An aerial photograph of a hurricane, showing the distinct eye and the surrounding inner core structure. The clouds are dense and white, with a clear blue center. The overall image is in grayscale.

Inner Core Structures and Intensity Change Simulated with the Advanced Hurricane WRF Model

Kristen L. Corbosiero

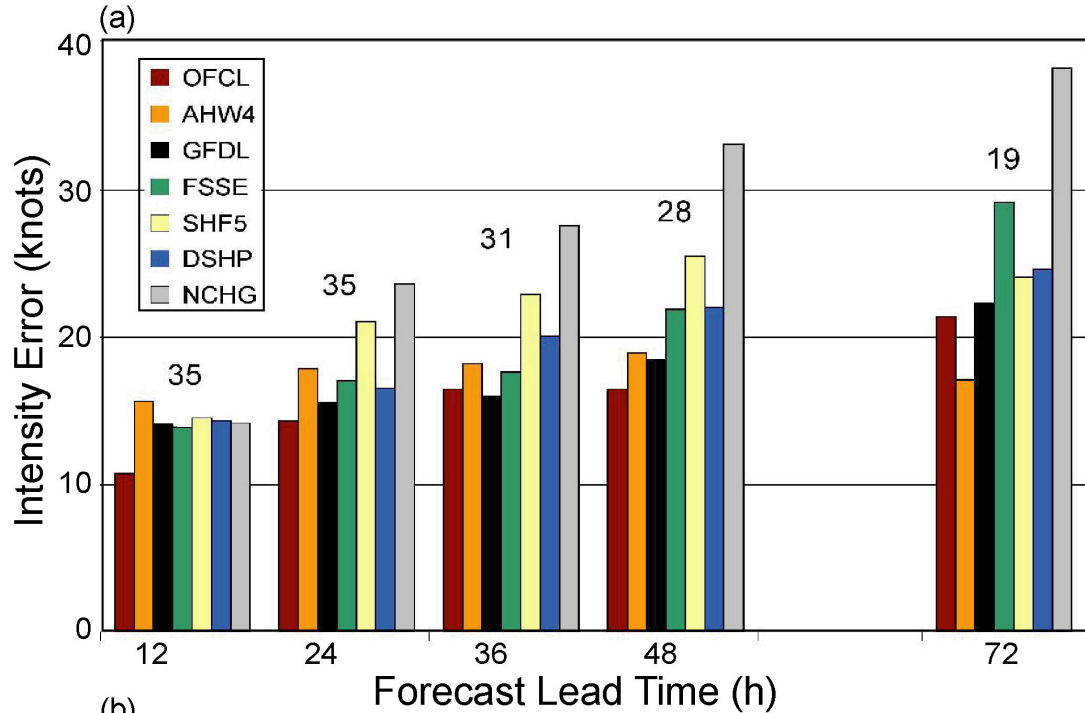
University of California, Los Angeles

Wei Wang, James Done, and Chris Davis

National Center for Atmospheric Research

The Advanced Hurricane WRF

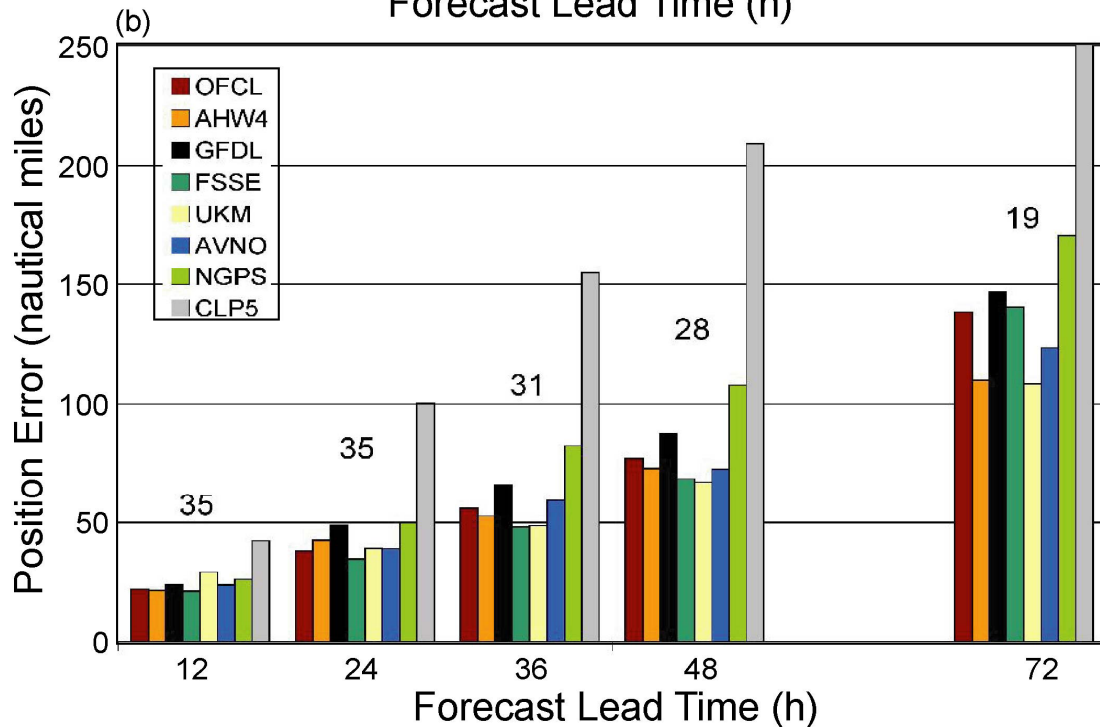
- Run in real-time at NCAR since 2004
- Two or three domains (12, 4, 1.33 km) with two-way moveable nests that follow the hurricane center
- Initialized from the Geophysical Fluid Dynamics Laboratory (GFDL) model at 00 UTC and/or 12 UTC
- Kain-Fritsch cumulus parametrization (12 km only), WSM3(5) microphysics, YSU planetary boundary layer scheme, drag (Donelan) and surface enthalpy coefficients (Carlson-Boland) for TCs
- Available on the web at http://www.wrf-model.org/plots/realtime_main.php



