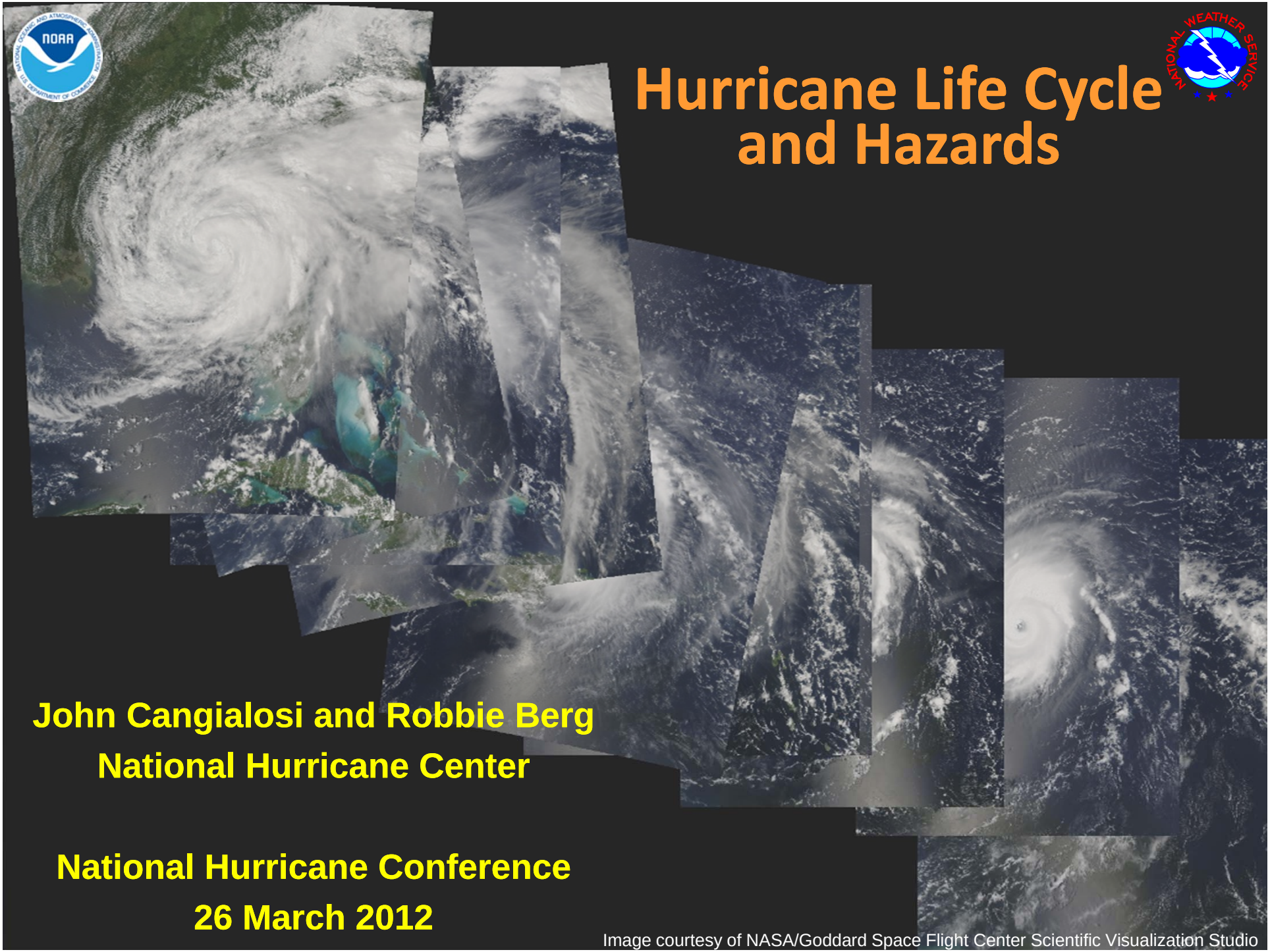
Hurricane Life Cycle and Hazards



John Cangialosi and Robbie Berg
National Hurricane Center

National Hurricane Conference
26 March 2012

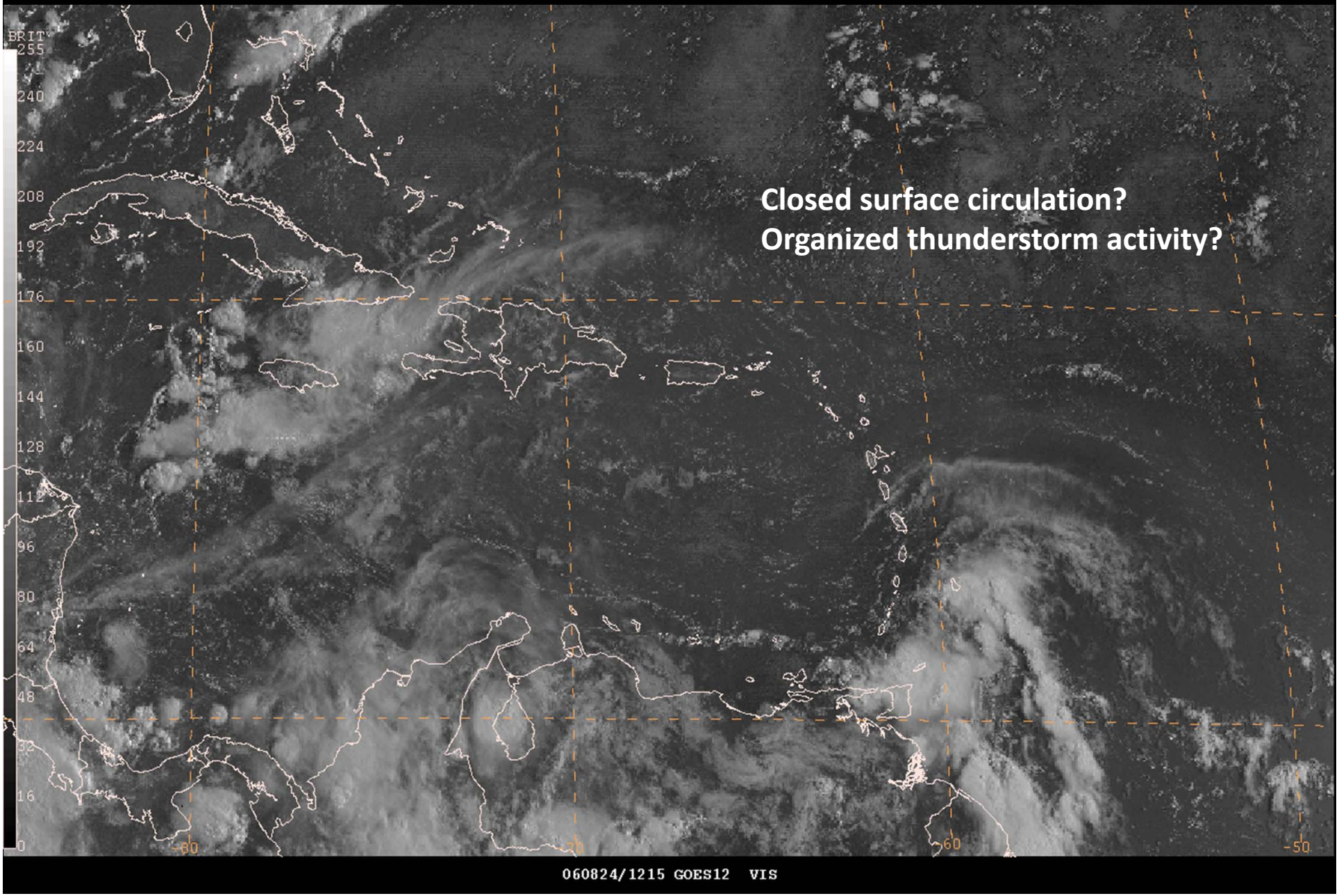
Image courtesy of NASA/Goddard Space Flight Center Scientific Visualization Studio

What is a Tropical Cyclone?

- A relatively large and long-lasting low pressure system
  - Can be dozens to hundreds of miles wide, and last for days
- No fronts attached
- Forms over tropical or subtropical oceans
- Produces organized thunderstorm activity
- Has a closed surface wind circulation around a well-defined center

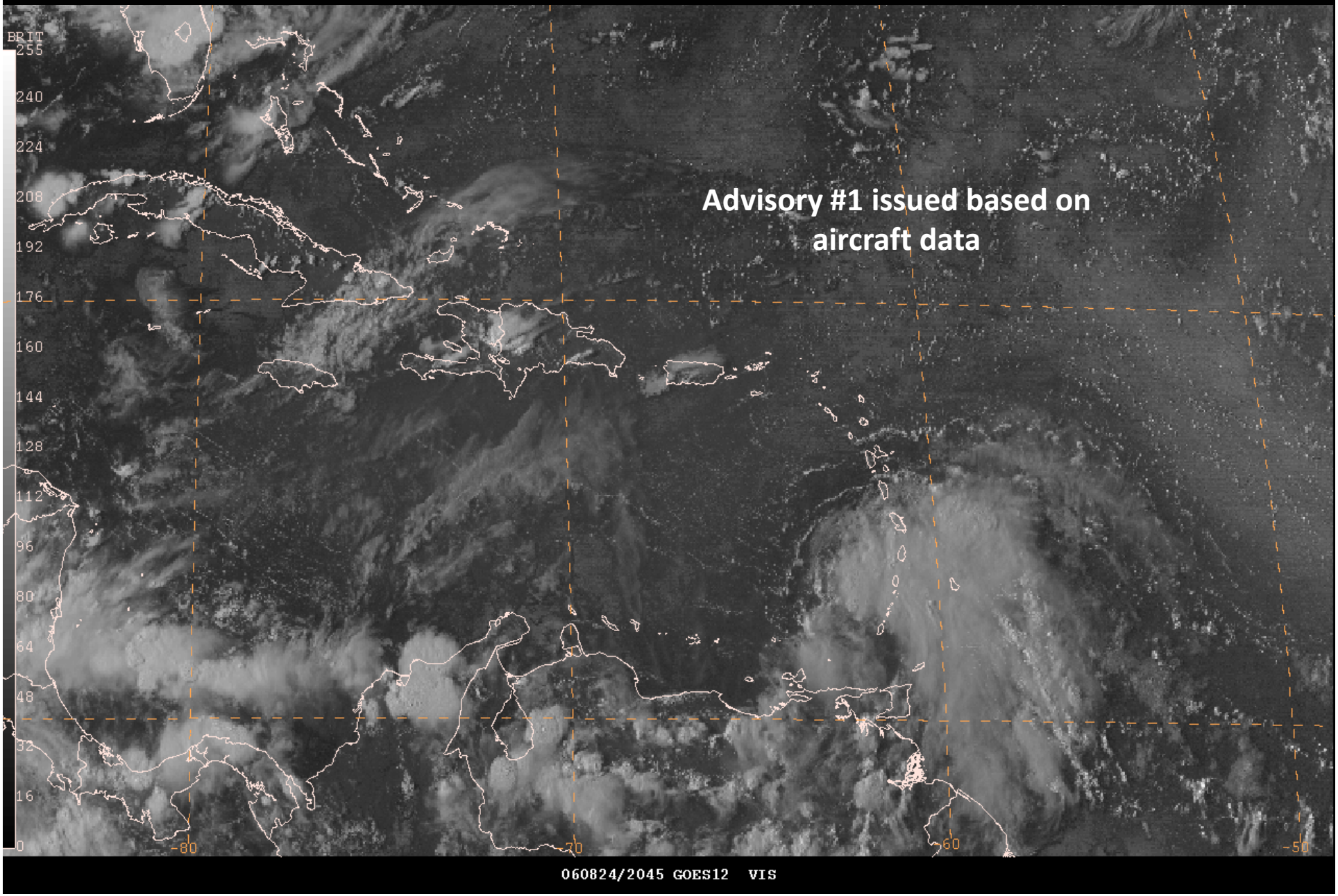
- Classified by maximum sustained surface wind speed
  - Tropical depression: < 39 mph
  - Tropical storm: 39-73 mph
  - Hurricane: 74 mph or greater
    - Major hurricane: 111 mph or greater

Is This a Tropical Cyclone?

