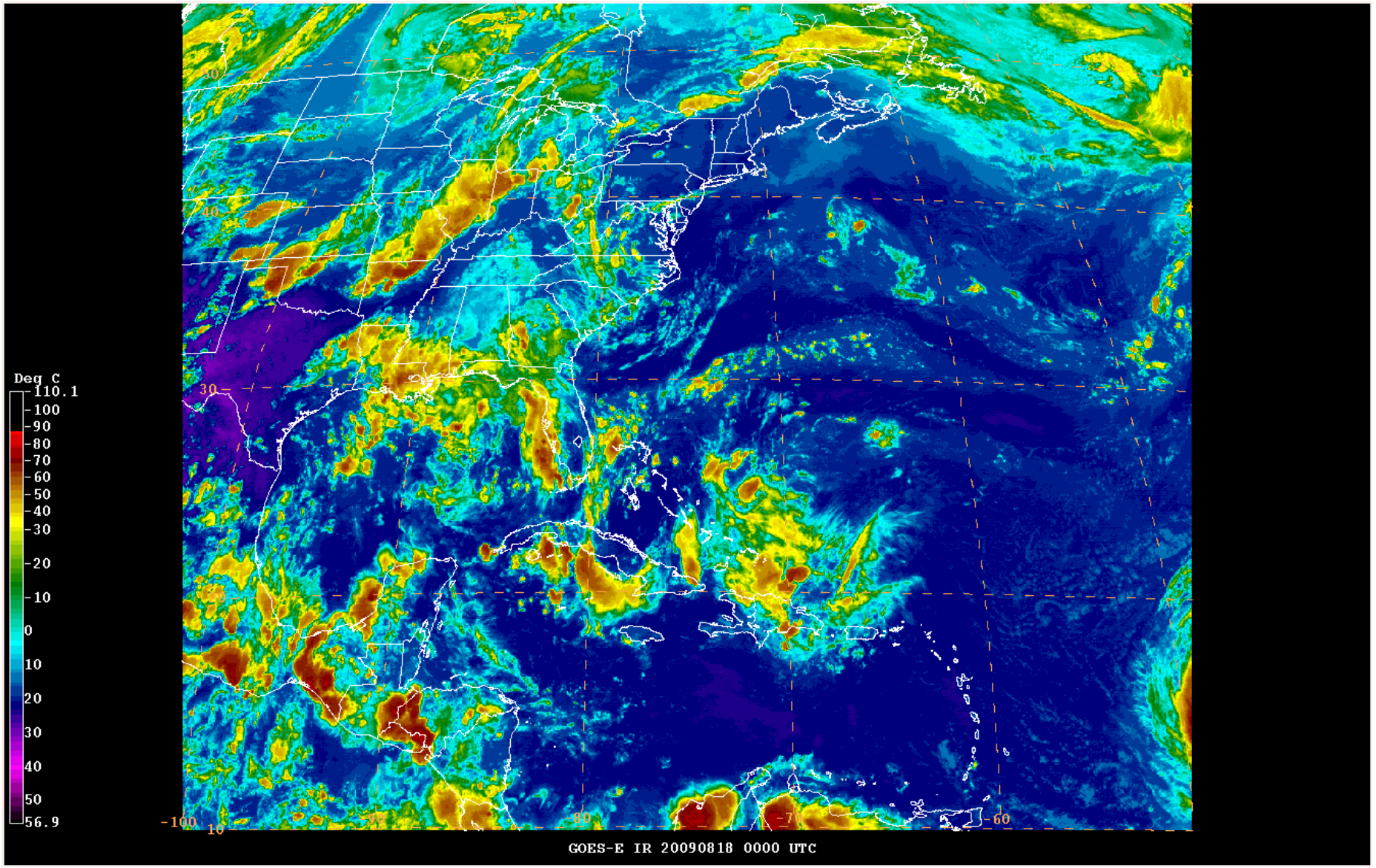
Hurricane Lifecycle – Cape Verde Hurricanes 5

Hurricane Lifecycle – Cape Verde Hurricanes 6

Hurricane Lifecycle – Cape Verde Hurricanes 7



Hurricane Bill (2009)



Hurricane 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 TS Formation

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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

Tropical waves

- About 70% of all Atlantic basin formations
- Most major hurricanes

Decaying cold fronts

- Formation often near Gulf of Mexico and southeastern United States
- Typically early- or late-season storms

Non-tropical lows and thunderstorm complexes

- Often subtropical systems

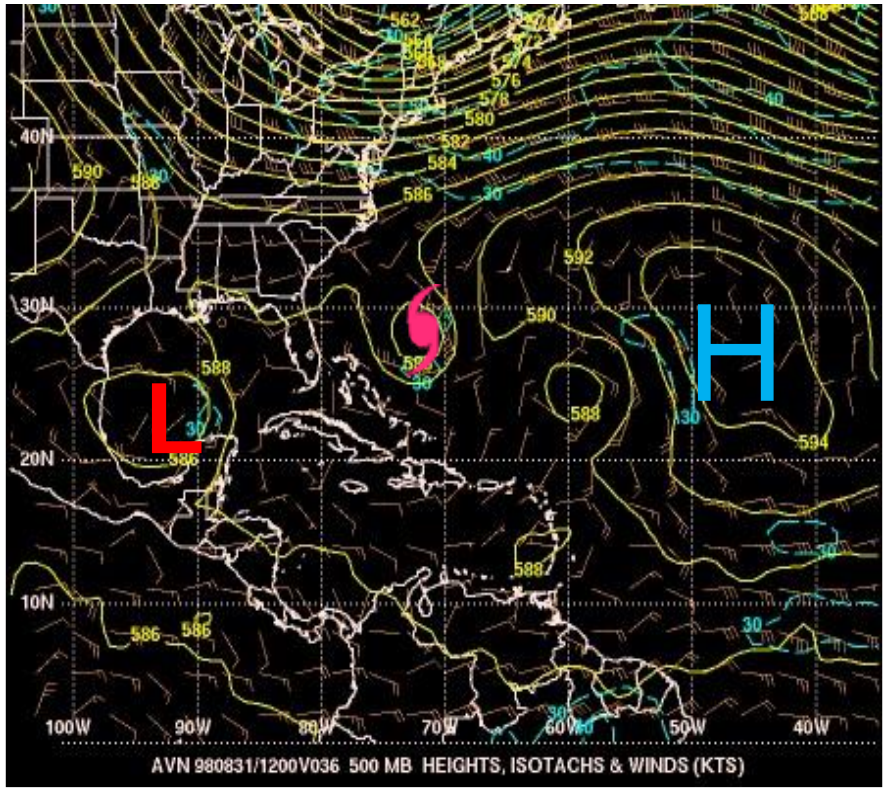
Storm Motion and Track

Track forecast is usually controlled by large-scale weather features

- "Cork in the stream" analogy

Numerical computer models forecast track quite well

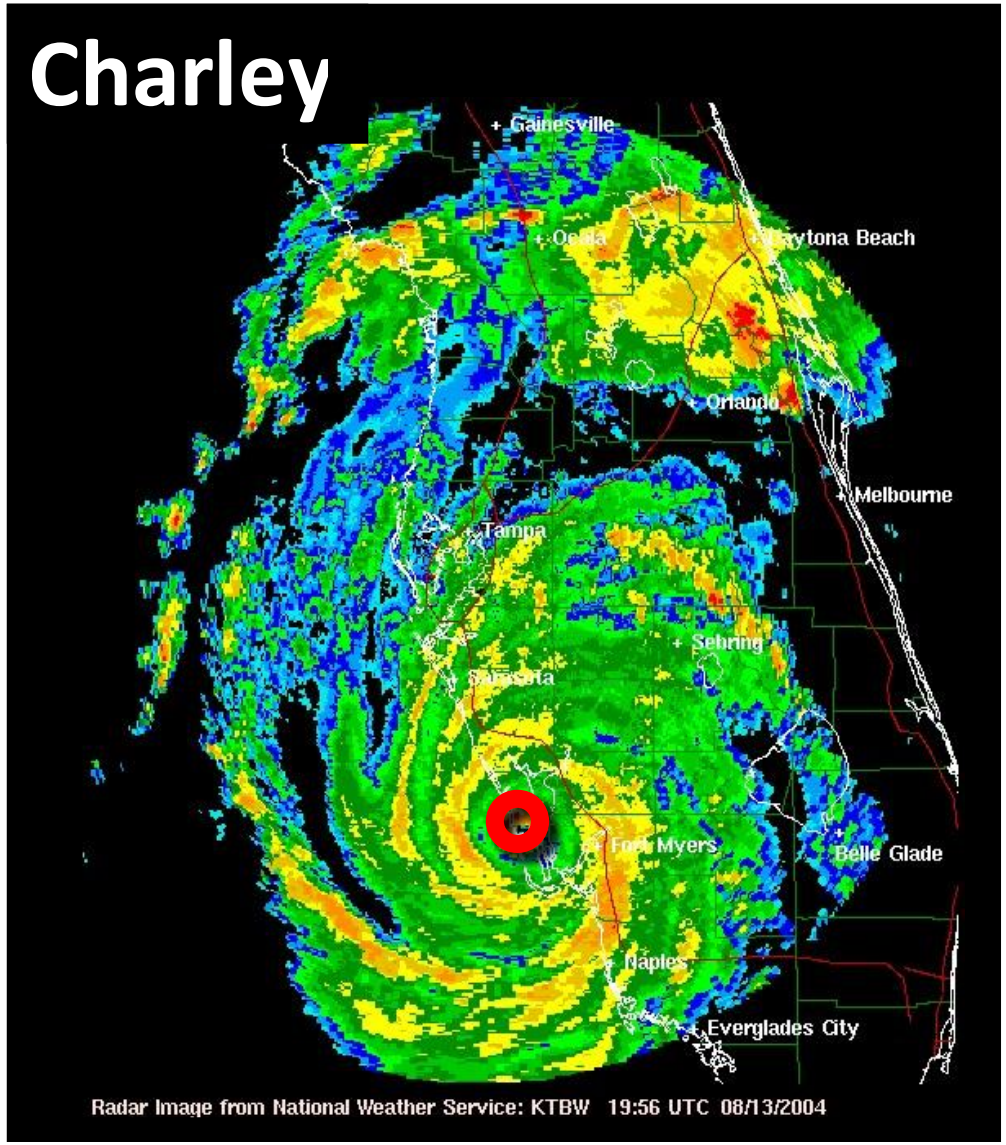
- Constantly upgrading model physics and resolution
- Long ago surpassed statistical models in accuracy