2005 performance
Seven tropical cyclone
forecast systems

AHW4
AHWRF 4 km

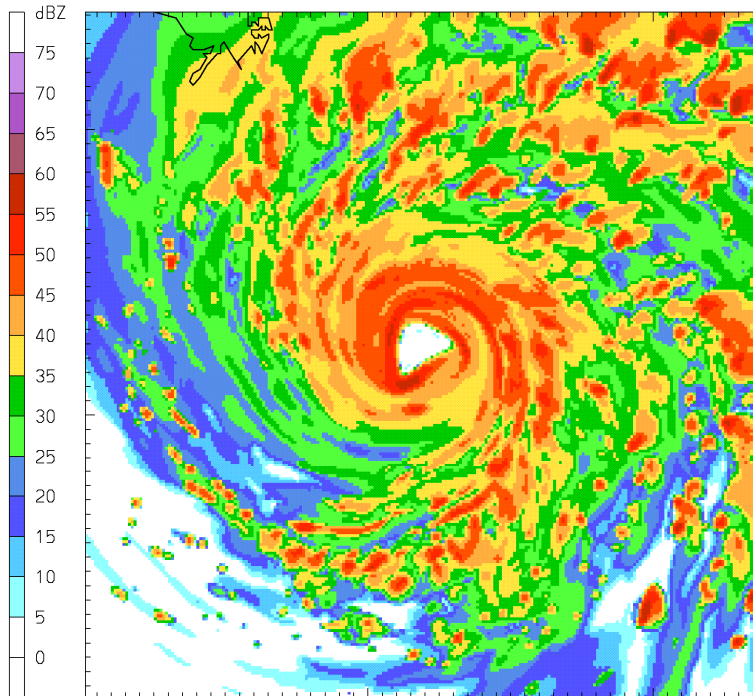
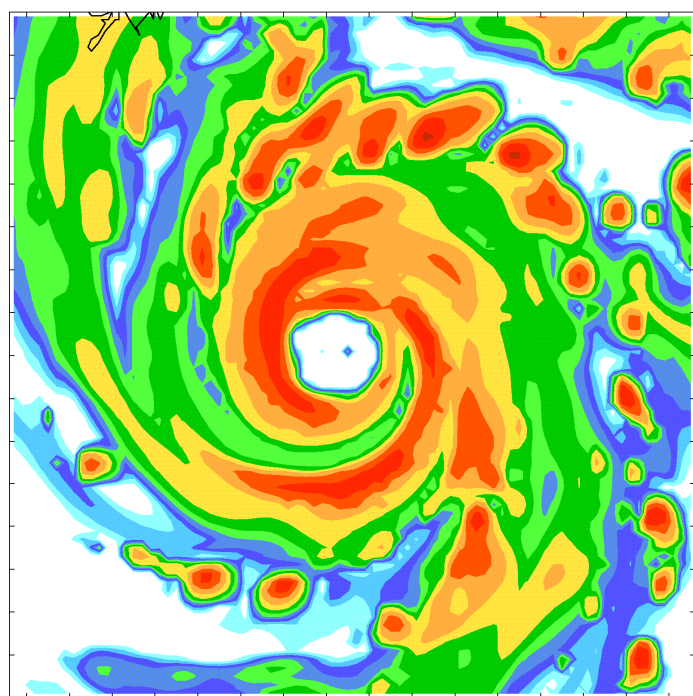
OFCL
National Hurricane
Center official



GFDL
Geophysical Fluid
Dynamics Laboratory

FSSE
Florida State
Super Ensemble

Davis et al. (2008)



