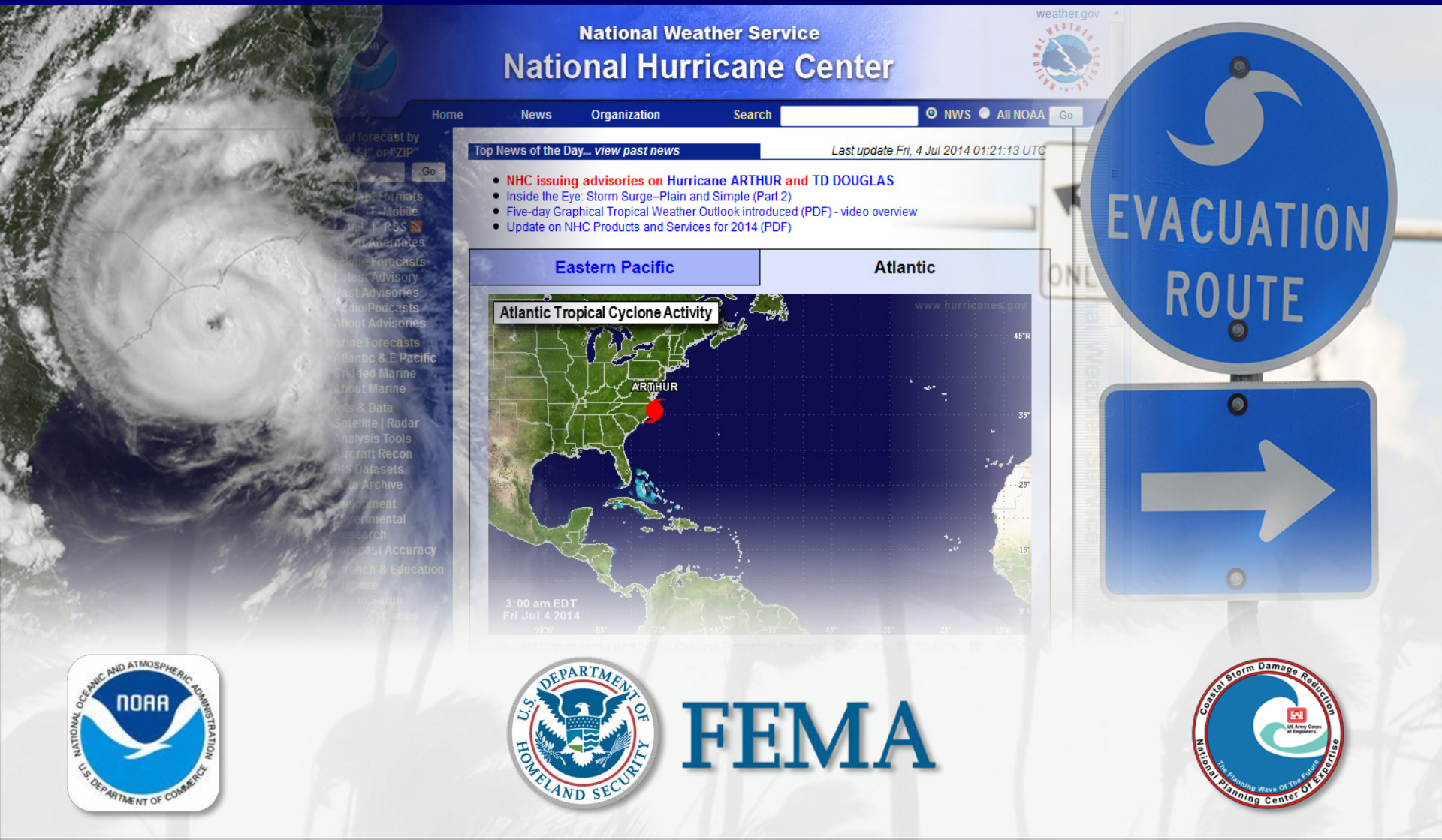
L-311

Hurricane Readiness



NOAA — National Oceanic and Atmospheric Administration — U.S. Department of Commerce

U.S. Department of Homeland Security — FEMA

Coastal Storm Damage Reduction — National Planning Center Of Expertise — The Planning Wave Of The Future

L-311

Administrative Details

- **Course application – FF119-25-2**
  - Must have an SID# (replaces SSN)
  - Include your email address
  - Sign the application
- **EMI Evaluation Form (scantron)**
  - Evaluate instruction and content
  - Provide comments and suggestions
- **EMI certificate**
  - Must attend the entire course to receive credit
  - EMI certificates will be sent via email

L-311

FEMA Student Identification (SID)

https://cdp.dhs.gov/femasid

- **Click on "Register for a FEMA SID"**
  - Follow instructions and you *will receive an email with your SID #*
- **If you think you have an SID**
  - Call 866-291-0696

L-311

Evaluations

Appropriate wording includes;

"This has been the best learning experience!"

"The instructors totally blew me away with their insightful knowledge and presentation skills."

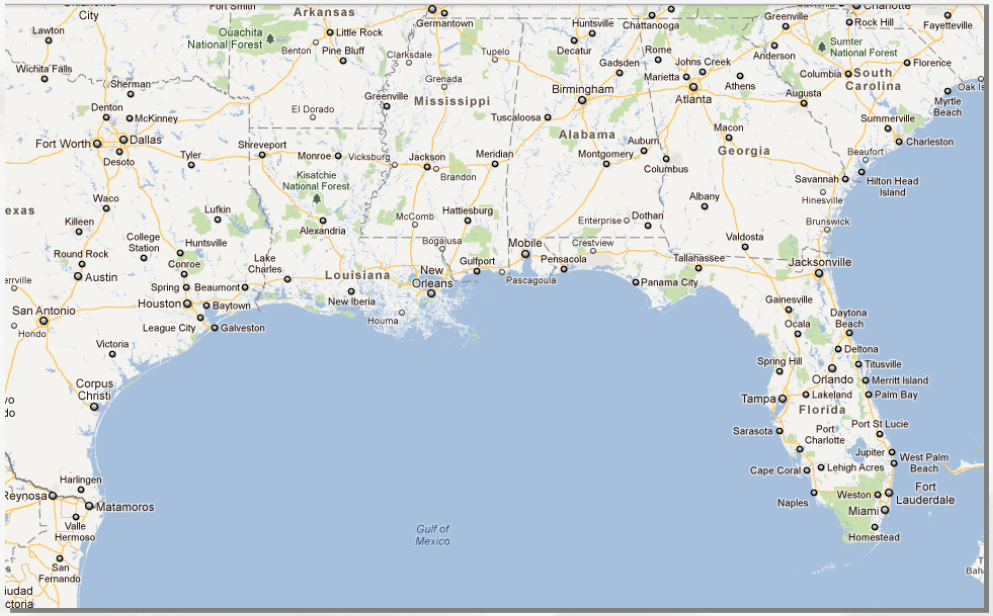
"I feel 1000% ready for the next hurricane threat."

"You had me at "hurricanes."

L-311

State Codes

- **Texas** **49**
- **Louisiana** **22**
- **Mississippi** **29**
- **Alabama** **02**
- **Florida** **12**
- **Georgia** **13**
- **South Carolina** **45**
- **North Carolina** **31**
- **Virginia** **51**
- **Maryland** **24**
- **DC** **10**



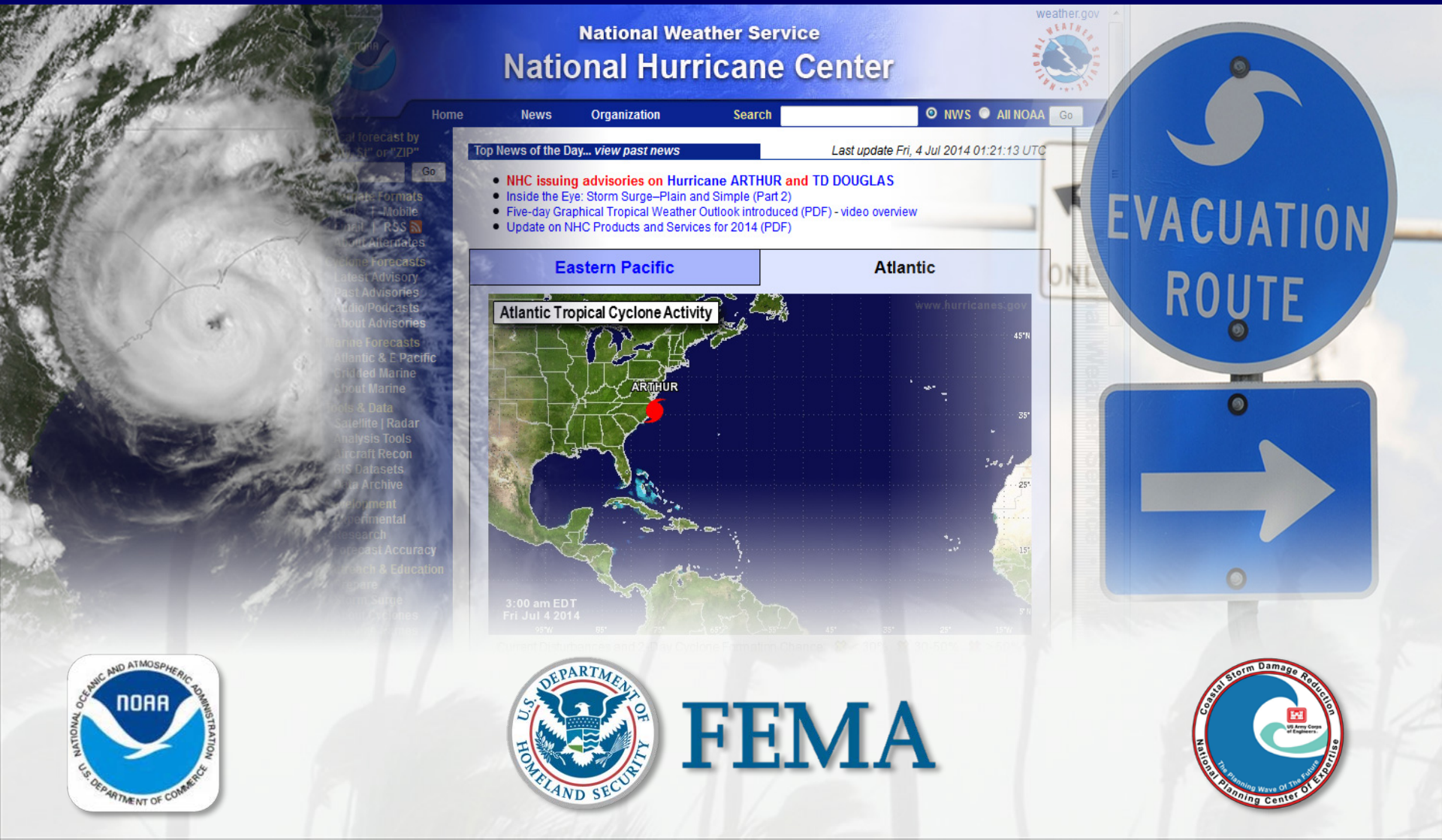
L-311

State Codes

- Connecticut 8
- Delaware 11
- Maryland 24
- Maine 25
- Massachusetts 23
- New Hampshire 34
- New Jersey 35
- New York 38
- Pennsylvania 42
- Puerto Rico 43
- Virgin Islands 52
- Vermont 53

L-311

Hurricane Readiness



NOAA — National Oceanic and Atmospheric Administration — U.S. Department of Commerce

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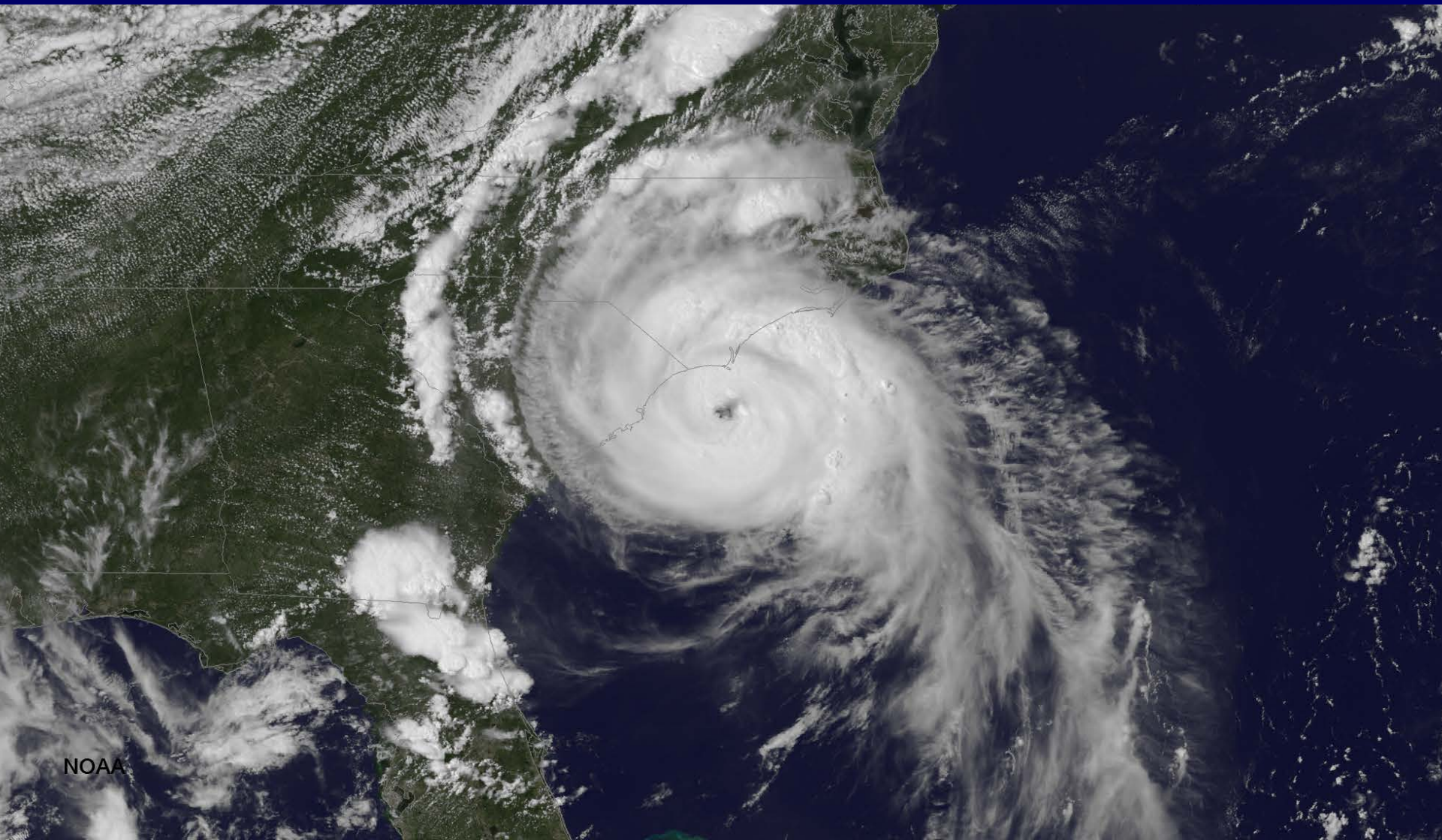
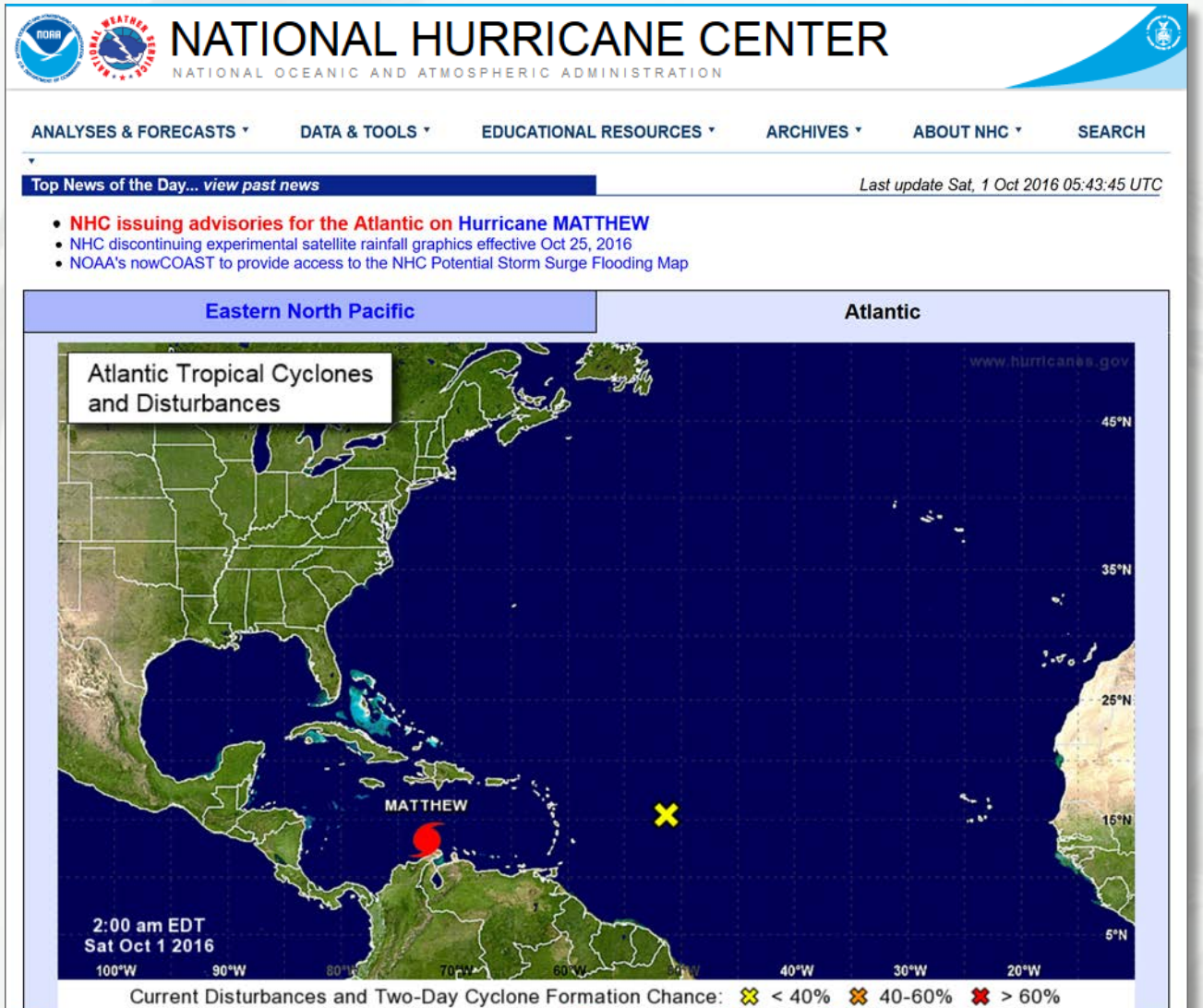
L-311

Hurricane Basics



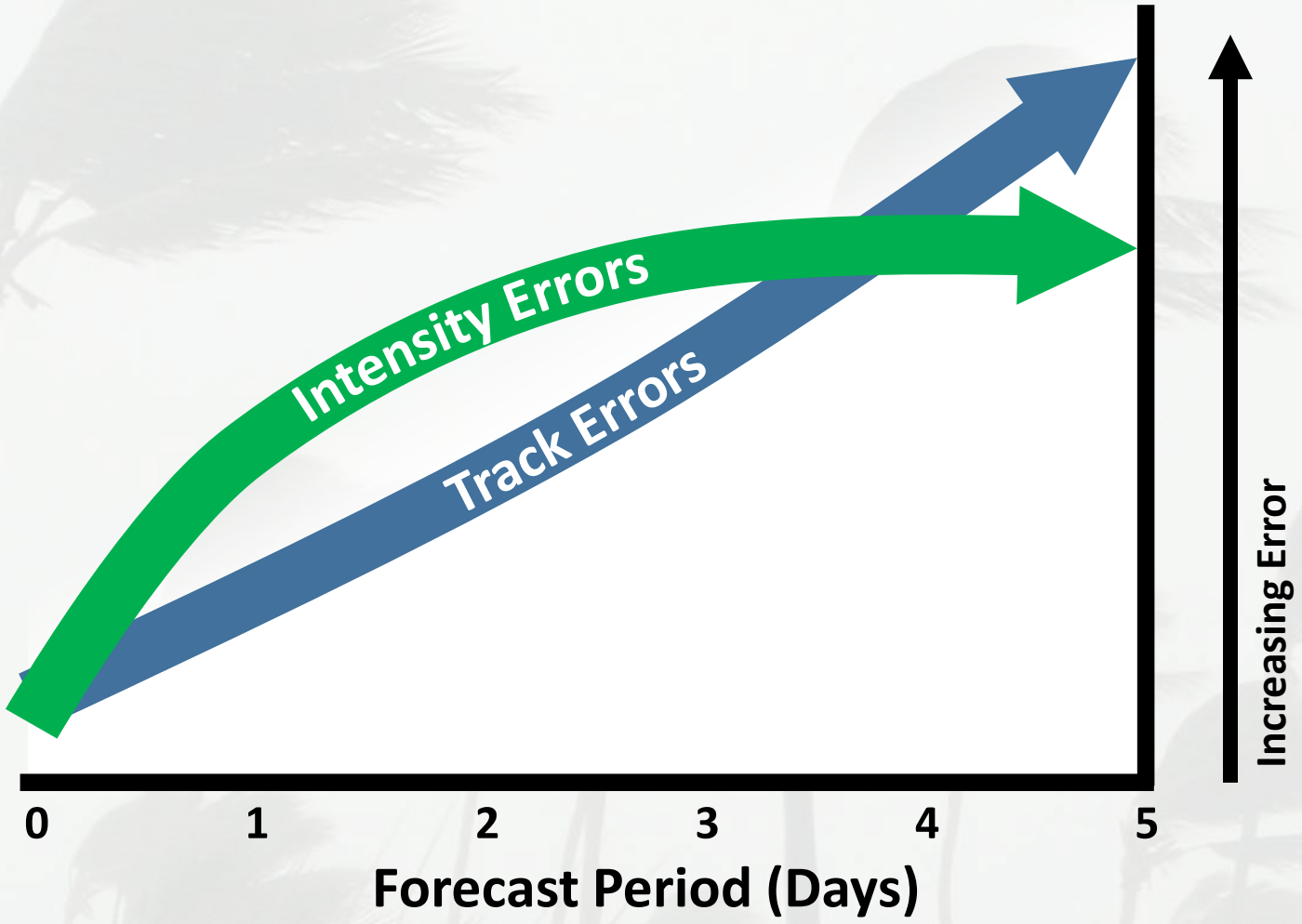
L-311

There is a Storm. What's the Info?