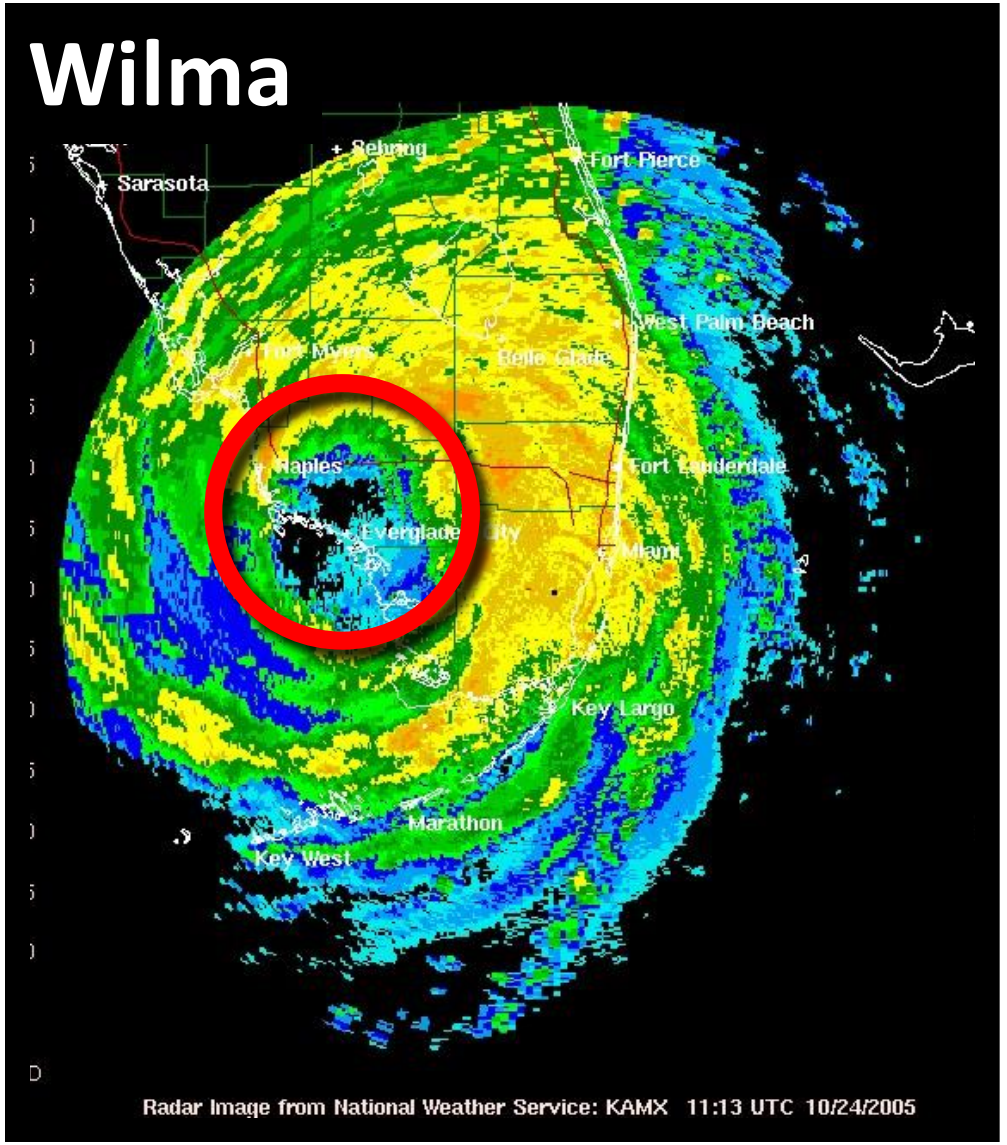


Intensity Factors

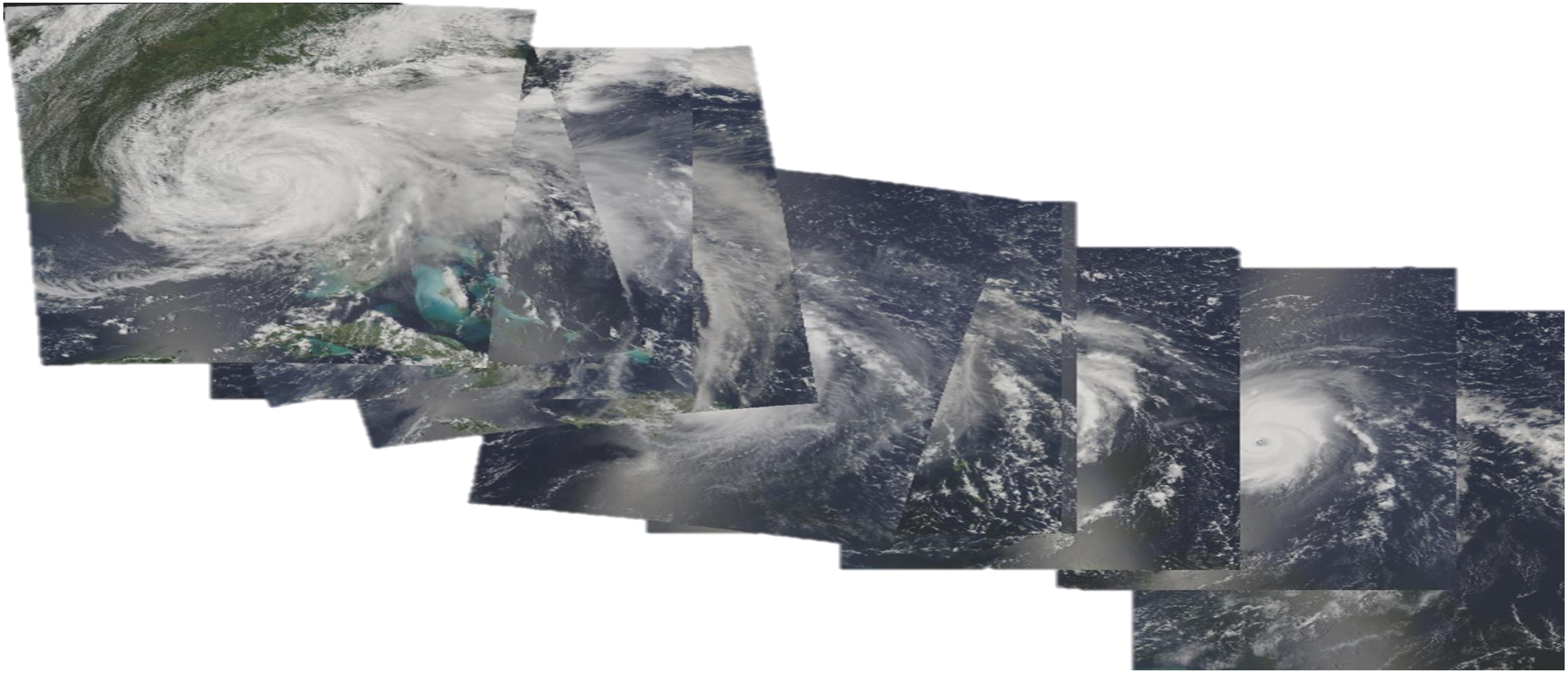
- Upper-Ocean Temperatures
  More heat favors a stronger storm
- Interaction with Land/Topography
  Land weakens the storm
- Vertical Wind Shear
  Shear limits strengthening
- Moisture in Storm Environment
  Dry air can limit strengthening
- Structural Changes and Eyewall Replacement
  Difficult to forecast and not straightforward
- Interactions with other weather systems

Tropical Cyclones Come n All Sizes





Questions?



Tropical Cyclone Hazards – Knowledge Check

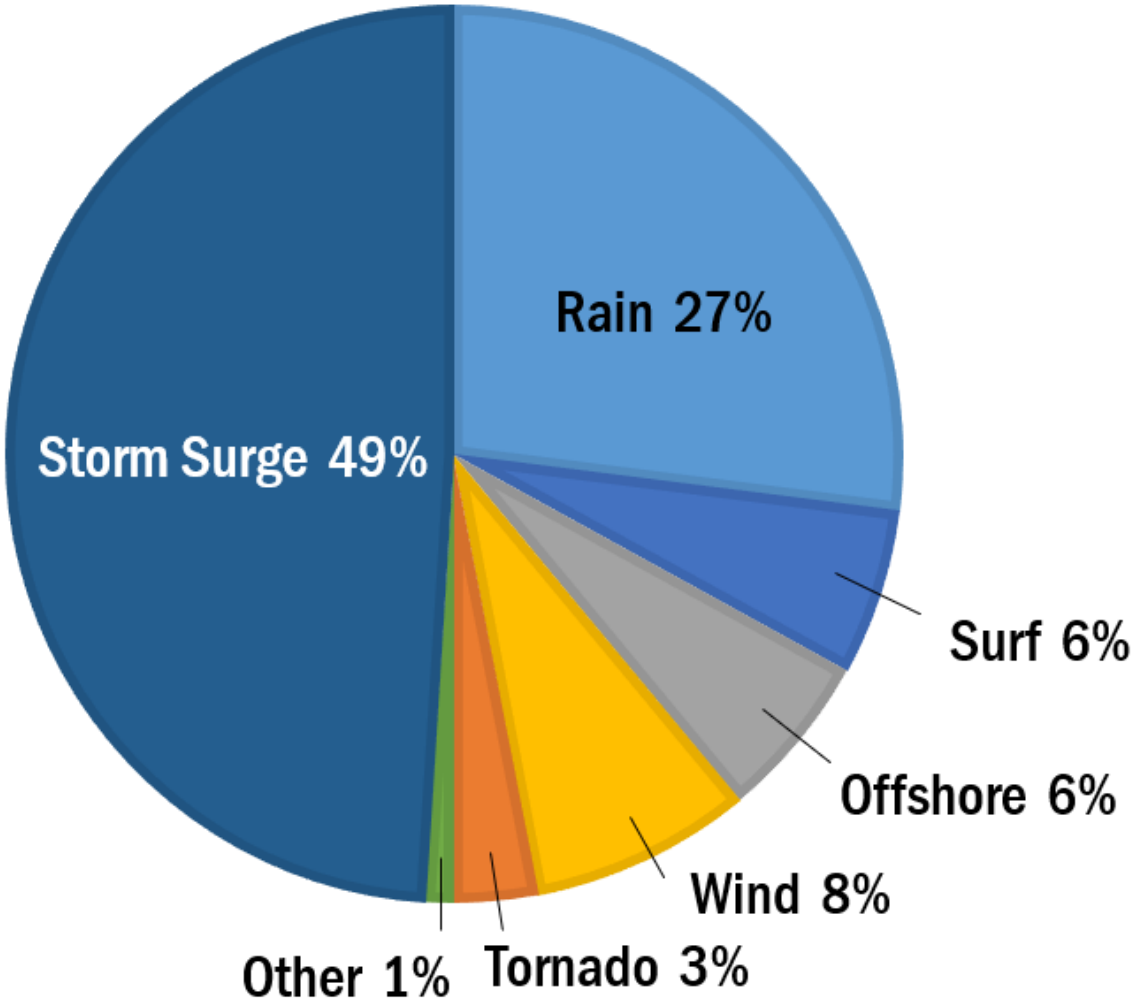
Which hazard has the greatest potential for large loss of life?

A. Wind
B. Rain-induced flooding
C. Tornadoes
D. Storm Surge

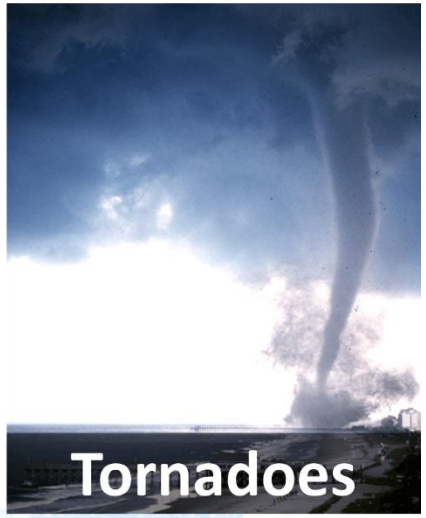
Atlantic Tropical Cyclone Deaths

U.S. tropical cyclone direct fatalities

- 1963-2012



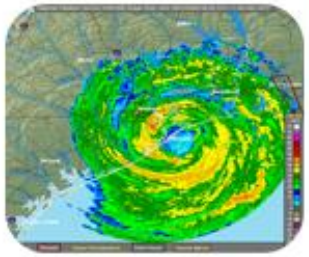
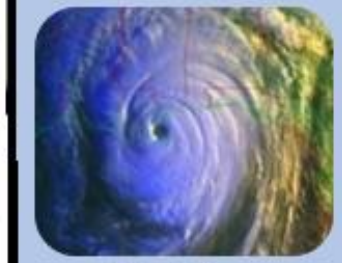
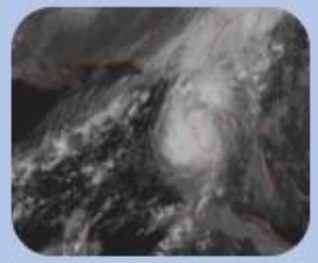
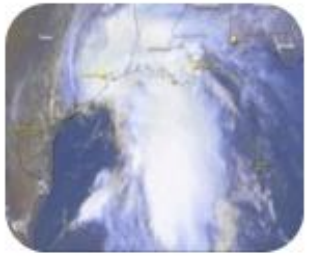
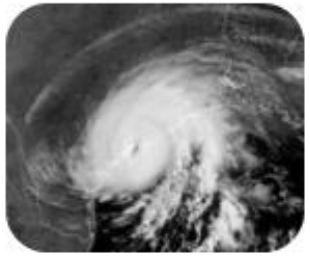
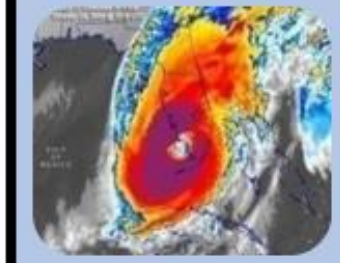
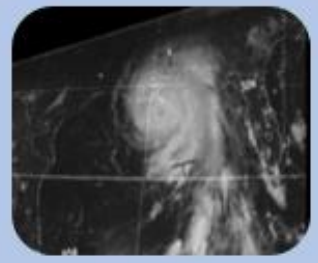
Hurricane Hazards



Saffir-Simpson Scale

FEMA

MAJOR HURRICANES

TROPICAL STORM 39 – 73 mph (34 – 63 kt)	CATEGORY 1 74 – 95 mph (64 – 82 kt)	CATEGORY 2 96 – 110 mph (83 – 95 kt)	CATEGORY 3 111 – 129 mph (96 – 112 kt)	CATEGORY 4 130 – 156 mph (113 – 136 kt)	CATEGORY 5 > 156 mph (> 136 kt)
 Debby (2012)	 Isaac (2012)	 Ike (2008)	 Katrina (2005)	 Charley (2004)	 Andrew (1992)
 Allison (2001)	 Claudette (2003)	 Isabel (2003)	 Wilma (2005)	 Hugo (1989)	 Camille (1969)

Category 1 (74-95 mph)


Humberto (2007) Southeast TX


Isaias (2020) Oak Island, NC

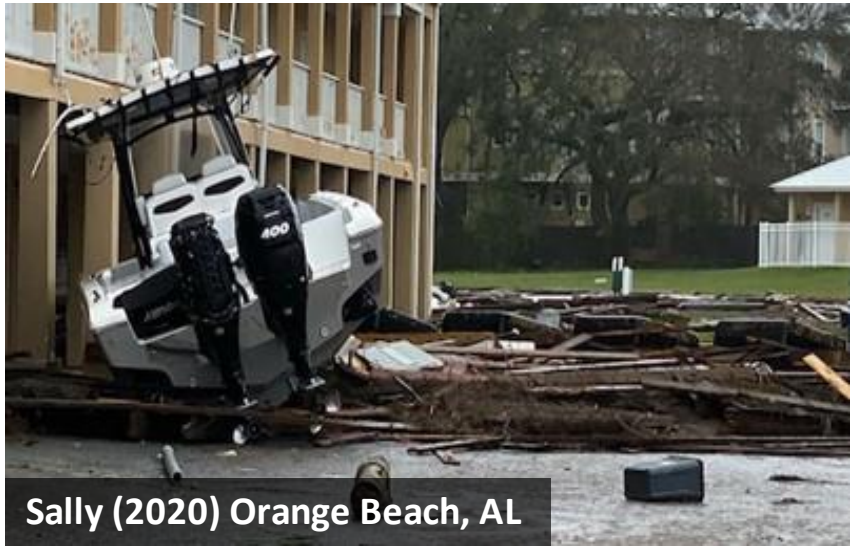

Lili (2002) Louisiana

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

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 weeks.