320 km

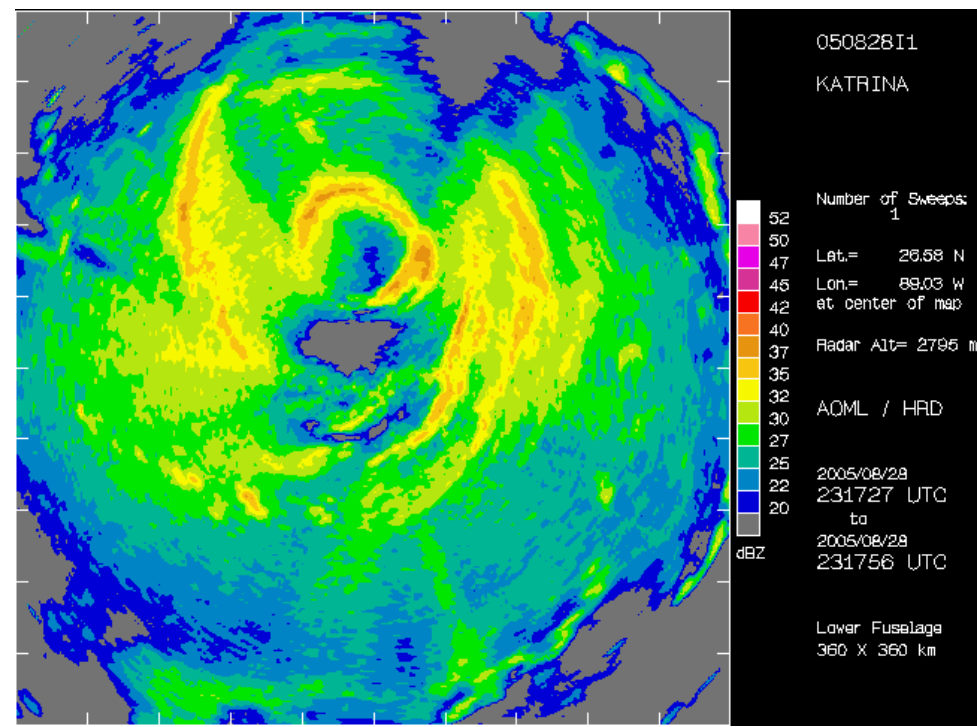


Katrina 2005 Radar Reflectivity

~00 UTC 29 August

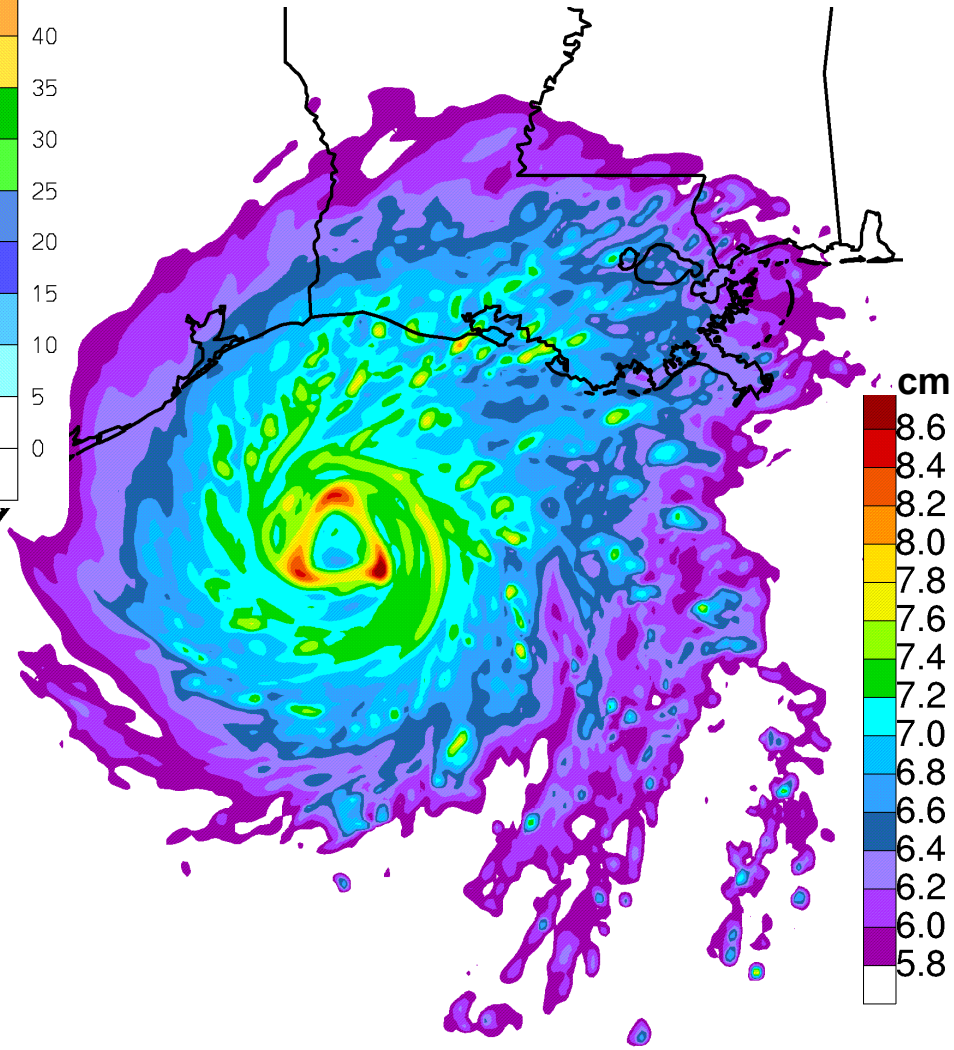
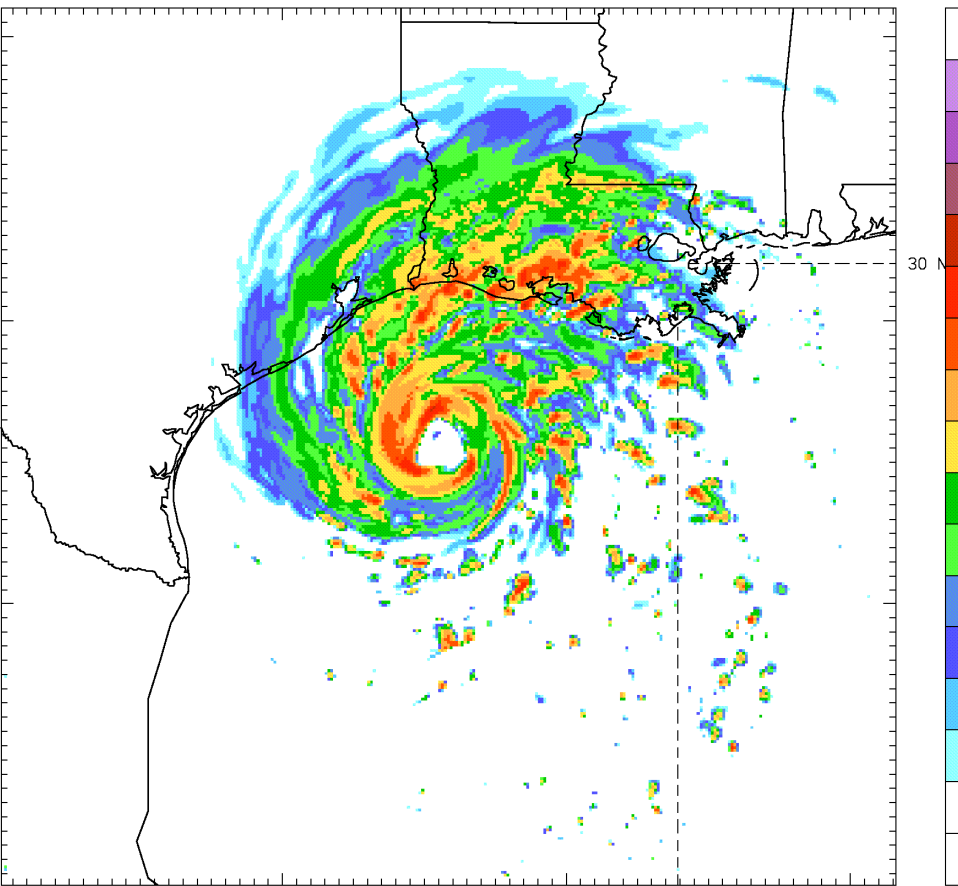
Top: AHWRF 4 km (left),
1.33 km (right)

Right: NOAA P3 LF radar



Hurricane Rita

**03 UTC 24 September
39 hr forecast**



**Column maximum
reflectivity**



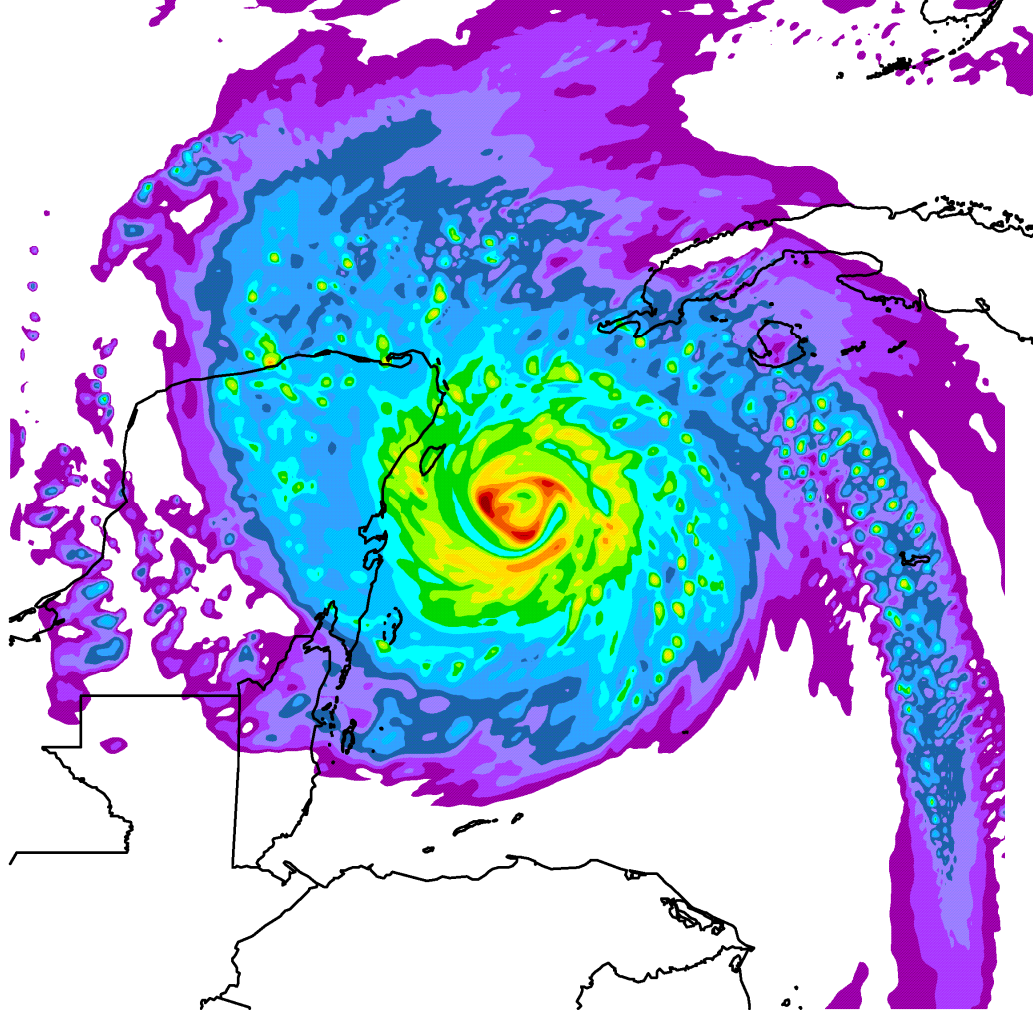
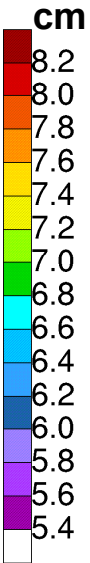
AHWRF 4 km

