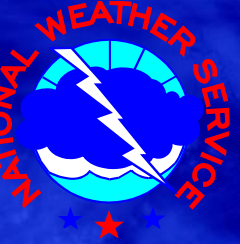


Cyclone Types: What do they mean and how do we forecast them?

JACK BEVEN
NATIONAL HURRICANE CENTER

WHERE AMERICA'S CLIMATE AND WEATHER SERVICES BEGIN

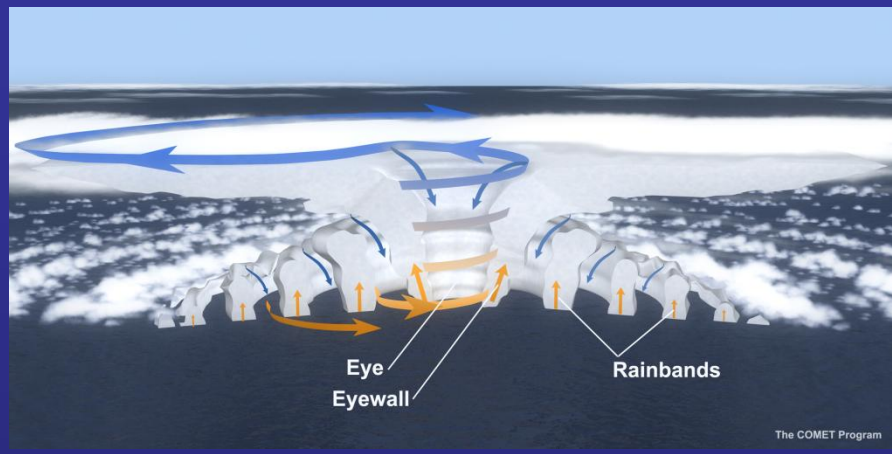
True or False?

All large-scale cyclonic storms with winds of 75 mph or greater are hurricanes

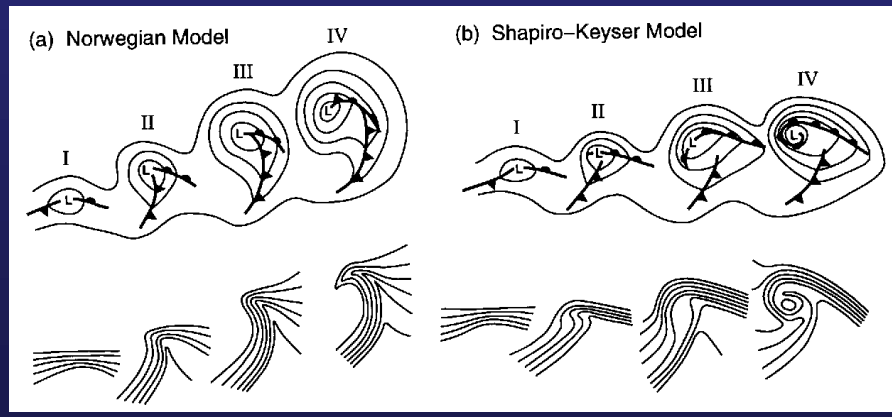
FALSE!

Some background

- Tropical cyclones are driven by *diabatic* energy from warm ocean waters released as heat in thunderstorms fueled by warm moist air
- Extratropical cyclones are driven by *baroclinic* energy from the temperature contrast of warm/cold air along fronts
- Other cyclones (monsoon systems mostly seen in the Eastern hemisphere) are driven by *barotropic* energy from shear in the horizontal wind
- <u>Cyclones can change types and energetics during their life cycle!</u>

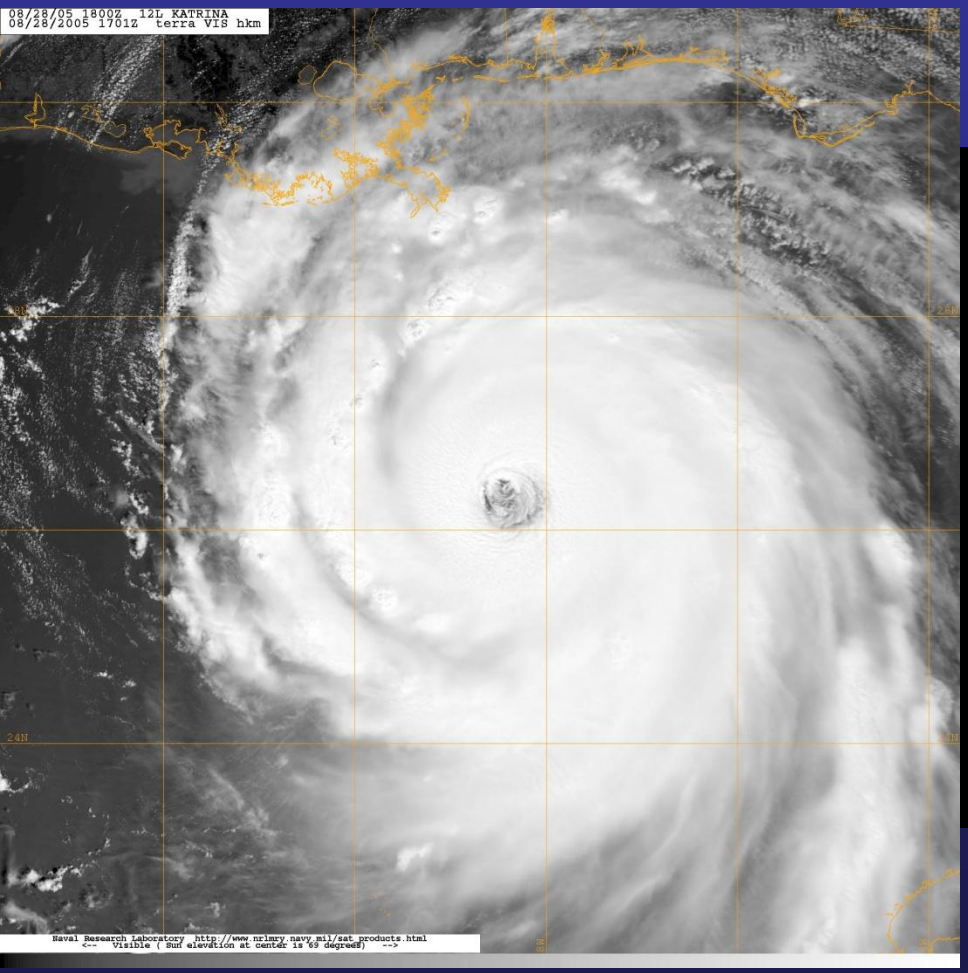


Tropical cyclone structure

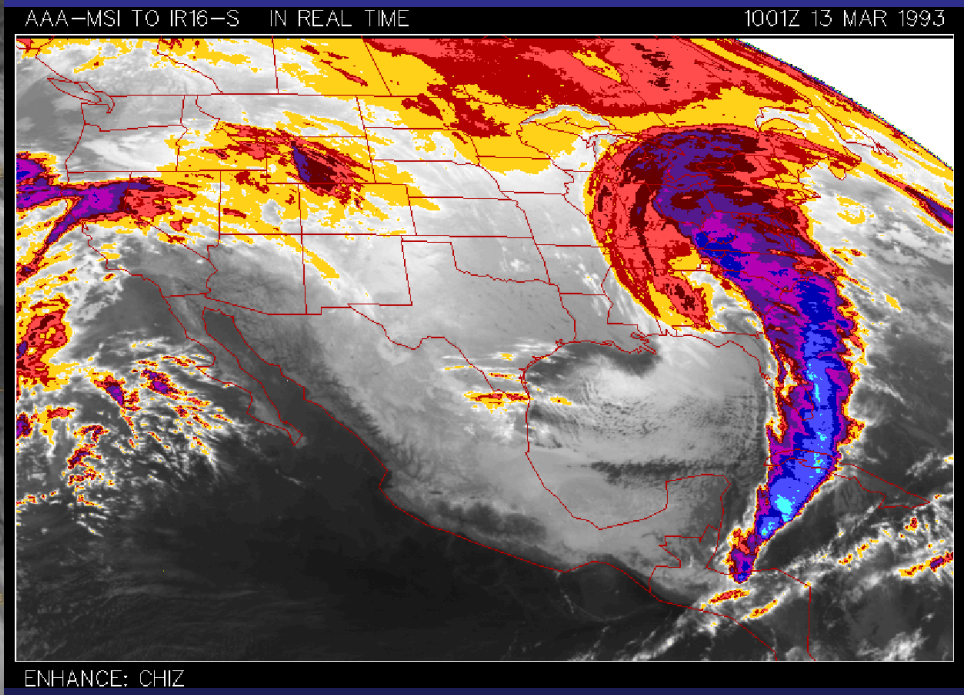


Extratropical cyclone structure

The Extremes: Tropical vs. Extratropical Cyclones

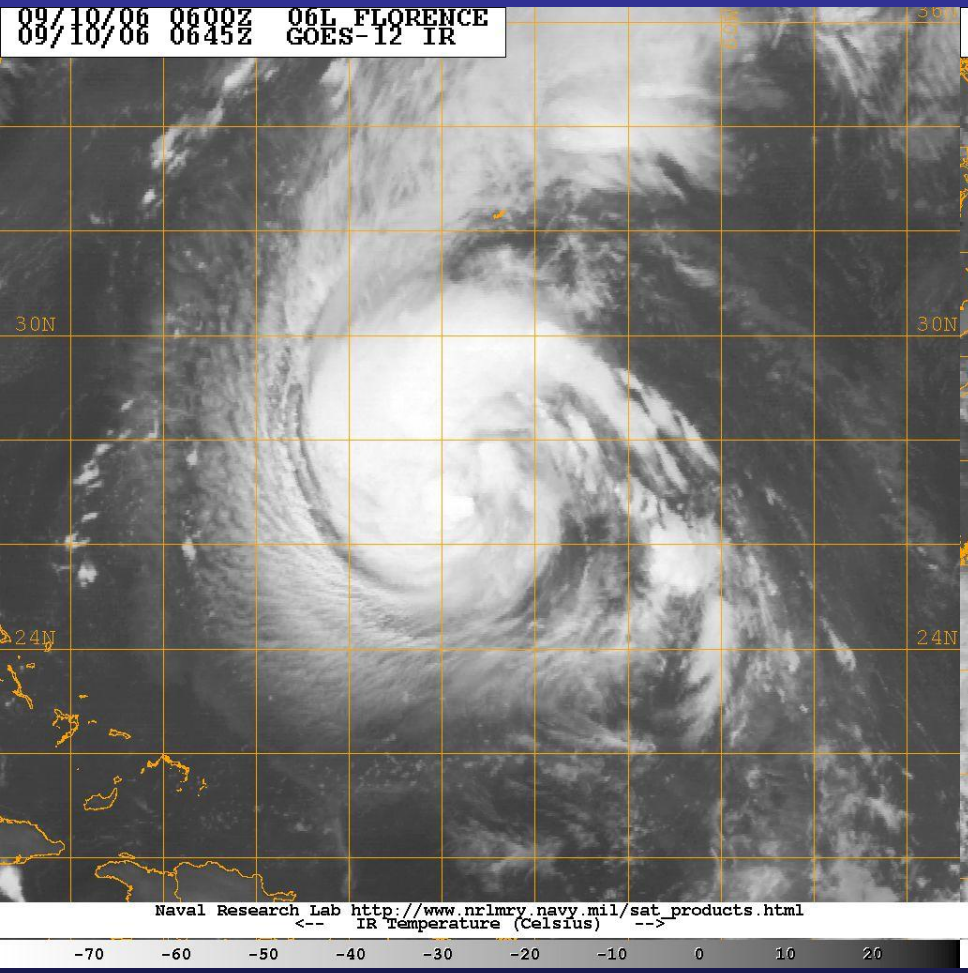


Hurricane Katrina (2005)

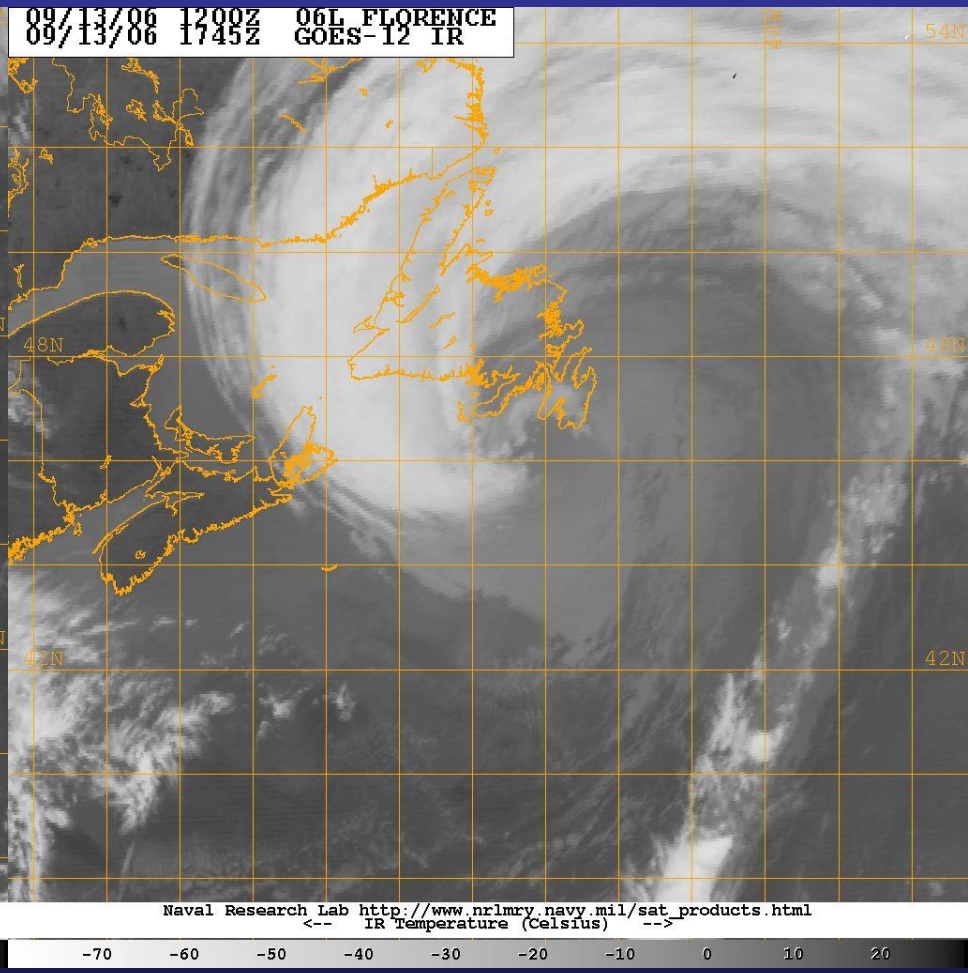


Superstorm Blizzard of March 1993

Hurricane Florence (2006)