Category 3 (111-129 mph)

Jeanne (2004) Cape Canaveral, FL


Zeta (2020) Metairie, LA


Rita (2005) Orange, TX

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

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

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)

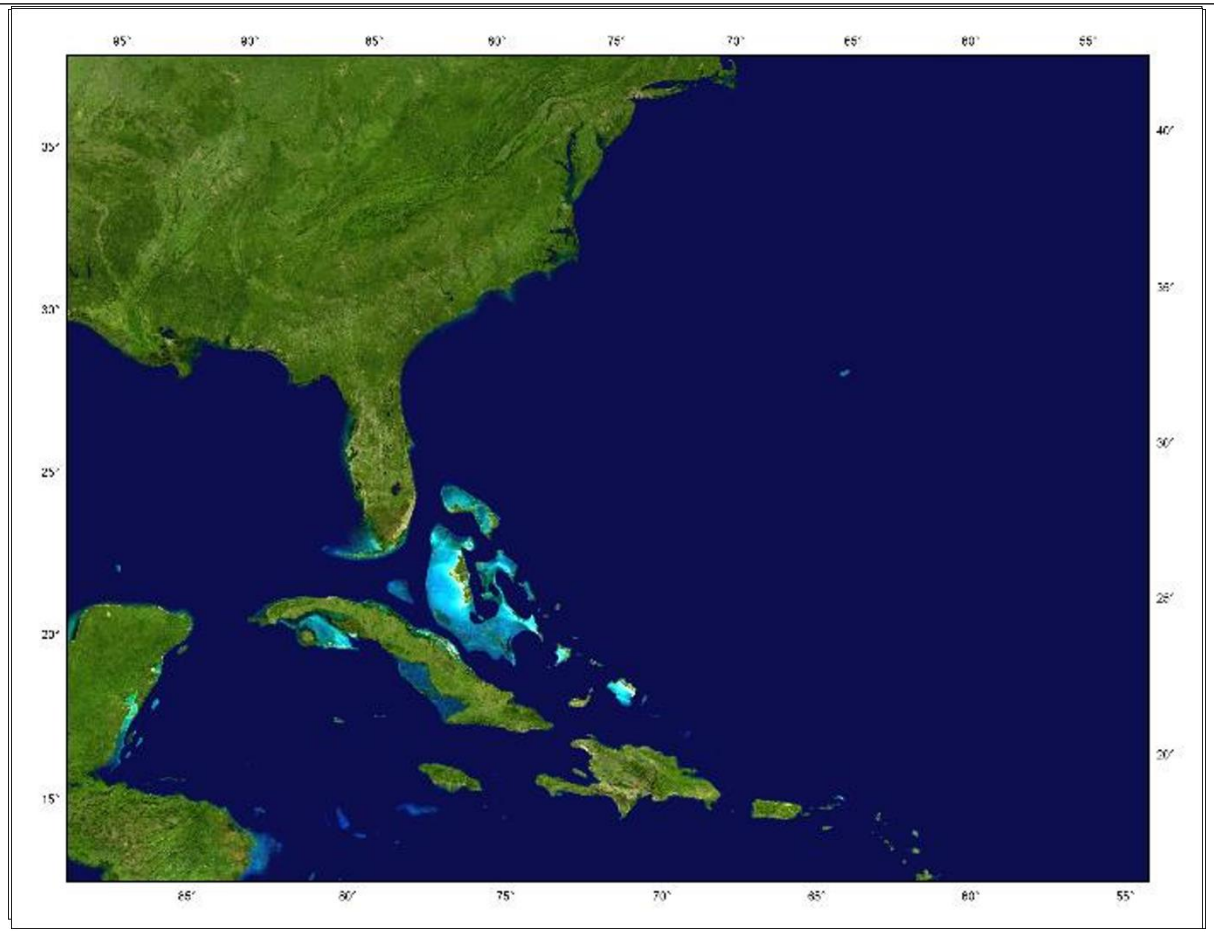
Where were these hurricanes **5 days** before landfall?

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)

73 deaths

$75 billion damage (2020 USD)

Hurricane Katrina (2005)

1200 deaths

$170 billion damage (2020 USD)

Storm Surge vs Storm Tide vs Inundation

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STORM SURGE

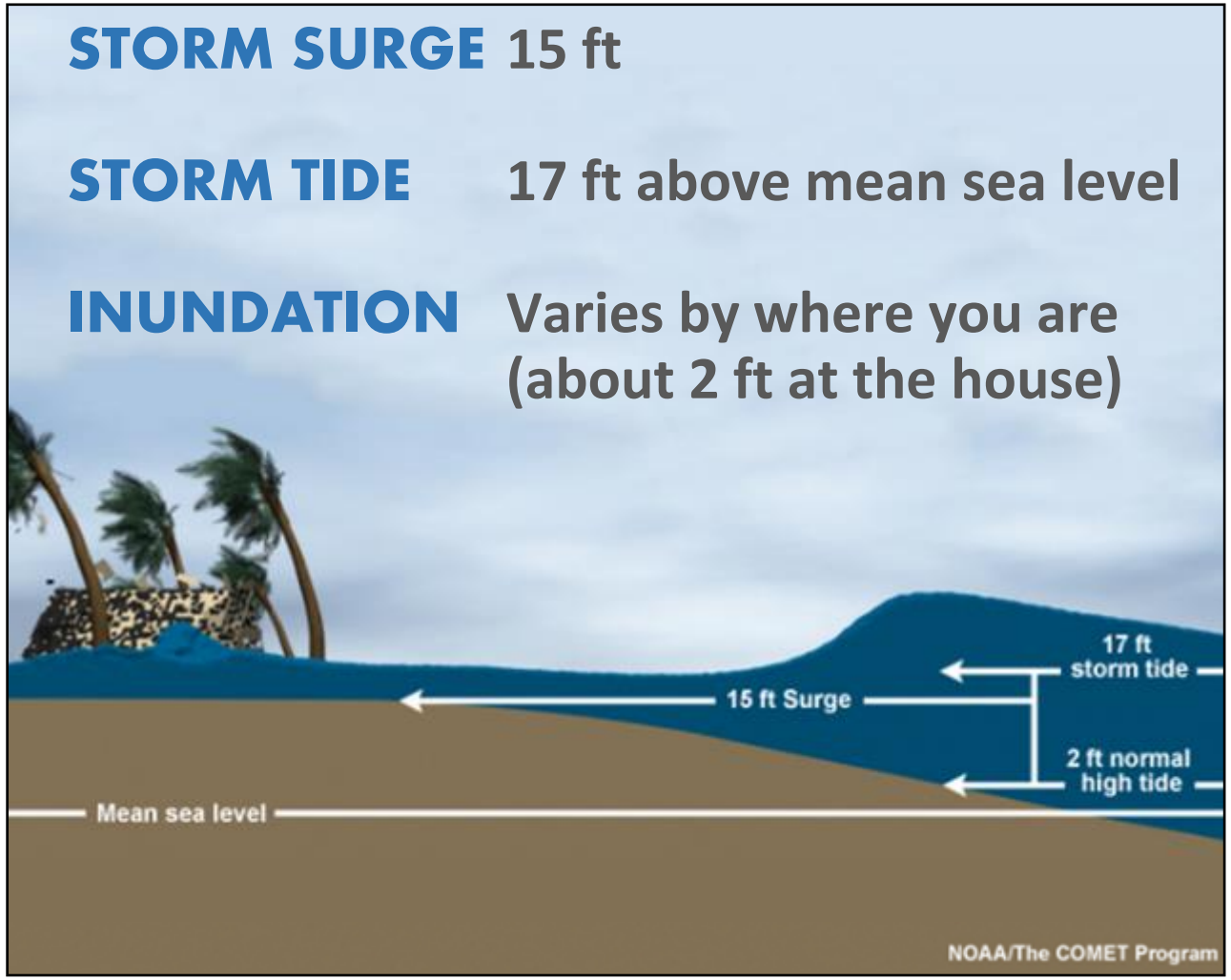
An abnormal rise of water generated by a storm, over and above the predicted astronomical tide.

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: Gulf Coast

STORM SURGE HISTORY - Waveland, Mississippi

Kimberly and David King

Storm Surge: Southeast

Storm Surge: Mid-Atlantic

Storm Surge: New England

Where Does Storm Surge Occur?

FEMA

Storm Surge – Knowledge Check

Which of the following is NOT a significant factor in determining how much storm surge could occur for a storm?

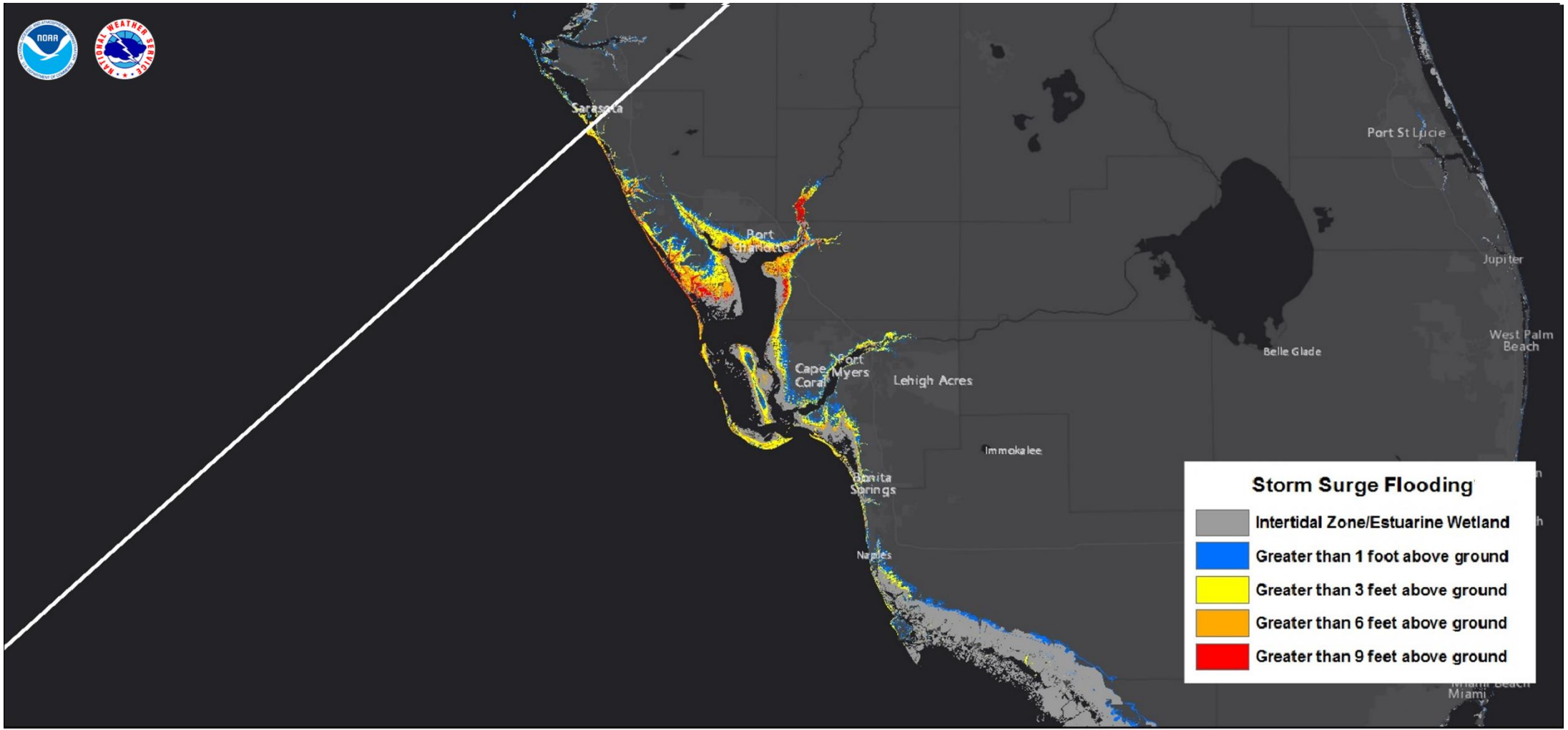
A. Size of the storm
B. Forward speed of the storm
C. Central pressure of the storm
D. Width and slope of the continental shelf