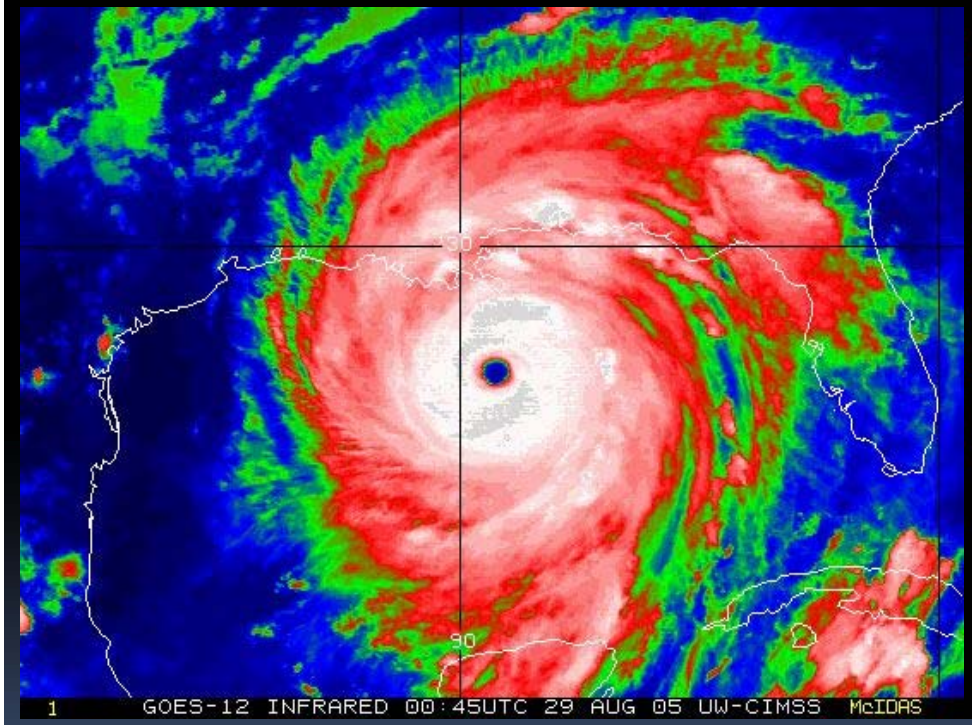


Closed surface circulation?
Organized thunderstorm activity?

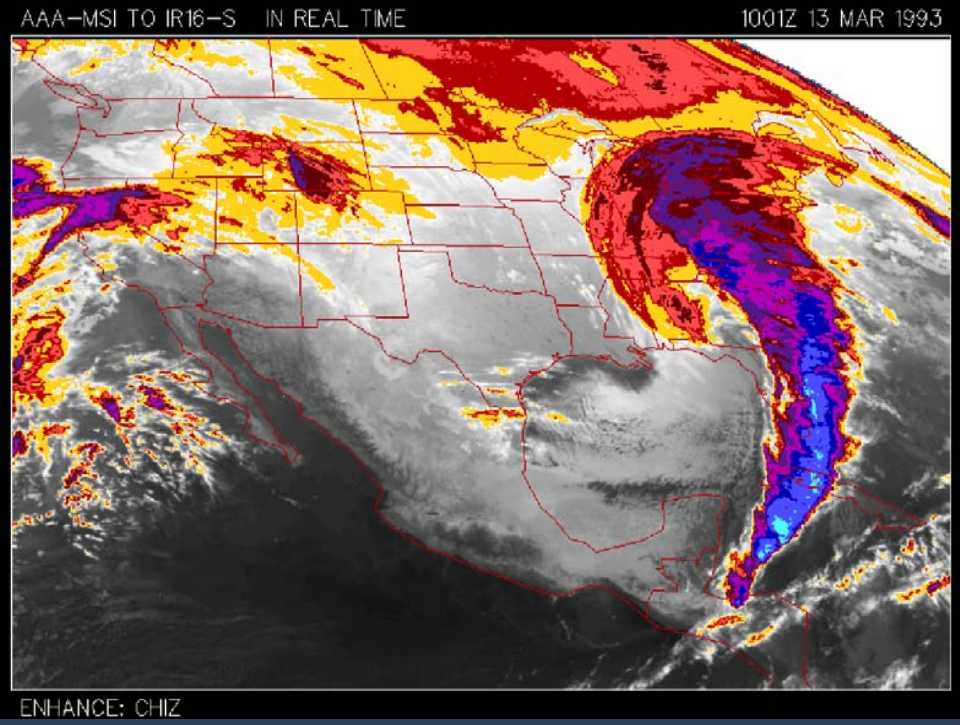
Tropical Depression #5 (later Ernesto)



The Extremes:
Tropical vs. Extratropical Cyclones

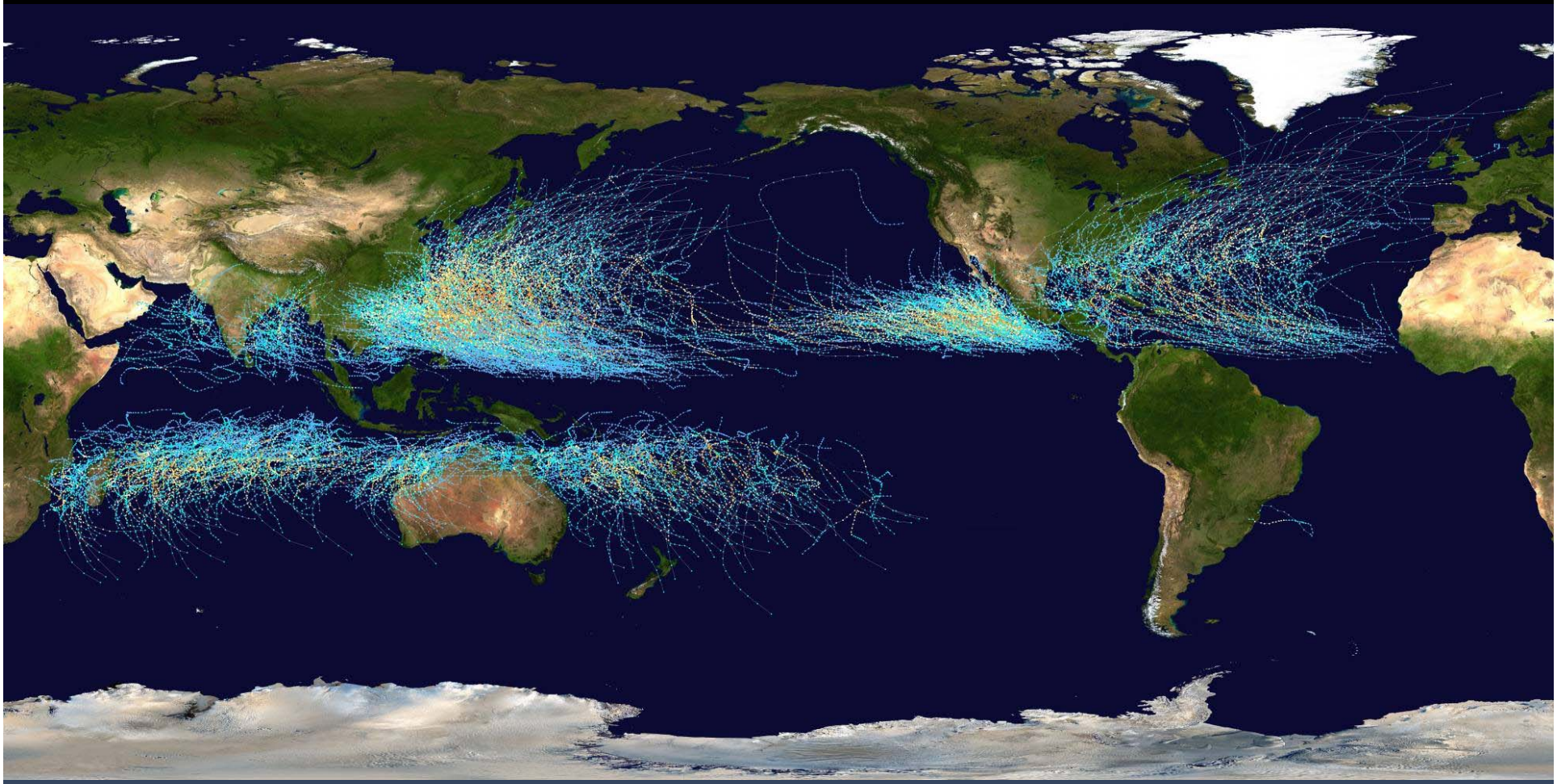


Hurricane Katrina (2005)



