Introduction to Tropical Cyclones

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National Hurricane Center

Florida Governor's Hurricane Conference

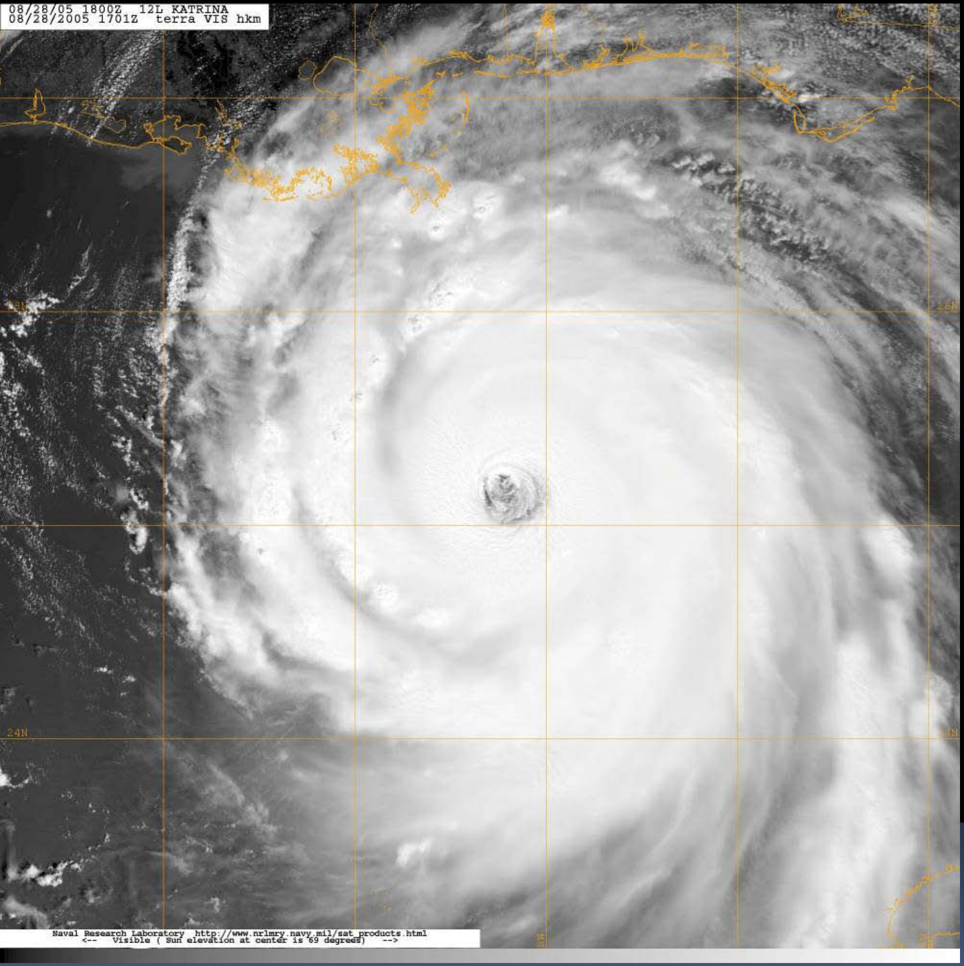
24 May 2010

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

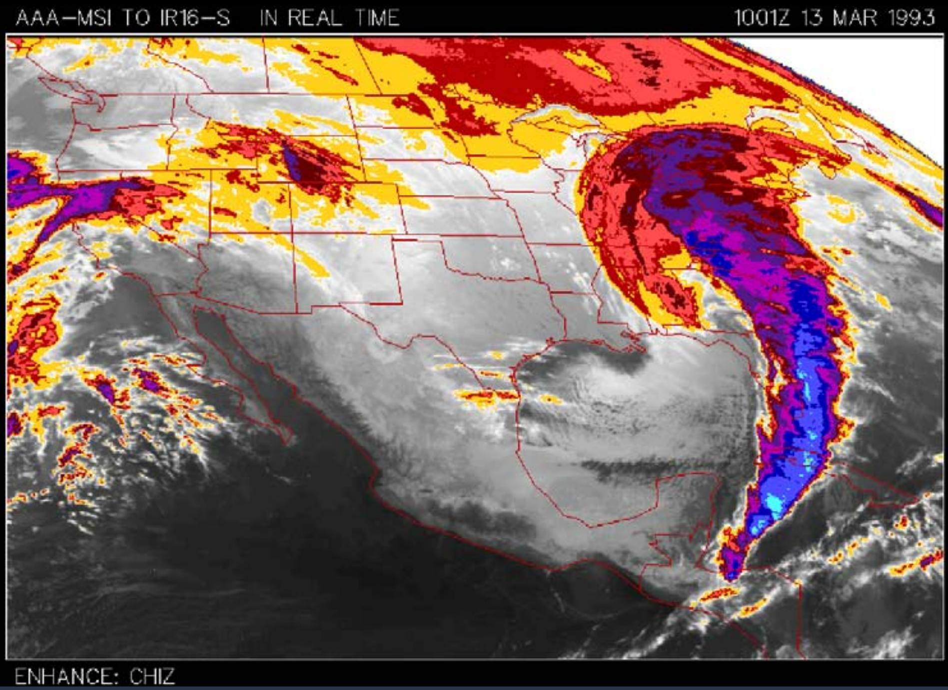
What is a Tropical Cyclone?

- 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

The Extremes:
Tropical vs. Extratropical Cyclones

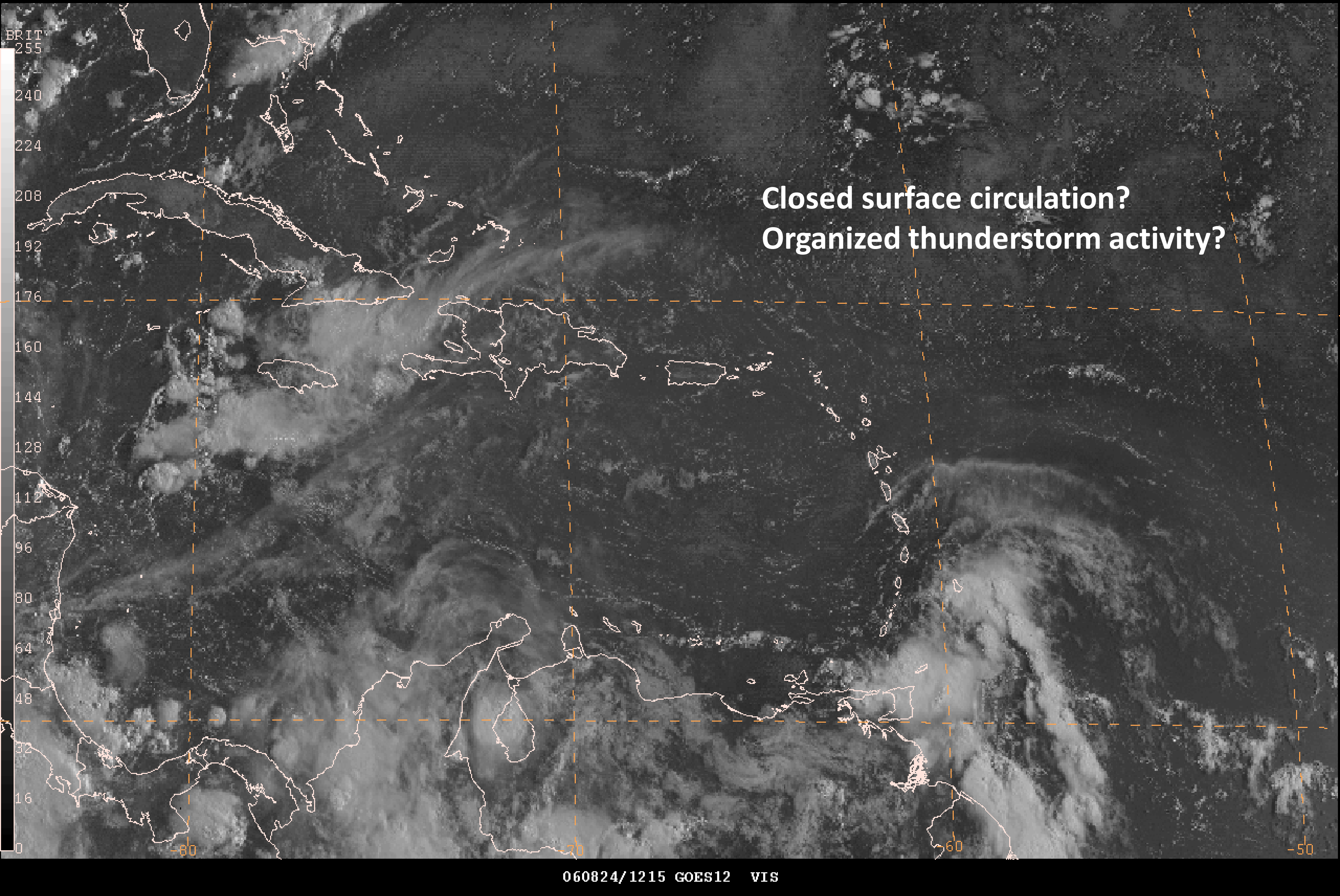


Hurricane Katrina (2005)

