Double (Concentric) Eyewalls in Hurricane Katrina at Landfall:

A Key to the Storm's Huge Size and Devastating Impact over a Three-State Coastal Region

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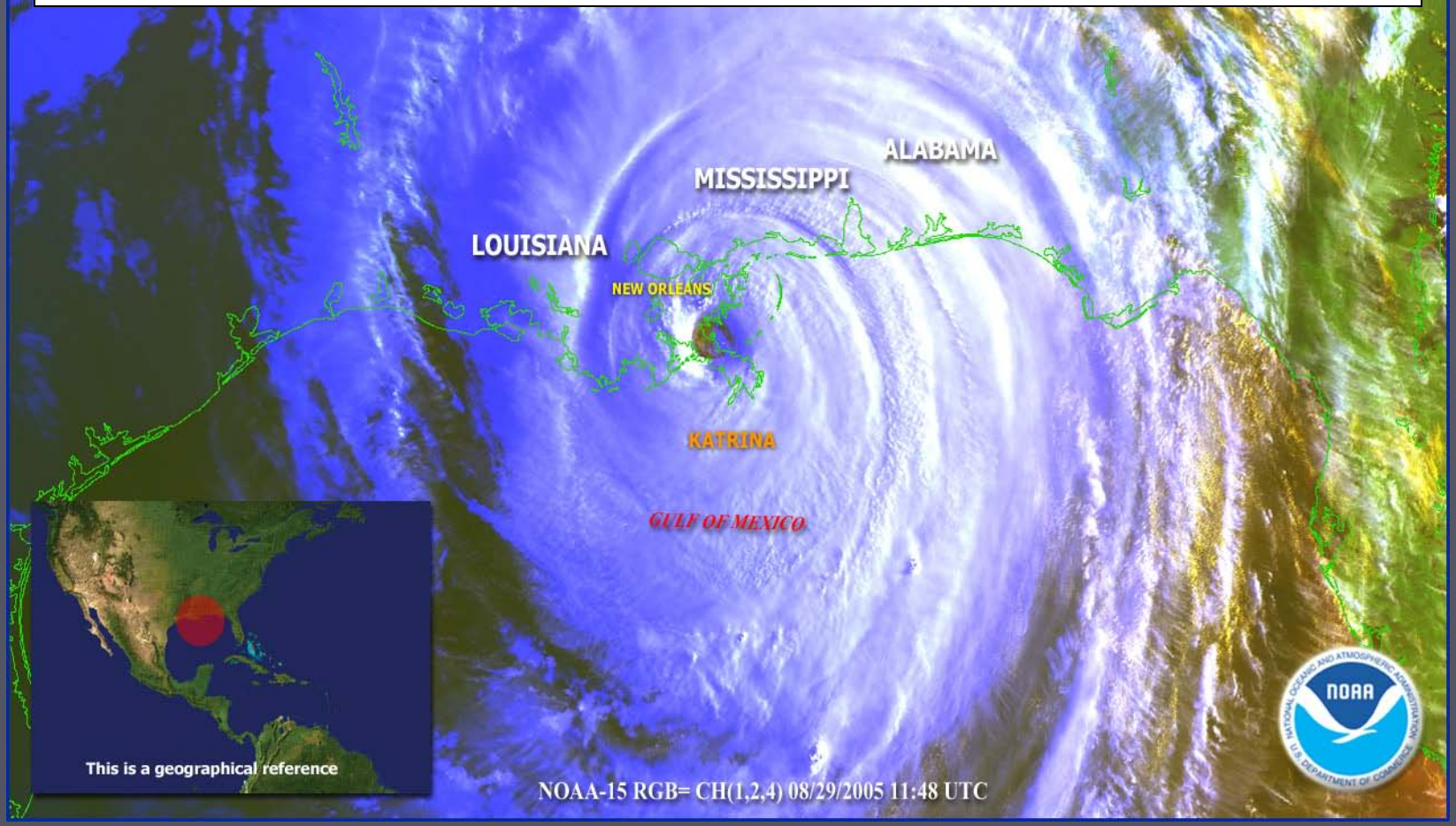
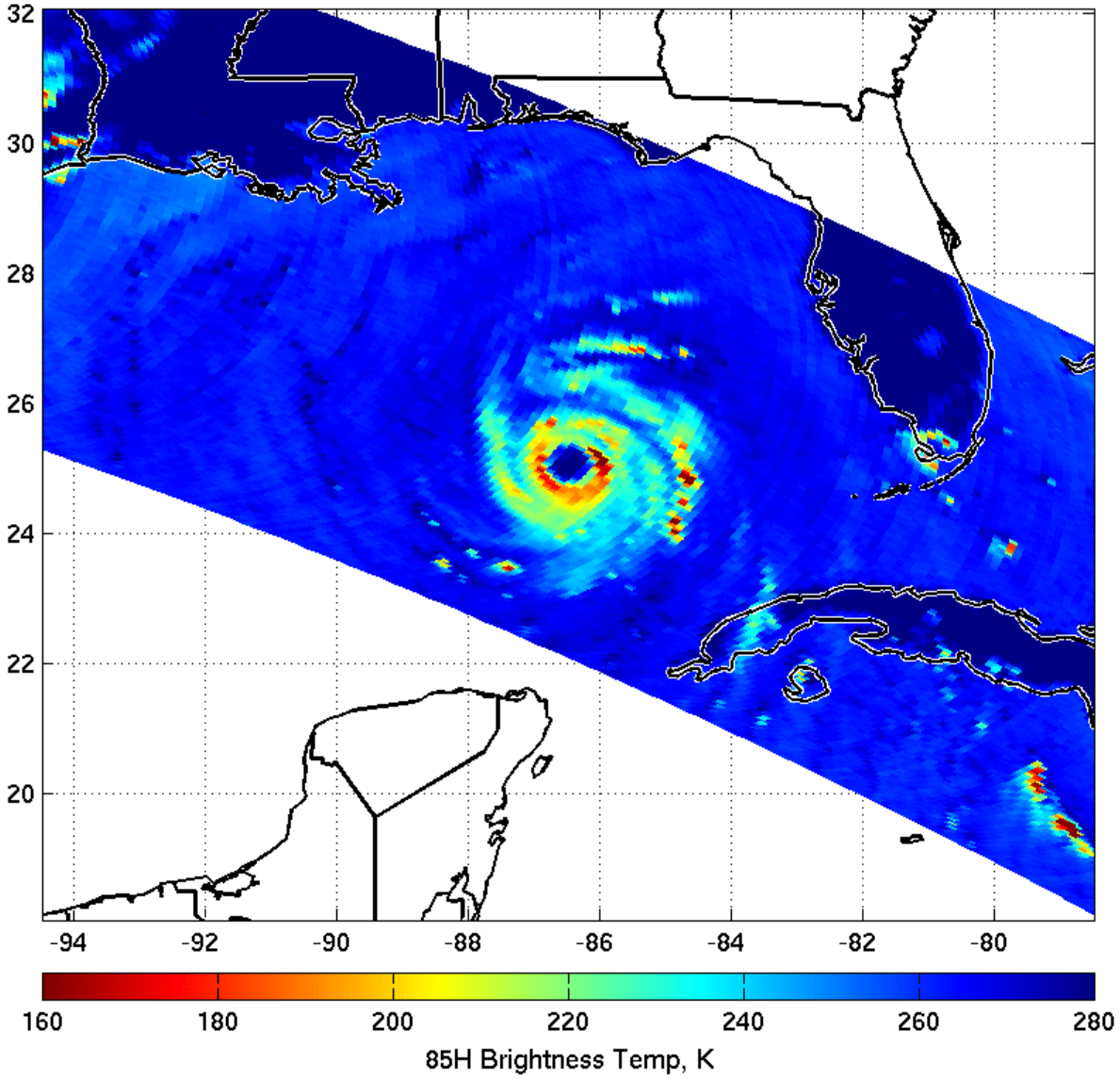
Katrina made landfall with the third-lowest central pressure (920 hPa) of any U.S. hurricane, but was only labeled a category 3. Why were the winds not stronger?



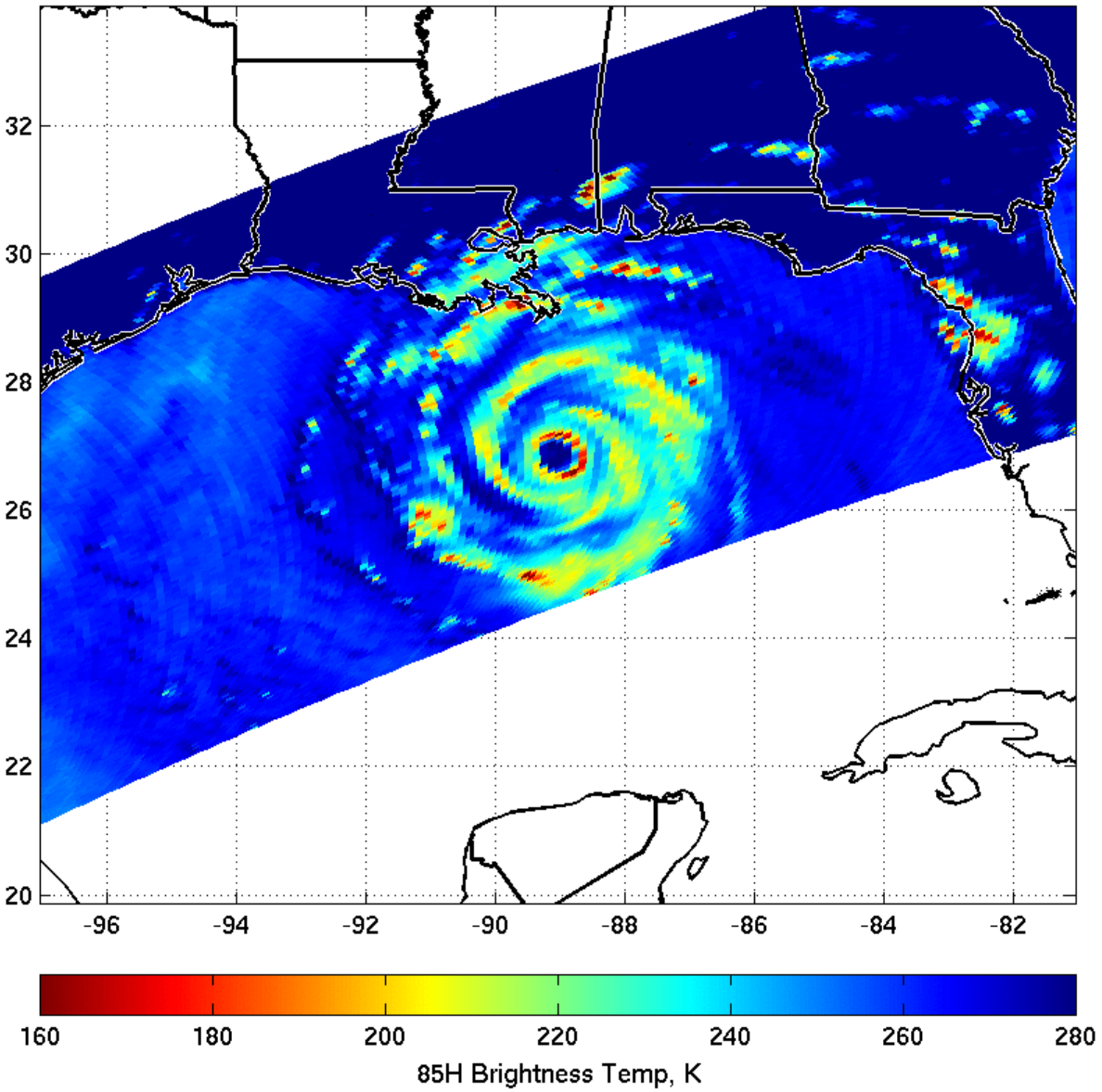
- *Hurricane Katrina making landfall along the Louisiana and Mississippi coasts, as captured in visible imagery from the NOAA-15 satellite at 6:48 am CDT, 29 August 2005 (Image courtesy of NOAA).*

- The color microwave imagery displays Katrina with an intense single eyewall.
- The storm was rapidly strengthening over the Gulf Loop Current at this time.
- (Image courtesy of CIMSS.)