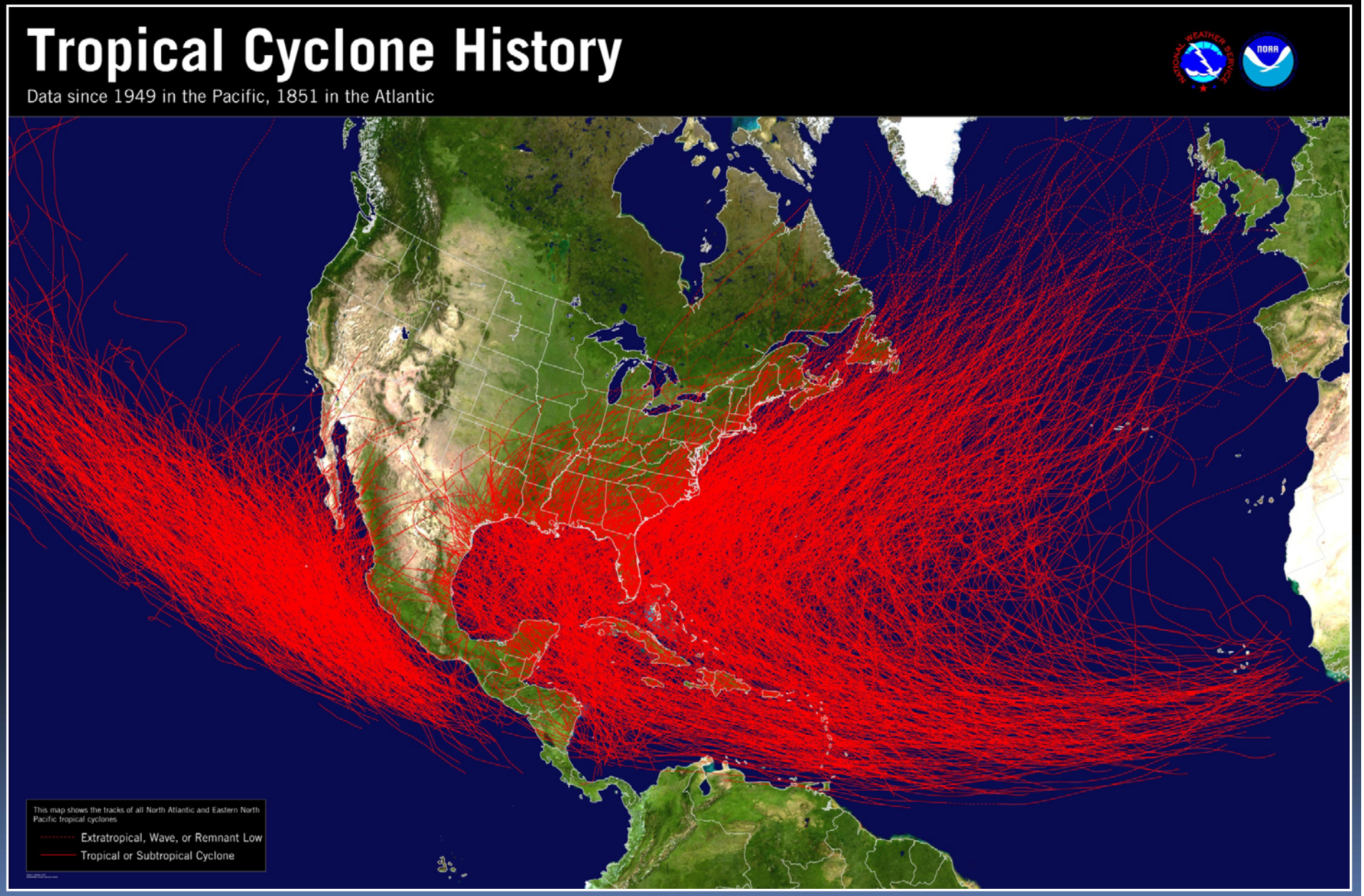
Superstorm Blizzard of March 1993

Tropical Cyclones Occur Over Tropical and Subtropical Waters Across the Globe



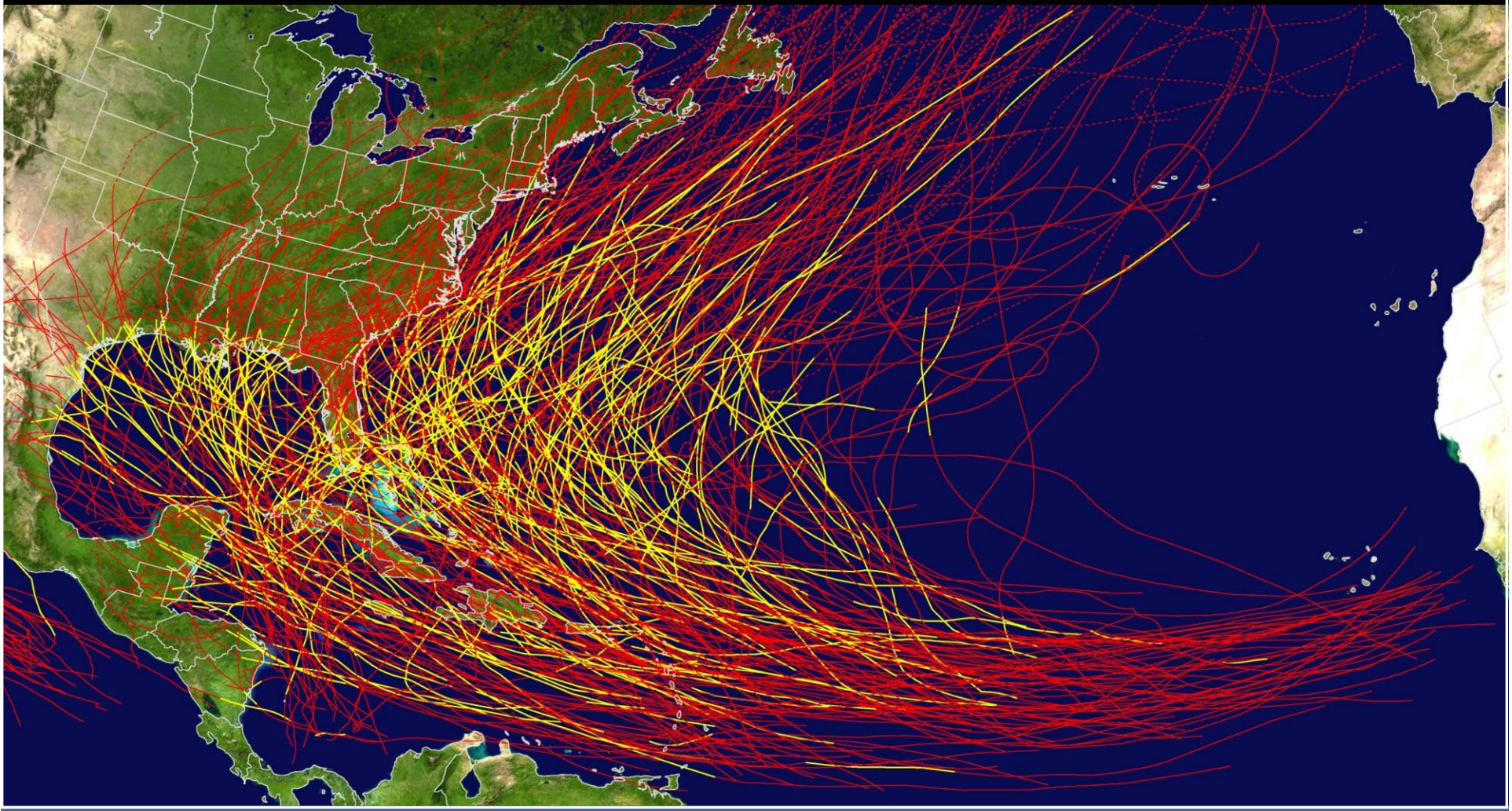
Tropical cyclones tracks between 1985 and 2005