As an 80 mph tropical hurricane



As an 80 mph extratropical low

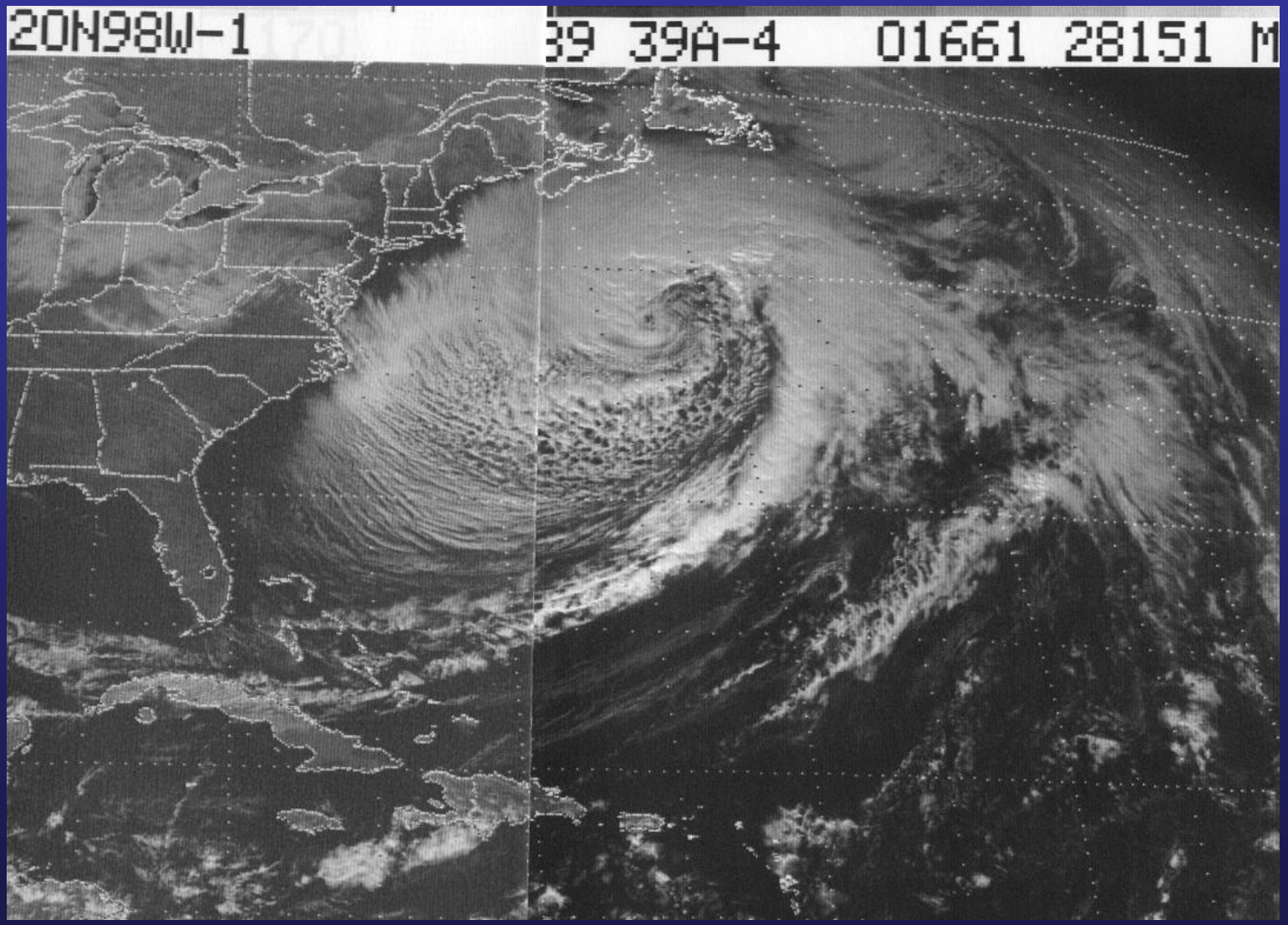
Cyclone characteristics

Tropical Cyclones	Extratropical Cyclones
• Warm core	• Generally cold core
• Don't have fronts	• Have fronts
• Have convection near the center	• Generally don't have convection near the center
• Strongest winds near the center (100 n mi or less)	• Larger wind field with strongest winds farther away from the center
• Generally symmetric rainfall pattern	• Very asymmetric rainfall pattern

Cyclone characteristics

Subtropical Cyclones	Monsoon Cyclones
• Warm core beneath cold core	• Cold core
• Don't have fronts	• Don't have fronts
• Have some convection near the center	• Often don't have convection near the center
• Distance of strongest winds from the center can vary	• Very large wind field with strongest winds far from the center
• Often asymmetric rainfall pattern	• Very asymmetric rainfall pattern

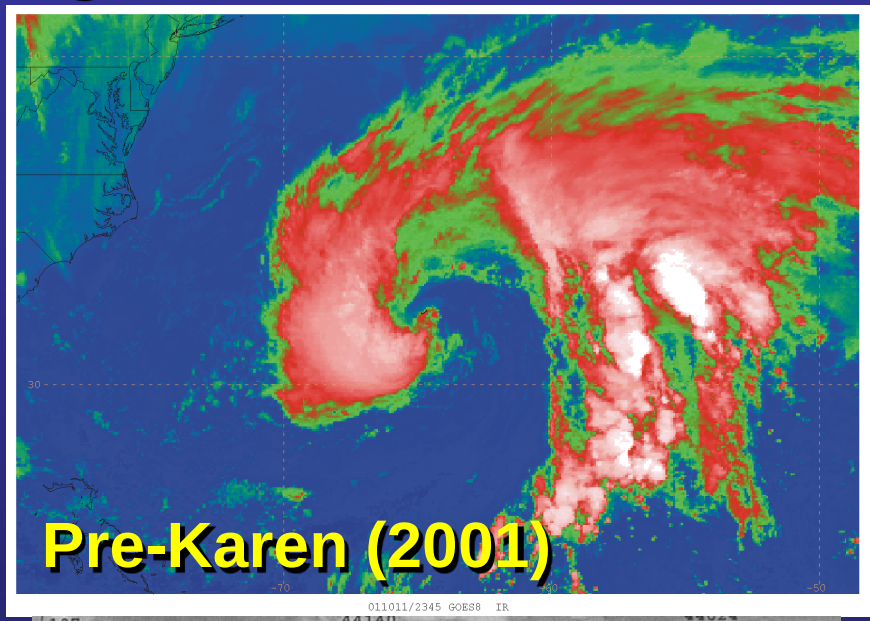
Project ERICA Ultrabomb Storm

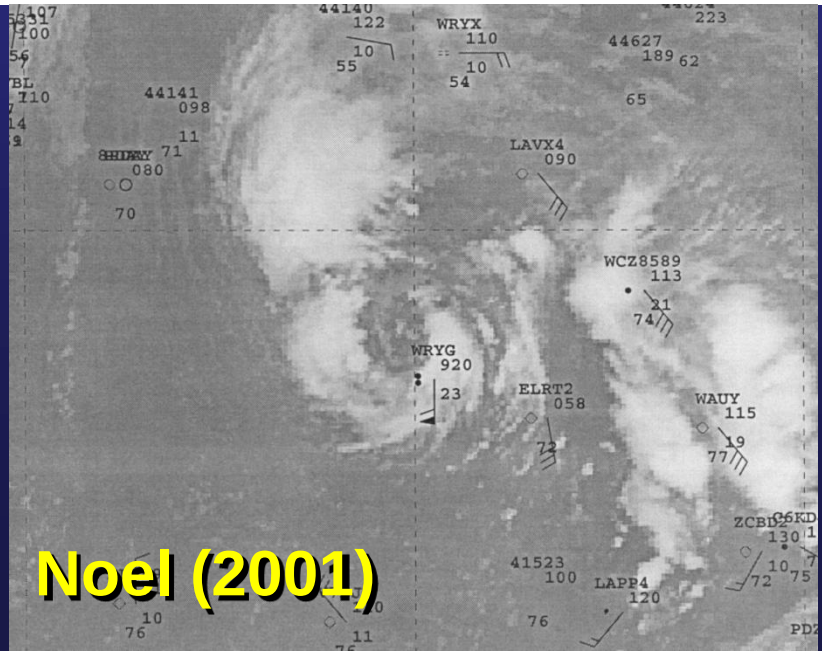


Warm core, but with well-defined frontal systems!

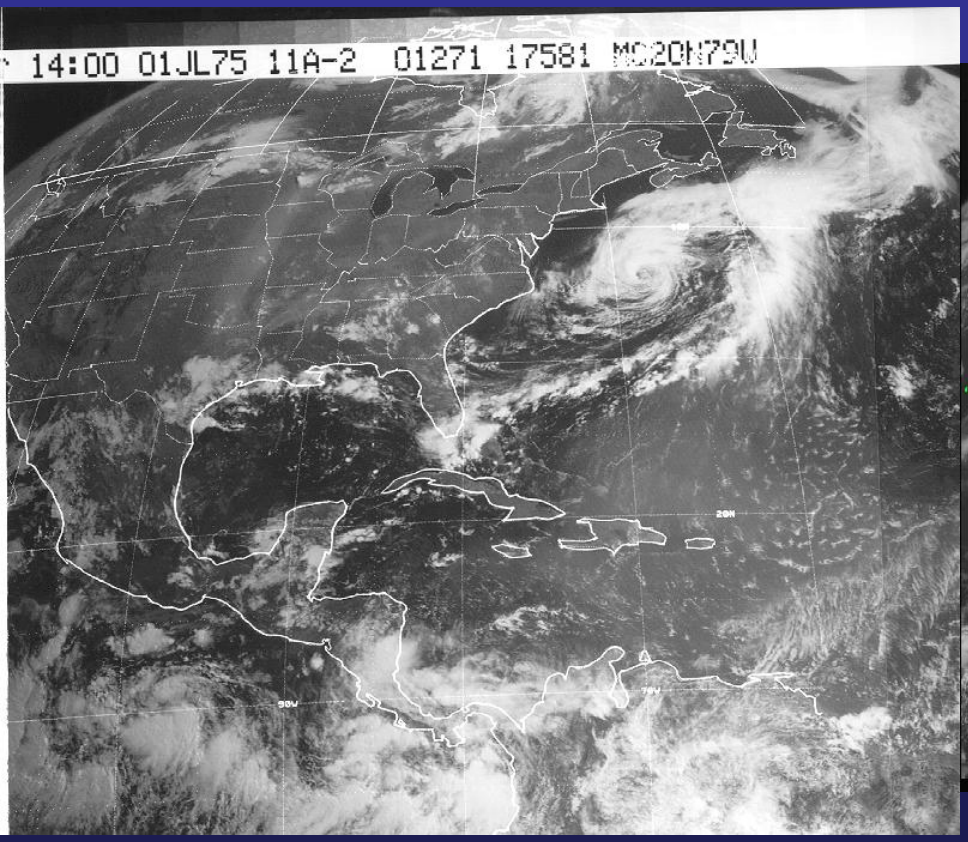
Subtropical cyclones

- Non-frontal cyclone with characteristics of both tropical and extratropical cyclones - can come in a variety of sizes and structures
- Or half tropical, half non-tropical
- Subtropical cyclones often become tropical cyclones through a process called *tropical transition* (TT)

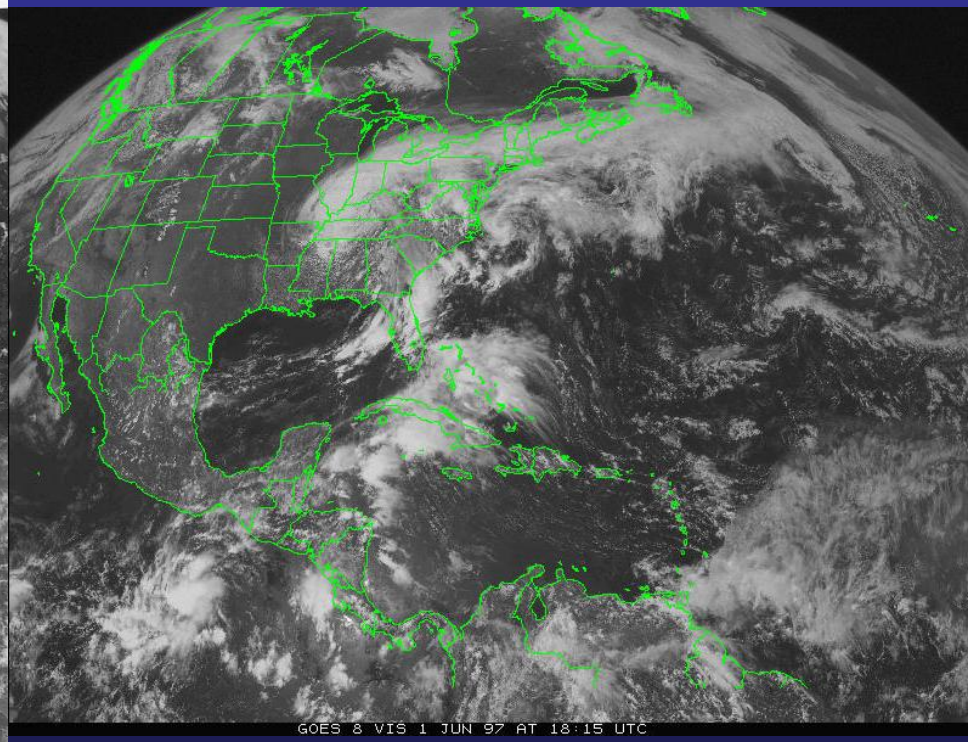




Cyclone Type Not So Clear Cut



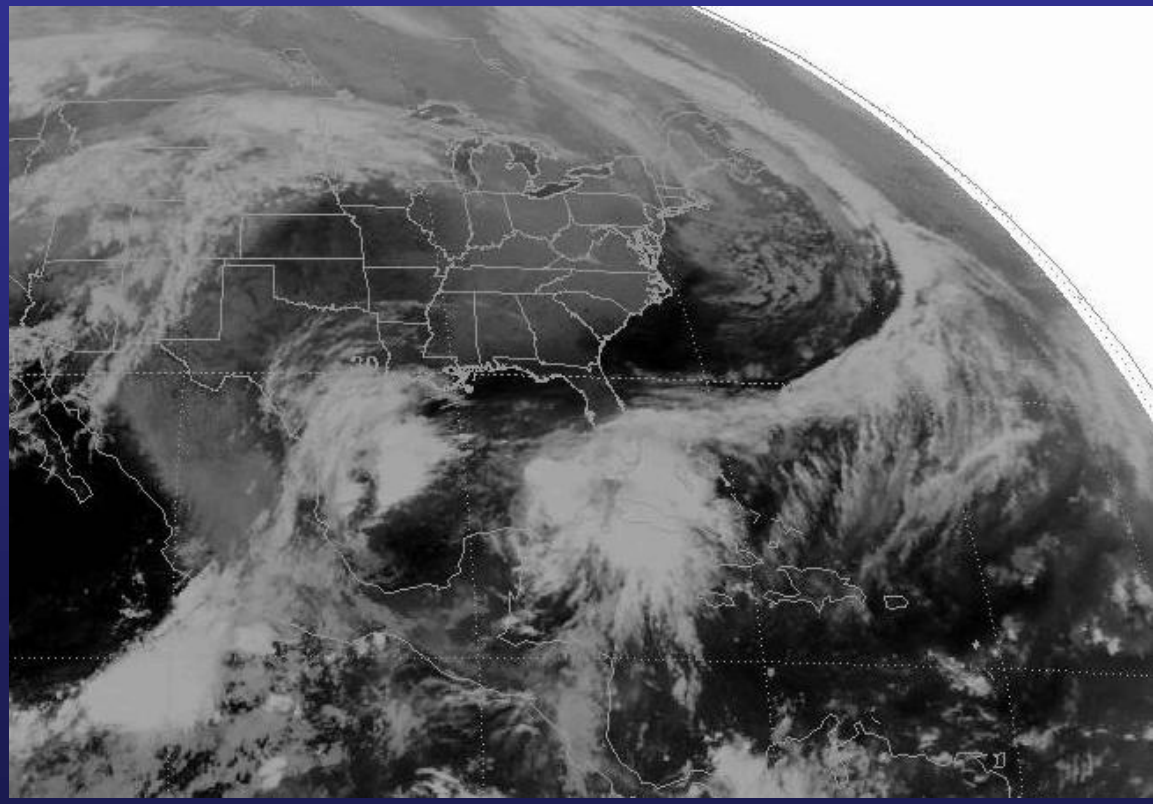
Tropical Storm Amy
(July 1975)



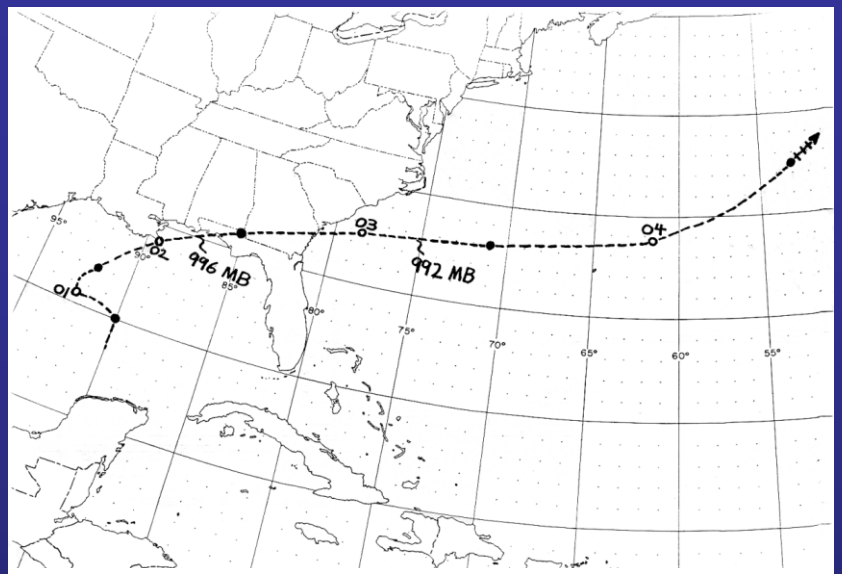
Unnamed Subtropical Storm
(June 1997)