L-311

Forecast Uncertainty. What, Me Worry?



L-311

Making Better Decisions

L-311

Agenda

830 AM - 10 AM

Hurricane Basics: Lifecycle, Climatology and Hazards

1030 AM - Noon

There is a Storm. What's the Info?

130 PM - 3 PM

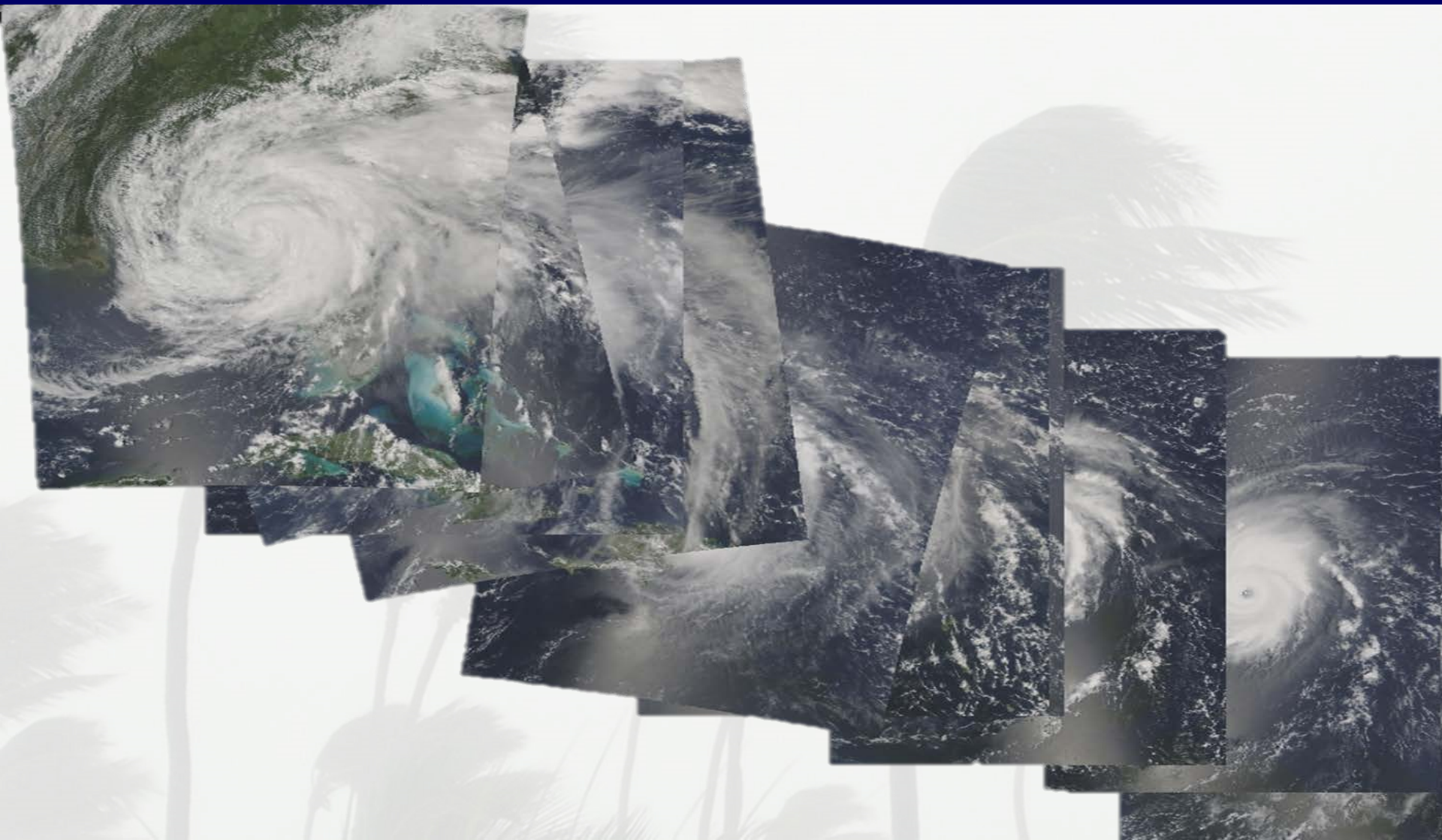
Forecast Uncertainty. What, Me Worry?

330 PM - 5 PM

Making Better Decisions

Hurricane Basics

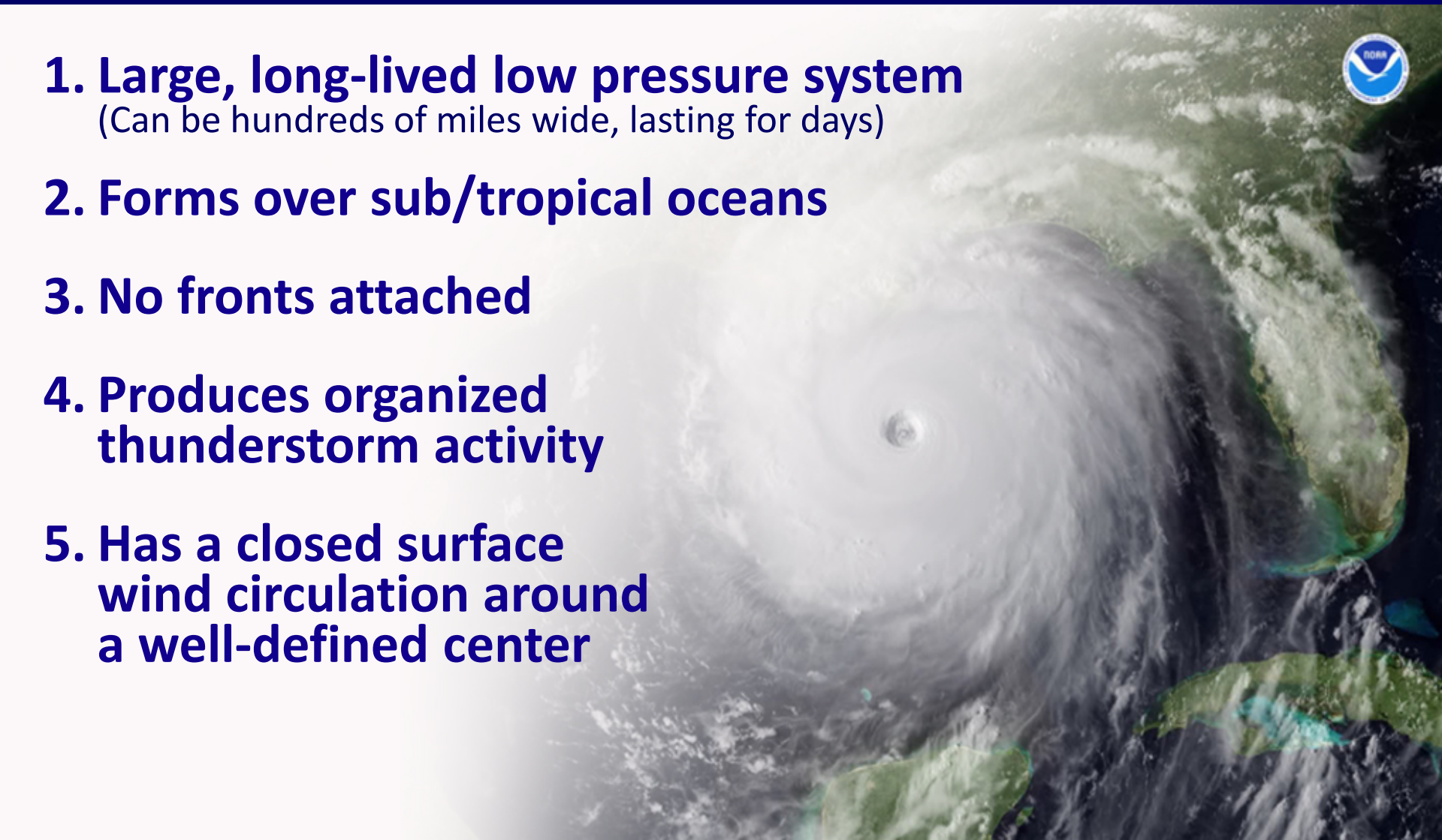
Life Cycle. Climatology. Hazards.



Tropical Cyclones

Hurricane. Typhoon. Tropical Storm.

1. **Large, long-lived low pressure system**
   (Can be hundreds of miles wide, lasting for days)
2. **Forms over sub/tropical oceans**
3. **No fronts attached**
4. **Produces organized thunderstorm activity**
5. **Has a closed surface wind circulation around a well-defined center**



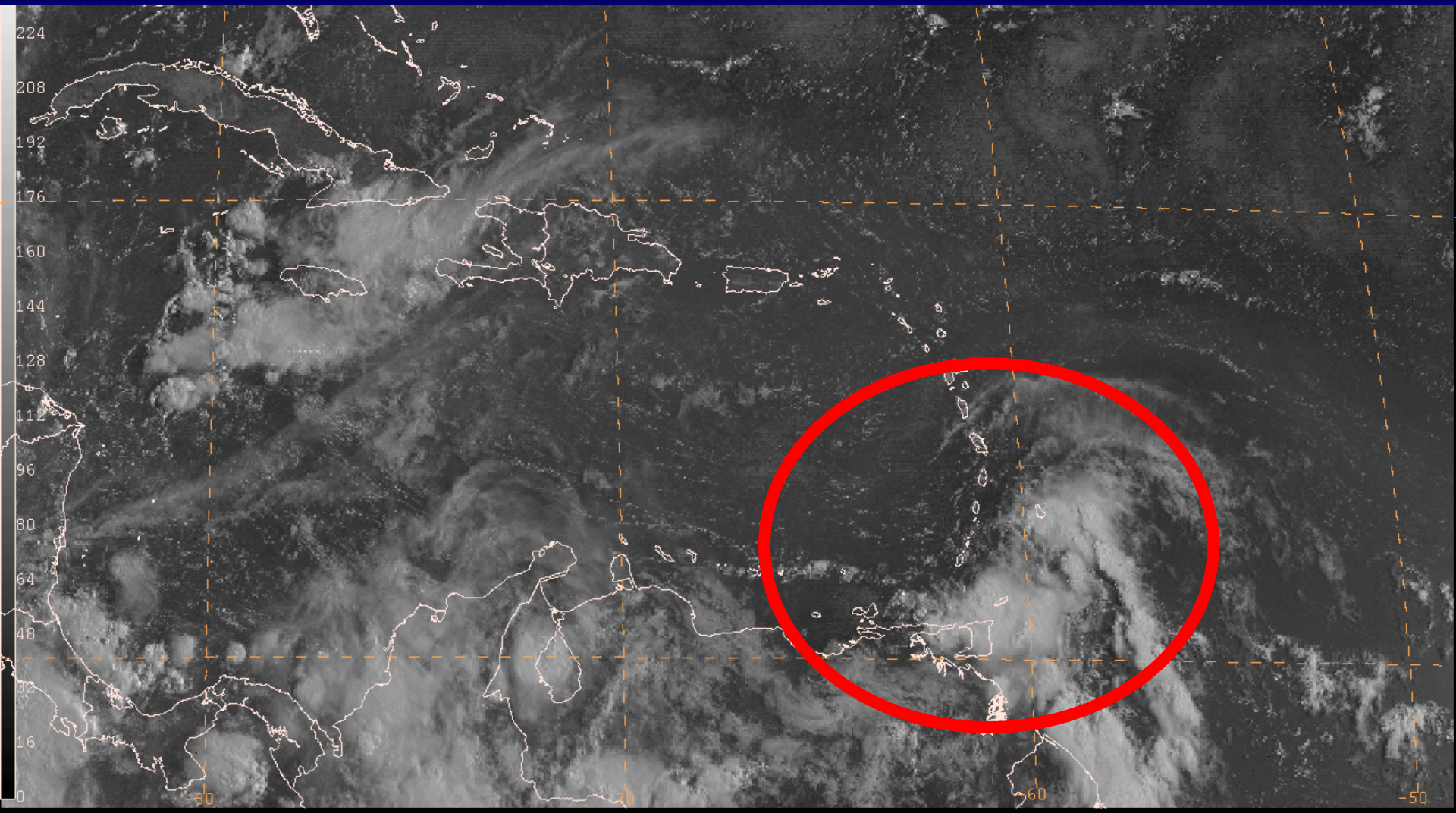
Tropical Cyclones

Classified by Maximum Wind Speed

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

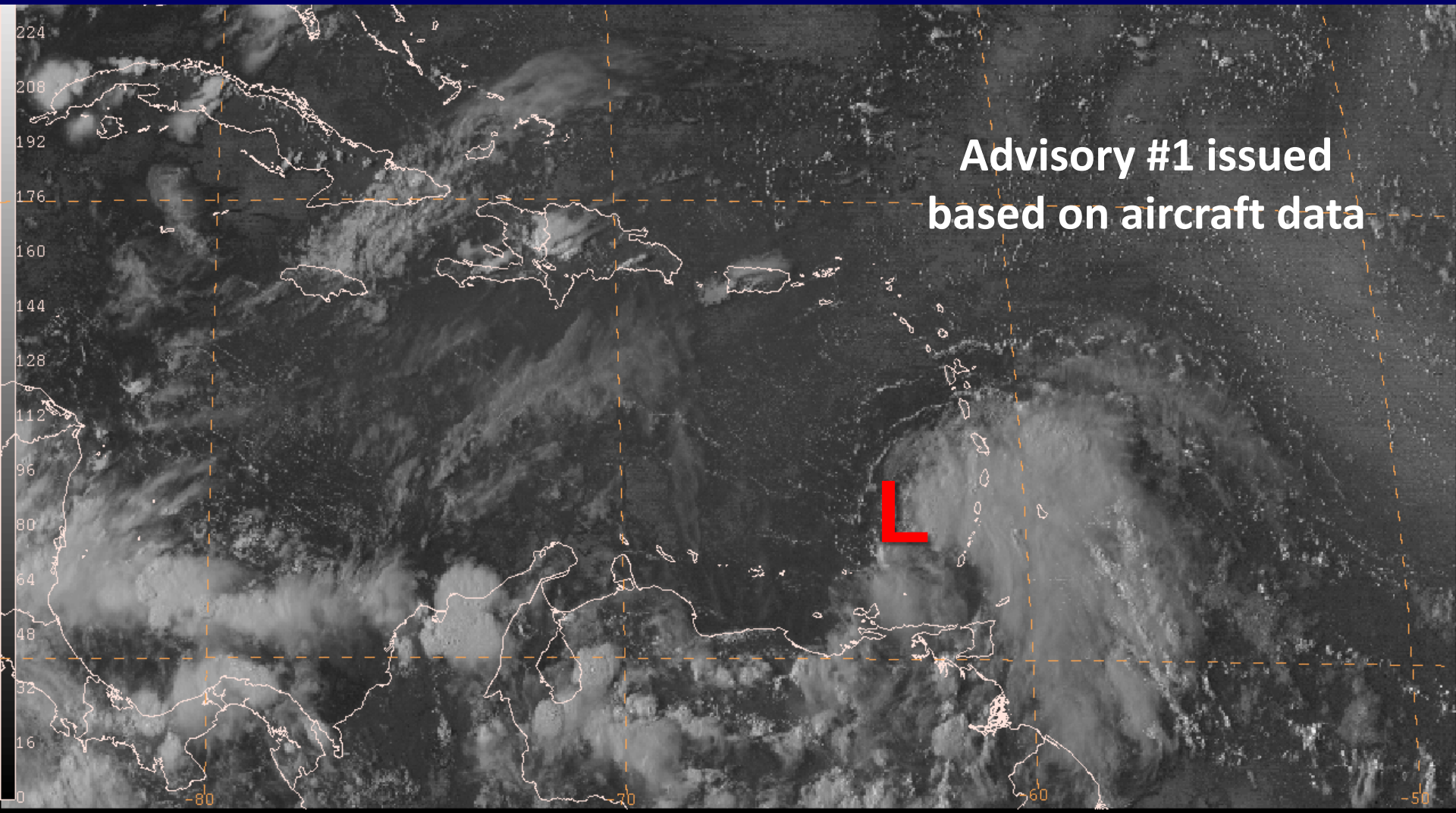
Tropical Cyclones

Surface Circulation? Organized?