Precipitable water

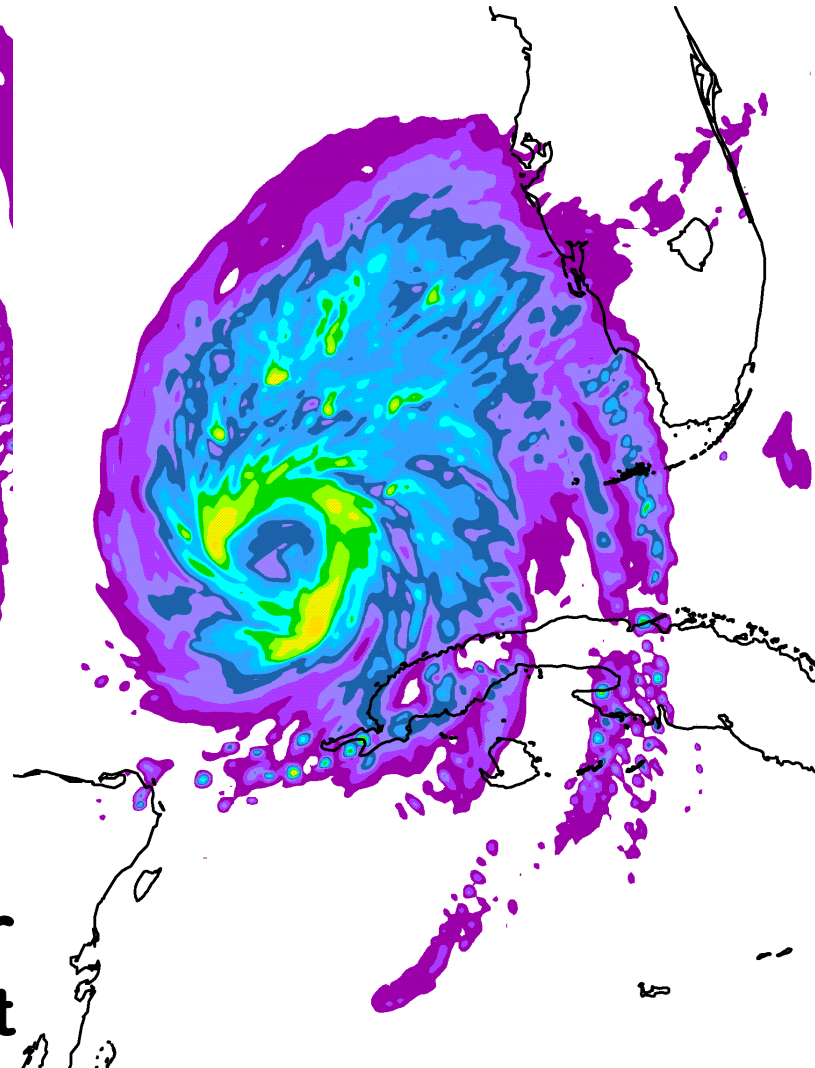


Hurricane Wilma

4 km Precipitable water

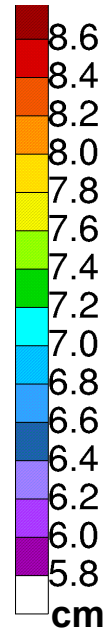
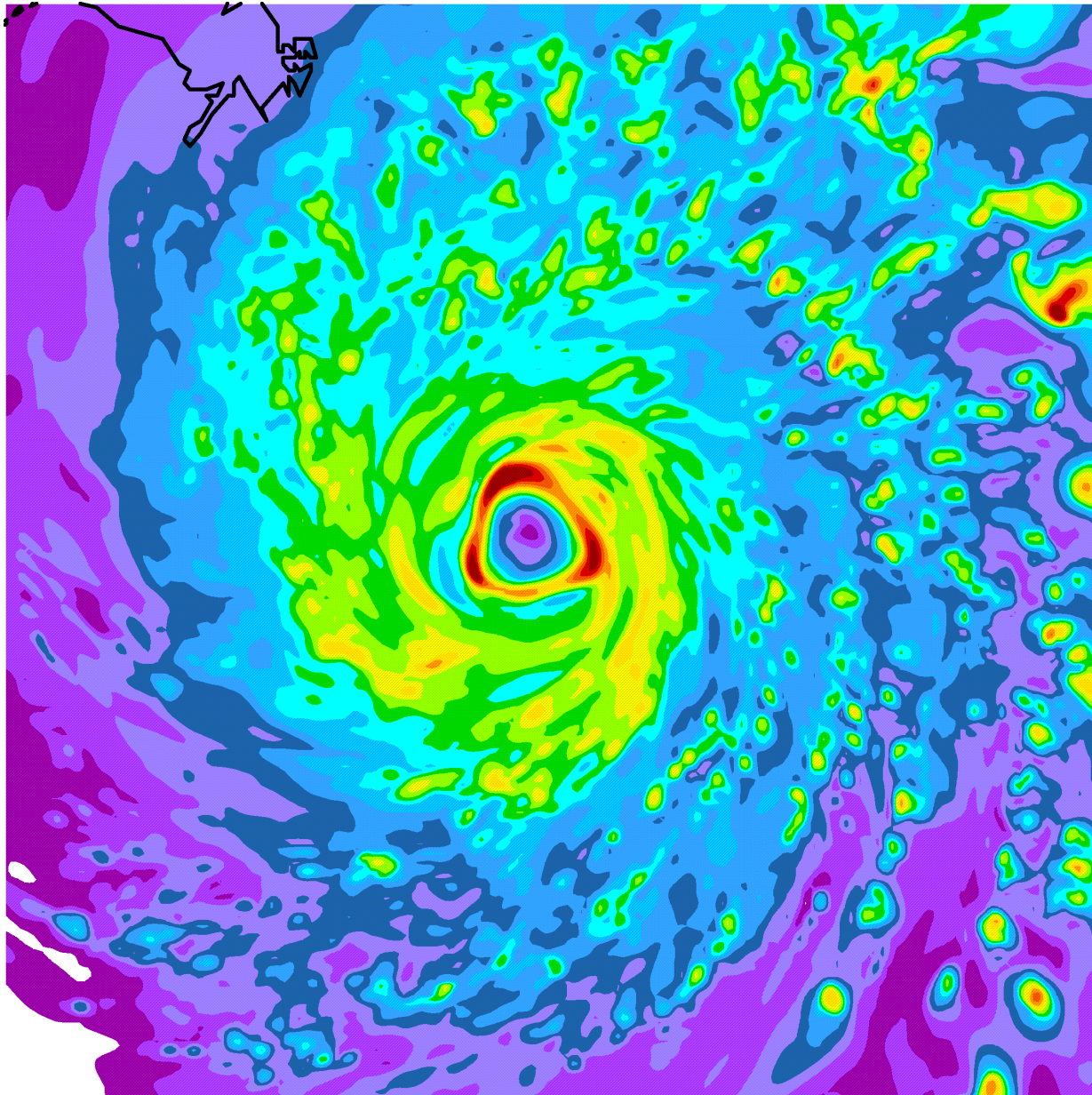