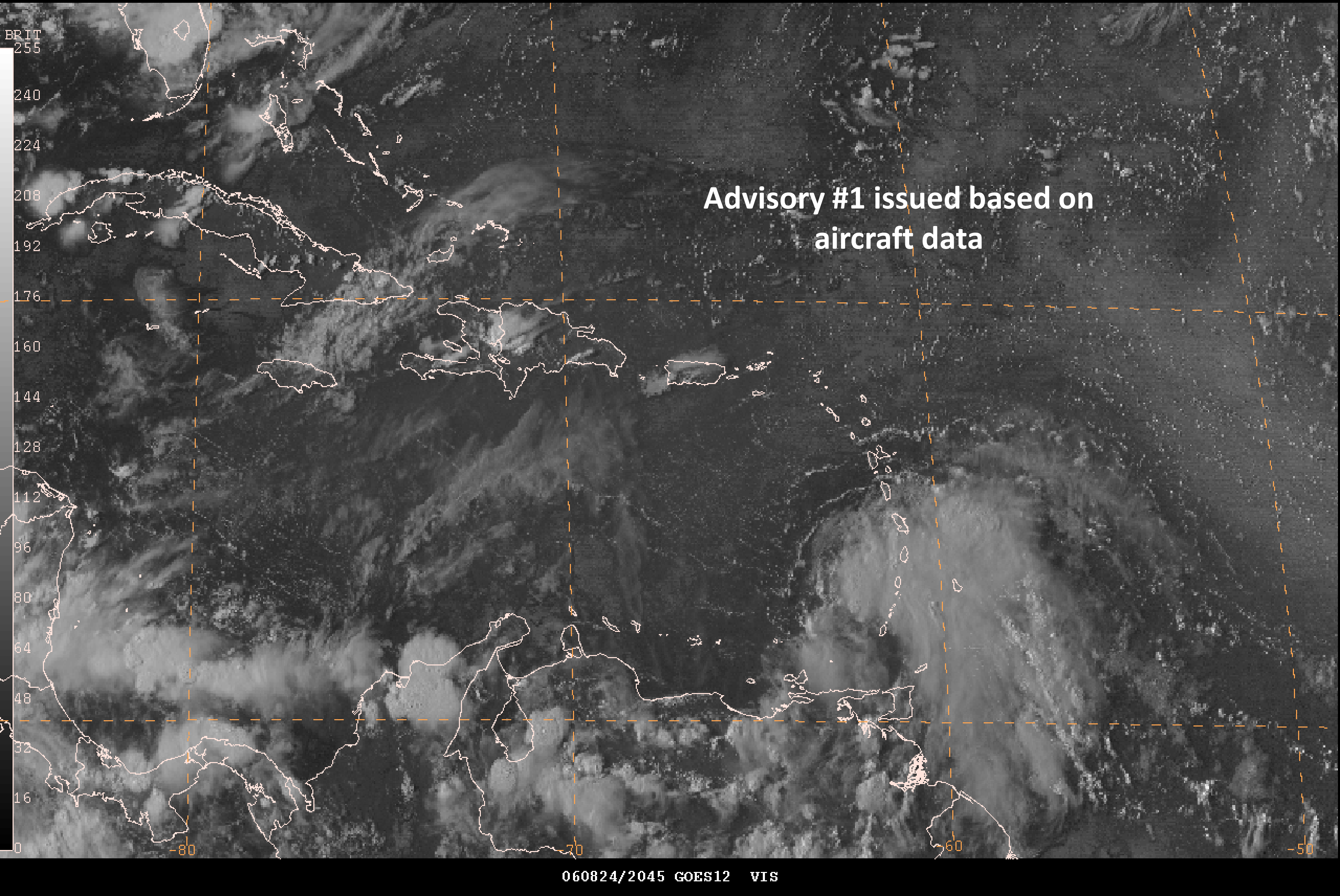


Superstorm Blizzard of March 1993

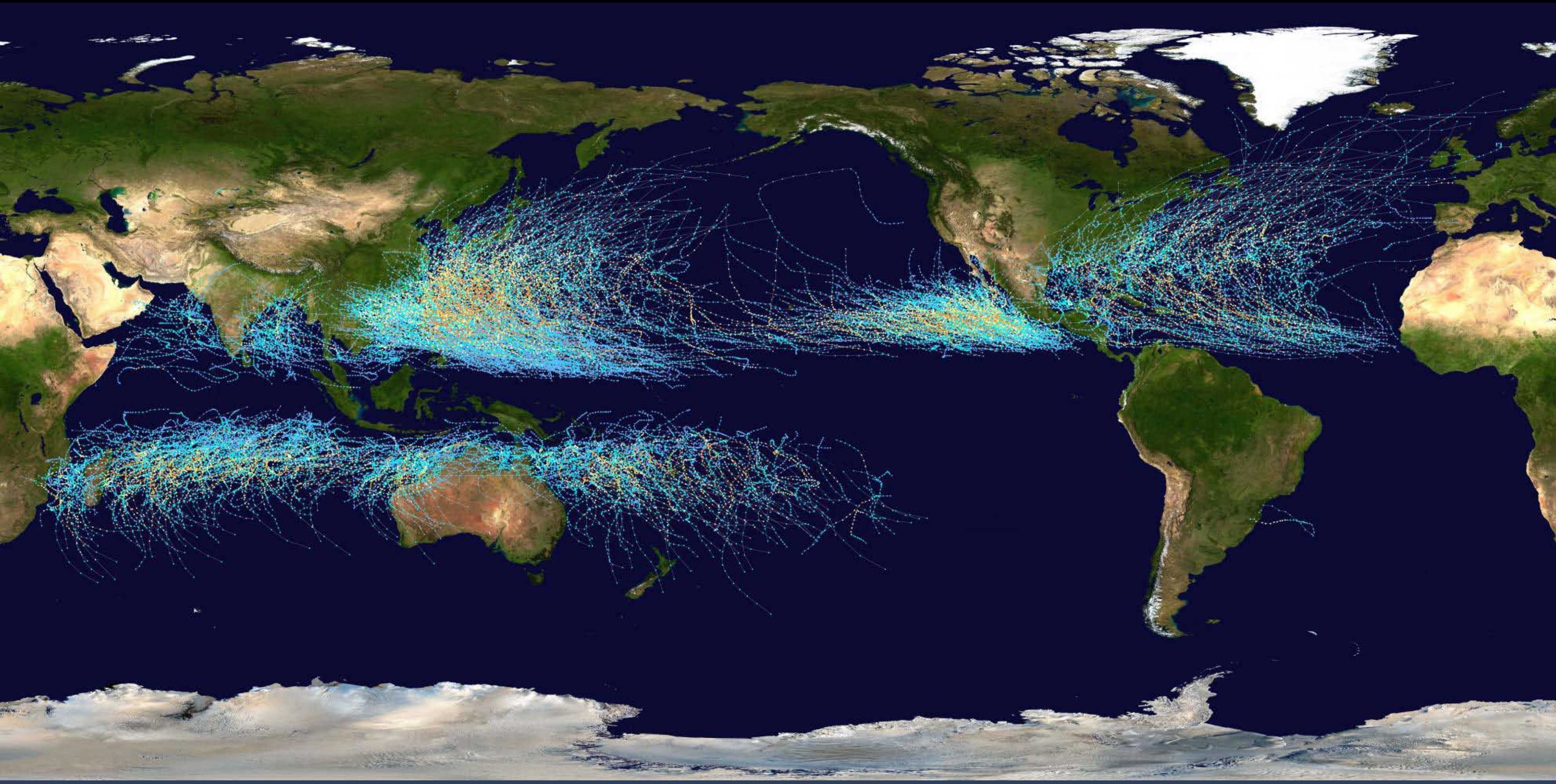
Is This a Tropical Cyclone?



Tropical Depression #5 (later Ernesto)

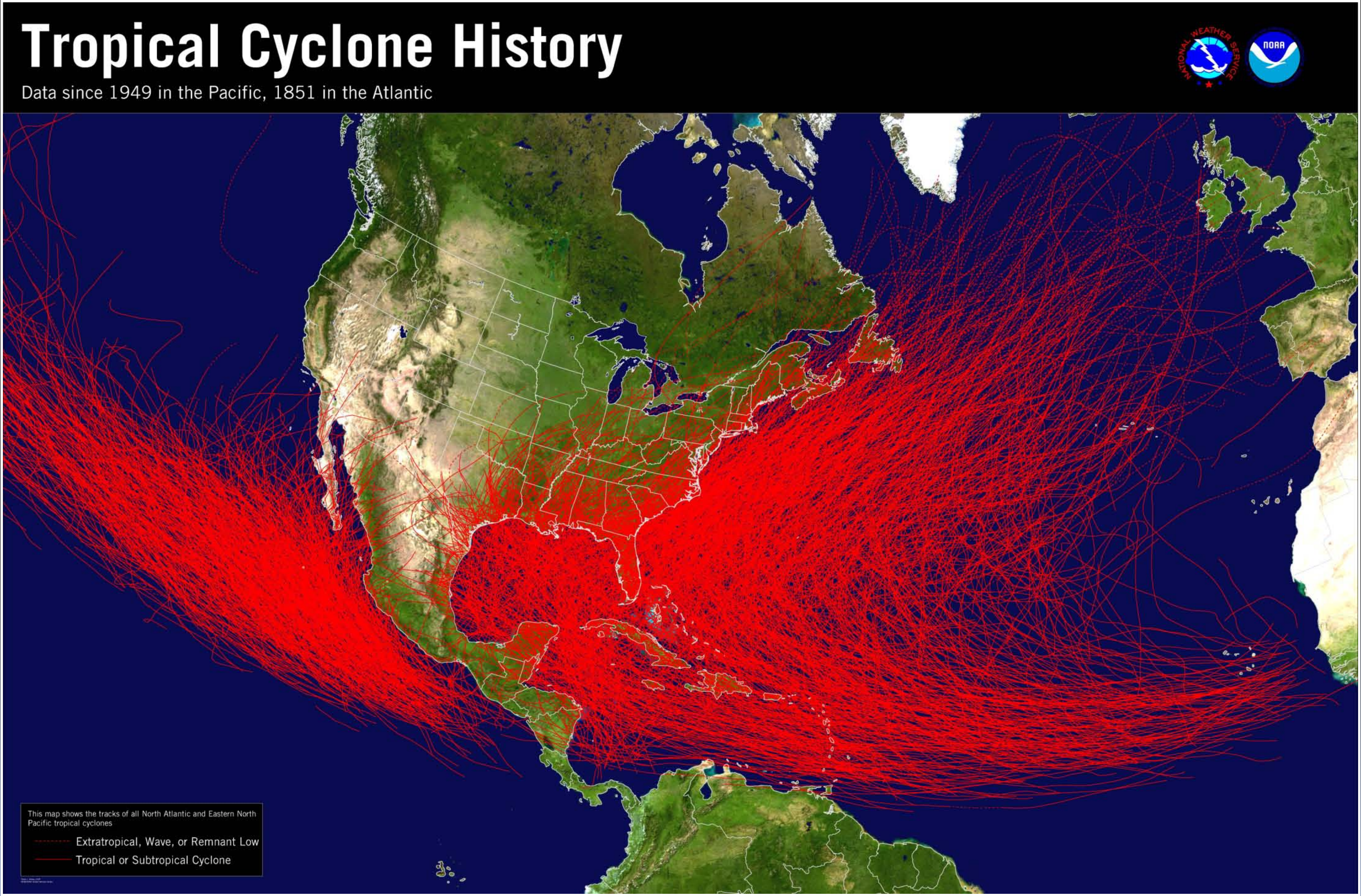


Tropical Cyclones Occur Over Tropical and Subtropical Waters Across the Globe



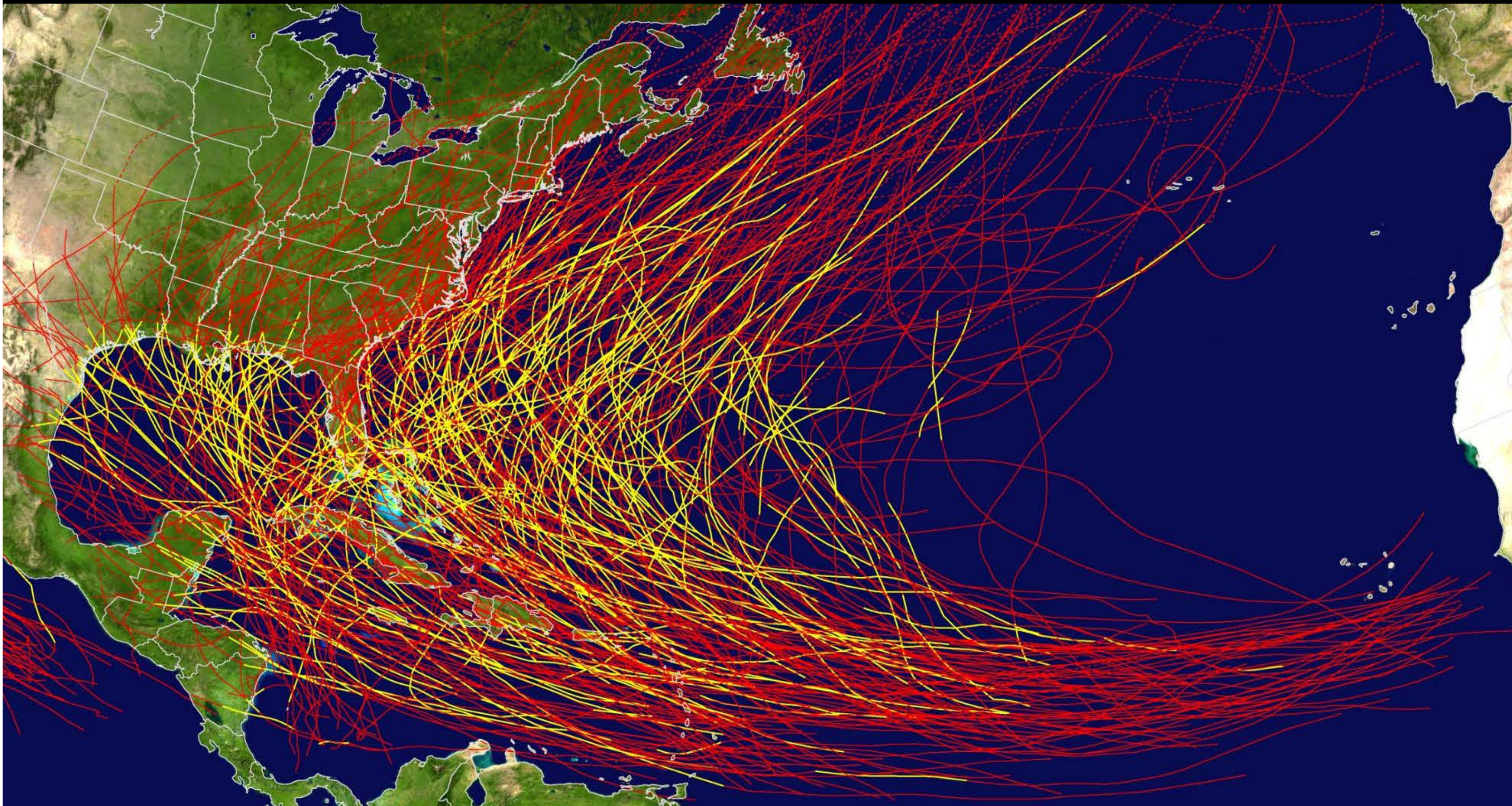
Tropical cyclones tracks between 1985 and 2005

Atlantic Basin Tropical Cyclones Since 1851



Major Hurricane History

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



How to Build a Tropical Cyclone

<table>
<tr><th>Mechanical</th><th>Thermodynamic</th></tr>
<tr><td>1) A pre-existing disturbance (vorticity or spin)
</td><td>4) Warm sea-surface temperatures (usually at least 80°F)

