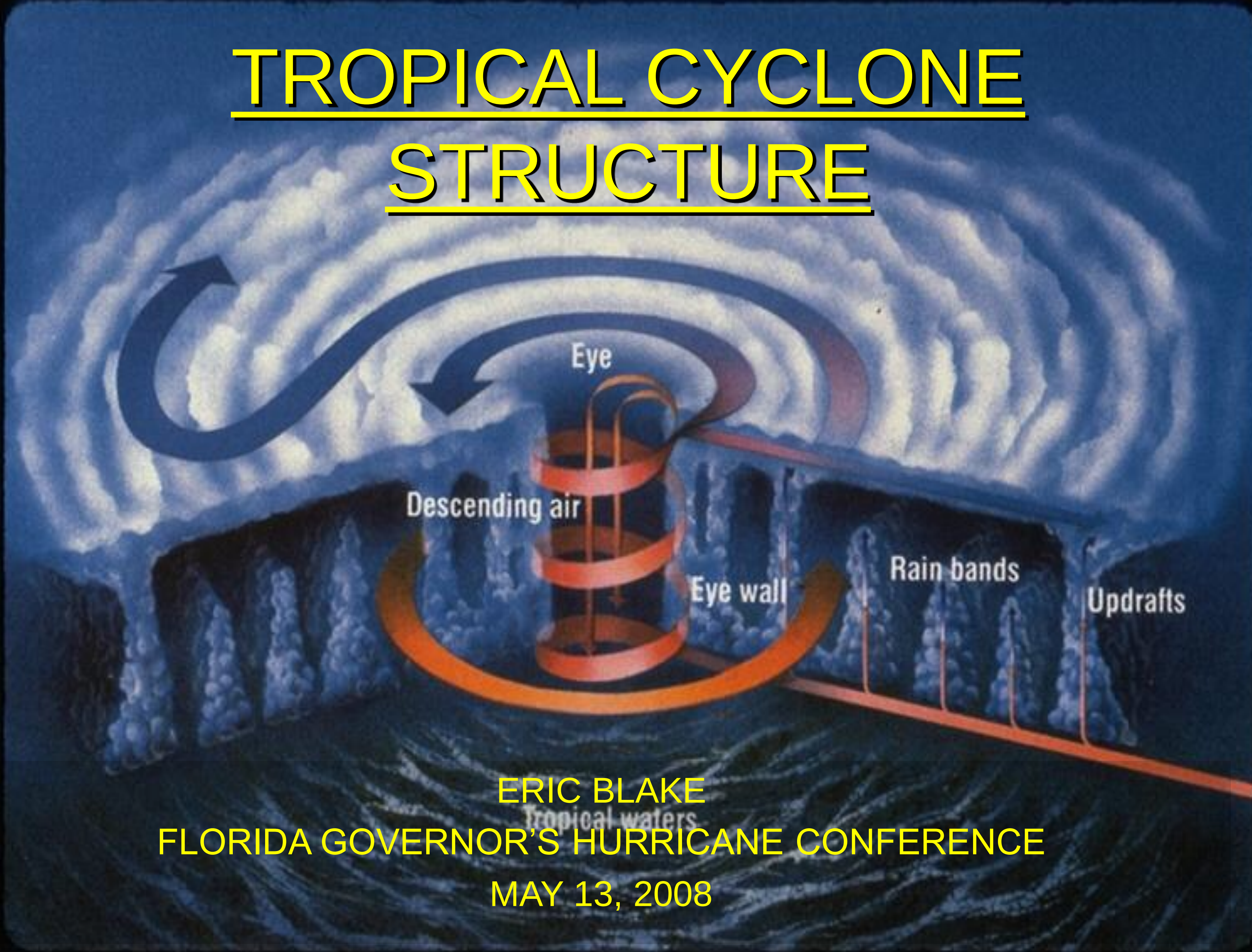
TROPICAL CYCLONE STRUCTURE



ERIC BLAKE

FLORIDA GOVERNOR'S HURRICANE CONFERENCE

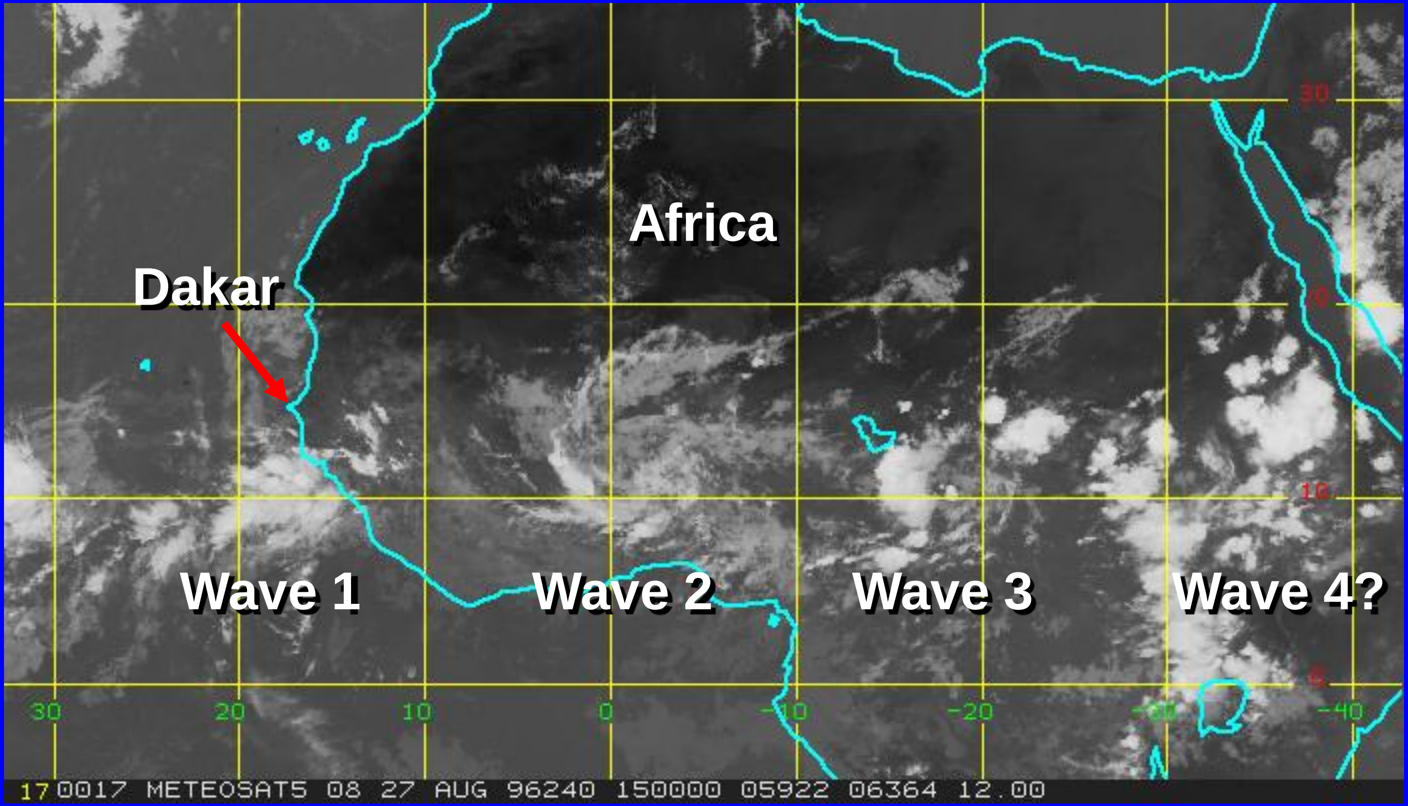
MAY 13, 2008

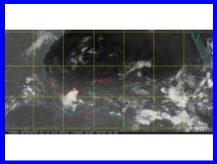
Outline

- Initial stages of development
- Lifecycle
- Mature hurricane structural differences
- Identifying hurricane characteristics using radar and satellite

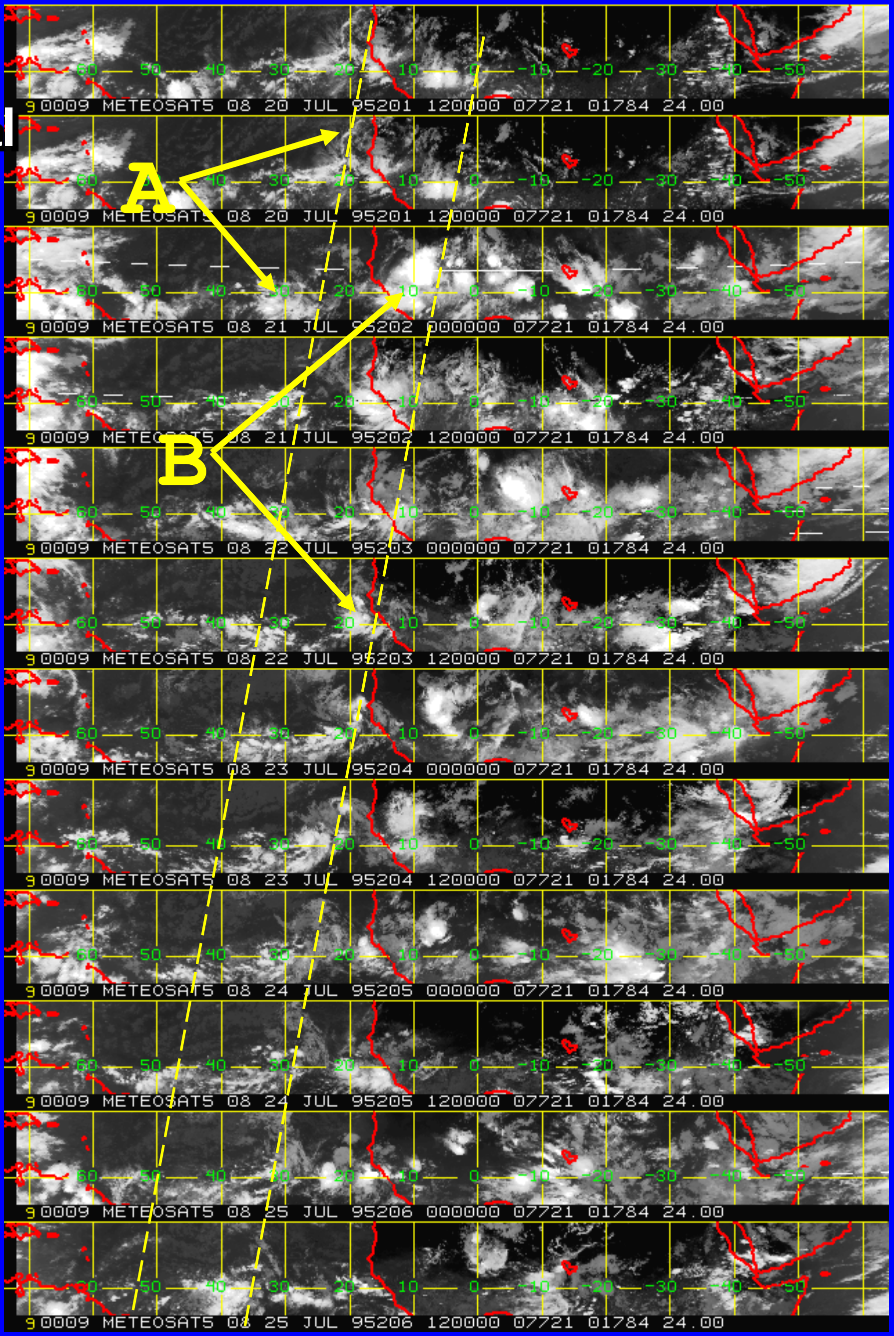
1 GOES-FLOATER VISIBLE - DEC 31 05 16:45 UTC McIDAS

Precursors of a tropical cyclone…
African easterly waves





Hovmöller diagrams used to track tropical waves as they move from Africa toward the Caribbean Sea.