22 UTC 20 October
22 hr forecast

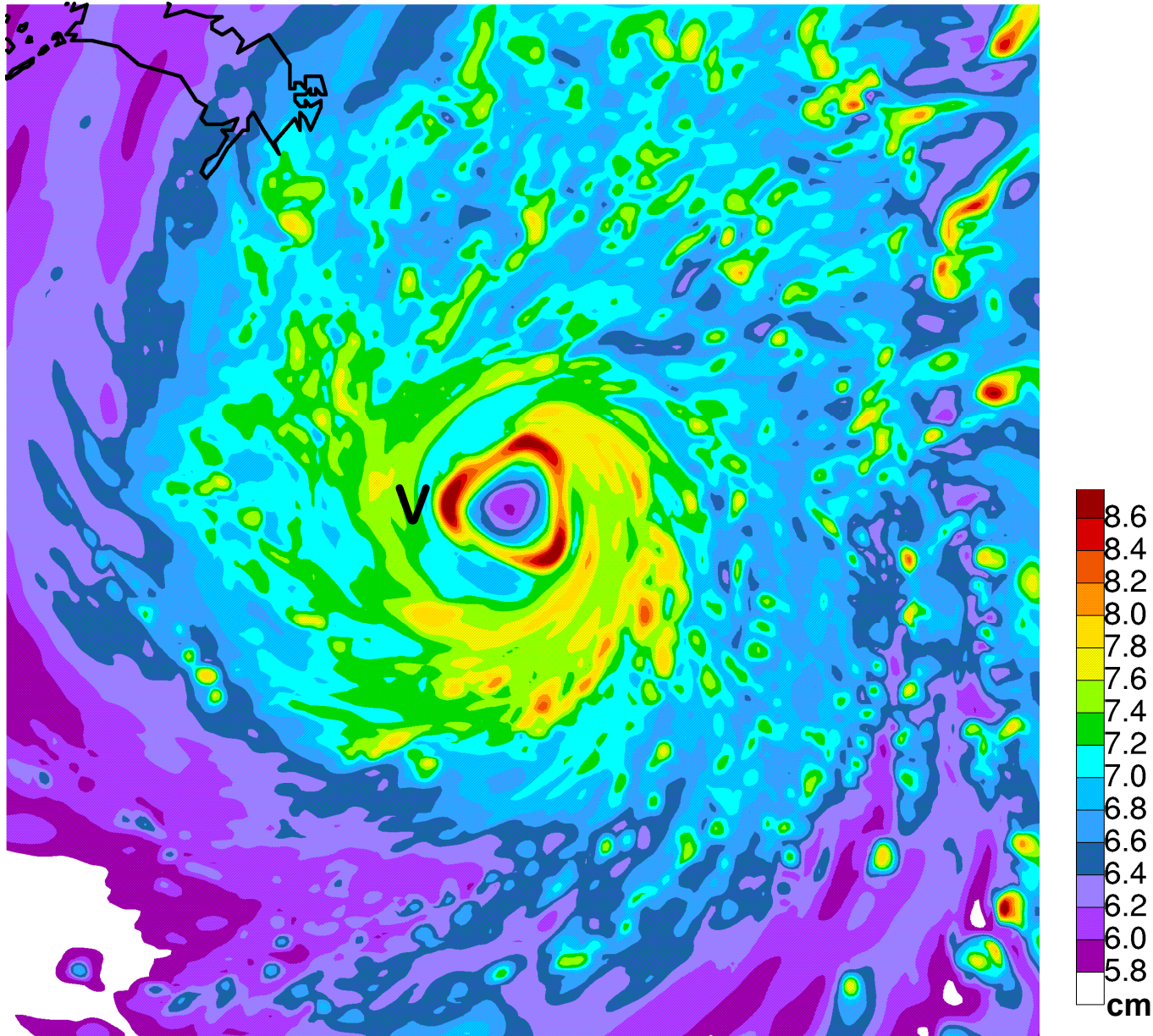


05 UTC 24 October
77 hr forecast

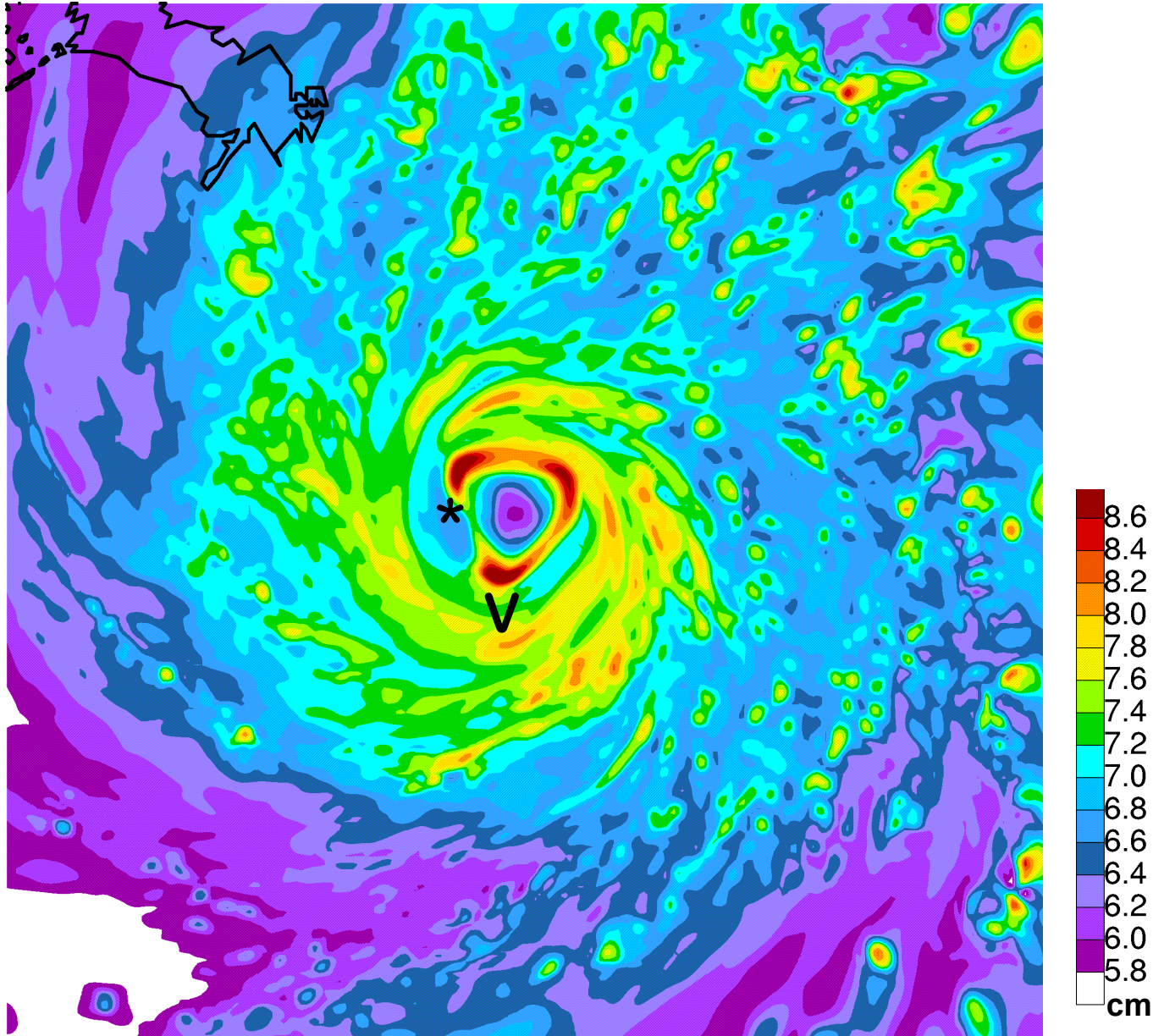
**Katrina 2005 Precipitable water AHWRF 1.33 km
01 - 03 UTC 8/29 (every 10 min)**