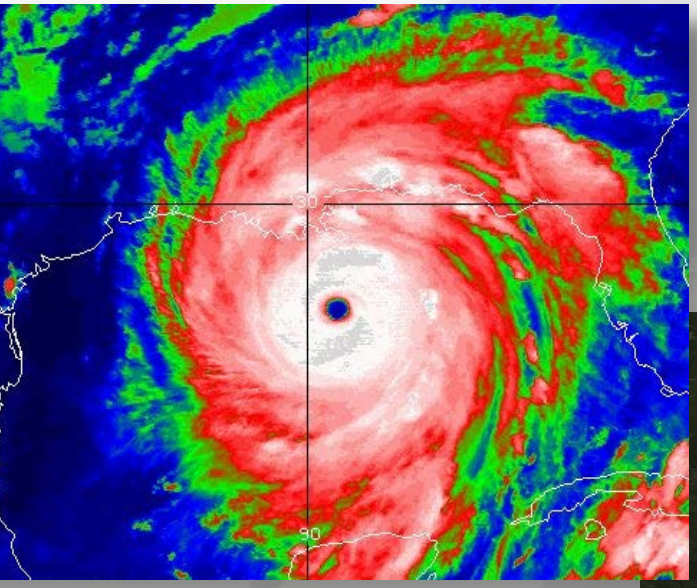
Tropical Cyclones

Ernesto 2006

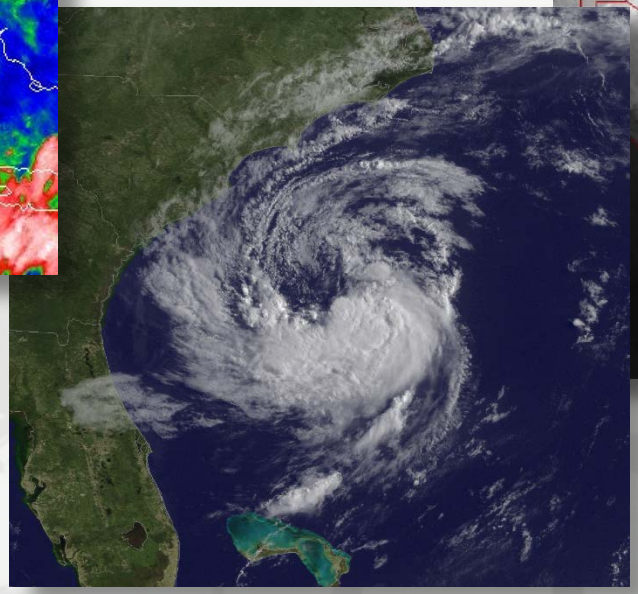


Cyclones

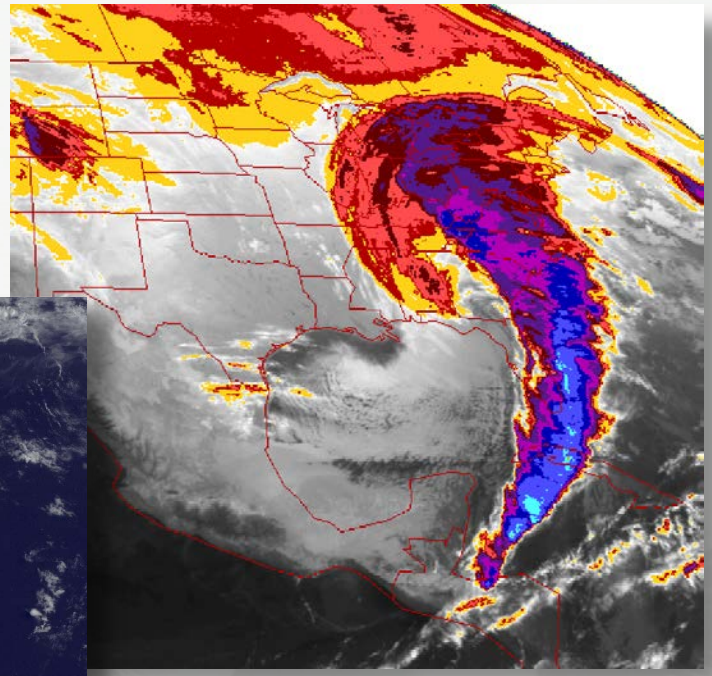
Tropical, Subtropical and Extratropical



Hurricane Katrina 2005



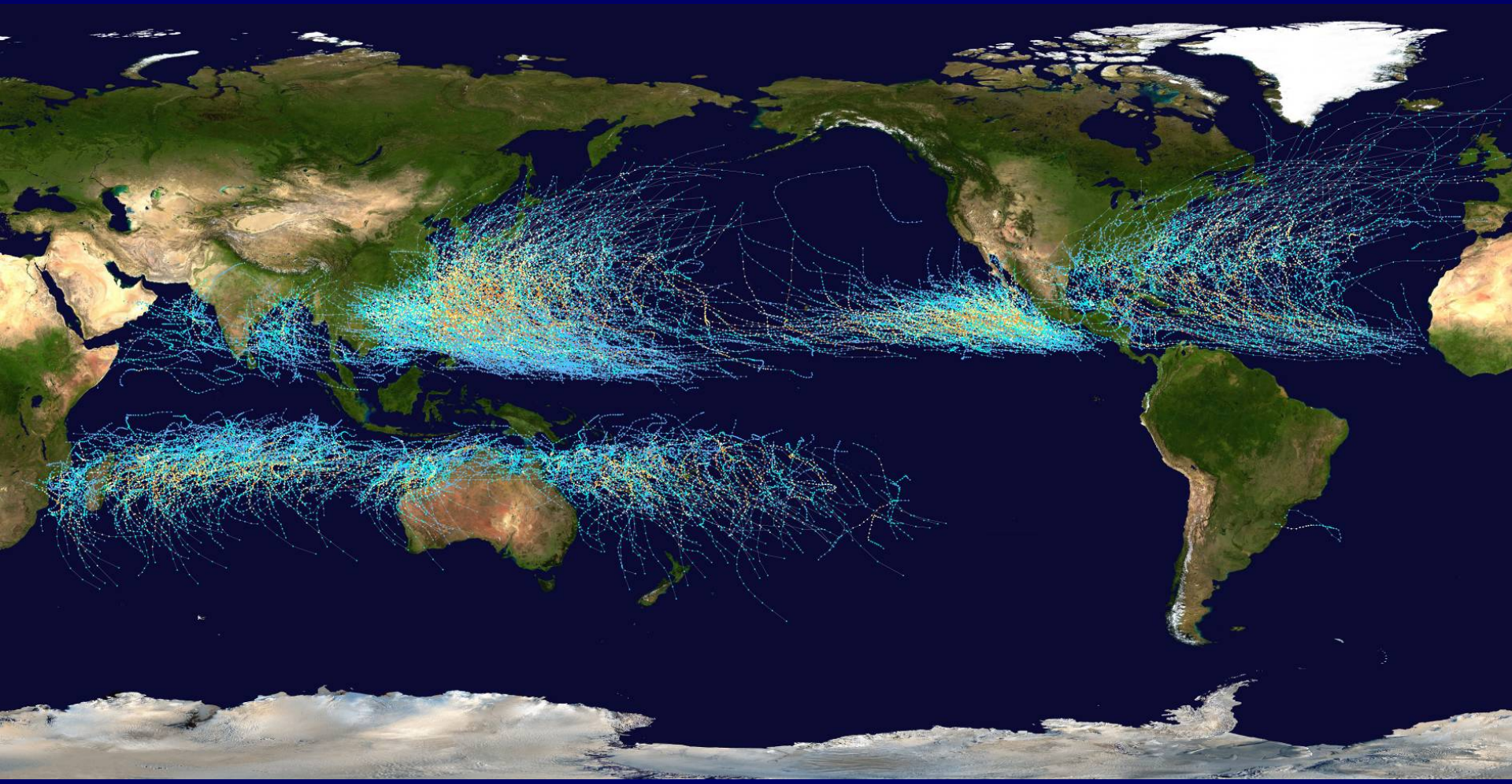
Subtropical Storm Ana 2015



March Superstorm 1993

Tropical Cyclones

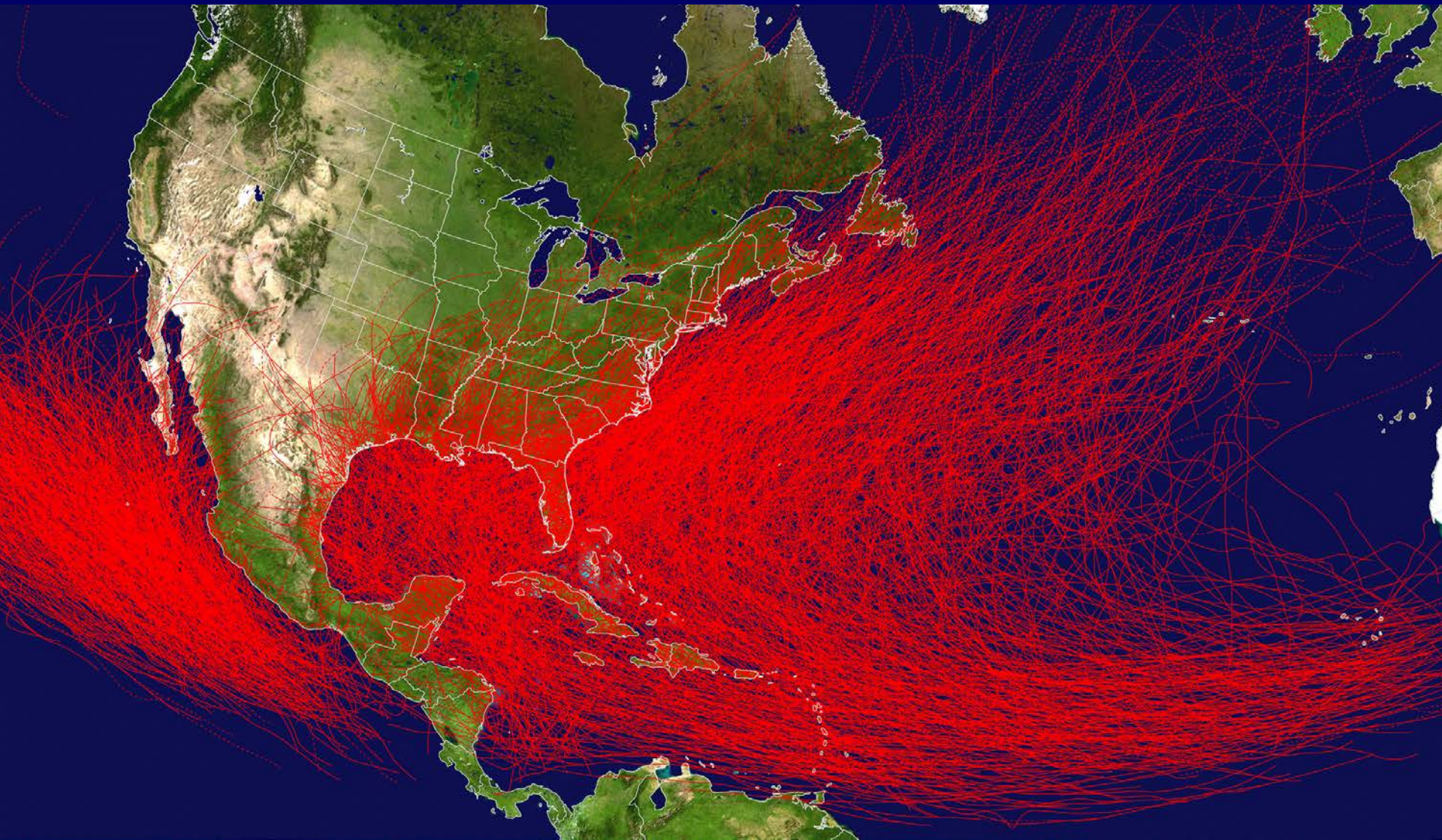
Tropics / Subtropics around the World



Tropical cyclone tracks 1985 – 2005

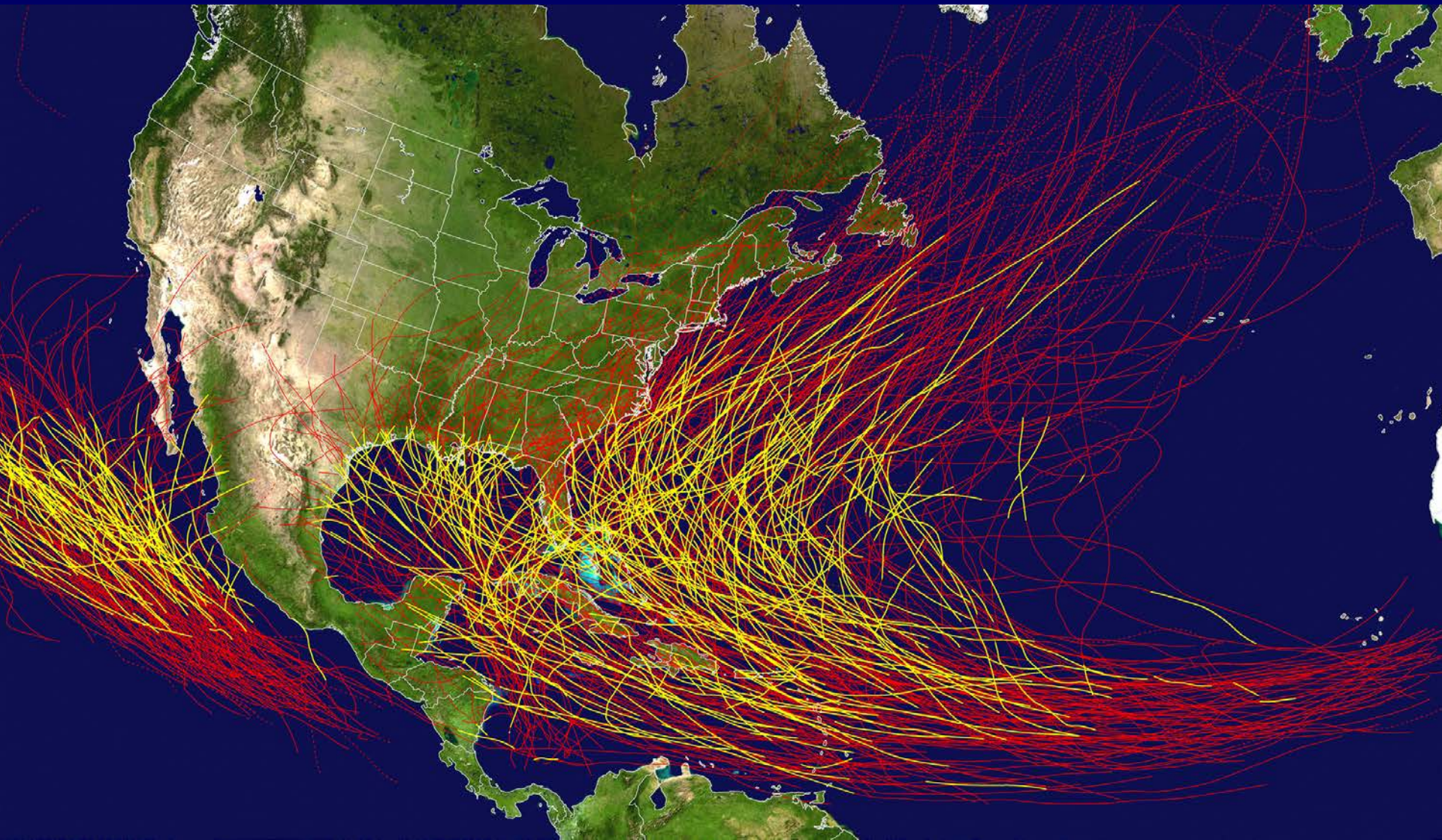
Tropical Cyclones

Atlantic since 1851. Pacific since 1949.



Major Hurricanes

Atlantic since 1851. Pacific since 1949.



Hurricane Quiz

What month has the most hurricane activity in the Atlantic?

A. December

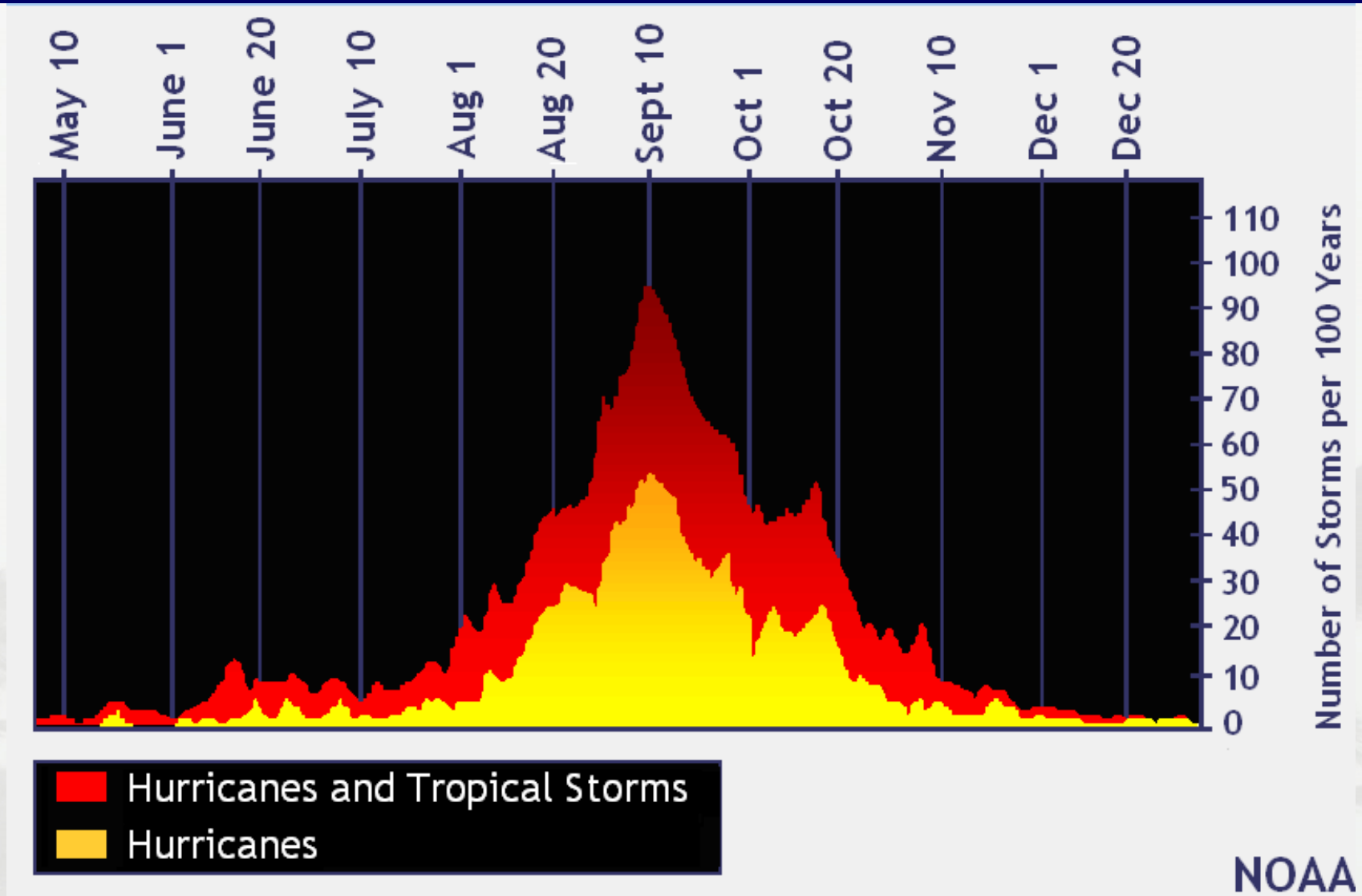
B. August

C. June

D. September

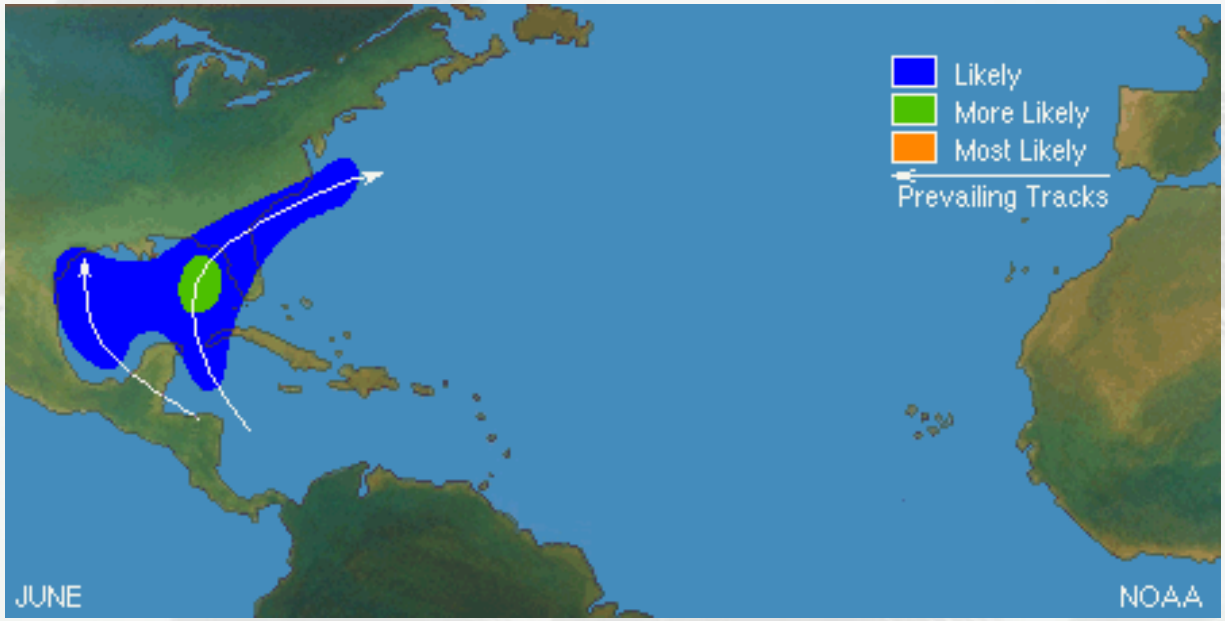
Climatology

Atlantic Hurricanes & Tropical Storms



Climatology

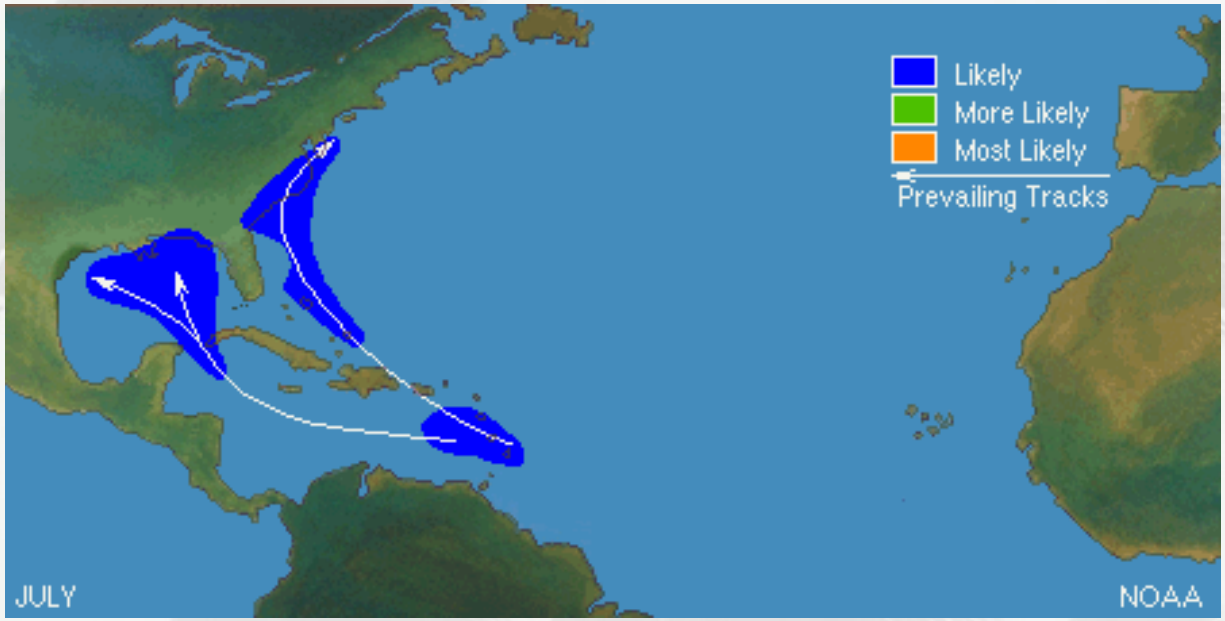
June Formation Areas



- **On average about 1 storm every other year.**
- **Most June storms form in the NW Caribbean Sea or Gulf of Mexico.**