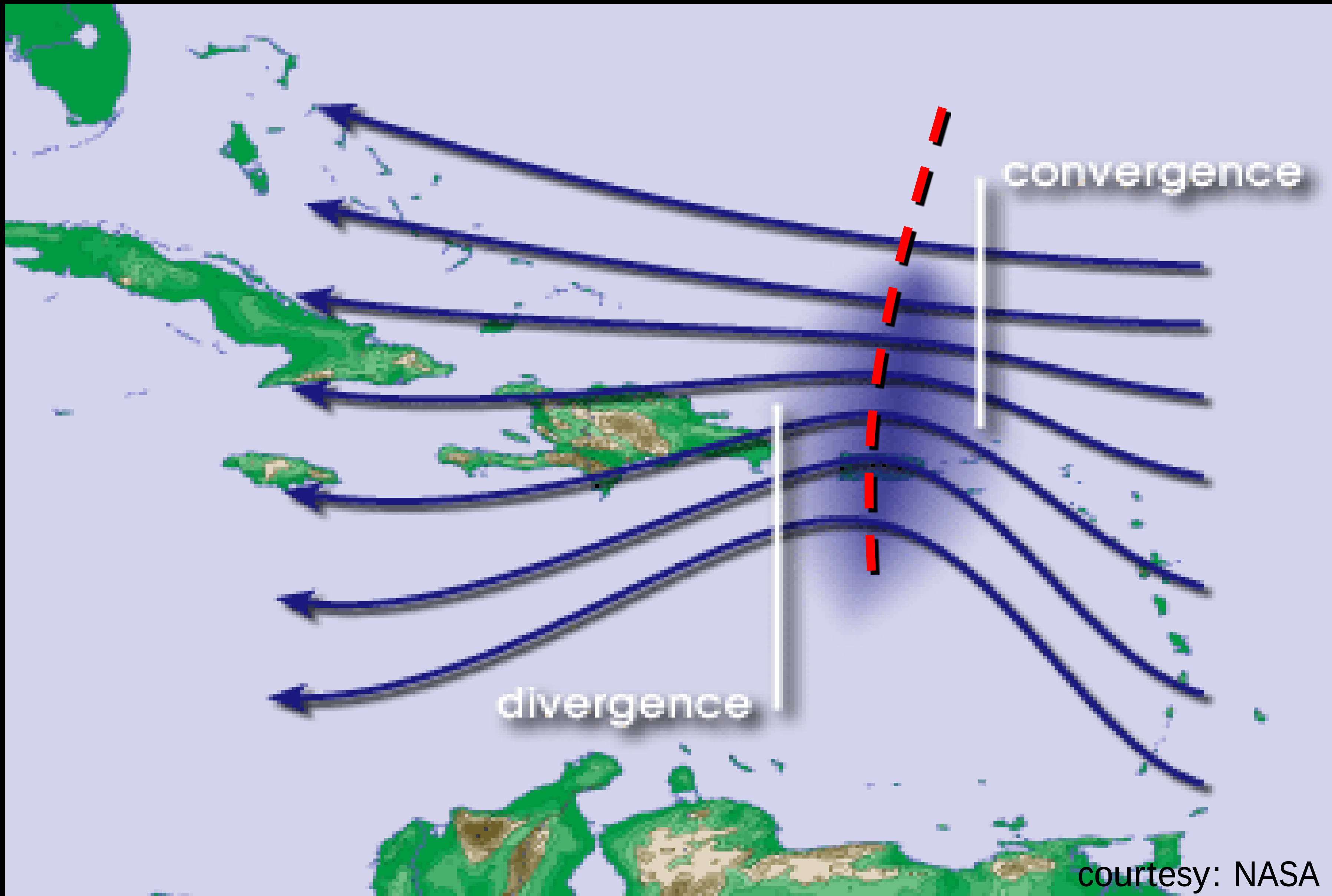
</td></tr>
<tr><td>2) Location several degrees north of the equator
</td><td>5) Unstable atmosphere (temperature goes down as you go up)
</td></tr>
<tr><td>3) Little change in wind speed and/or direciton with height (vertical wind shear)
</td><td>6) High atmospheric moisture content (relative humidity)

</td></tr>
</table>

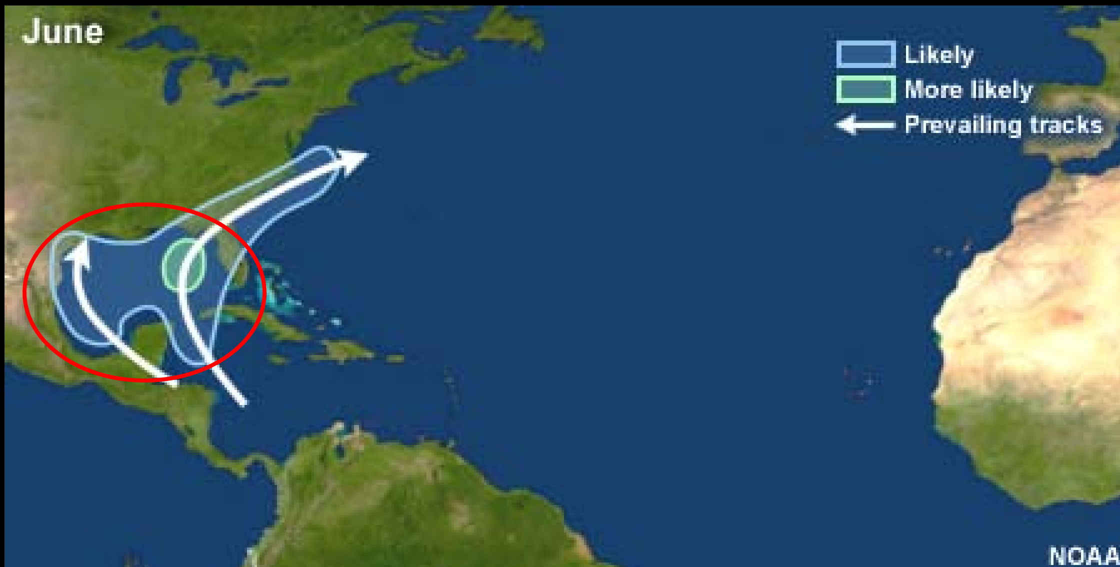
Pre-existing Disturbances

- 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 (*i.e.* Grace 2009)
- Decaying frontal systems (*i.e.* T.D. One 2009)
- Thunderstorm clusters produced by non-tropical weather systems (Danny 1997)

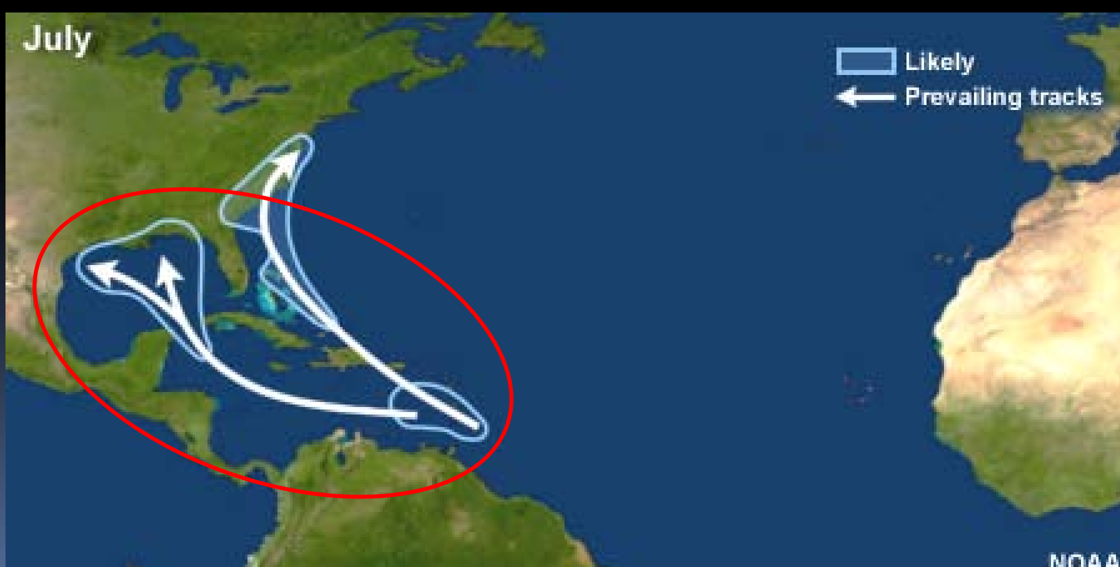

Tropical Wave



Climatological Areas of Origin and Tracks

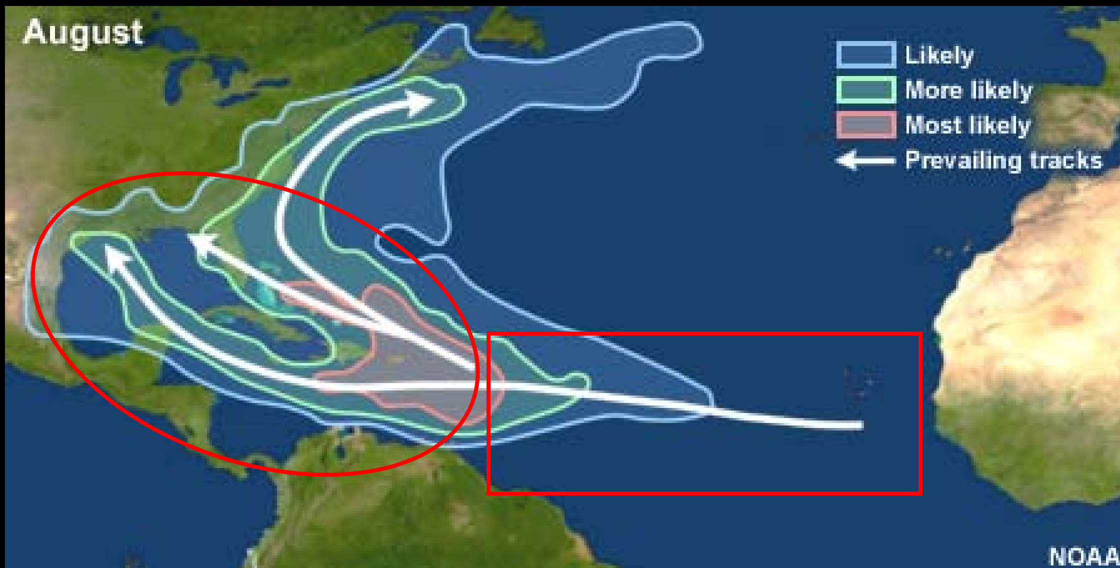


June: On average about 1 storm every other year. Most June storms form in the northwest Caribbean Sea or Gulf of Mexico.



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

Climatological Areas of Origin and Tracks

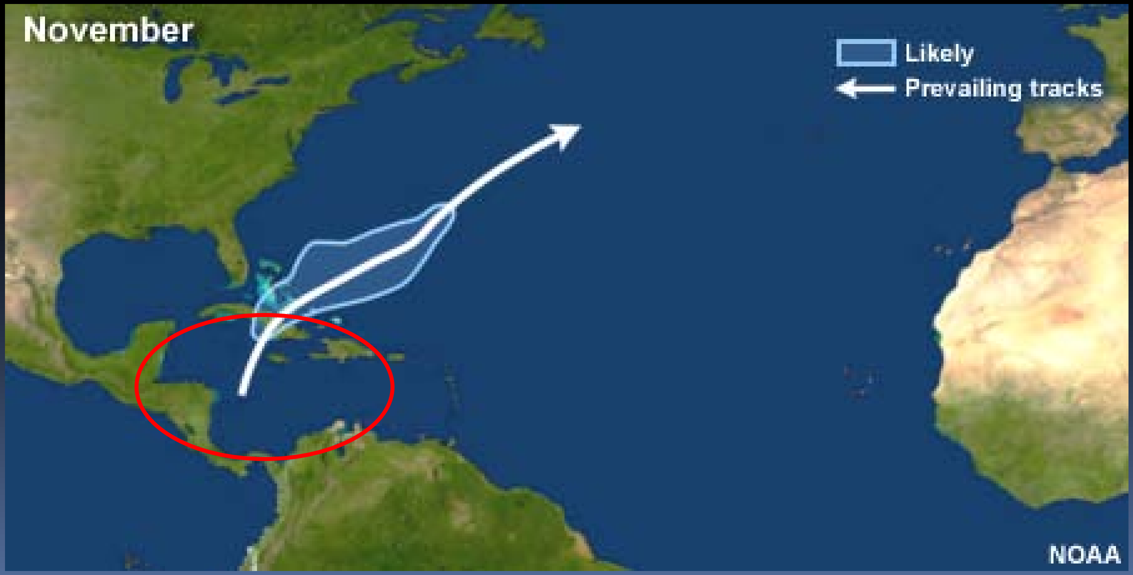


August: Activity usually increases in August. On Average about 2-3 storm for in August. The Cape Verde season begins.