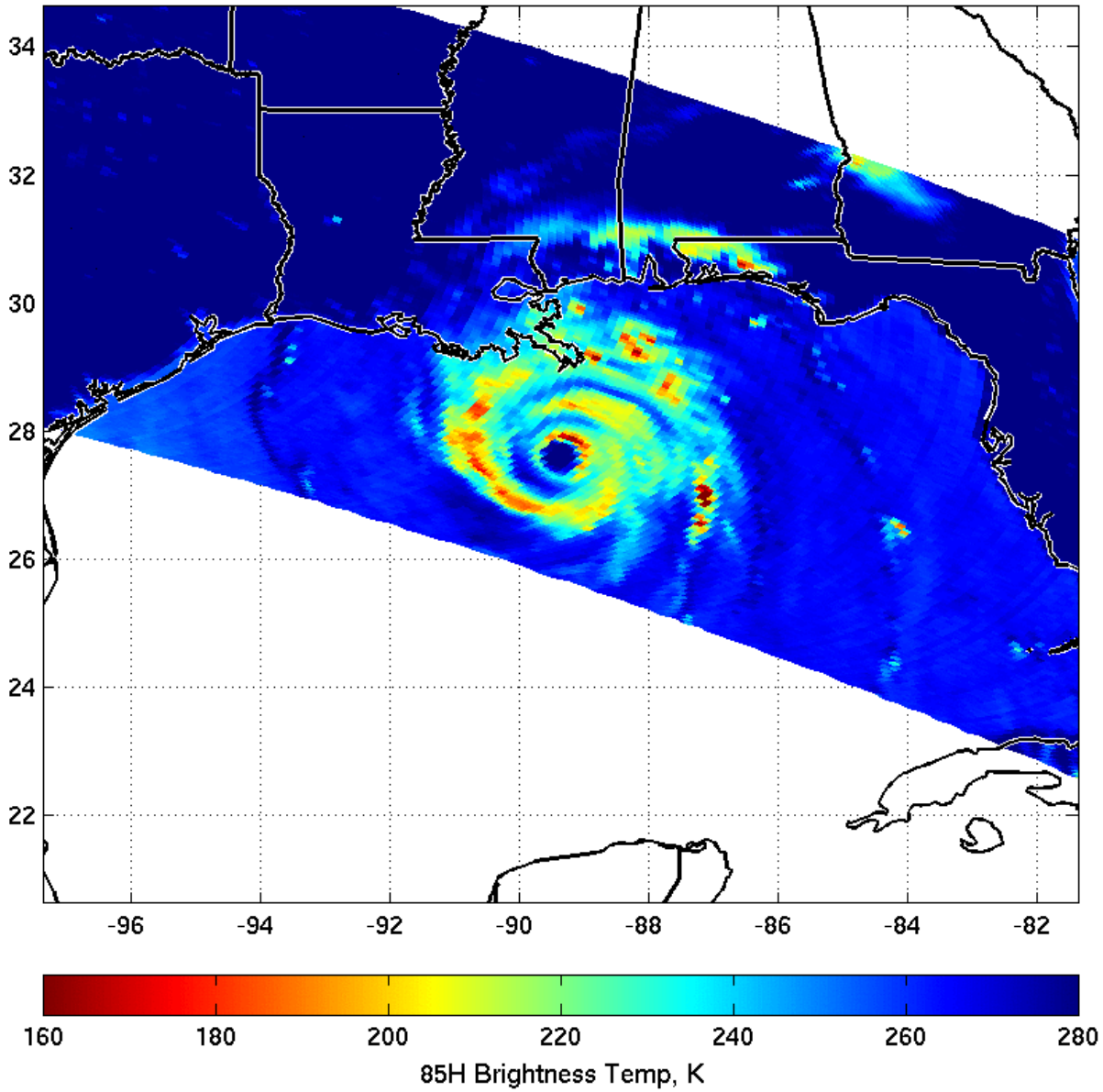


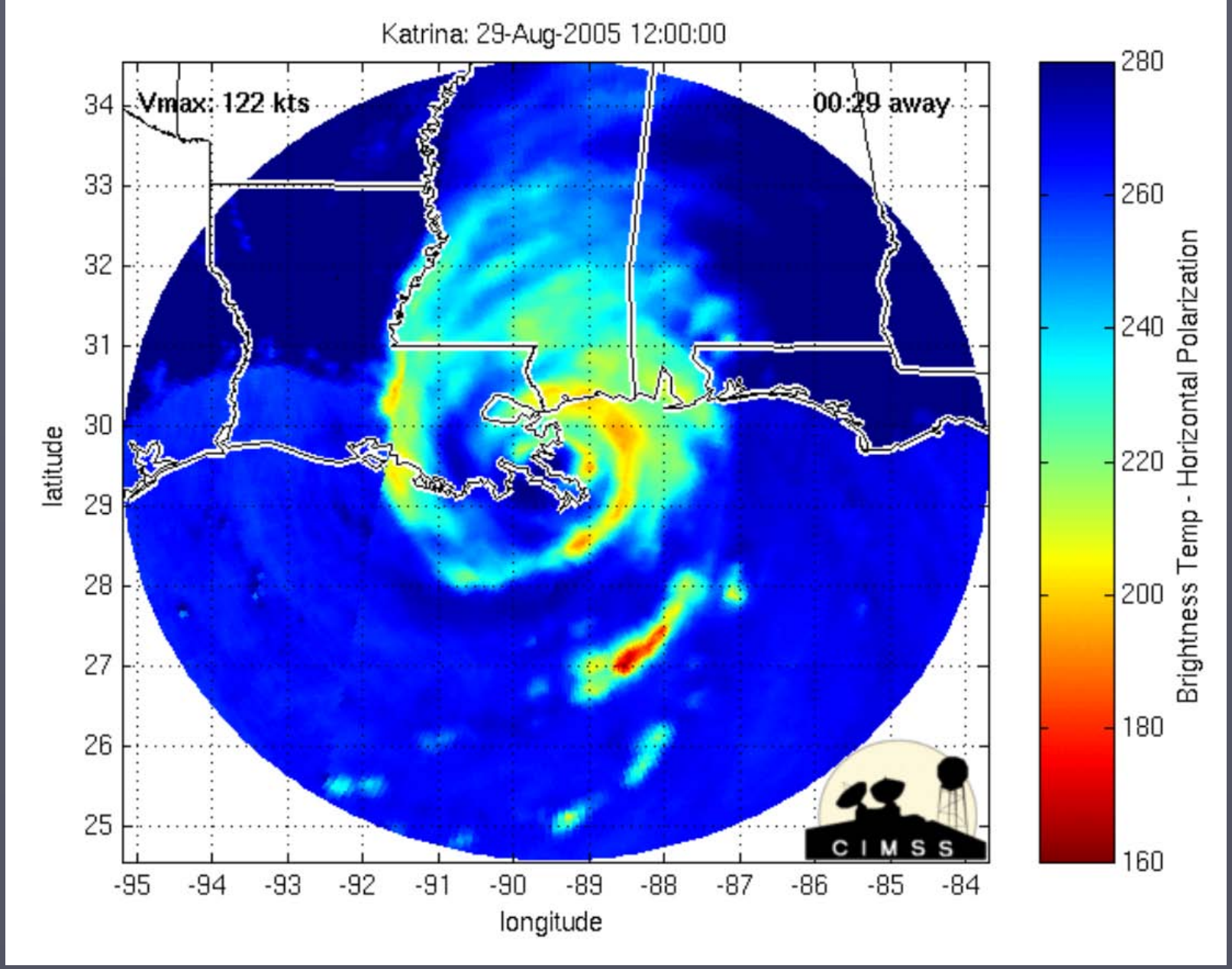
- The color microwave imagery indicates that Katrina has begun an eyewall replacement cycle as spiral bands begin to coalesce into an outer eyewall.

- (Image courtesy of CIMSS.)

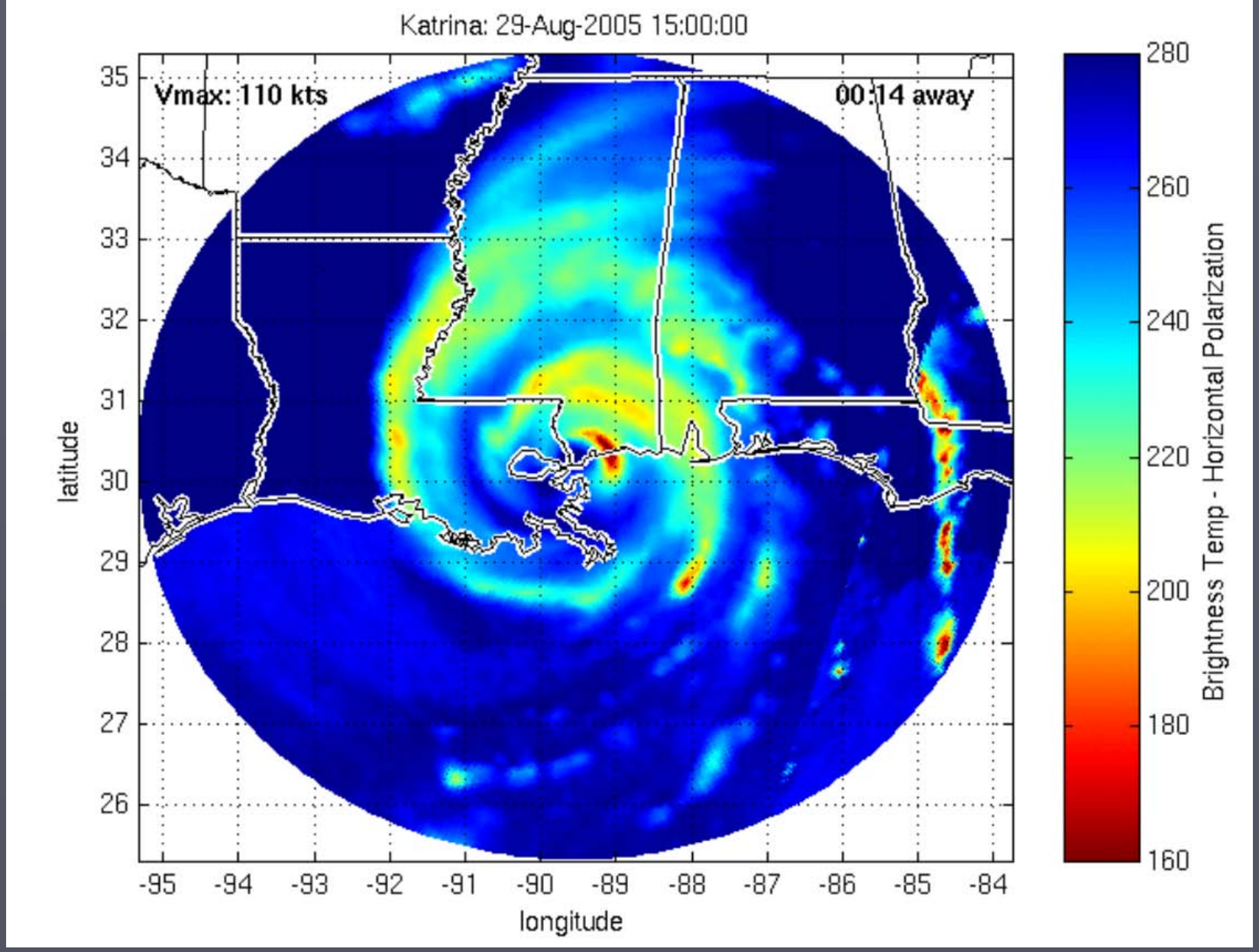


- Microwave imagery continues to indicate the development of an outer eyewall in Katrina which almost completely encircles the inner eyewall.
- This ongoing eyewall replacement was one factor aiding the reduction of Katrina's maximum winds from earlier.
- However, the development of this outer eyewall greatly increased the size of the storm.
- (Image courtesy of CIMSS.)