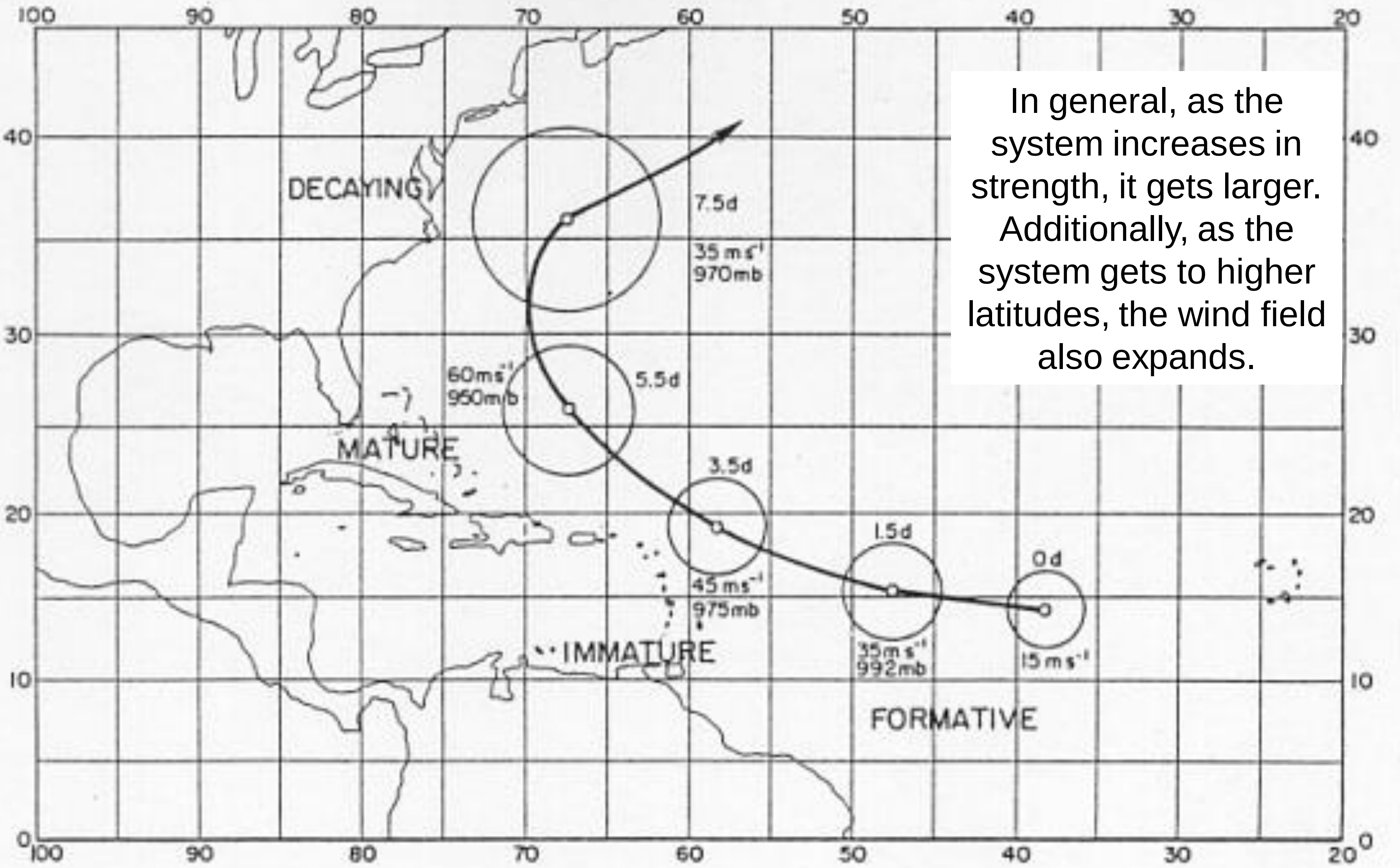
720/00Z

723/00Z

725/12Z

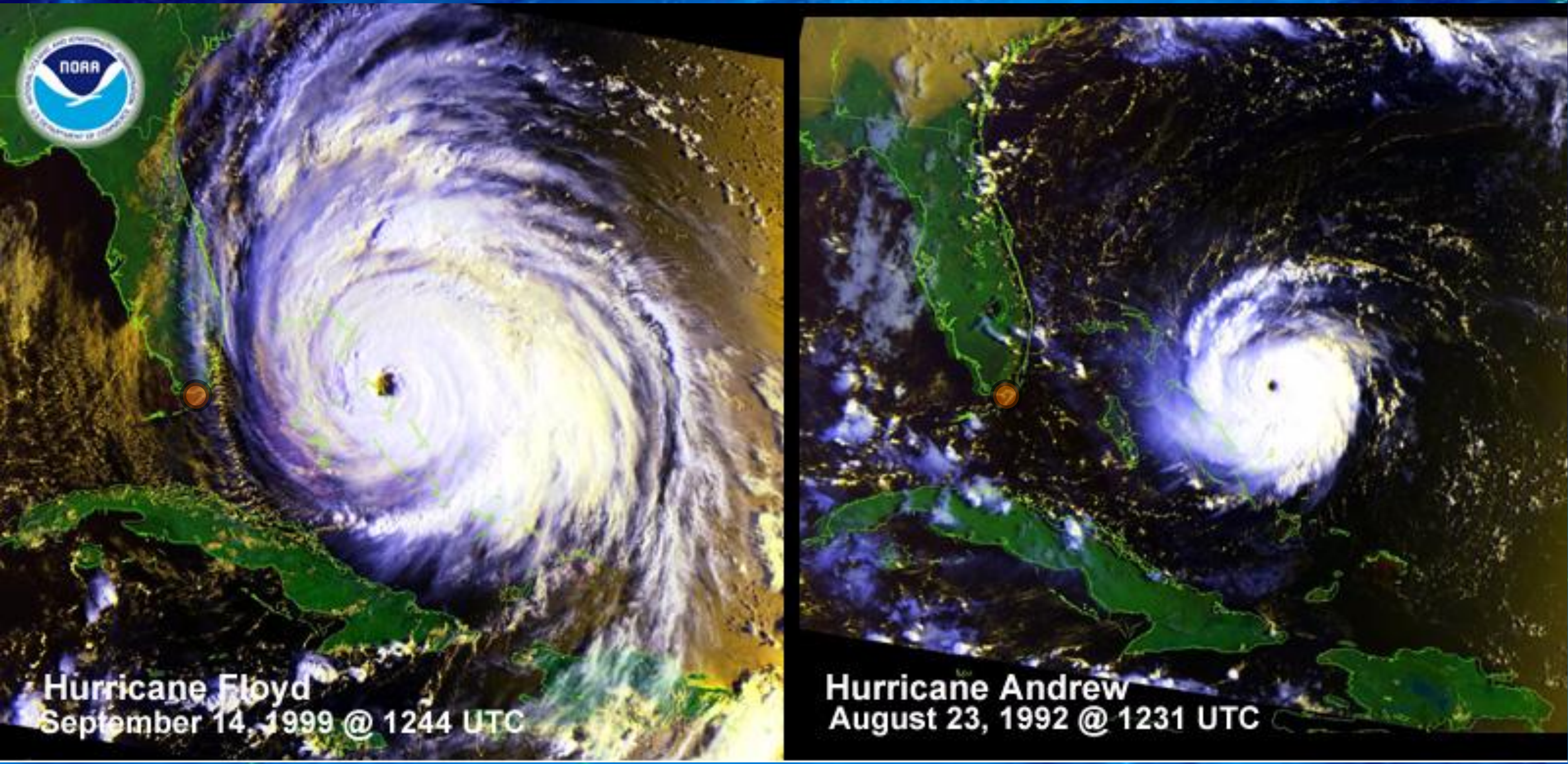
60W 20W 40E

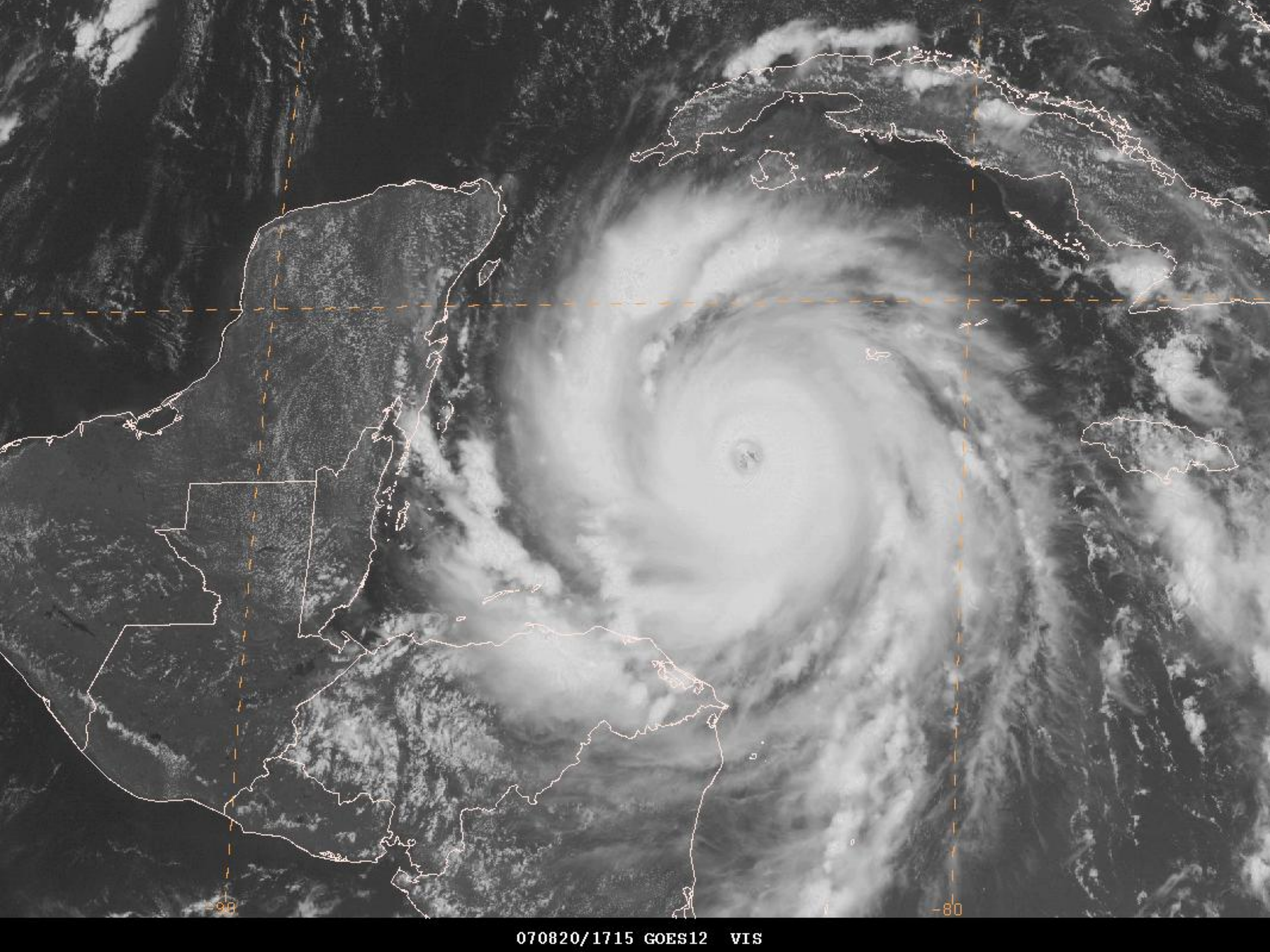
Typical Tropical Cyclone Size Lifecycle

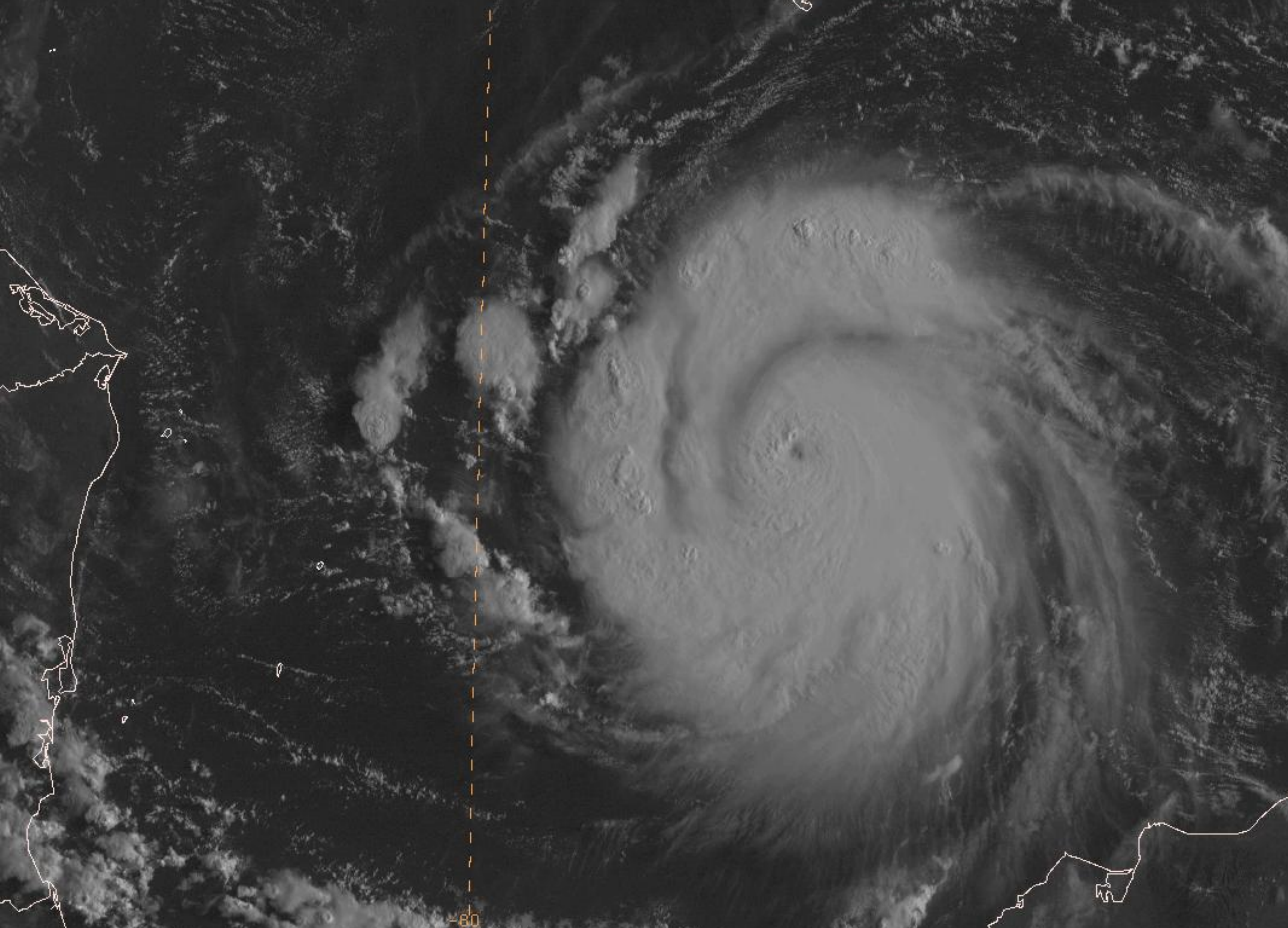


In general, as the system increases in strength, it gets larger. Additionally, as the system gets to higher latitudes, the wind field also expands.