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

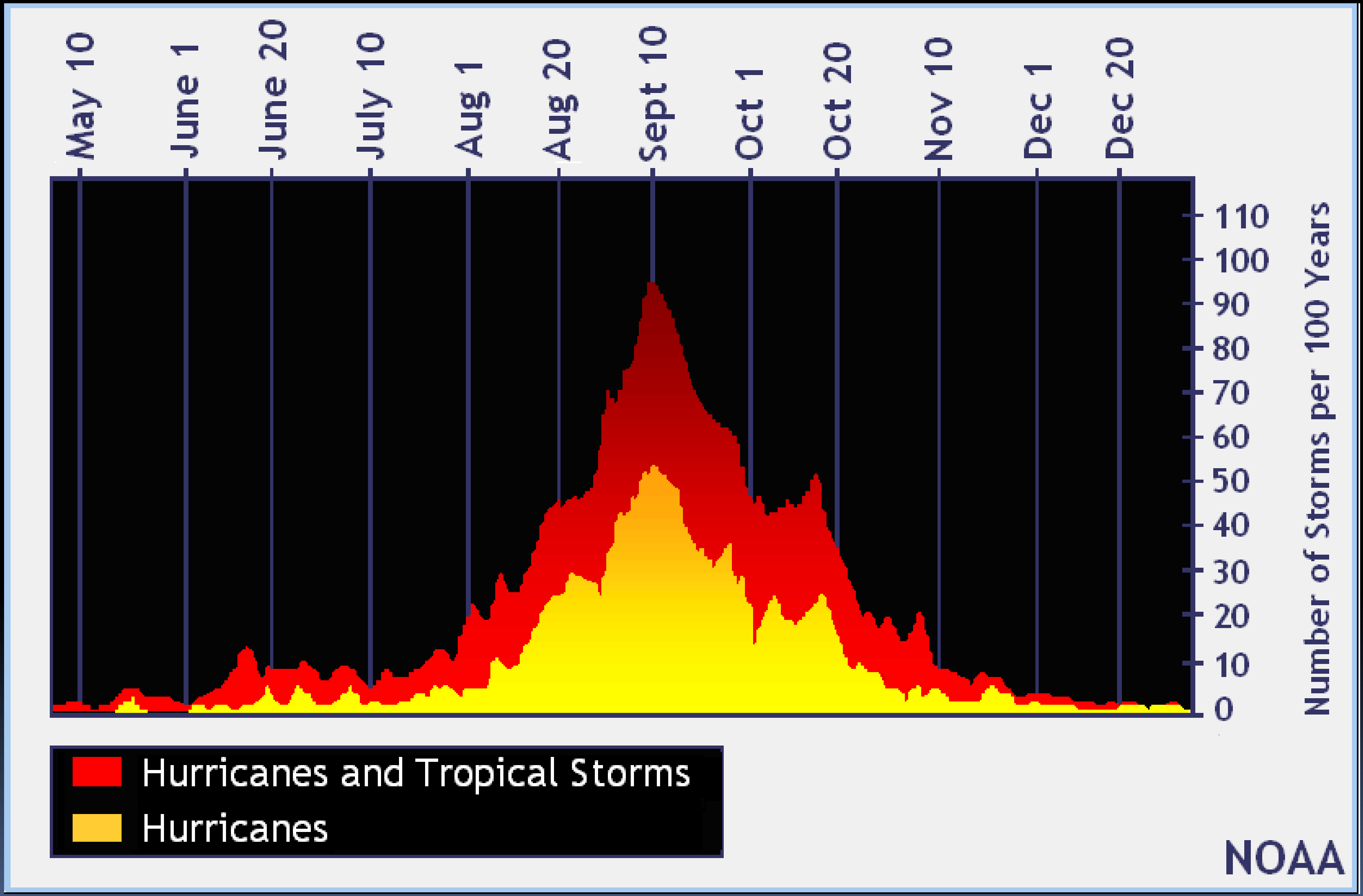
Climatological Areas of Origin and Tracks

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.



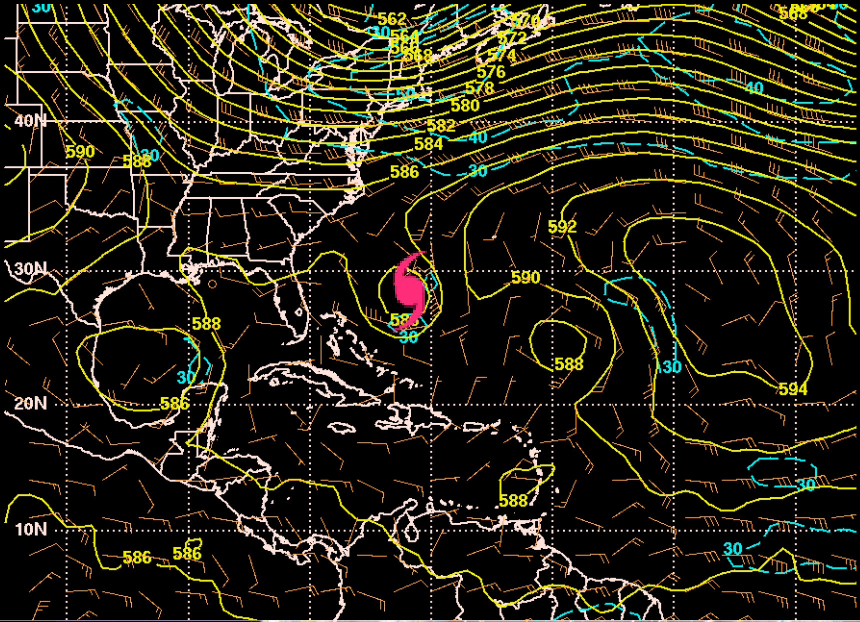
November: Season usually slows down with about 1 storm occurring ever other year. Storm that do form typically develop in central Caribbean.

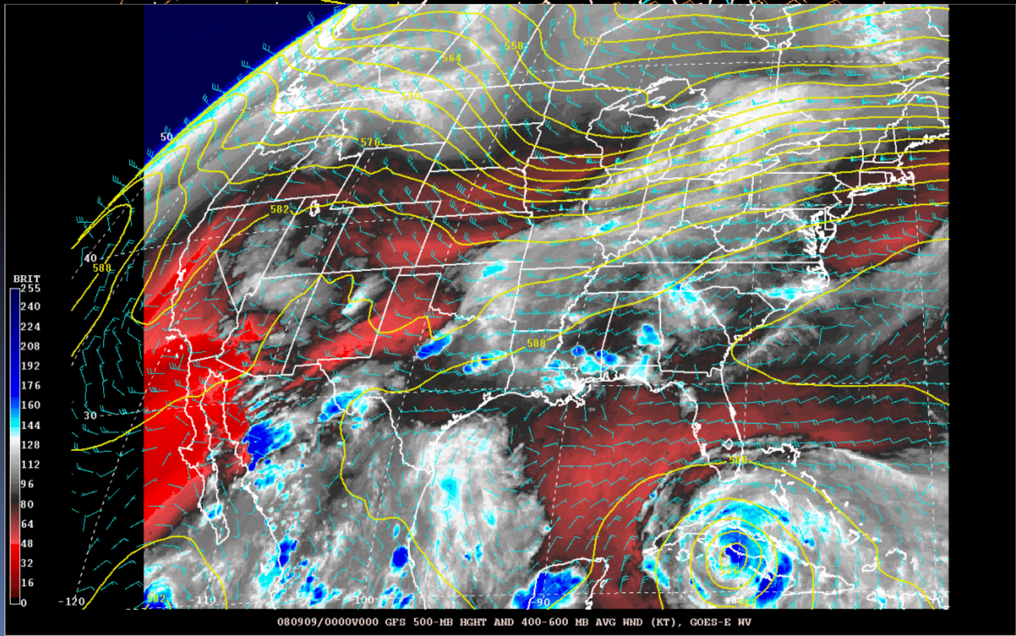
Annual Climatology of Atlantic Hurricanes



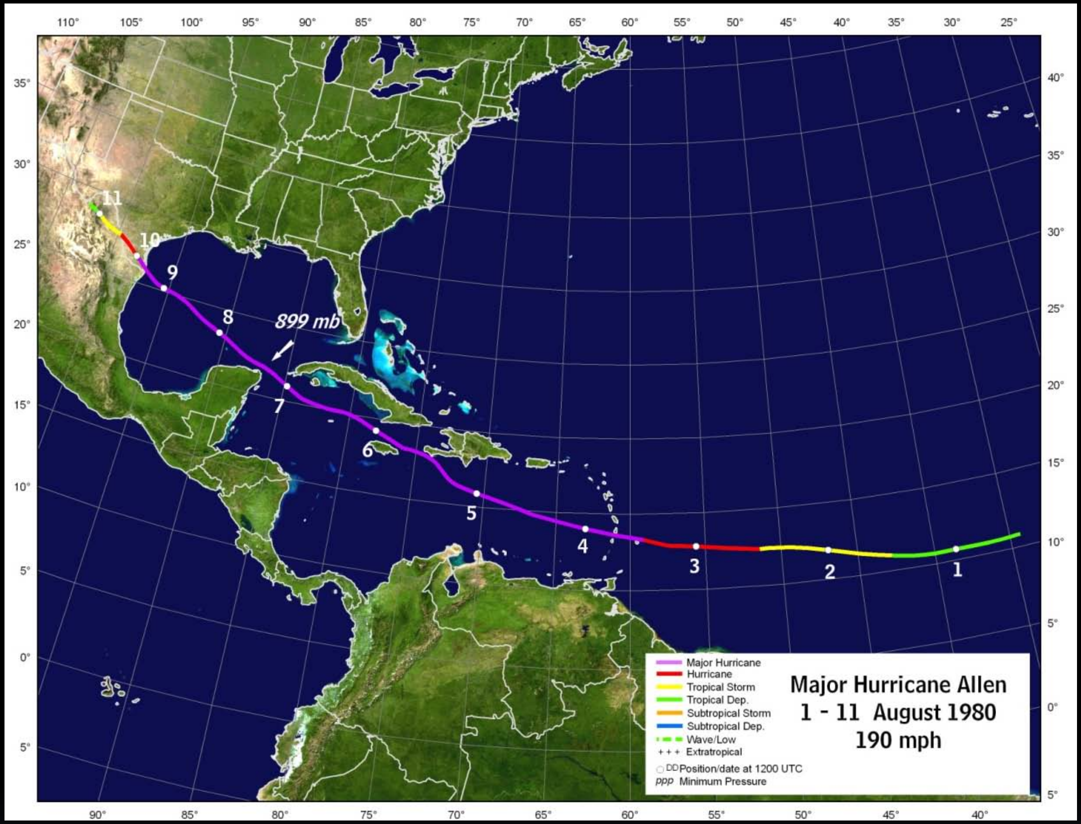
Tropical Cyclone Motion

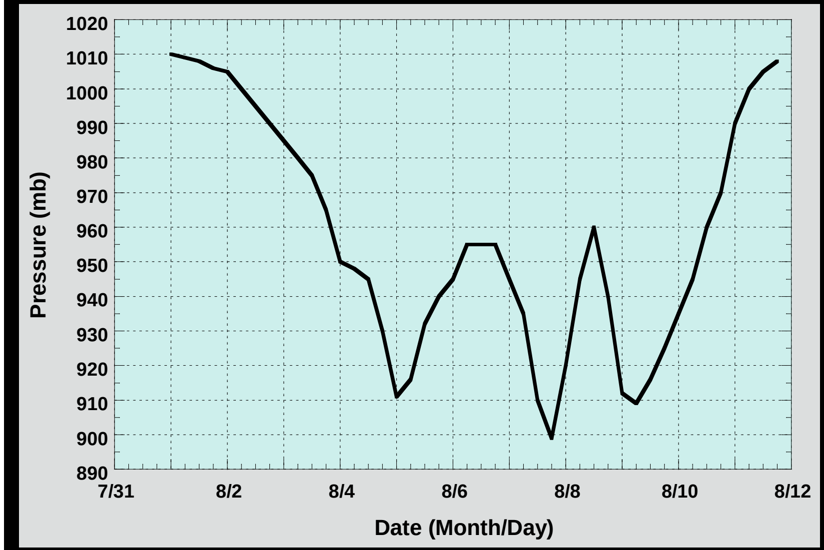
- Track forecasting is a relatively simple problem with well-understood physics
  - Cork in stream analogy
- Important atmospheric features are relatively large and easy to measure
- Numerical computer models forecast track quite well
  - Constantly improving with upgrades to model physics and resolution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