Climatology

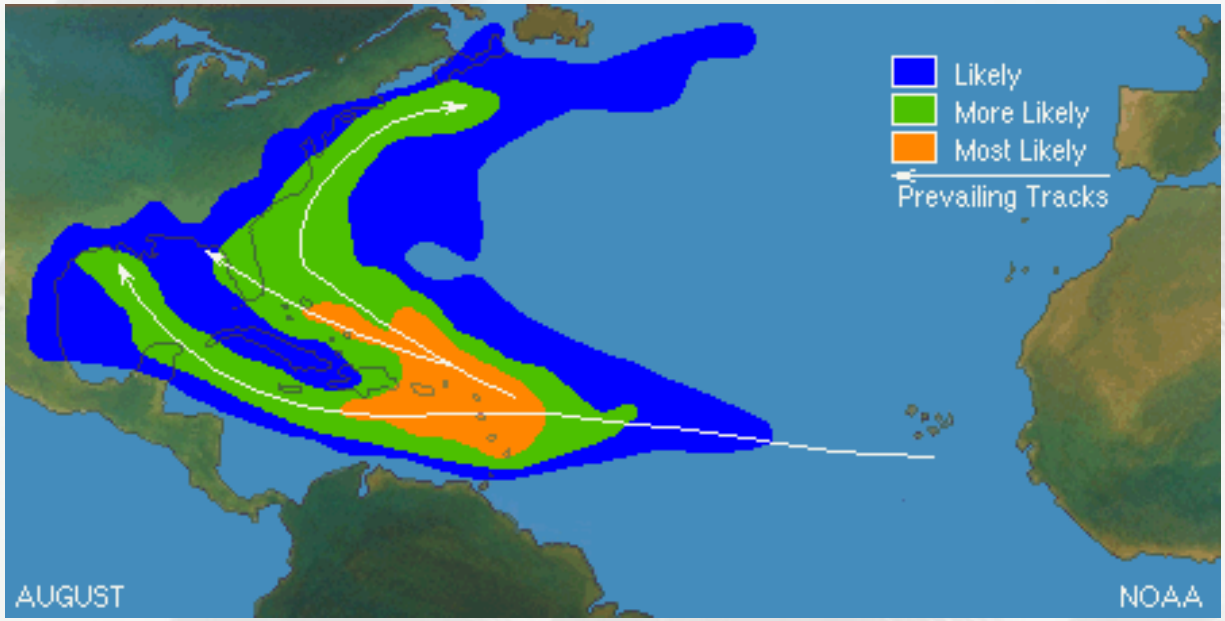
July Formation Areas



- **On average about 1 storm every year.**
- **July development areas spread east and covers the western Atlantic, Caribbean, and Gulf of Mexico.**

Climatology

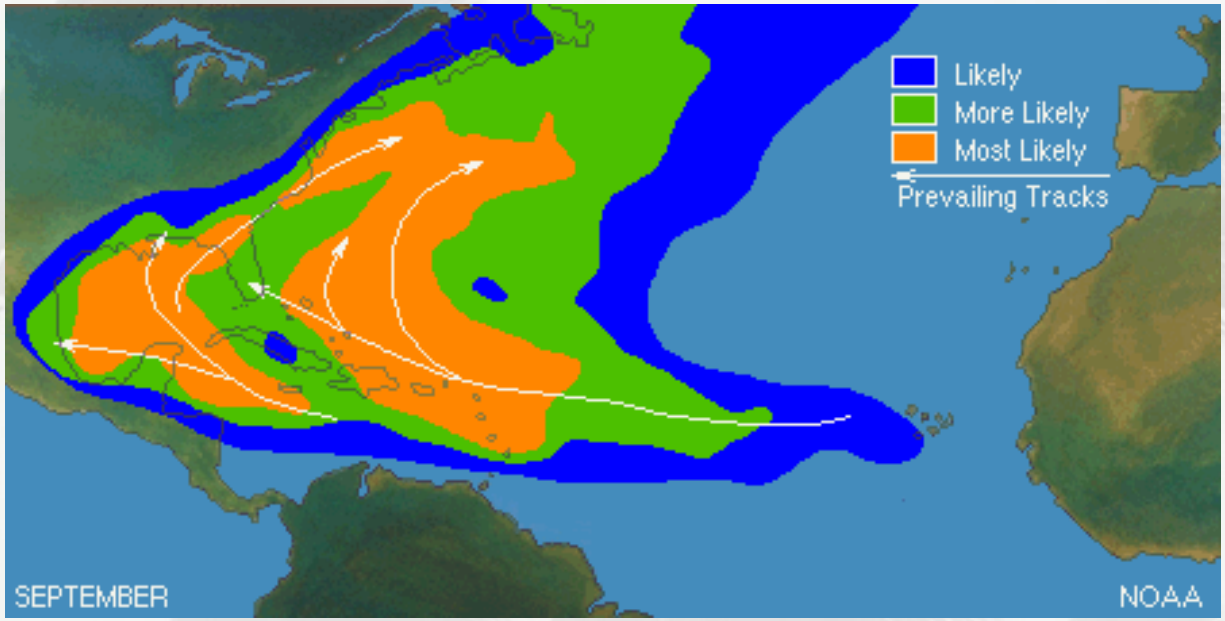
August Formation Areas



- **On average about 2-3 storms form each year.**
- **The Cape Verde season usually begins in August.**

Climatology

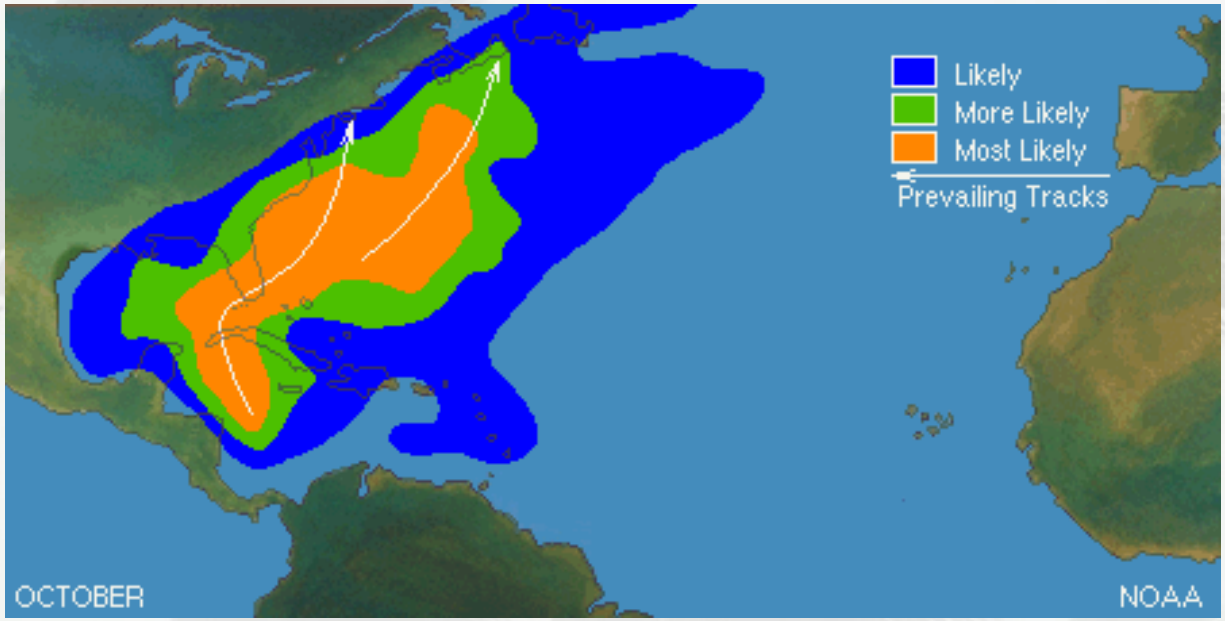
September Formation Areas



- **September is the climatological peak of the season.**
- **Storms can form nearly anywhere in the basin; Long track Cape Verde storms.**

Climatology

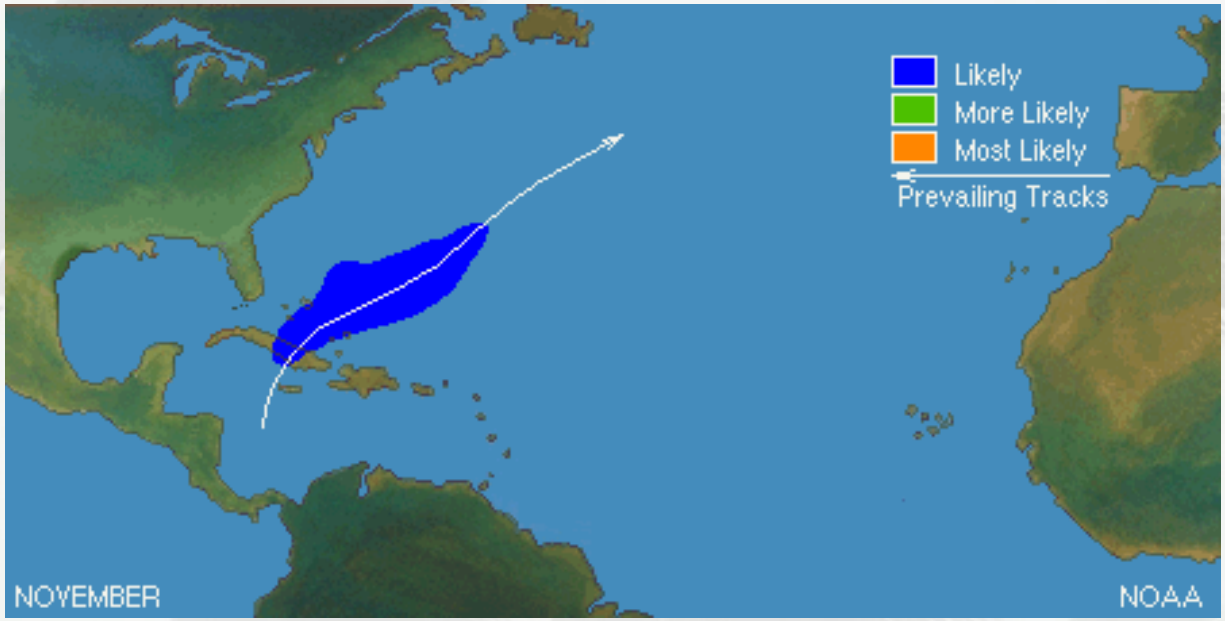
October Formation Areas



- **Secondary peak of season in mid-October.**
- **Cape Verde season ends. Development area shifts back to the Gulf, Caribbean and western Atlantic.**

Climatology

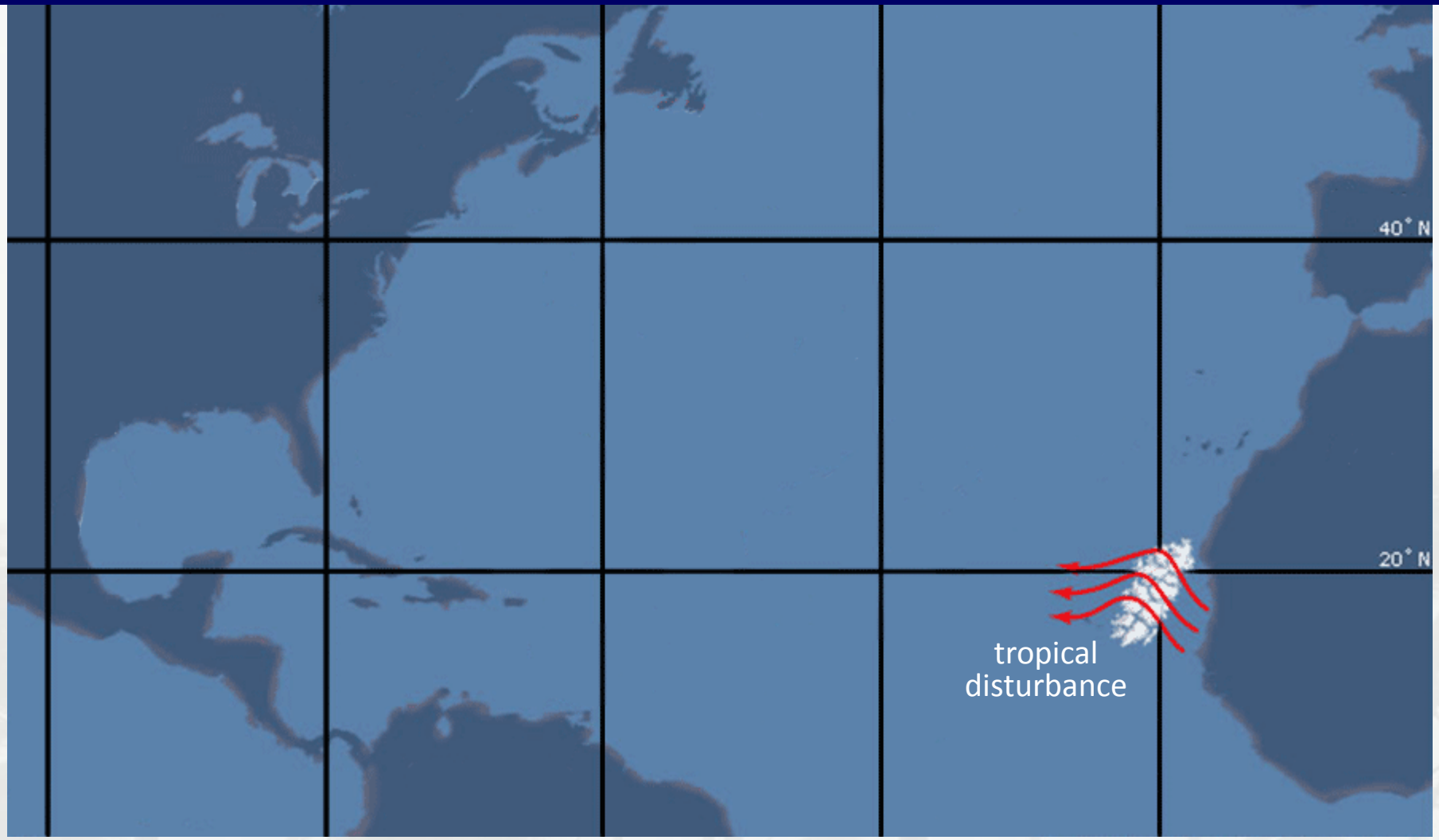
November Formation Areas



- **On average about 1 storm ever other year.**
- **Storms that do form typically develop in central Caribbean or western Atlantic.**