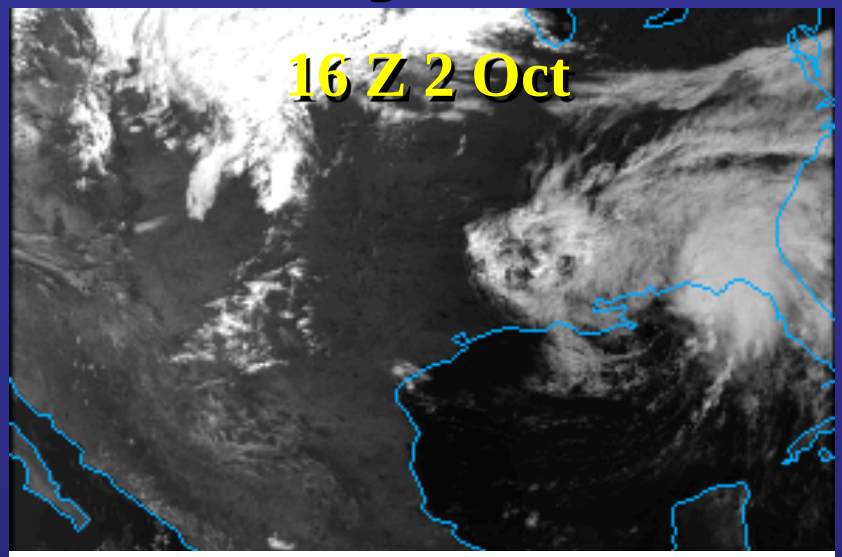
1994 Gulf-Atlantic Hybrid

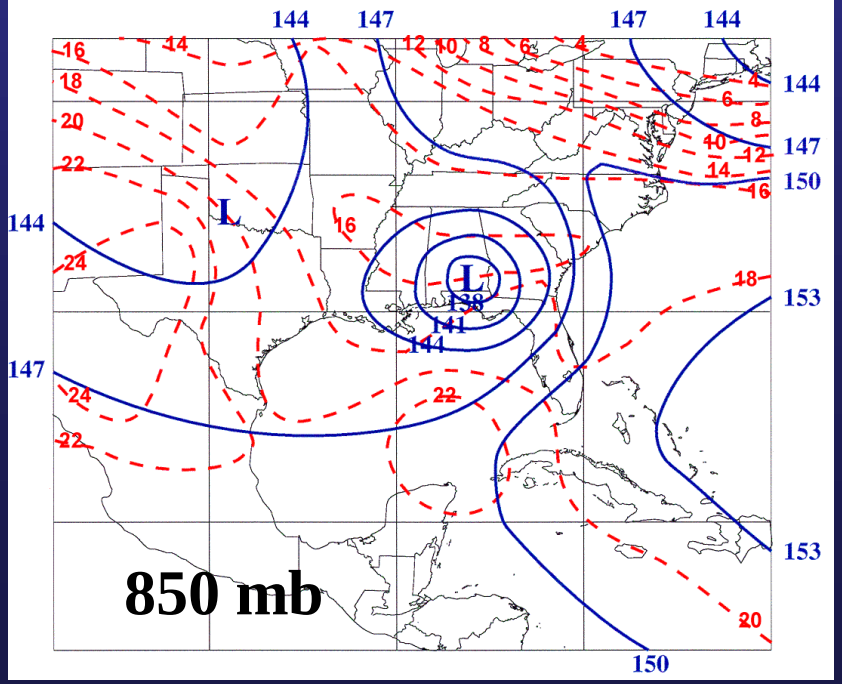
- System with wind structure resembling an extratropical low and temperature structure resembling a tropical cyclone
- Five tornadoes and 6-11 inches of rain across portions of northern Florida and southern Georgia

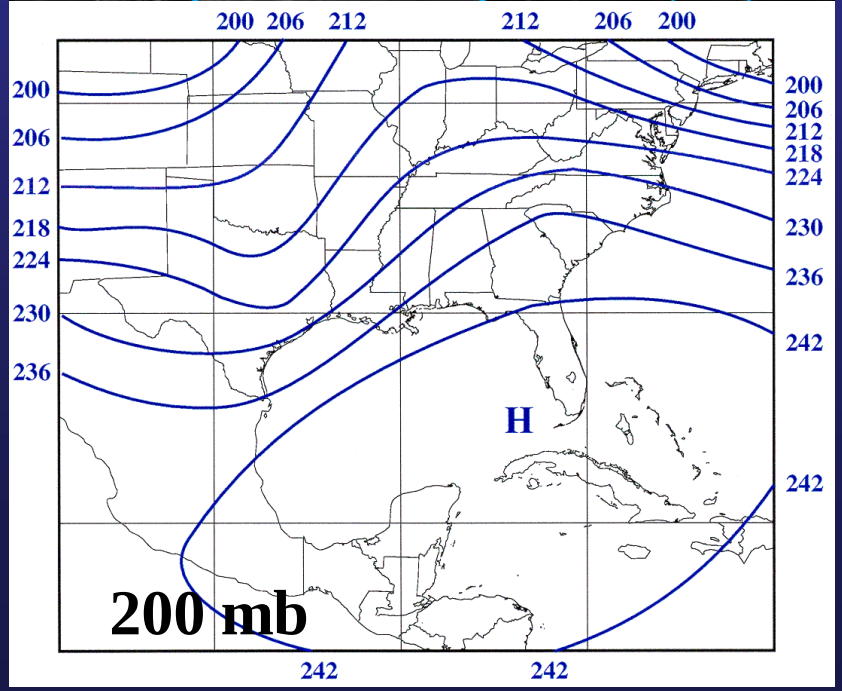


1994 Gulf-Atlantic Hybrid

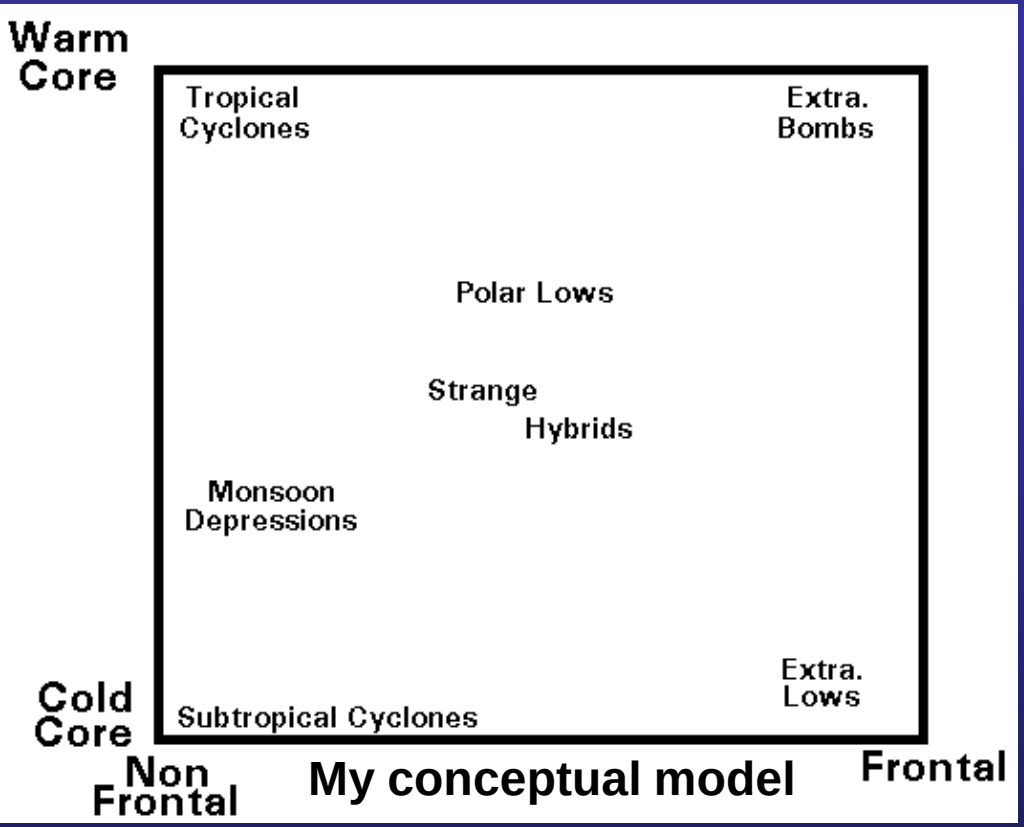


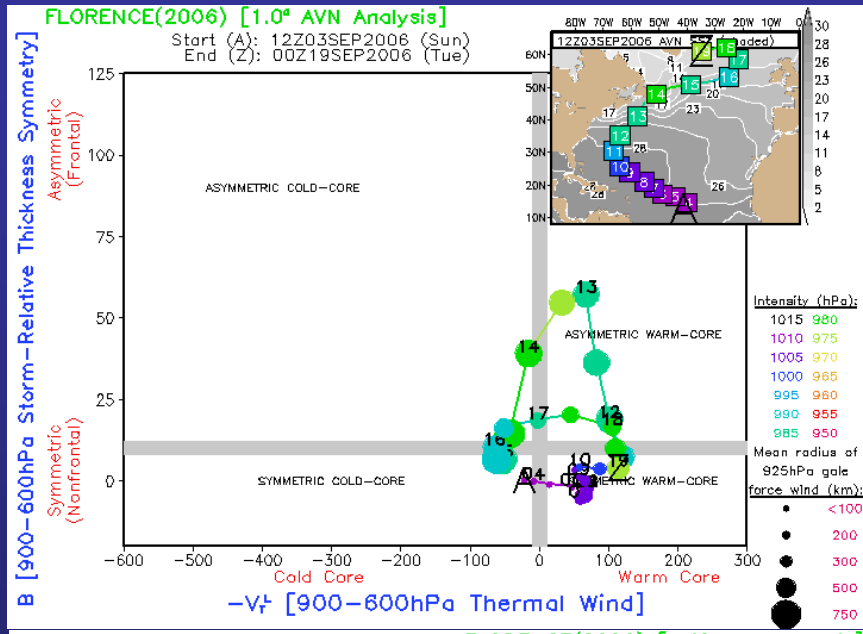


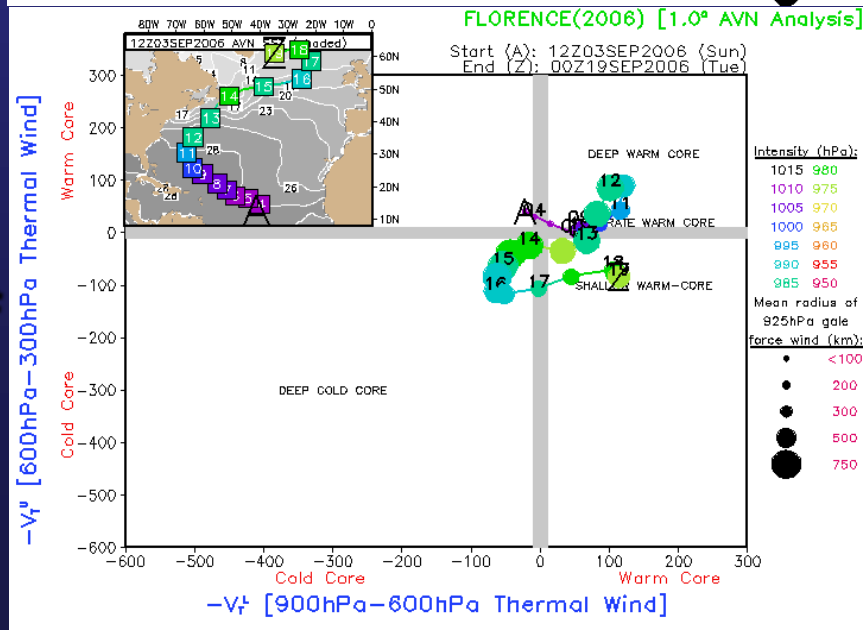




Reality has lots of shades of gray





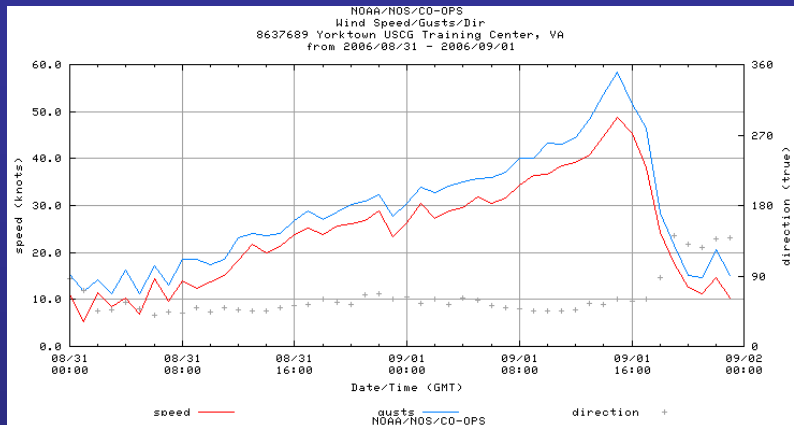


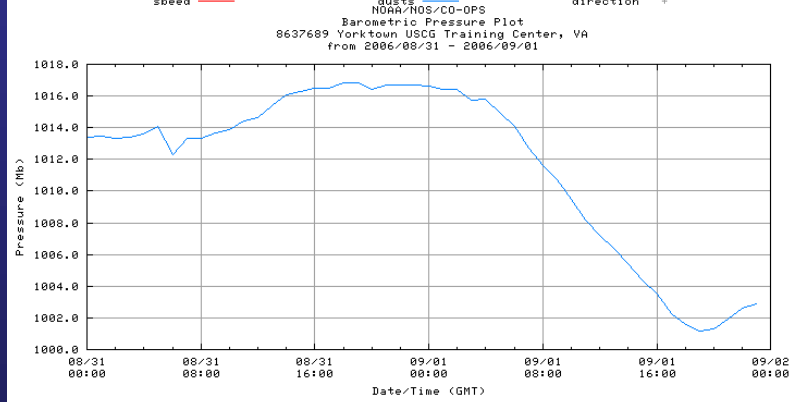
Cyclones occur in a continuum of structures rather than in discrete types

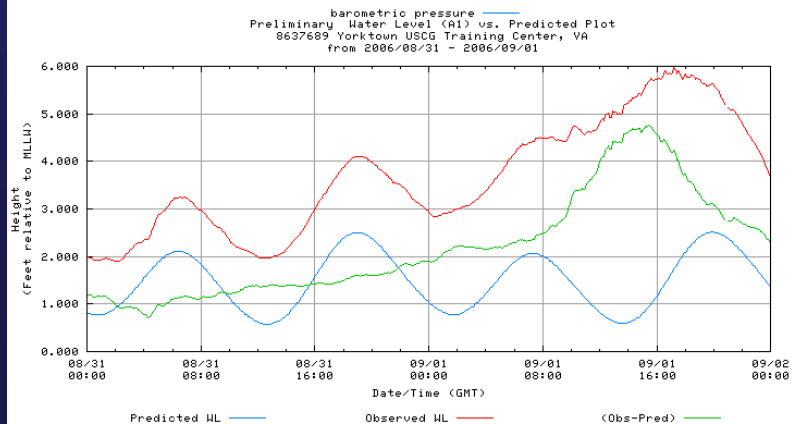
Hart and Evans Cyclone Phase Space

Why is the distinction important?

- Cyclone type and the associated transitions are ‘shades of grey’ or continuum issues
- Operational handling of cyclone types is a ‘black and white’ or ‘yes or no’ response
- This situation can lead to inconsistencies in the warning process and response
- But, if <u>you</u> get hit by 70 mph winds, 6 ft above normal tides, and/or 12 in of rain, does the exact nature of the system really matter?