Factors Affecting Storm Surge

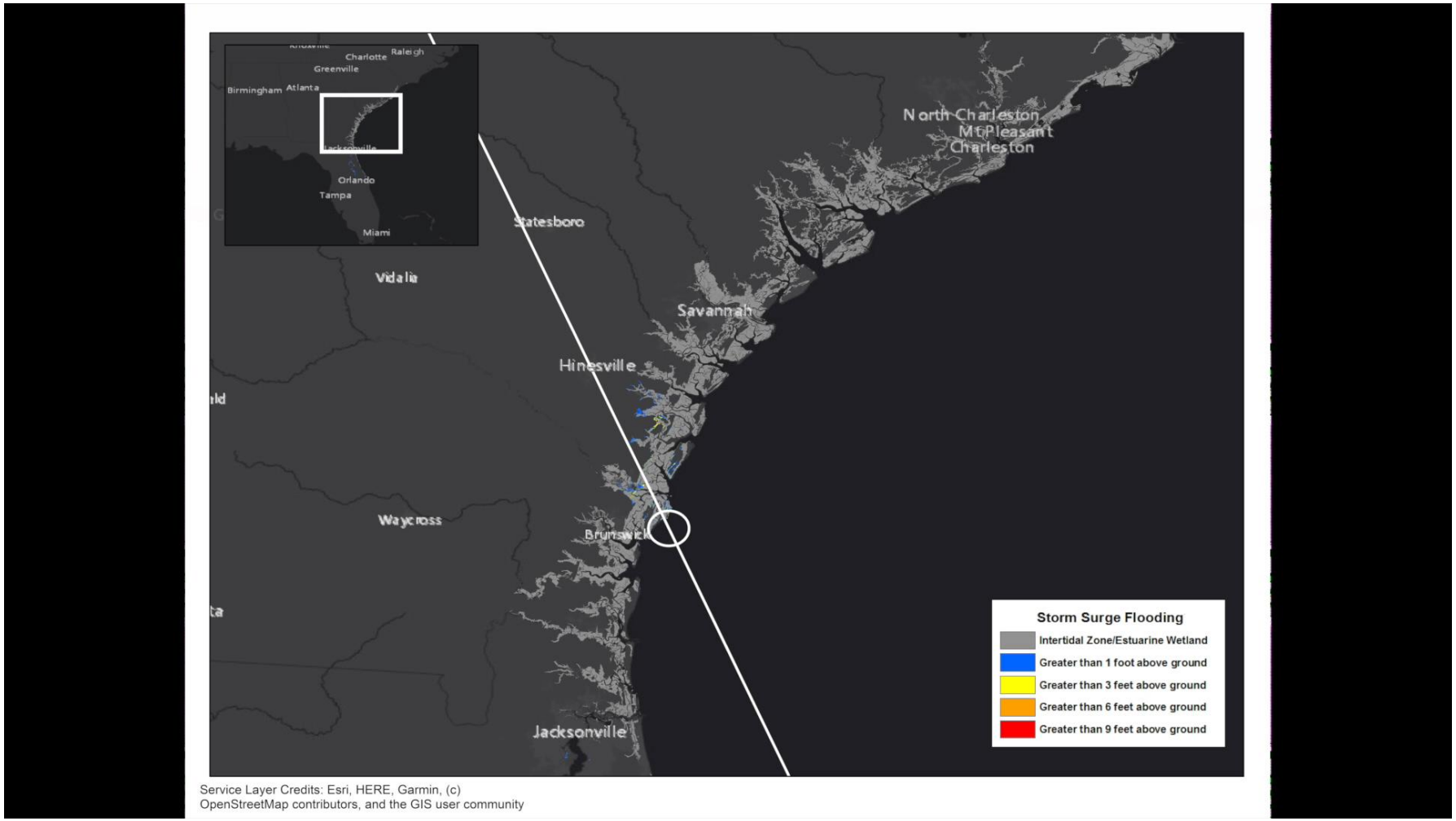
- Intensity
  Stronger storm = More storm surge
- Size (Radius of Maximum Winds)
  Larger storm = More storm surge
- Forward Speed
  Slower storm = Storm surge farther inland
- Angle of Approach
  Alters focus of storm surge
- Width and Slope of Shelf (Bathymetry)
  Gradual shelf = More storm surge