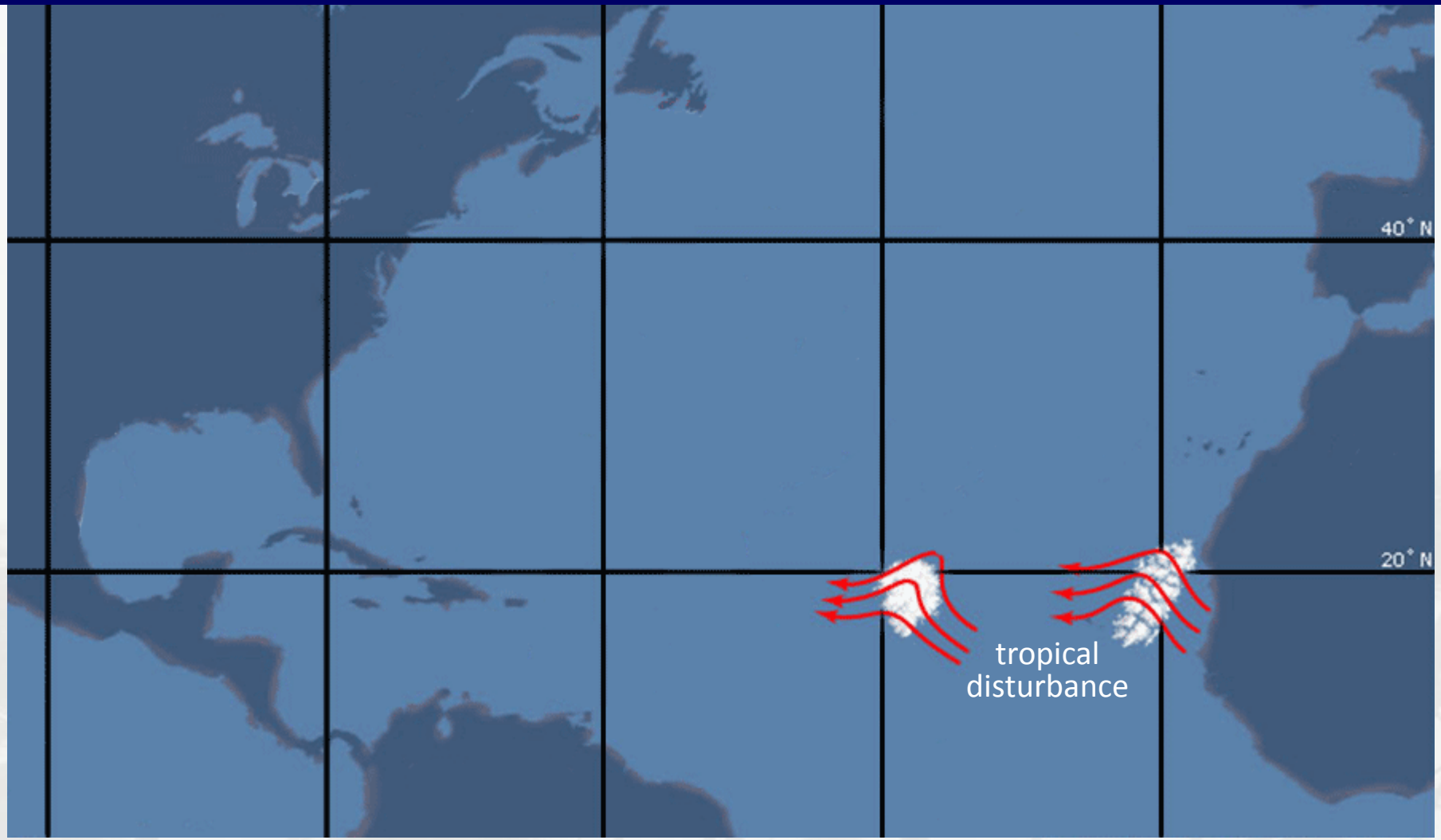
Hurricane Lifecycle

Cape Verde Hurricanes



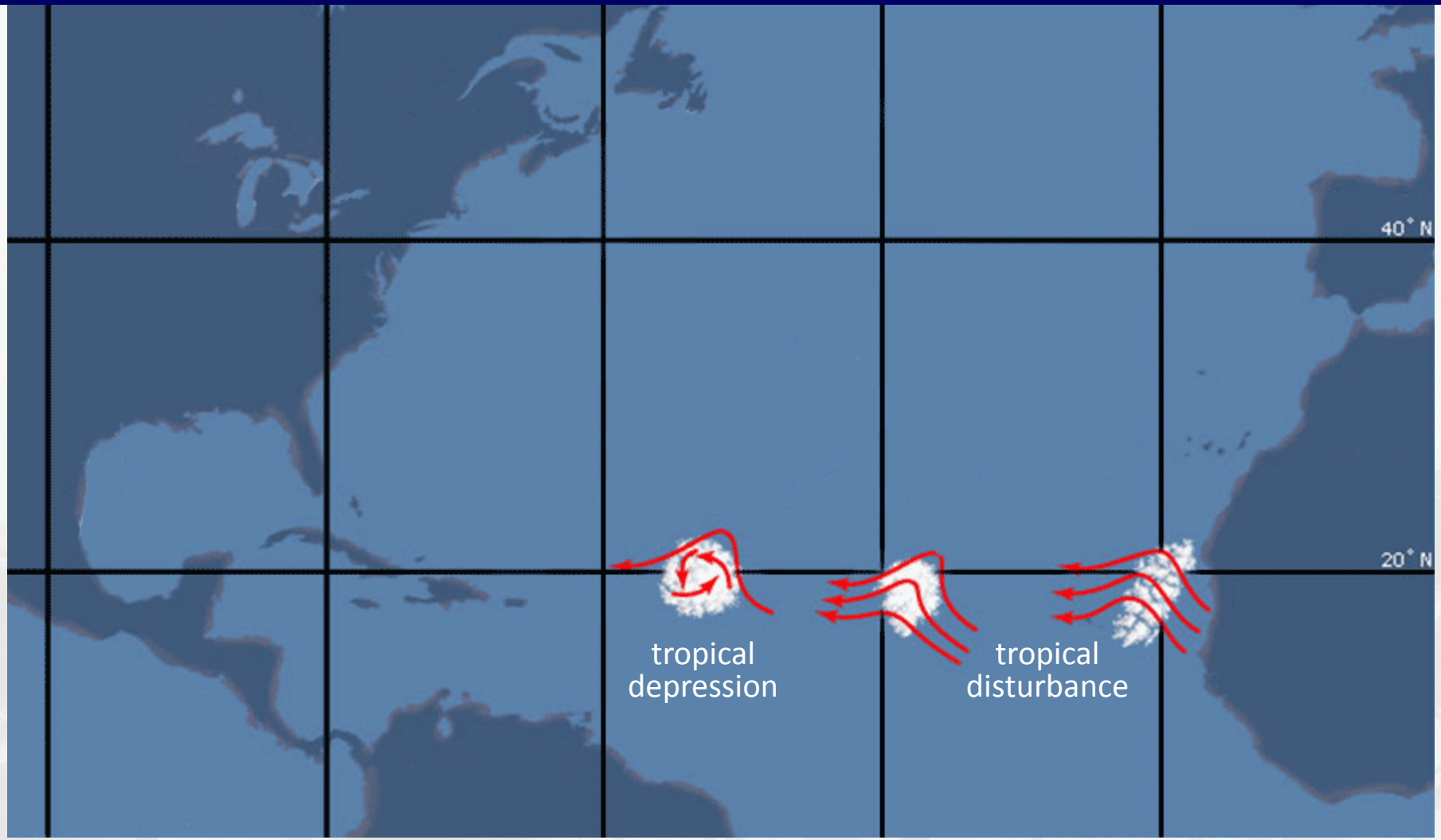
Hurricane Lifecycle

Cape Verde Hurricanes



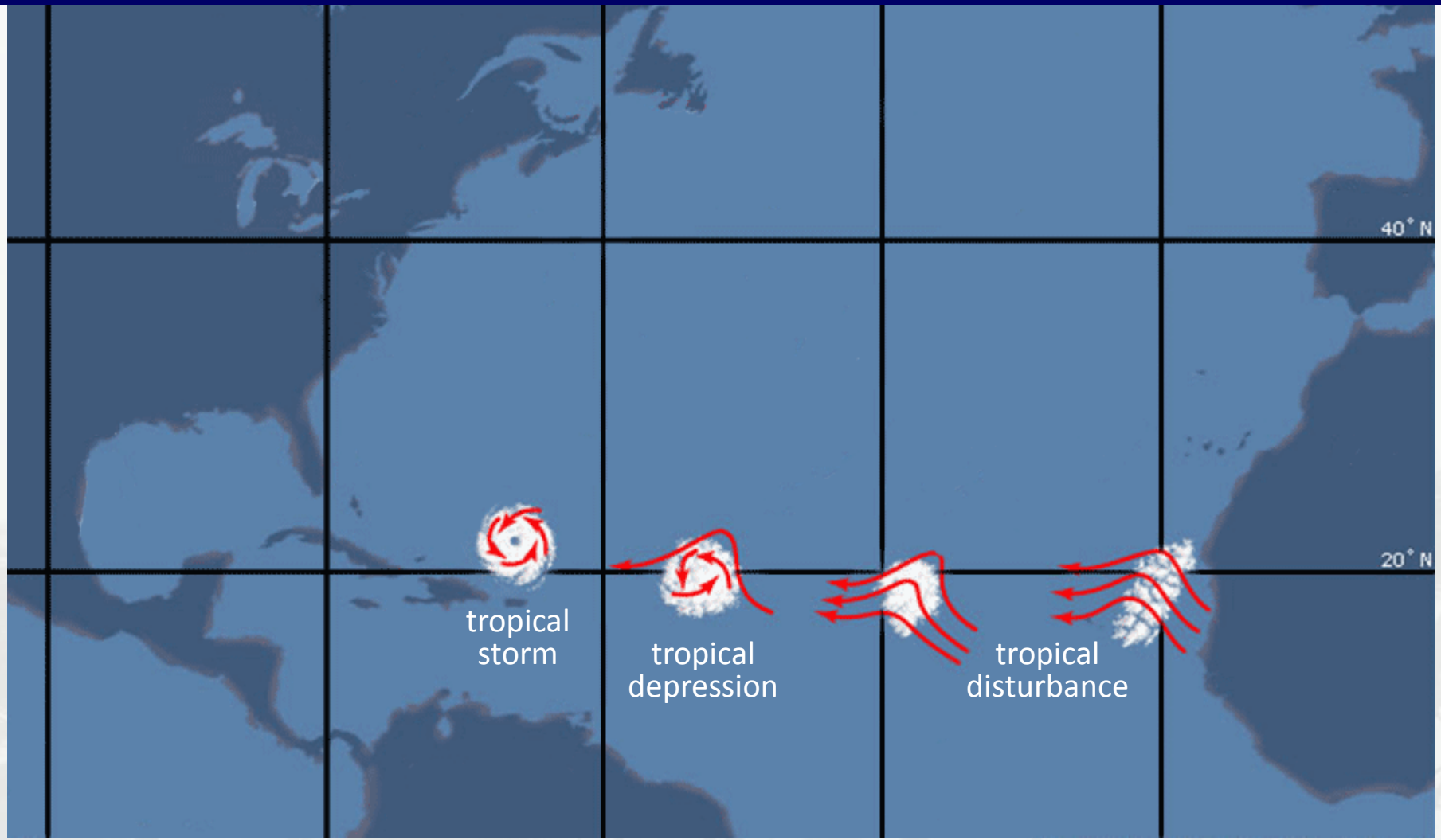
Hurricane Lifecycle

Cape Verde Hurricanes



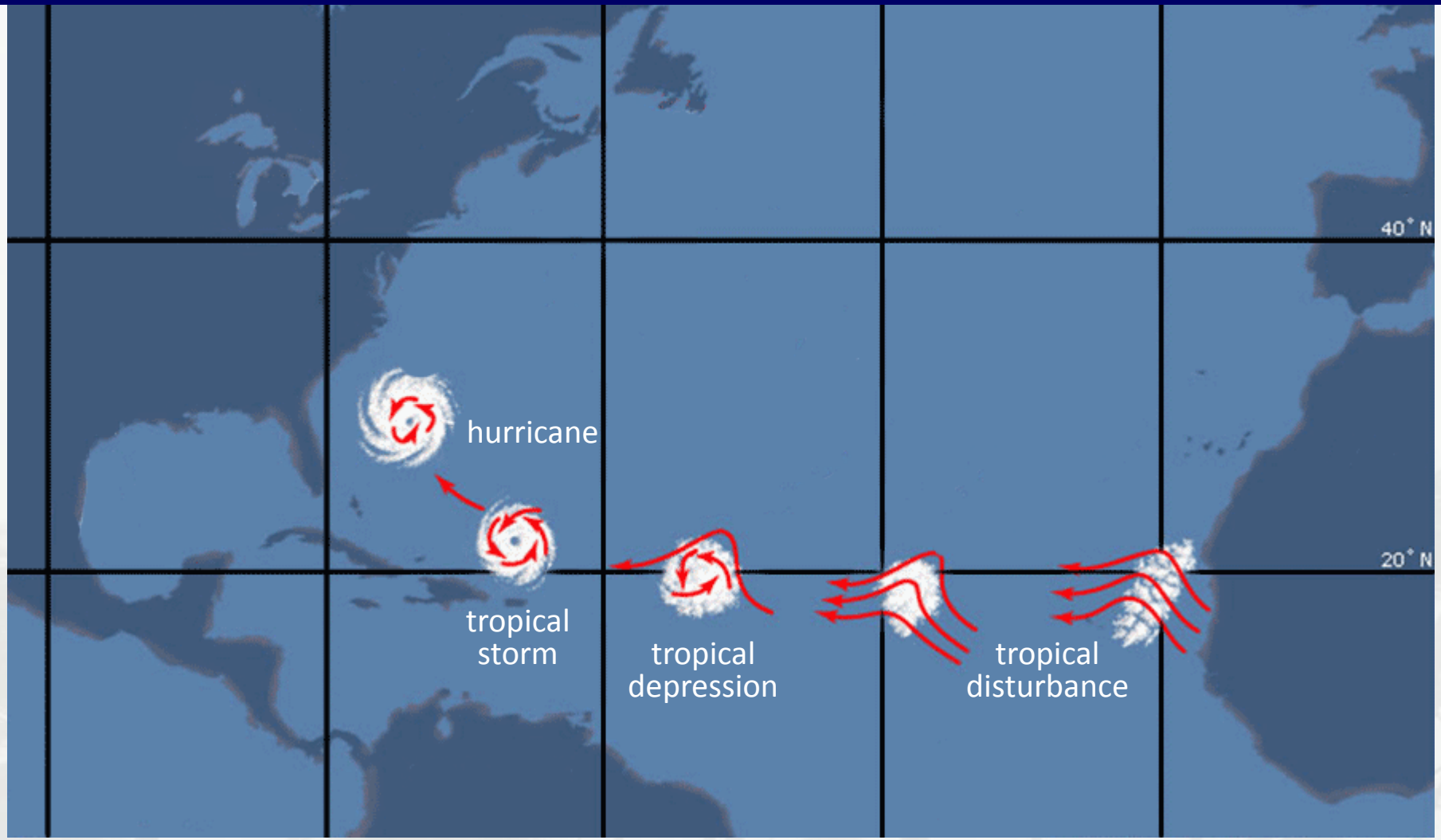
Hurricane Lifecycle

Cape Verde Hurricanes



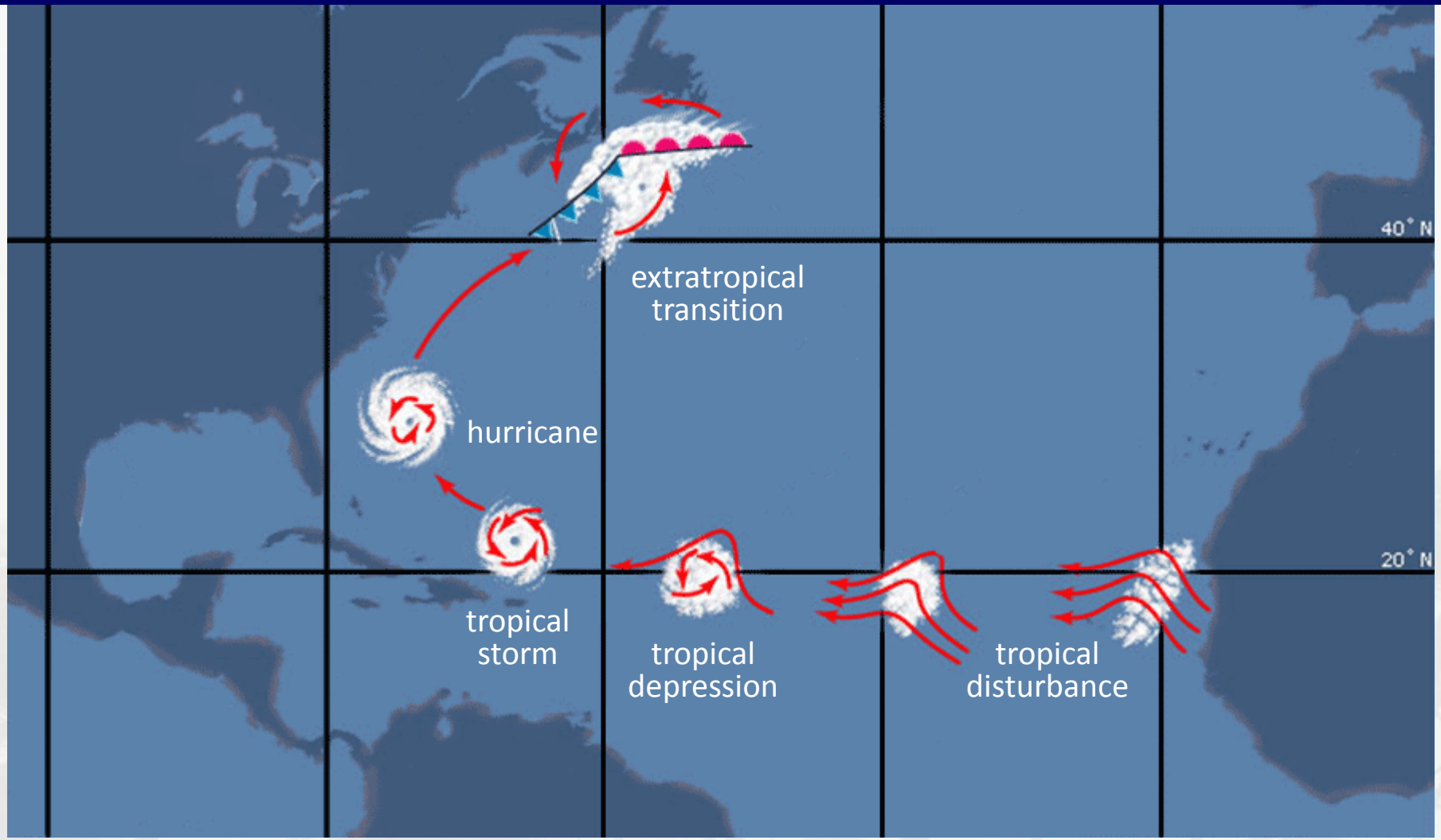
Hurricane Lifecycle

Cape Verde Hurricanes



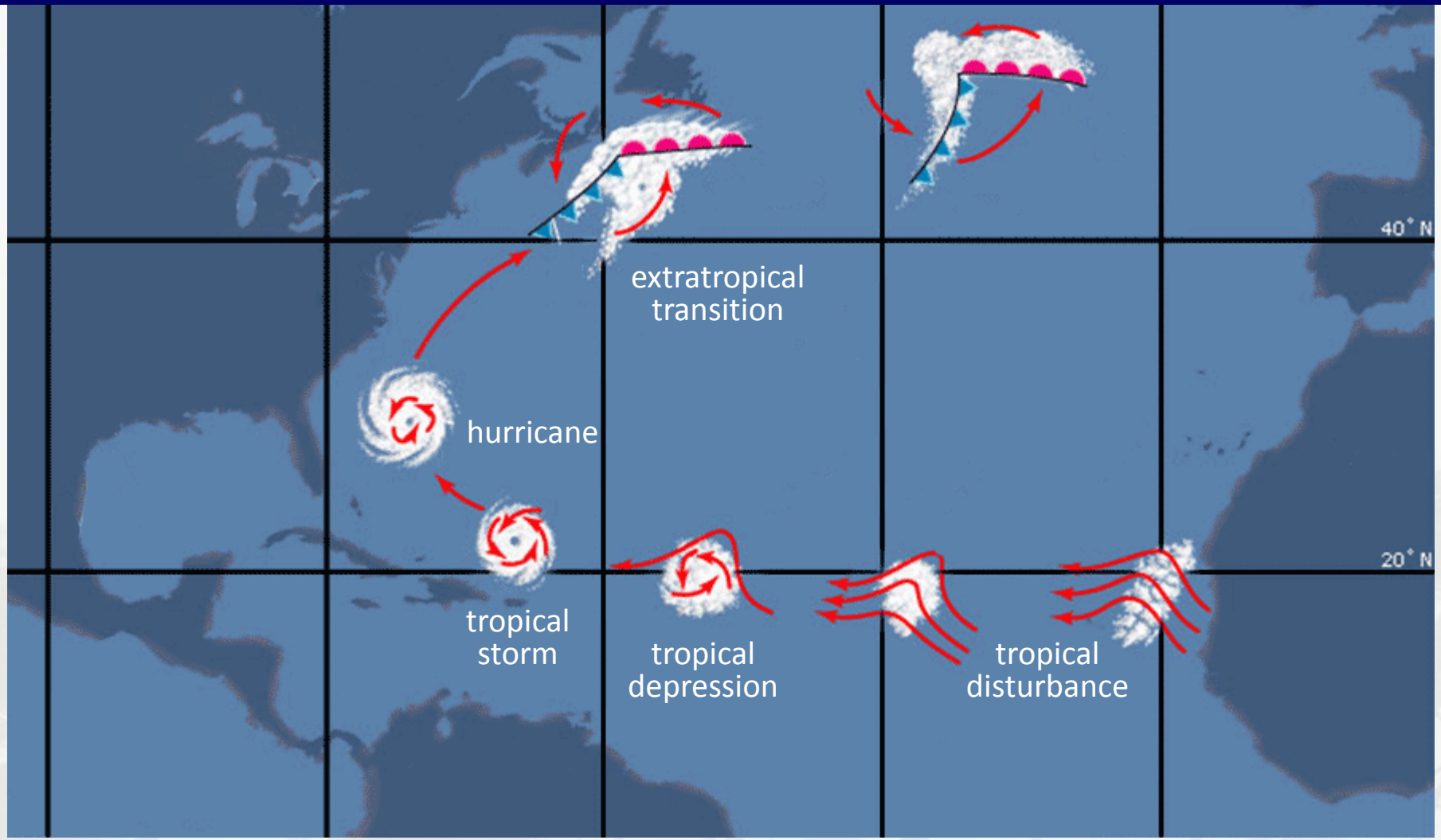
Hurricane Lifecycle

Cape Verde Hurricanes



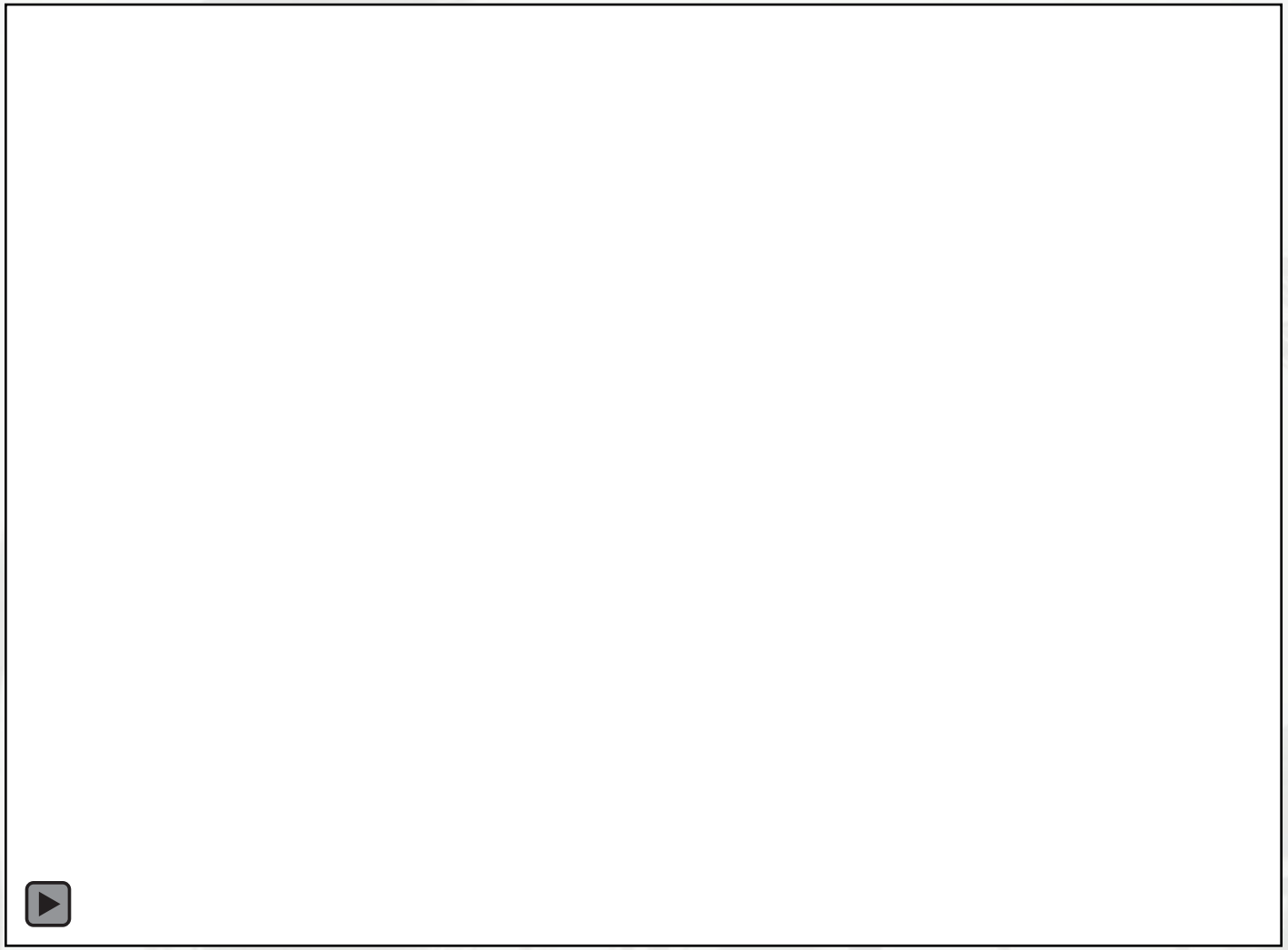
Hurricane Lifecycle

Cape Verde Hurricanes



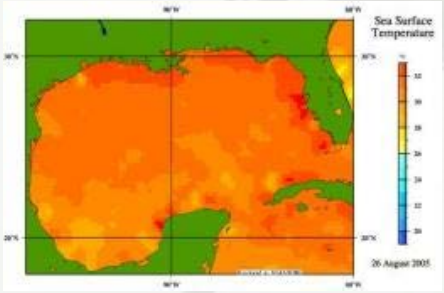
Hurricane Lifecycle

Hurricane Bill (2009)



Hurricane Quiz

Which of these are ingredients for hurricane development?