Size differences with two powerful Atlantic hurricanes

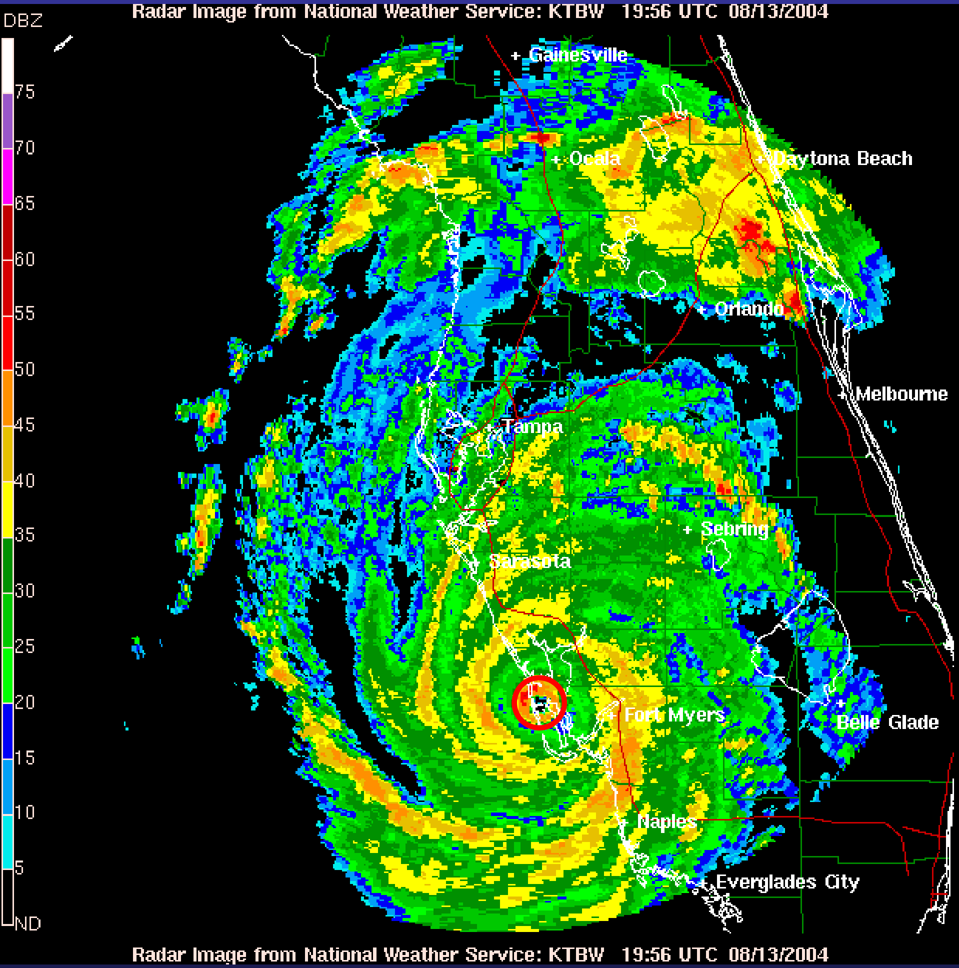


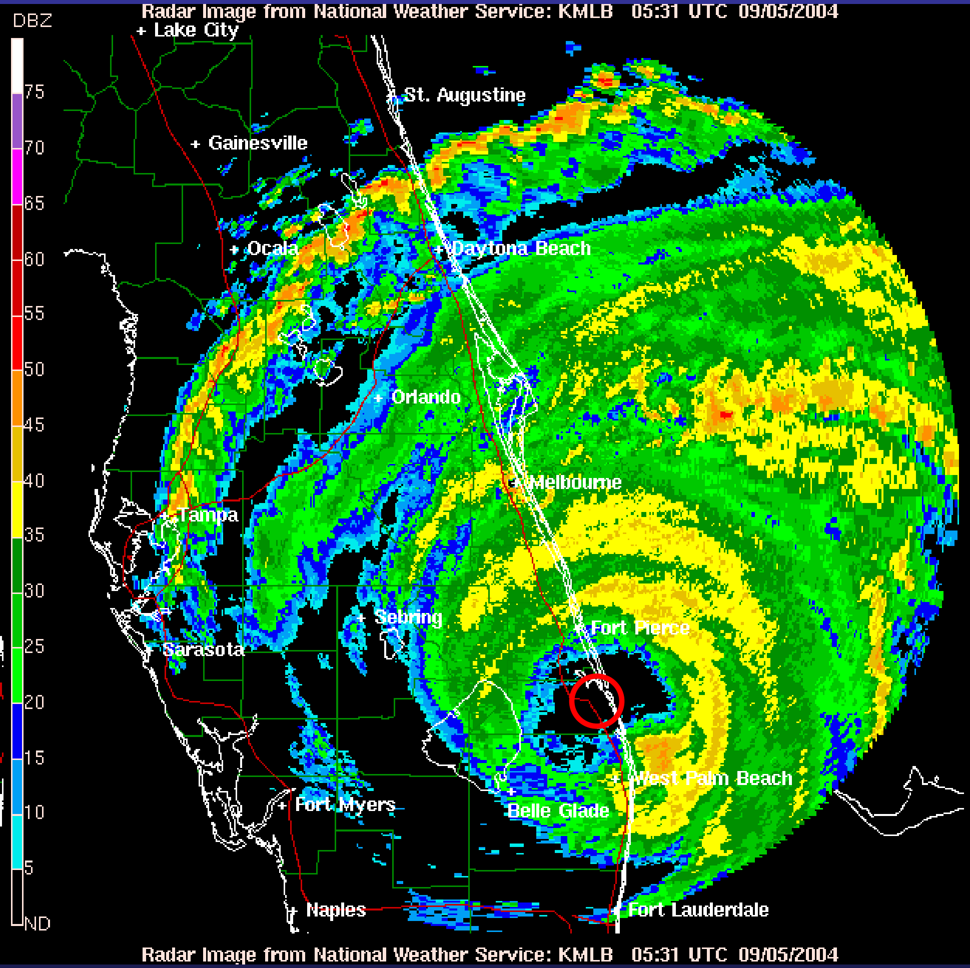

-90
-80
070820/1715 GOES12 VIS



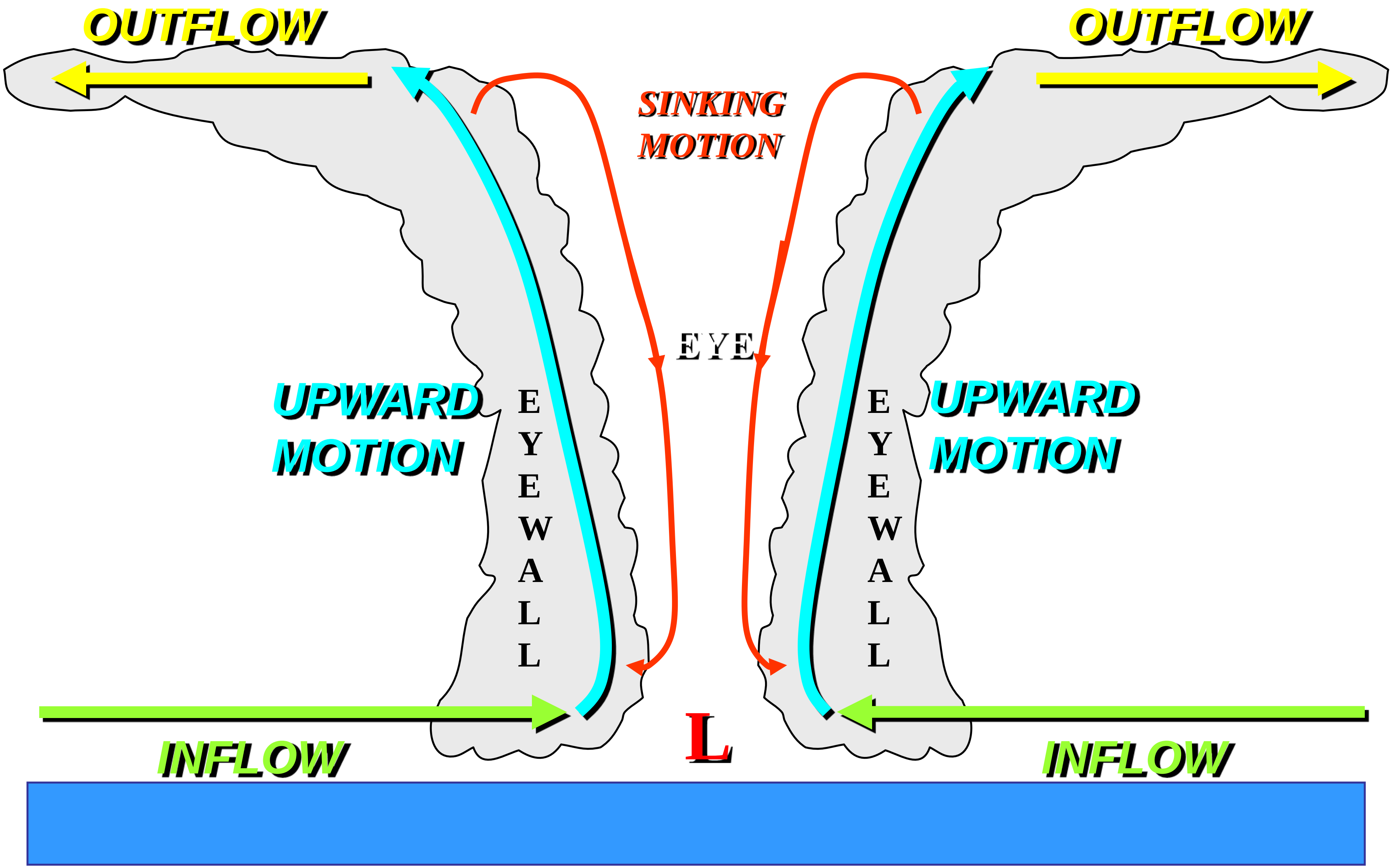
070903/1245 GOES12 VIS

Charley/Frances Core Sizes

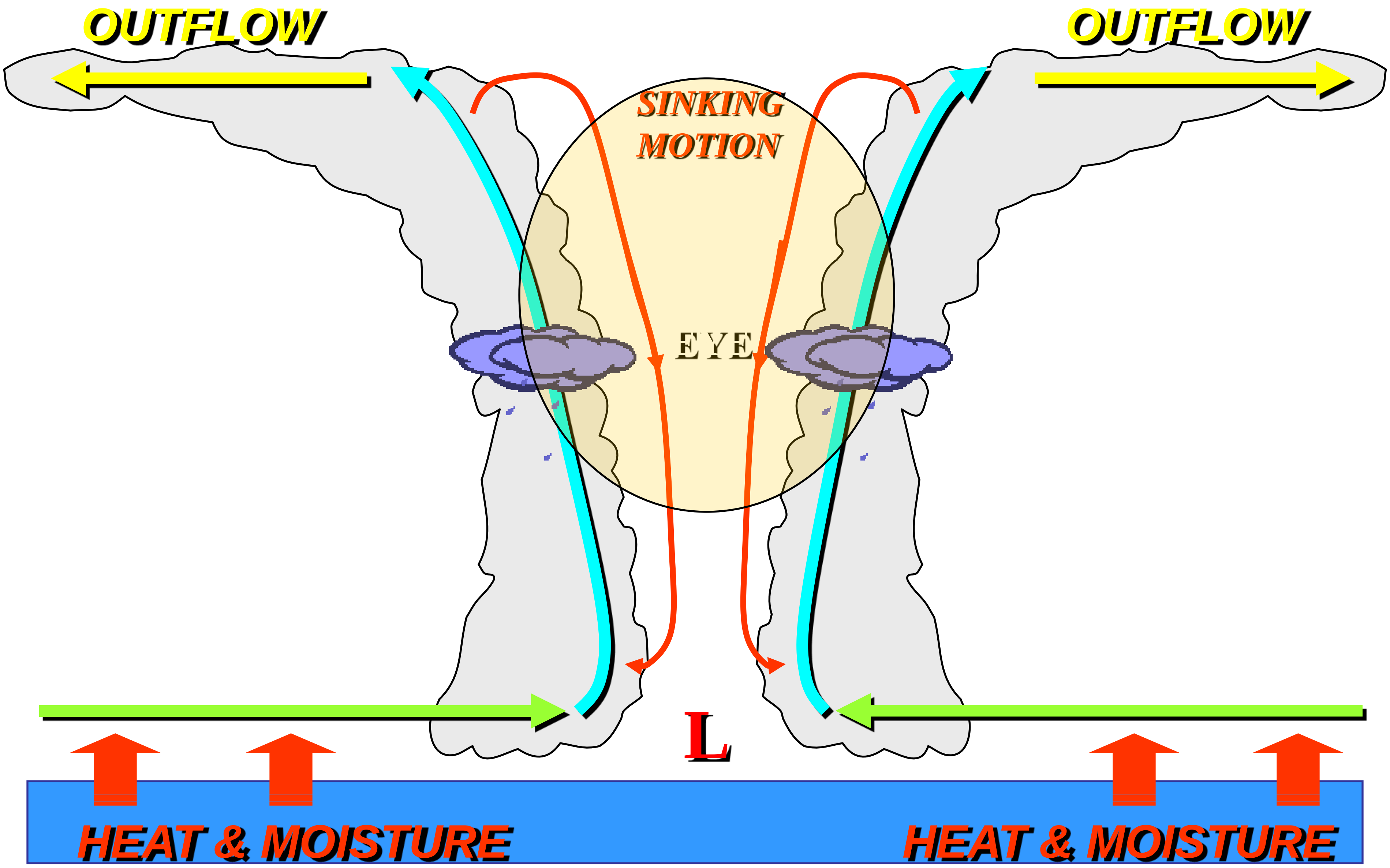




THE WARM CORE IS A CONSEQUENCE OF BOTH LATENT HEAT RELEASE AND WARMING BY SUBSIDENCE

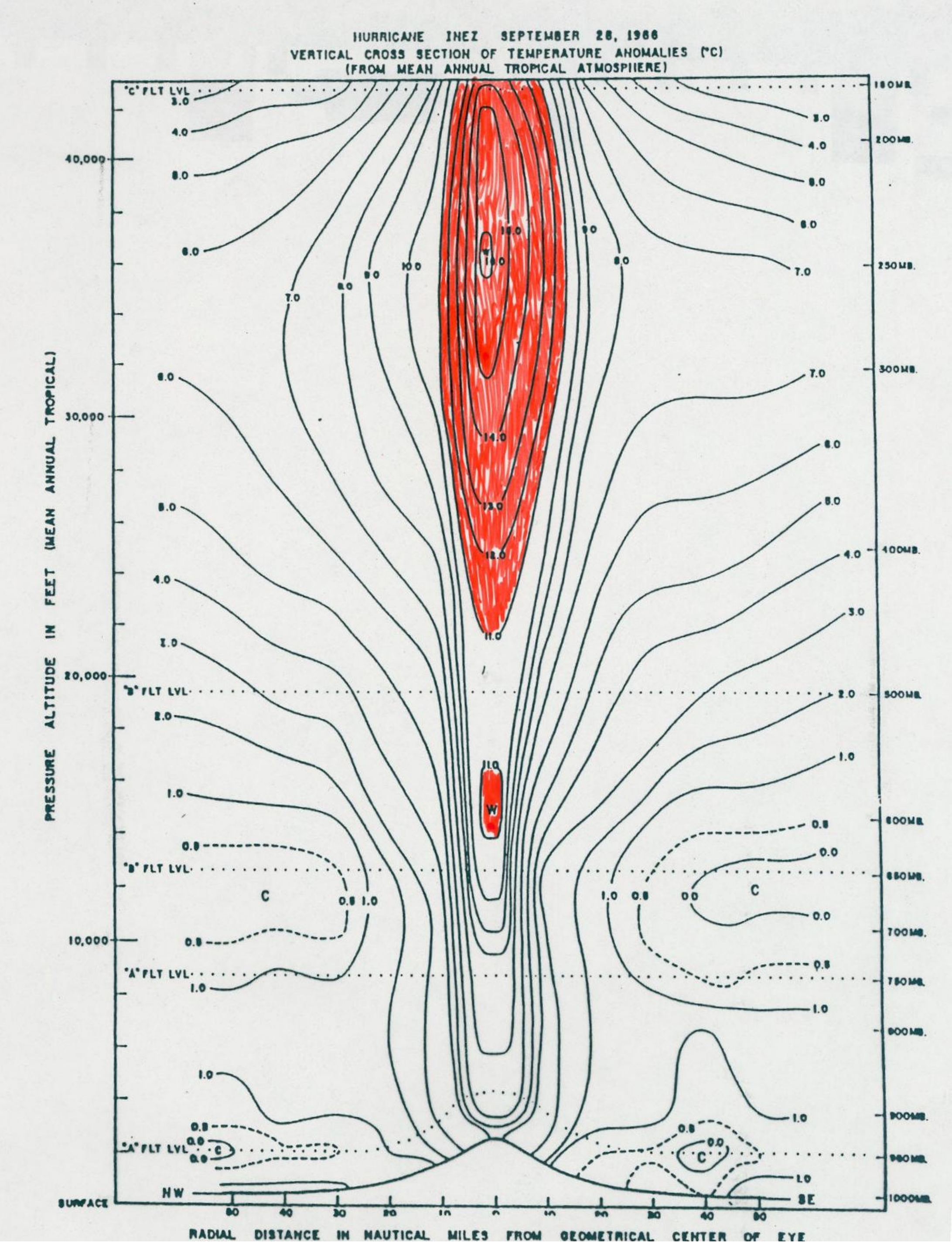


THE WARM CORE IS A CONSEQUENCE OF BOTH LATENT HEAT RELEASE AND WARMING BY SUBSIDENCE

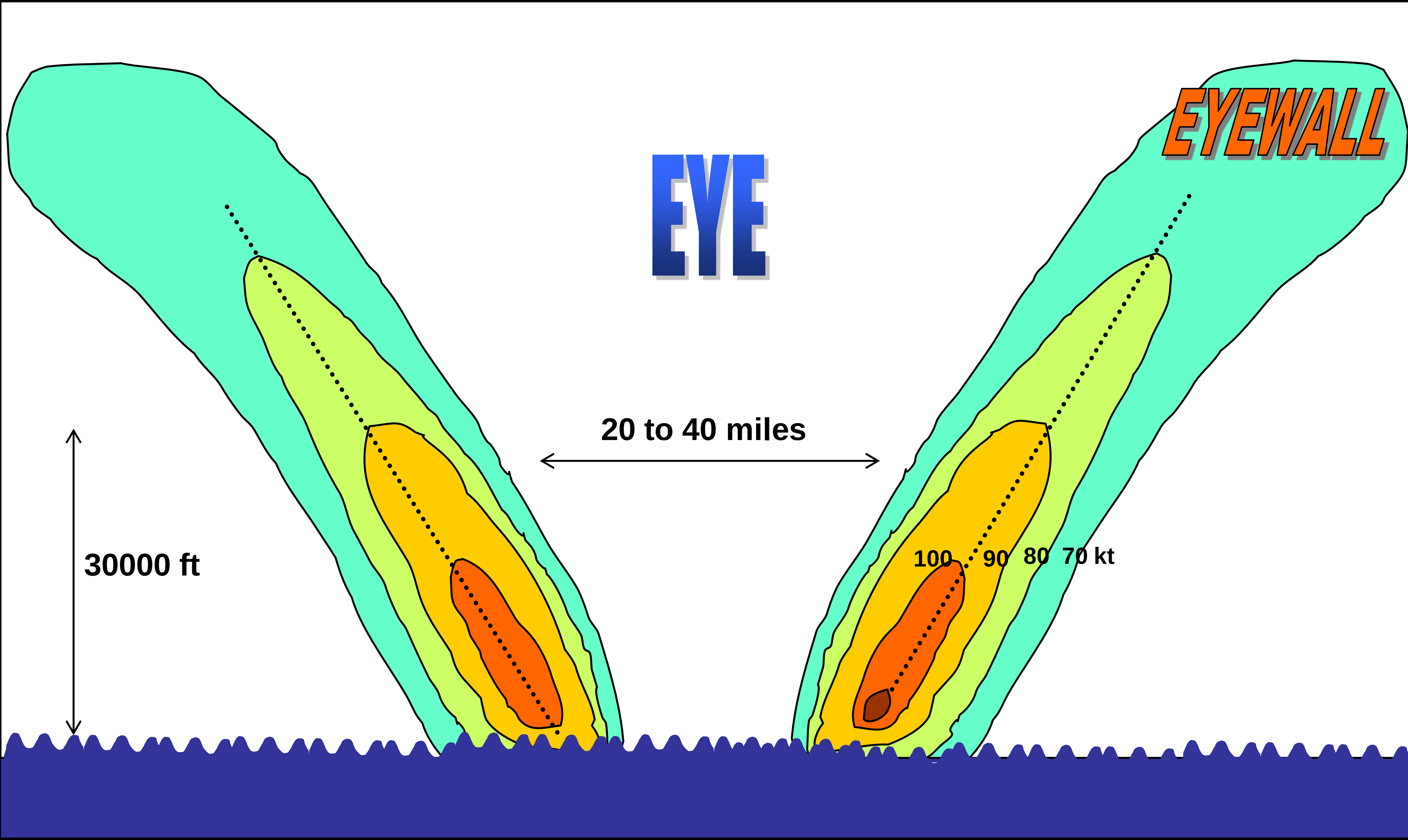


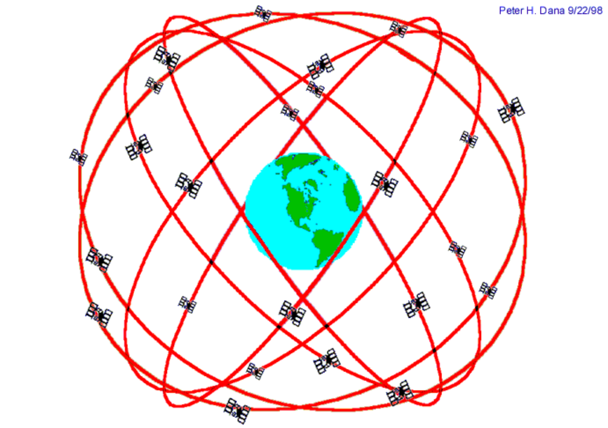
Characteristics of a hurricane:

- Intense warm core aloft: Can be 25F warmer than normal tropical values.
- Winds decrease with height and maximize just above the surface.
- Highest wind and rain are concentrated in a narrow ring of storms around the center– the eyewall.

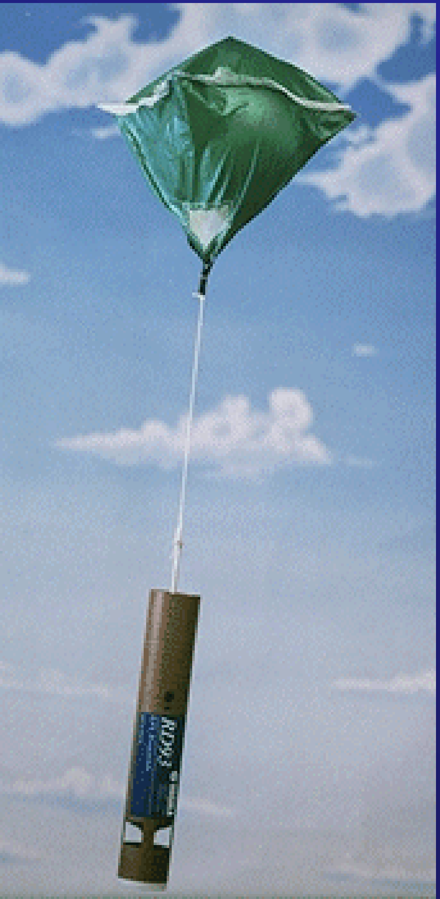


EYEWALL SCHEMATIC





GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

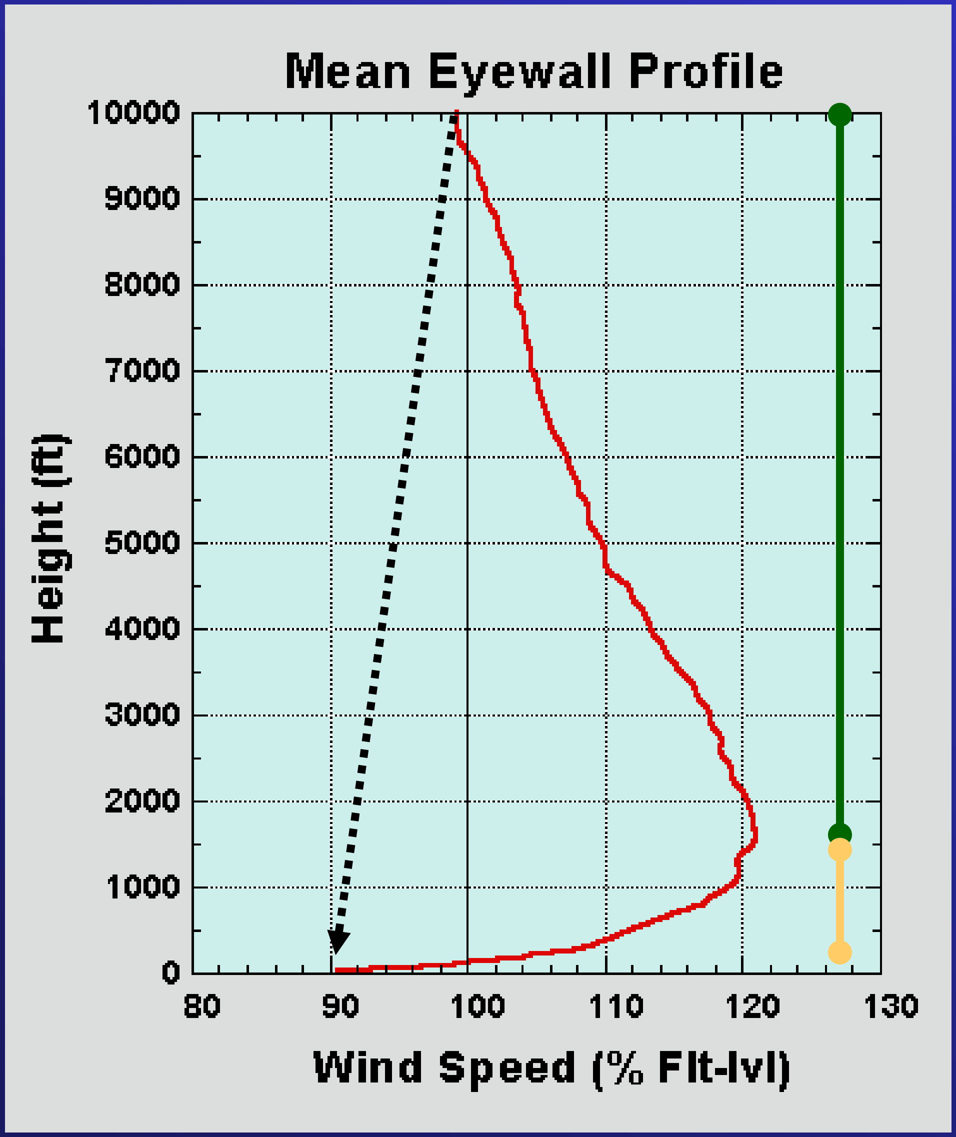


GPS DROPWINDSONDE

- **Developed in conjunction with the NOAA Gulfstream-IV jet aircraft. First systematic use for intensity was in 1998's Hurricane Bonnie.**