Effect of Storm intensity

Category 4



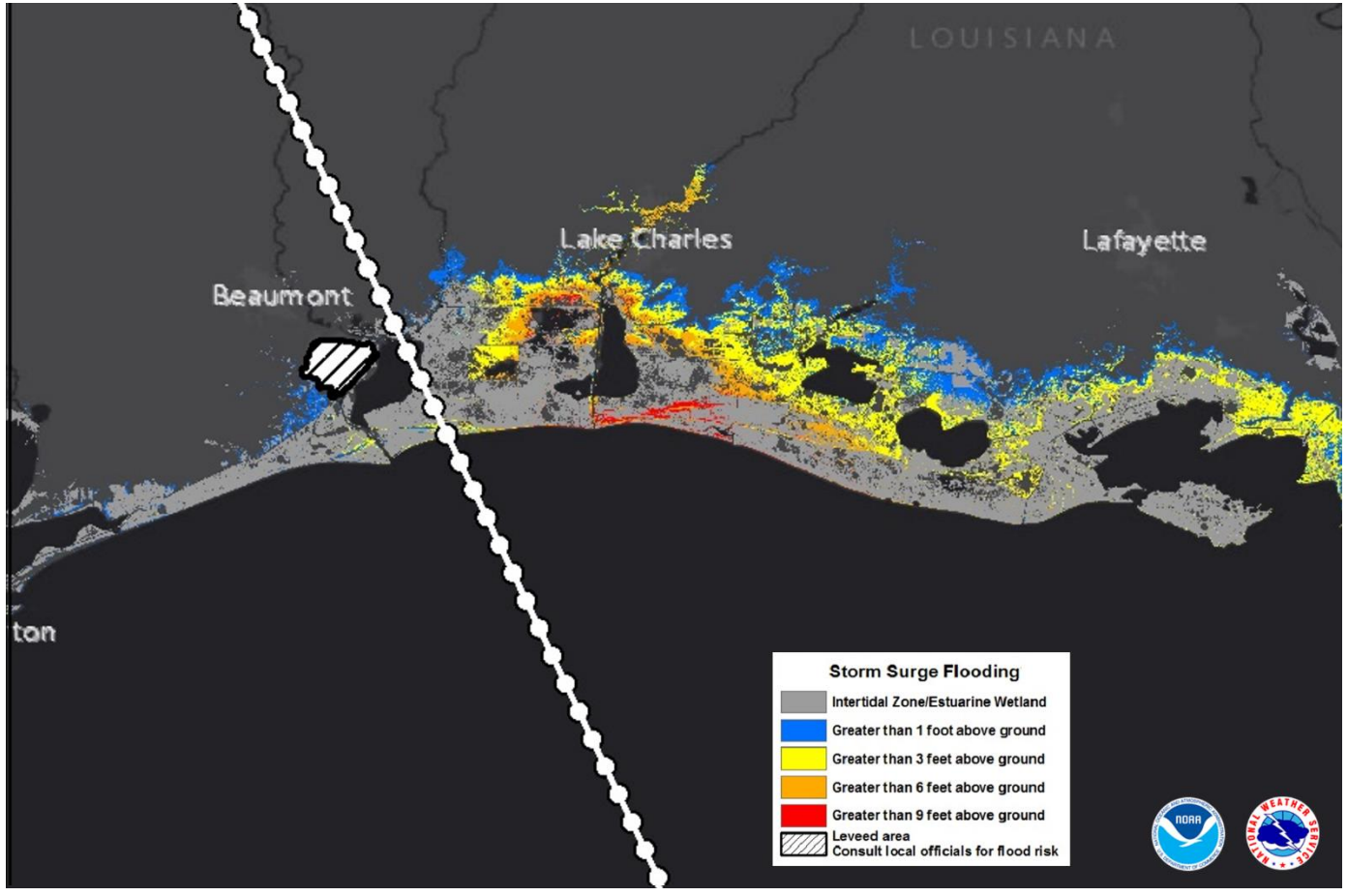
Effect of Storm Size



Effect of Forward Speed

Forward Speed

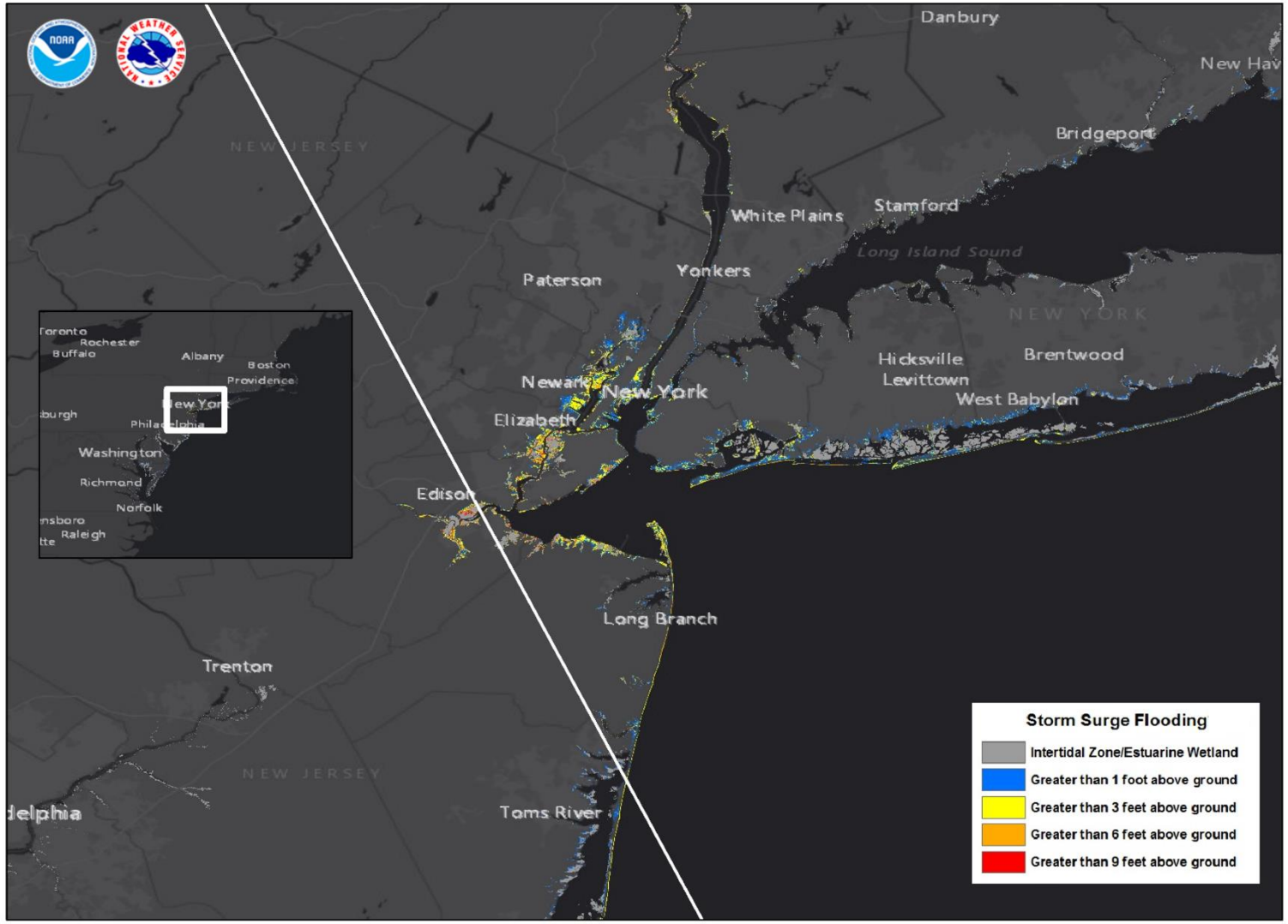
25 mph



Faster Storms:
Higher maximum at coast

Slower Storms:
Farther inland penetration

Effect of Angle of Approach



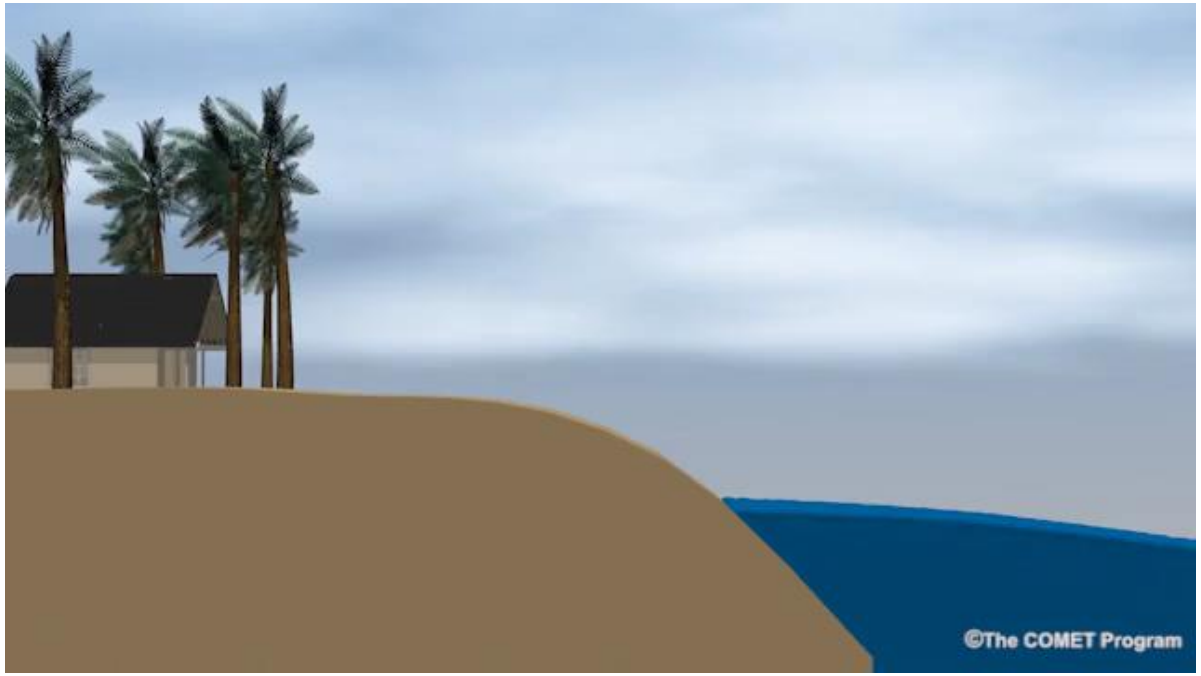
Service Layer Credits: Esri, HERE, Garmin, (c)
OpenStreetMap contributors, and the GIS user community