Atlantic Basin Tropical Cyclones Since 1851

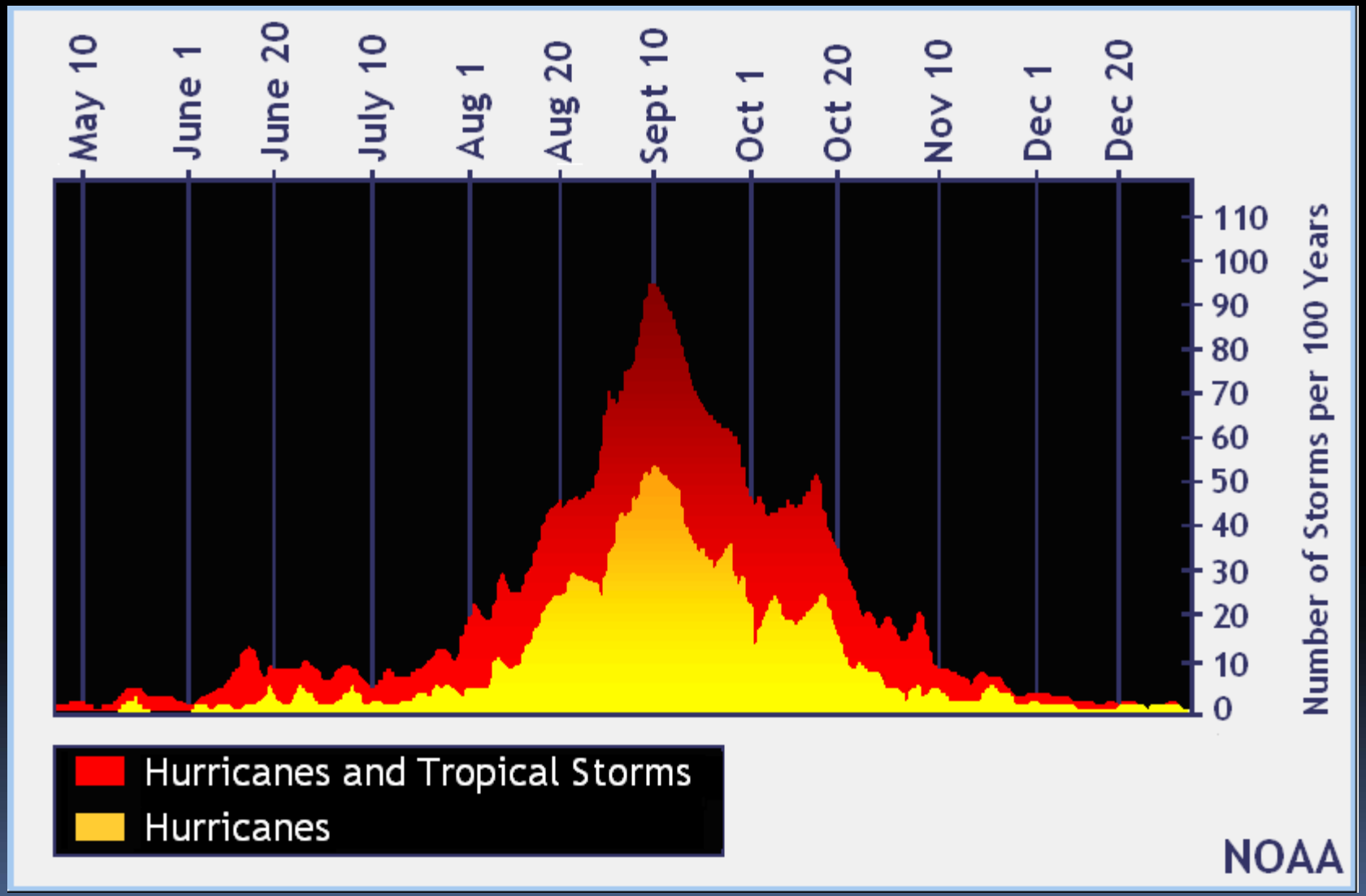


Major Hurricane History

Data since 1949 in the Pacific, since 1851 in the Atlantic

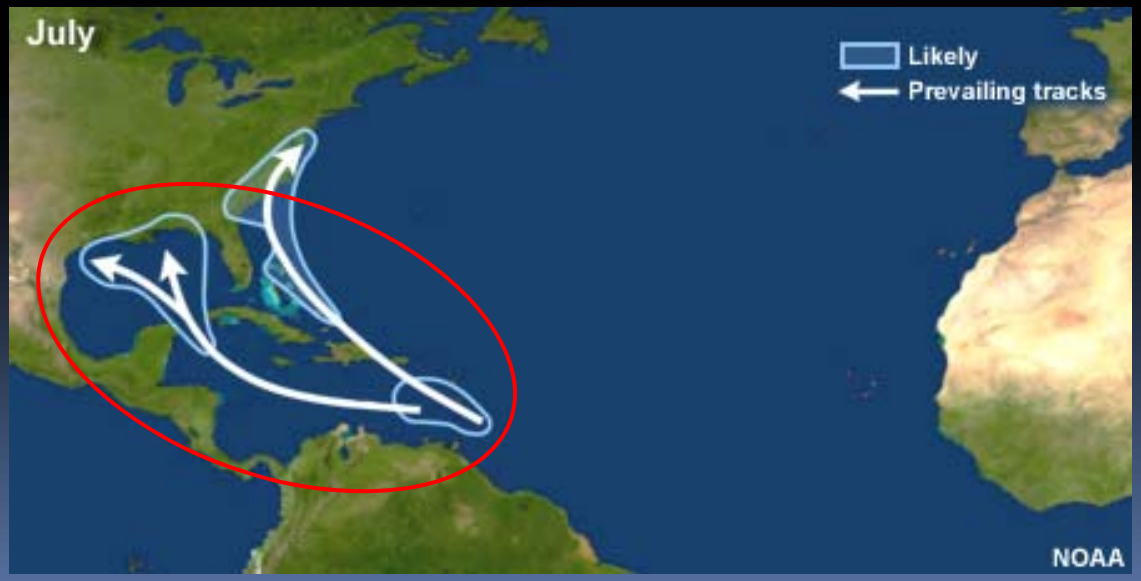


Annual Climatology of Atlantic Hurricanes



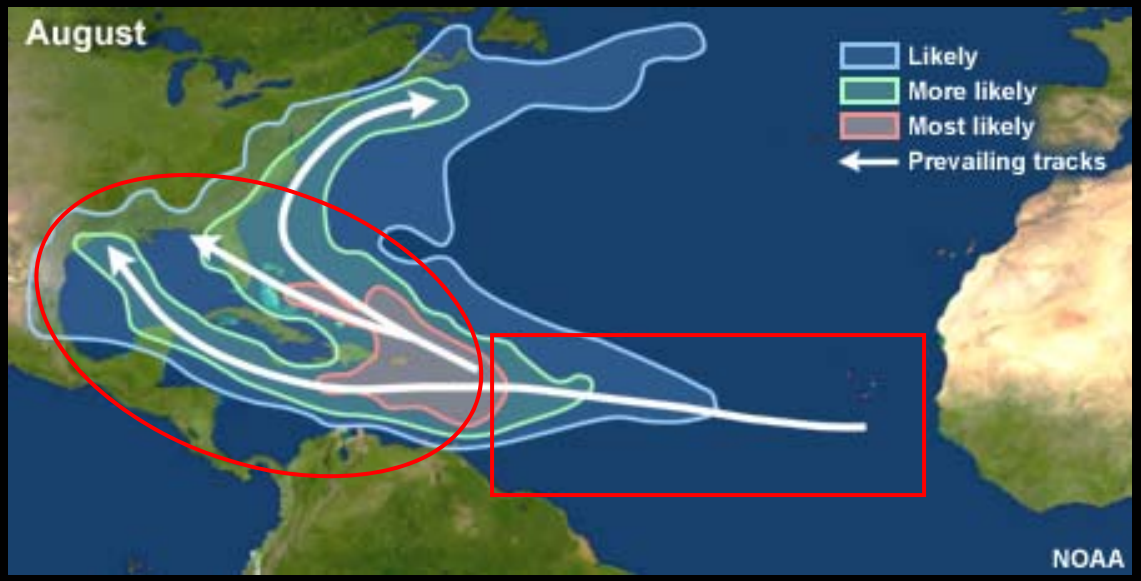
Climatological Areas of Origin and Tracks

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

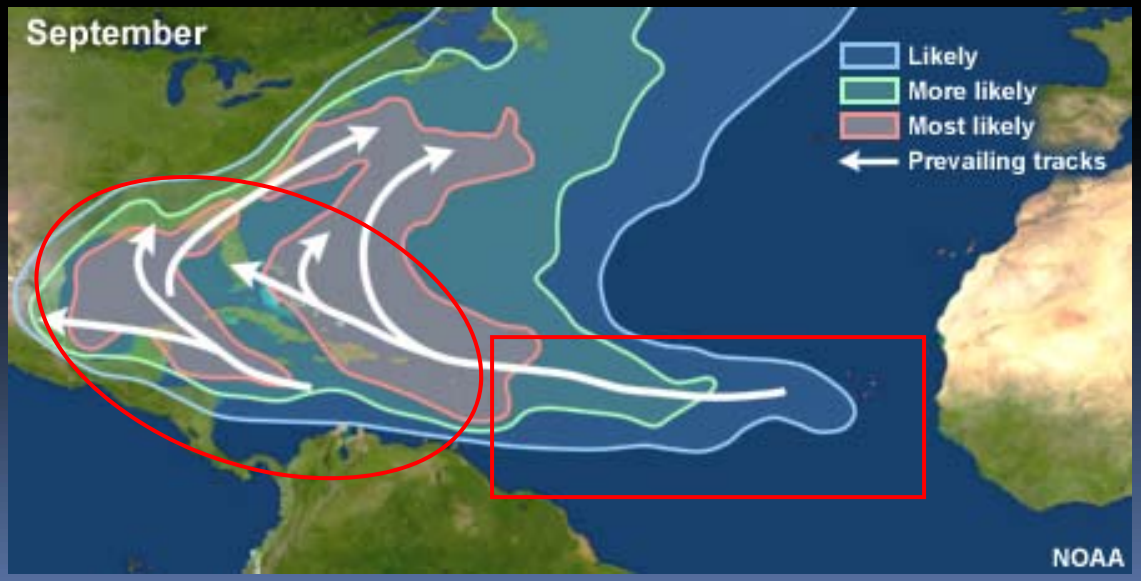


July: On average about 1 storm every year . Areas of possible development spreads east and covers the western Atlantic, Caribbean, and Gulf of Mexico.

Climatological Areas of Origin and Tracks



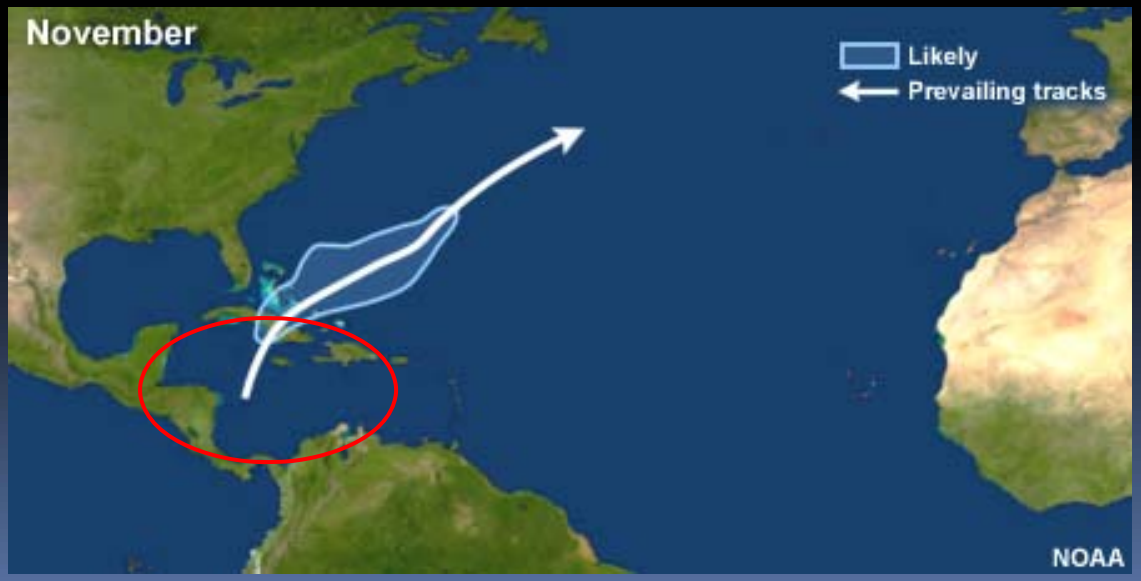
August: Activity usually increases in August. On average about 2-3 storms form in August. The Cape Verde season begins.



September: The climatological peak of the season. Storms can form nearly anywhere in the basin. Long track Cape Verde storms very possible

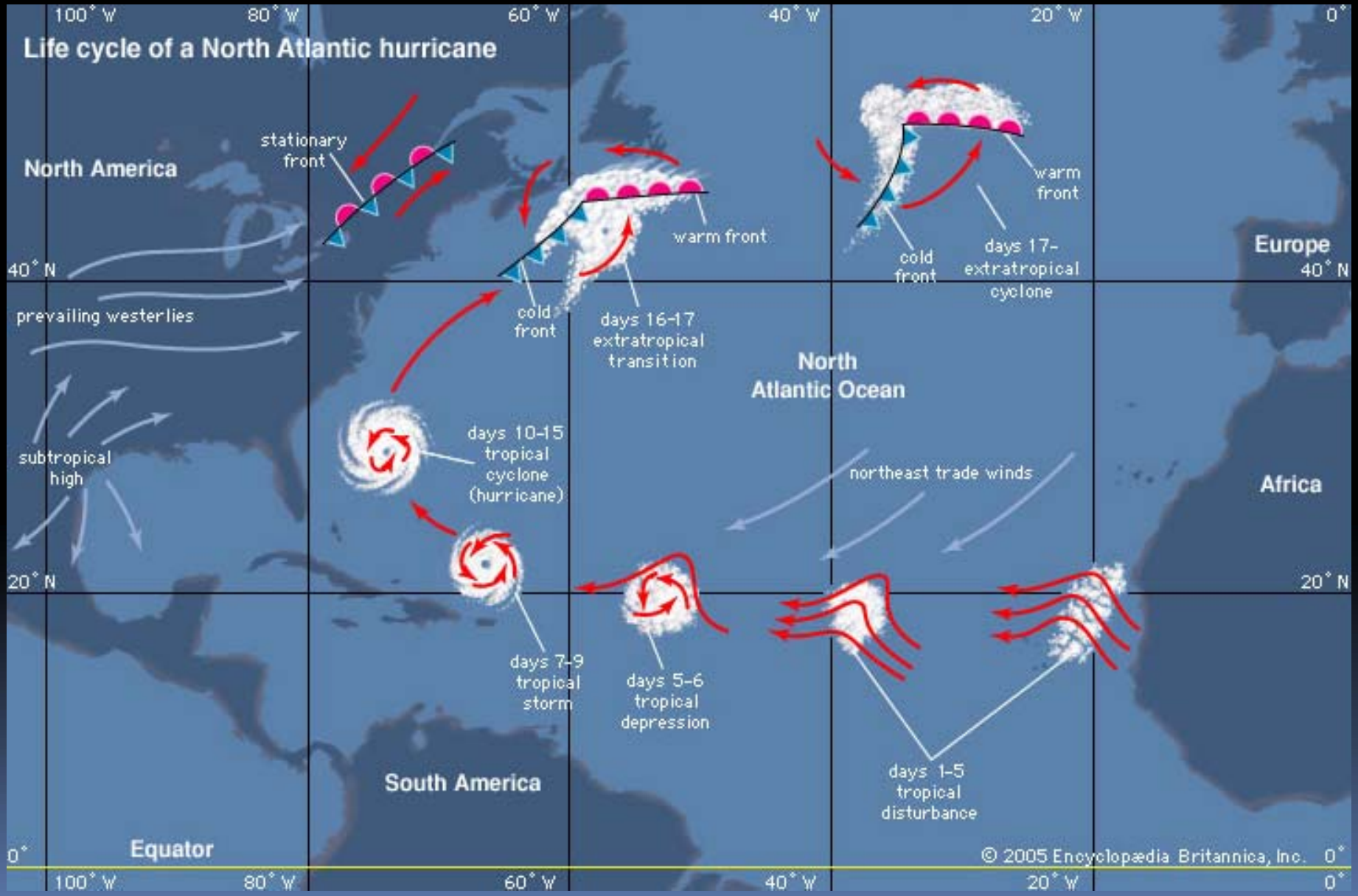
Climatological Areas of Origin and Tracks