Intensity and Motion



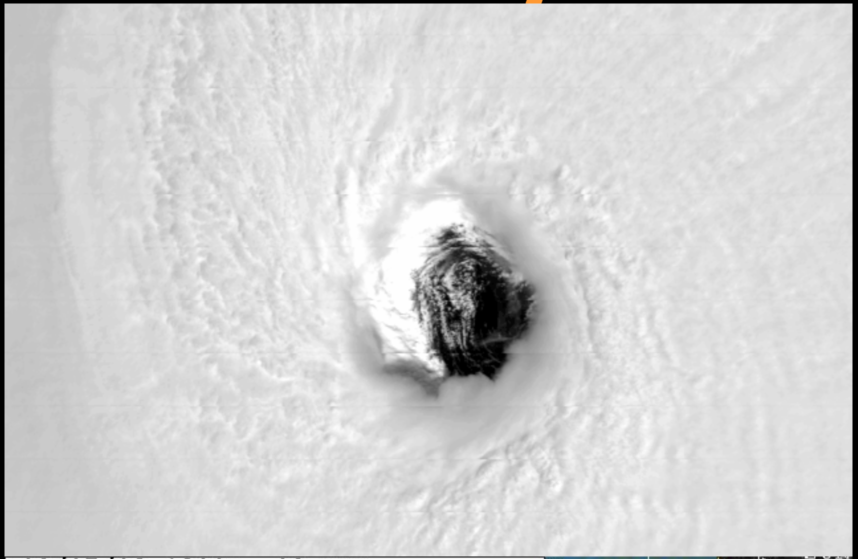


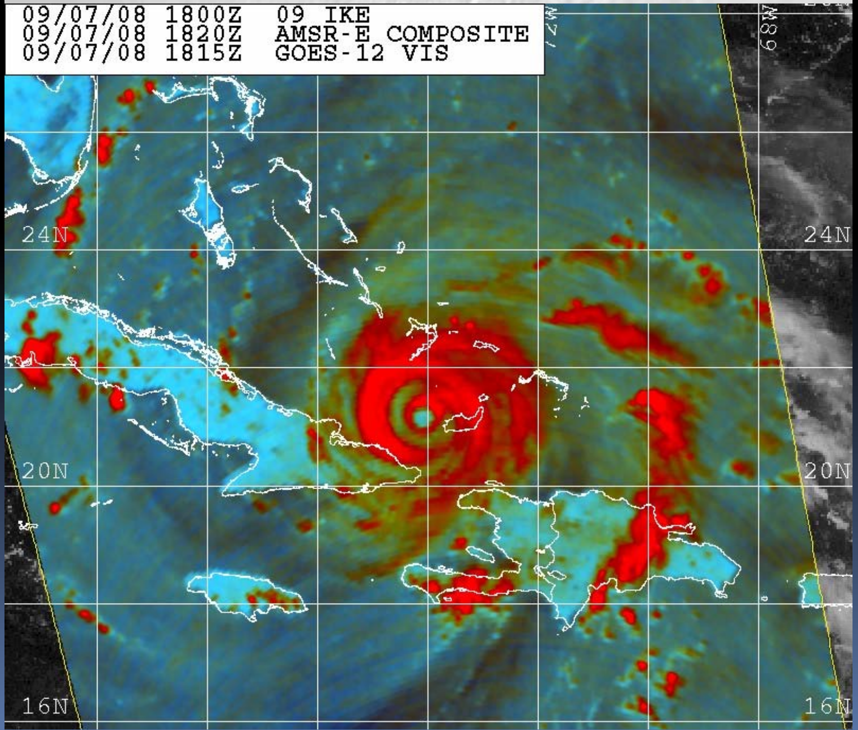
Hurricane Allen (1980)
Central pressure vs. time

- With the exception of very weak TCs with little thunderstorm activity, changes in intensity generally have little direct influence on track
- Because of this, highly successful track forecasts can be obtained by focusing on the evolution of the environment, rather than the storm itself

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



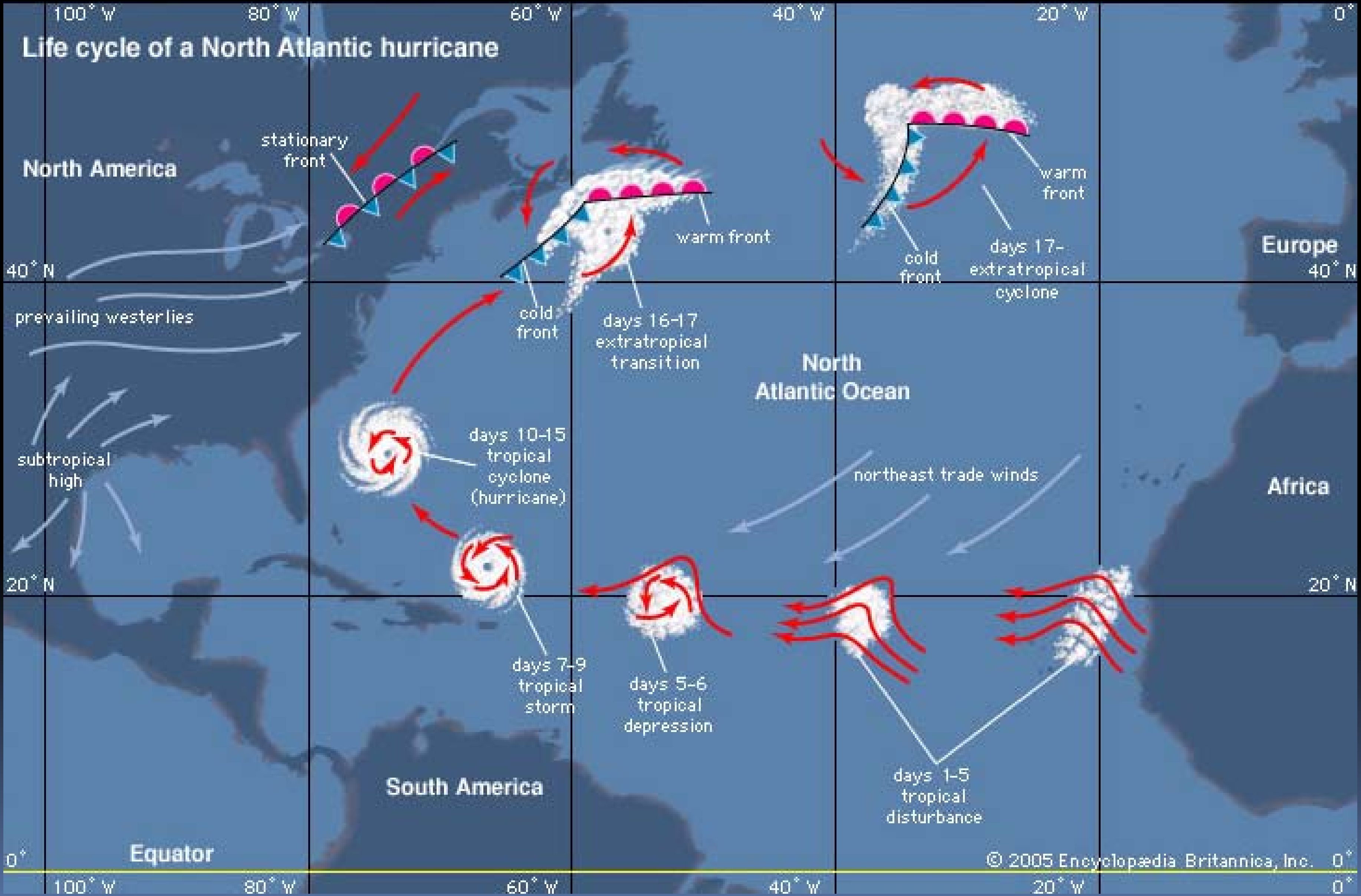


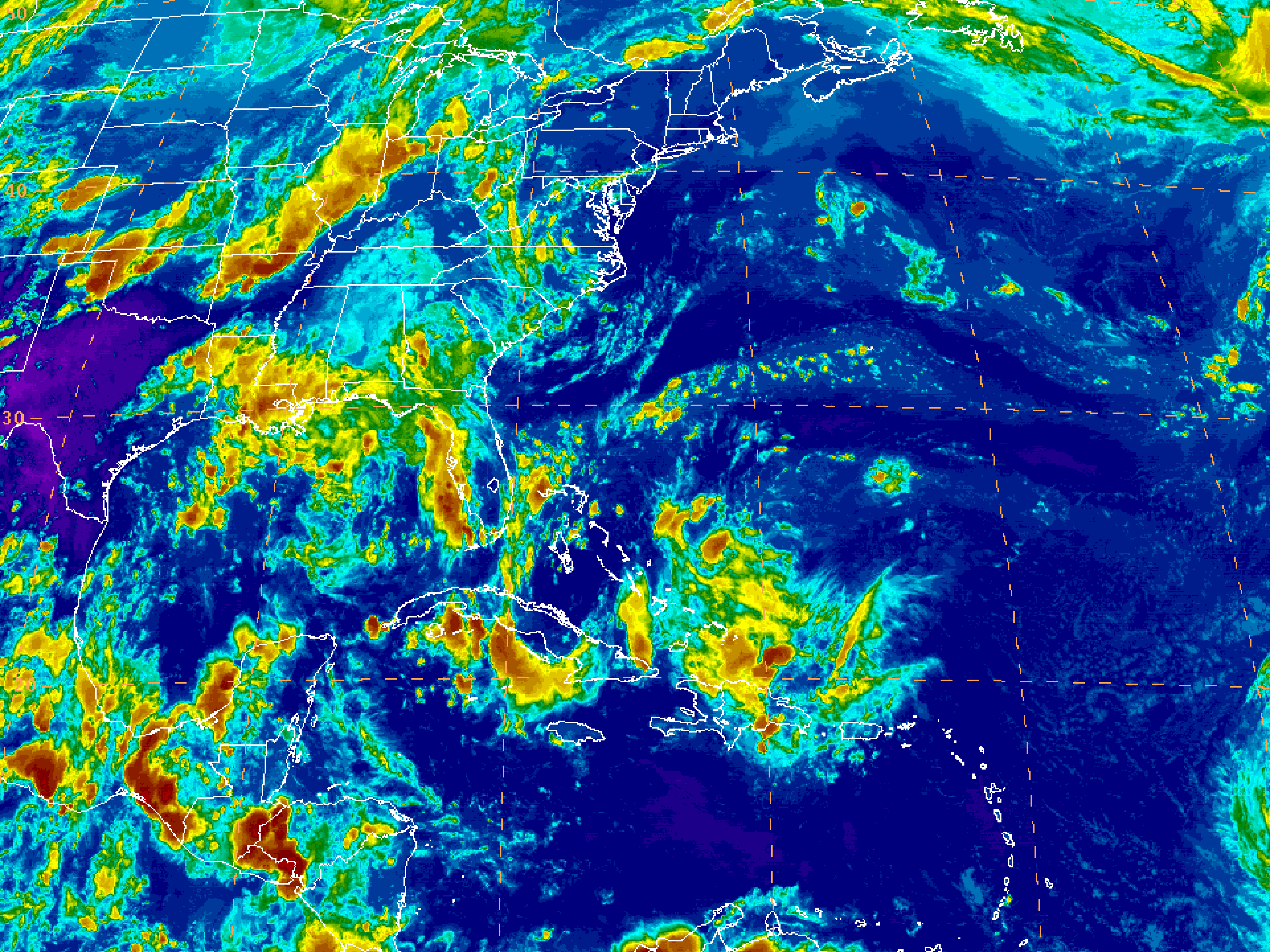
Factors Influencing TC Intensity

many of the same factors that govern development

- Sea surface temperature (SST) and upper ocean heat content (OHC)
- Interaction with land
- 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