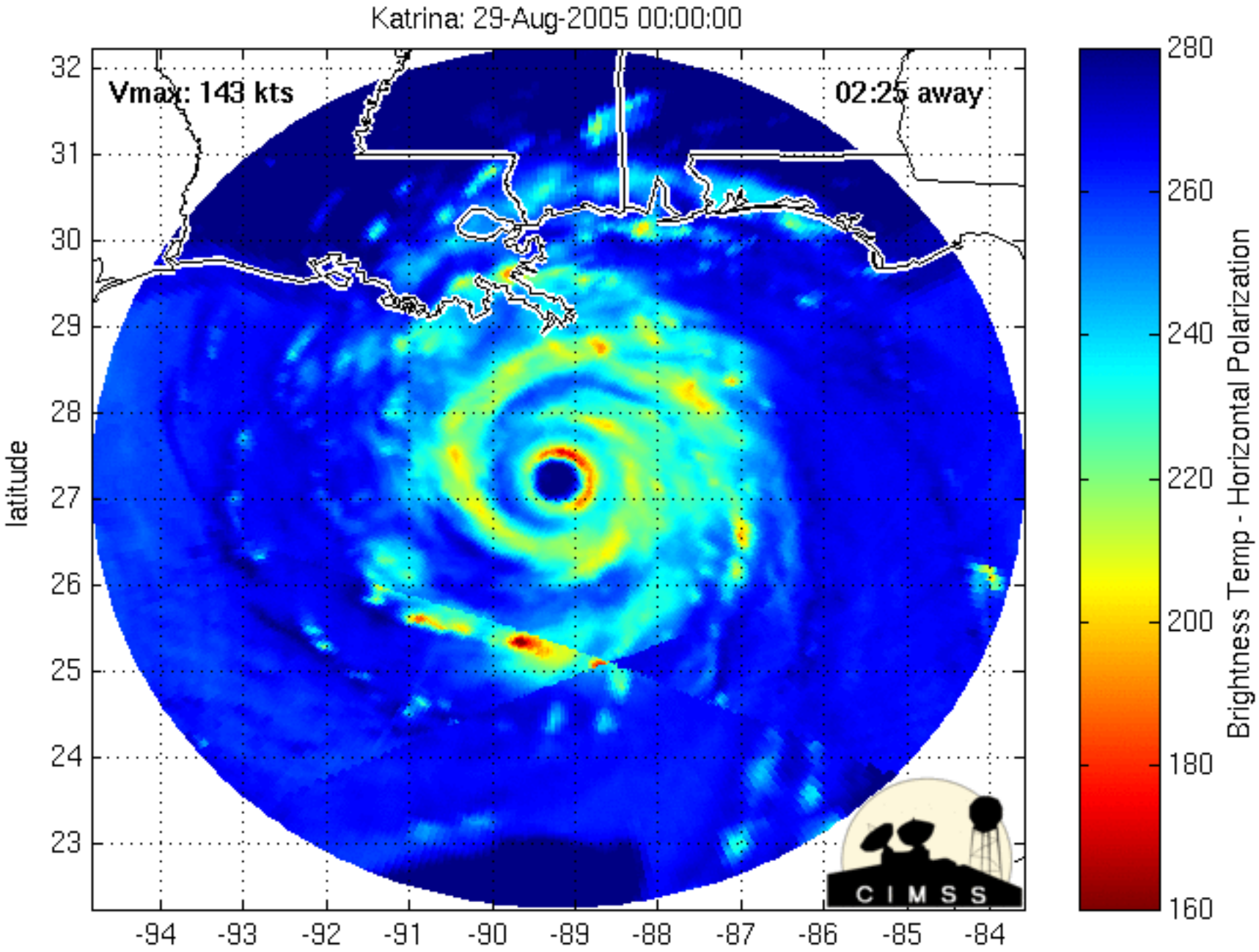




- Color morphed microwave imagery of Hurricane Katrina at 7:00 am CDT, 29 August 2005 from the MIMIC (Morphed Integrated Microwave Imagery at CIMSS) system showing the double eyewall structure of Katrina as it makes landfall along the northern Gulf Coast.



- Color morphed microwave imagery of Hurricane Katrina at 10:00 am CDT, 29 August 2005 from MIMIC showing continued evidence of an “open” double eyewall structure of Katrina as the inner eyewall crosses the Mississippi coast. Image courtesy of CIMSS.

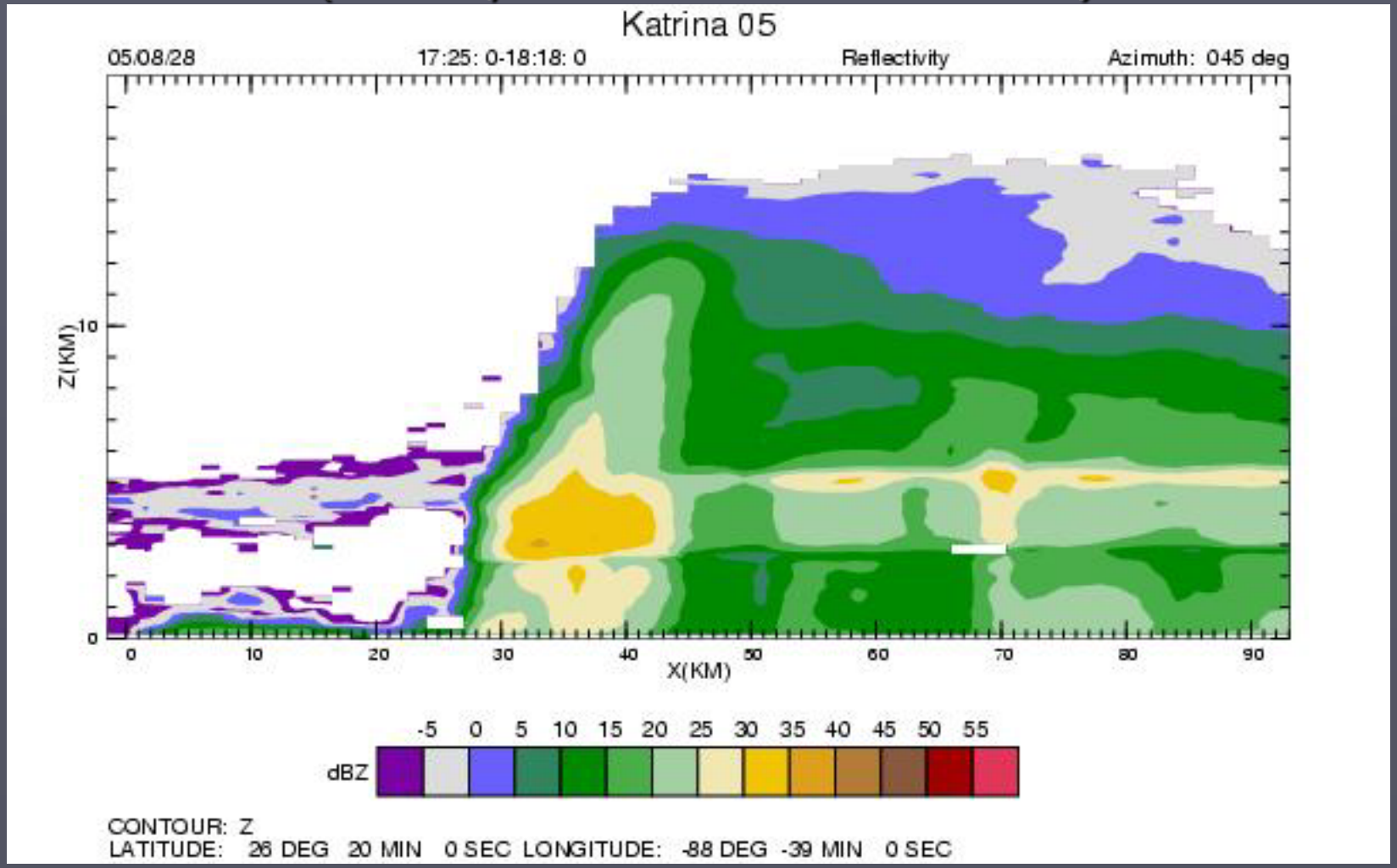


MIMIC Microwave Loop

Concentric Eyewall Structure

NOAA Aircraft Reflectivity Cross Section [Single Eyewall]

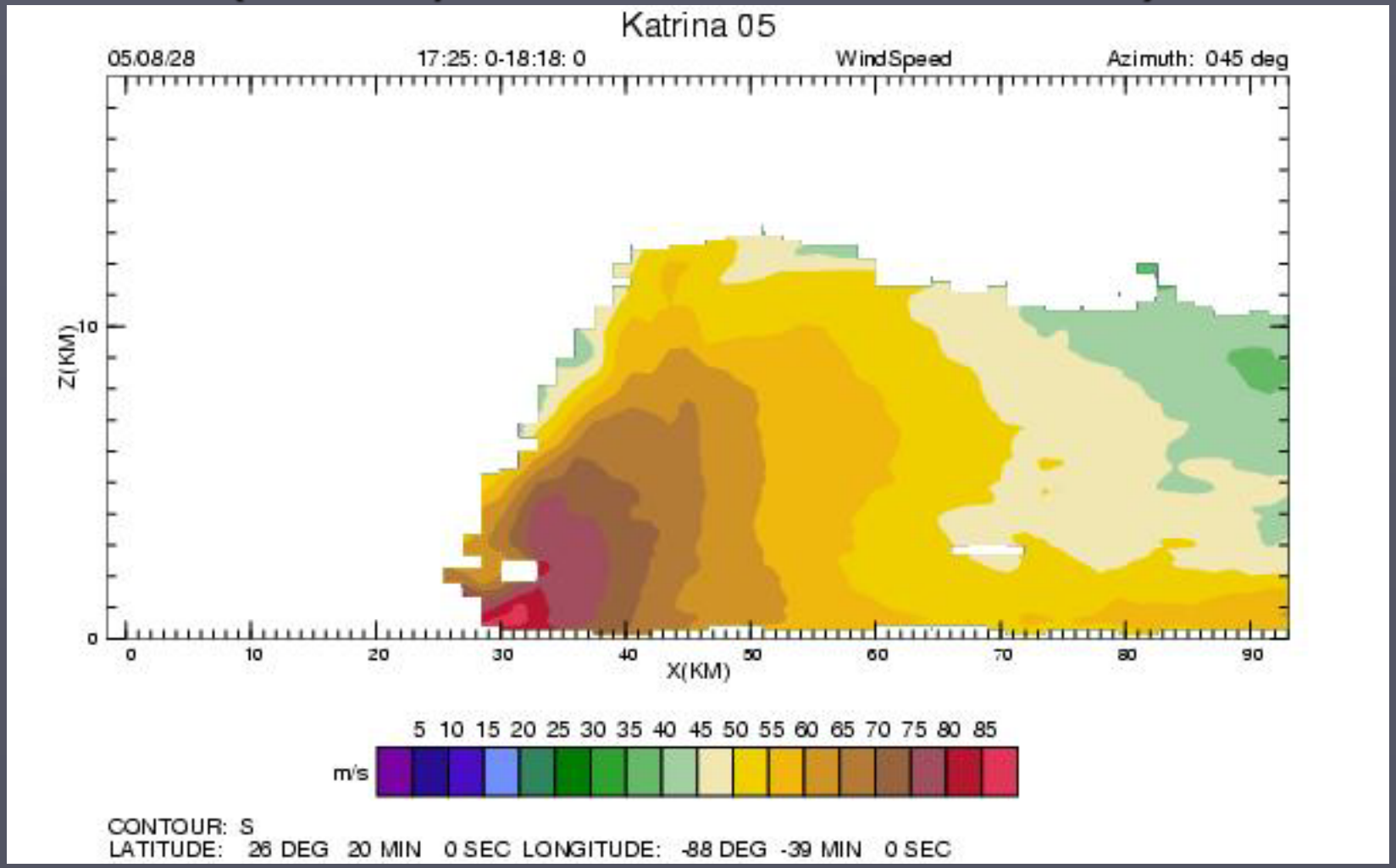
(Courtesy Hurricane Research Division)



NOAA Aircraft: N49RF, 1725-1818 UTC, 28 Aug 2005 (Northeast Quad)

NOAA Aircraft Velocity Cross Section [Single Eyewall]