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

Hurricane Lifecycle

Ingredients for Formation

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) 

Hurricane Forecasting

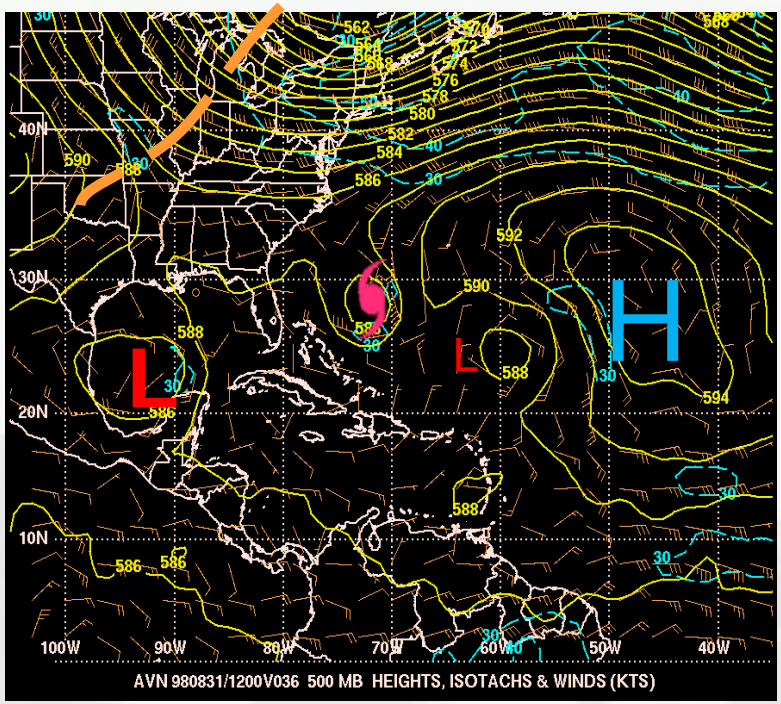
Pre-Existing Disturbances

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

Hurricane Forecasting

Storm Motion and Track

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



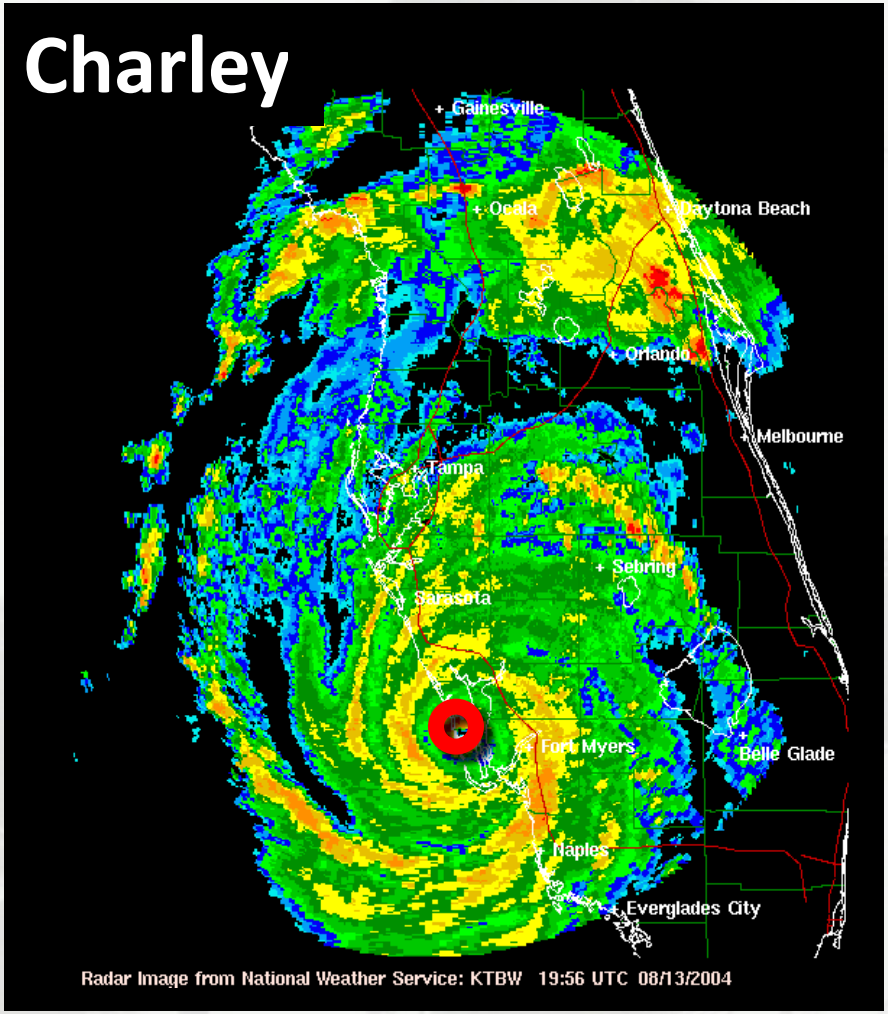
Hurricane Forecasting

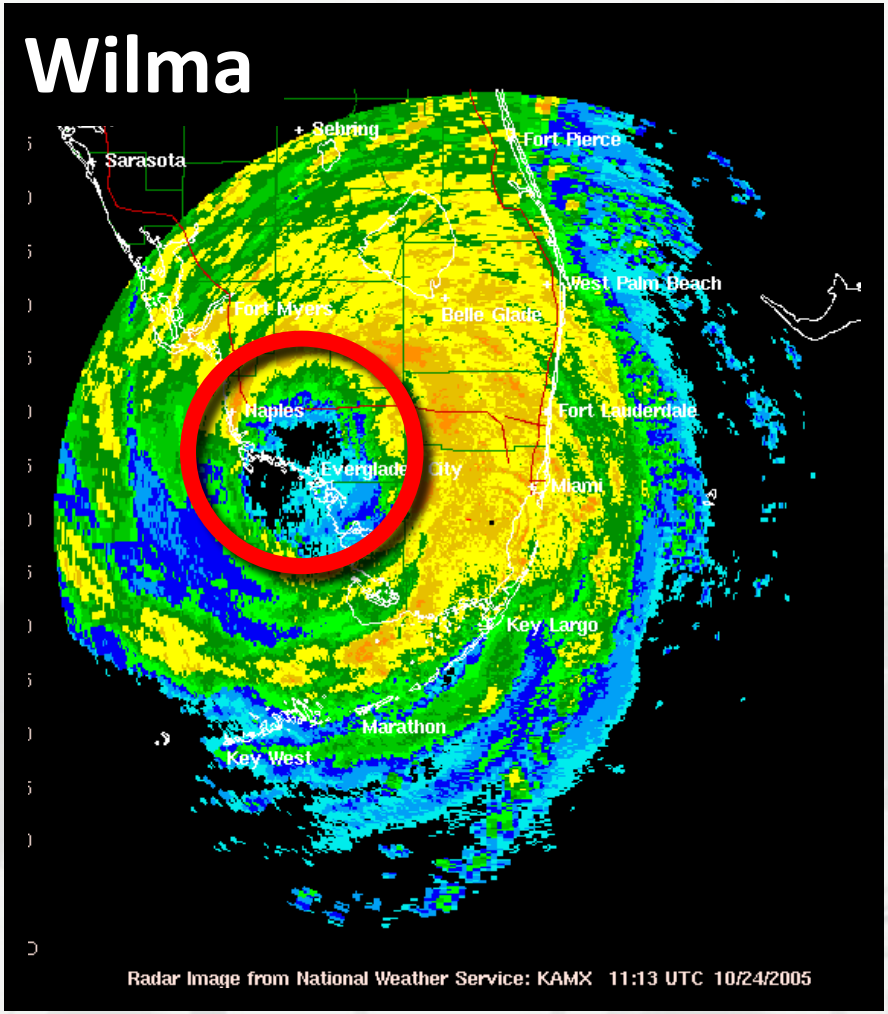
Factors that Influence Intensity

- **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**

Hurricane Forecasting

One Size Does Not Fit All





Hurricane Quiz

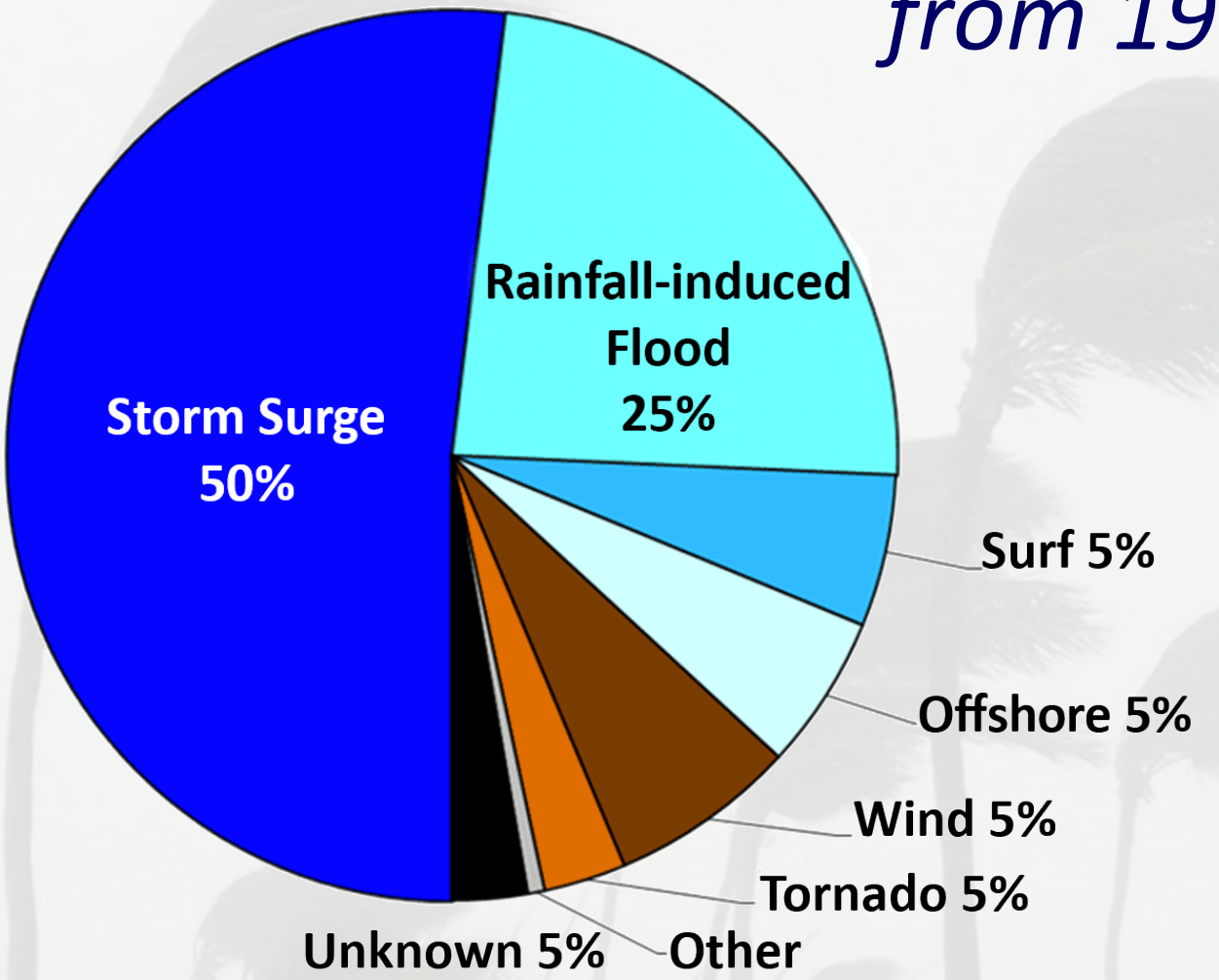
Which hurricane hazard has the greatest potential for large loss of life?

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

U.S. Tropical Cyclone Deaths

Water is responsible for vast majority

from 1963 - 2012



Hurricane Hazards

Surge. Wind. Flood. Tornado. Waves.


Wind


Waves / Rip Currents

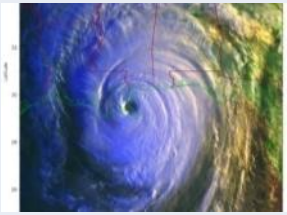
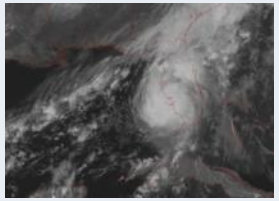
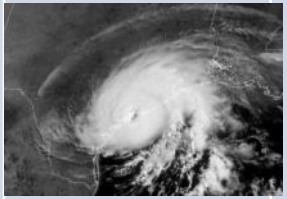
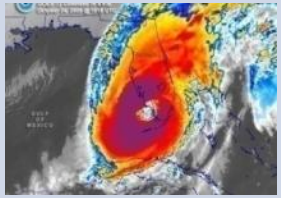
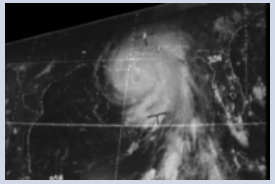

Tornadoes


Storm Surge


Inland Flooding

Saffir-Simpson Scale

Estimates Wind Damage

			MAJOR HURRICANES		
Tropical Storm	**Category 1**	**Category 2**	**Category 3**	**Category 4**	**Category 5**
39-73 mph (34-63 kt)	**74-95mph (64-82 kt)**	**96-110 mph (83-95 kt)**	**111-129 mph (96-112 kt)**	**130-156 mph (113-136 kt)**	**> 156 mph (> 136 kt)**
 **Debby** (2012)	 **Isaac** (2012)	 **Ike** (2008)	 **Katrina** (LA - 2005)	 **Charley** (2004)	 **Andrew** (1992)
 **Allison** (2001)	 **Claudette** (2003)	 **Isabel** (2003)	 **Wilma** (FL- 2005)	 **Hugo** (1989)	 **Camille** (1969)

Cat 1 (74 – 95 mph)

Dangerous Winds. Some Damage.

Humberto (2007) Southeast TX

Katrina (2005) Miami, FL

Claudette (2003) Palacios, TX

Lili (2002) Louisiana

Cat 2 (96 – 110 mph)

Extremely Dangerous. Extensive Damage.

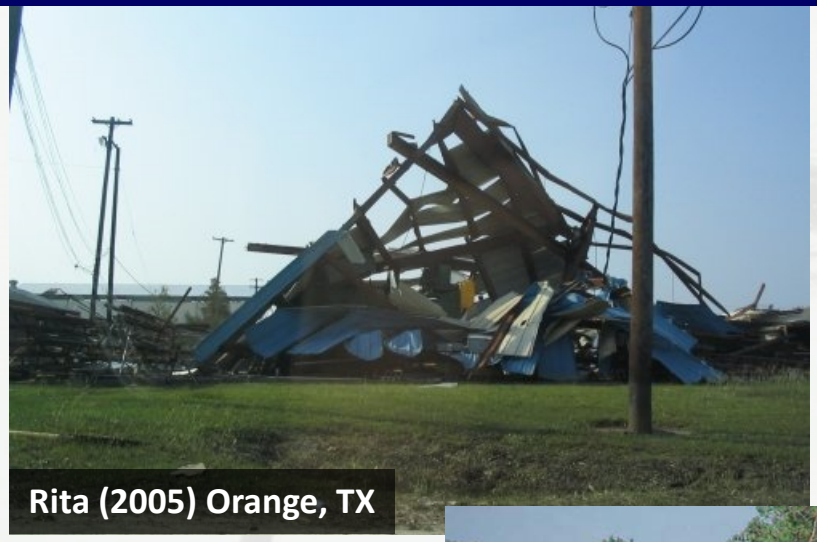
Ike (2008) Houston, TX

Wilma (2005) SE Florida

Juan (2003) Halifax, NS

Cat 3 (111 – 129 mph)

Devastating Damage



Rita (2005) Orange, TX

Jeanne (2004) Cape Canaveral, FL

Rita (2005) Orange, TX

Cat 4 (130 – 156 mph)

Catastrophic Damage

Charley (2004) Punta Gorda, FL

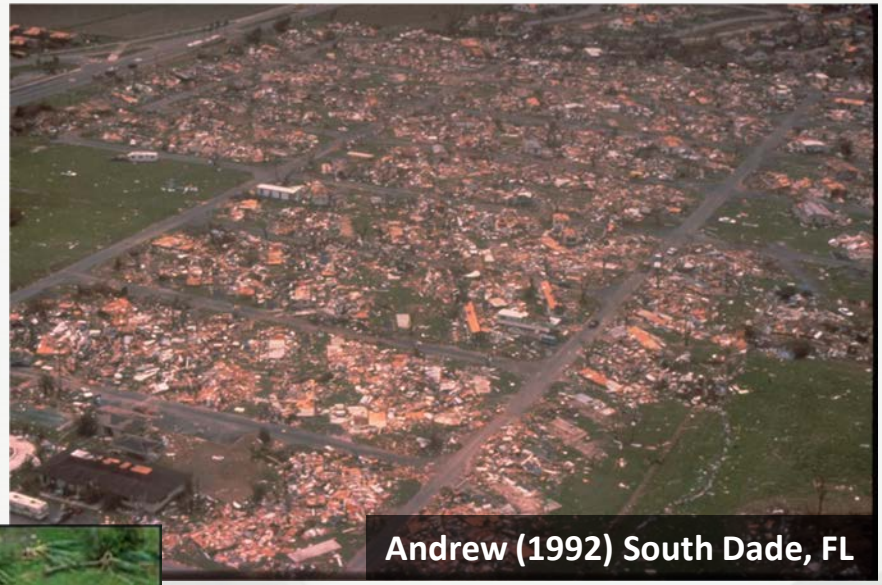
Hugo (1989) Sullivans Island, SC

Ike (2008) Holguin, Cuba

Cat 5 (> 156 mph)

Catastrophic Damage

Andrew (1992) Florida City, FL


Andrew (1992) South Dade, FL


Felix (2007) Nicaragua

Storm Surge

Greatest potential for large loss of life.