Life Cycle of a Cape Verde Hurricane

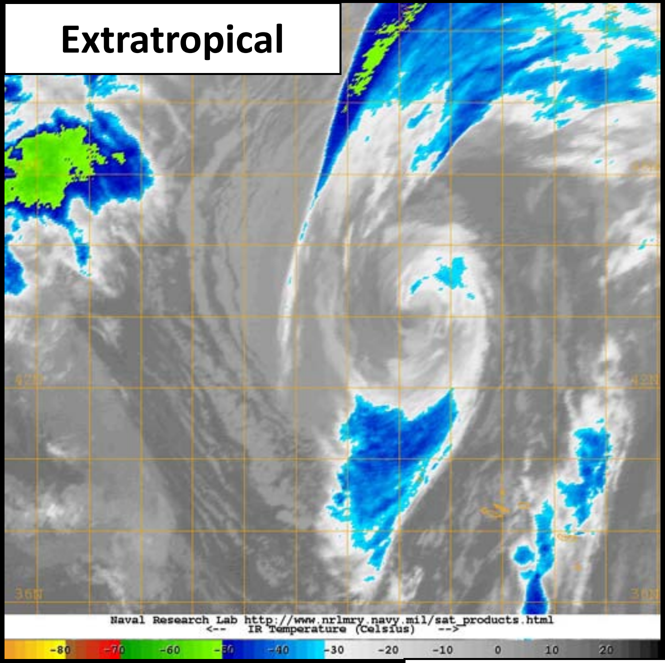


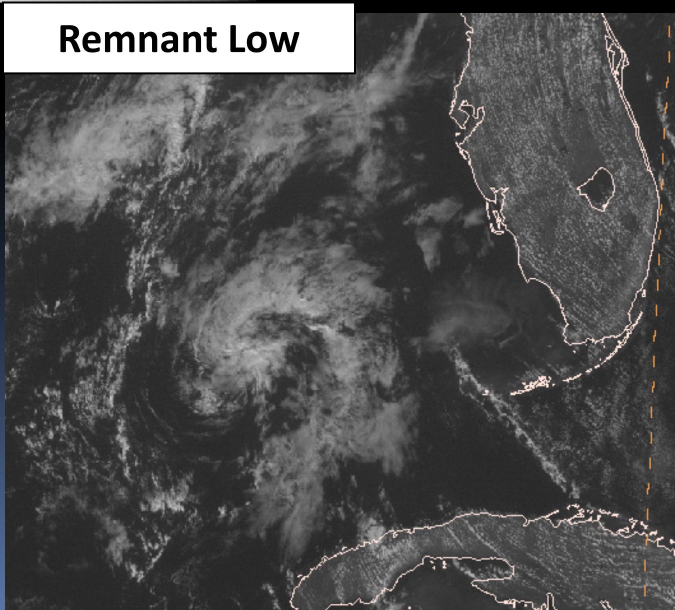


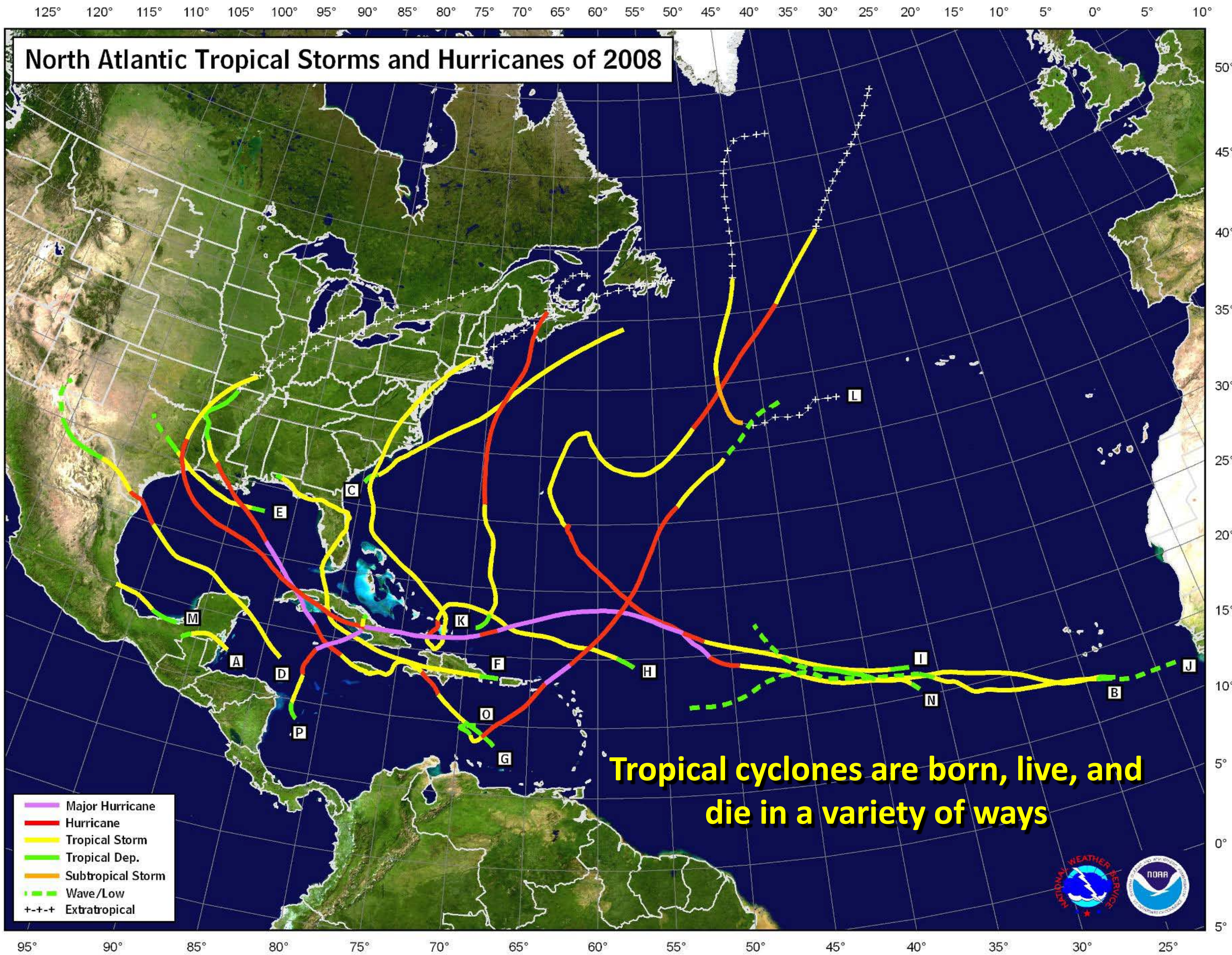
50
40
30
20

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)






North Atlantic Tropical Storms and Hurricanes of 2008
Major Hurricane
Hurricane
Tropical Storm
Tropical Dep.
Subtropical Storm
Wave/Low
+-+-+ Extratropical
Tropical cyclones are born, live, and die in a variety of ways

Structure of a Hurricane

Stay tuned for Dr. Jack Beven after the break

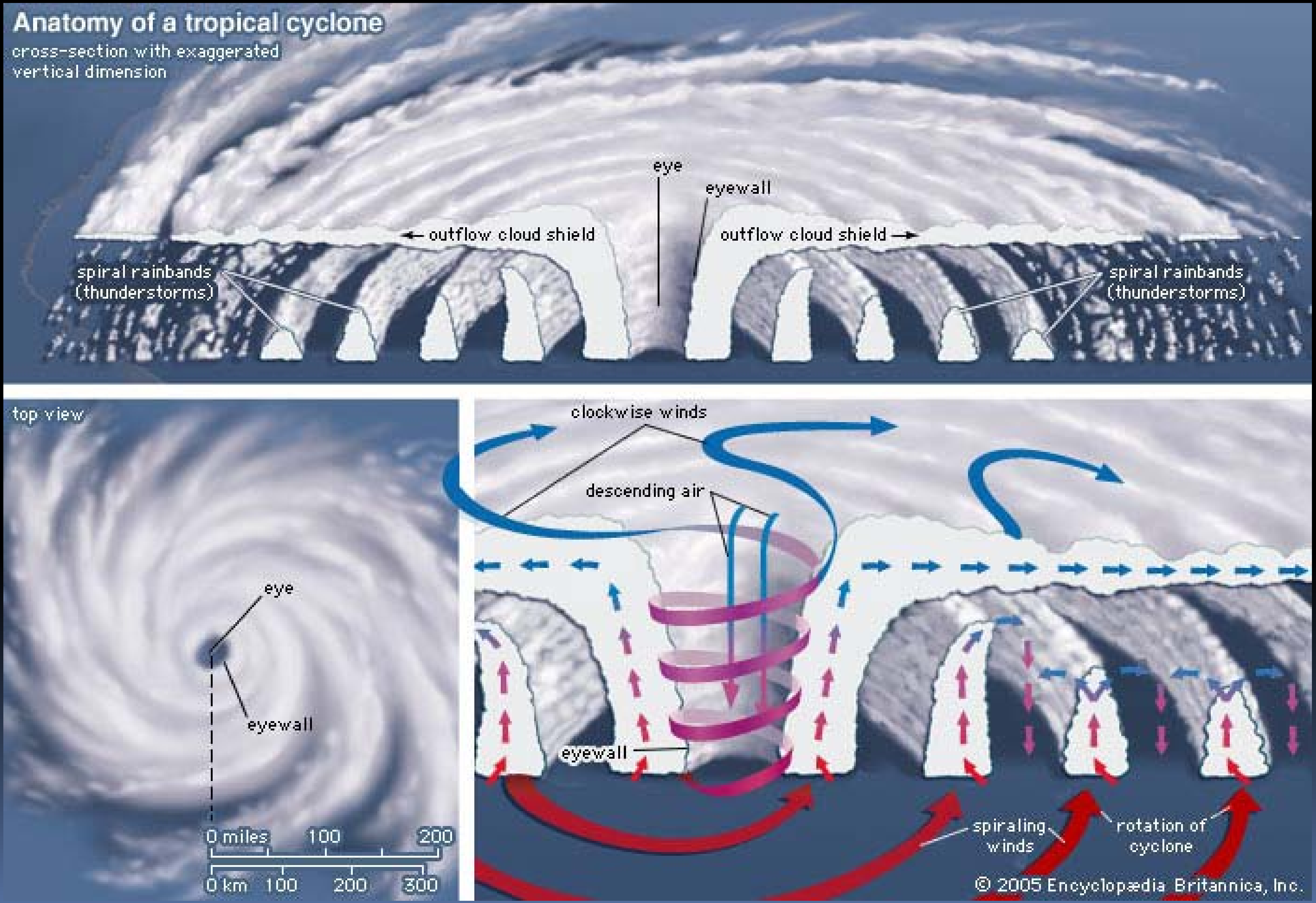
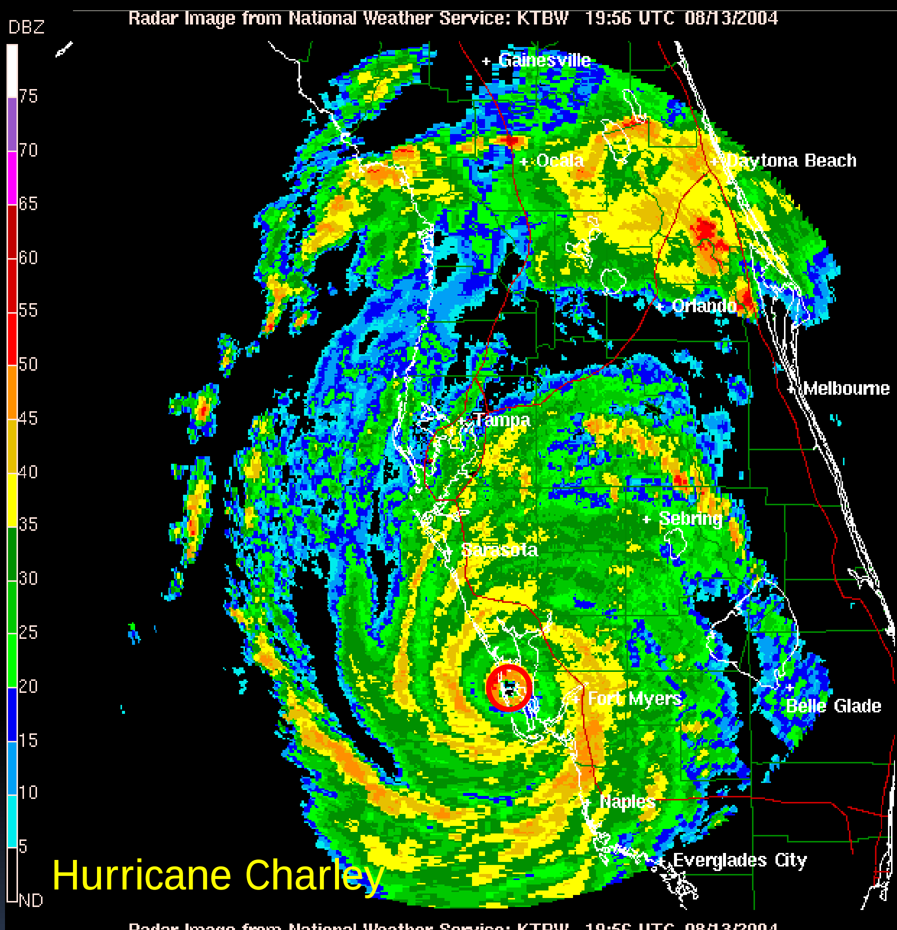
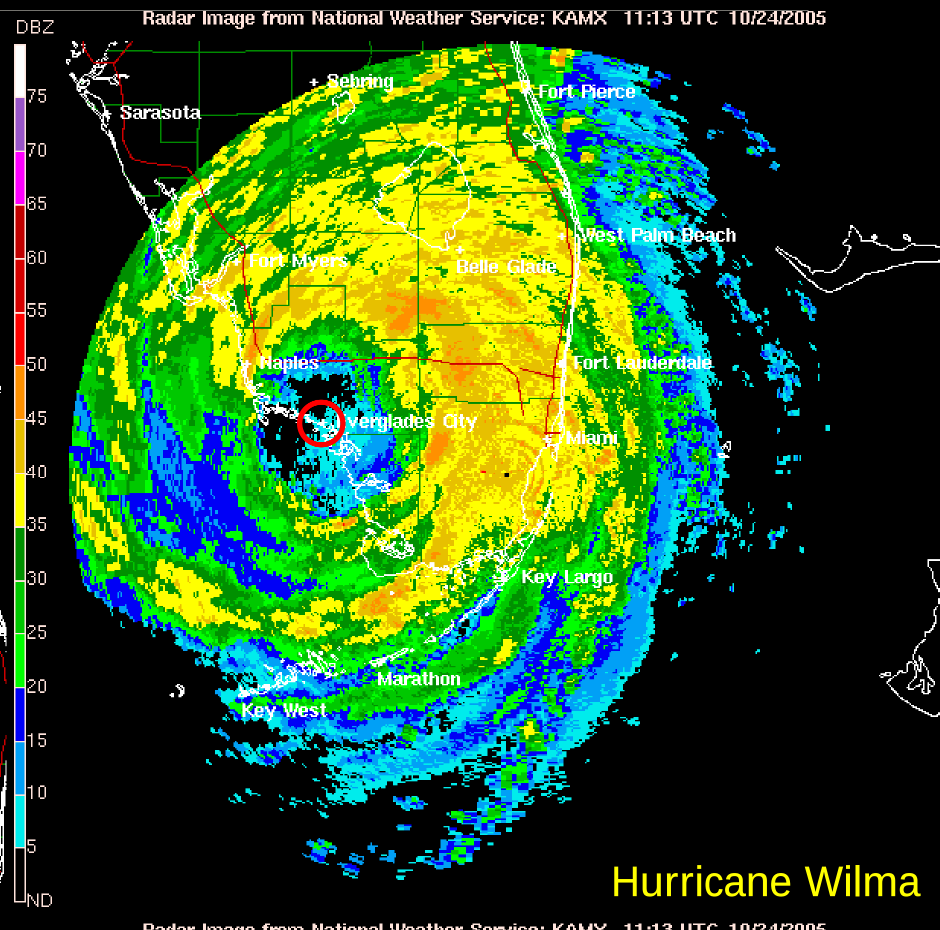