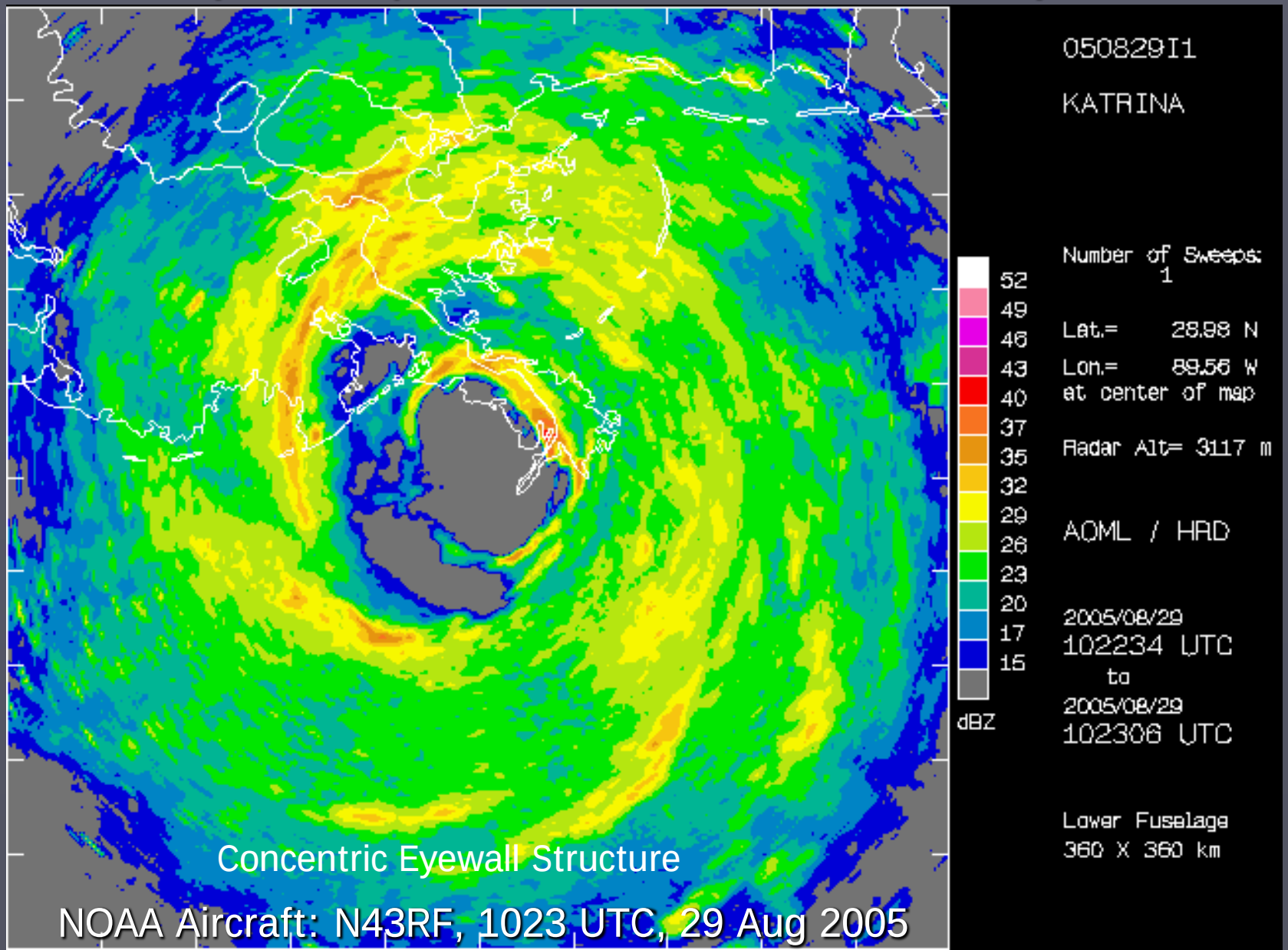
(Courtesy Hurricane Research Division)



NOAA Aircraft: N49RF, 1725-1818 UTC, 28 Aug 2005 (Northeast Quad)

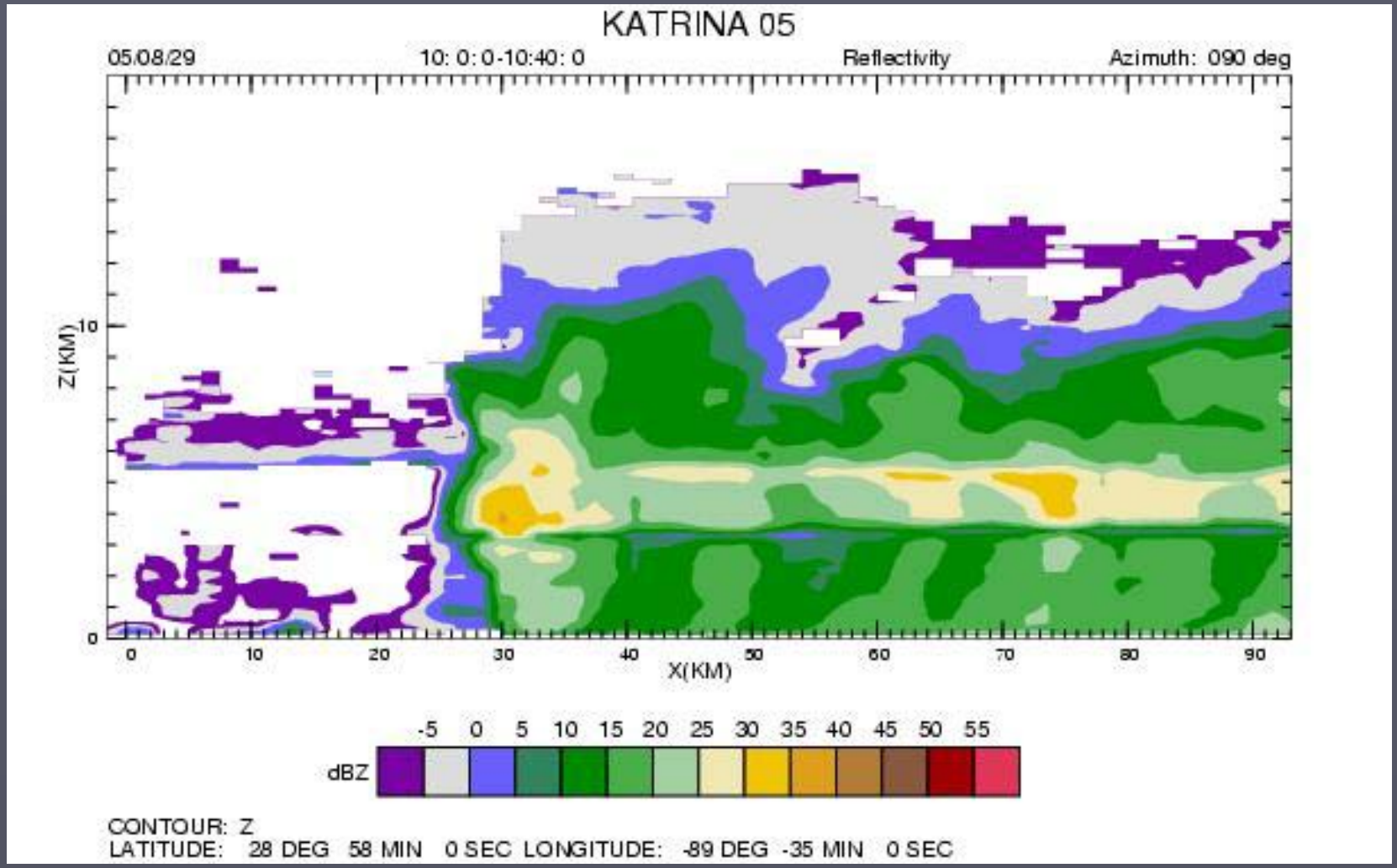
NOAA Aircraft Radar Reflectivity

(Courtesy Hurricane Research Division)



NOAA Aircraft Reflectivity Cross Section [Double Eyewall]

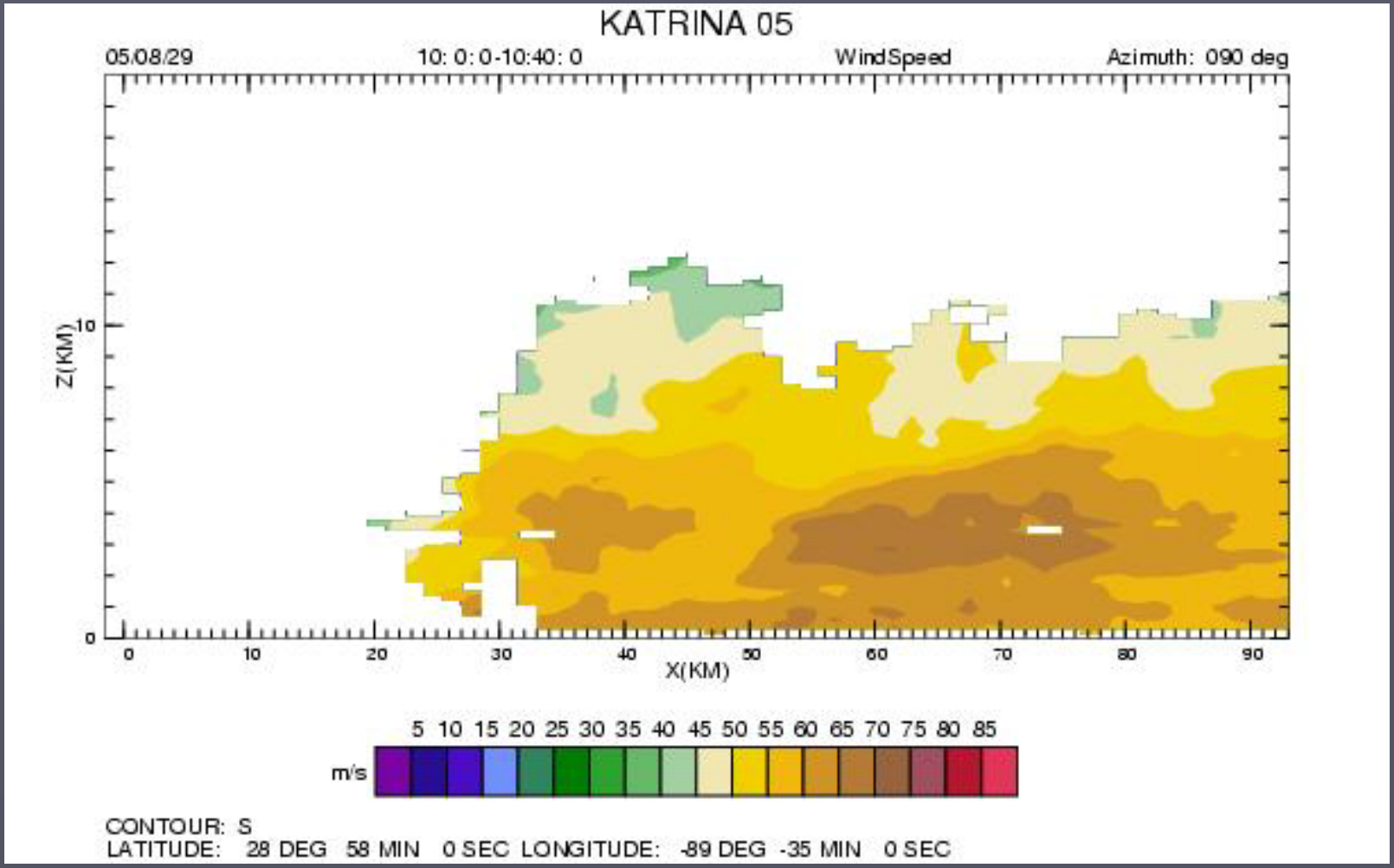
(Courtesy Hurricane Research Division)



NOAA Aircraft: N43RF, 1000-1040 UTC, 29 Aug 2005 (East Quad)