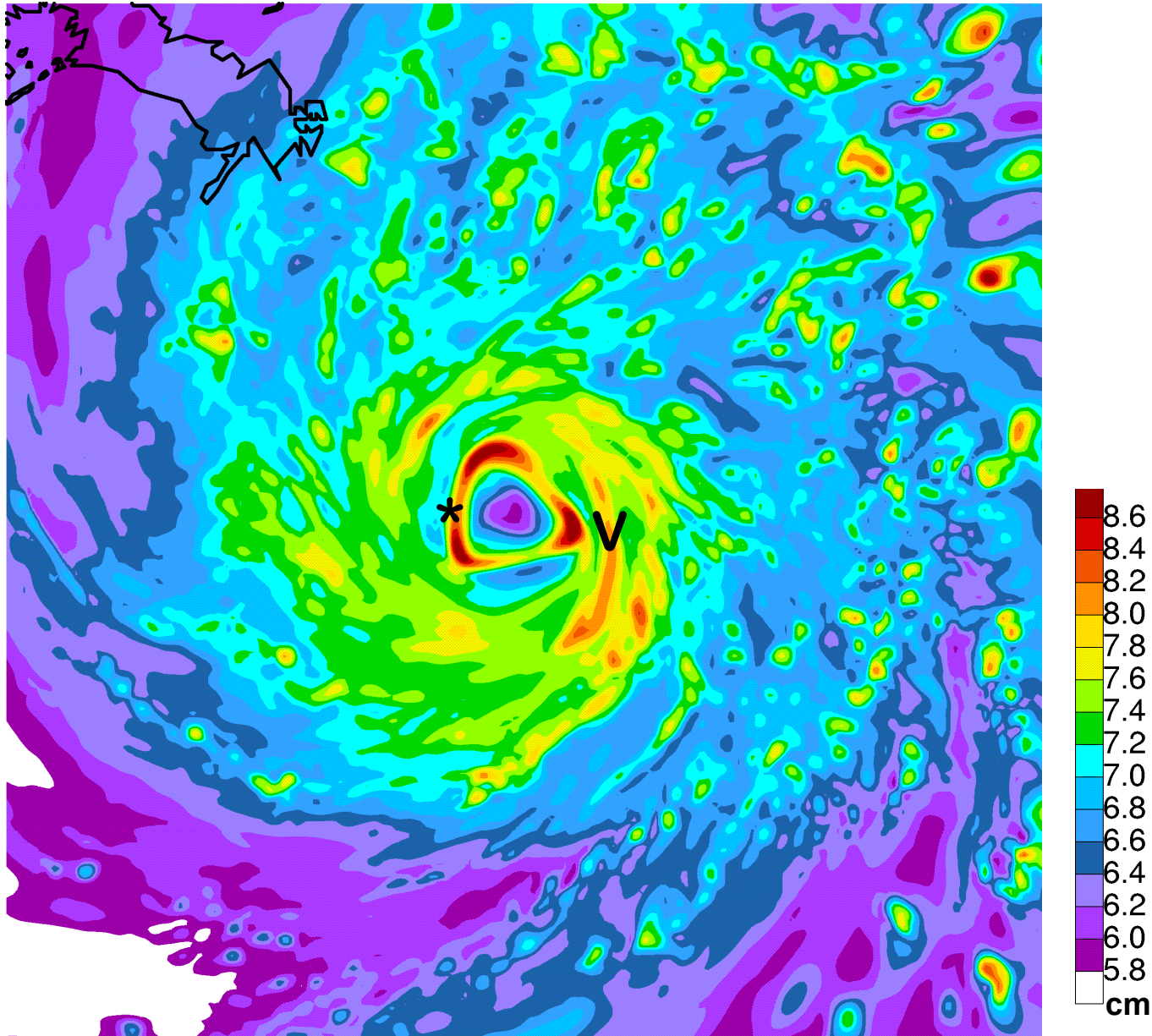
**Katrina Precipitable water AHWRF 1.33 km
0140 UTC 8/29**



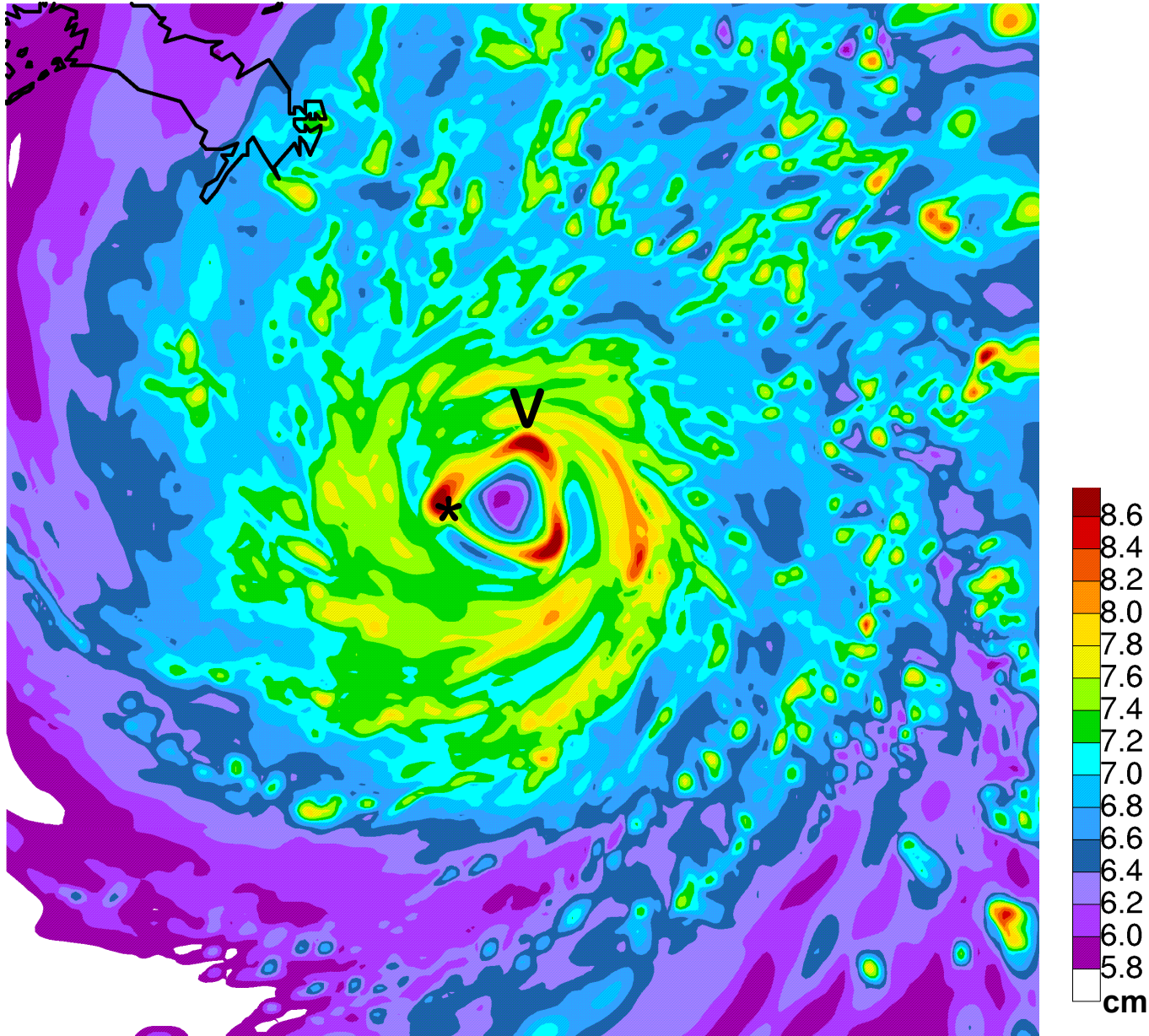
**Katrina Precipitable water AHWRF 1.33 km
0150 UTC 8/29**