- **GPS dropsondes provide direct measurements of the winds at low levels in the hurricane eyewall.**

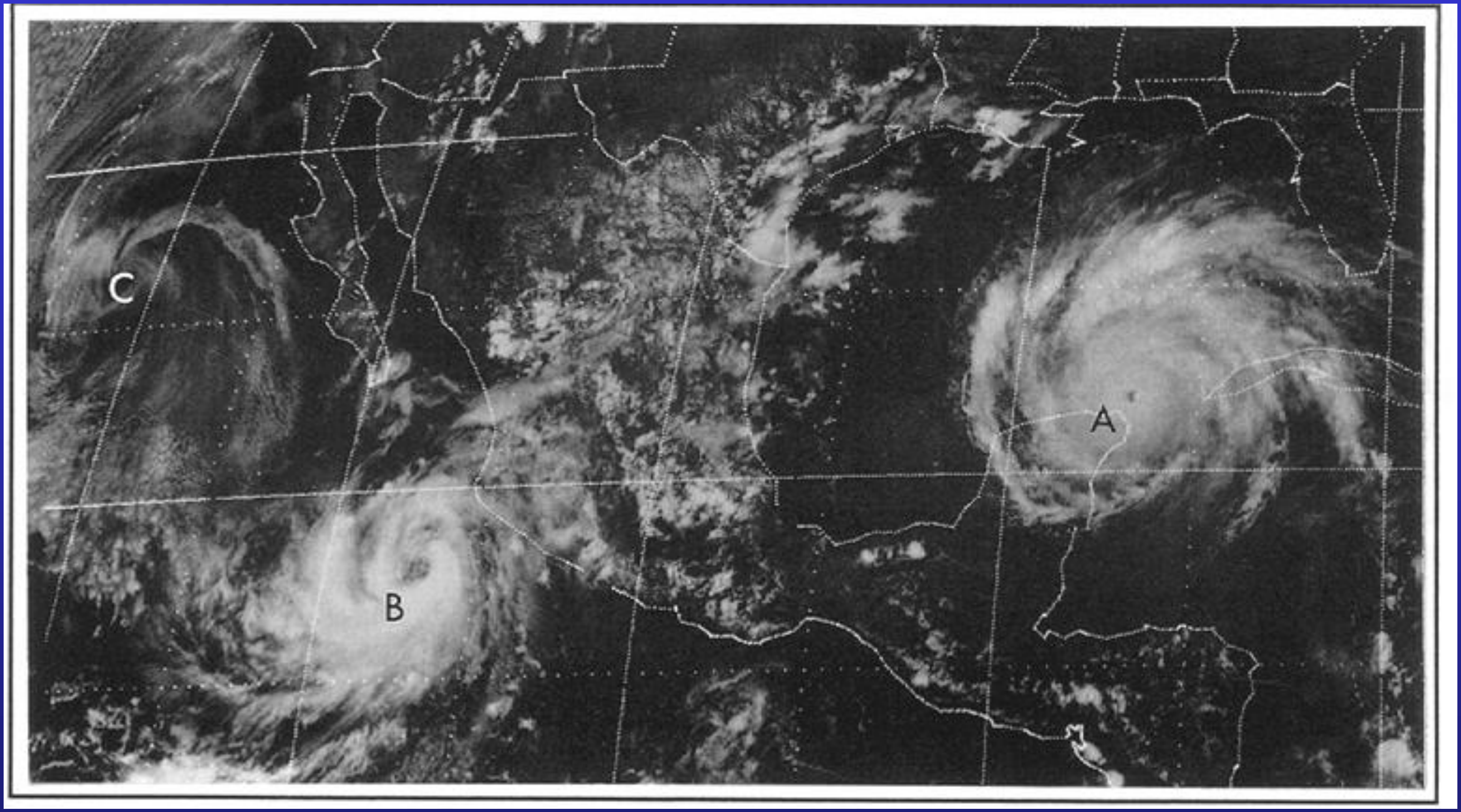
- **Dropsonde data reveal that the structure of the eyewall is very complex, and can vary tremendously from storm to storm.**



Because the hurricane is “warm-core”, winds increase downward from flight-level (10000 ft).

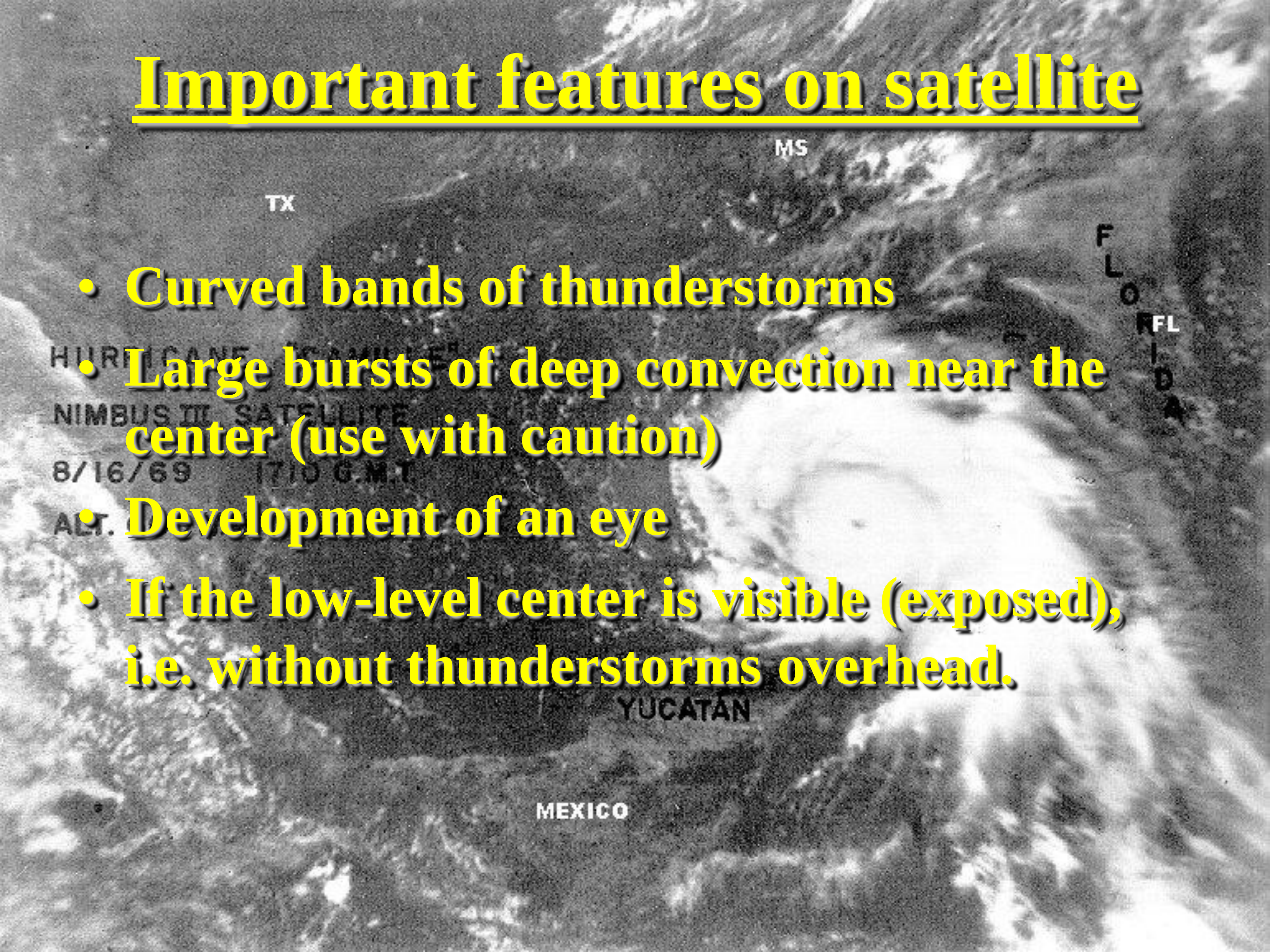
Friction decreases wind in the lowest 1500 ft of the eyewall.

Dvorak Technique Premise



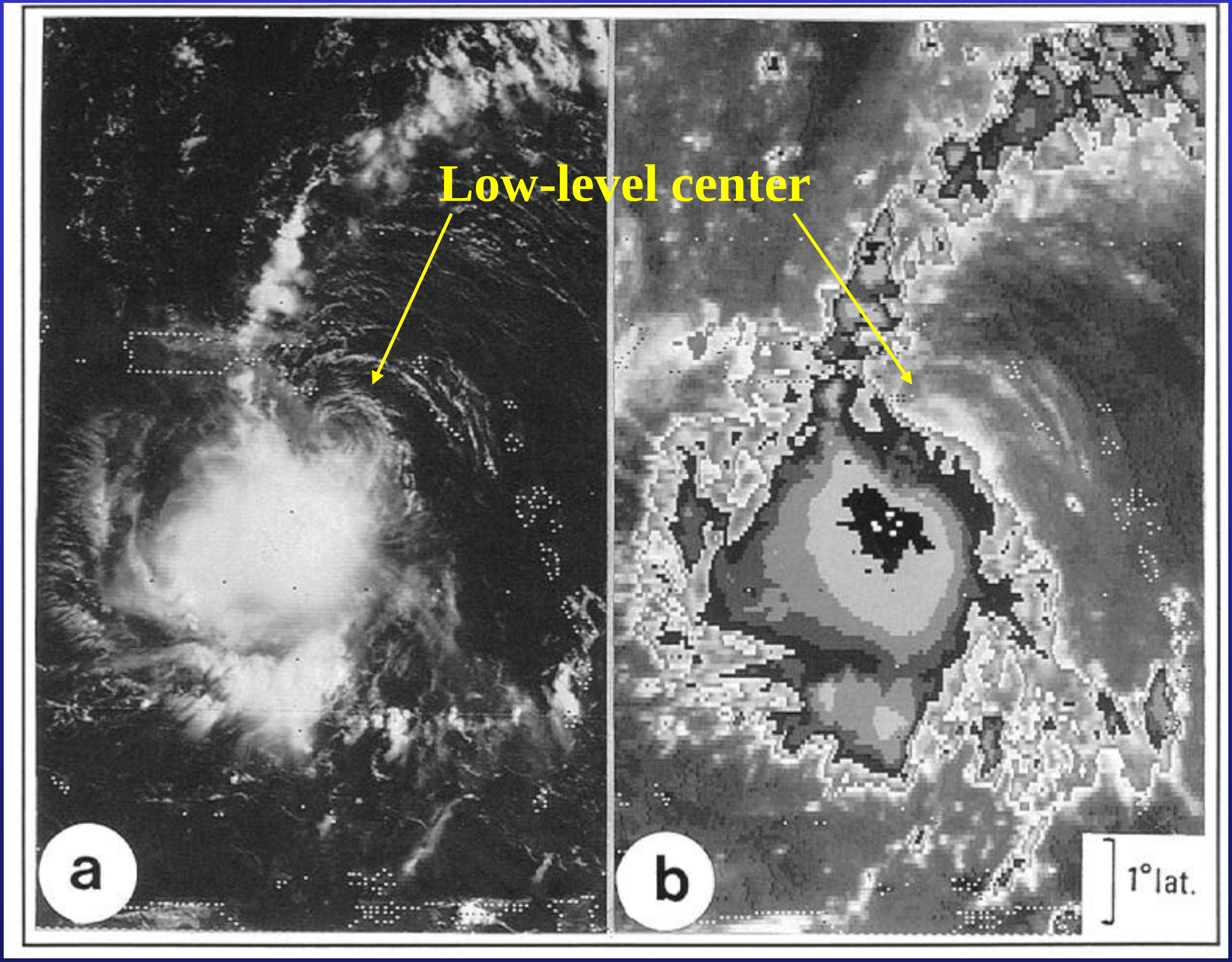
- Tropical cyclones have characteristic evolutions of cloud patterns that correspond to stages of development and certain intensities.

Important features on satellite

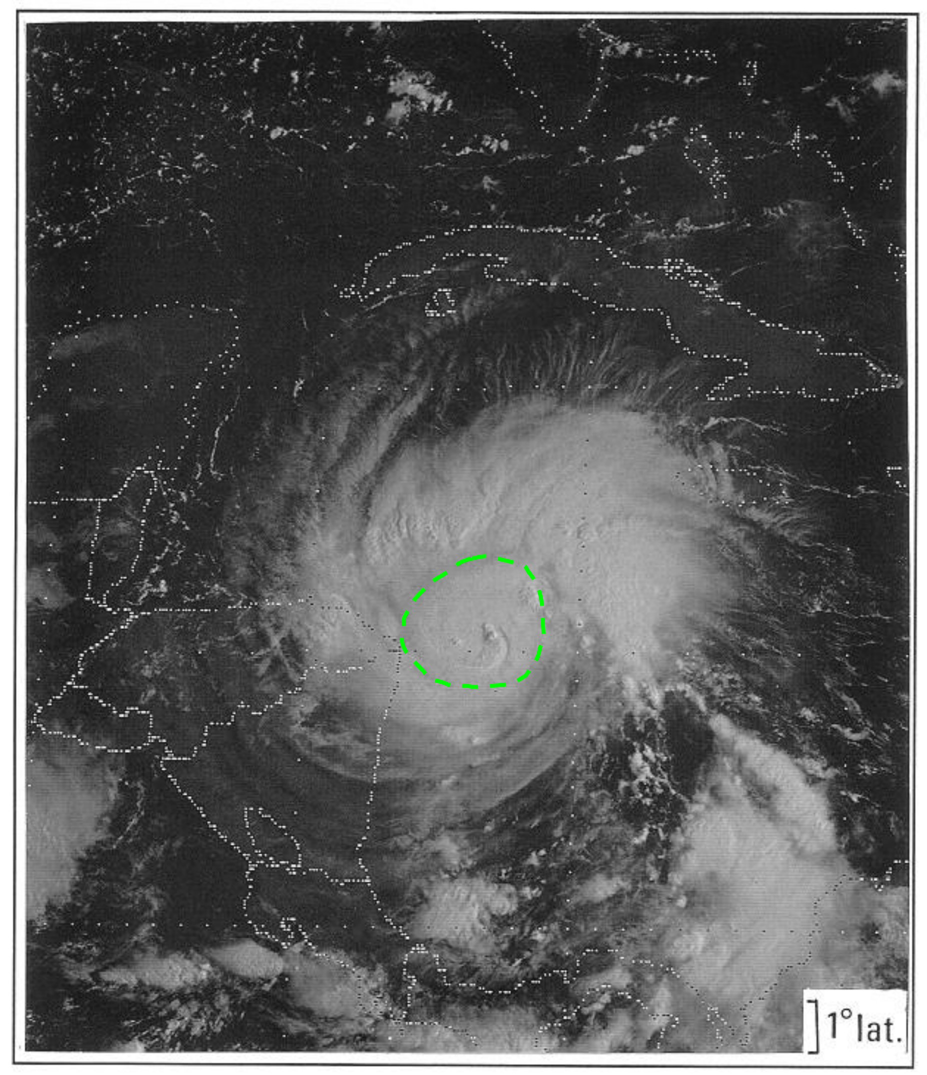


- Curved bands of thunderstorms
- Large bursts of deep convection near the center (use with caution)
- Development of an eye
- If the low-level center is visible (exposed), i.e. without thunderstorms overhead.