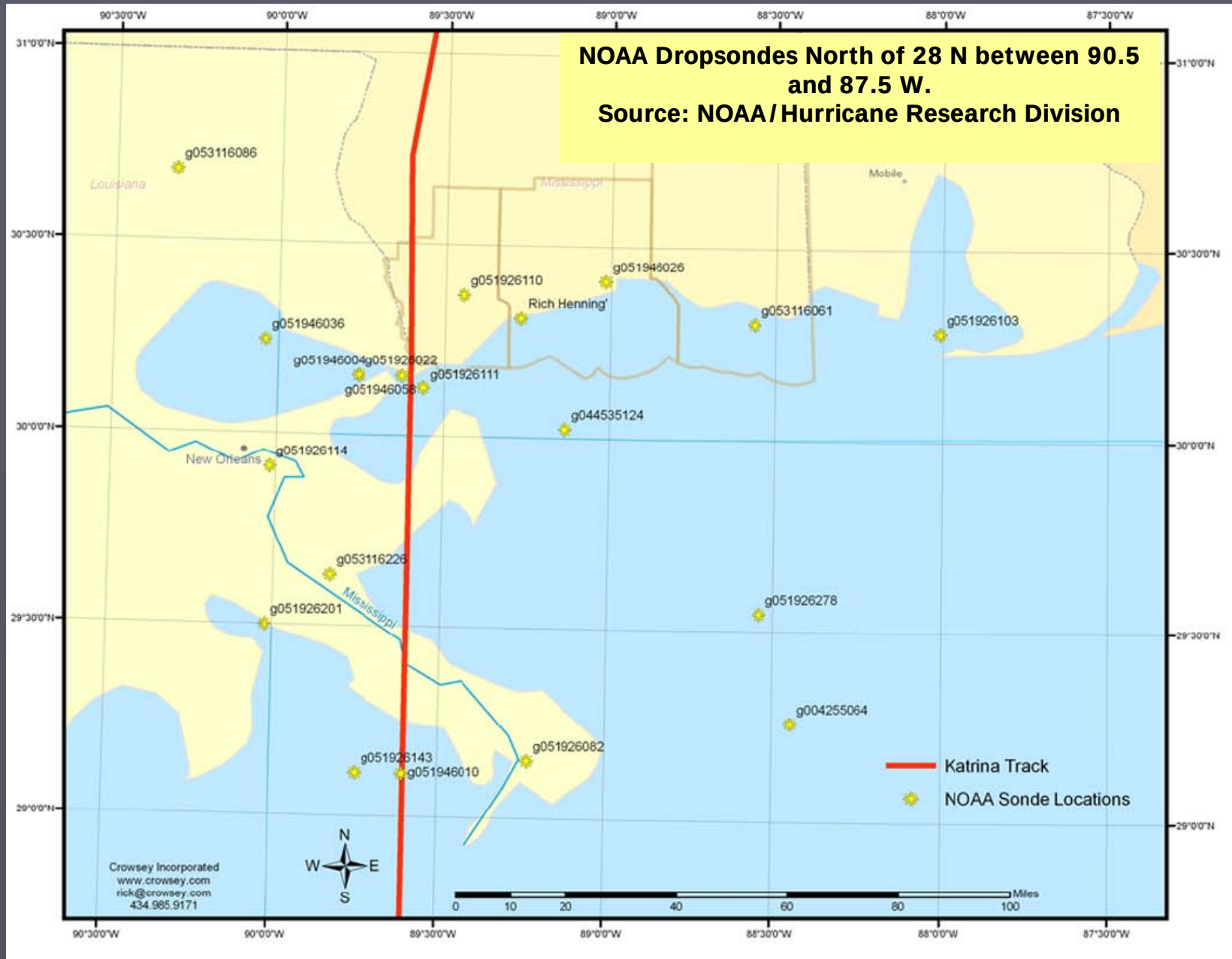
NOAA Aircraft Velocity Cross Section [Double Eyewall]

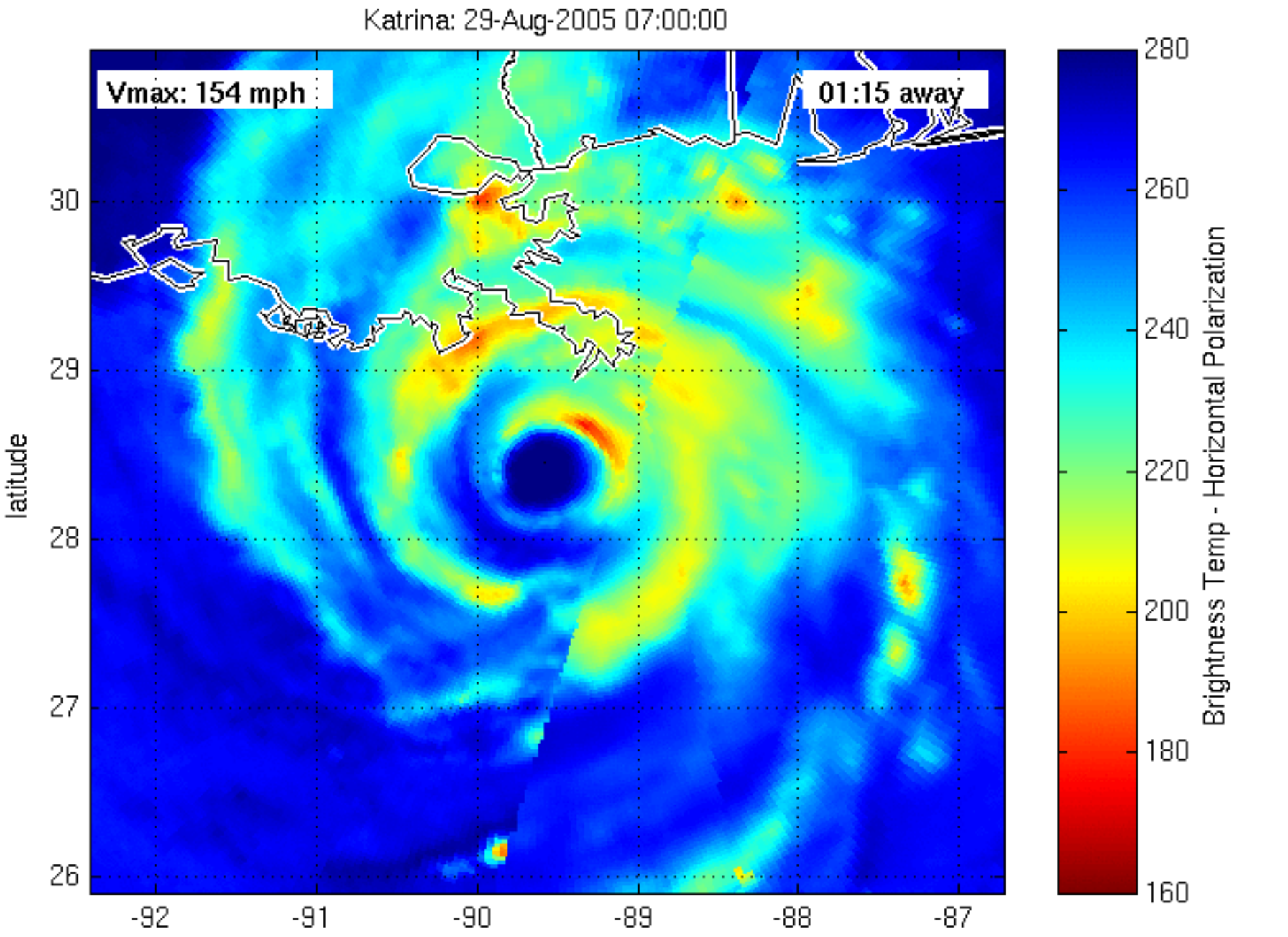
(Courtesy Hurricane Research Division)



NOAA Aircraft: N43RF, 1000-1040 UTC, 29 Aug 2005 (East Quad)