Angle of Approach

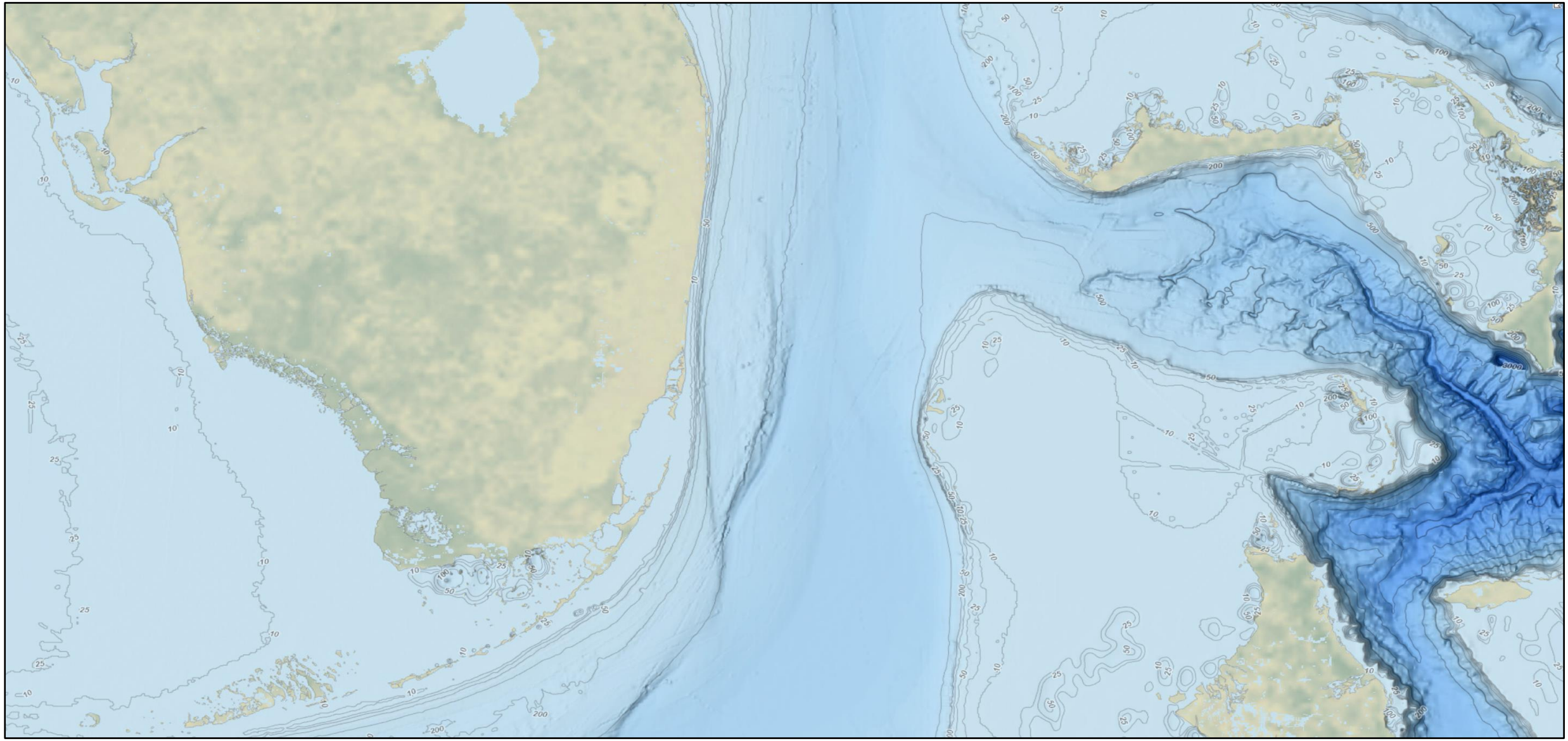
NNW

WNW

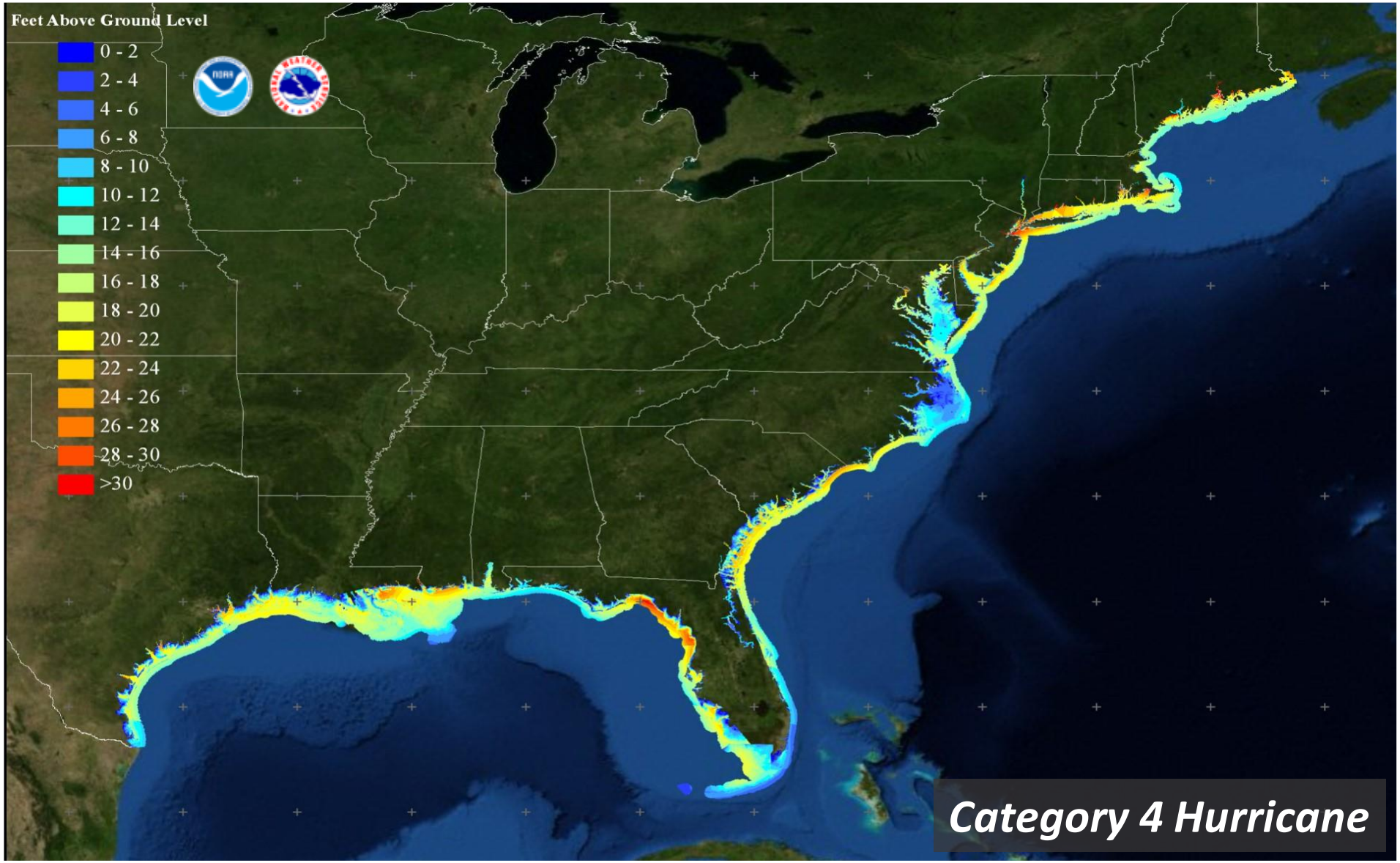
Effect of Width/Slope of Shelf



Effect of Width/Slope of Shelf – FL

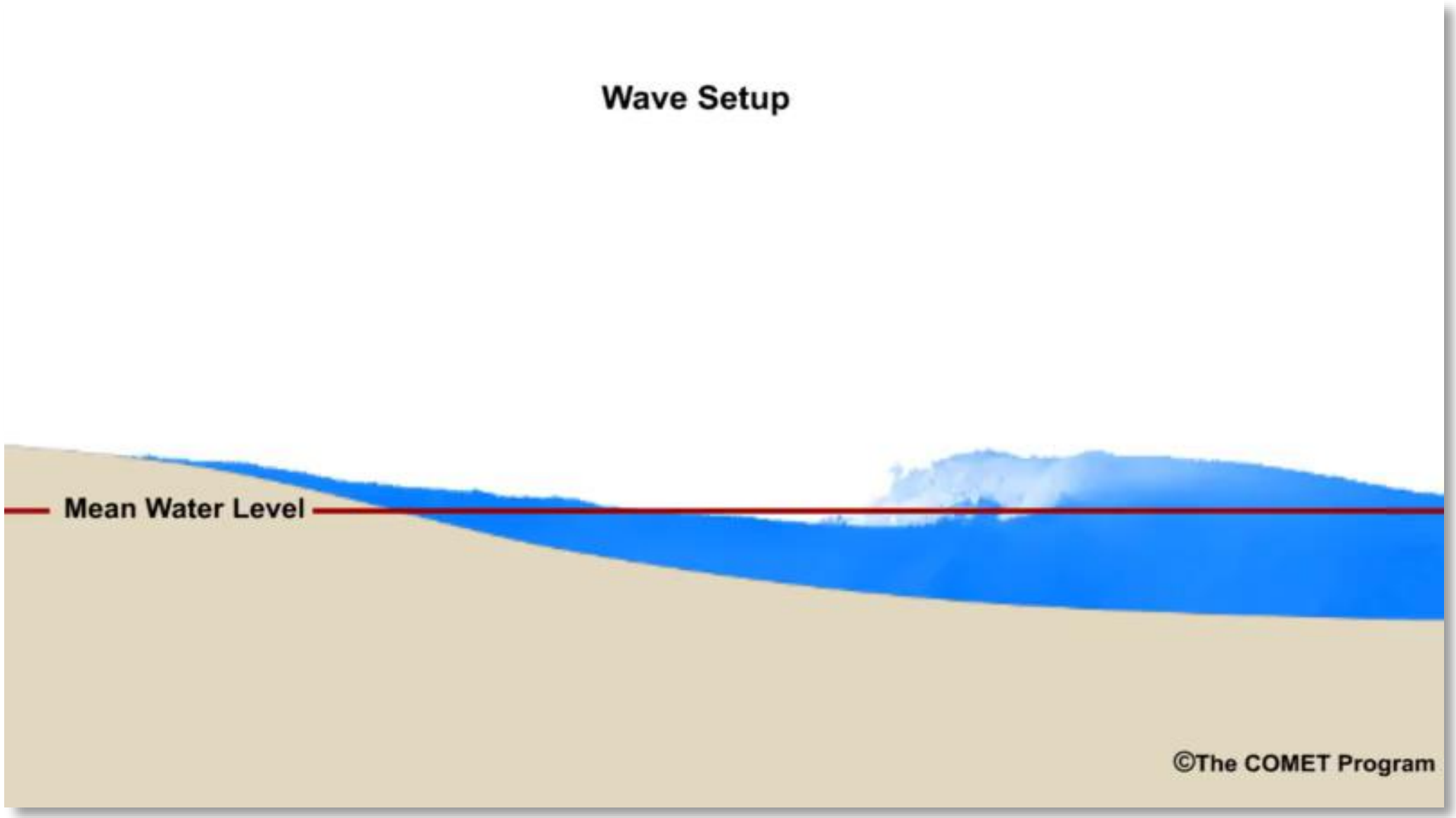


Location, Location, Location.



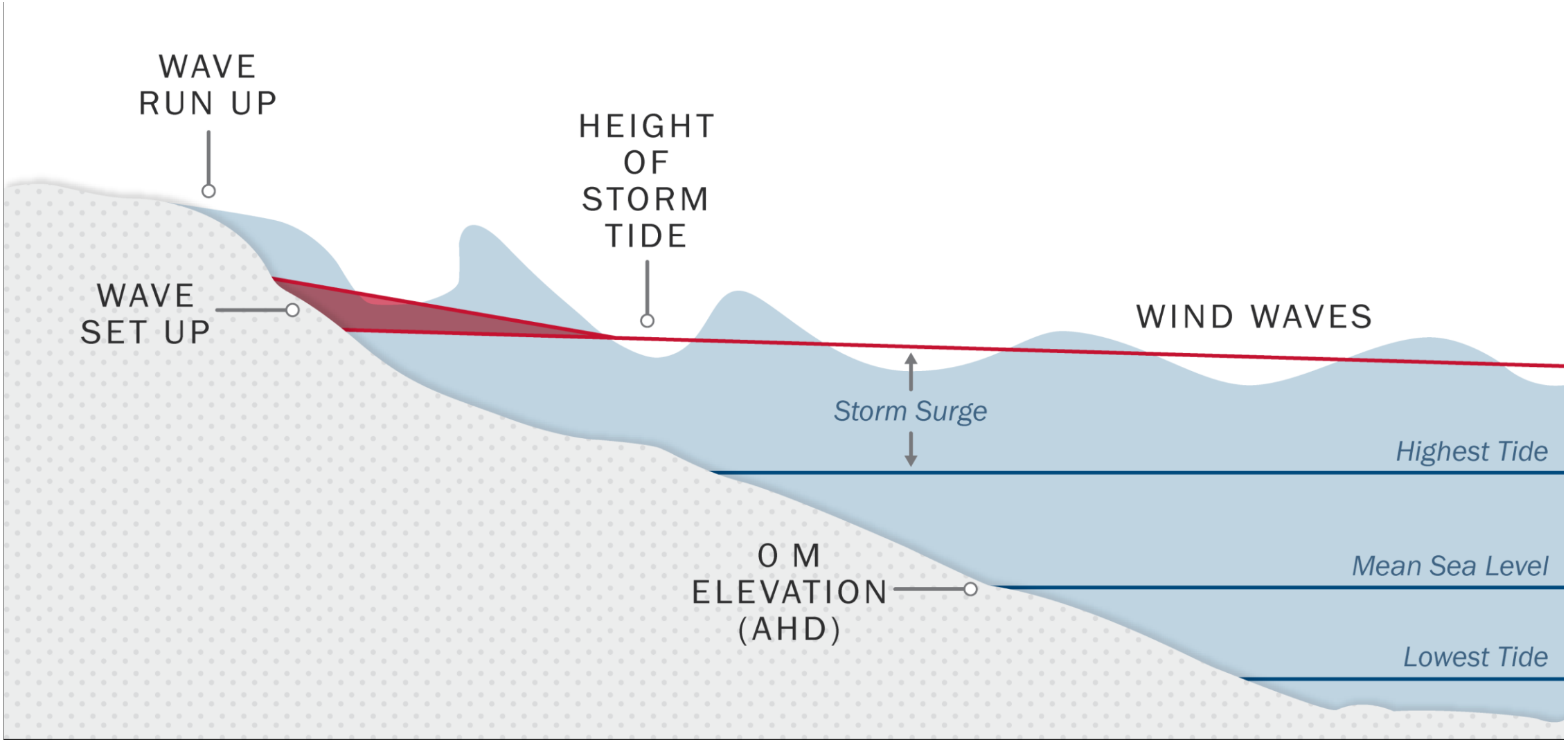
Category 4 Hurricane

Wave Setup



Components of Total Water Level

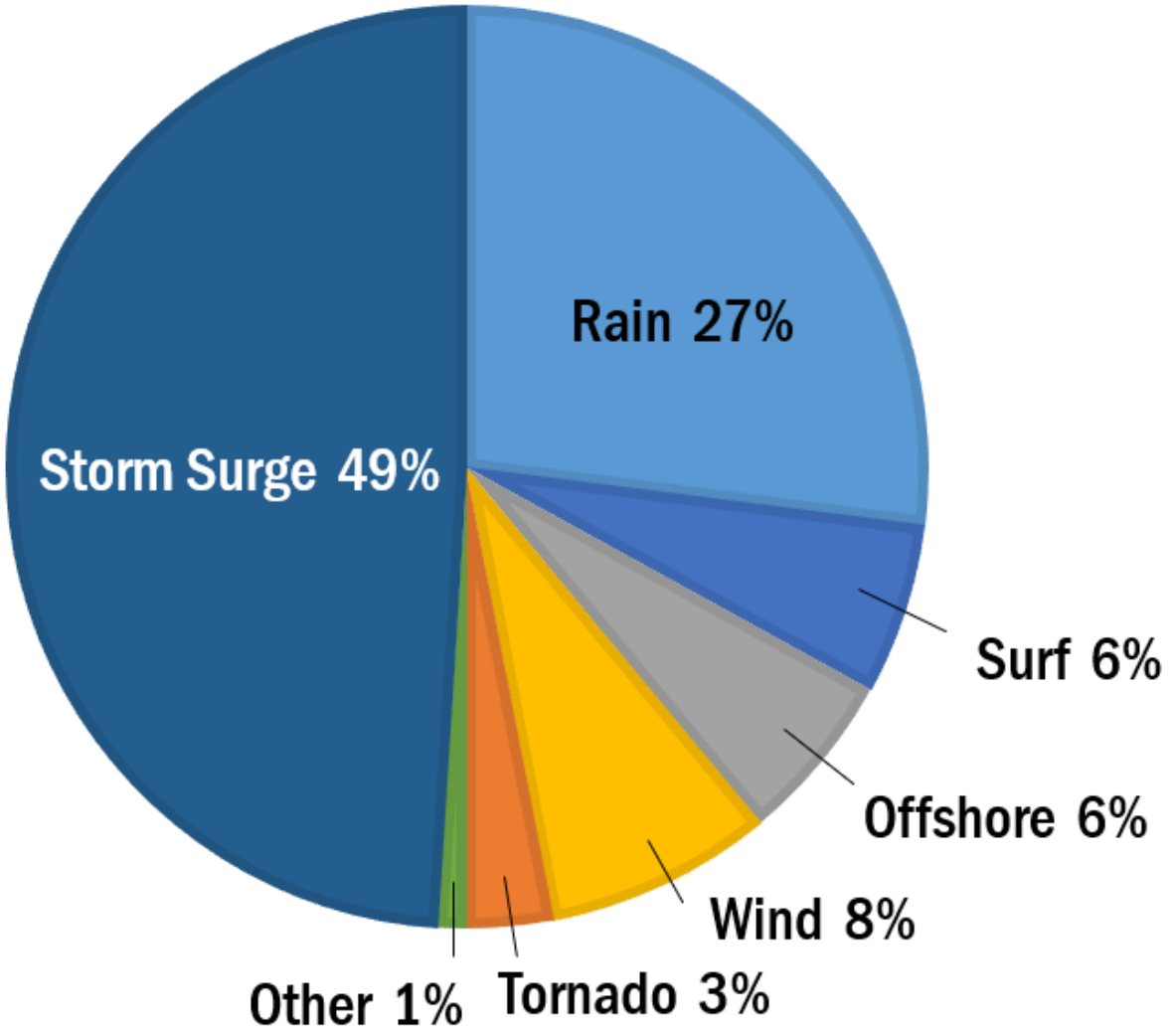
Storm Surge + Tides + Wave Setup + Freshwater



Atlantic Tropical Cyclone Deaths 2

U.S. tropical cyclone direct fatalities

- 1963-2012



Flash Floods. Riverine Flooding.