Sheared Tropical Cyclone



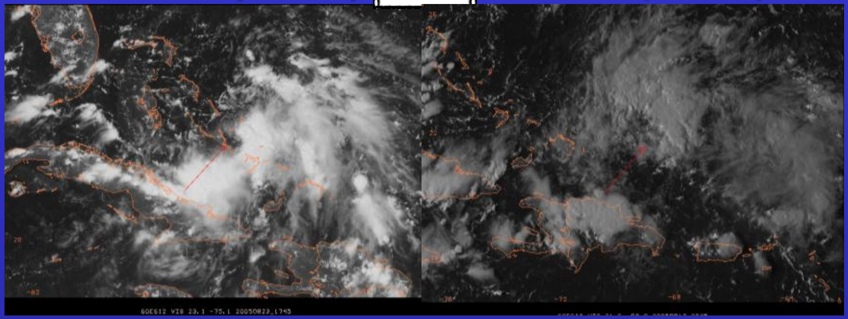
CDO- Central Dense Overcast



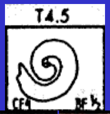
The CDO is the green circled area.

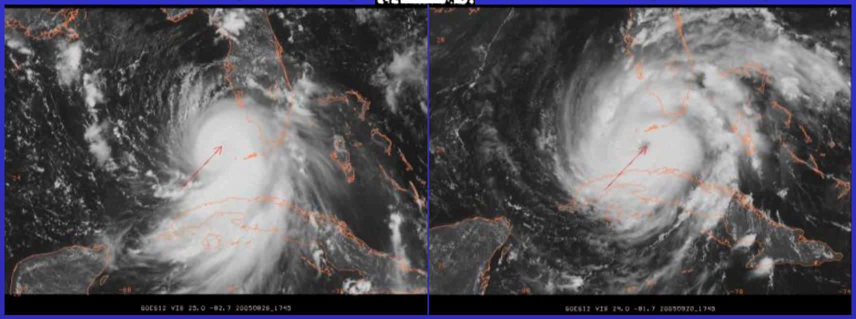
TC Cloud Patterns – Developing

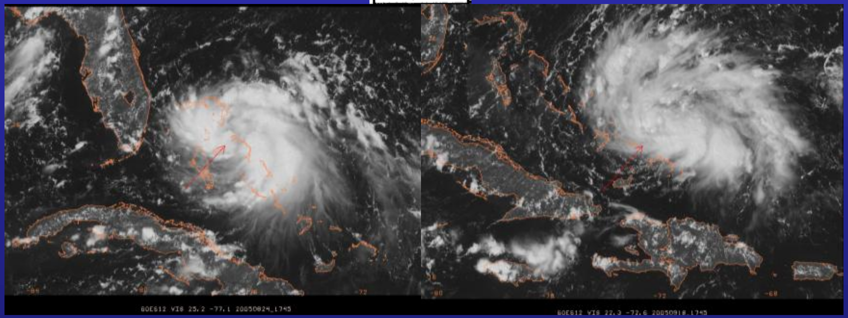
Katrina (2005) Rita (2005)

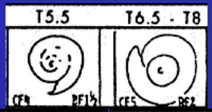


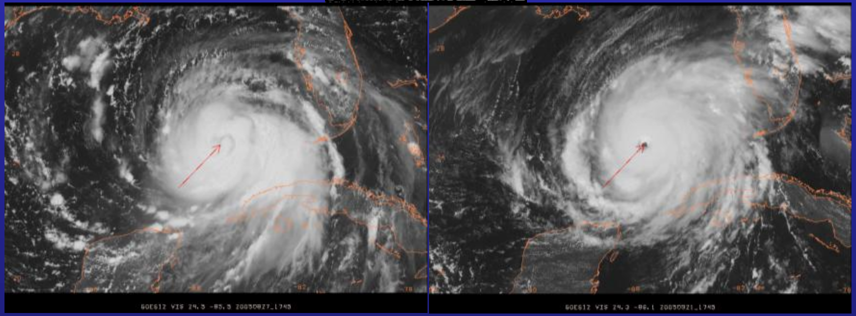
Katrina (2005) Rita (2005)