Hurricane Sandy (2012)

73 deaths

$65 billion damage

Hurricane Katrina (2005)

1200 deaths

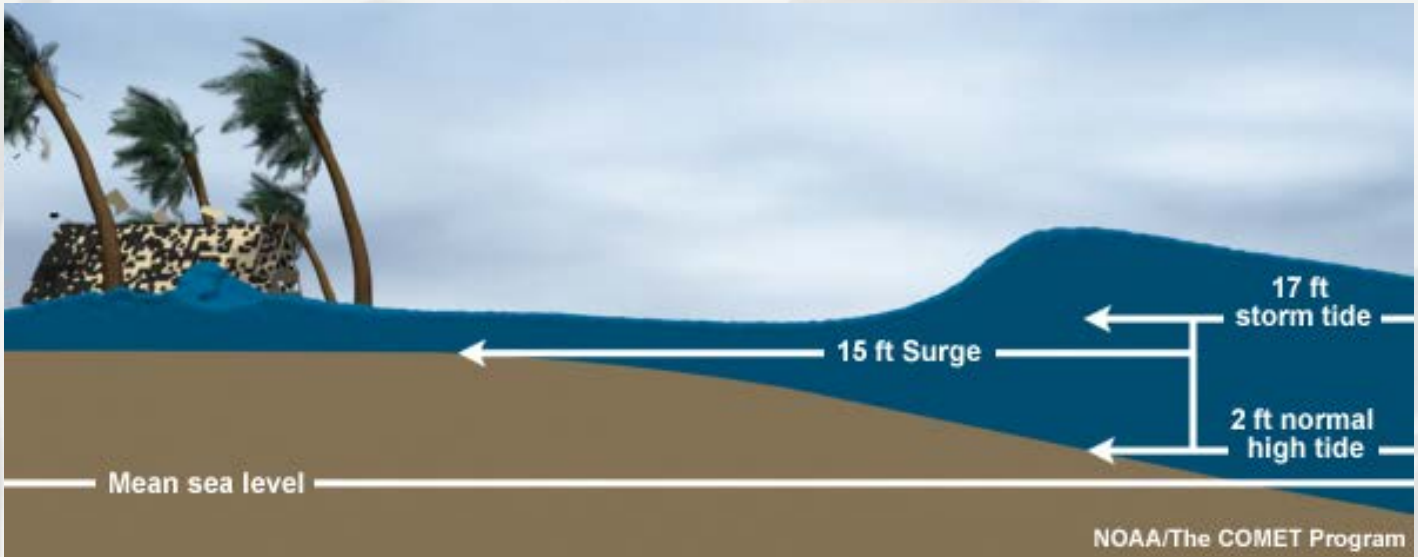
$108 billion damage

Storm Surge

Storm Surge vs Storm Tide

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

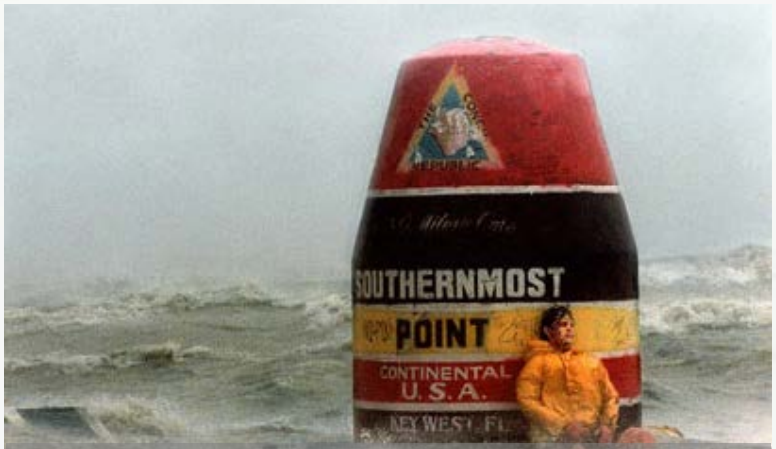
STORM TIDE – The water level rise due to the combination of storm surge and the astronomical tide.



Storm Surge History

Gulf Coast

Hurricane Katrina (2005)



Hurricane Georges (1998)

Hurricane Rita (2005)

Hurricane Ike (2008)

Storm Surge History

Waveland, Mississippi

Kimberly and David King

Storm Surge History

Southeast

Hurricane Isabel (2003)

Hurricane Hugo (1989)

TS Fay (2008)

Hurricane Jeanne (2004)

Storm Surge History

Mid-Atlantic

Hurricane Isabel (2003)


Hurricane Isabel (2003)


Hurricane Sandy (2012)


Hurricane Sandy (2012)

Storm Surge History

New England

Hurricane Carol (1954)

Hurricane Irene (2011)

1938 Hurricane

Hurricane Sandy (2012)

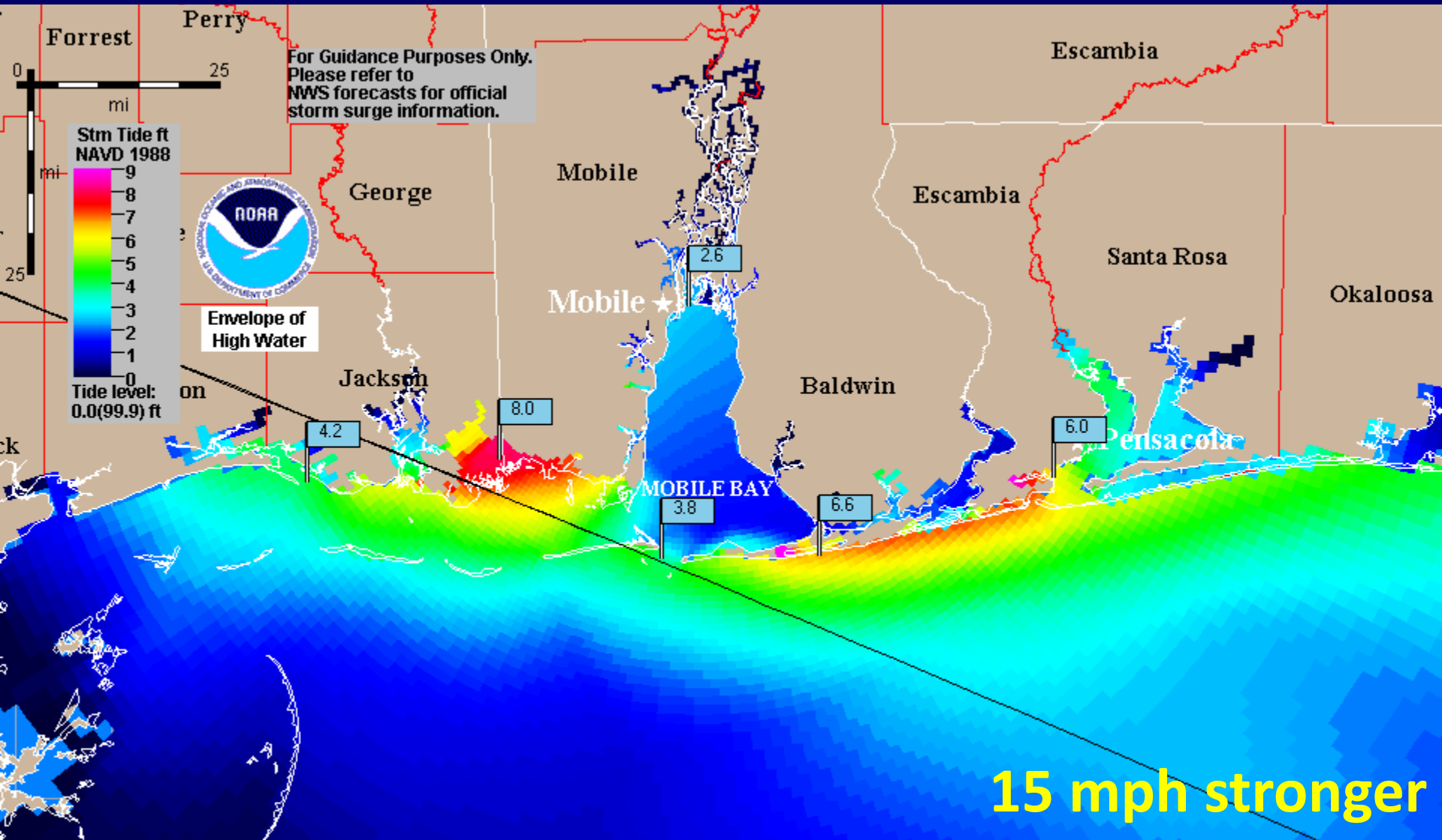
Storm Surge

Factors Affecting Storm Surge

- **Intensity**
  Stronger storm = More storm surge
- **Size (RMW)**
  Bigger storm = More storm surge
- **Forward Speed**
  Slower storm = Storm surge farther inland
- **Width and Slope of Shelf (Bathymetry)**
  Gradual shelf = More storm surge
- **Angle of approach**
  Alters focus of storm surge
- **Central Pressure**
  Pressure driven surge about 5% of total storm surge

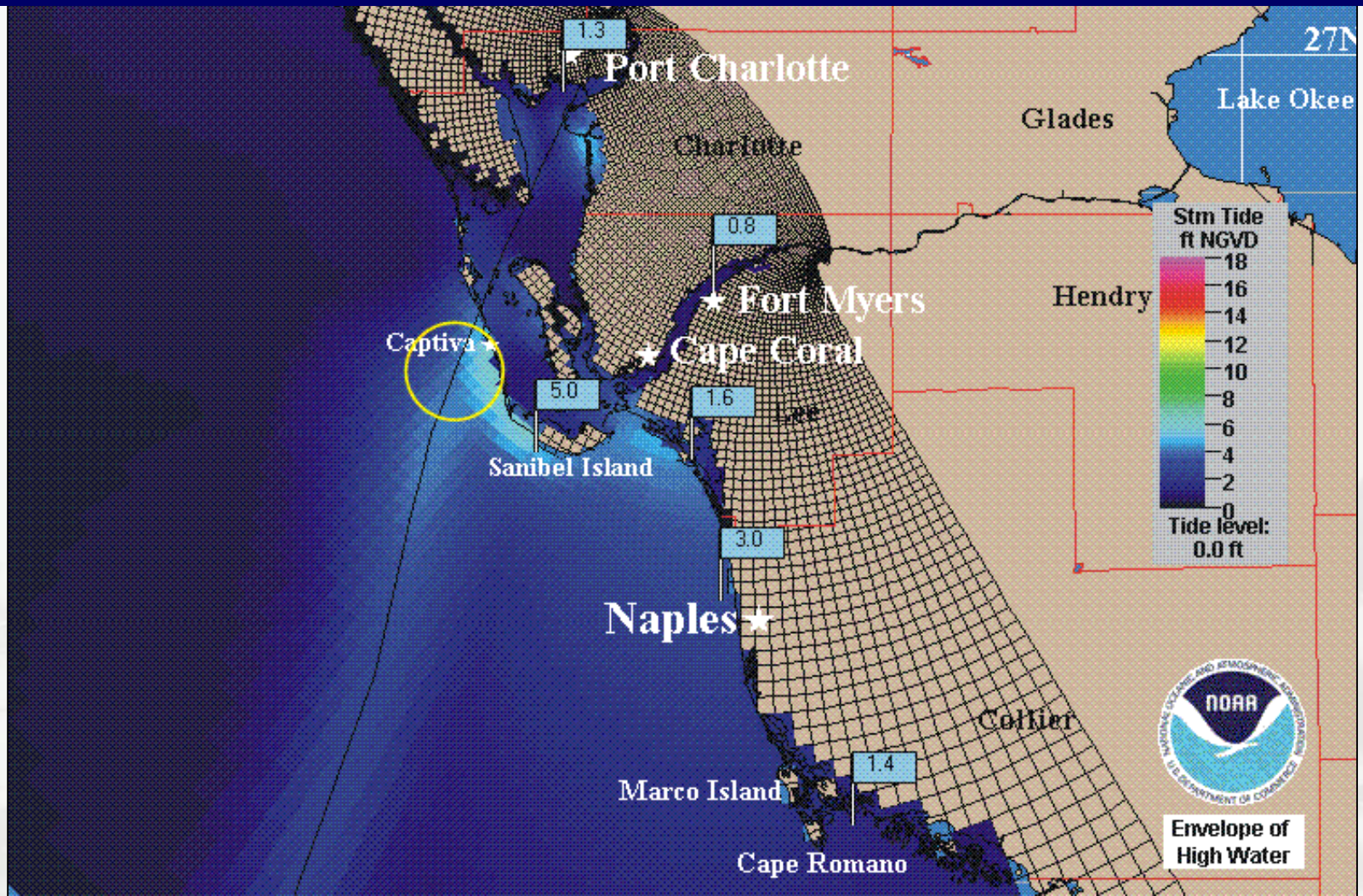
Storm Surge

What's the effect of intensity?



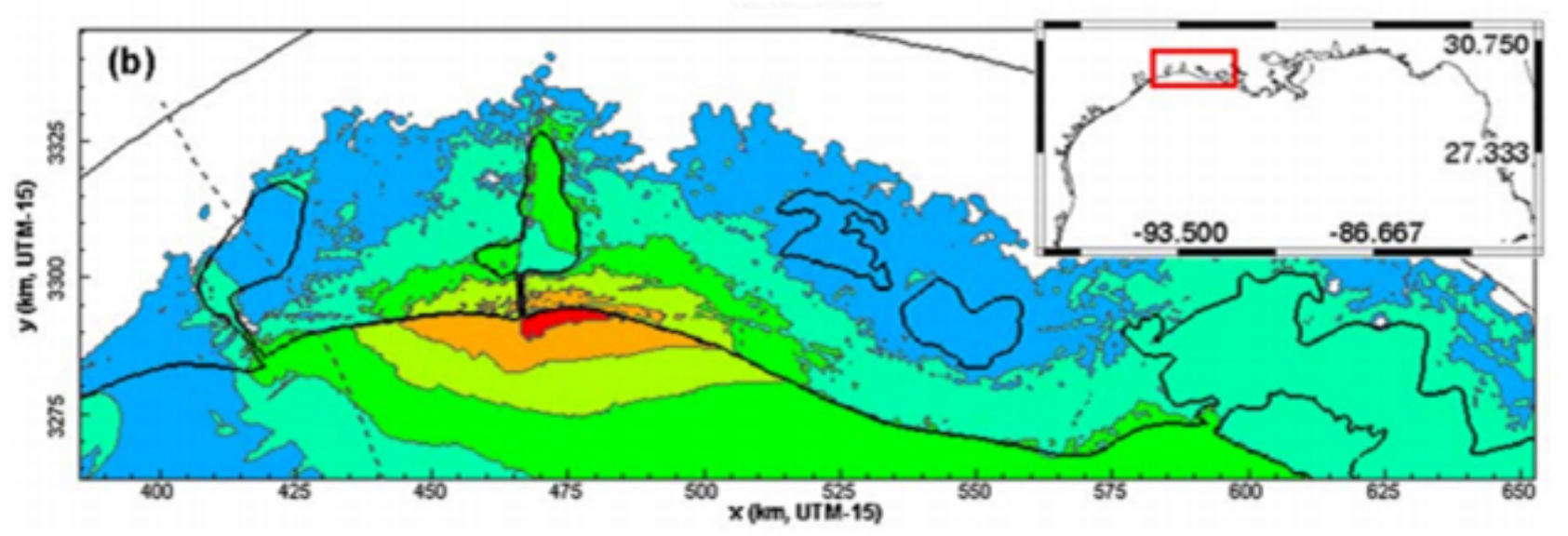
Storm Surge

What's the effect of size?



Storm Surge

What's the effect of forward speed?

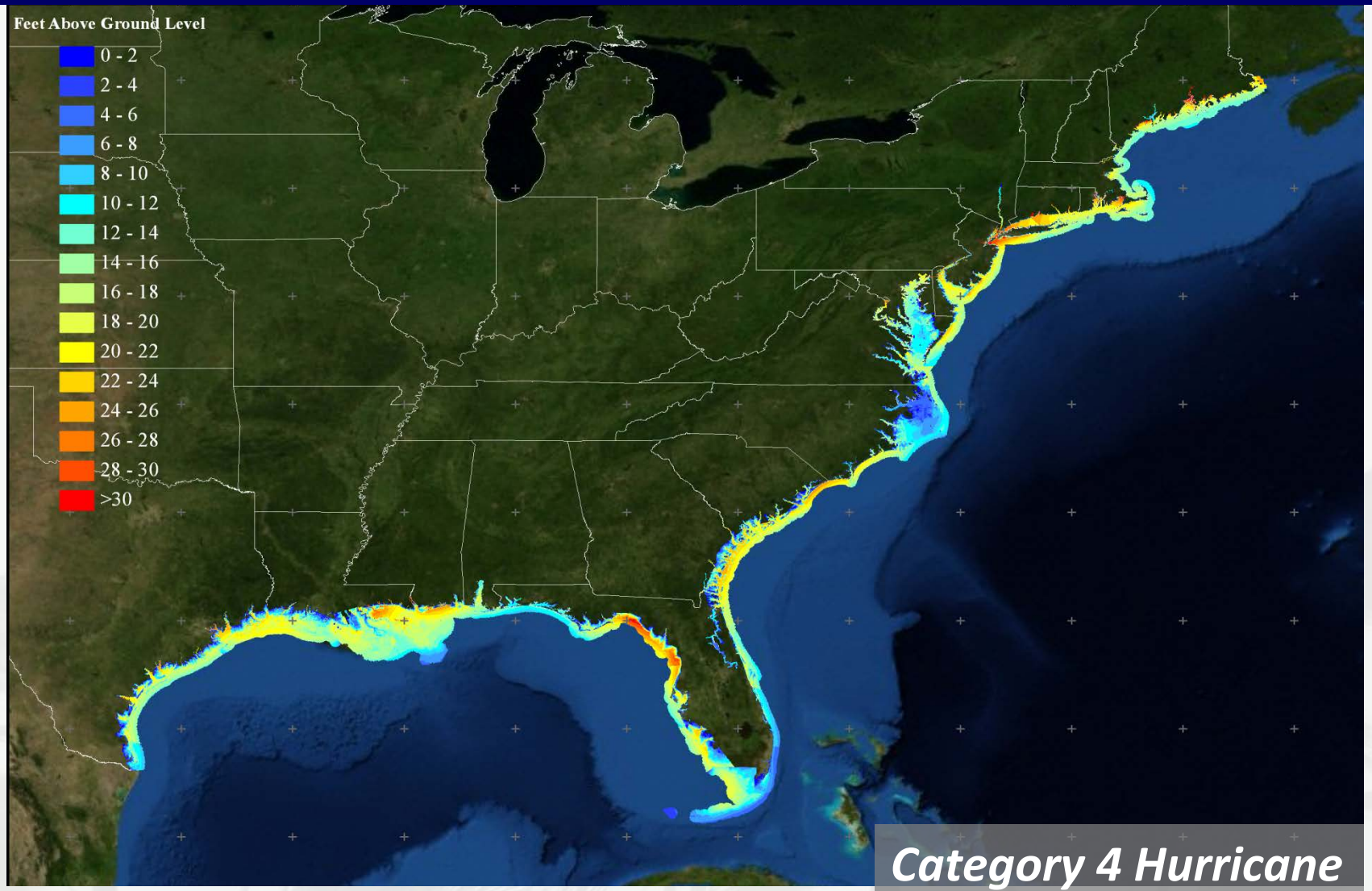


Fast Speed (25 mph)

- Higher maximum

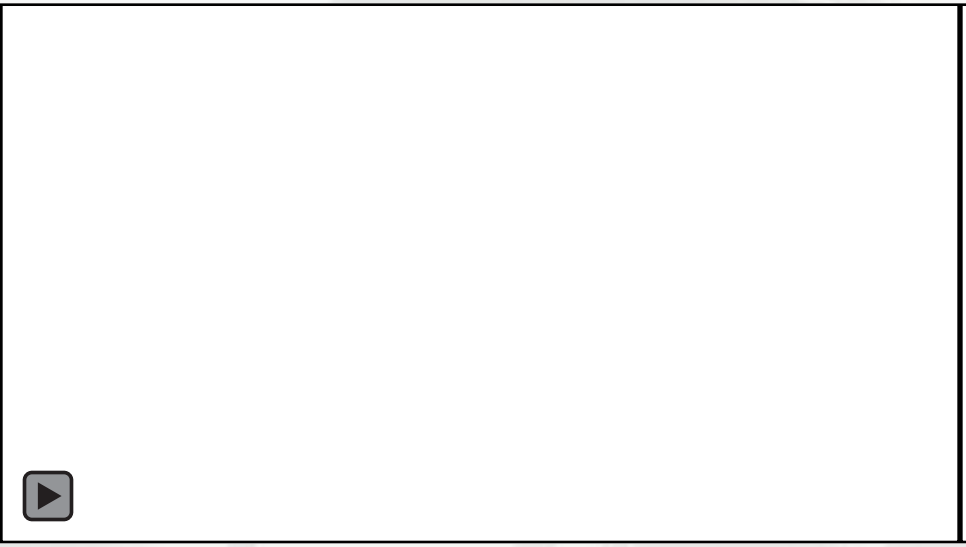
Storm Surge

Location. Location. Location.