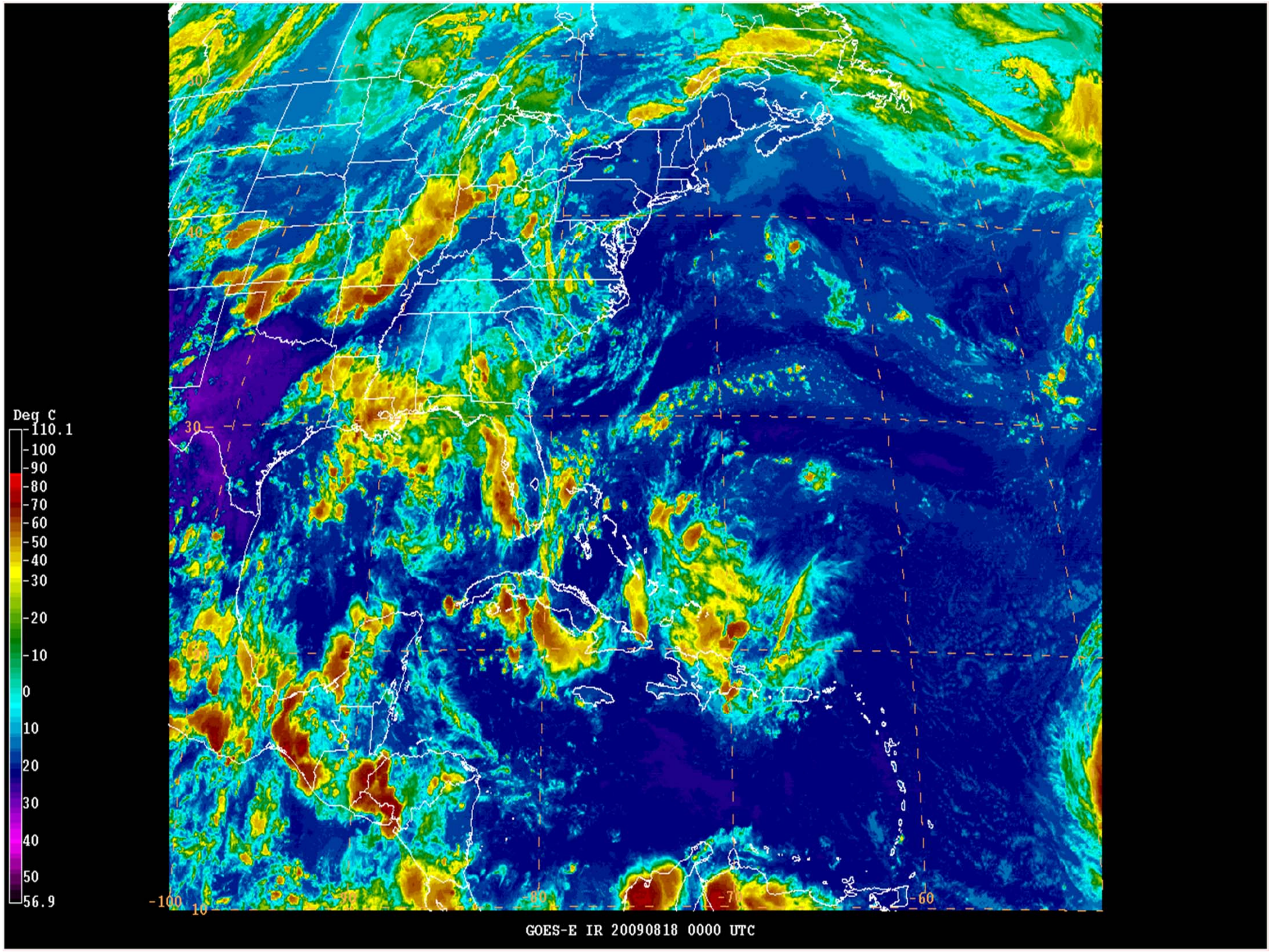
October: Secondary peak of season in mid-October. Cape Verde season ends. Development area shifts westward, back into the Caribbean, Gulf of Mexico, and western Atlantic.



November: Season usually slows down with about 1 storm occurring ever other year. Storm that do form typically develop in central Caribbean.

Life Cycle of a Cape Verde Hurricane

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40
30
-100
-80
-70
-60
GOES-E IR 20090818 0000 UTC

How to Build a Tropical Cyclone

Mechanical

1) A pre-existing disturbance (vorticity or spin)

2) Location several degrees north of the equator

3) Little change in wind speed and/or direciton with height (vertical wind shear)

Thermodynamic

4) Warm sea-surface temperatures (usually at least 80°F)

5) Unstable atmosphere (temperature goes down as you go up)

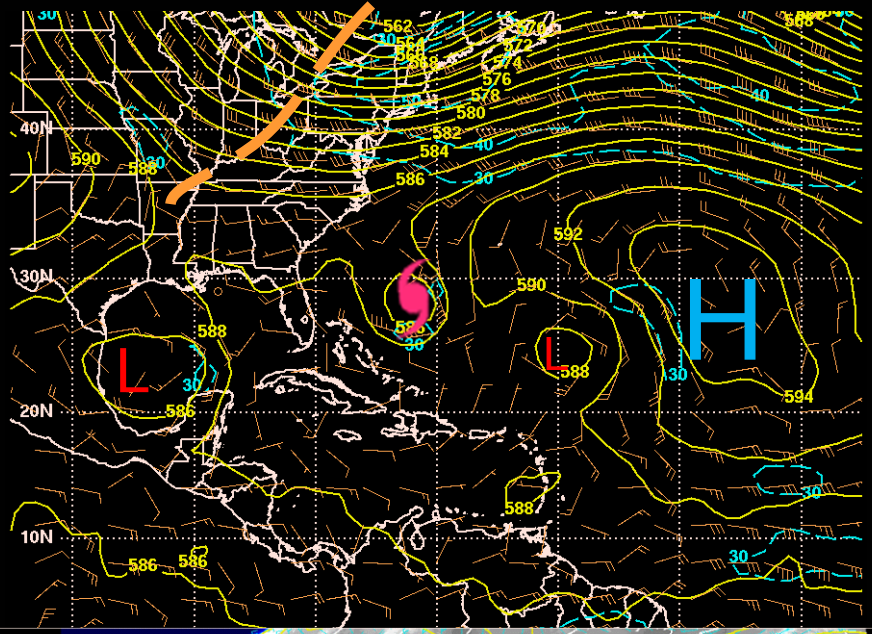
6) High atmospheric moisture content (relative humidity)

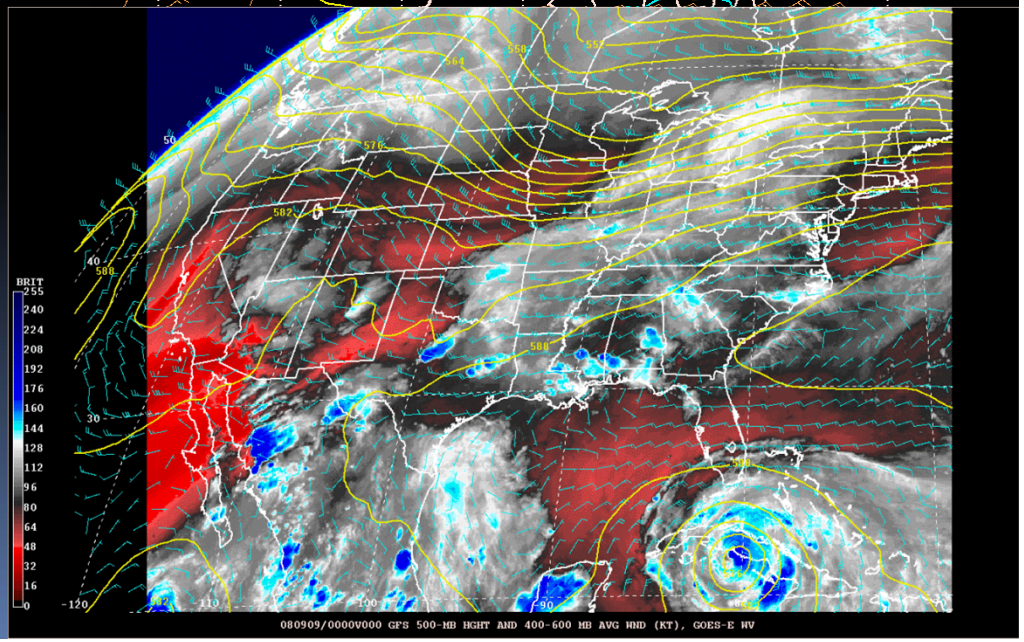
Pre-existing Disturbances

- Tropical waves play a role in about 70% of all Atlantic basin TC formations
- Cold-core low pressure systems in the upper levels of the atmosphere (Sean 2011)
- Decaying frontal systems (Franklin 2011)
- Thunderstorm clusters produced by non-tropical weather systems (Danny 1997)

Tropical Cyclone Motion

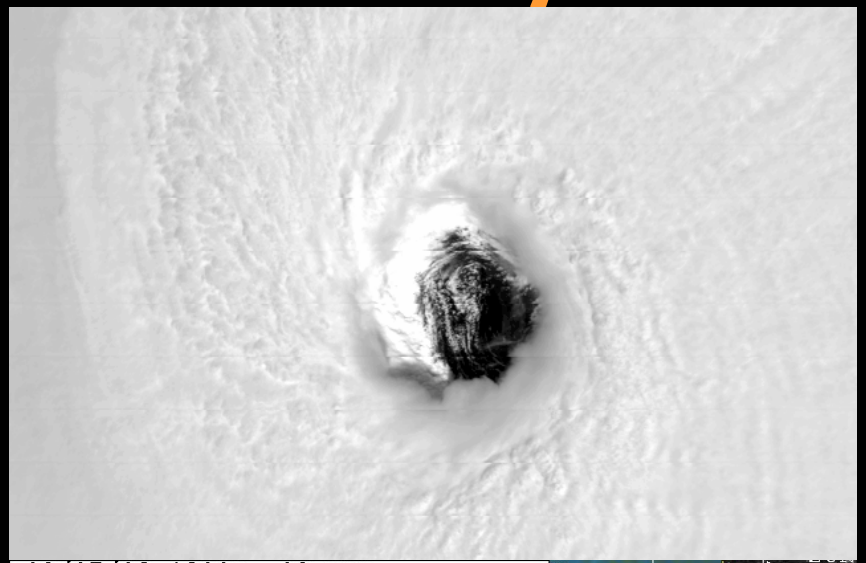
- Track forecasting is a relatively simple problem with well-understood physics
  - Cork in stream analogy
- Important atmospheric features are relatively large and easy to measure
- Numerical computer models forecast track quite well
  - Constantly improving with upgrades to model physics and resolution
  - Long ago surpassed statistical models in accuracy