Katrina Dropsondes



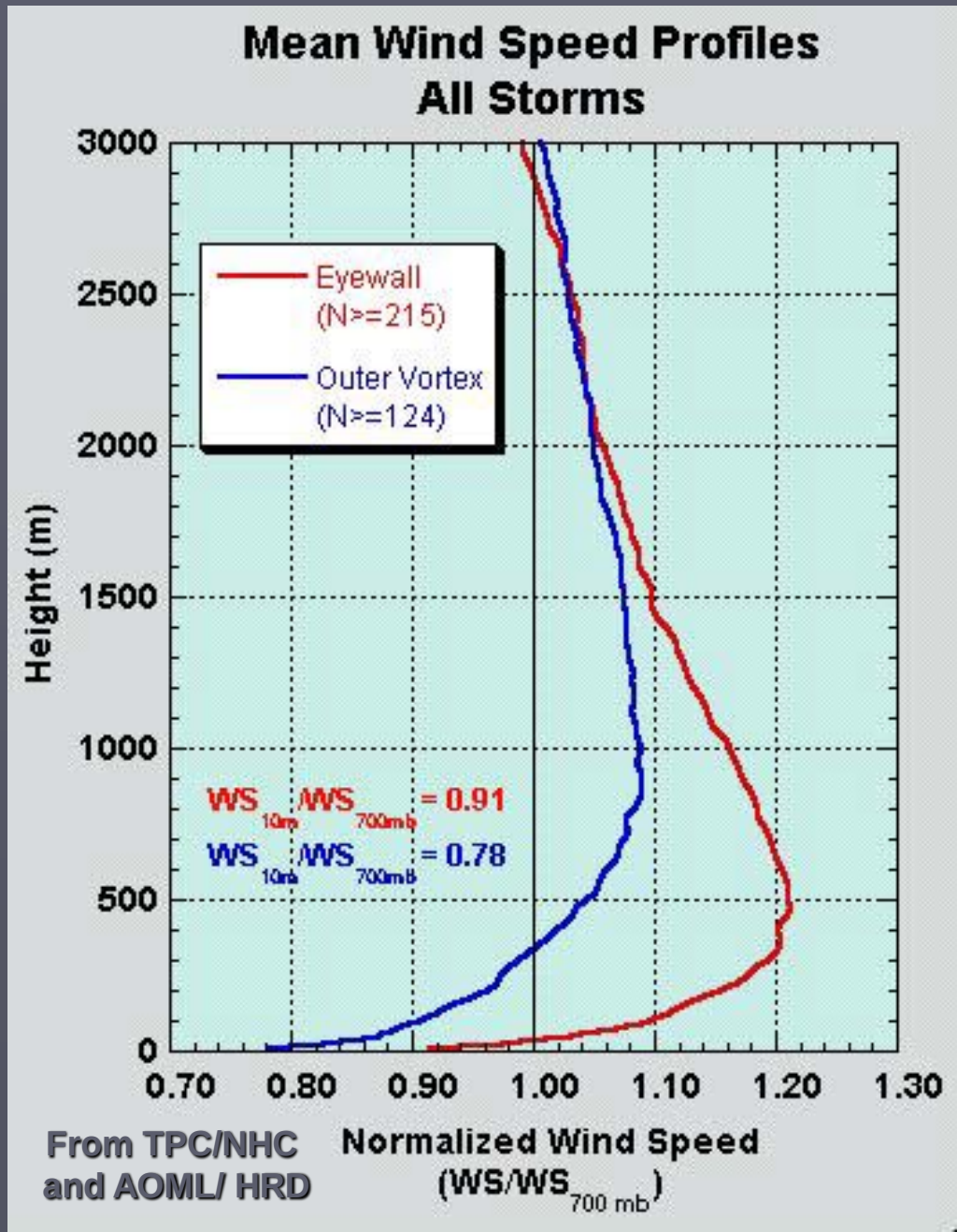


MIMIC Microwave Loop

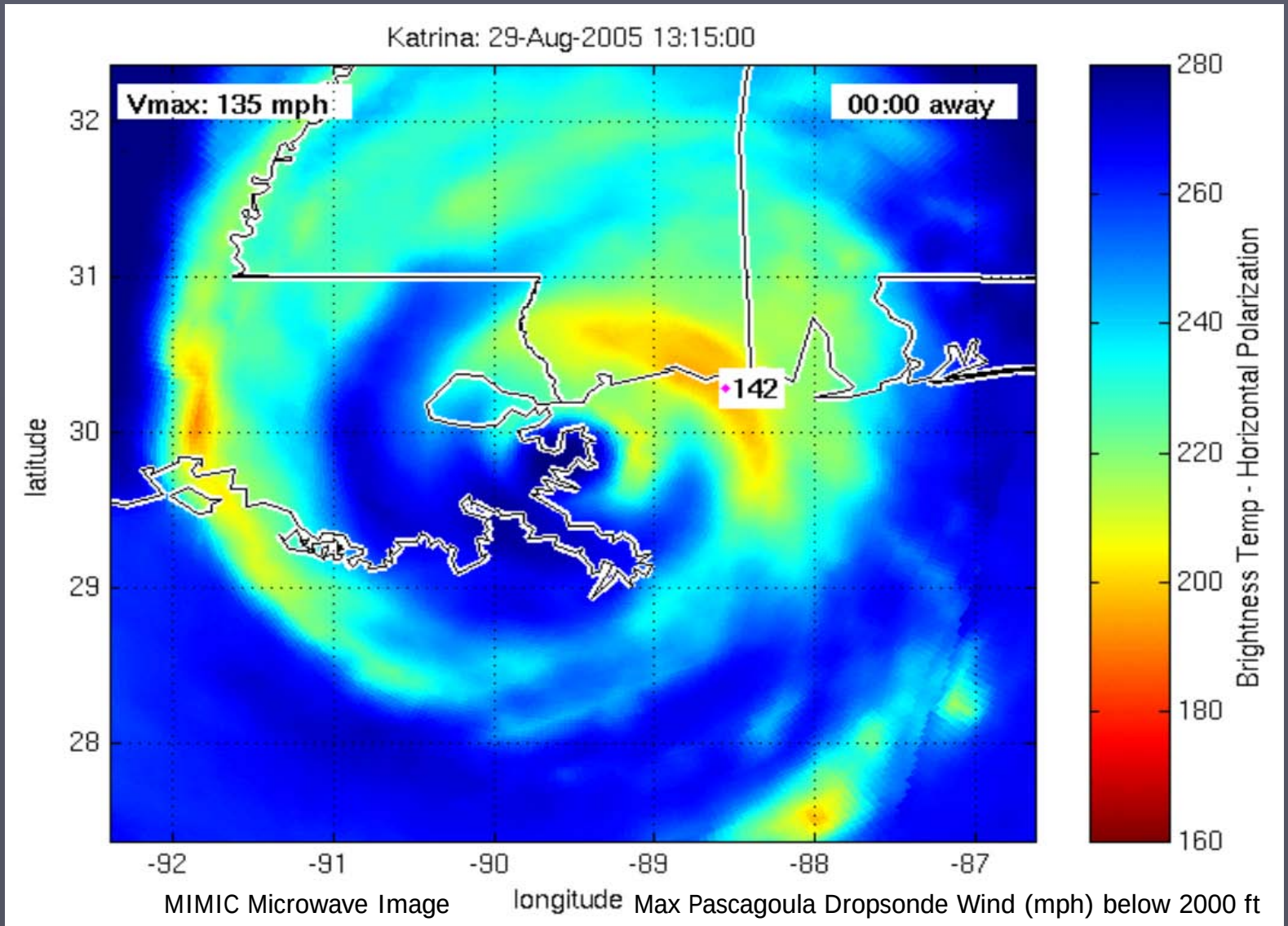
Max Dropsonde Winds (mph) below 2000 ft

Dropsonde Mean Wind Profiles

- Eyewall wind maxima are found near 500 m (1600 ft) elevation.
- Non-eyewall wind maxima are found much higher (closer to 1000 m [3000 ft])
- (From Franklin et al., 2003 and TPC/NHC webpage)



Dropsonde Max Wind (mph) (sfc-2000 feet) Overlaid on Microwave Satellite Imagery

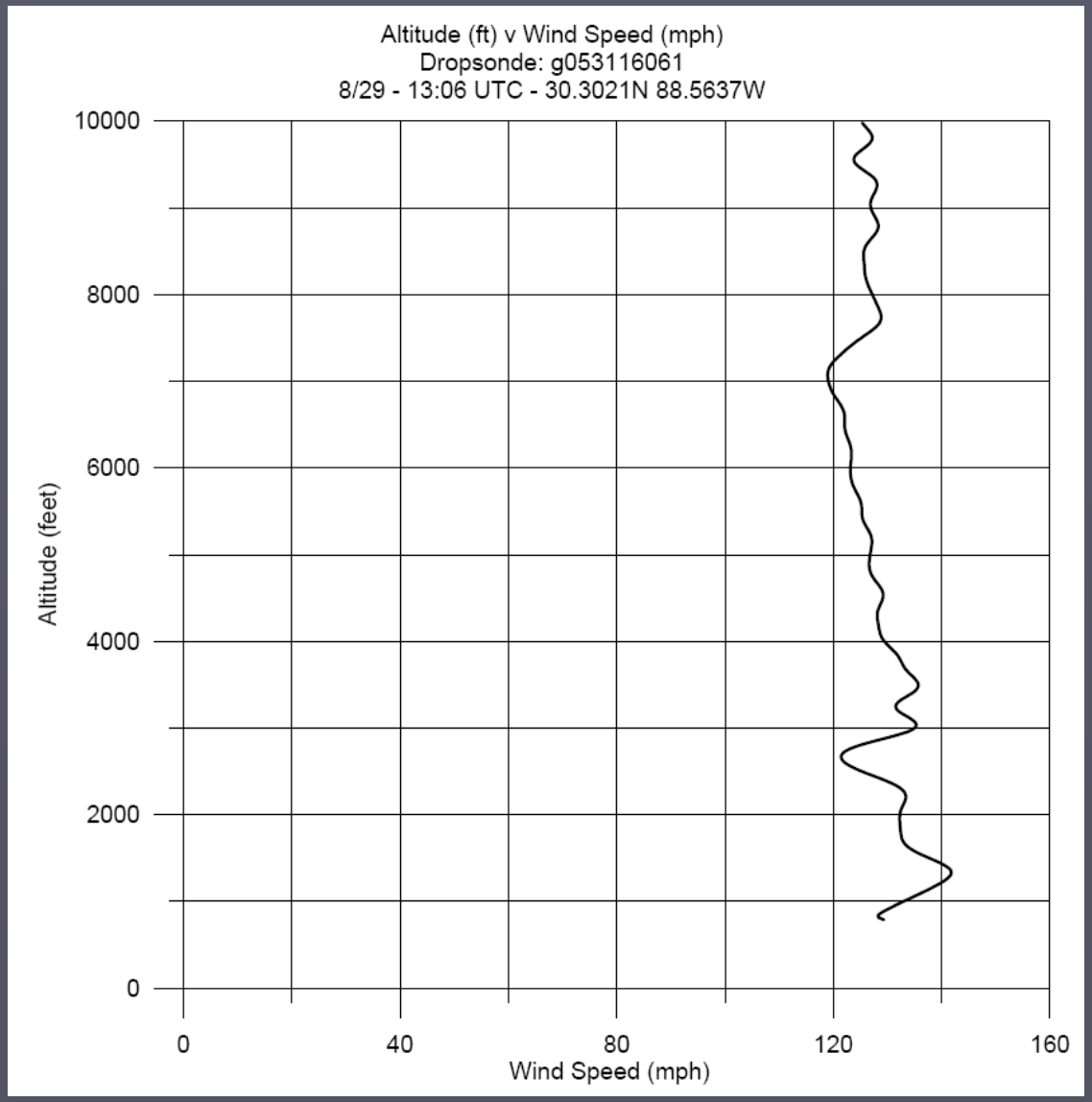


MIMIC Microwave Image

Max Pascagoula Dropsonde Wind (mph) below 2000 ft

Pascagoula Dropsonde Profile in Outer Eyewall

(Courtesy Hurricane Research Division)



Surface Wind Estimates in the Outer Eyewall over Water

- Per Franklin et al. 2003, NHC Operational Procedures, and Franklin personal communication (March 2007), a surface (10 m) sustained wind can be estimated from the Pascagoula dropsonde (g052116016) by averaging the winds over a 150 m layer centered on the following levels:

- Method 1) 90% of 700 hPa wind
  - 90% of 126 mph at 700 hPa (9435 feet) = 113 mph (113.4 mph) at 10 m.

- Method 2) 80% of 850 hPa wind
  - 80% of 130 mph at 850 hPa (4000 feet) = 104 mph at 10 m.

- Method 3) Midpoint percent of the lowest 150 m of wind reports in dropsonde
  - 76.5% of 134 mph at 285 m (961 feet) = 103 mph at 10 m.

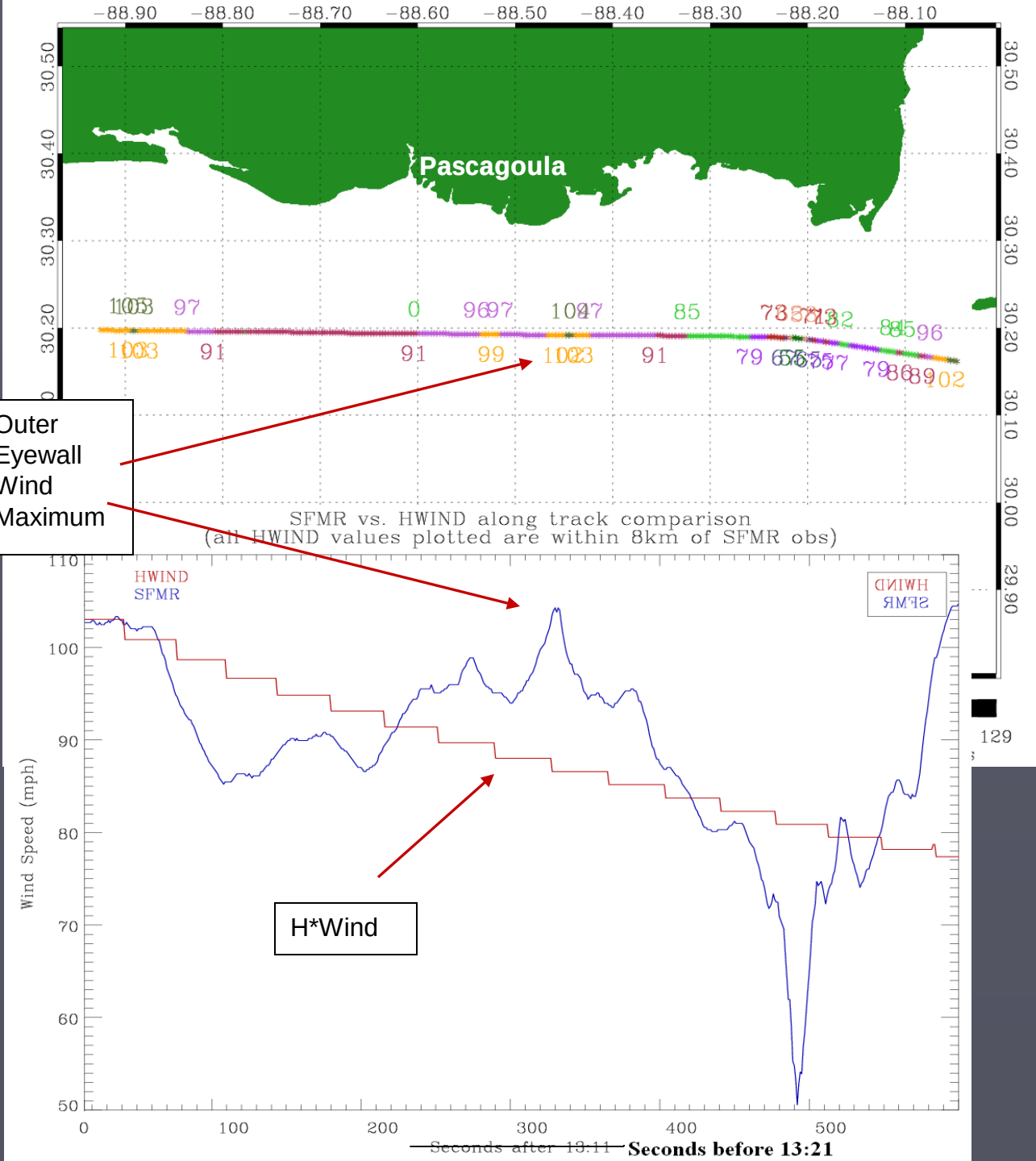
- These estimates represent sustained 1 minute wind estimates.