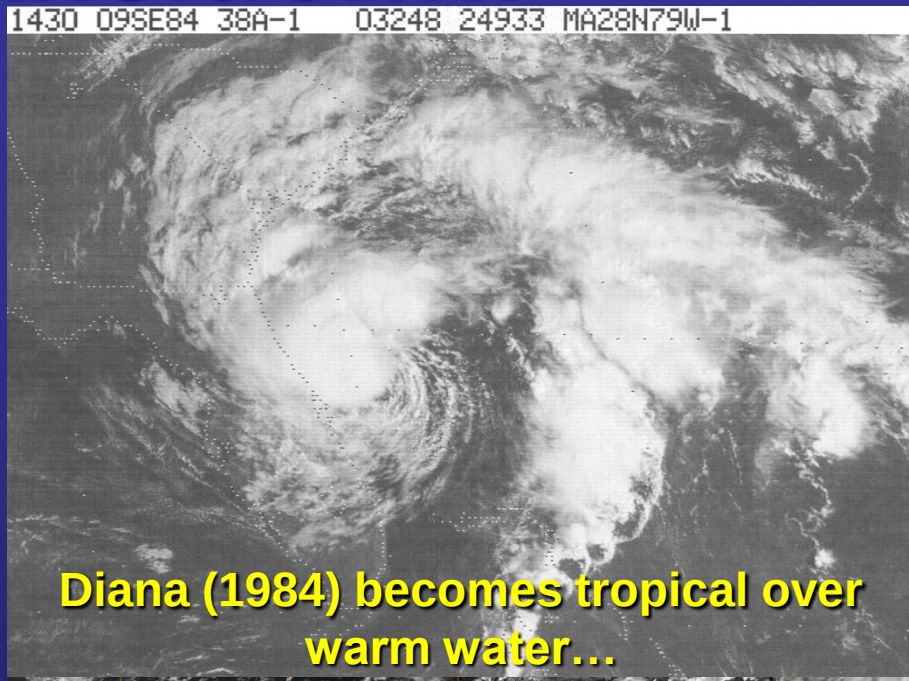
Operational Procedures

- ***Tropical/Subtropical Cyclone*: NHC is the WMO-designated agency for TC forecasts in the Atlantic and eastern Pacific. Associated coastal, marine, rainfall, severe weather, and local forecasts/warnings are tied to the NHC forecast track, intensity, and wind radii. NHC extensively coordinates these forecasts with the agencies involved.**

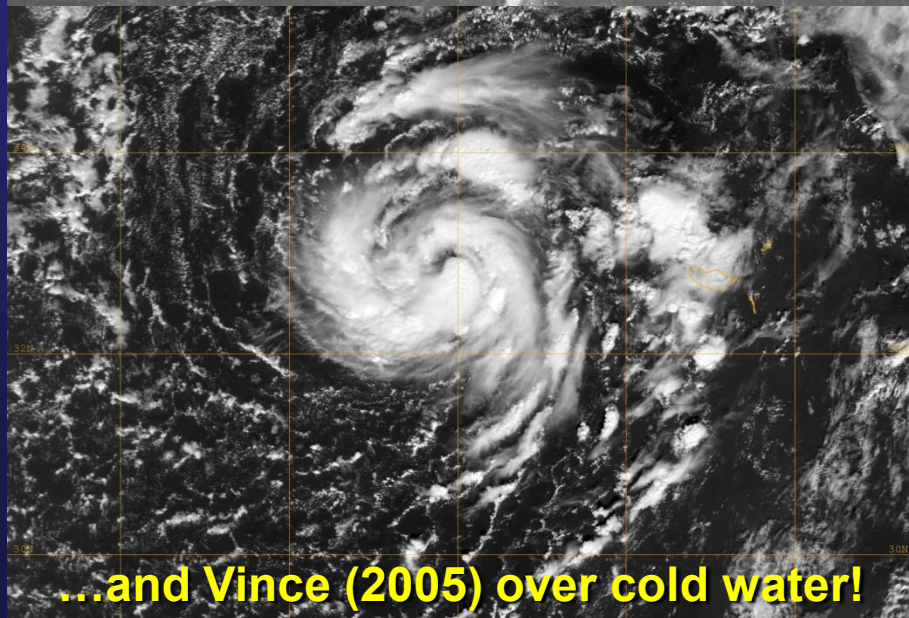
- ***Extratropical cyclone*: There is no lead or central forecast authority. The suite of warnings issued is different from that for tropical cyclones and causes a different response. Many NWS national centers, local NWS offices, and other national meteorological services play roles in the forecasts/warnings. There is a much different level of coordination.**

Tropical transition…

- Occurs as a non-tropical cyclone encounters an environment favorable for the development of organized central convection (showers and thunderstorms)
- Can occur over sea surface temperatures of less than 26ºC!



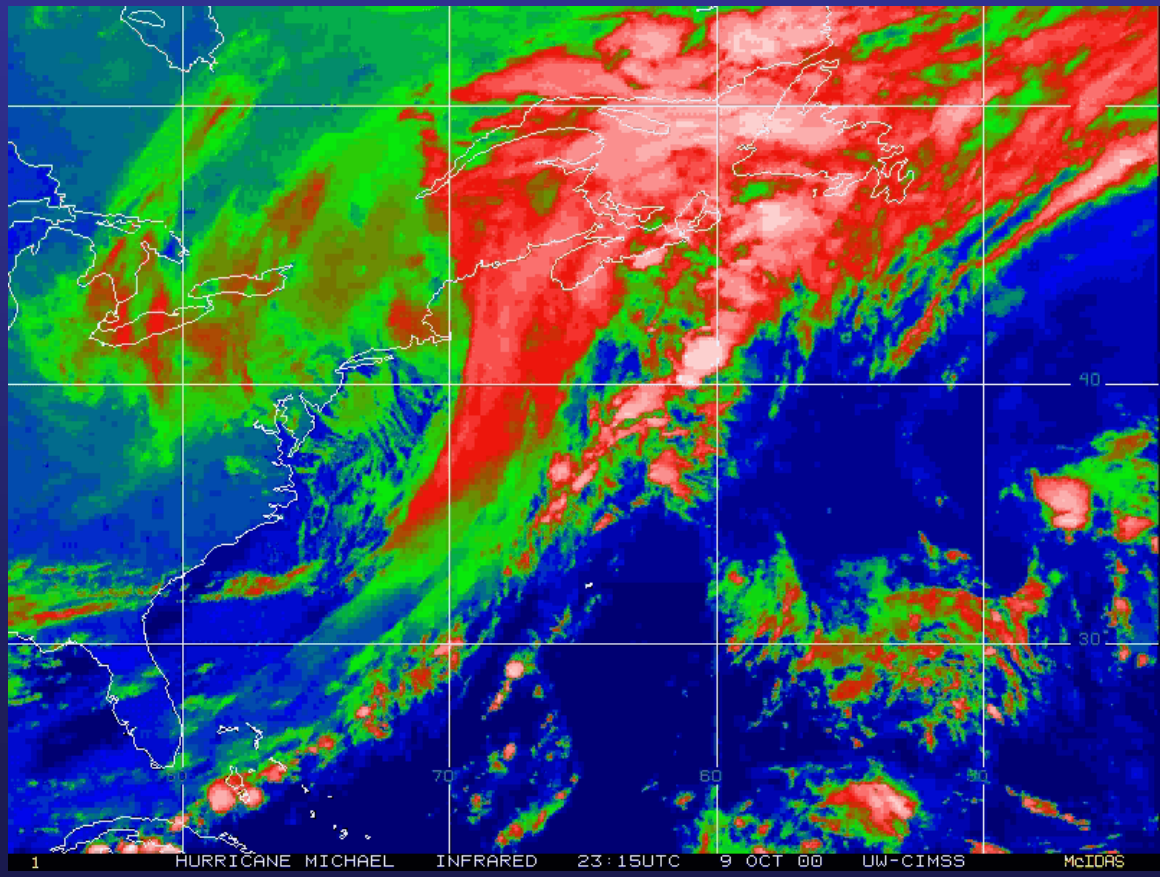
Diana (1984) becomes tropical over warm water…



…and Vince (2005) over cold water!

As a system becomes a tropical cyclone…

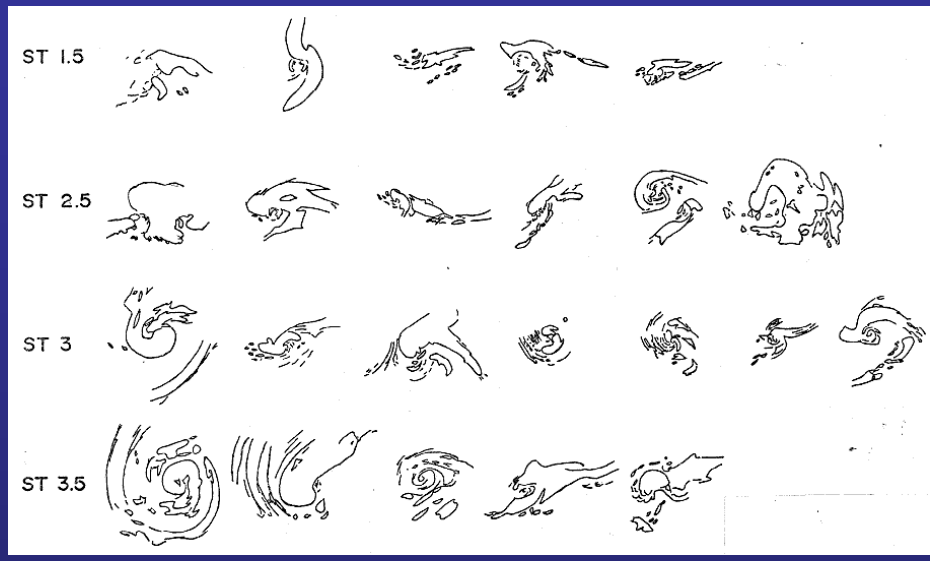
- The wind field becomes tighter around the center or an inner wind core develops
- Organized showers/ thunderstorms form near the center
- A convectively-driven warm core develops



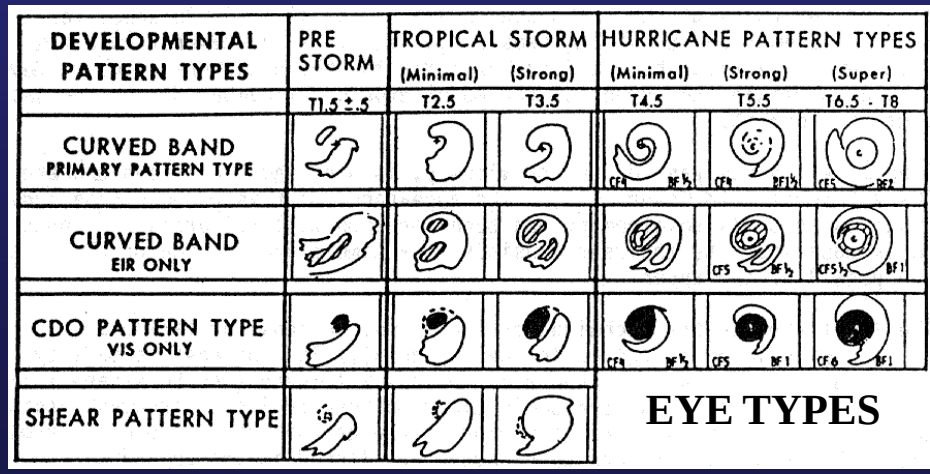
Hurricane Michael (2000)

Analyzing and forecasting TT

- Satellite data, particularly microwave soundings and interpretation of imagery through the Hebert-Poteat and Dvorak techniques, are useful in diagnosing TT.
- Numerical models can forecast large-scale changes during TT which are interpreted through the Cyclone Phase Space. There are limits on how well the models can resolve core features.
- TT forecasts are not currently verified by NHC.



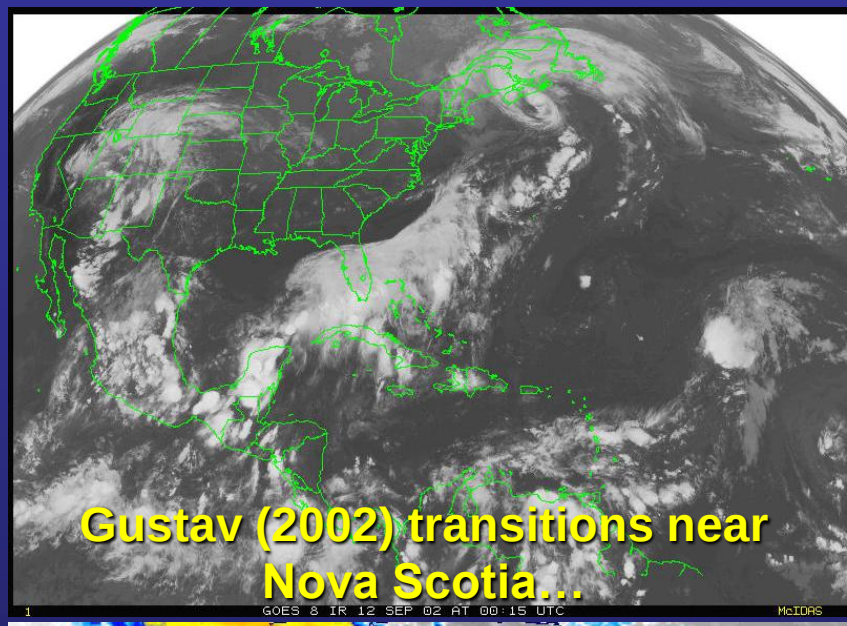
Hebert-Poteat Technique Cloud Patterns



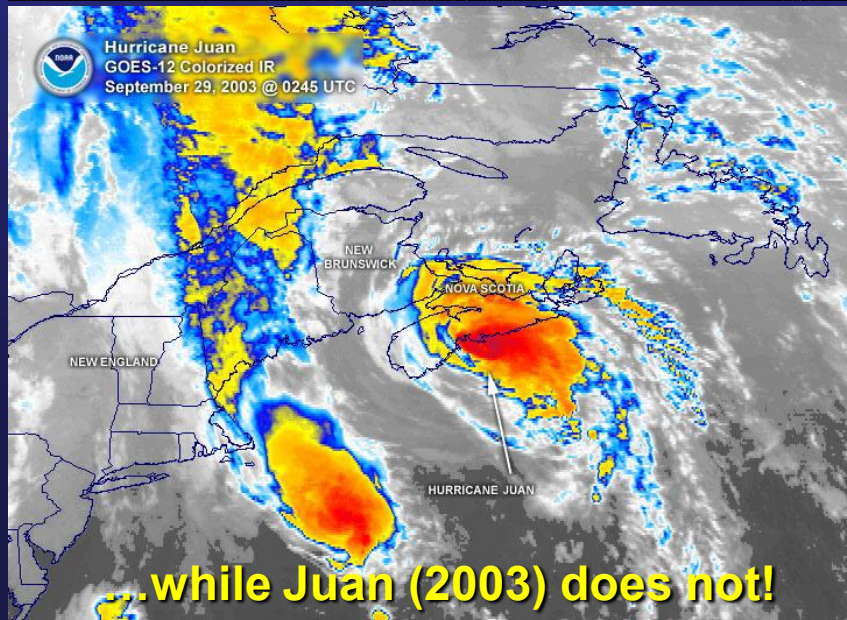
Dvorak Technique Cloud Patterns

Extratropical transition (ET)…

- Occurs as the tropical cyclone interacts with cold air and vertical wind shear associated with the westerly jet stream
- Generally, but <u>not always</u>, occurs at higher latitudes (north of 35N)



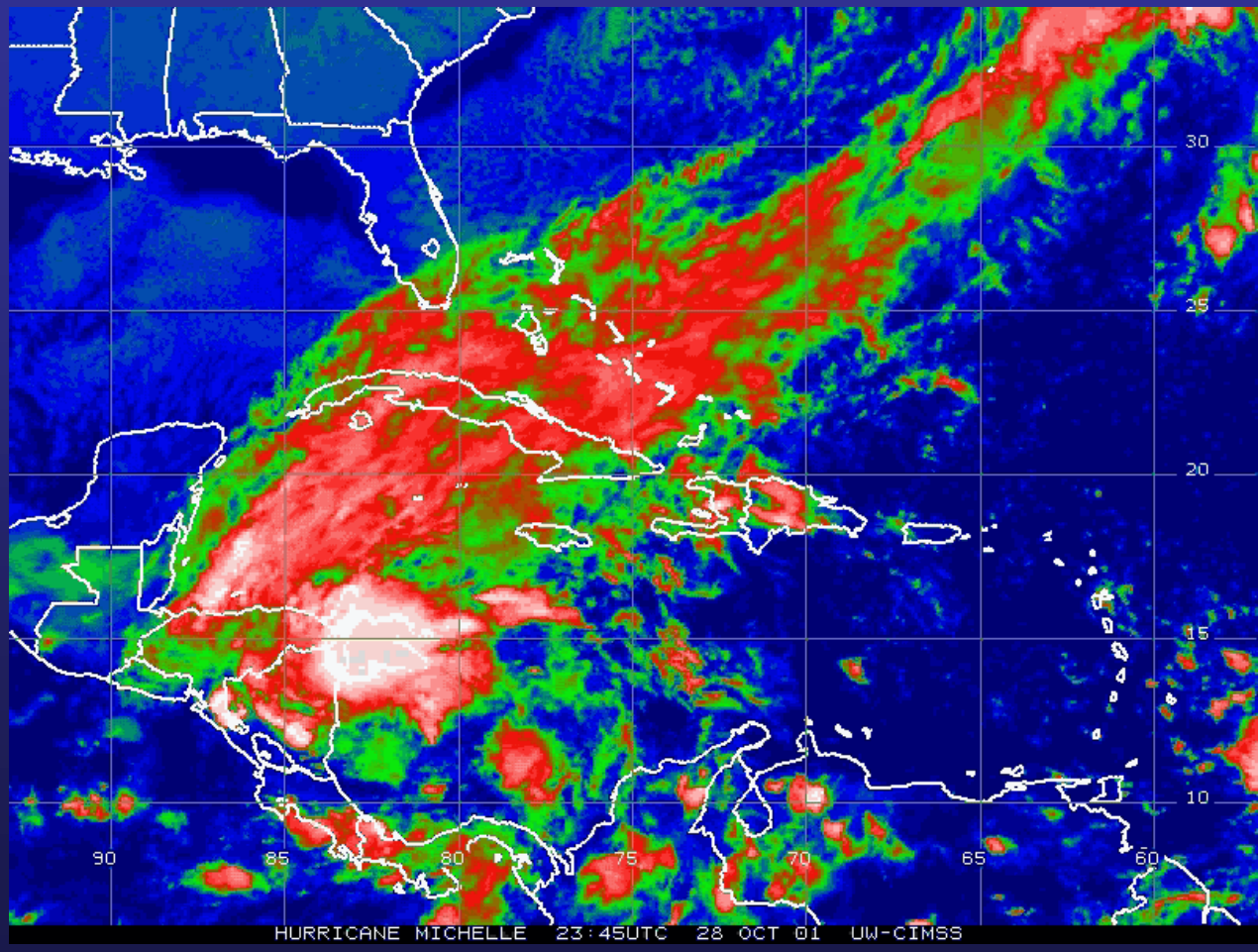
Gustav (2002) transitions near Nova Scotia…



…while Juan (2003) does not!