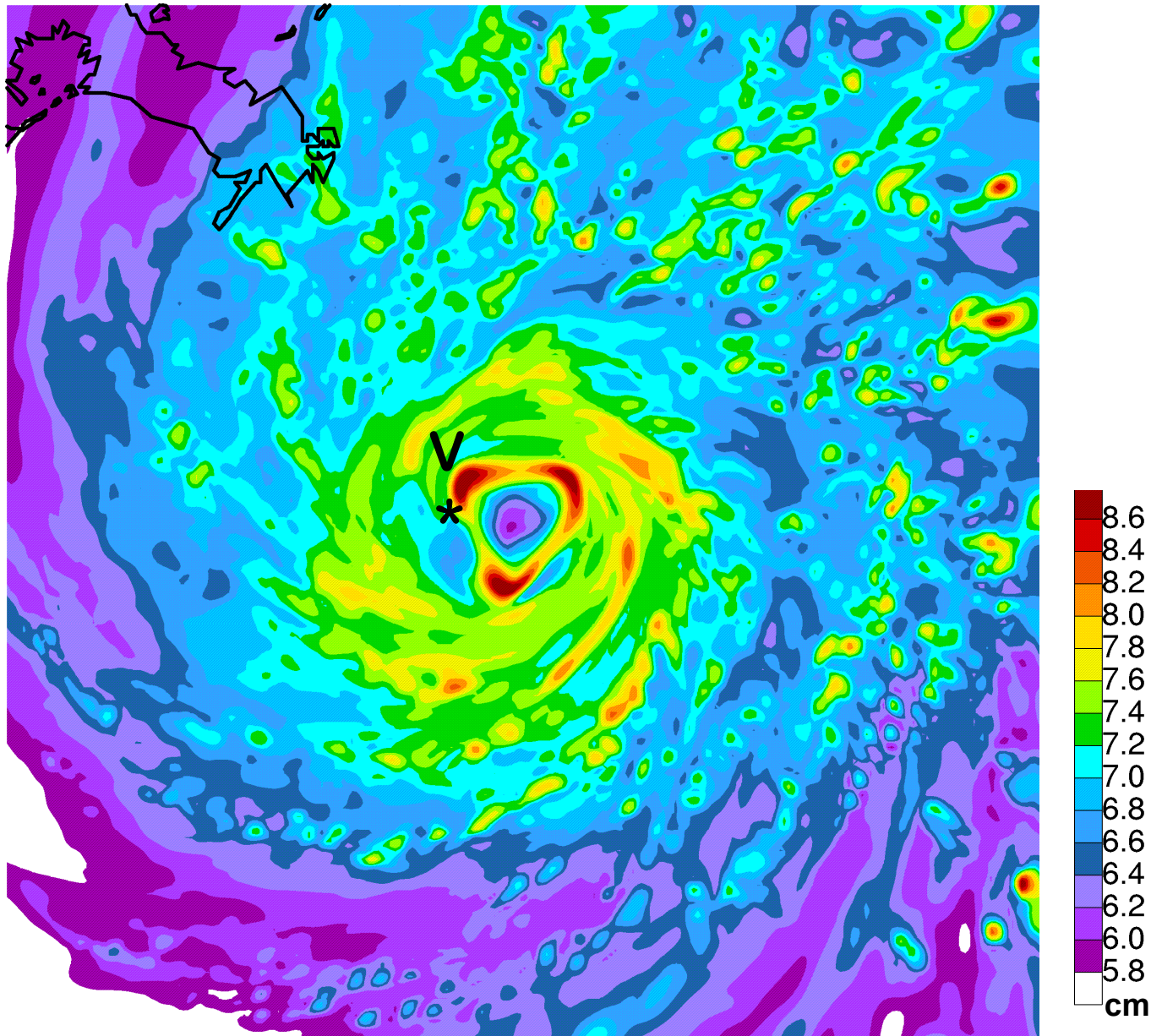
**Katrina Precipitable water AHWRF 1.33 km
0200 UTC 8/29**



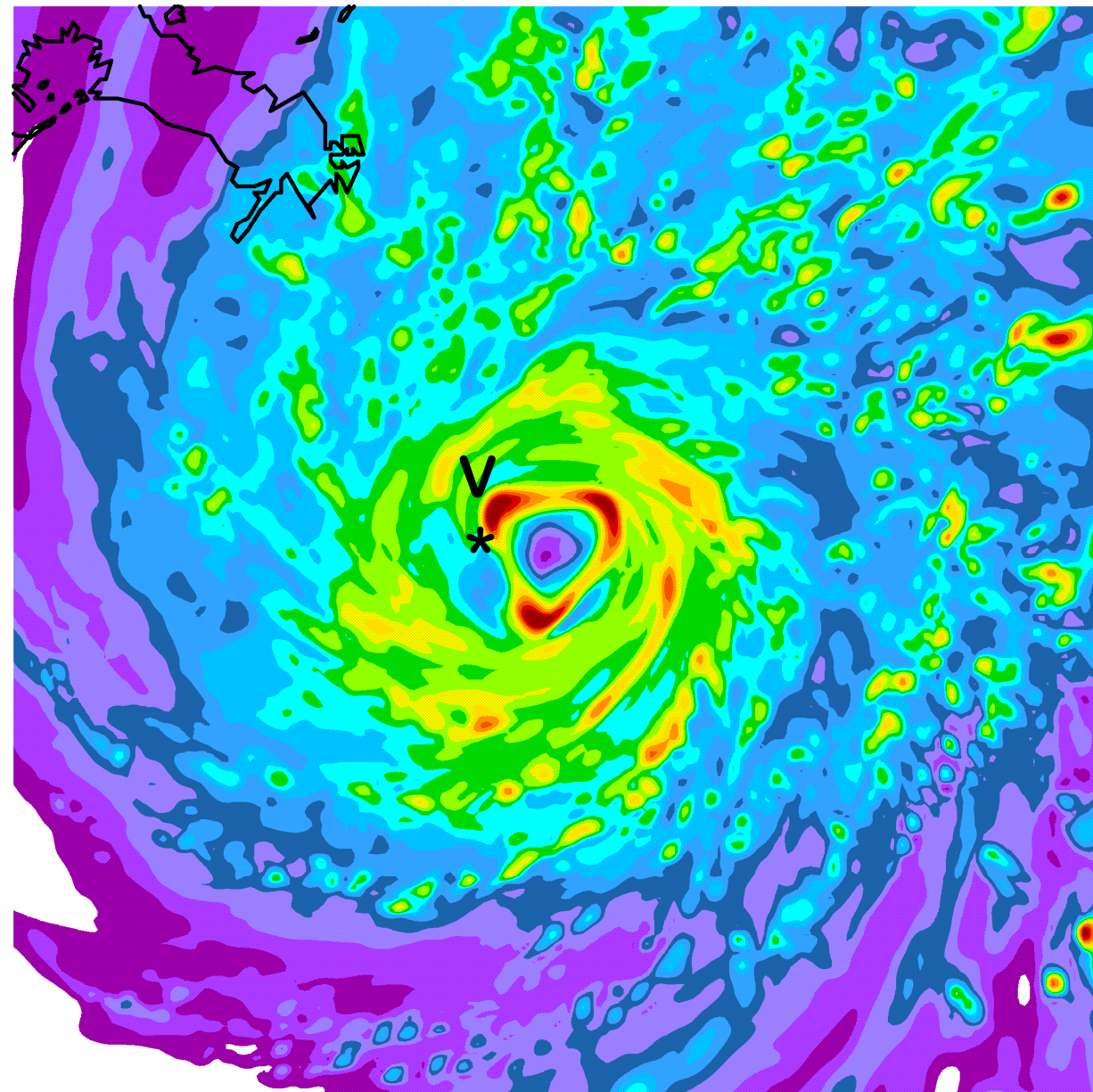
**Katrina Precipitable water AHWRF 1.33 km
0210 UTC 8/29**