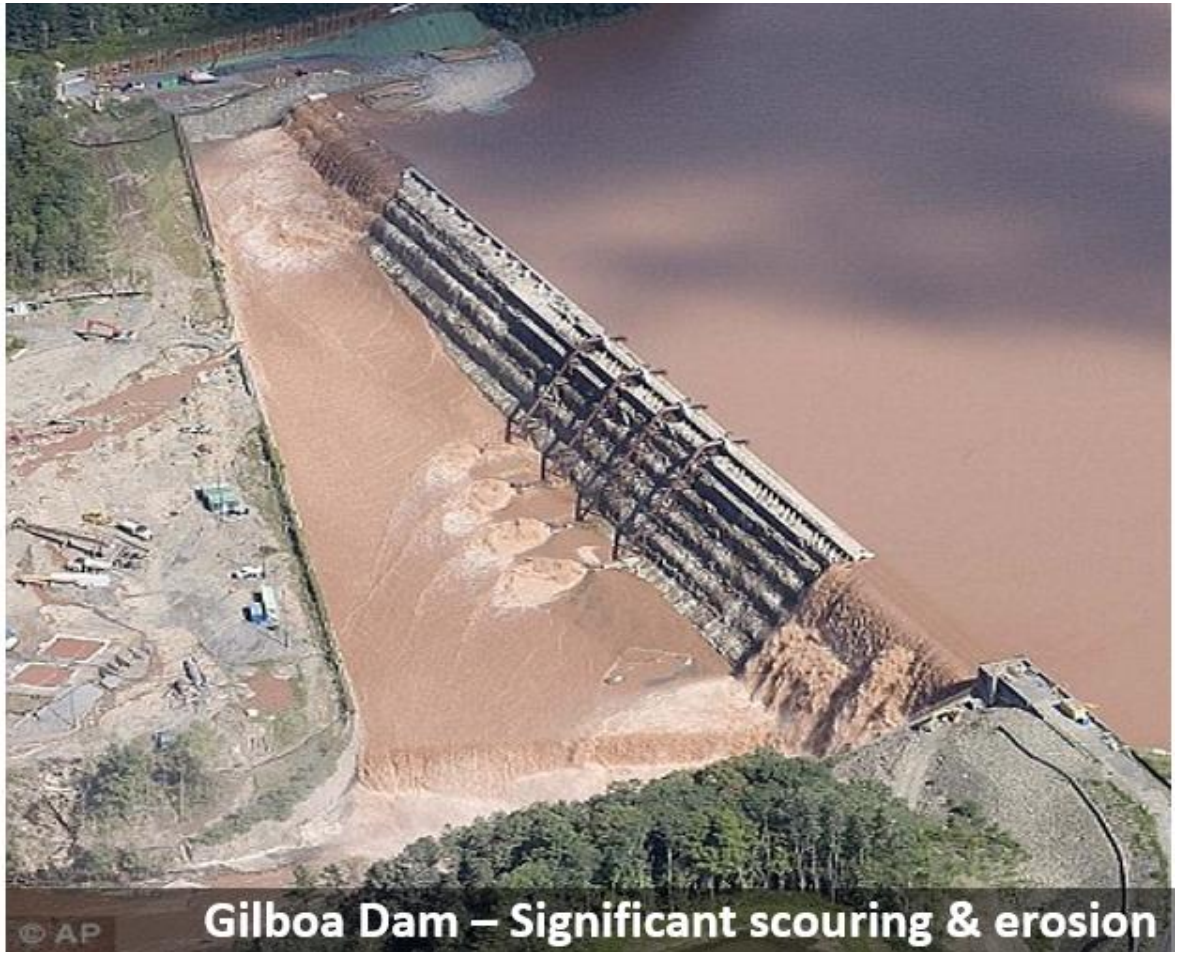
TS Allison (2001)– I-10

Hurricane Harvey (2017) Flooding

Hurricane Harvey (2017) Flooding 2

Hurricane Irene (2011) Flooding

Hurricane Irene (2011) Flooding 2

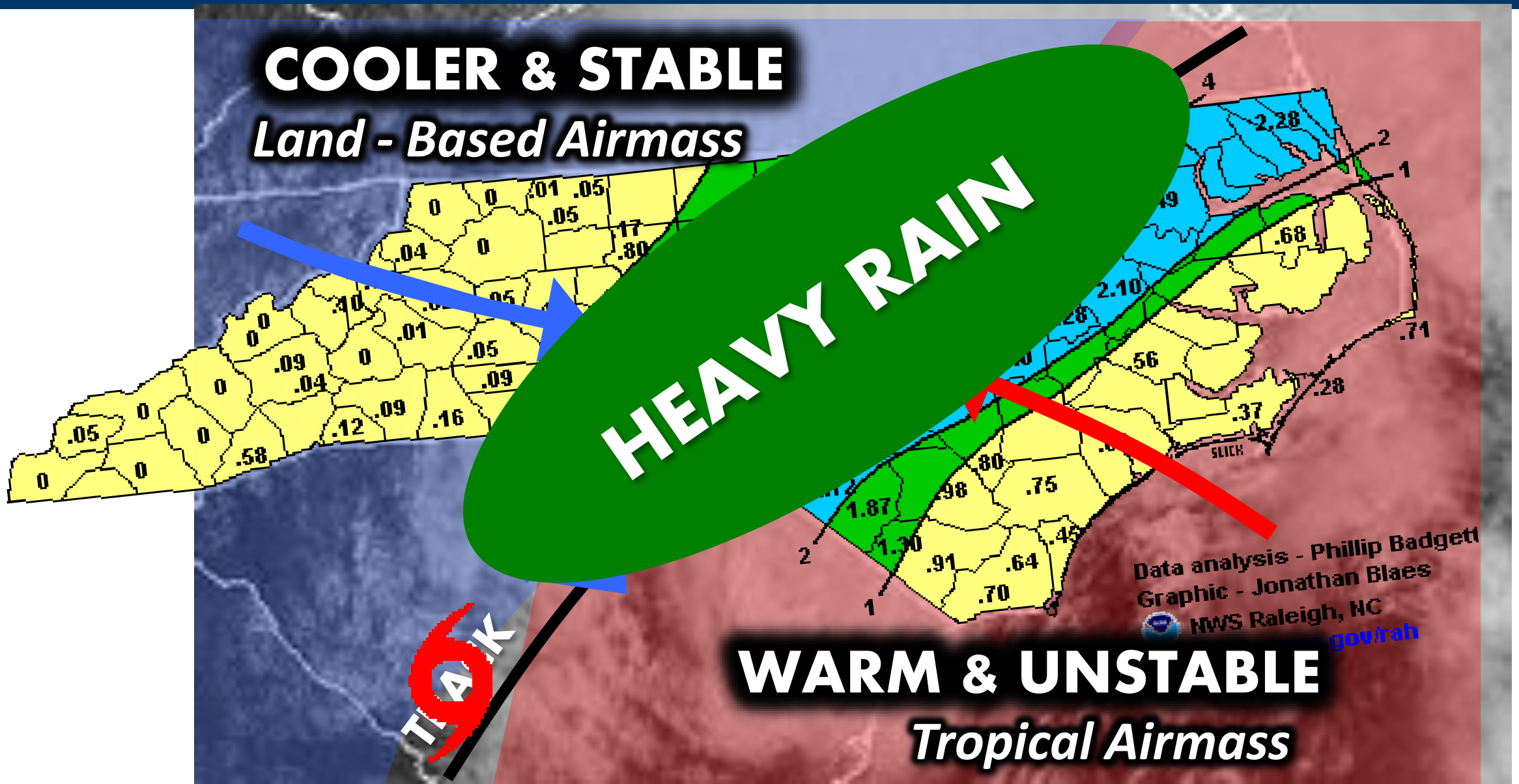


Factors Affecting Tropical Cyclone Rainfall

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

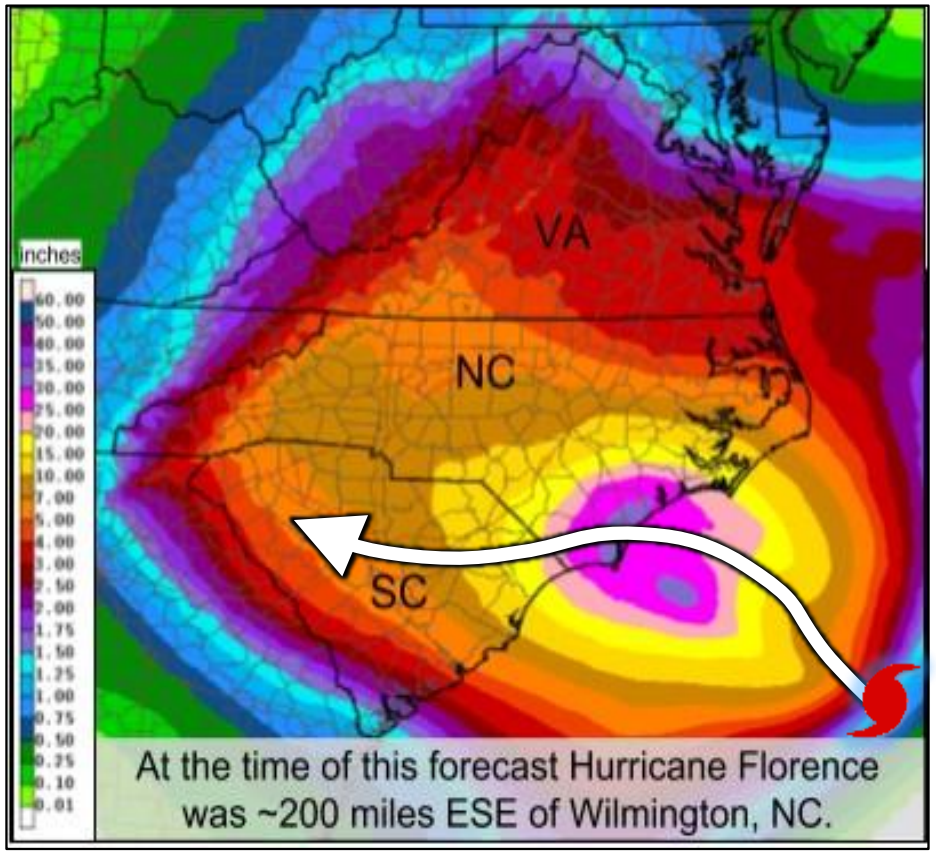
TS Alberto (2016)

FEMA

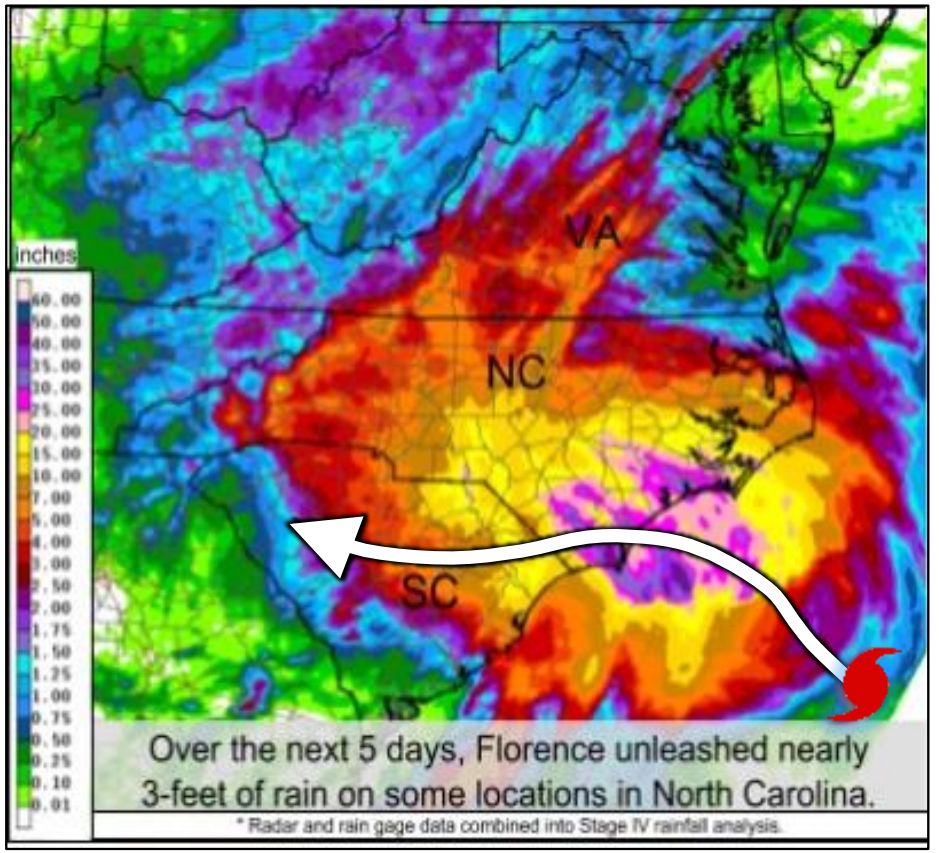


Hurricane Florence (2018)