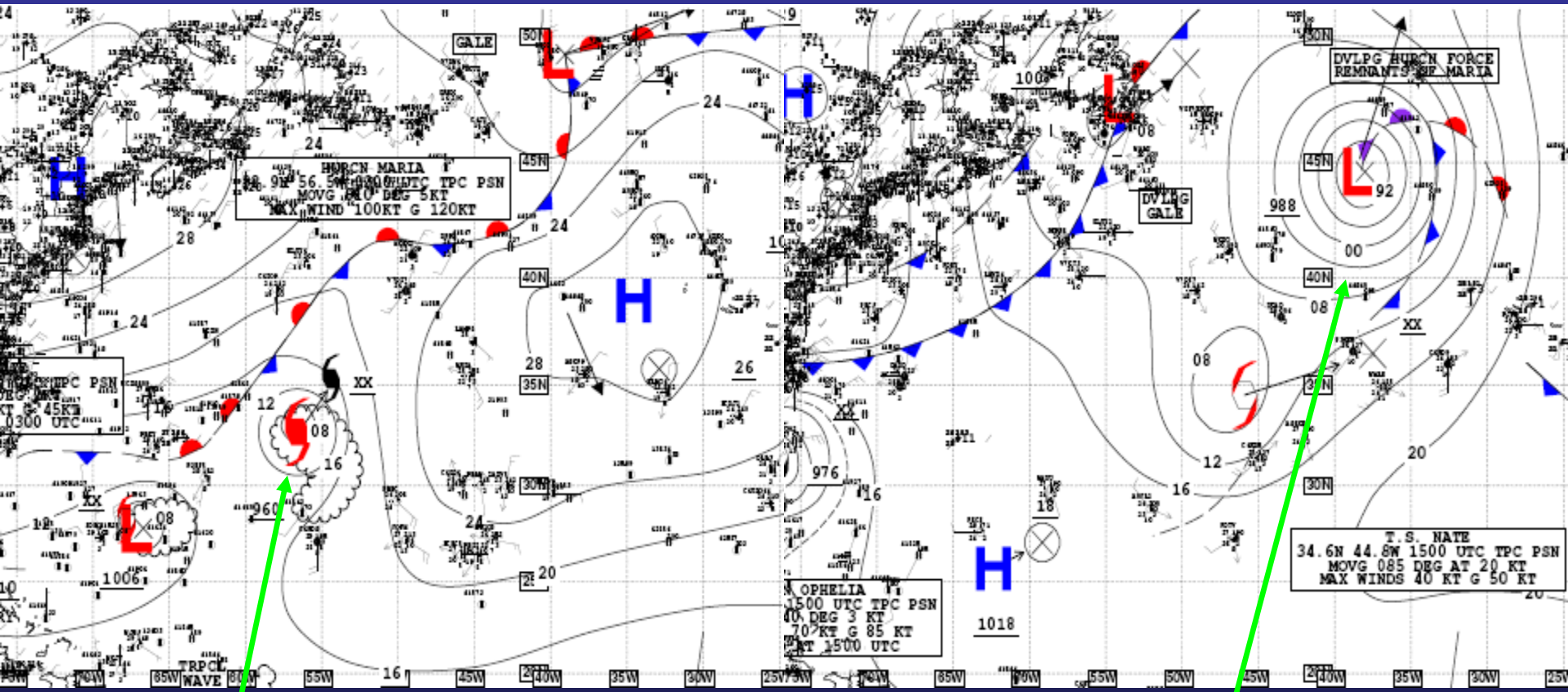
As a tropical cyclone loses tropical characteristics…

- The maximum winds generally (but not always) decrease
- The wind field generally spreads out, causing a larger area of impact
- The cyclone rainfall pattern changes significantly



Hurricane Michelle (2001)

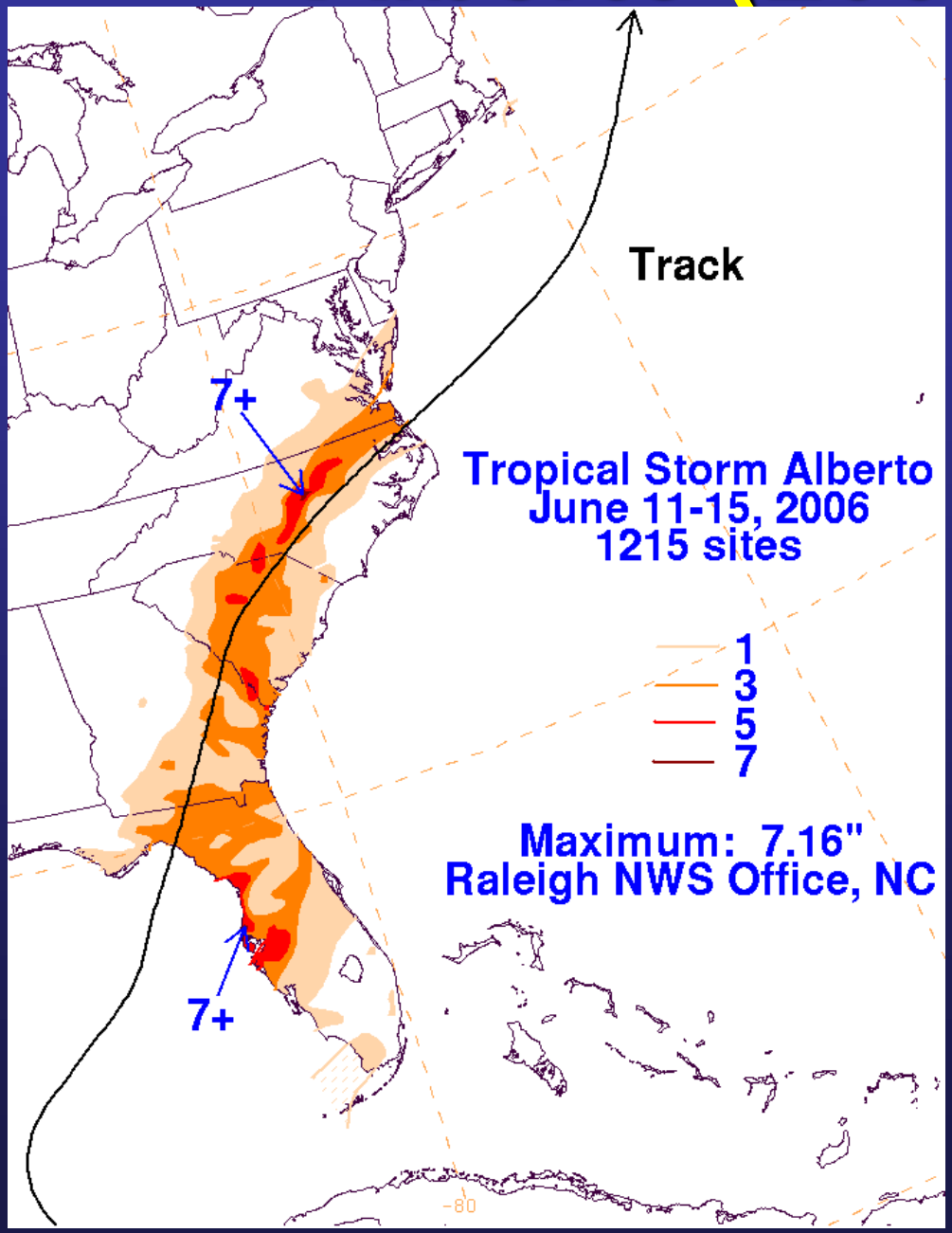
Hurricane Maria (2005)



Relatively small major hurricane

Much larger extratropical low

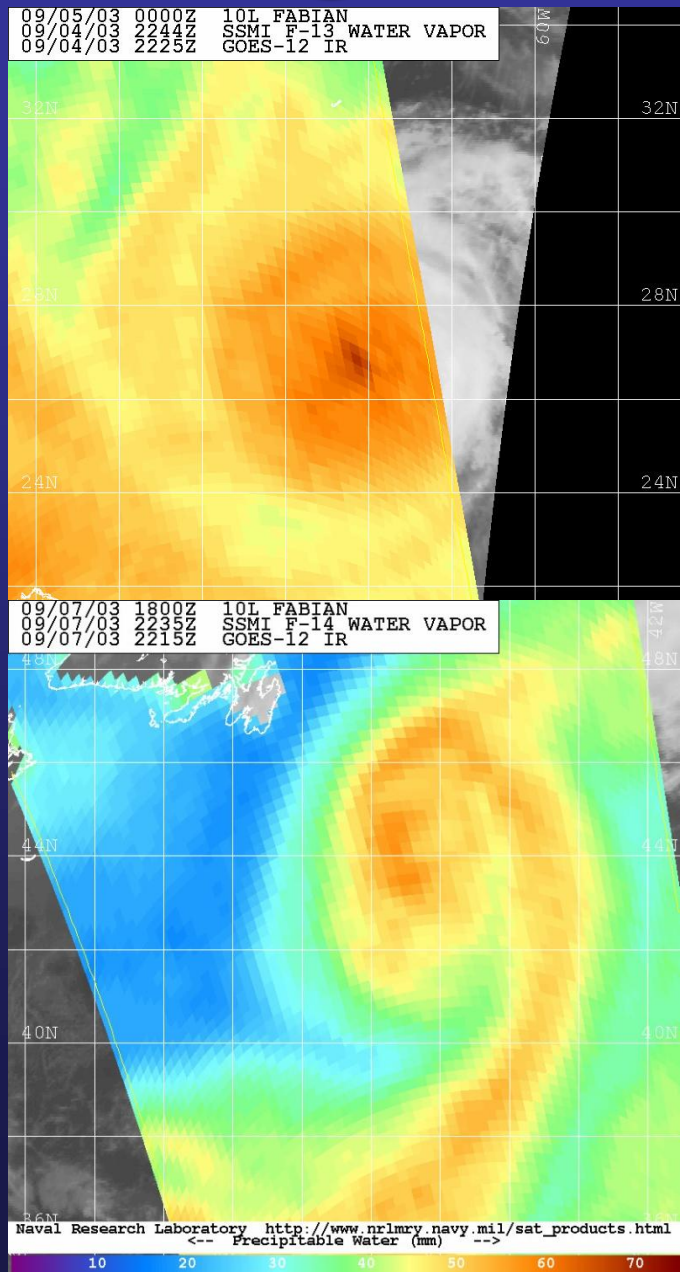
Alberto (2006) Rainfall



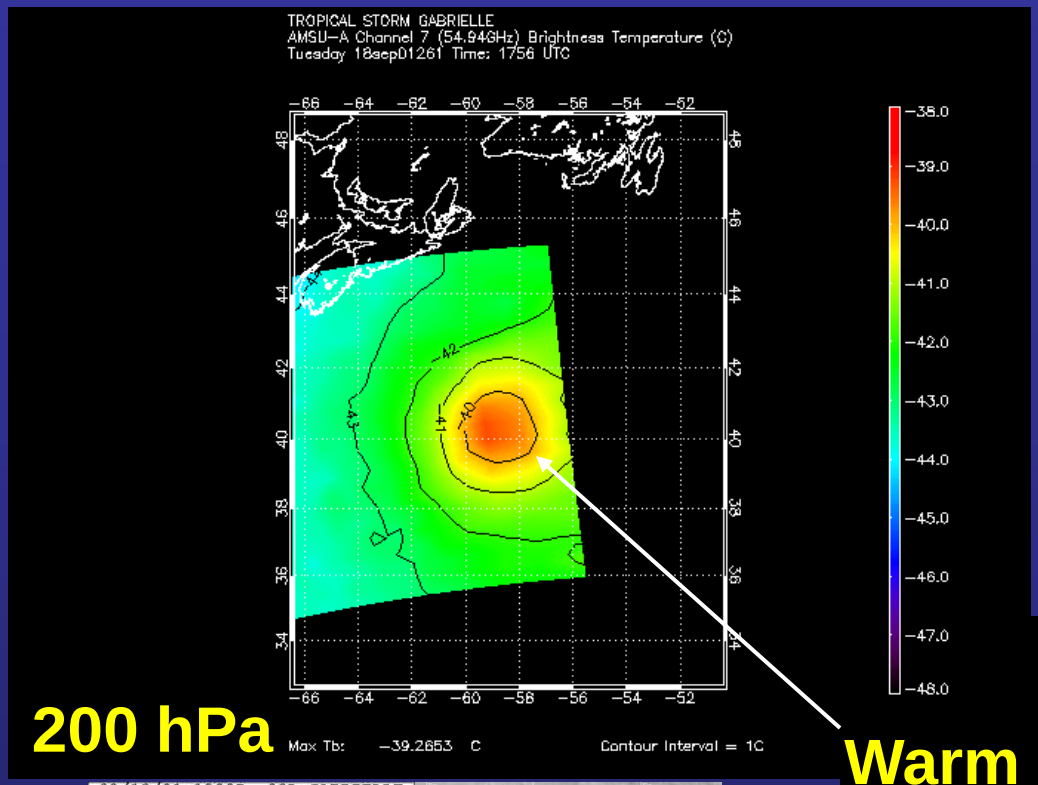
Note that the heaviest rain is to the right of the storm track in Florida and to the left of the storm track in the Carolinas. This change occurred as Alberto transitioned to an extratropical cyclone.

Analyzing and forecasting ET

- Satellite data, particularly soundings and deep-layer precipitable water, are useful in diagnosing ET.
- Numerical models can forecast large-scale changes during ET which are interpreted through the Cyclone Phase Space.
- ET forecasts are currently not a formal part of the NHC forecast verification process. However, there has been informal verification.