Image courtesy of NOAA / AOC

Tropical Cyclones Come in All Sizes





Hurricane Hazards

Wind

Waves / Rip Currents

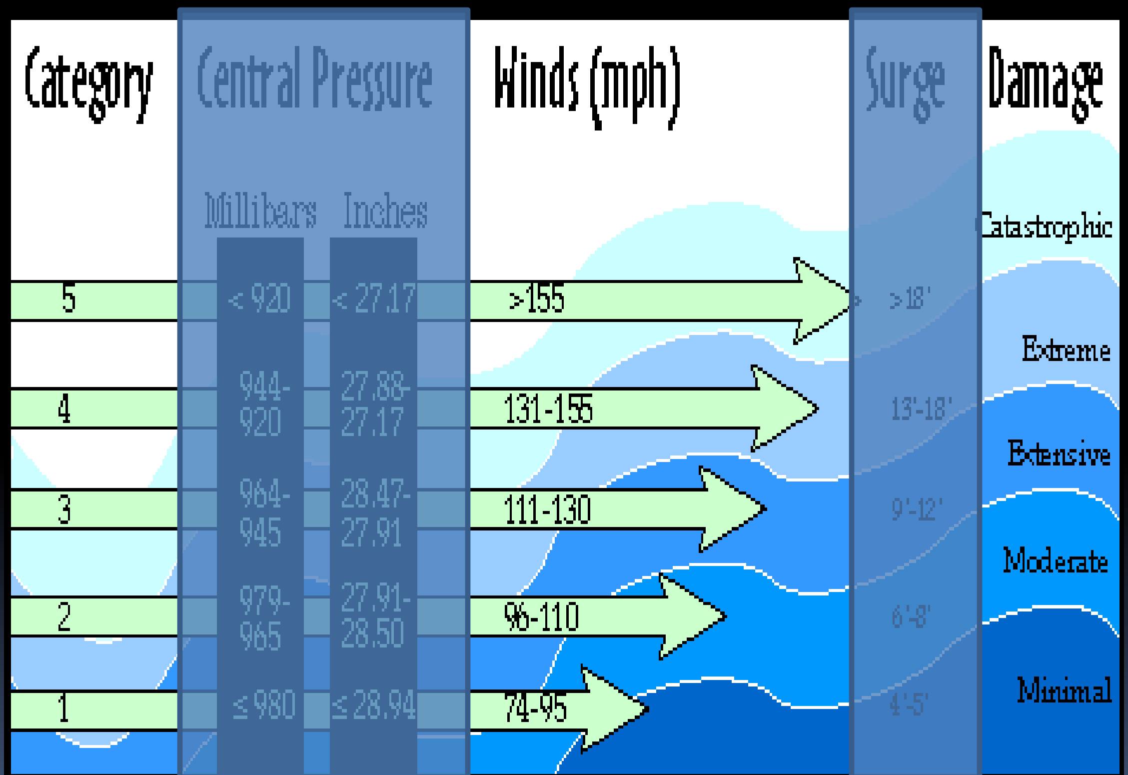
Tornadoes

Storm Surge

Rainfall / Inland Flooding

Saffir-Simpson Hurricane Wind Scale

Surge, rainfall, and pressure fit the scale
like a square peg in a round hole



KATRINA (3)

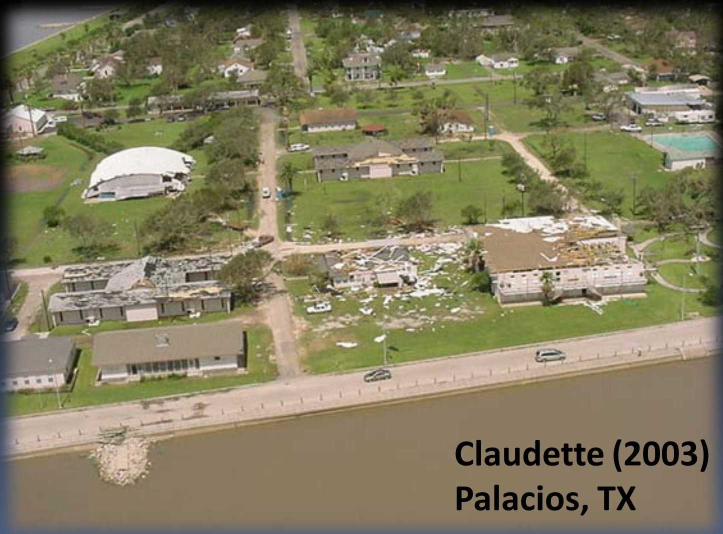
IKE (2)

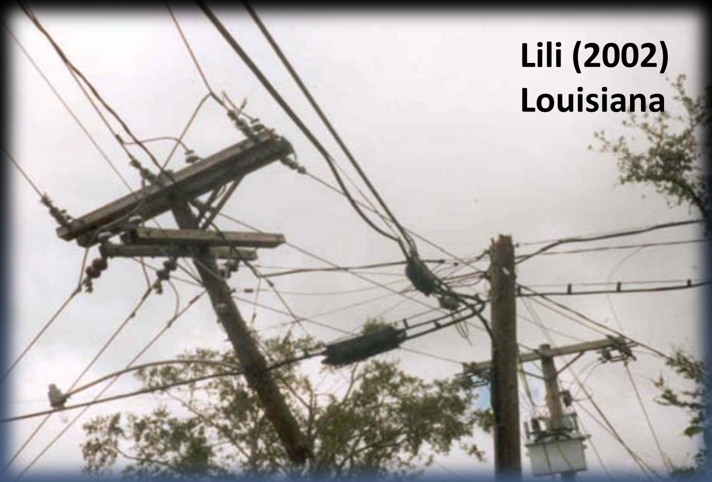
CHARLEY (4)

www.nhc.noaa.gov/aboutsshs.shtml

Category 1 (74 – 95 mph)

Very dangerous winds will produce some damage





Category 2 (96 – 110 mph)

Extremely dangerous winds will cause extensive damage

Category 3 (111 – 130 mph)

Devastating damage will occur

Category 4 (131 – 155 mph)

Catastrophic damage will occur

Category 5 (greater than 155 mph)

Catastrophic damage will occur

Andrew (1992)
Florida City, FL

Andrew (1992)
South Dade, FL

Felix (2007)
Nicaragua

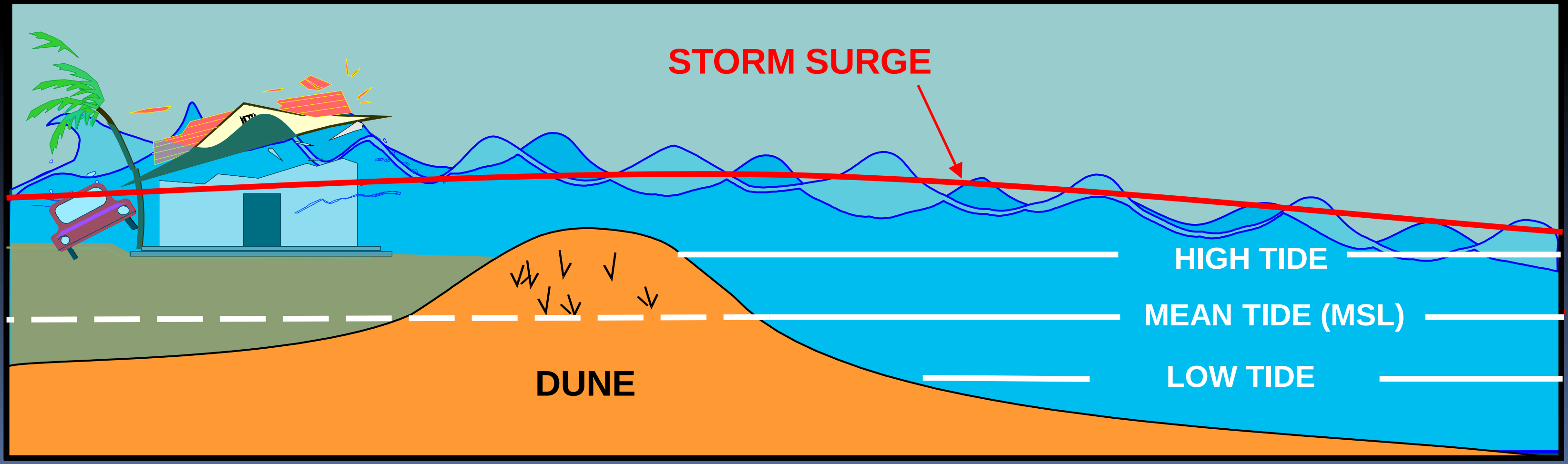
Wind-blown Debris can Become Deadly Projectiles in a Hurricane

11:45 AM

Storm Surge

More this afternoon on storm surge from Jamie Rhome

- Abnormal rise in water generated by a storm, over and above the astronomical tide
- Caused primarily by force of wind blowing across water surface
- Contribution by low pressure within center of storm is minimal