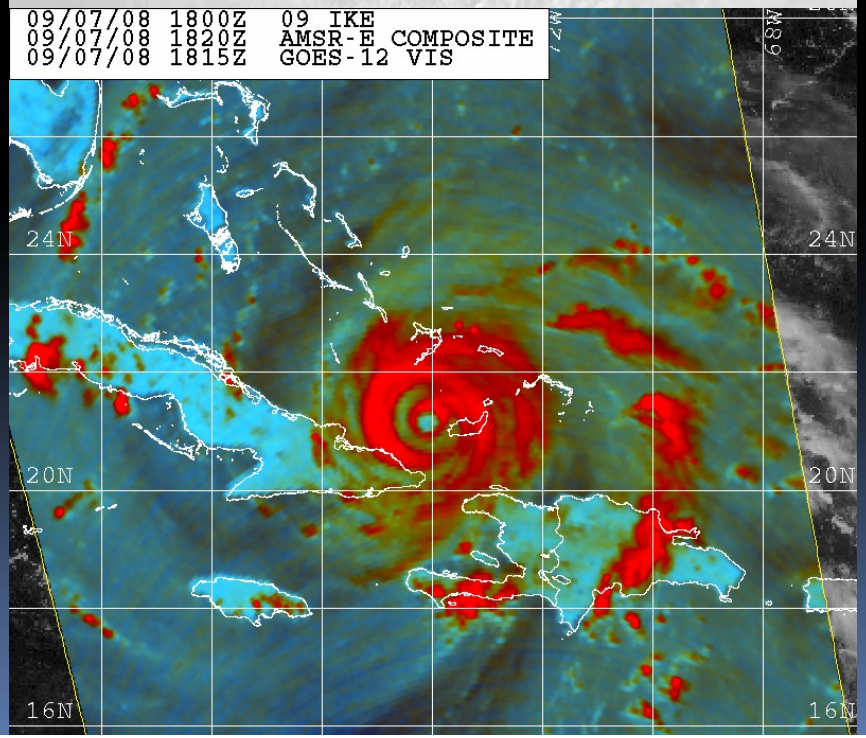




Tropical Cyclone Intensity

- Multi-scale problem that involves complex interactions between thunderstorms in the core and the environment, as well as atmosphere-ocean interactions
- Depends strongly on track
  - Interactions with land or subtle variations in sea-surface temperature and/or ocean heat content
- Depends critically on wind, temperature, and moisture patterns over the core and near environment
  - Often difficult or impossible to measure
- Depends on internal processes, such as eyewall replacement cycles, that are poorly understood

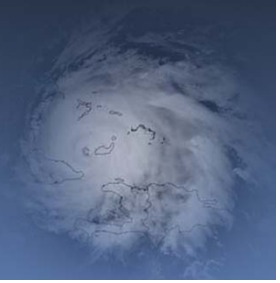




Factors Influencing TC Intensity

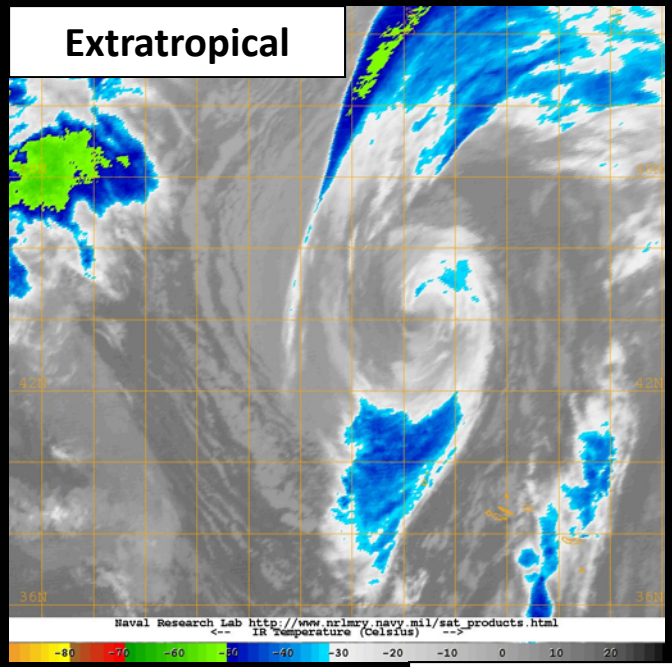
many of the same factors that govern development

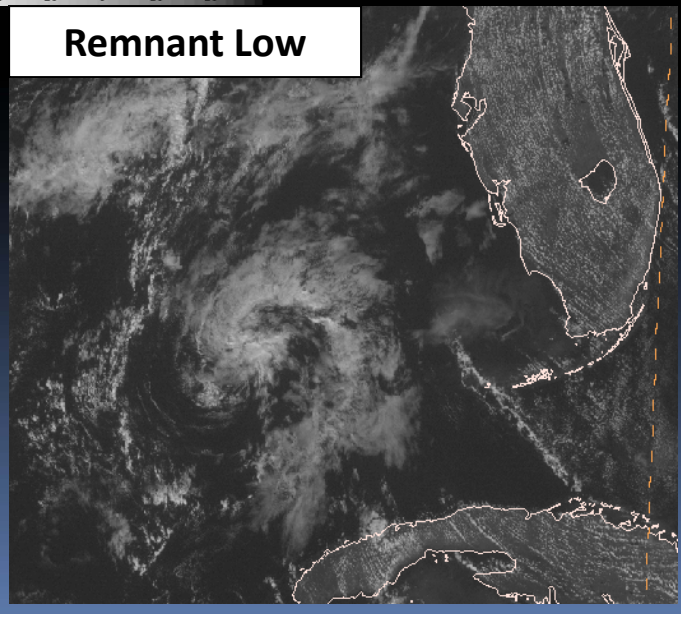
- Sea surface temperature (SST) and upper ocean heat content (OHC)
- Interaction with land/topography
- Vertical wind shear
- Interactions with upper-level troughs, other cyclones (tropical and extratropical)
- Temperature and moisture patterns in the storm environment
- Internal structural changes, such as eyewall replacement cycles

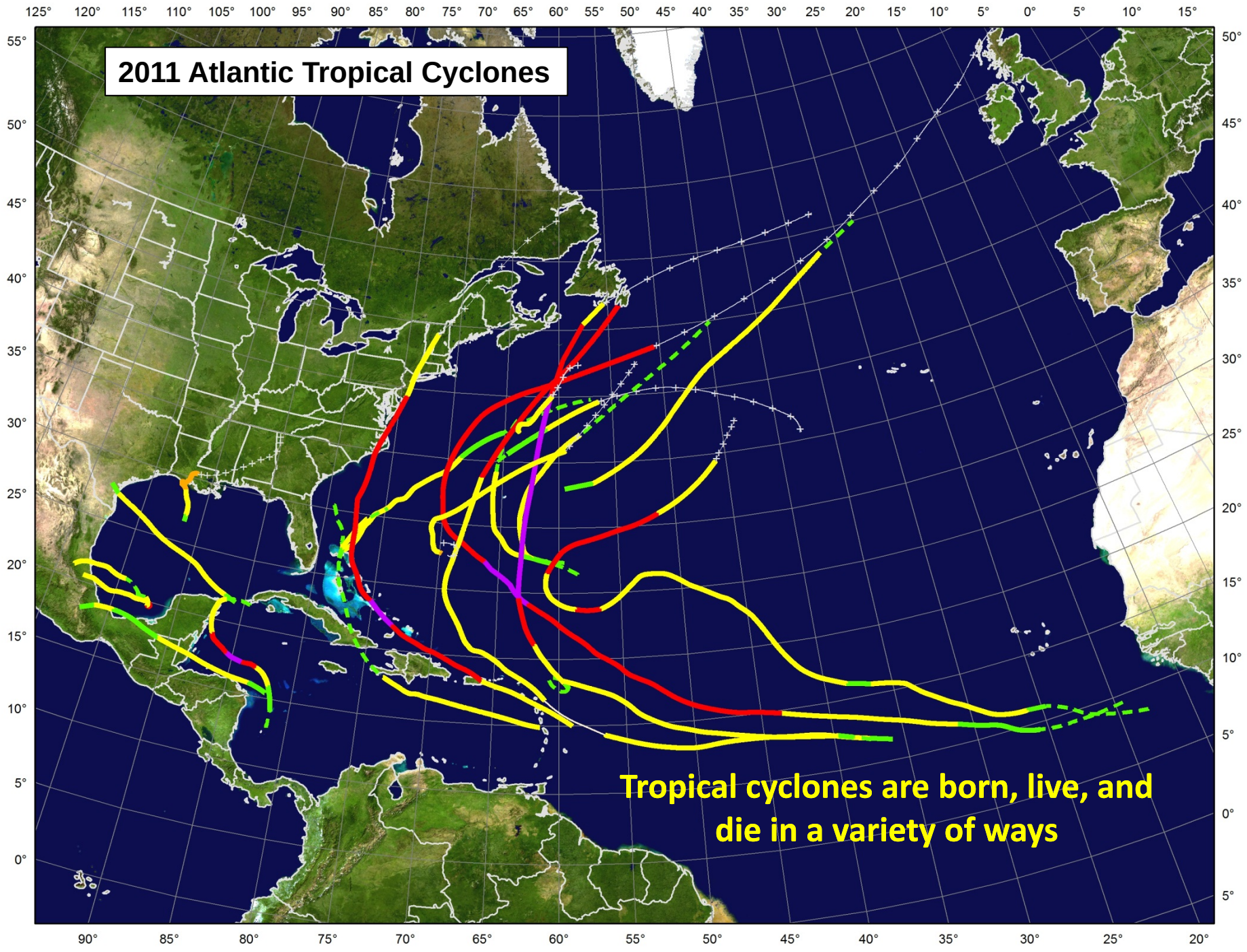


How do Tropical Cyclones die?

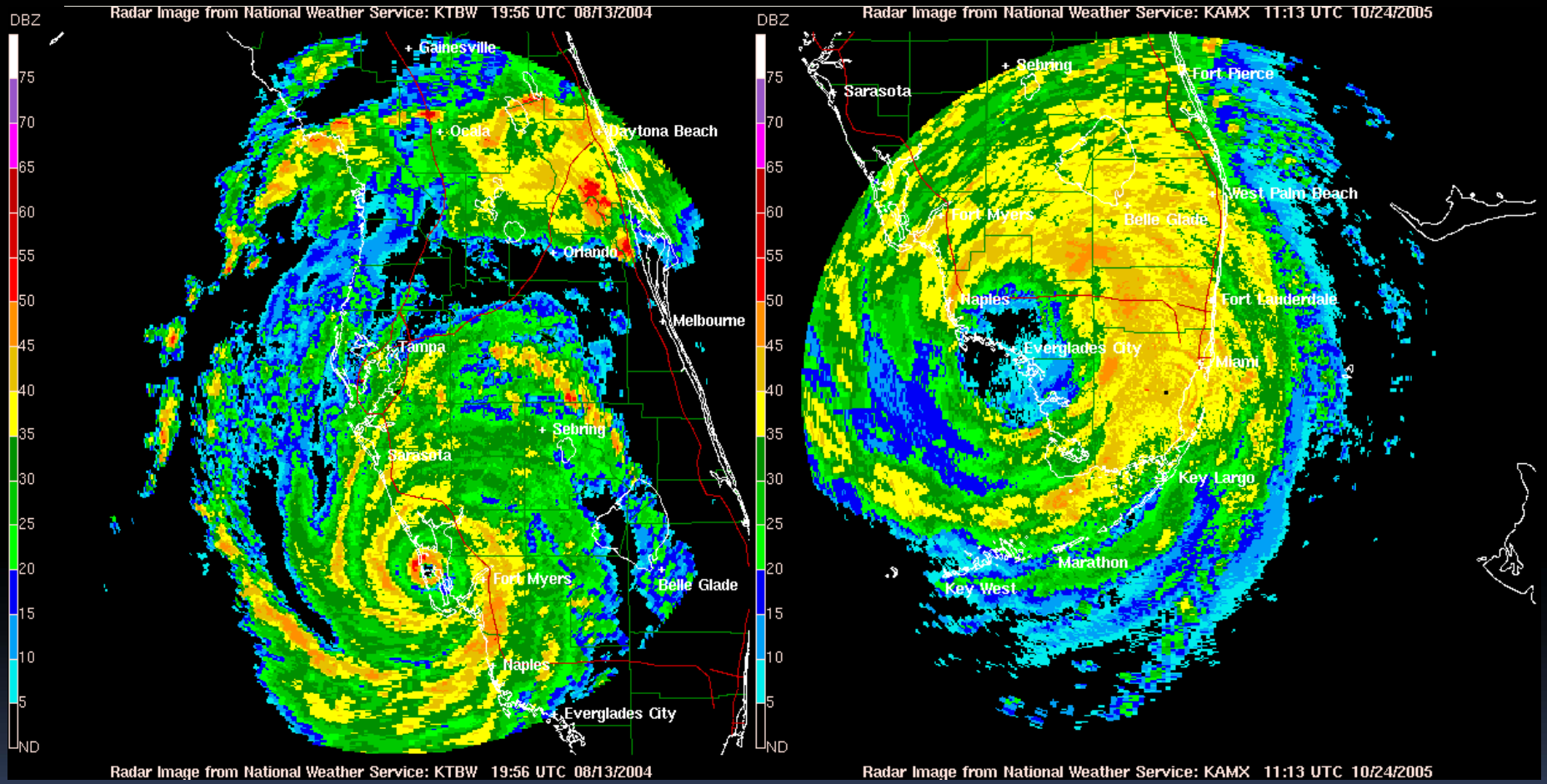
- Weaken over land
- Become "post-tropical"
  - Transform into an extratropical cyclone
  - Weaken over water due to hostile environmental conditions such as strong wind shear or cool SSTs, leaving a remnant low
- Merge with or be absorbed by a larger weather system (usually an extratropical cyclone or front)