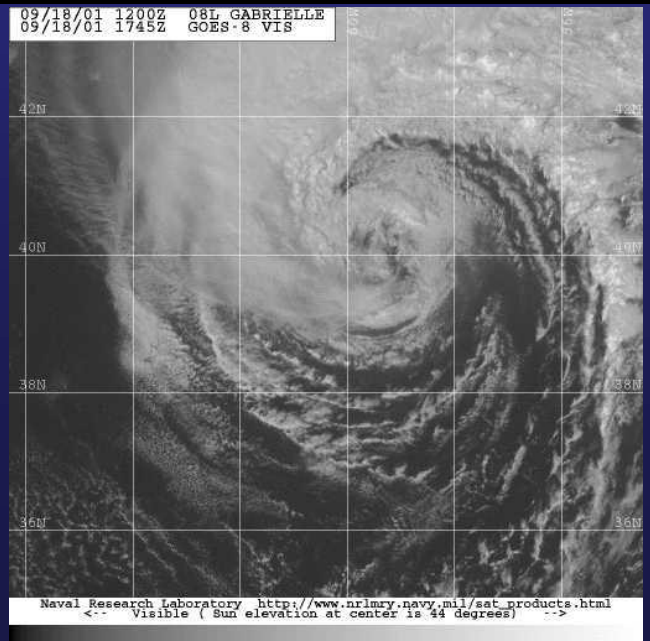


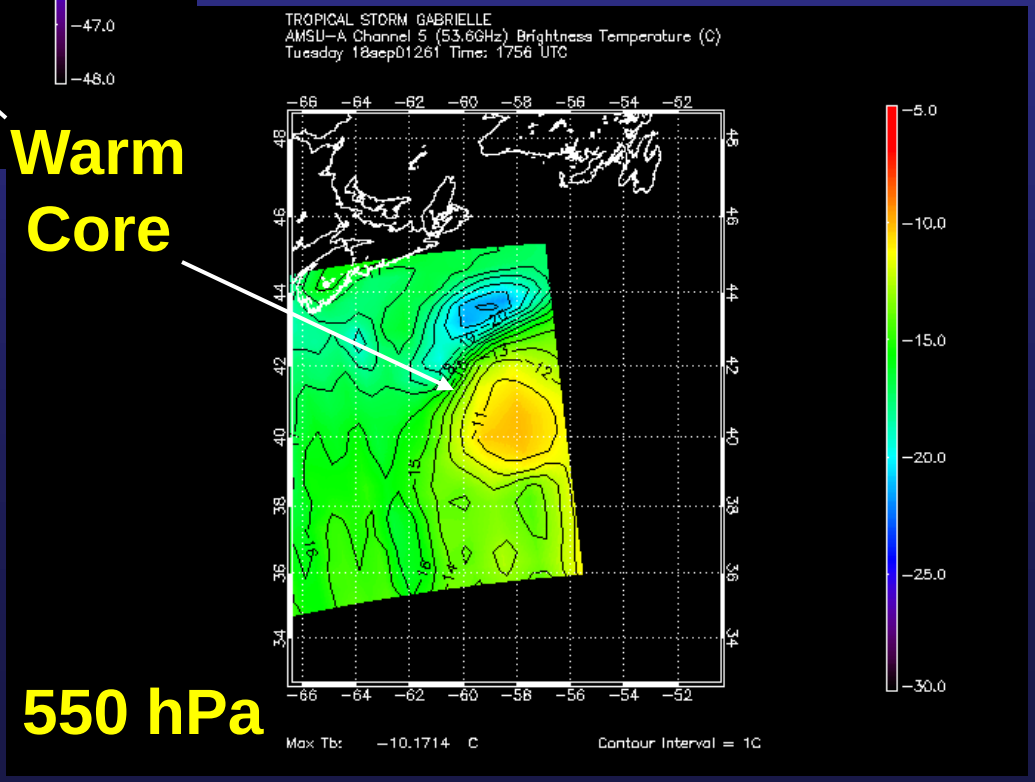
Gabrielle AMSU Data 1756 UTC 18 Sep 2001



200 hPa

Warm Core





550 hPa

Verification for ET Forecasts

- Based on yes-no 2-D contingency diagram based on whether ET occurred/was forecast at any time in the forecast period
- Two versions: One includes forecasts for all TCs, while the other includes only TC where ET was forecast and/or did occur – both versions done for 5-day and 3-day forecasts
- Includes verification of the timing of the ET forecast – how wrong temporally was the forecast of ET when ET occurred

ET Verification

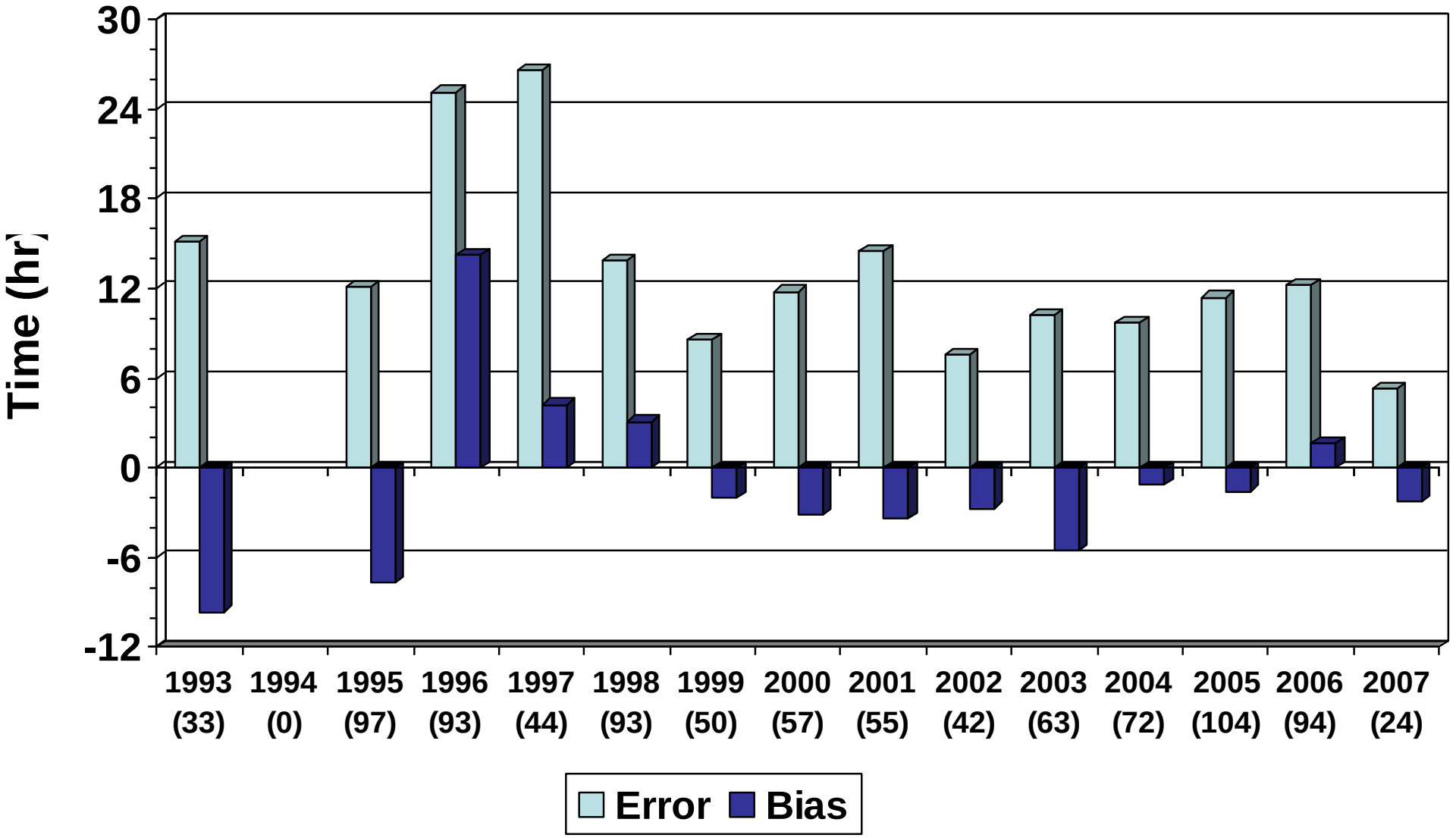
ET Forecast	663 forecasts in 2005	ET Observed: Yes	ET Observed: No
Yes		155 (successful ET forecasts)	57 (false alarms)
No		49 (missed transitions)	402 (successful non-ET forecasts)

2-D Contingency Table

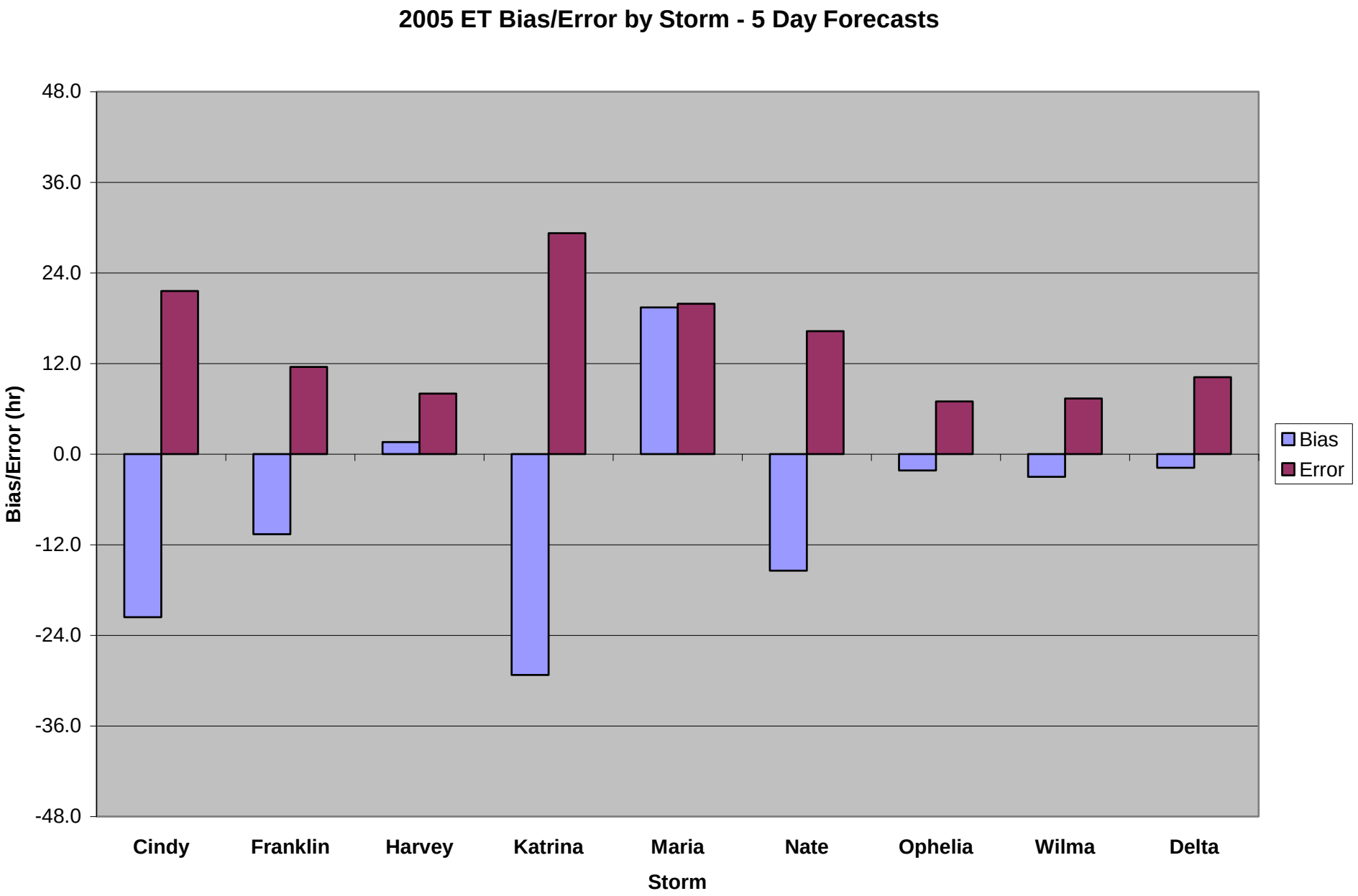
Skill Measure	Range	Skillful Values
Critical Success Index	0.0 to 1.0	Near 1.0
Probability of Detection	0.0 to 1.0	Near 1.0
False Alarm Ratio	0.0 to 1.0	Near 0.0
Percentage Correct	0.0 to 1.0	Near 1.0
Event Bias	0.0 to ?	Near 1.0
Gilbert Skill Score	-0.33 to 1.0	Near 1.0
Heidke Skill Score	-1.0 to 1.0	Near 1.0
True Skill Statistic	-1.0 to 1.0	Near 1.0