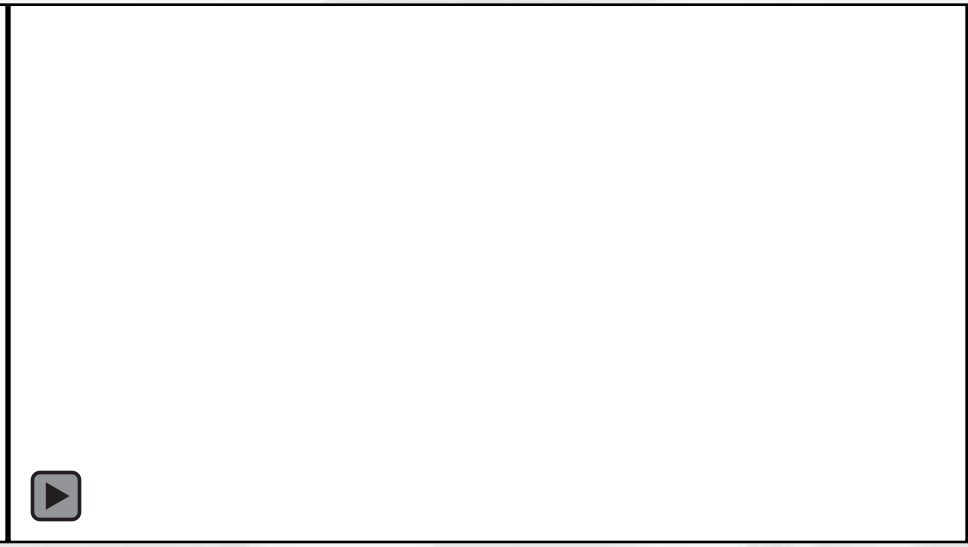


Storm Surge

What's the effect of width/slope of shelf?



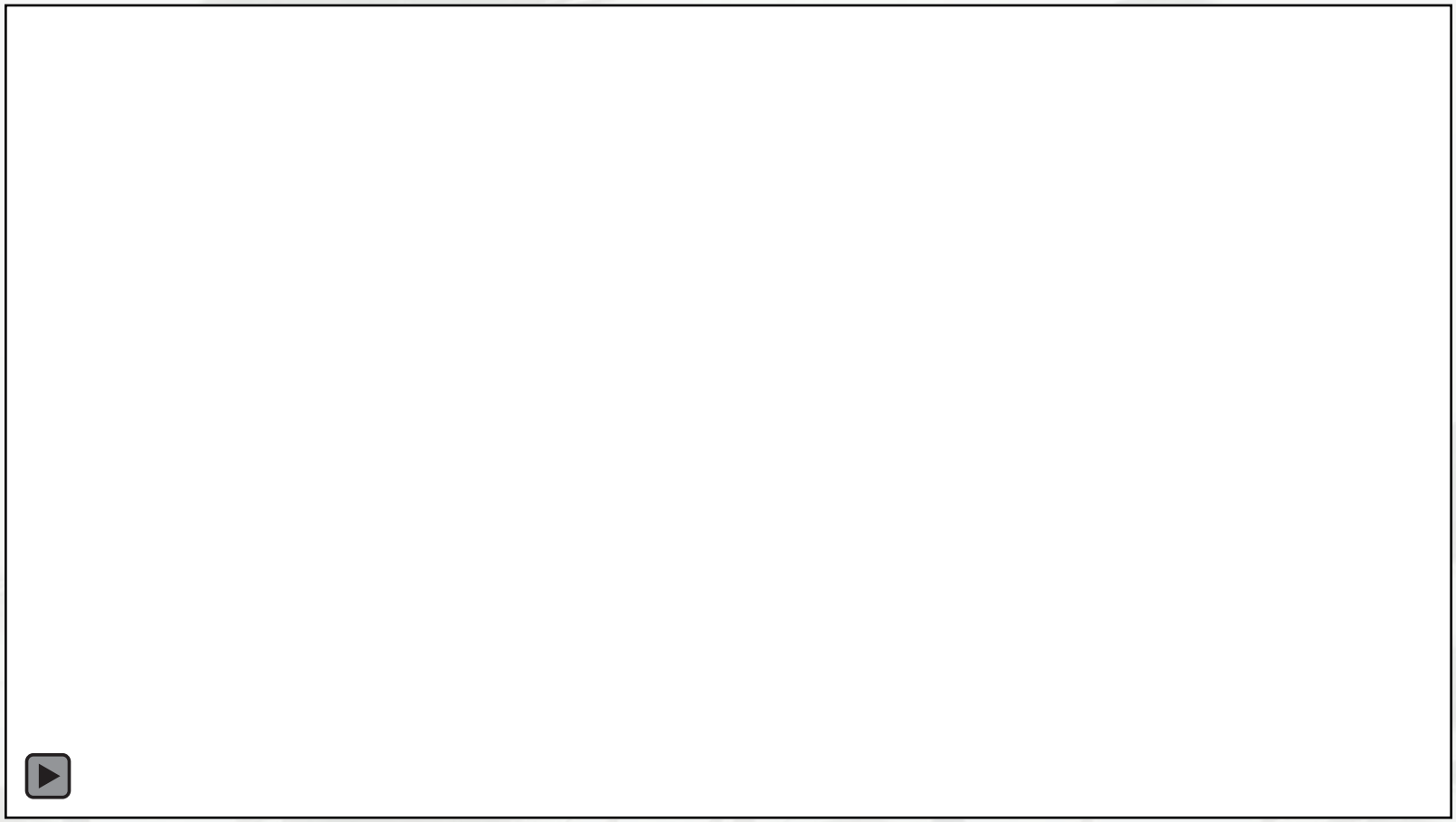
Wide shelf – Gentle slope



Narrow shelf – Sharp slope

Storm Surge

Wave Setup

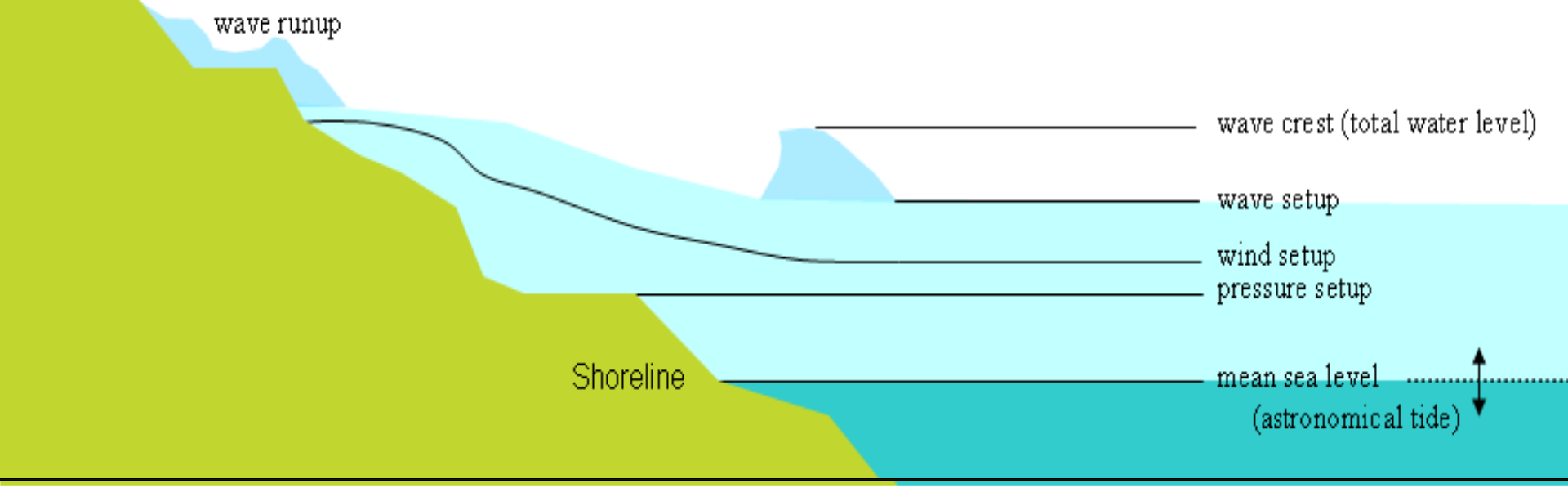


Storm Surge

Components of 'Total Water Level'

Total Water Level

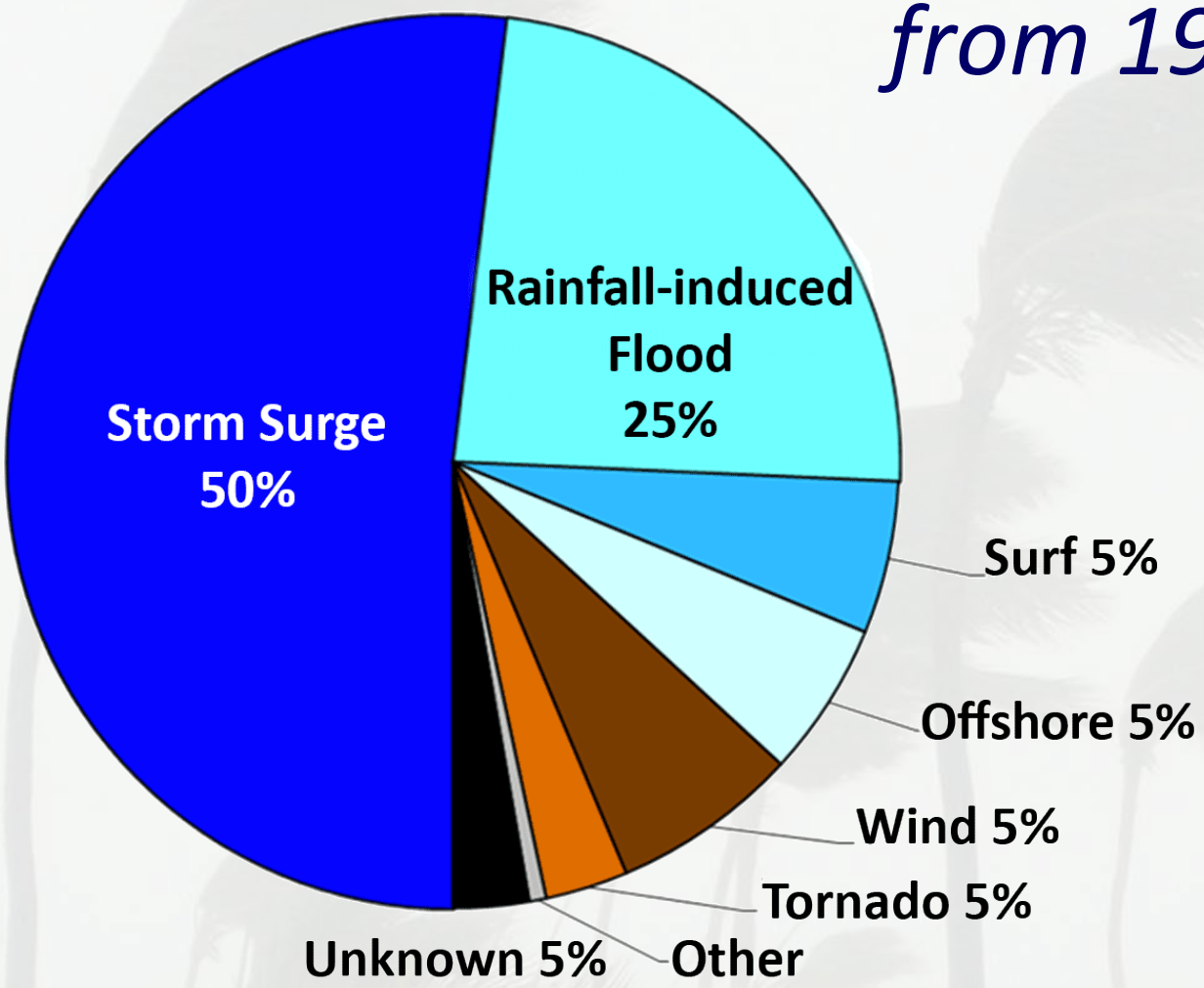
Storm surge + Tides + Wave Setup + Freshwater



Freshwater Flooding

U.S. Atlantic Tropical Cyclone Deaths

from 1963 - 2012



Freshwater Flooding

Flash Floods. Riverine Flooding.

US Army Corps of Engineers

Times Herald

Mansfield Heliflight

Freshwater Flooding

Floyd (1999) – Tarboro, NC

Freshwater Flooding

Interstate 10 – Houston, TX

Freshwater Flooding

TS Allison (2001) – Houston, TX

Freshwater Flooding

Factors Affecting Tropical Cyclone Rainfall.

1. **Forward Speed**
   (Slower storm = More rain)
2. **Size**
   (Bigger storm = More rain)
3. **Rain Rate**
   (Higher rain rate = More rain)
4. **Vertical Wind Shear**
   (More rain on one side)
5. **Topography / Mountains**
   (More rain on windward side)
6. **Fronts / Upper-Level Troughs**

Tornadoes

Landfalling hurricanes spawn tornadoes

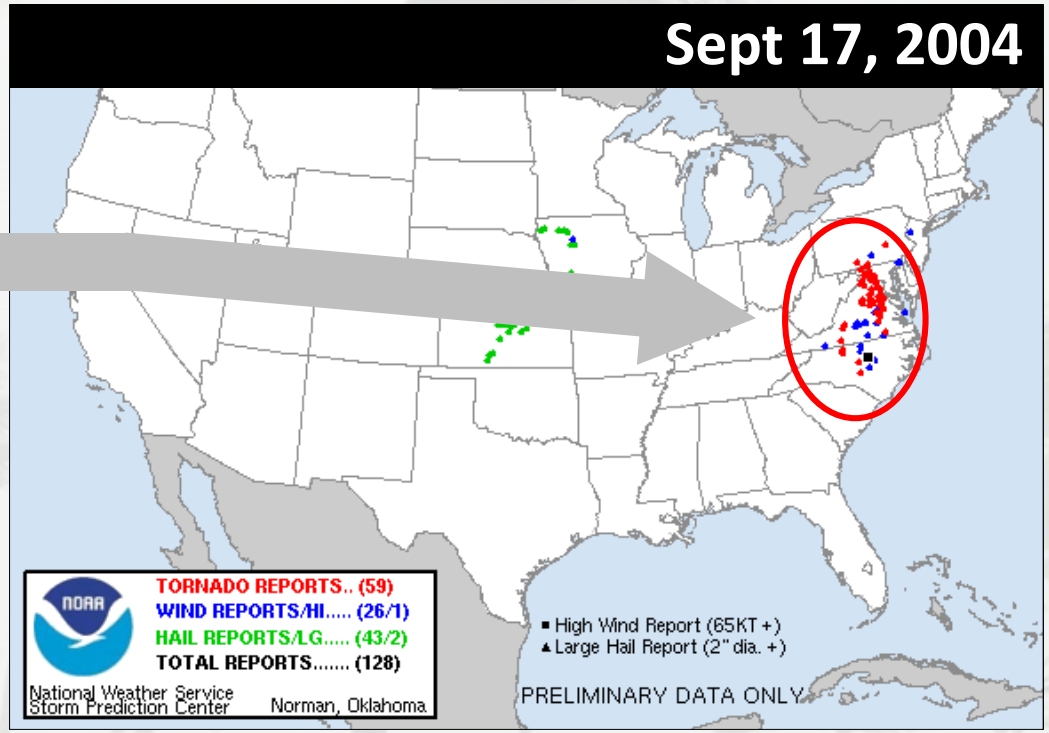
- 70% produce at least 1 tornado
- 40% produce more than 3 tornadoes

Tornado "outbreak"

Hurricane Ivan (2004)

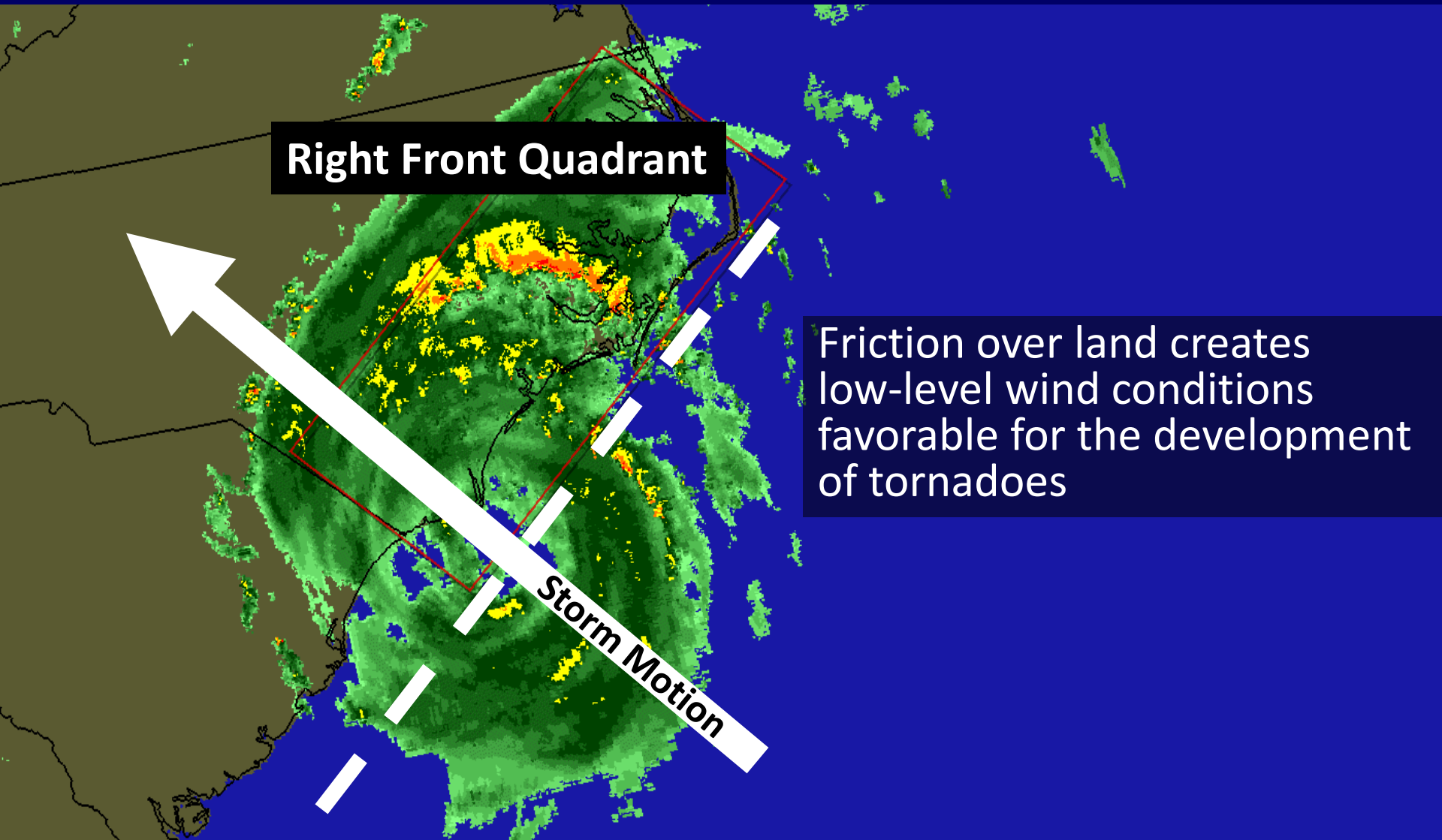
- 117 Tornadoes

1. Hurricane Beulah (1967): 141
2. Hurricane Ivan (2004): 117
3. Hurricane Frances (2004): 101
4. Hurricane Camille (1969): 80
5. Hurricane Katrina (2005): 43



Tornadoes

Landfalling Hurricanes Spawn Tornadoes

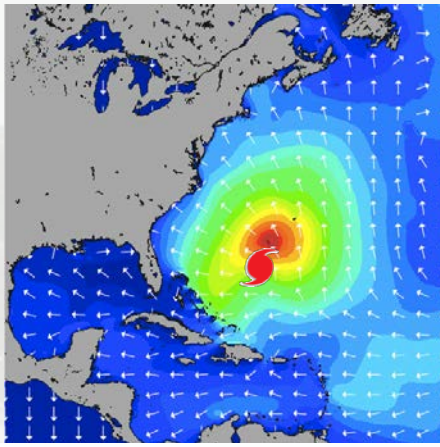


Friction over land creates low-level wind conditions favorable for the development of tornadoes

Waves and Rip Currents

Can occur when a storm is well offshore

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



Hurricane Bertha (2008)

- Over 1500 rescues in Ocean City, Maryland
- 3 people drowned along the coast of New Jersey

Hurricane Bill (2009)

- 1 person died in Maine
- 1 person died in Florida

Hurricane Basics

Questions?