5-Day Forecast vs. Observed Rainfall

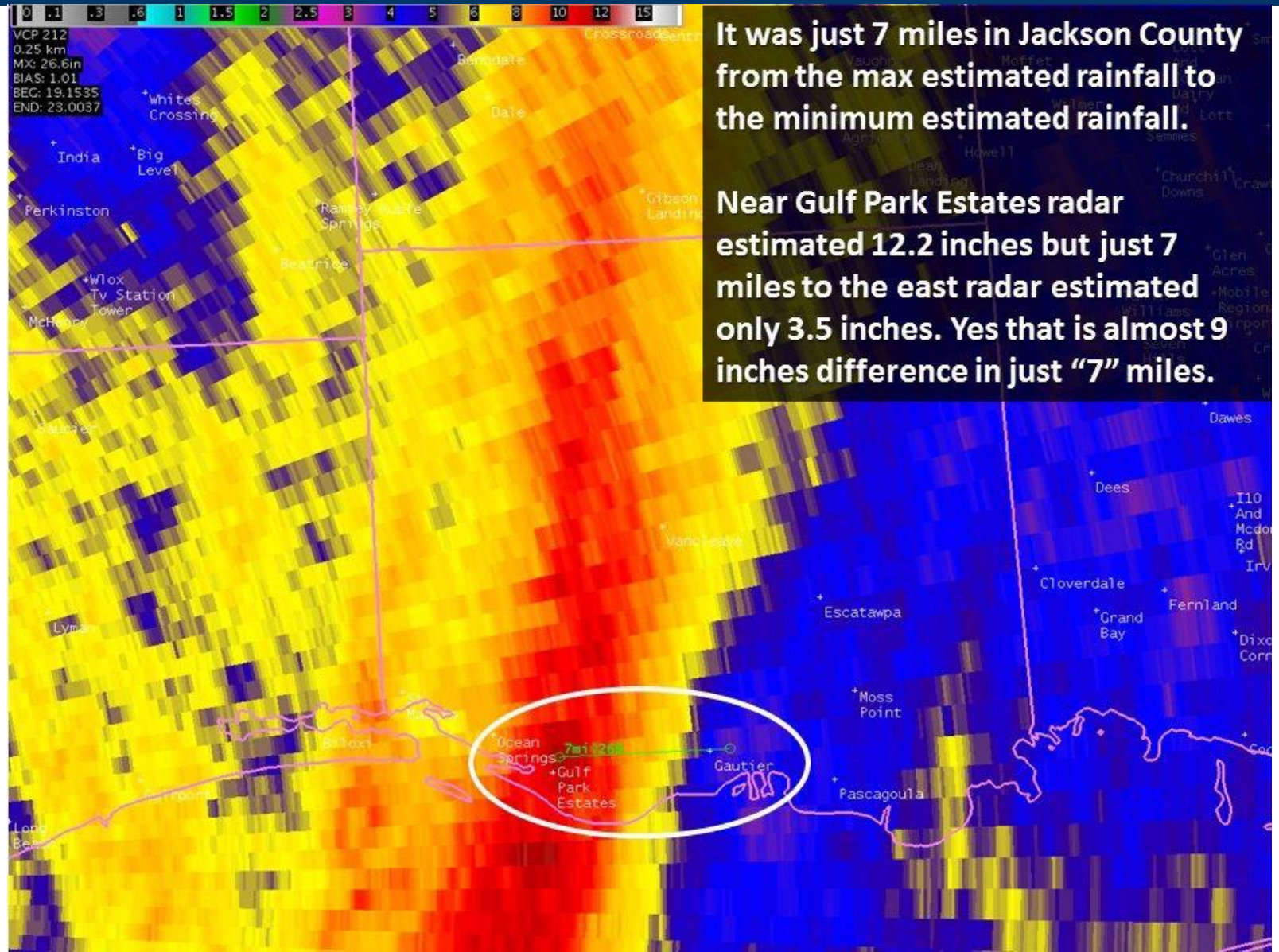


5-day Rainfall Forecast – Issued Sep 13, 2018

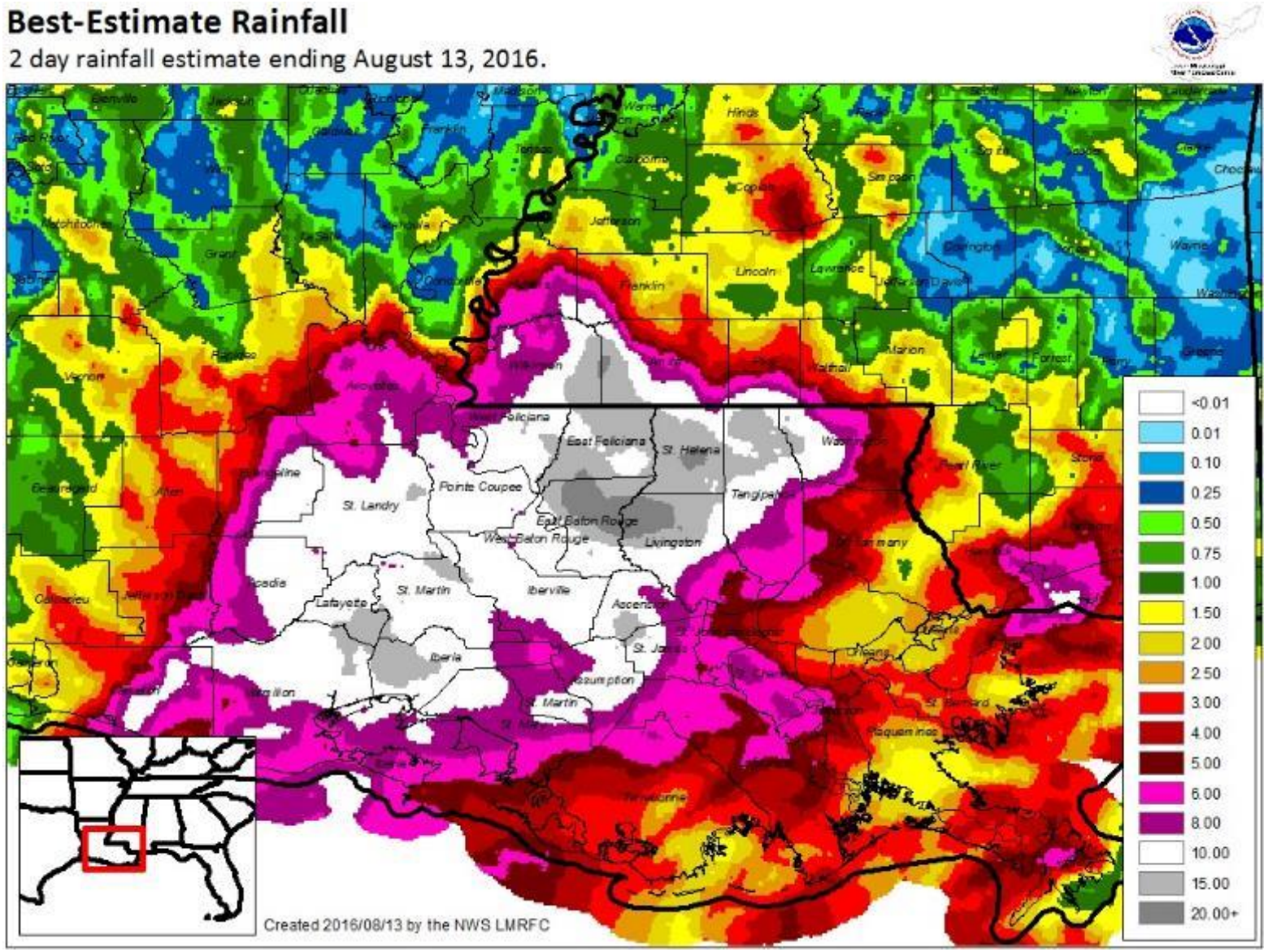


5-day Rainfall – Sep 13-18, 2018

TS Cindy (2017)



Unnamed Low (2016)



Landfalling Hurricanes Spawn Tornadoes

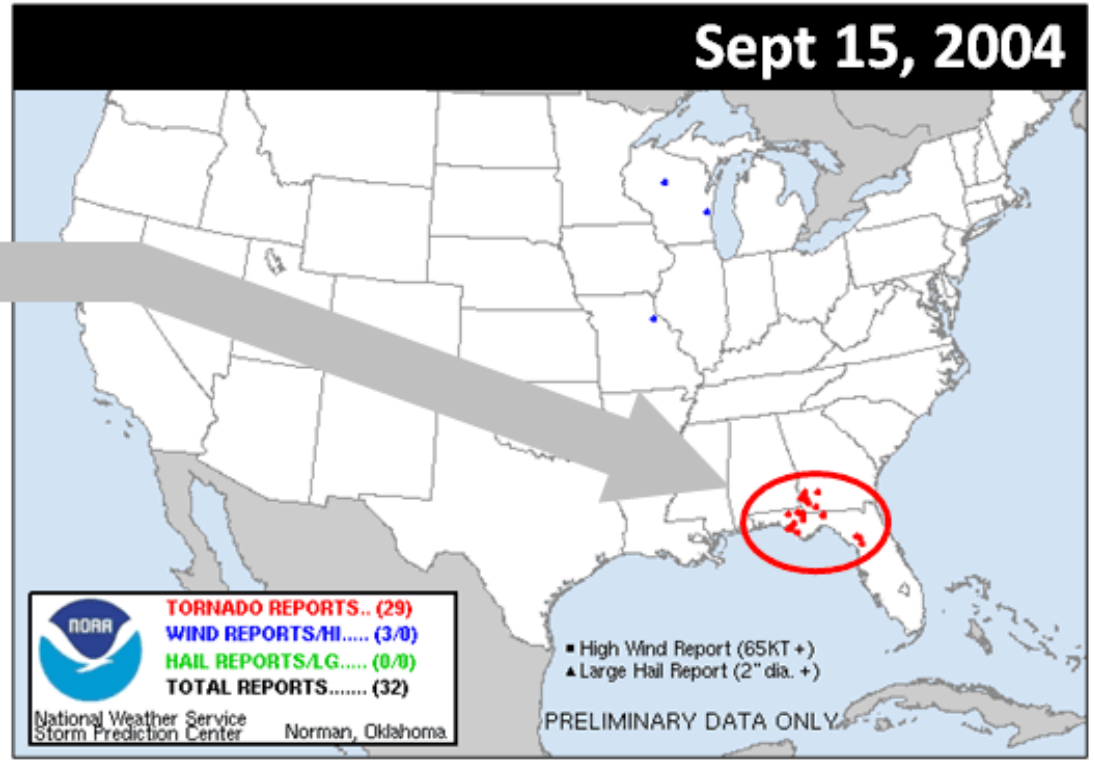
Tornadoes

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

Tornado "outbreak"

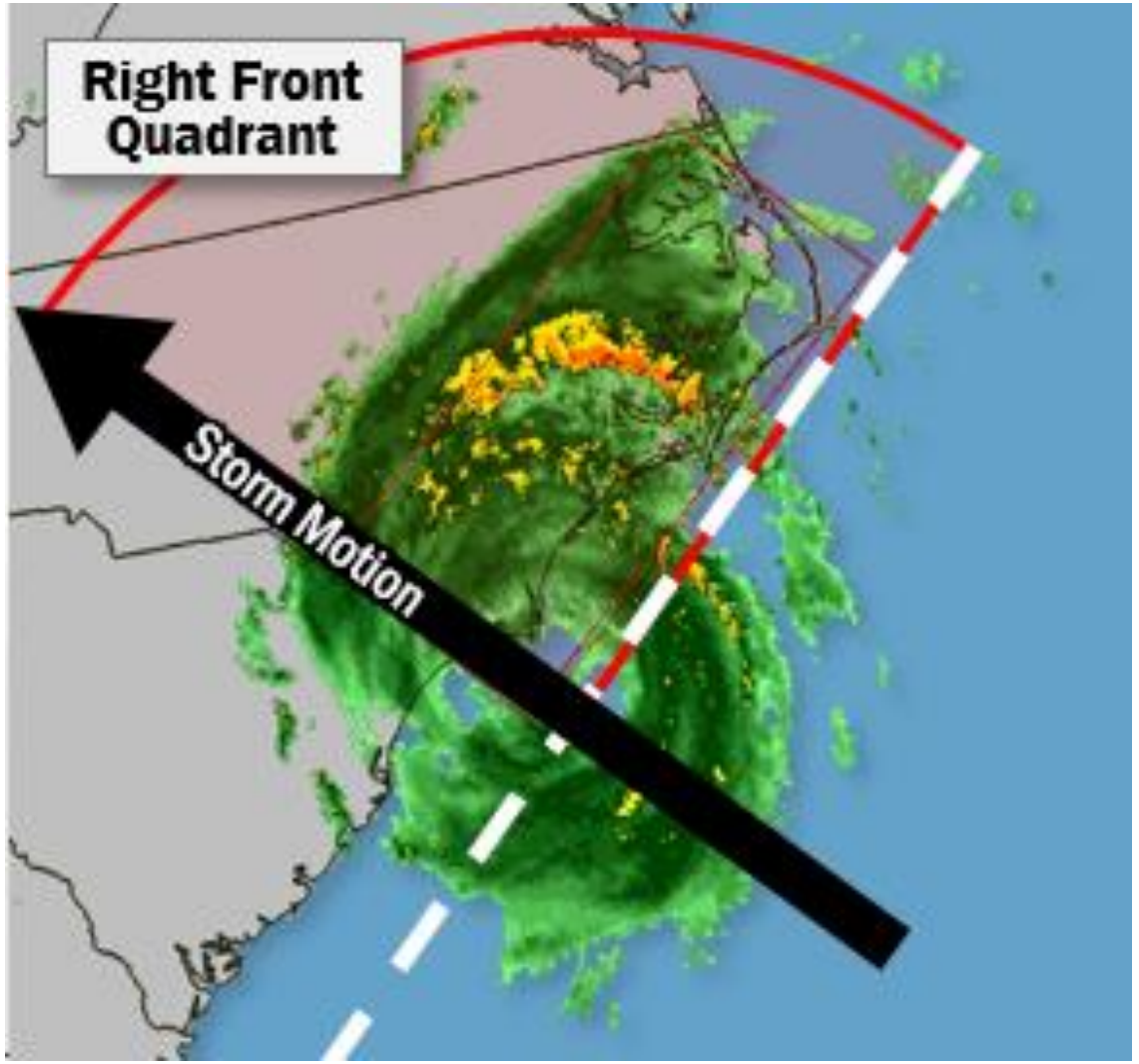
Hurricane Ivan (2004)

– 117 Tornadoes



Where Do They Spawn?

- Right front quadrant
- Friction over land creates low-level wind conditions favorable for the development of tornadoes



Waves and Rip Currents

Swells from a large hurricane can affect beaches of the entire western Atlantic

- **Hurricane Lorenzo (2019)**
  8 people drowned along U.S. East Coast in rip currents and hazardous surf
- **Hurricane Delta (2020)**
  2 people drowned along the NW Florida coast

Questions/Comments?