2011 Atlantic Tropical Cyclones
Tropical cyclones are born, live, and die in a variety of ways

Tropical Cyclones Come in All Sizes



Hurricane Charley

Hurricane Wilma

Hurricane Hazards

Wind

Waves / Rip Currents

Tornadoes

Storm Surge

Rainfall / Inland Flooding

Saffir-Simpson Hurricane Wind Scale

Category	Winds	Summary
1	74-95 mph	Very dangerous winds will produce some damage
2	96-110 mph	Extremely dangerous winds will cause extensive damage
3	111-129 mph	Devastating damage will occur
4	130-156 mph	Catastrophic damage will occur
5	157 + mph	Catastrophic damage will occur

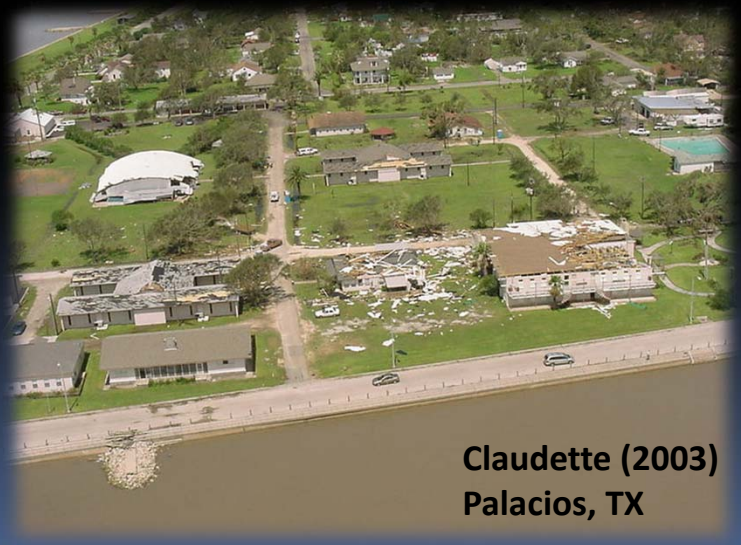
www.nhc.noaa.gov/aboutsshs.shtml

Category 1 (74 – 95 mph)

Very dangerous winds will produce some damage

Humberto (2007)
Southeast TX

Katrina (2005)
Miami, FL



Claudette (2003)
Palacios, TX

Lili (2002)
Louisiana

Category 2 (96 – 110 mph)

Extremely dangerous winds will cause extensive damage

Category 3 (111 – 129 mph)

Devastating damage will occur

Rita (2005)
Orange, TX

Jeanne (2004)
Cape
Canaveral, FL

Rita (2005)
Orange, TX

Category 4 (130 – 156 mph)

Catastrophic damage will occur

Category 5 (greater than 156 mph)

Catastrophic damage will occur

Andrew (1992)
Florida City, FL

Andrew (1992)
South Dade, FL

Felix (2007)
Nicaragua

Wind-blown Debris can Become Deadly Projectiles in a Hurricane

Storm Surge

Stayed tuned for Robbie Berg and Jamie Rhome this afternoon

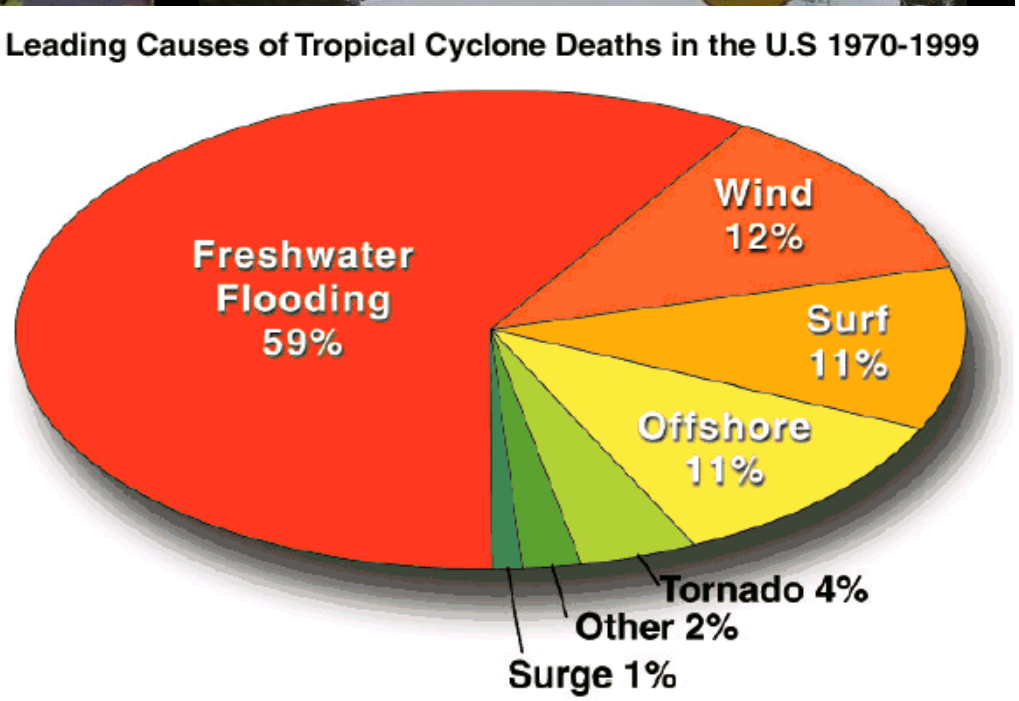
House of David and Kimberly King
Waveland, Mississippi

Fresh Water Flooding

US Army Corps of Engineers

NC DENR

IMPORTANT!
These years do not include Camille (1969) or Katrina (2005) – 2 big storm surge producers



Source: Edward Rappaport—Chief, Technical Support Branch, Tropical Prediction Center

About one quarter of all deaths from 1970-1999 occurred to people who drowned in, or attempted to abandon, their vehicles.

Fort Washington, PA

Times Herald

Hurricane Floyd (1999)

Inland Fresh Water Flooding - Tarboro, NC

Interstate 10

Houston, Texas

Interstate 10, Looking West, Houston, Texas

Tropical Storm Allison (2001)