- Are winds of approximately this strength found in any other dataset in the outer eyewall?

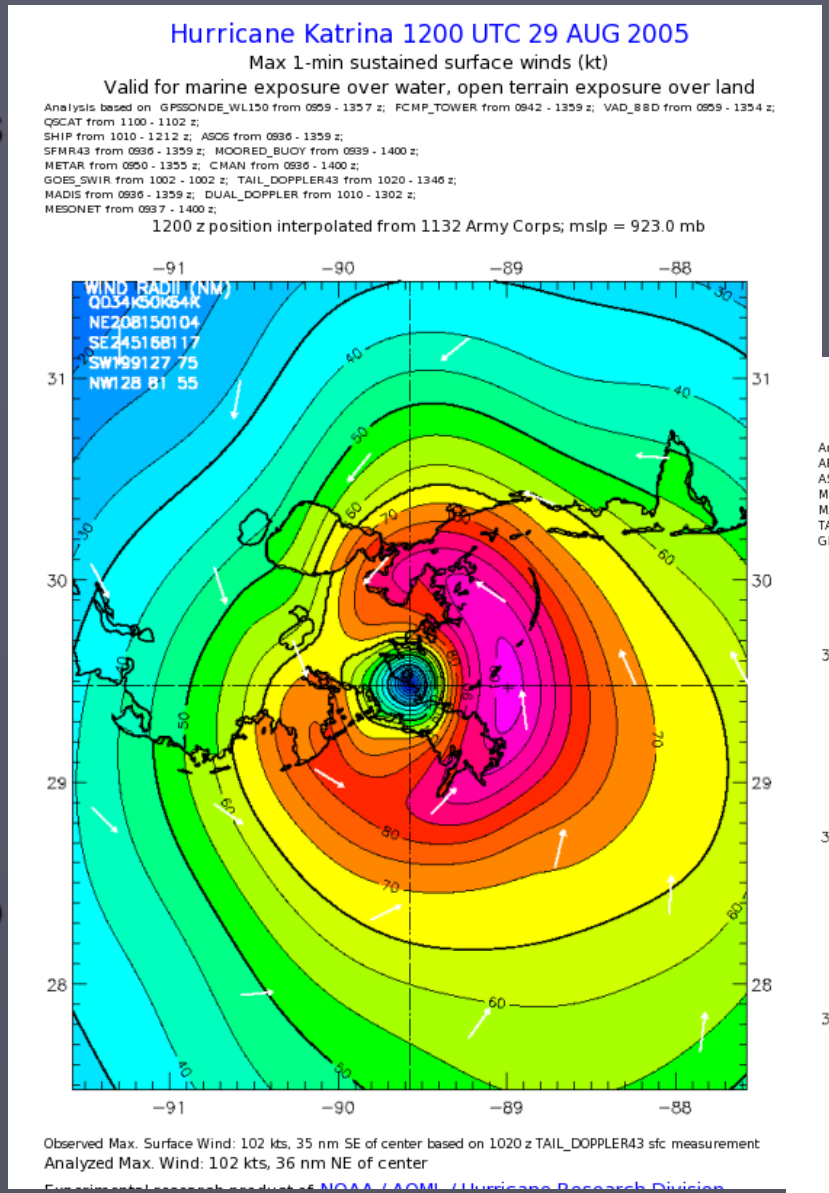
- Yes! NOAA aircraft Stepped Frequency Microwave Radiometer (SFMR) data shows an outer surface wind maximum up to 105 mph south of Pascagoula, directly within the outer eyewall and at nearly the same time as the Pascagoula dropsonde.

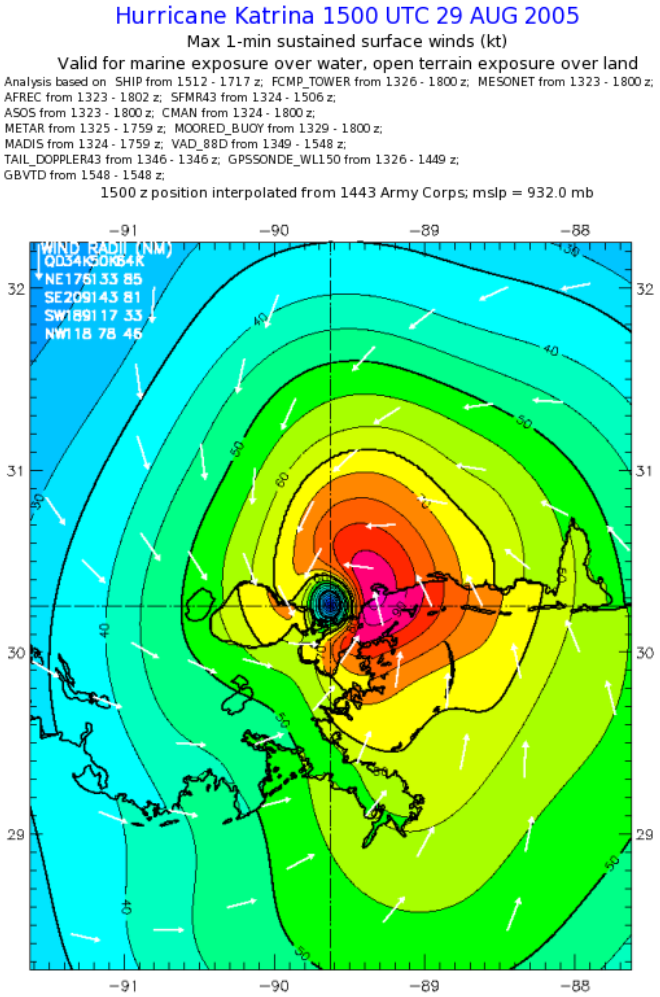
- HRD's H*Wind profile shows no such outer wind maximum.

Courtesy of Eric Uhlhorn (NOAA/AOML/HRD), Pat Fitzpatrick (Stennis/Miss State Univ.), and Ben Jelley (WorldWinds Inc.)



- Reconstructions of Katrina's wind field generally show only a single eyewall storm (i.e., a storm with only one RMW) making landfall.
- For instance, HRD's H*Wind analysis program fails to show a double eyewall structure in Katrina at landfall.





- Neither does the Corps of Engineer's IPET simulation
- Also, notice the likely erroneous decrease in radius of maximum wind (RMW) and storm size near landfall in Mississippi (similar to H*Wind).

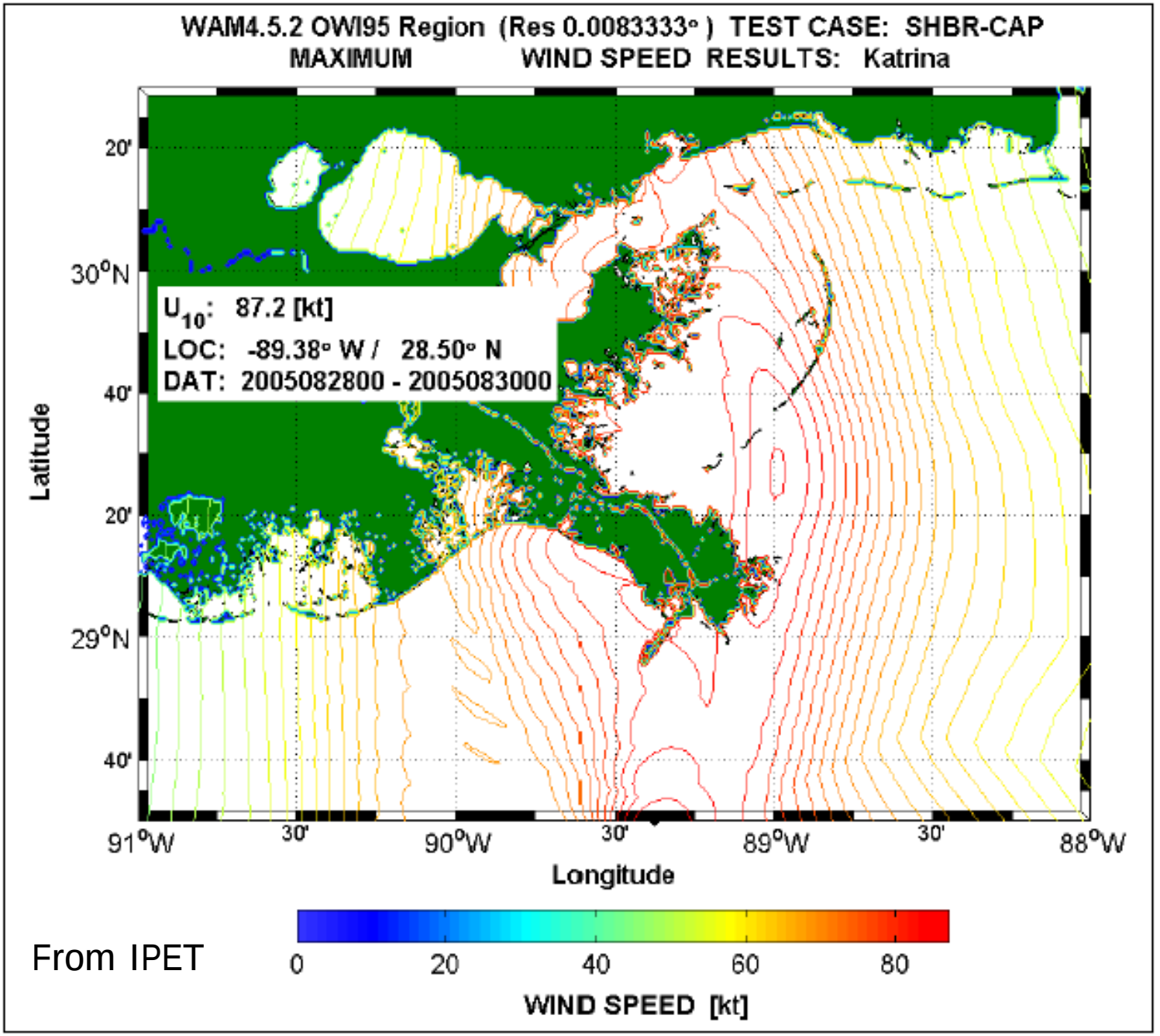


Figure 2-6. Wind speed maxima for the simulation period of Hurricane Katrina in the regional-scale domain.

We believe the IPET simulation (and possibly H*Wind) was confusing inner and outer eyewalls, resulting in rapid fluctuations in RMW near landfall.

These RMW fluctuations appear unrealistic.