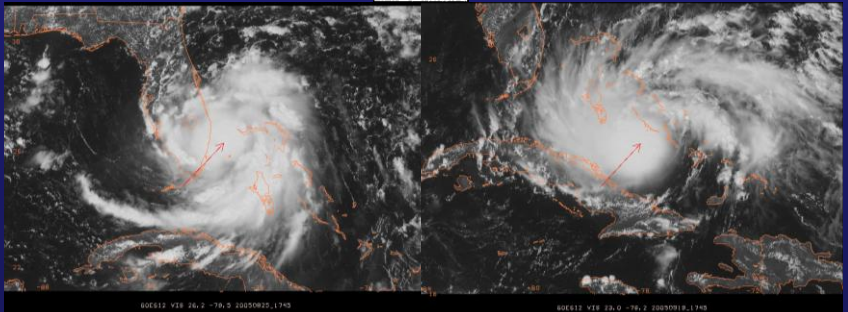


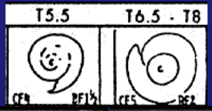


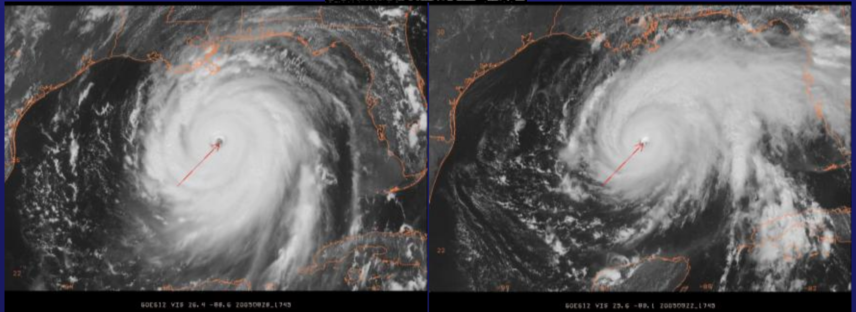




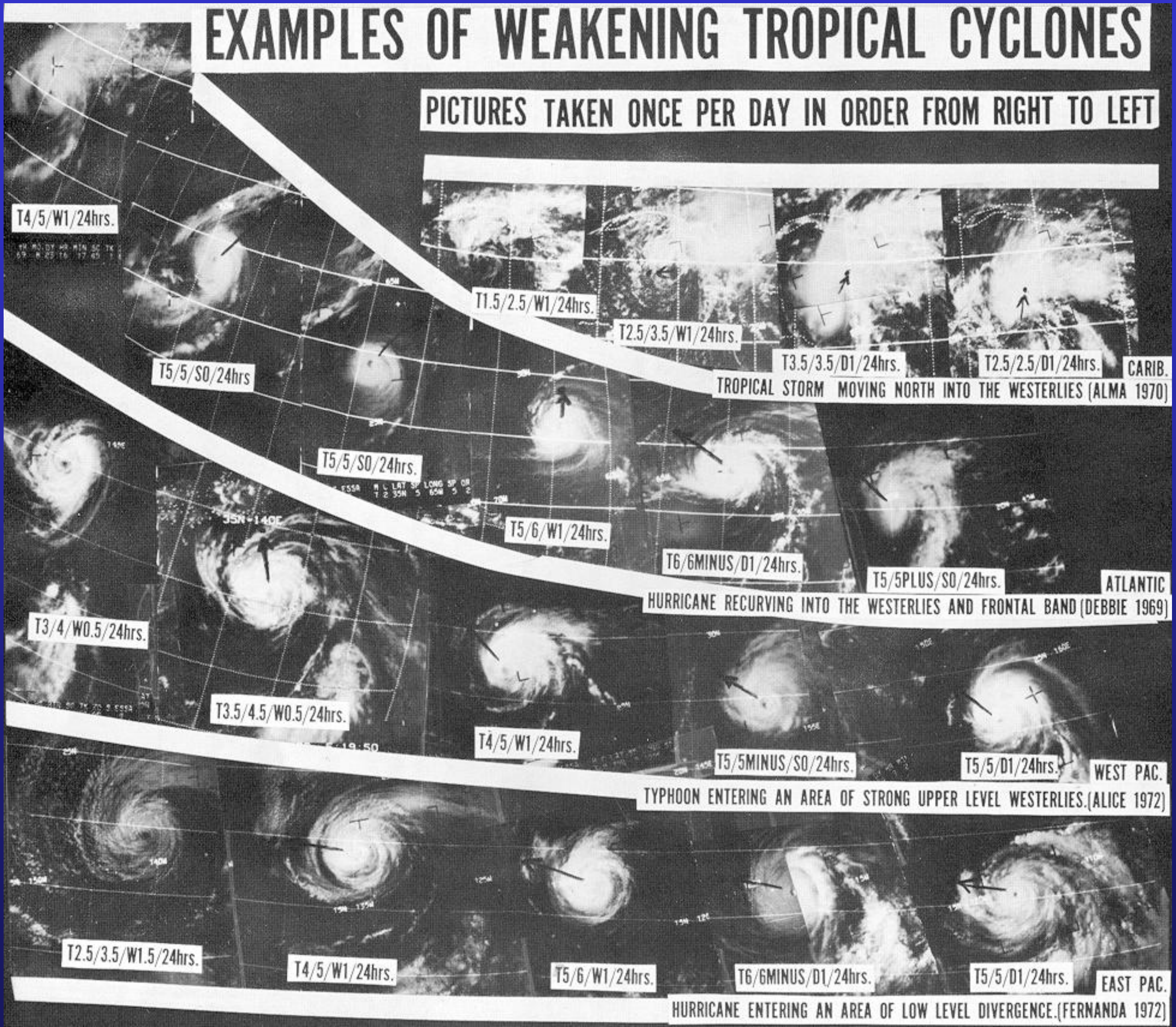




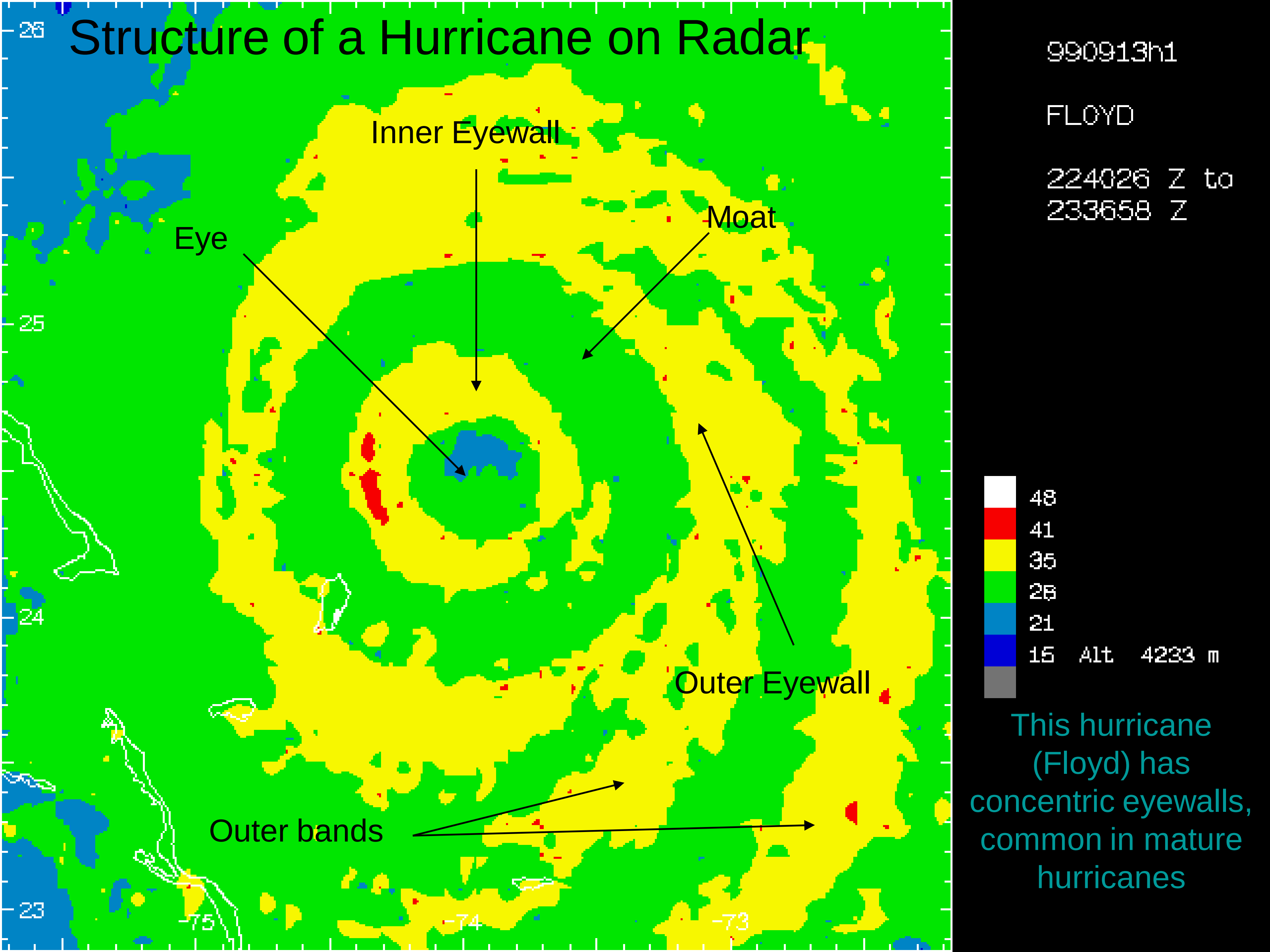




TC Cloud Patterns - Weakening

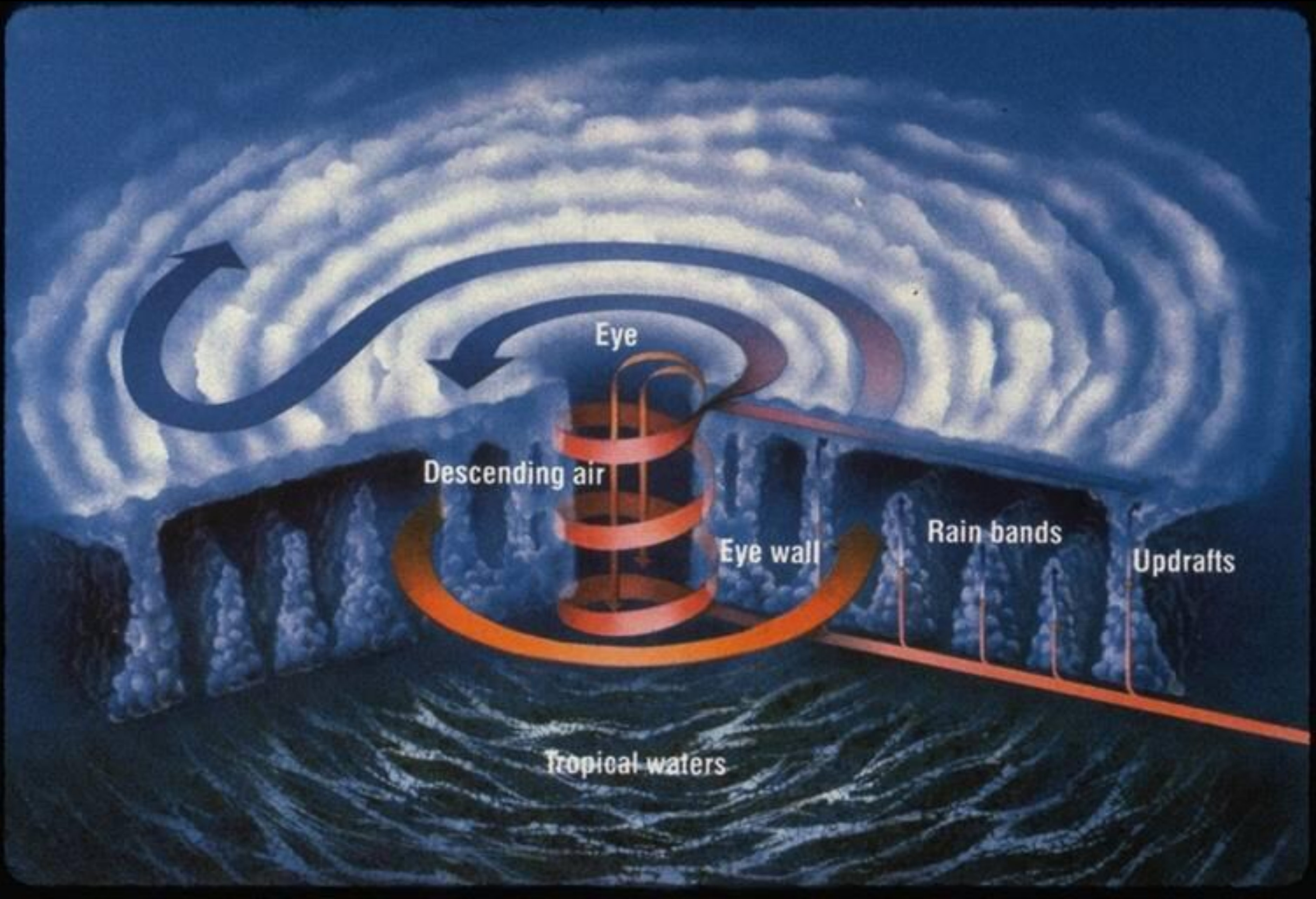


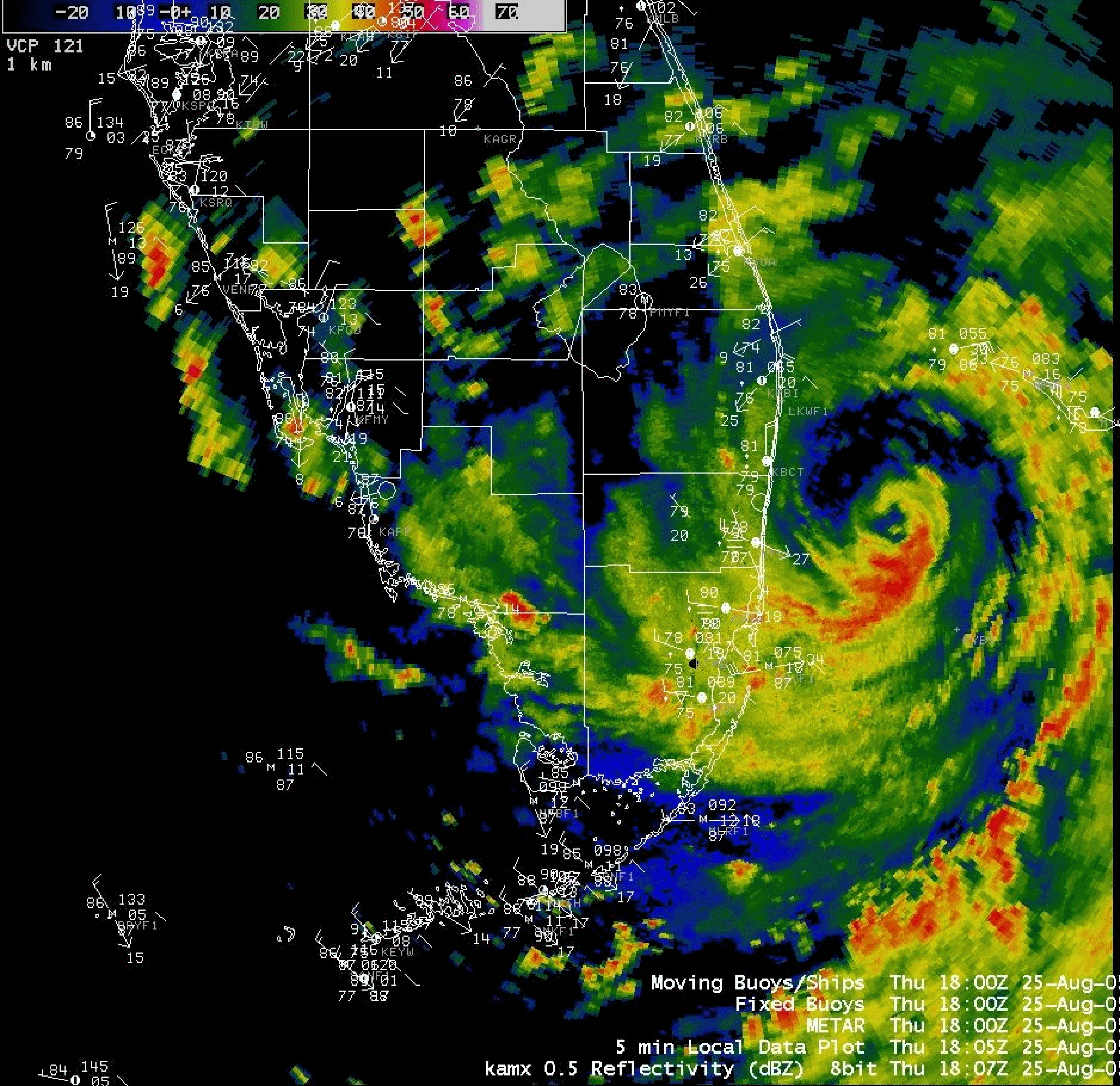
Structure of a Hurricane on Radar



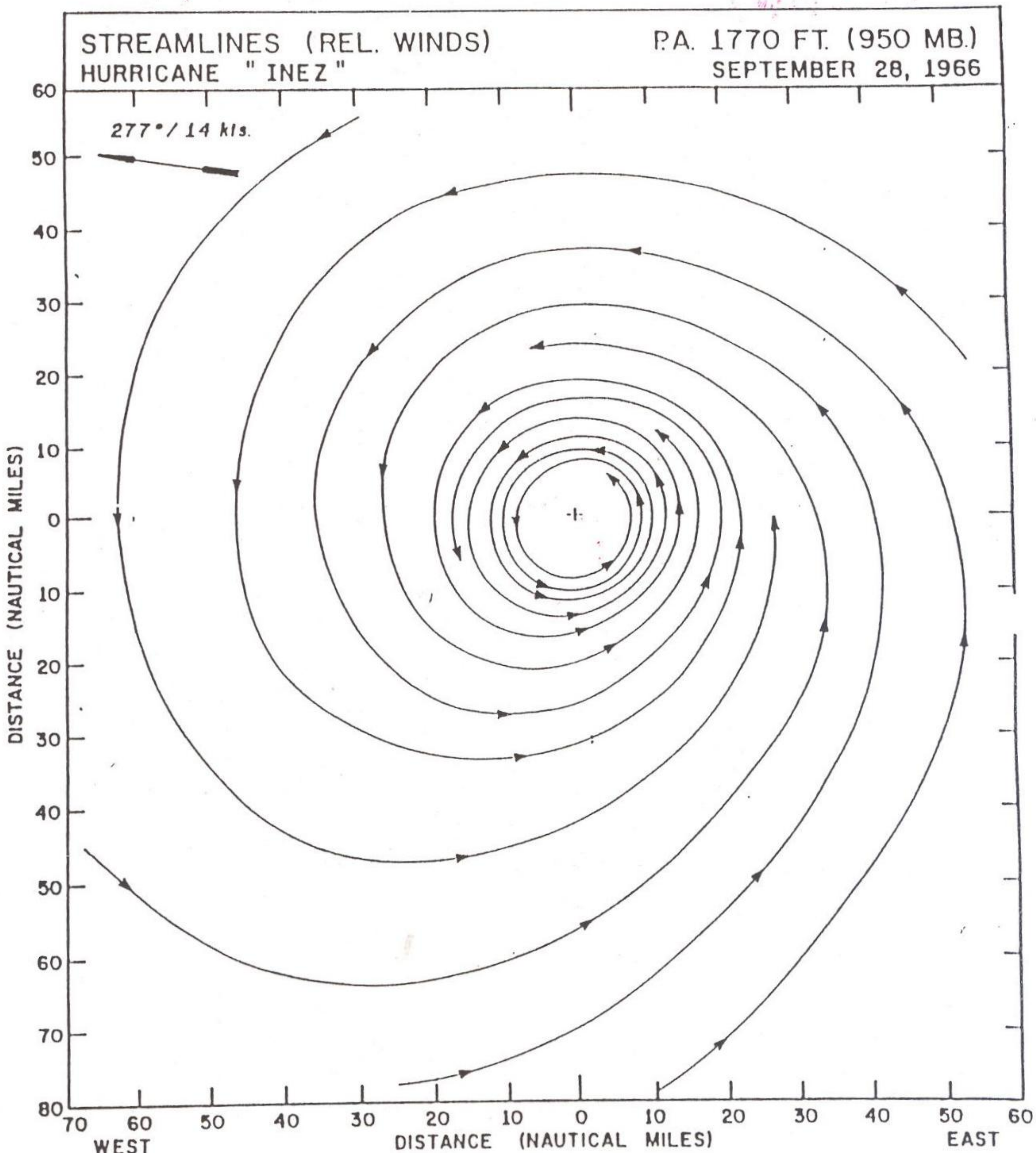
This hurricane (Floyd) has concentric eyewalls, common in mature hurricanes

Cross-Section of a Mature Hurricane



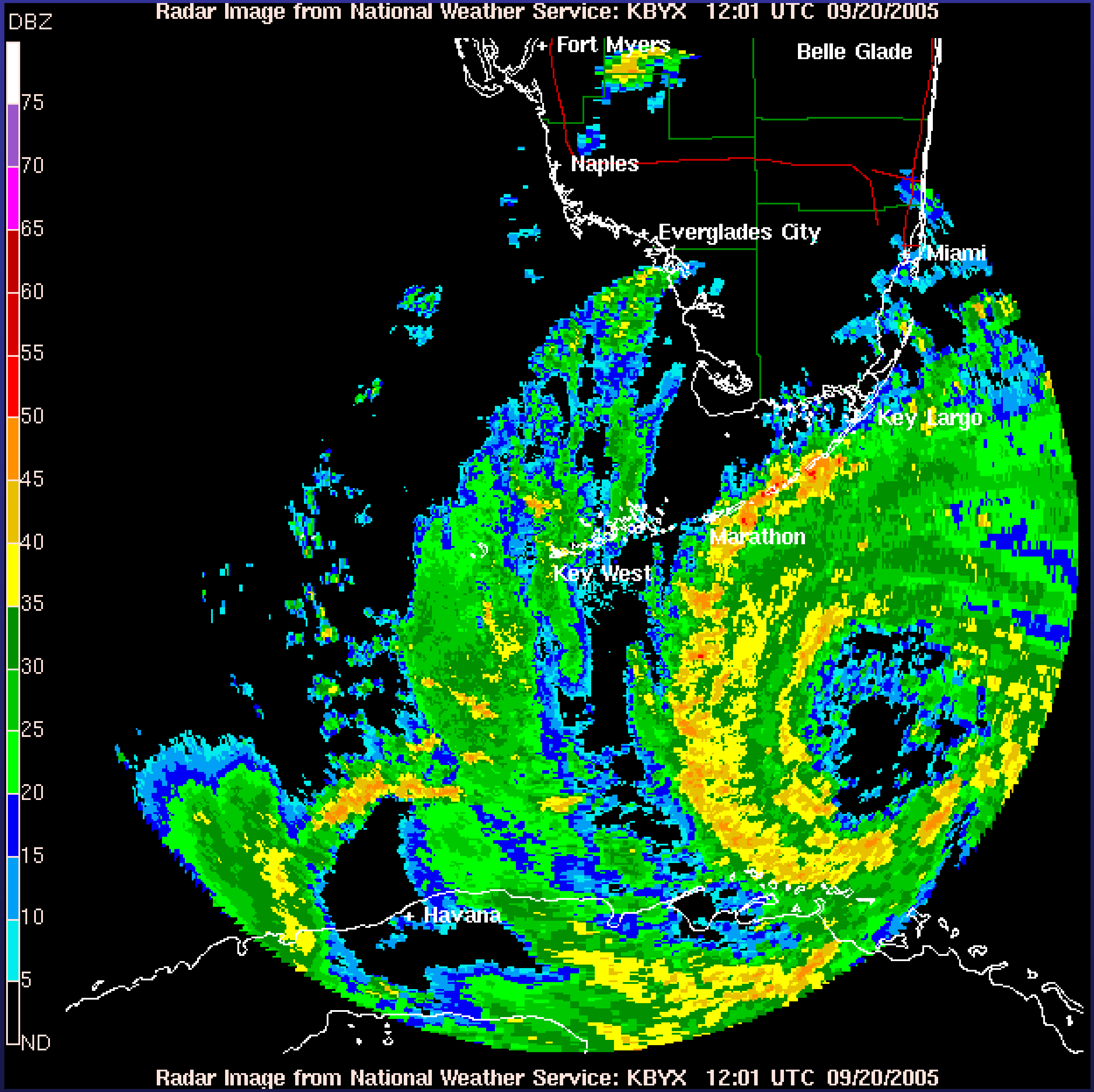


Northerly shear forces most of the showers and t-storms to be on the south side of the circulation.



SYMMETRIC, INWARD-SPRIALING FLOW

Hurricane Rita Passing the Florida Keys



During the loop, watch for a near complete eyewall at first, followed by the eyewall breaking down, then a reformation.

EYEWALL REPLACEMENT CYCLES:

INTENSITY CHANGE IS OFTEN CONTROLLED BY EYEWALL REPLACEMENT CYCLES (EYEWALL SUCCESSIONS) IN STRONG HURRICANES.

• AS THE EYEWALL CONTRACTS, THE CYCLONE DEEPENS (INTENSIFIES).

• AROUND THE TIME THE CYCLONE REACHES A PEAK IN INTENSITY, AN OUTER EYEWALL FORMS.

• THE INNER EYEWALL BEGINS TO DISSSIPATE, RESULTING IN A LARGER EYE, AND THE CYCLONE FILLS (WEAKENS).

• THE NEW EYEWALL CAN CONTRACT, RESULTING IN A RESTRENGTHENING AND POSSIBLE REPETITION OF THE CYCLE.

• TIME SCALE OF ONE CYCLE CAN RANGE FROM A FEW HOURS, AS WAS THE CASE OF HURRICANE ANDREW (1992), TO MORE THAN A DAY, AS IN THE CASE OF ALLEN (1980).