Houston, Texas

Interstate 10, Looking West, Houston, Texas
Tropical Storm Allison

Houston Chronicle

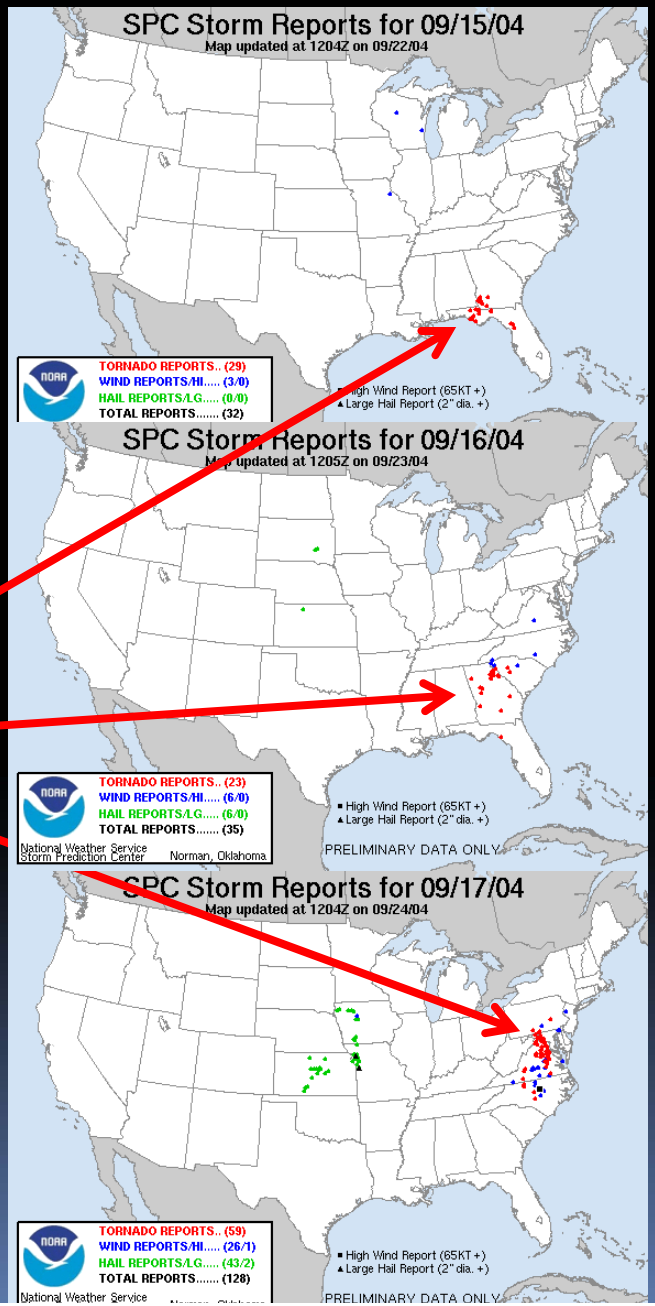
FACTORS AFFECTING RAINFALL AMOUNTS AND DISTRIBUTION IN TROPICAL CYCLONES

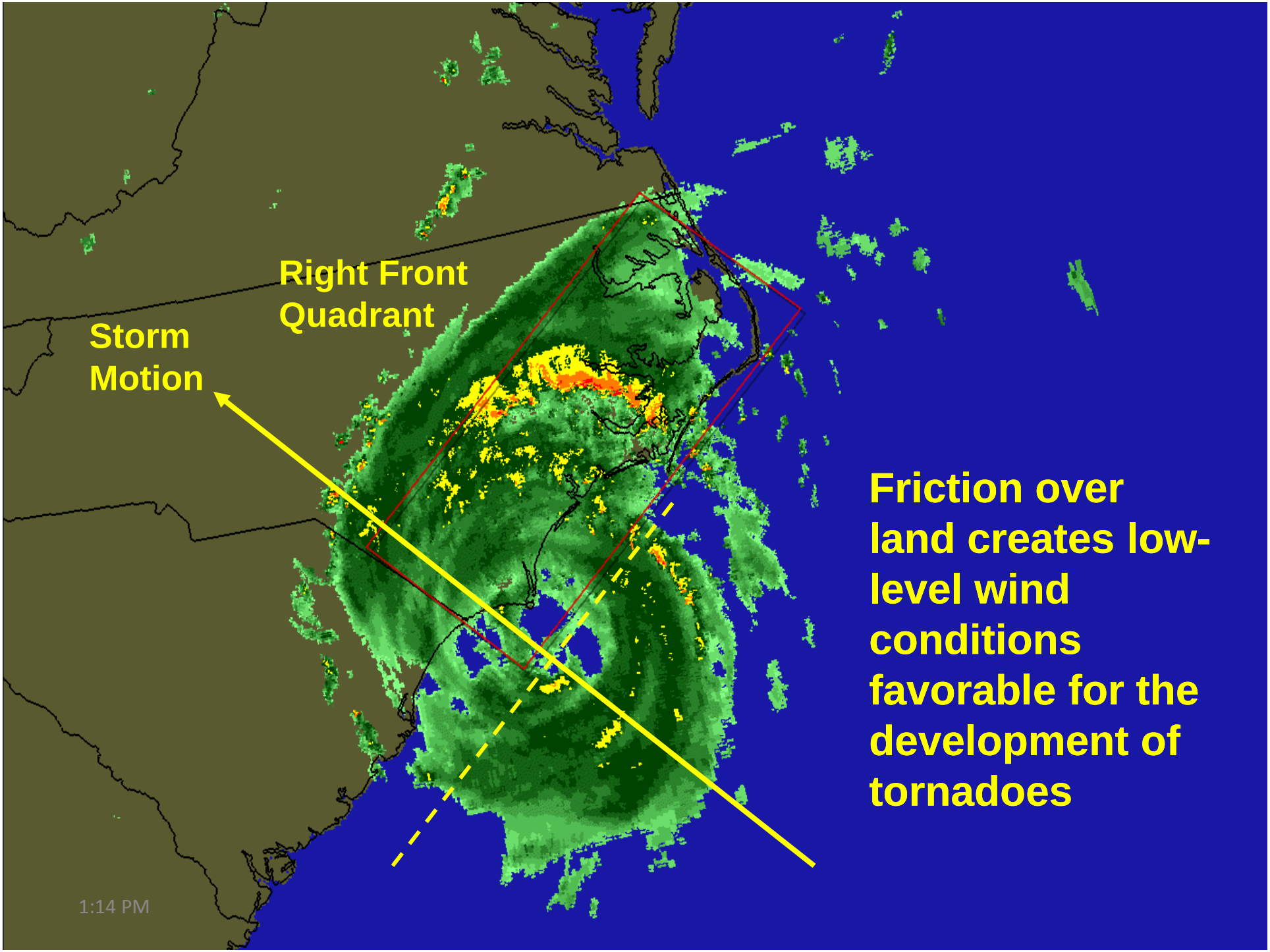
1. SIZE (Bigger storm = more rain)
2. MOTION (Slower storm = more rain)
3. RAIN RATE (Higher rain rate = more rain)
4. VERTICAL WIND SHEAR (more rain on one side)
5. TOPOGRAPHY (more rain on windward side)
6. FRONTAL BOUNDARIES / UPPER LEVEL TROUGHS

1:14 PM

Hurricane-Induced Tornadoes

- Nearly 70% of landfalling hurricanes (1948-2000) spawned at least 1 tornado
- 40% of landfalling hurricanes spawn more than 3 tornadoes
- Some hurricanes produce tornado “outbreaks”
  - Hurricane Beulah (1967): 141
  - Hurricane Ivan (2004): 117
  - Hurricane Frances (2004): 101
  - Hurricane Rita (2005): 90
  - Hurricane Camille (1969): 80
  - Hurricane Katrina (2005): 43




Right Front
Quadrant
Storm
Motion
Friction over land creates low-level wind conditions favorable for the development of tornadoes
1:14 PM

Waves and Rip Currents

6 deaths in the U. S. occurred during the 2010 hurricane season resulted from waves and rip currents along the coast.

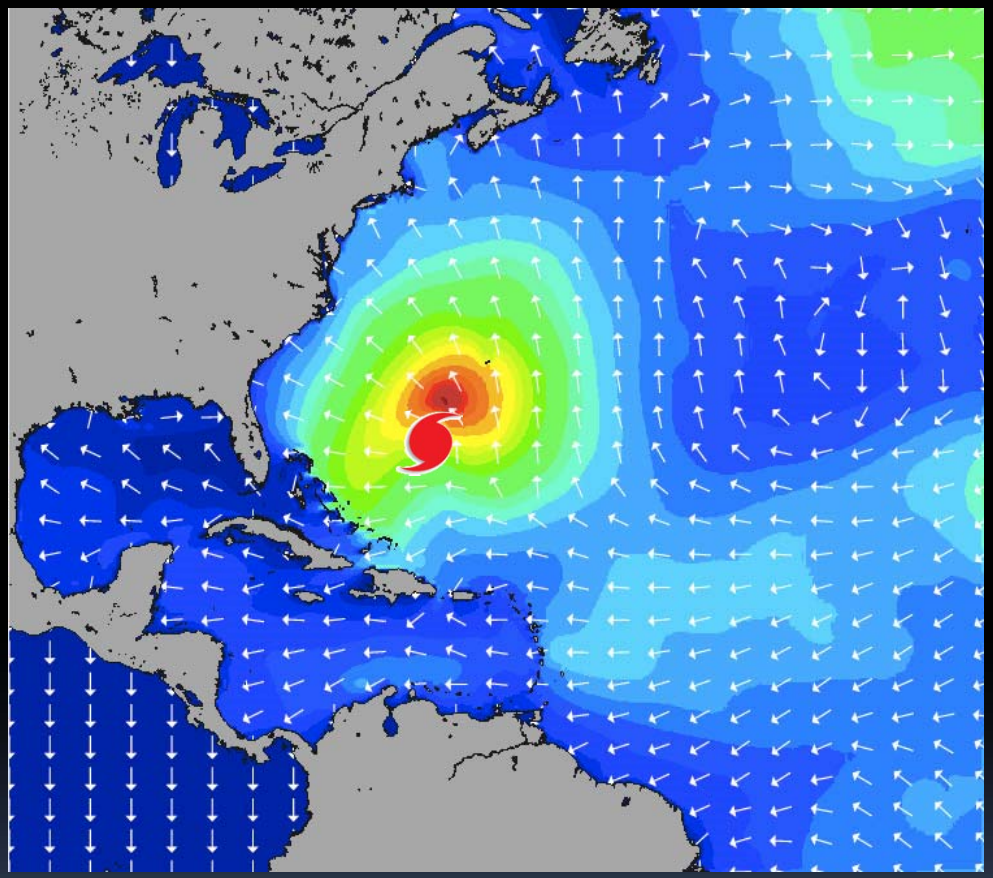
Hidden danger because it can occur when a storm is well offshore

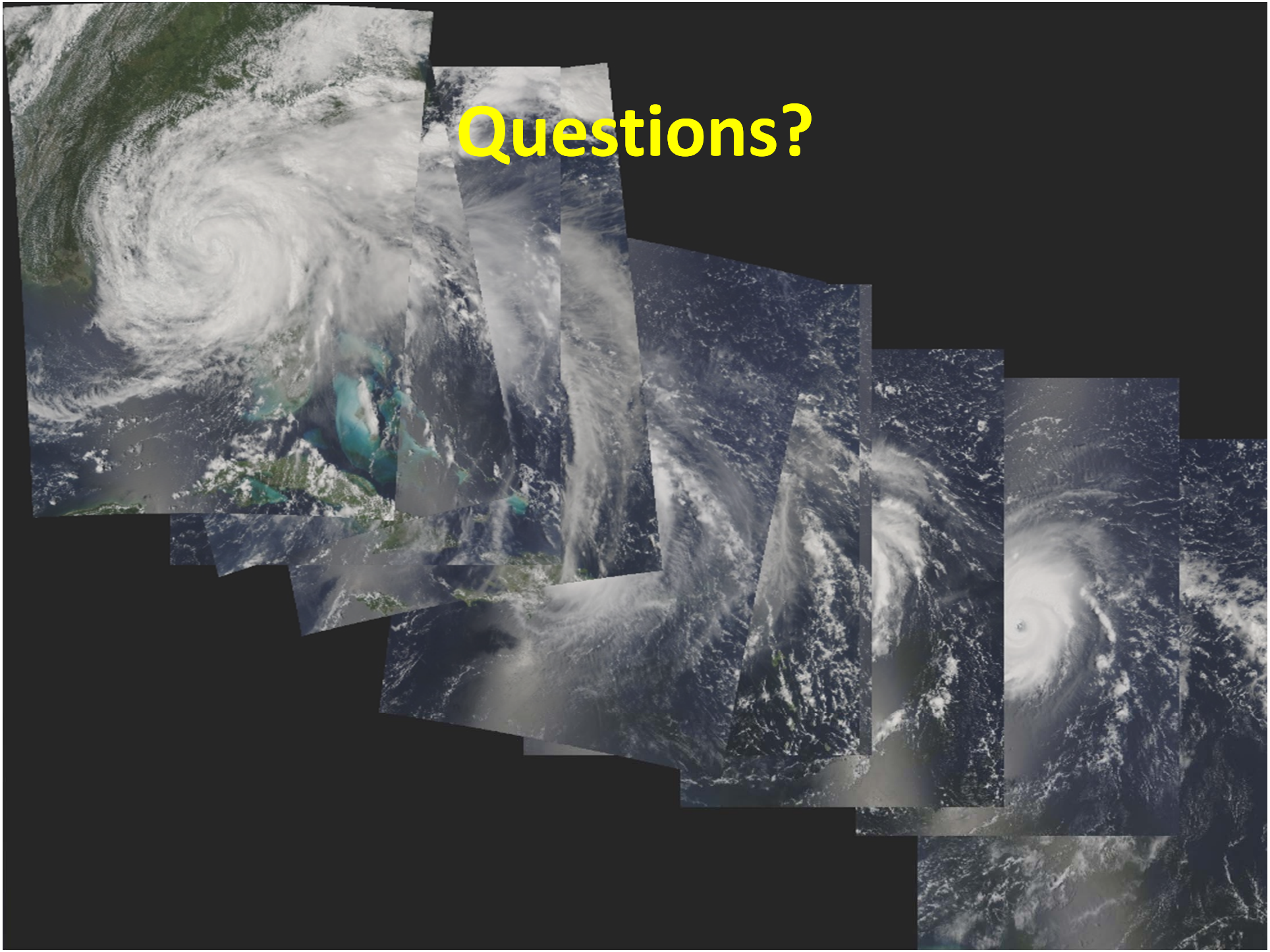
Waves and Rip Currents

Swell 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**




Questions?