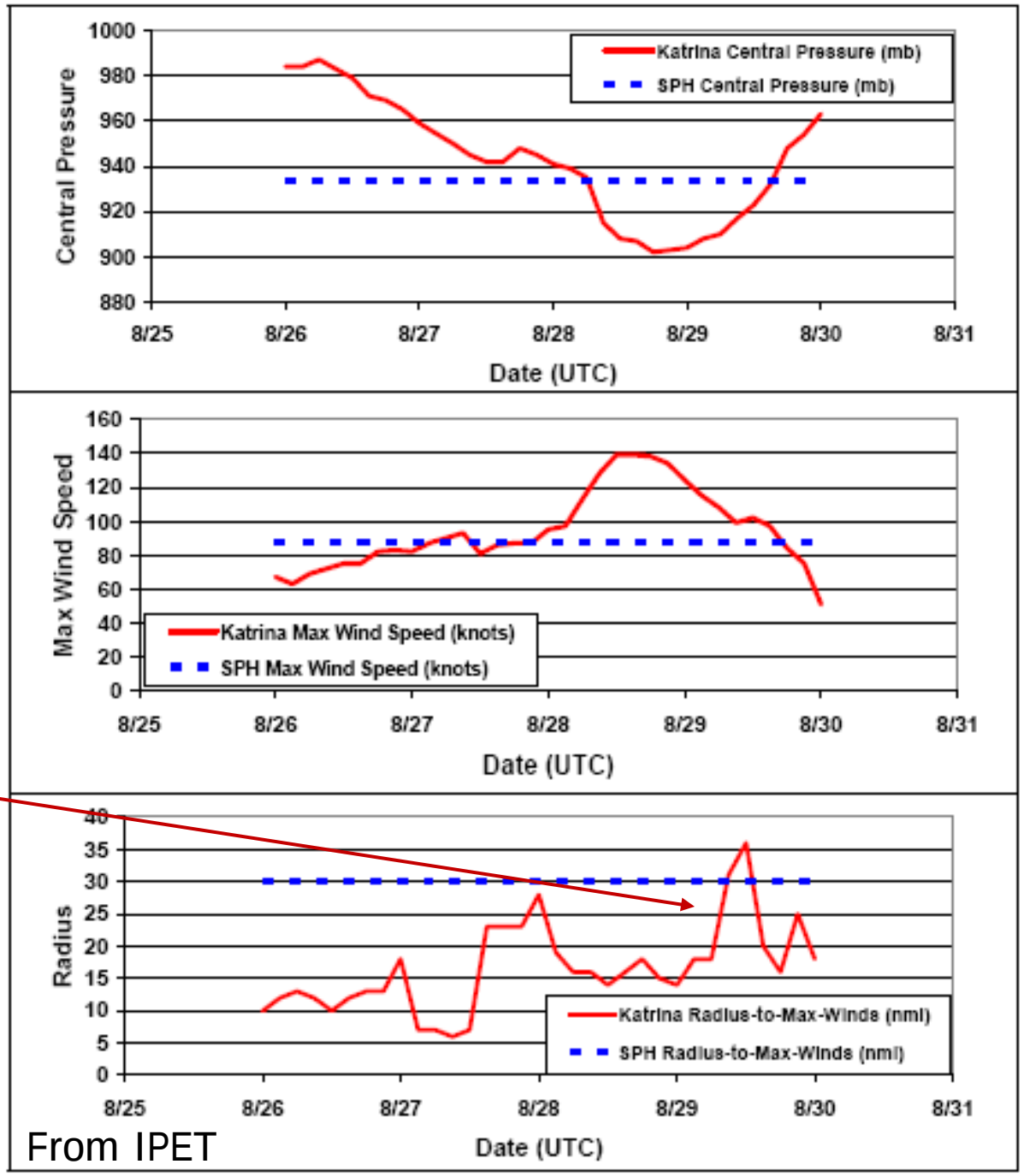
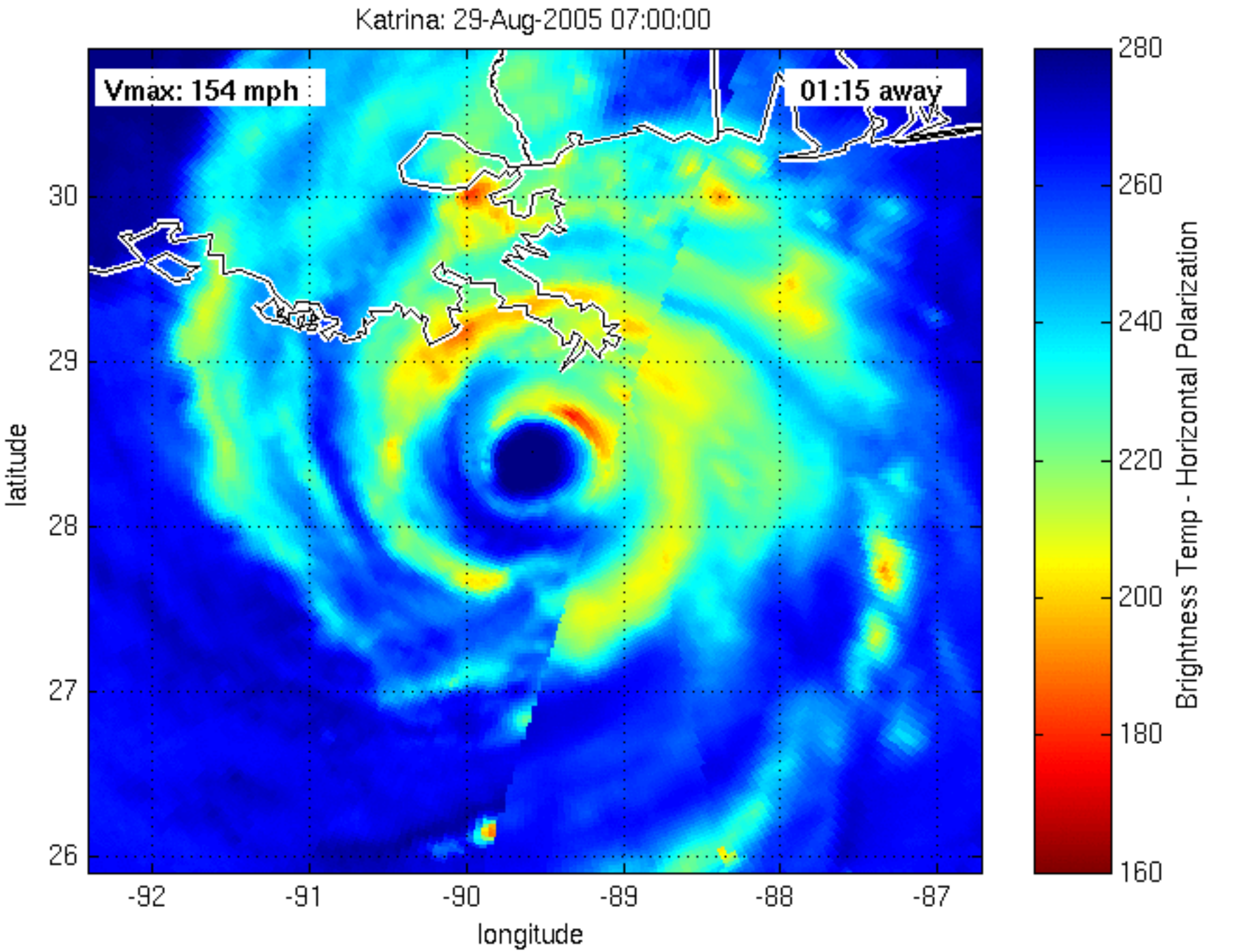


Figure 34. Comparison of Katrina and SPH storm parameters

Conclusions

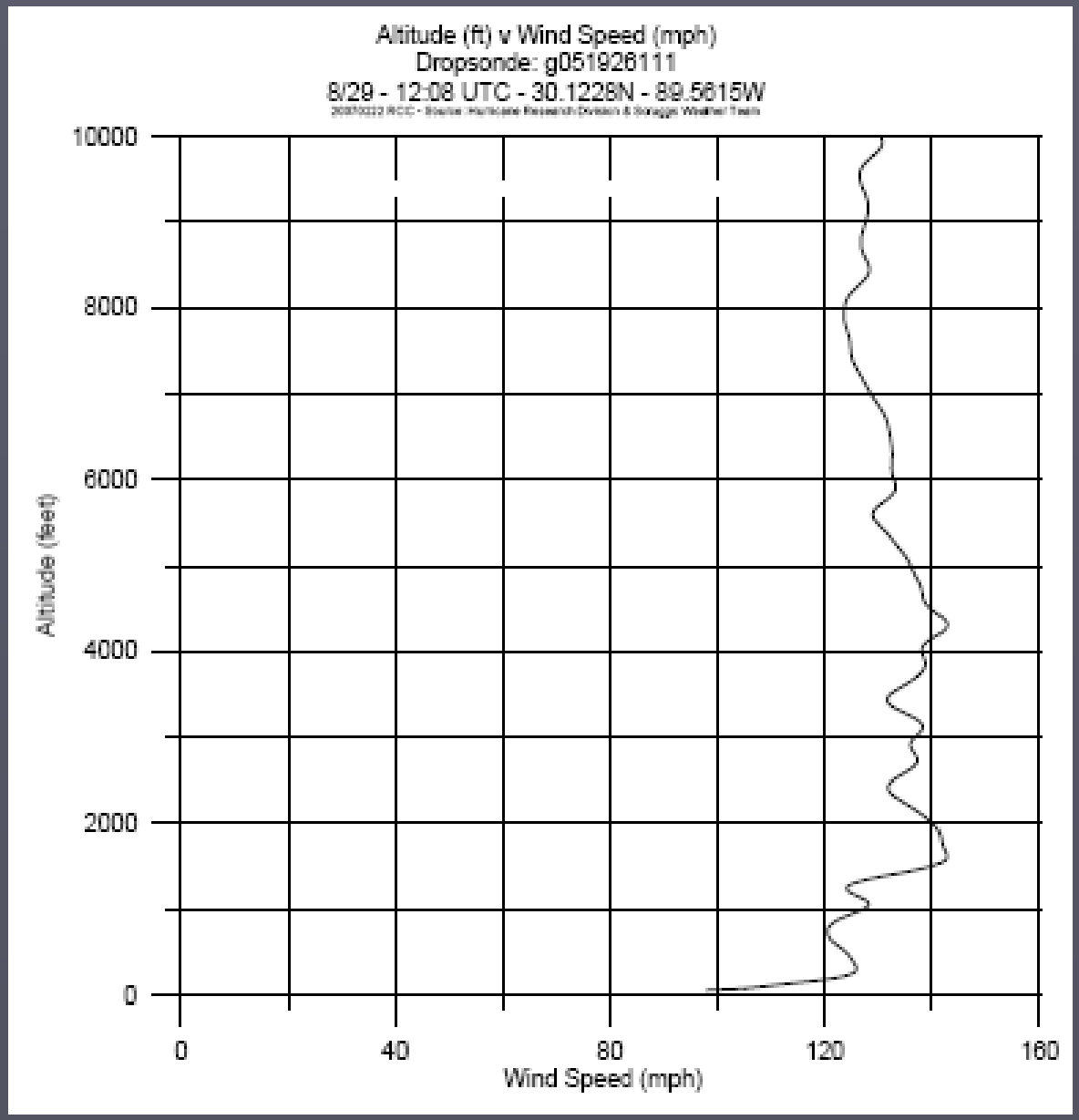
- The massive size of Katrina's wind field was a product of concentric (double) eyewall structure at and before landfall on the northern Gulf Coast.
- The strengthening of the outer eyewall reduced the maximum winds in the inner eyewall, thus allowing a 920-928 hPa storm to display only category 3 sustained winds at landfall.
- This double eyewall structure is not portrayed in most (if not all) storm re-constructions of Katrina's wind field at landfall.
- Virtually the entire Mississippi Coast suffered the impact of at least one eyewall in Katrina. Some locations received two eyewall impacts.
- The microwave satellite imagery shows potential for identifying regions in the hurricane containing strong sustained winds and gusts.
  - (based on comparisons with dropsondes, radar, SFMR, and some surface observations [not shown]).
  - Microwave and MIMIC imagery can provide an important operational nowcast tool for identifying eyewalls and regions of strong surface winds within hurricanes.


Katrina: 29-Aug-2005 07:00:00
Vmax: 154 mph
01:15 away
30
29
28
27
26
latitude
-92
-91
-90
-89
-88
-87
longitude
280
260
240
220
200
180
160
Brightness Temp - Horizontal Polarization

Slides Not Used, but kept for potential questions.

South of Pearlington MS Dropsonde in Outer Eyewall

(Courtesy Hurricane Research Division)



Surface Wind Estimates in the Outer Eyewall over Water

- Per Franklin et al. 2003, NHC Operational Procedures, and Franklin personal communication (March 2007), a surface (10 m) sustained wind can be estimated near Pearlington/Waveland from the dropsonde (g051926111) by averaging the winds over a 150 m layer centered on the following levels:

- Method 1) 90% of 700 hPa wind
  - 90% of 128 mph at 700 hPa (9017 feet) = 115 mph at 10 m.

- Method 2) 80% of 850 hPa wind
  - 80% of 135 mph at 850 hPa (3567 feet) = 108 mph at 10 m.

- Method 3) Midpoint percent of the lowest 150 m of wind reports in dropsonde
  - 83.8% of 121 mph at 95 m (301 feet) = 101 mph at 10 m.

- These estimates represent sustained 1 minute wind estimates. Thus, mid-to high category 2 sustained winds were likely in the outer eyewall in the vicinity of Pearlington/Waveland shortly after 7 am CDT.

- Slidell NWS Doppler also supports winds near the speeds shown in outer eyewall dropsondes.

- What were the gusts in this outer eyewall?