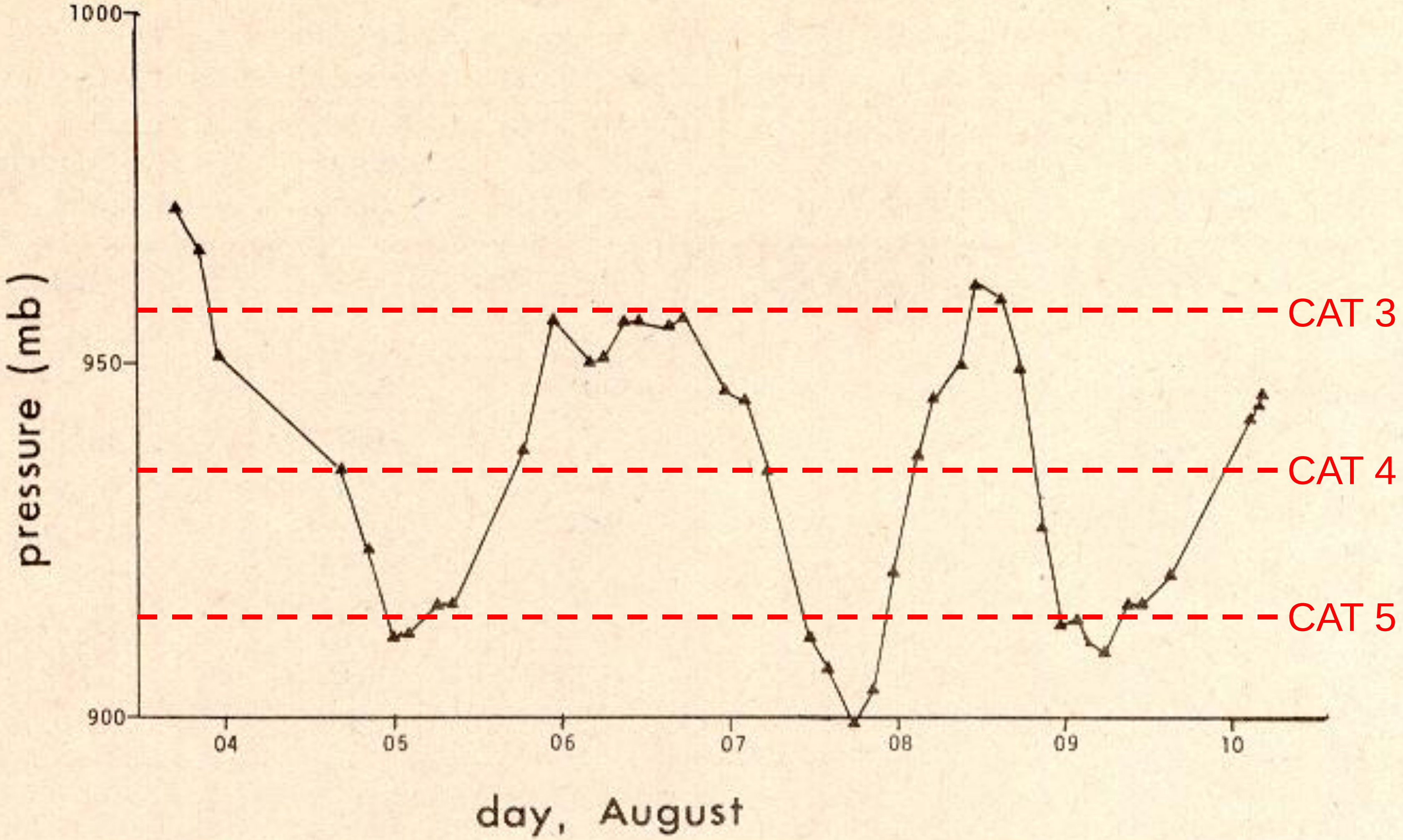
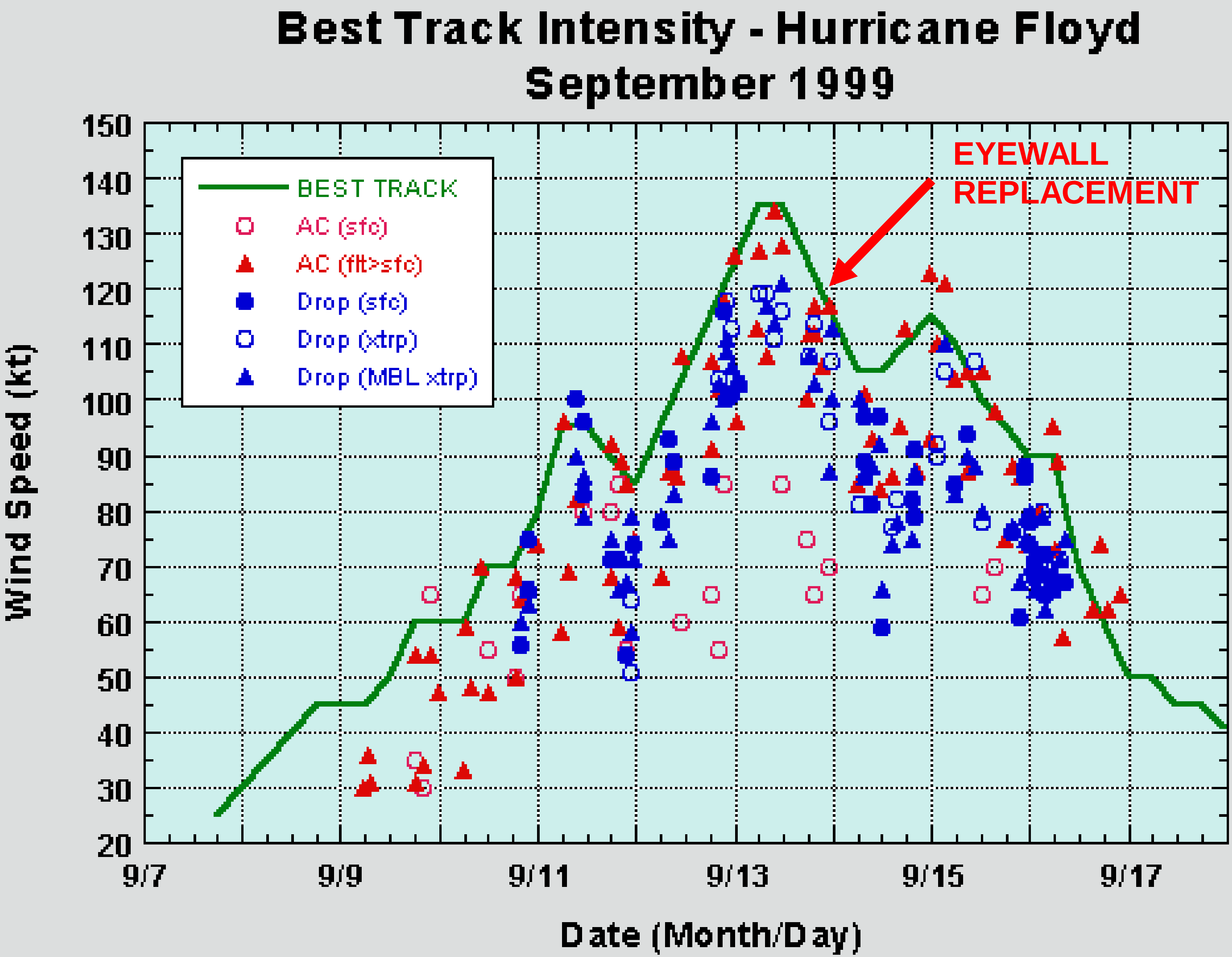
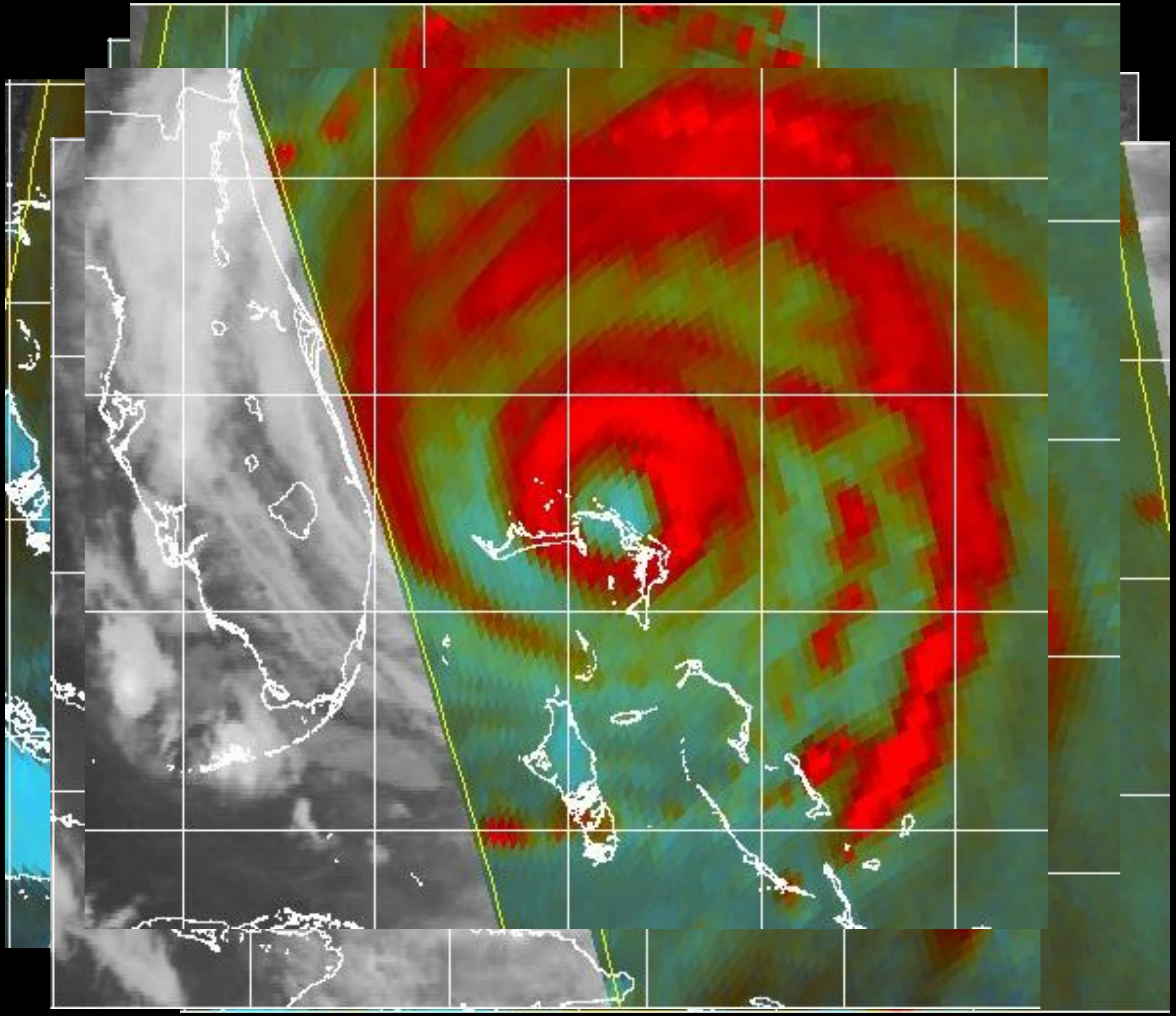


FIG. 3. Hurricane Allen: graph of minimum sea level pressure as a function of time, based on 44 aircraft observations.

CENTRAL PRESSURE VS. TIME FOR HURRICANE ALLEN, 1980: LARGE FLUCTUATIONS LARGELY DUE TO EYEWALL REPLACEMENT CYCLES


Best Track Intensity - Hurricane Floyd
September 1999
BEST TRACK
AC (sfc)
AC (flt>sfc)
Drop (sfc)
Drop (xtrp)
Drop (MBL xtrp)
EYEWALL
REPLACEMENT
Wind Speed (kt)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
9/7
9/9
9/11
9/13
9/15
9/17
Date (Month/Day)