Skill Metrics Table

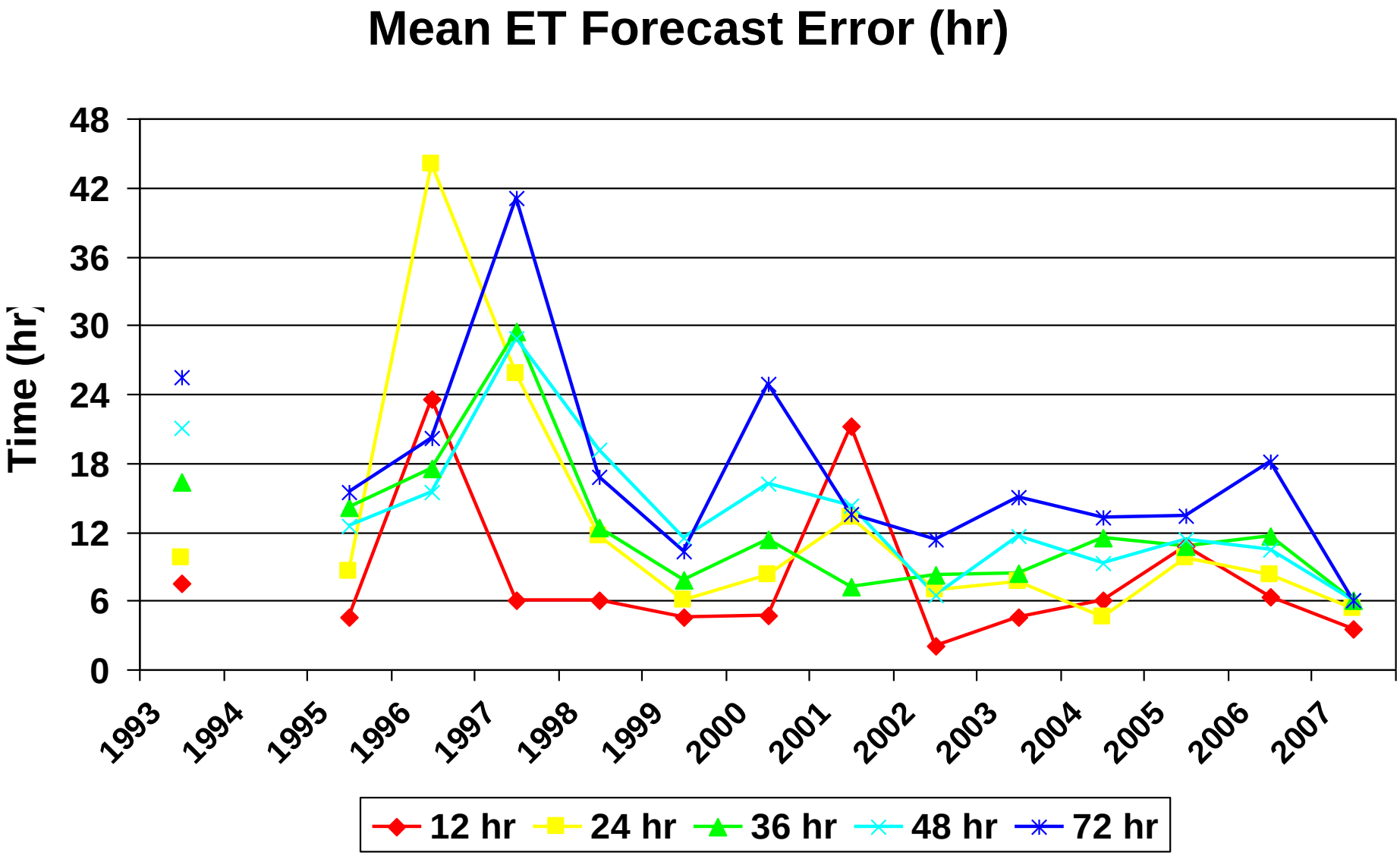
3-Day ET Timing Errors/Biases



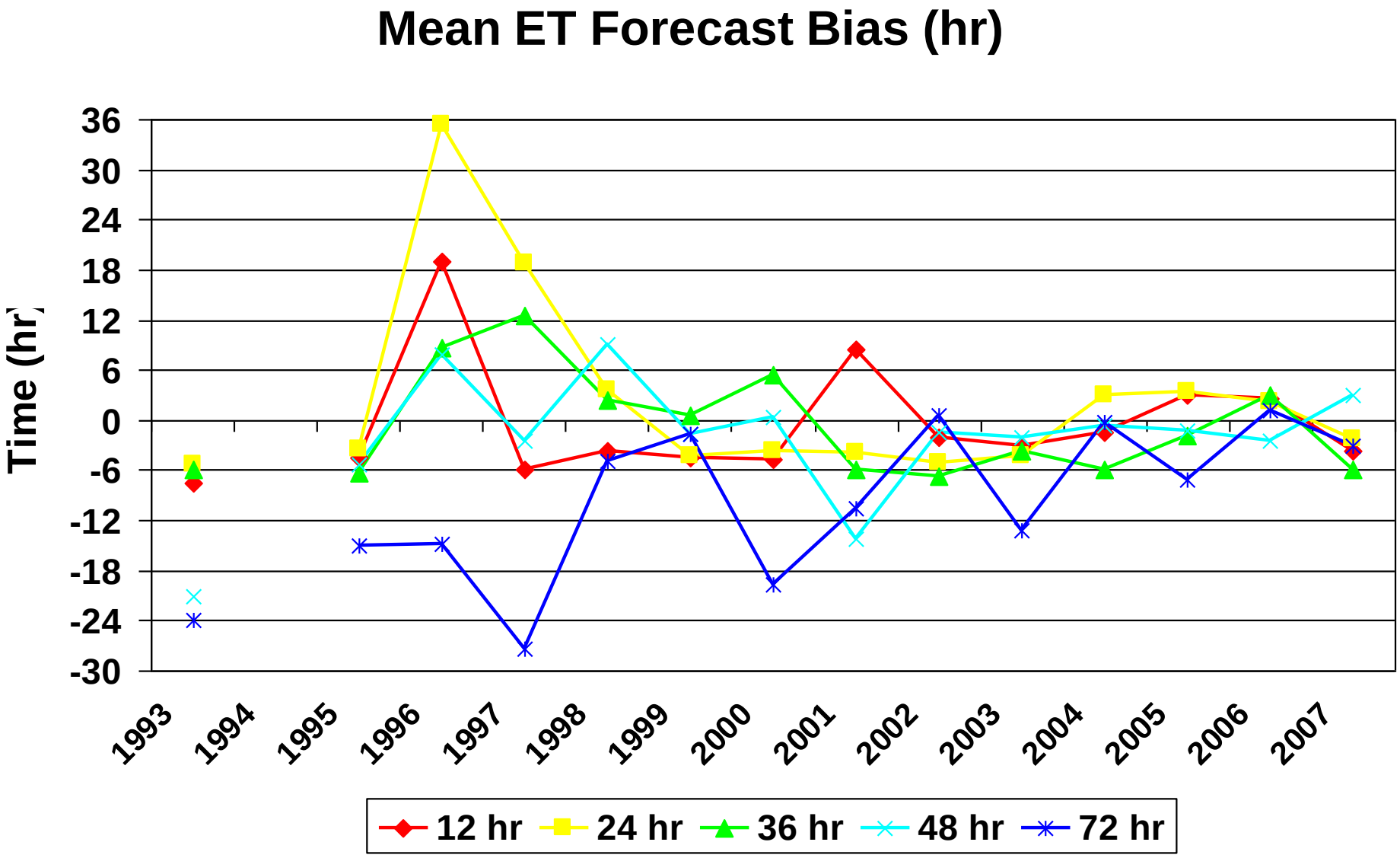
2005 Errors/Biases by Storm



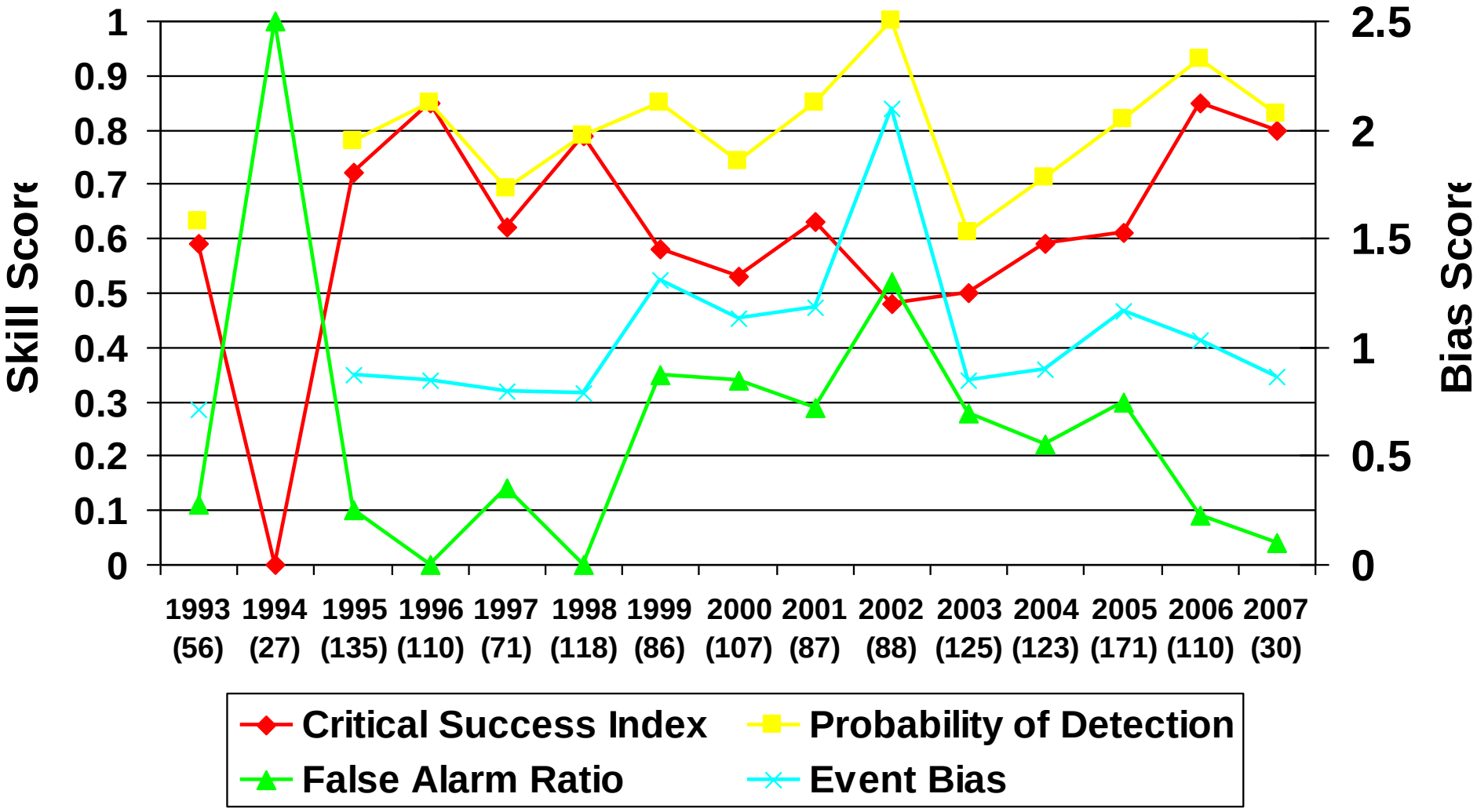
3-Day Individual Time Errors



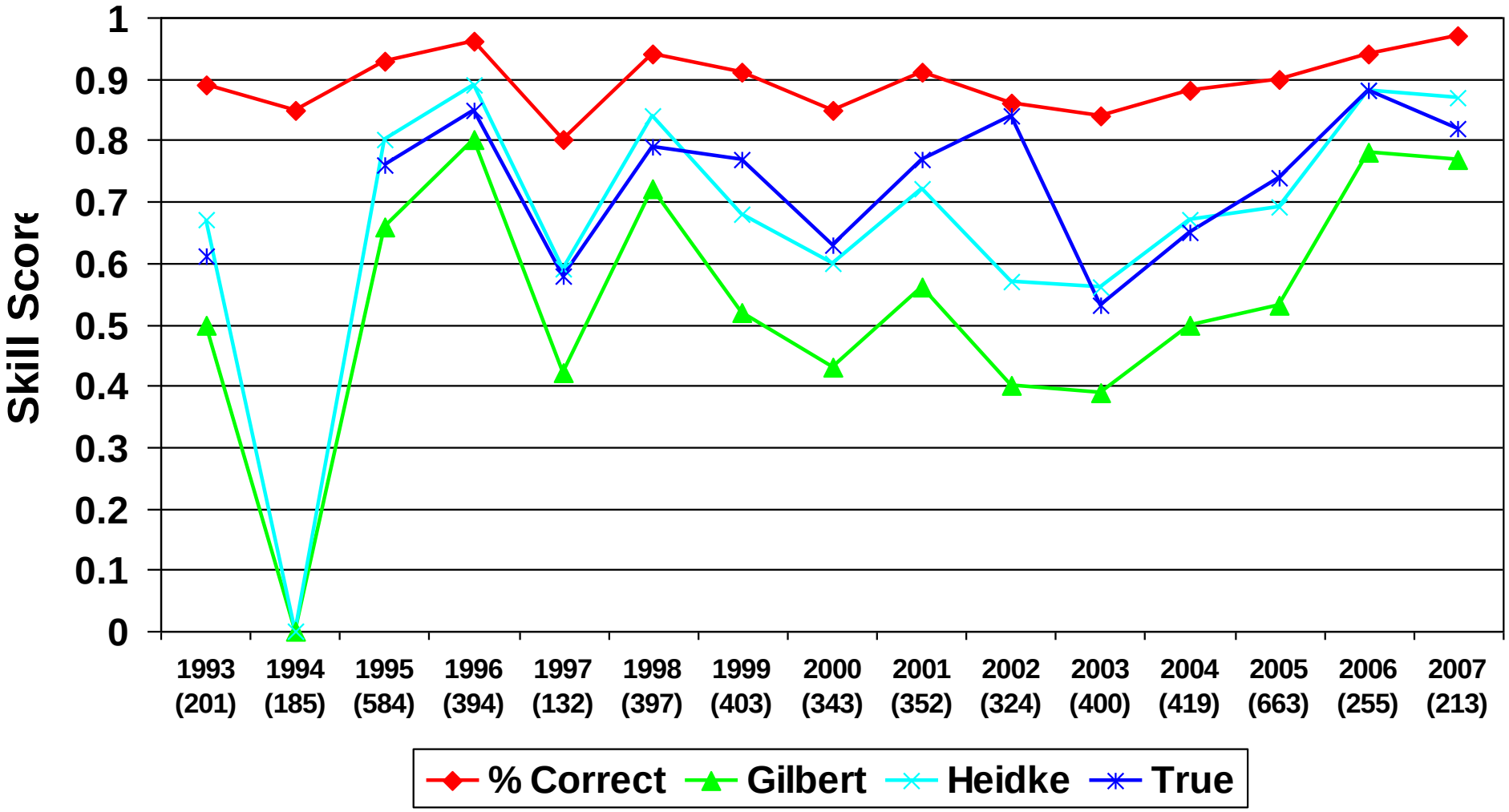
3-Day Individual Time Biases



3-Day Skill Scores



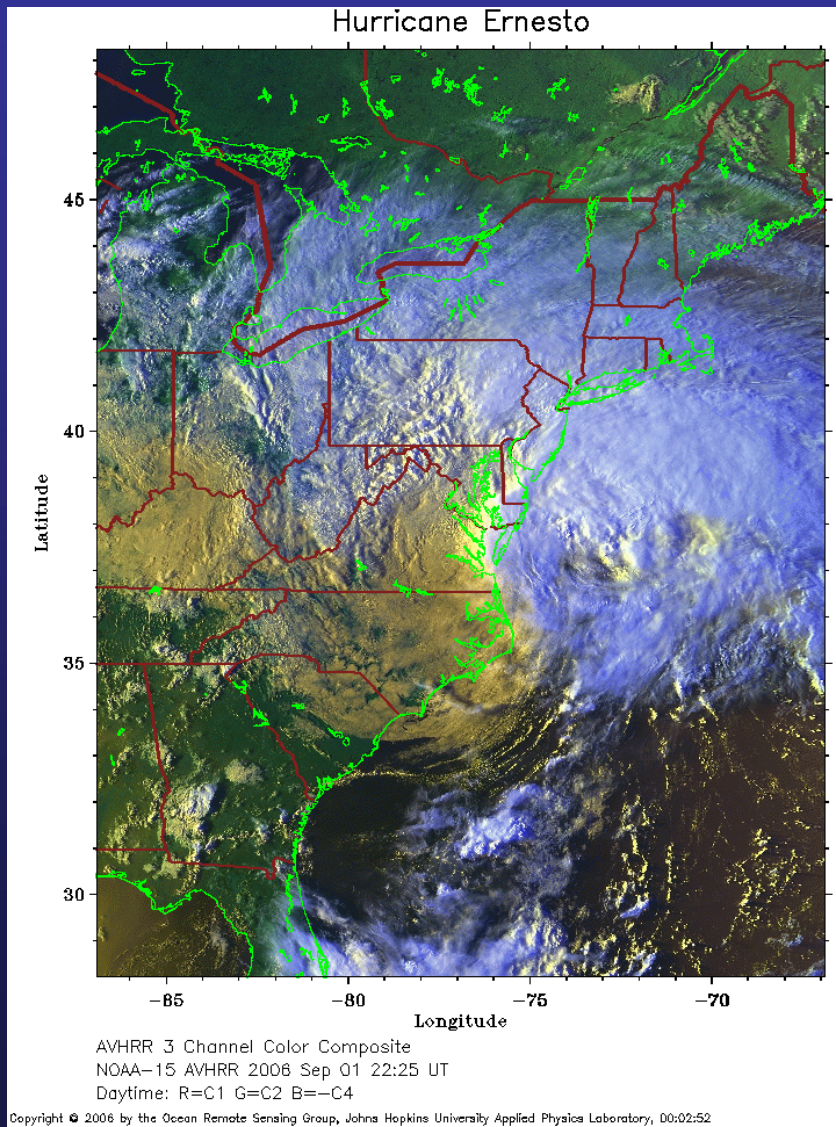
3-Day Skill Scores



ET Forecasting Issues

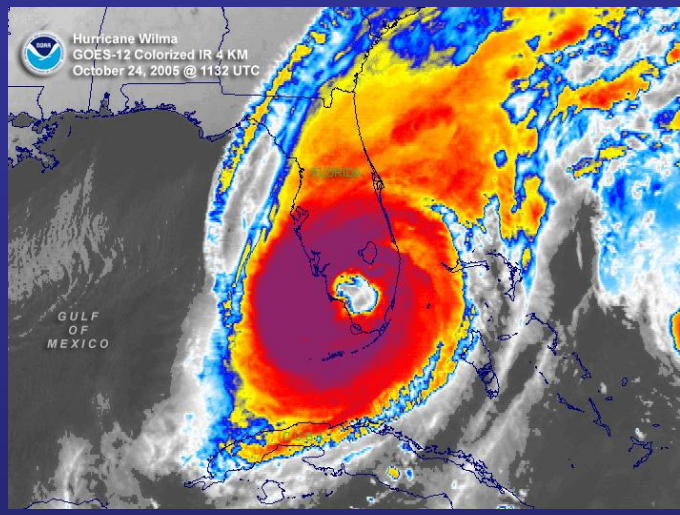
How will a system undergoing ET evolve?

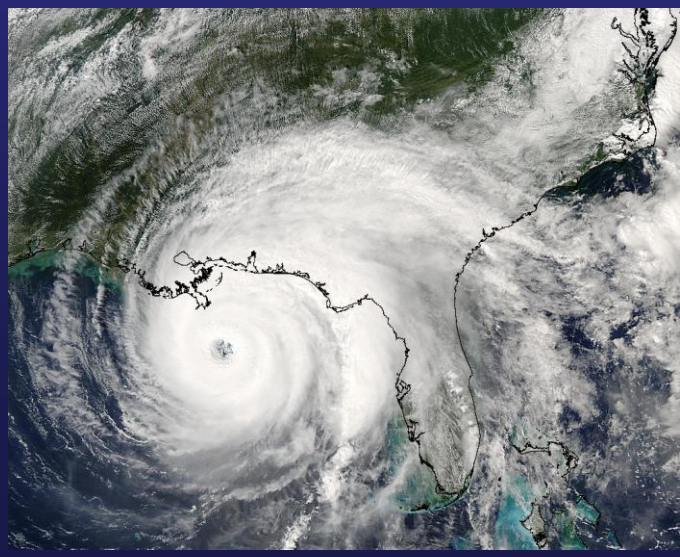
- Strengthening, weakening, or steady intensity?
- Straight transition to an extratropical cyclone? (Florence 2006)
- Absorbed by extratropical low or frontal system? (Florence 2000)
- Absorbing of extratropical low? (Gustav 2002)
- Delayed reaction regeneration? (Earl 1998, Alberto 2006)
- Interrupted transition? (Dennis 1999, Maria 2005, Helene 2006)
- Unusual synoptic pattern? (Ernesto 2006)
- None of the above – busted transition forecast?