Factors Determining Storm Surge Height at a Given Location

- Where the circulation center crosses the coast
- Storm direction of motion relative to coastline
- Strength of the winds (storm intensity)
- Radius of maximum winds
- Overall size of storm (outer wind radii)
- Slope of the continental shelf
- Shape of the coastline and other coastal features (examples: barrier islands, bays, rivers, levees)

House of David and Kimberly King
Waveland, Mississippi

Gulf Coast

Biloxi, Mississippi
Katrina (2005)

Key West, Florida
Georges (1998)

Laffite, Louisiana
Rita (2005)

Galveston, Texas
Ike (2008)

Southeast

Rodanthe, North Carolina
Isabel (2003)

Pawley's Island, South Carolina
Hugo (1989)

Jacksonville, Florida
Fay (2008)

North Hutchinson Island, Florida
(Jeanne 2004)

Mid-Atlantic

Baltimore, Maryland
Isabel (2003)

Hampton, Virginia
Isabel (2003)

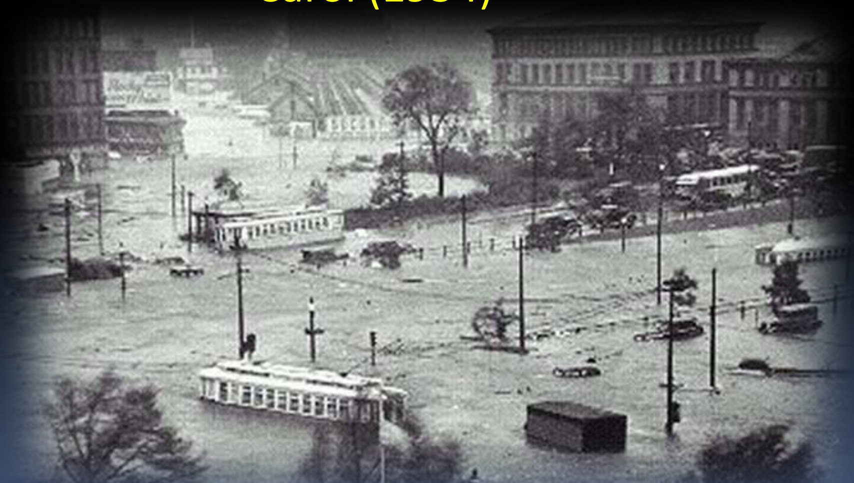
Surf City, New Jersey
Donna (1960)

Long Beach, New York
(Gloria 1985)

New England

Narragansett Bay, Rhode Island
Carol (1954)

Woods Hole, Massachusetts
Carol (1954)



Providence, Rhode Island
1938 Hurricane

Connecticut
Carol (1954)

Ike Storm Surge

Creole, LA

KPLC

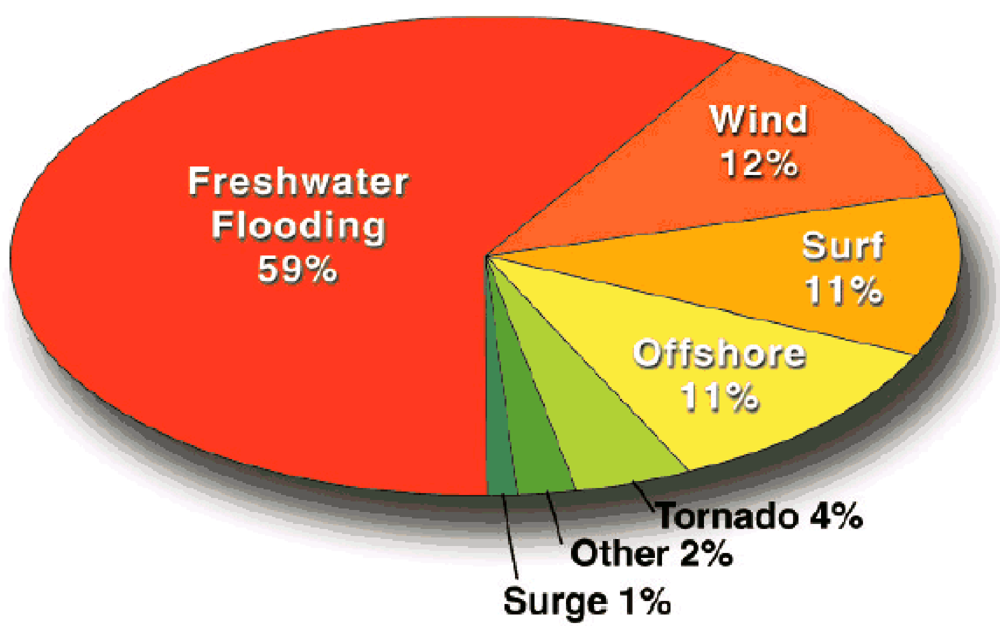
Fresh Water Flooding

more from John Feldt this afternoon


US Army Corps of Engineers

NC DENR

Leading Causes of Tropical Cyclone Deaths in the U.S 1970-1999



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

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

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

Interstate 10

Houston, Texas

Interstate 10, Looking West, Houston, Texas

Tropical Storm Allison (2001)

Houston, Texas

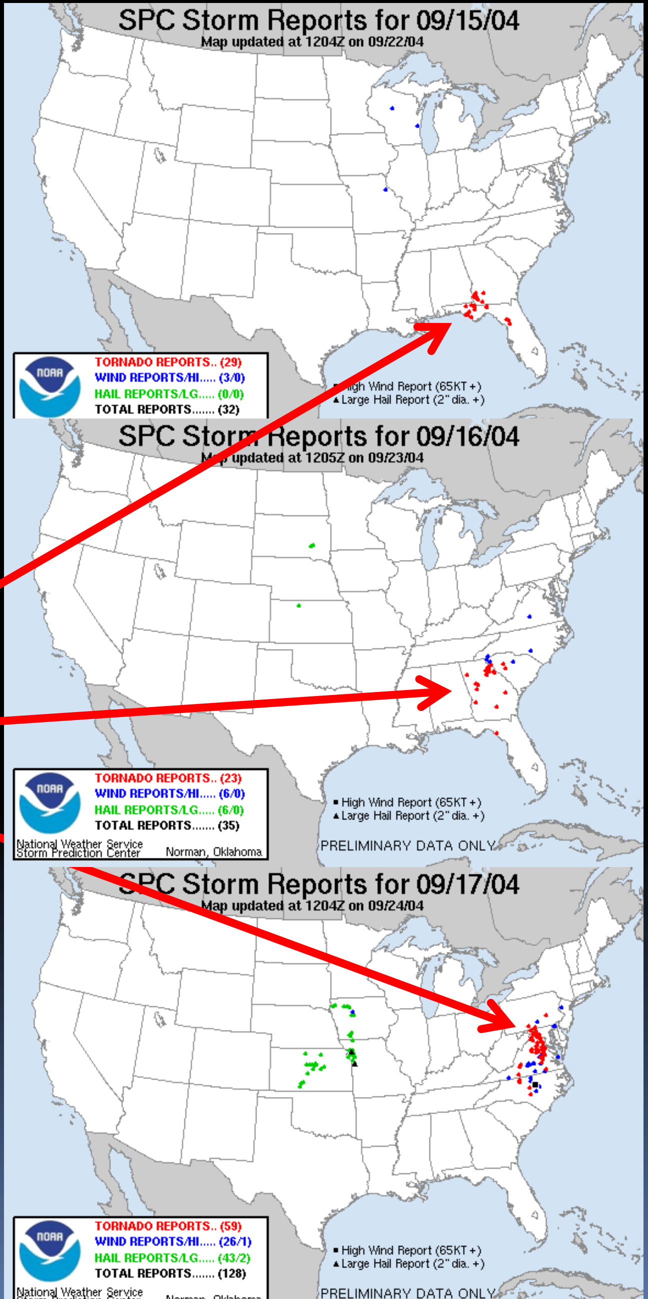
Interstate 10, Looking West, Houston, Texas
Tropical Storm Allison

Houston Chronicle

Hurricane-Induced Tornadoes

more from Bart Hagemeyer this afternoon

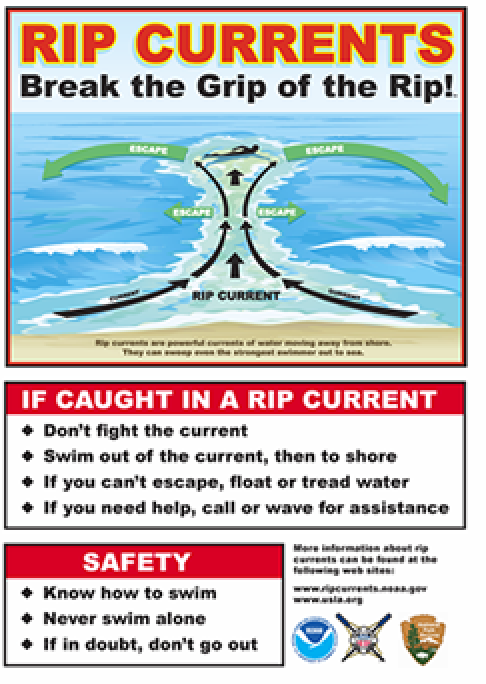
- Nearly 70% of landfalling hurricanes (1948-2000) spawned at least 1 tornado
- 40% of landfalling hurricanes spawn more than 3 tornadoes
- Some hurricanes produce tornado “outbreaks”
  - Hurricane Beulah (1967): 141
  - Hurricane Ivan (2004): 117
  - Hurricane Frances (2004): 101
  - Hurricane Rita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



Waves and Rip Currents

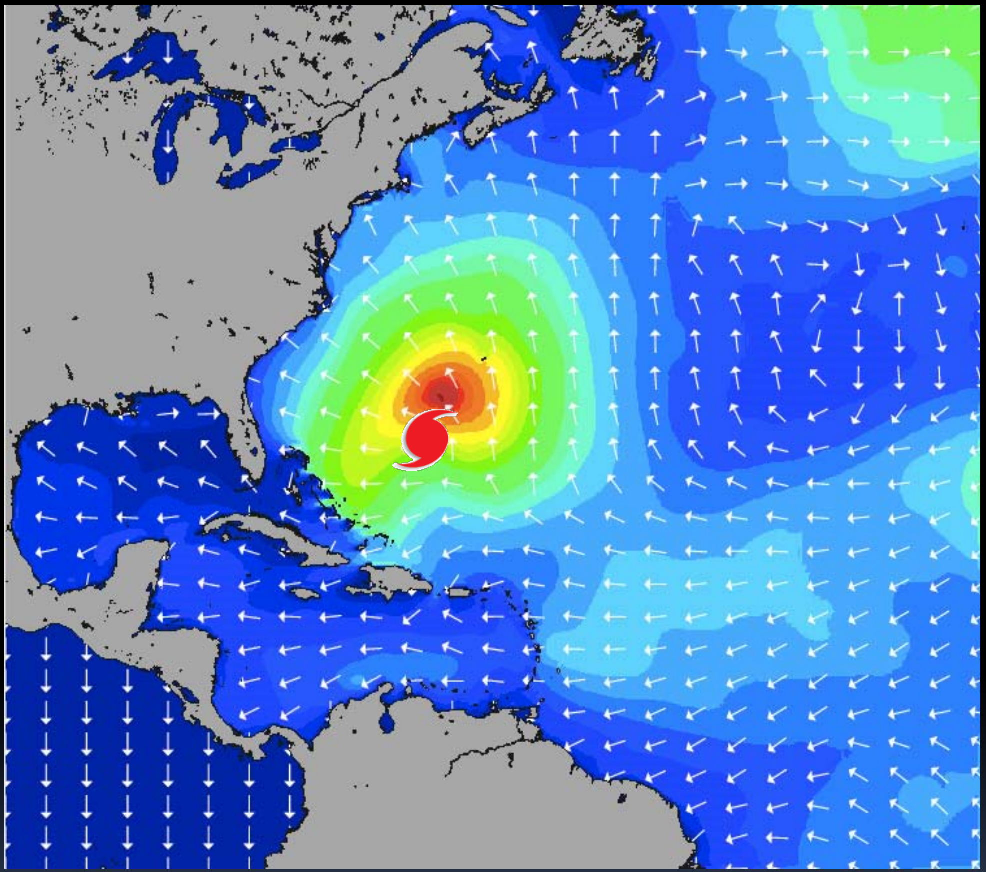
All 6 deaths in the U. S. during the 2009 hurricane season resulted from waves and rip currents along the coast.

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



Waves and Rip Currents

Swell from a large hurricane can affect the entire U. S. East Coast



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?