CONCENTRIC EYEWALL CYCLE
HURRICANE FLOYD



13 / 0116Z

13 / 1122Z

13 / 1347Z

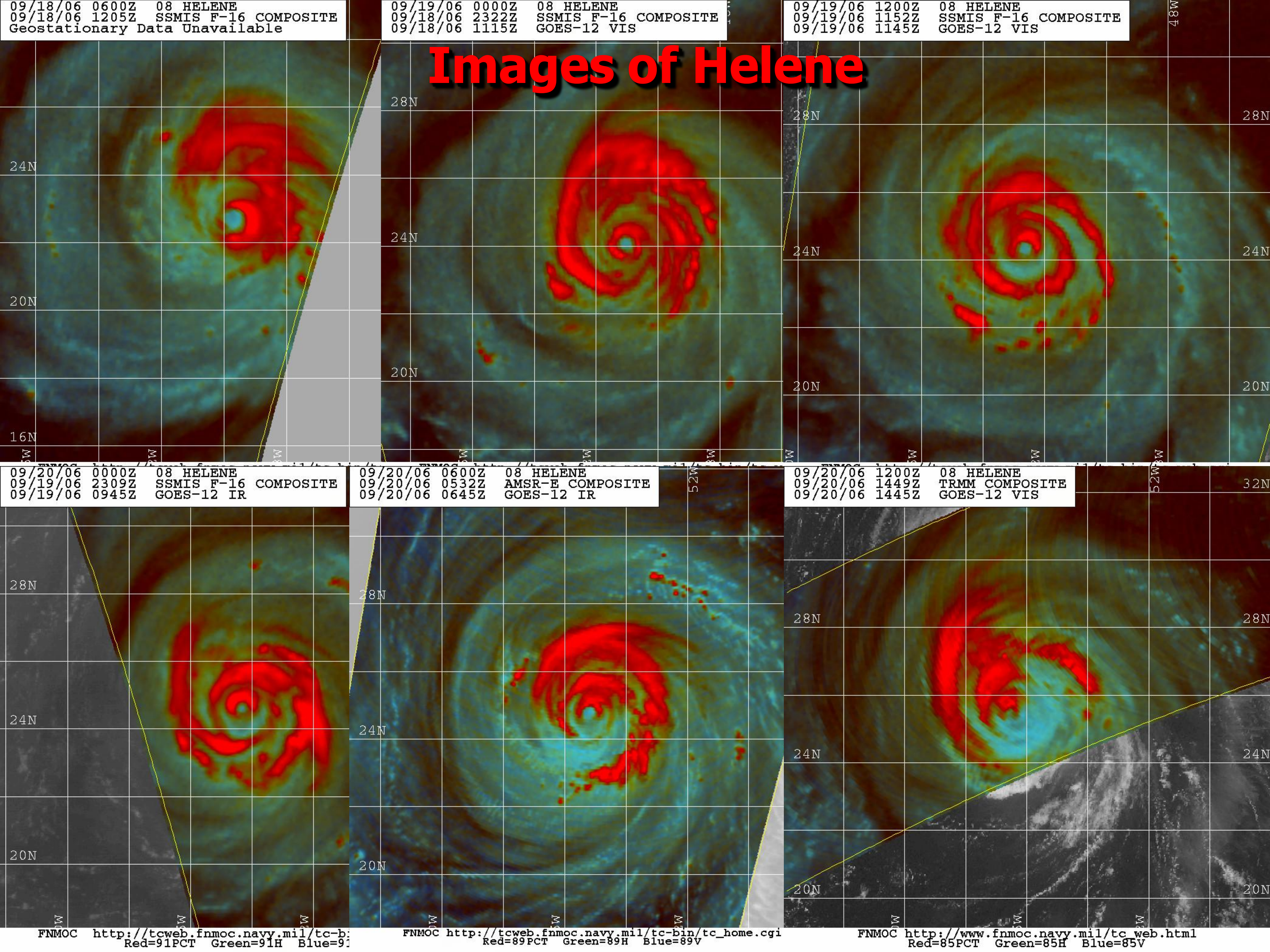
13 / 2240Z

14 / 0104Z

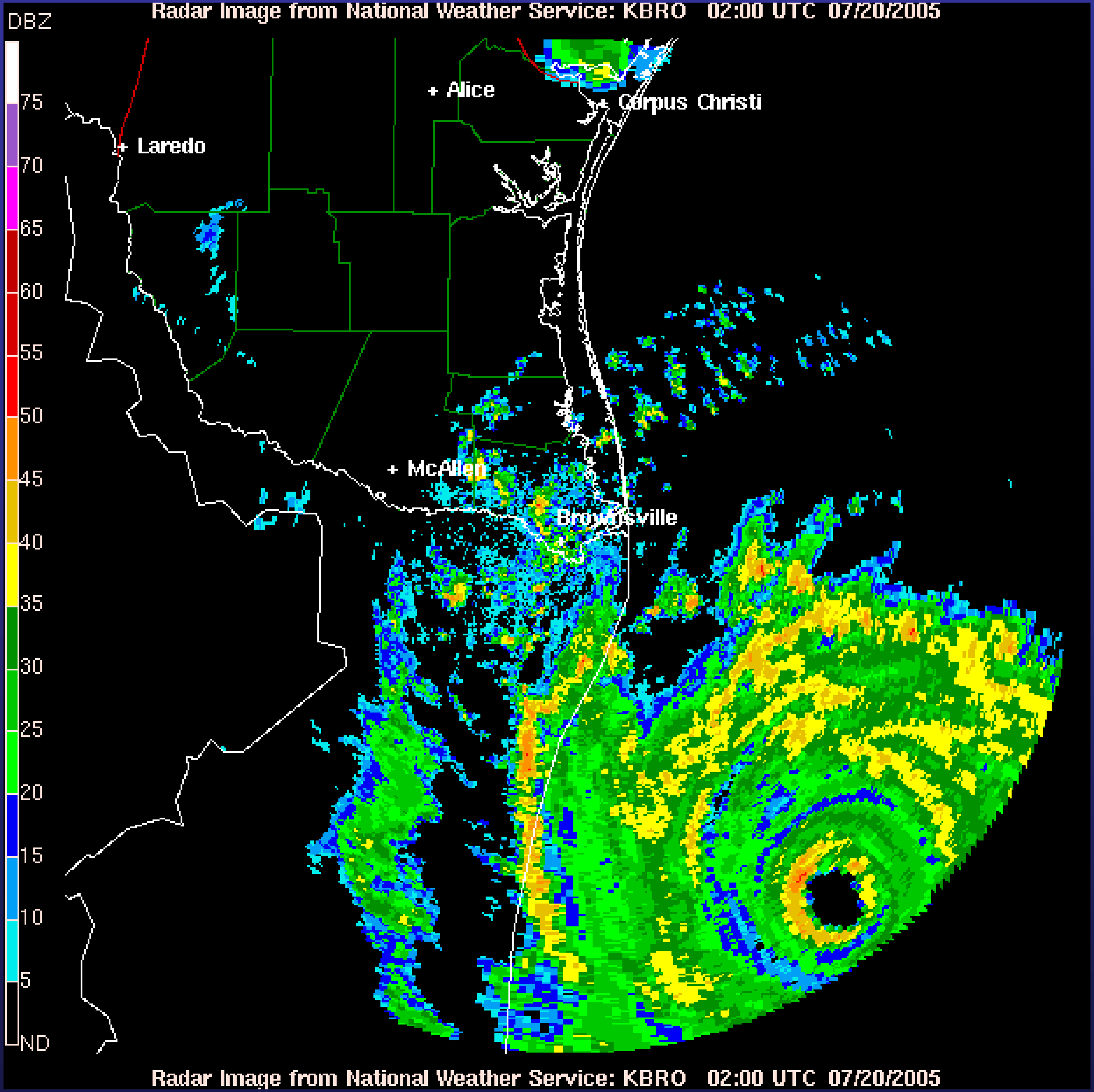
14 / 1110Z

14 / 2228Z

Images of Helene



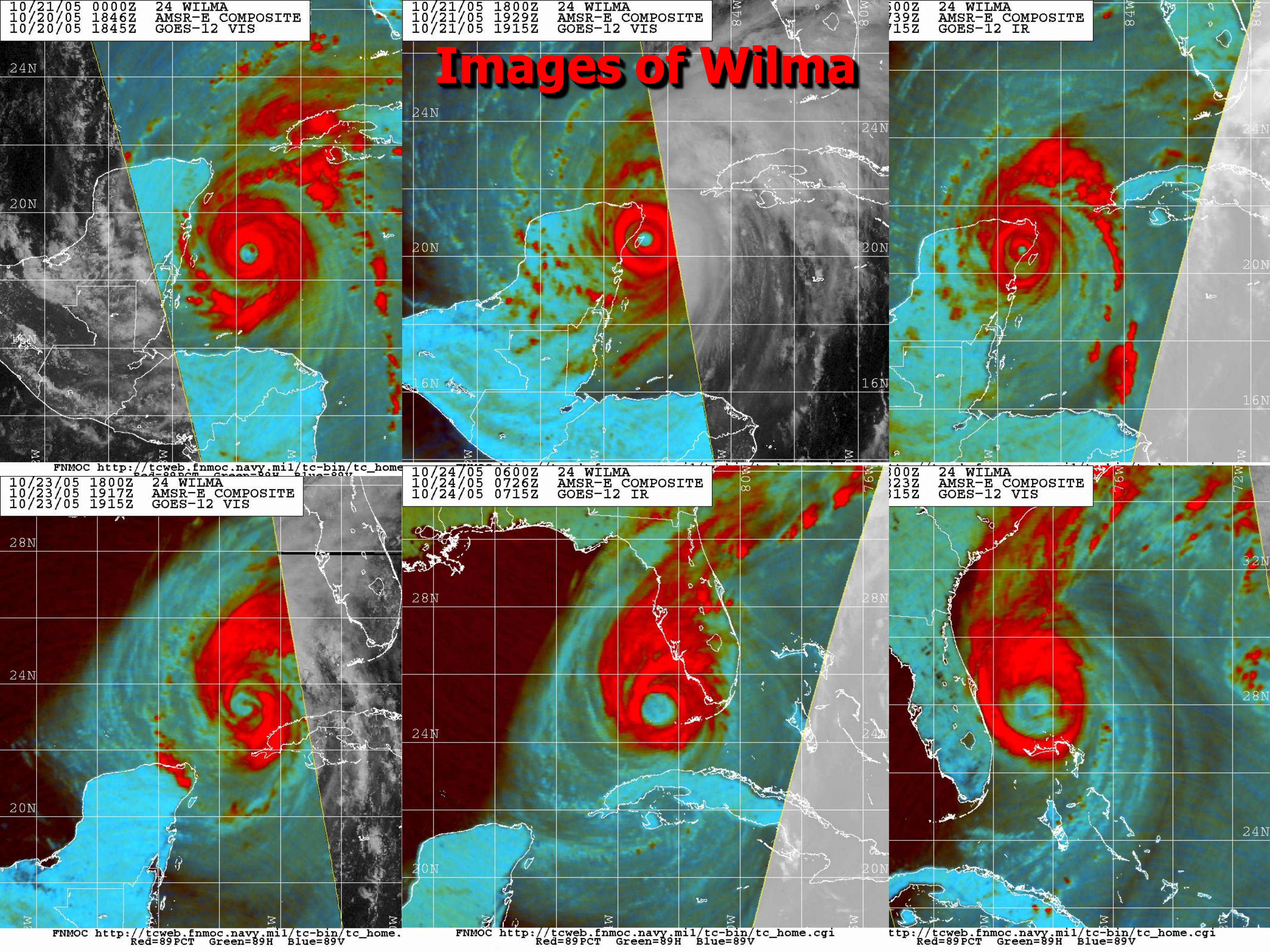
Hurricane Emily Landfall

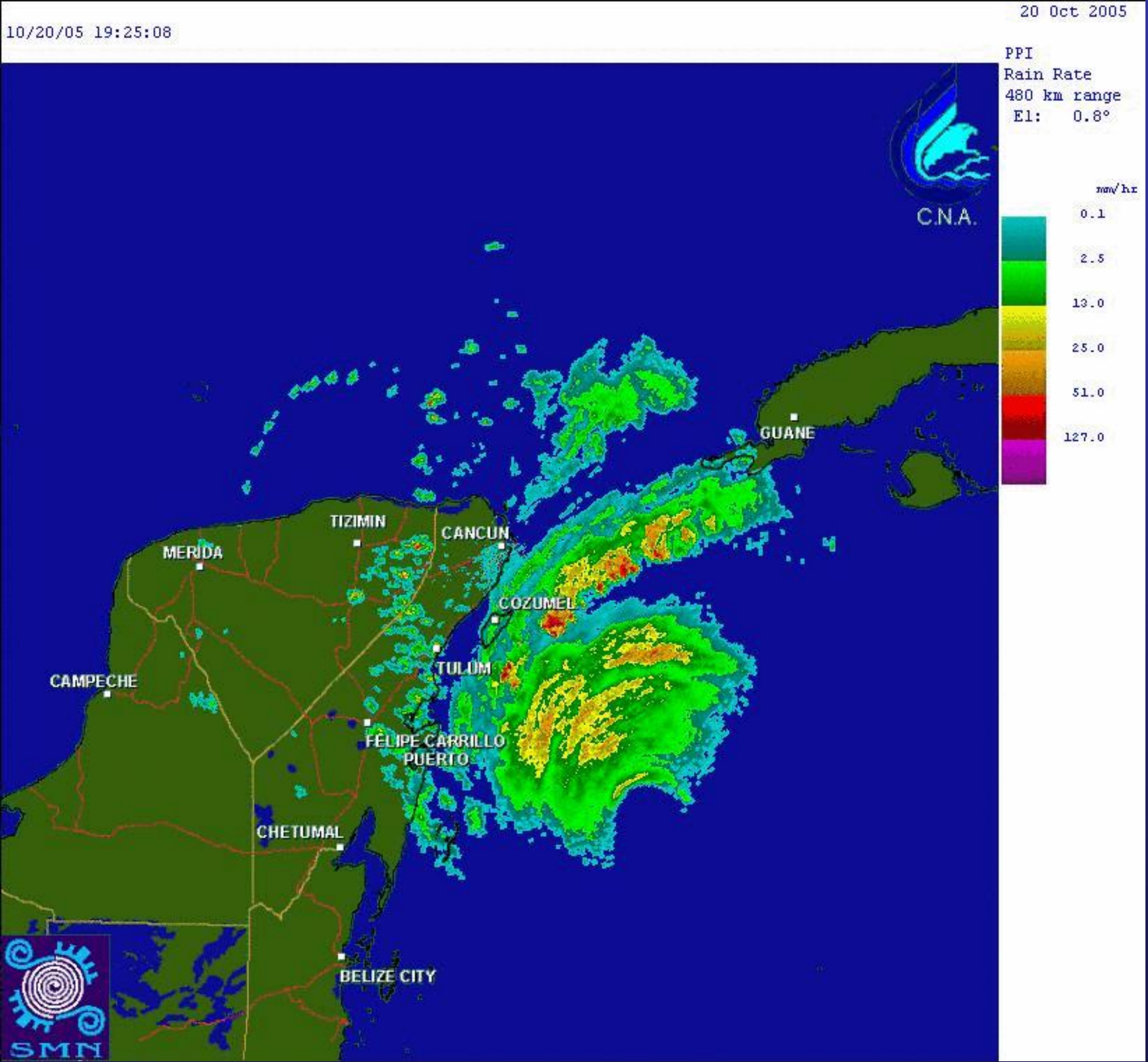


Note the inner eyewall rotating inside the larger eyewall. This is toward the end of an eyewall cycle.

Eventually the inner eyewall breaks up, and the outer eyewall becomes better-defined, right near the time of landfall.

Images of Wilma

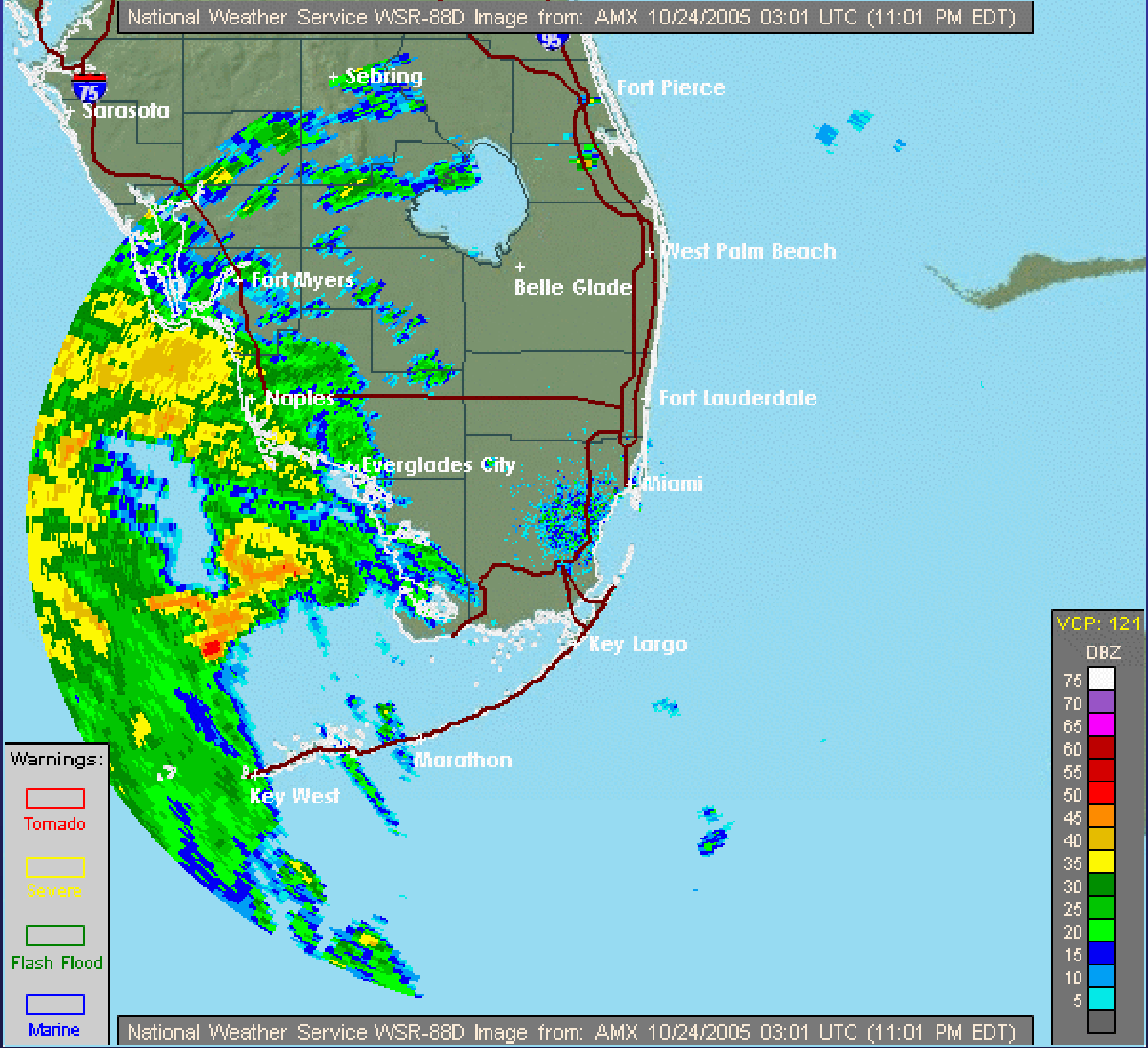




One eyewall is present at first. As Wilma approaches Yucatan, a larger eyewall forms.

Only fragments of the inner eyewall remain by the time Wilma emerges over the Gulf of Mexico.

Wilma keeps this larger eye for its Florida landfall.


National Weather Service WSR-88D Image from: AMX 10/24/2005 03:01 UTC (11:01 PM EDT)
Sebring
Fort Pierce
Sarasota
West Palm Beach
Fort Myers
Belle Glade
Naples
Fort Lauderdale
Everglades City
Miami
Key Largo
Marathon
Key West
Warnings:
Tornado
Severe
Flash Flood
Marine
VCP: 121
DBZ
75
70
65
60
55
50
45
40
35
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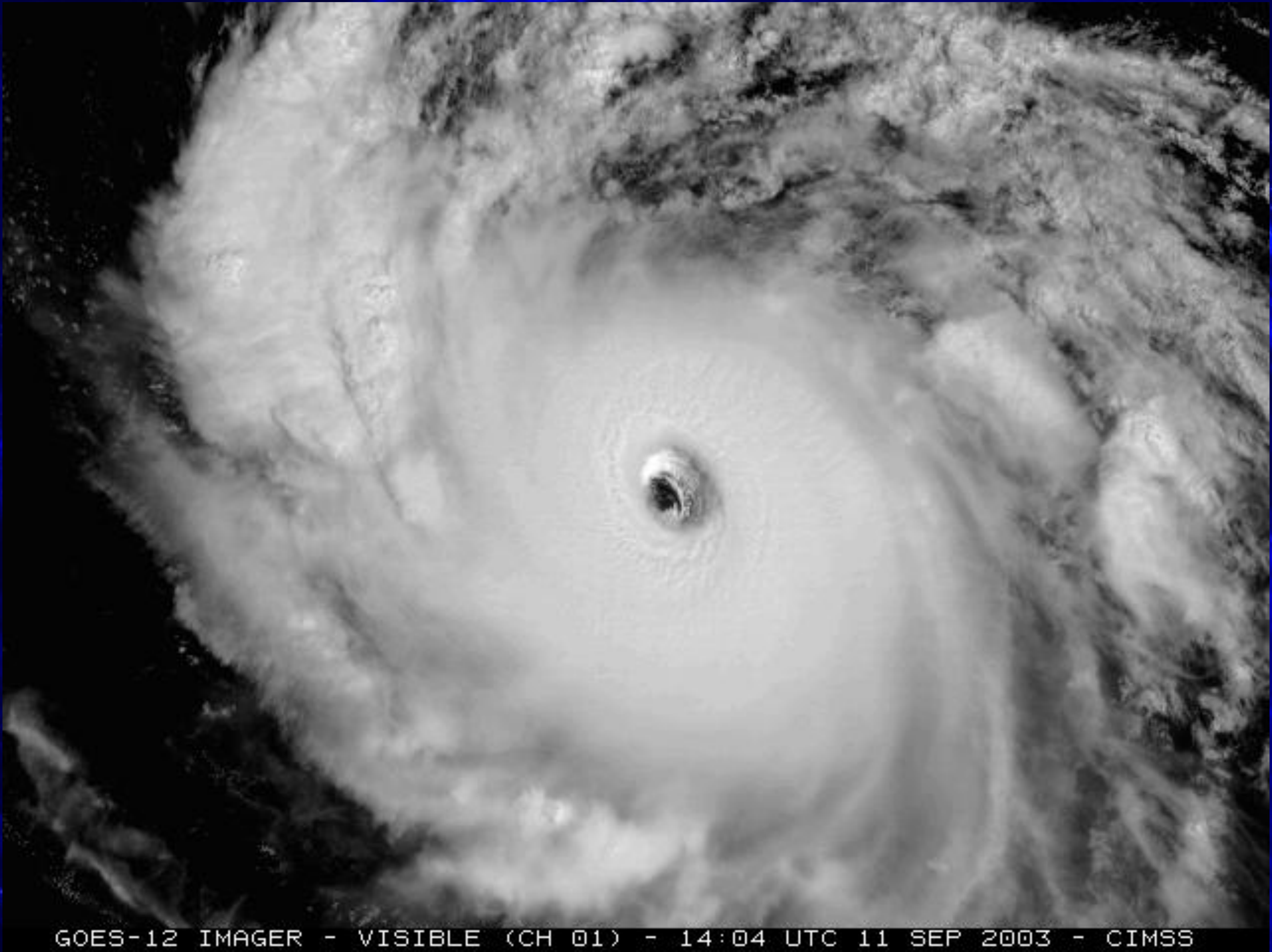
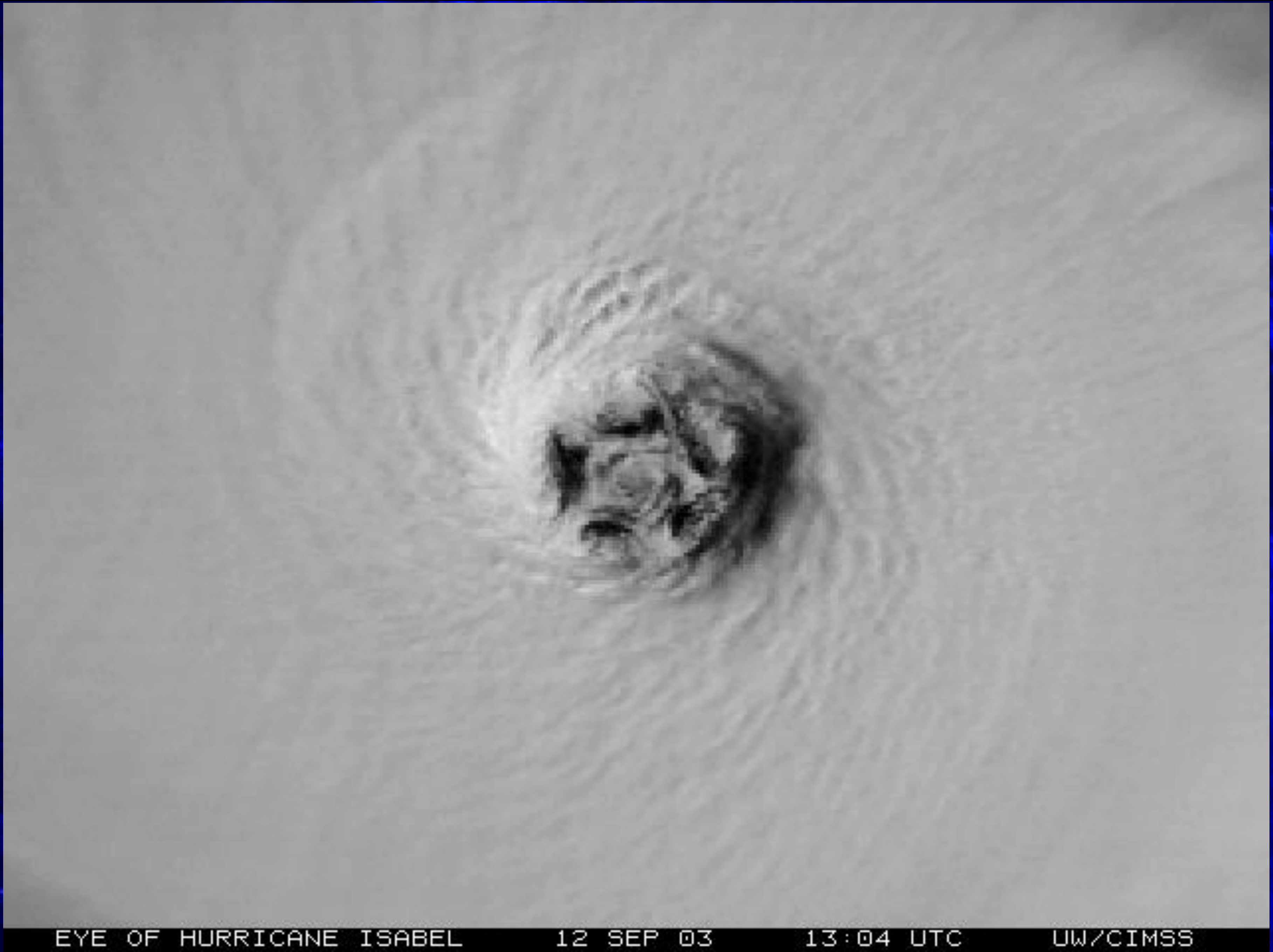
5
National Weather Service WSR-88D Image from: AMX 10/24/2005 03:01 UTC (11:01 PM EDT)

Eye Of Hurricane Isabel on September 11, 2003



Eye Of Hurricane Isabel on September 12, 2003



Summary

- Hurricanes come in many different sizes, recently ranging from Charley in 2004 to Katrina in 2005.
- Size is somewhat related to intensity, but the relationship is weak.
- During the major hurricane phase, eyewall replacement cycles can cause big intensity changes without any apparent external forcing. The causes for these cycles are poorly understood and a major source of error in intensity forecasts.