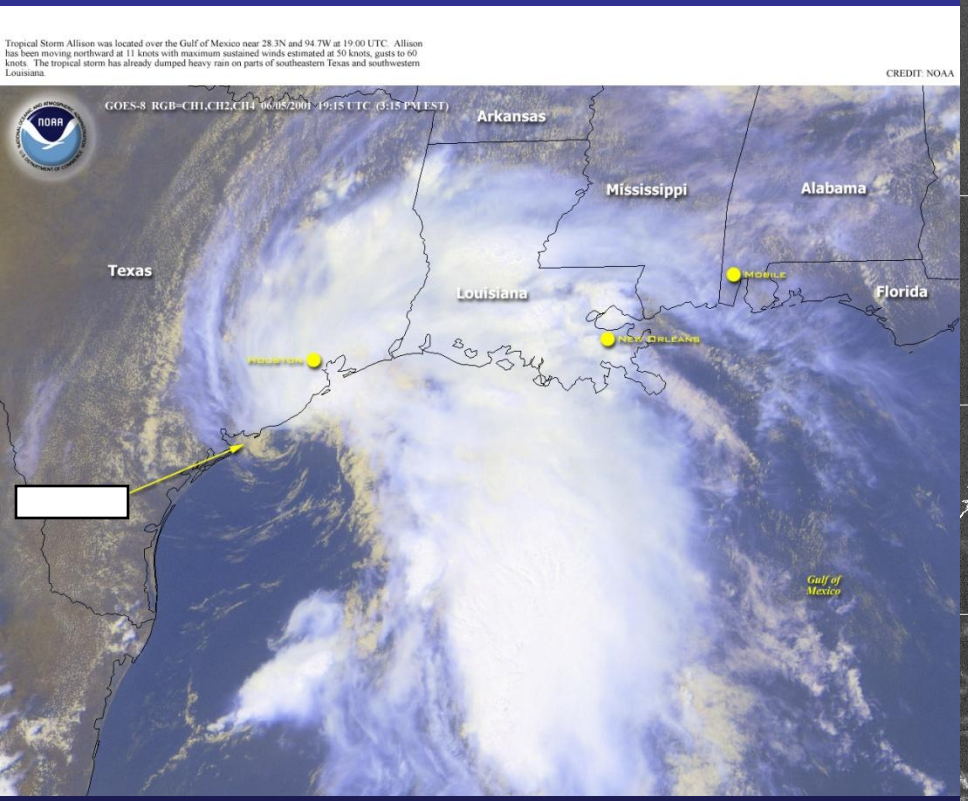
Some General Issues

- Atlantic TCs often intensify through TC processes after recurvature, probably more often than in any other parts of the world
- Bad ET forecast can result from a variety of issues, including bad track and intensity forecasts
- Cyclone type decisions could have impact on TC climatology - e. g. the Australian “Duck” storm of 2001, Barry of 2007, and others
- Mid-latitude influences can enhance the tornado threat in transitioning and hybrid cyclones, and can do the same in fully tropical systems

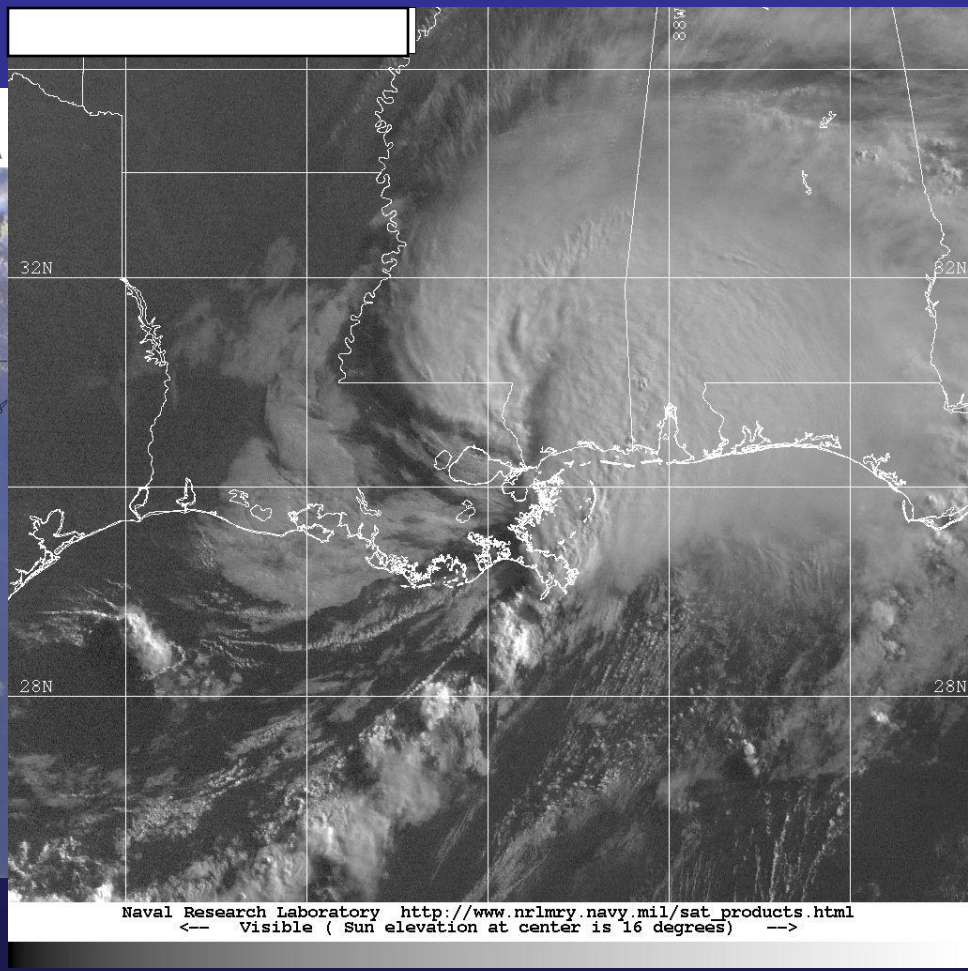




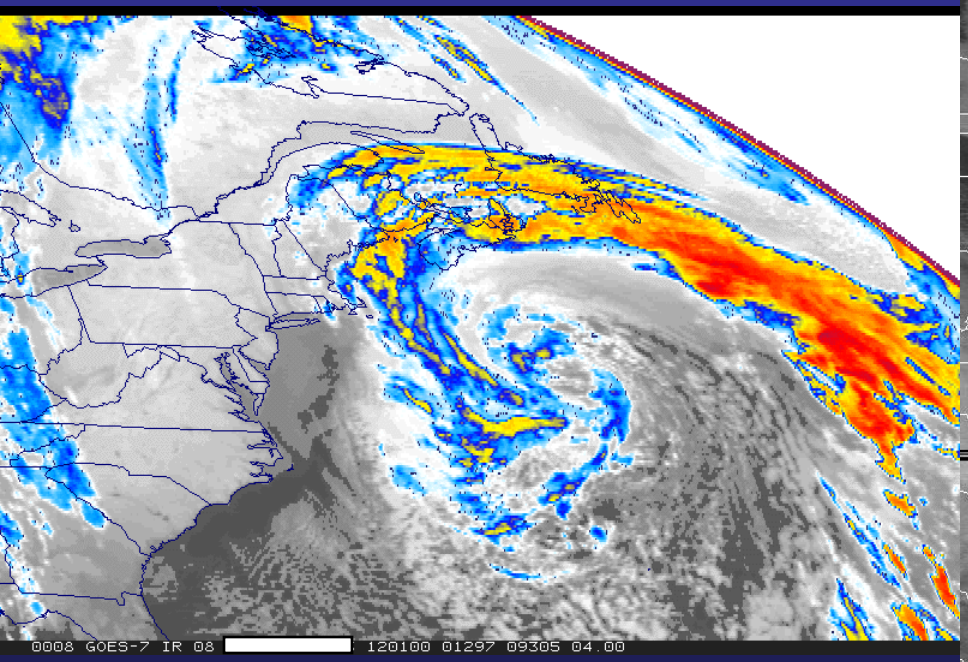
Tropical, Subtropical, or Extratropical?



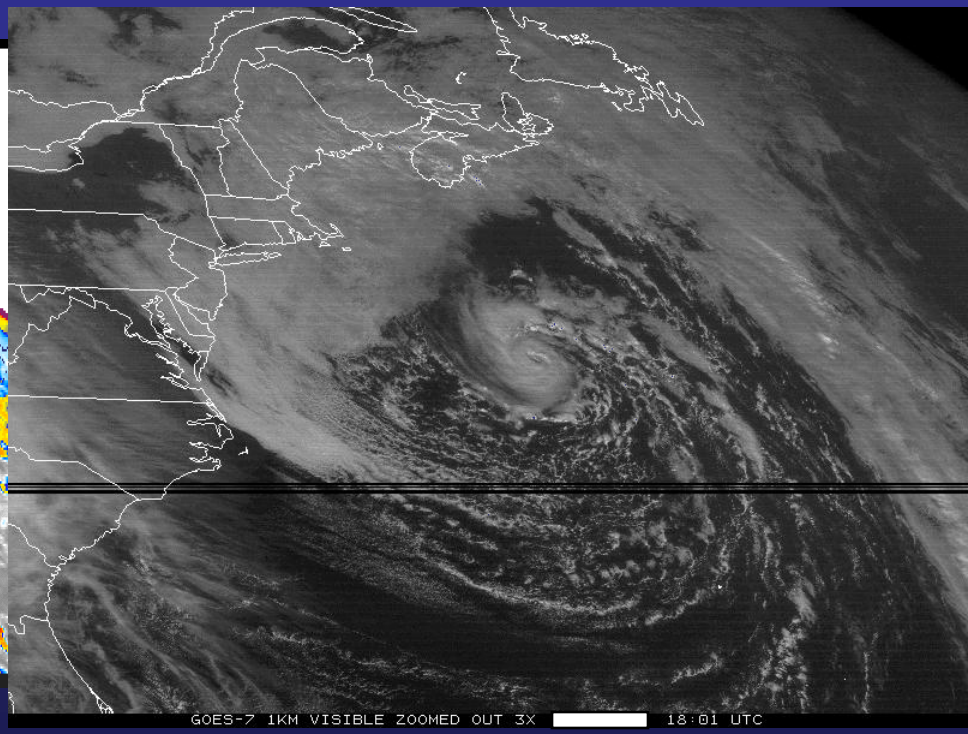
Tropical Storm Allison (2001)



Tropical, Subtropical, or Extratropical?

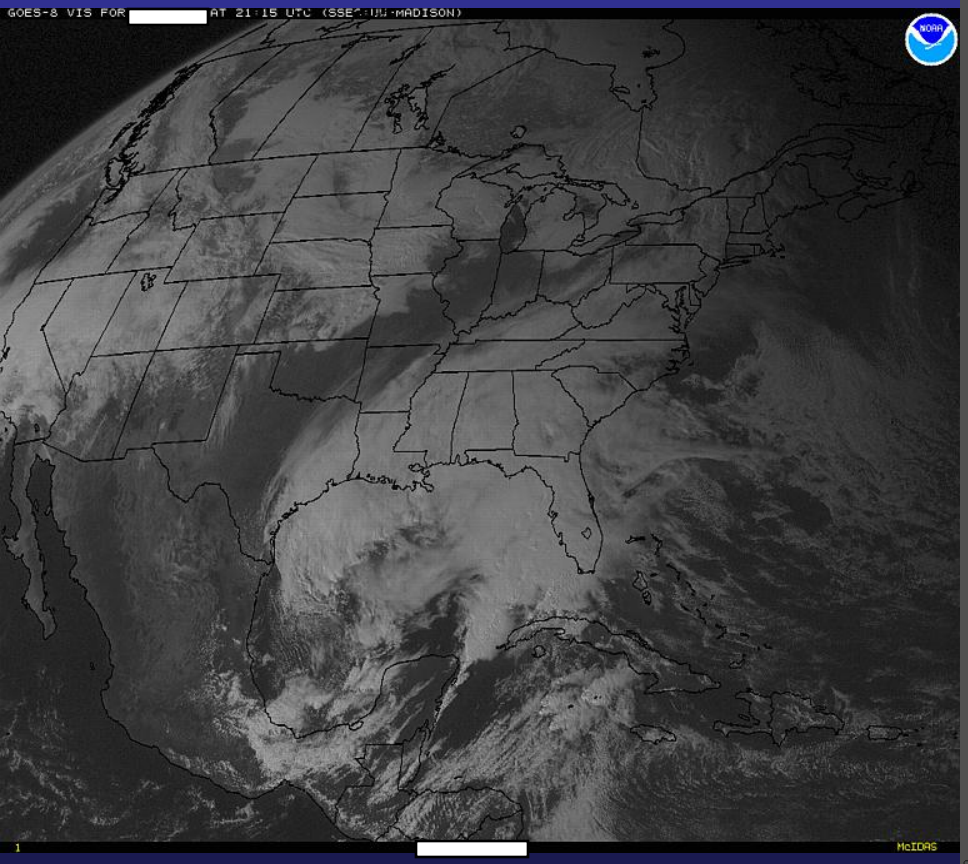


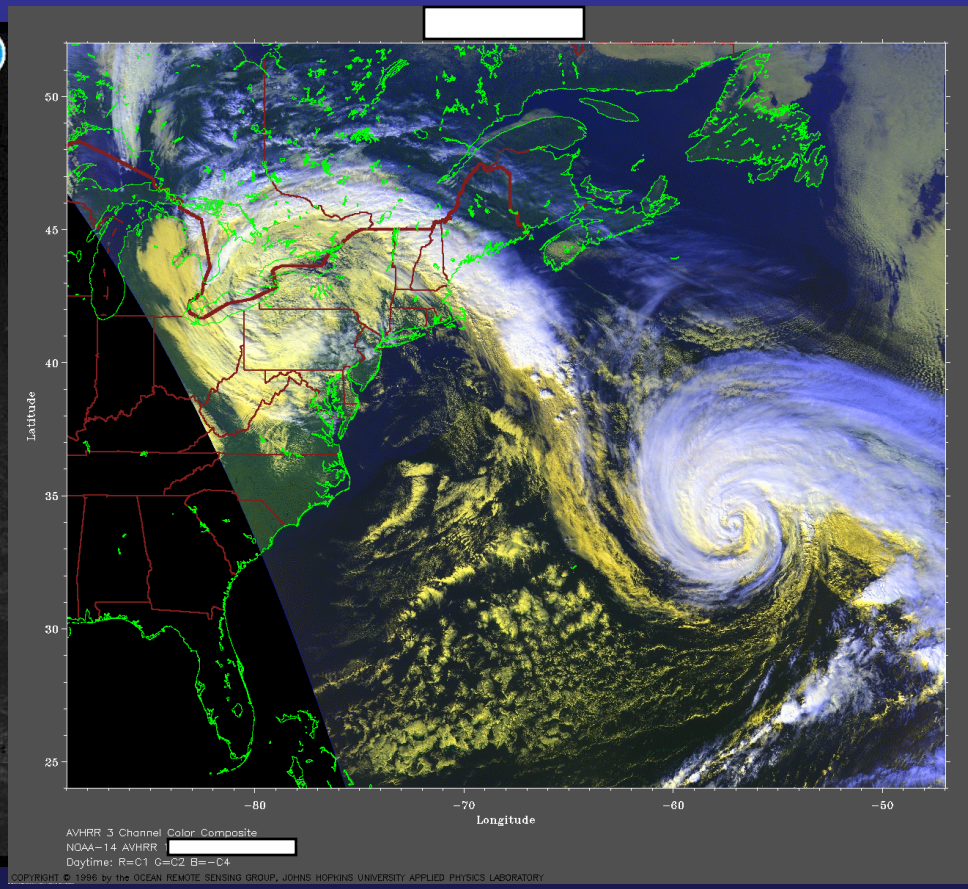
Perfect Storm - Extratropical



Perfect Storm - Hurricane

Tropical, Subtropical, or Extratropical?





February 2 1998 Extratropical

Extratropical and Lili (1996)

Summary

- Atmospheric cyclones come in a great variety of structures driven by several different energy sources
- Significant changes in structure occur as cyclones undergo tropical or extratropical transition, which can result in significant changes in impacts
- Warning processes for tropical and extratropical cyclones differ considerably, which can be problematic if transitions occur near a coast or over land