**Katrina Precipitable water AHWRF 1.33 km
0220 UTC 8/29**



**Katrina Precipitable water AHWRF 1.33 km
0220 UTC 8/29**



**The vortex
completed one full
rotation in just over
40 minutes.**

Radius ~ 20 km

$$C_v \sim 50 \text{ m s}^{-1}$$

**Consider the vortex
to propagate like a
PV edge wave:**

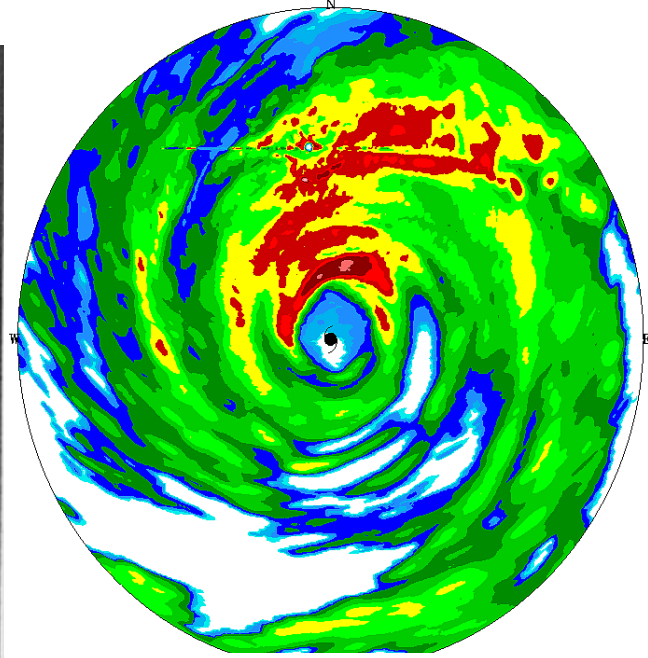
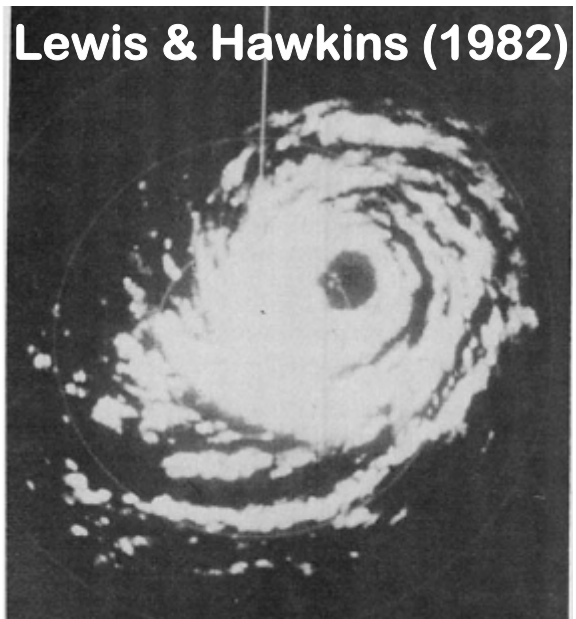
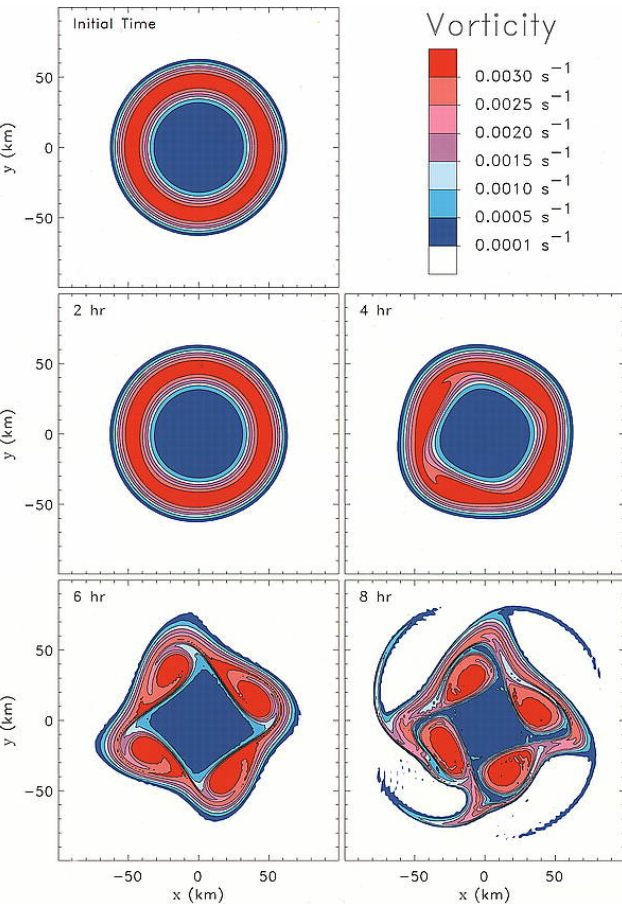
$$C_\lambda = V_{\max}(1 - 1/n)$$

n = wavenumber (3)

$$V_{\max} \sim 70 \text{ m s}^{-1}$$

$$C_\lambda \sim 47 \text{ m s}^{-1}$$

(Lamb 1932)

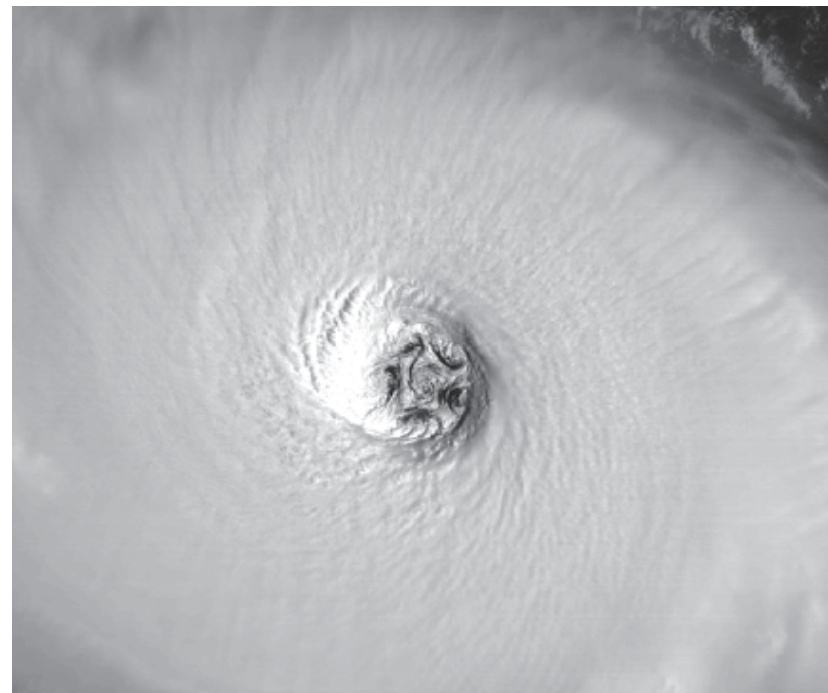
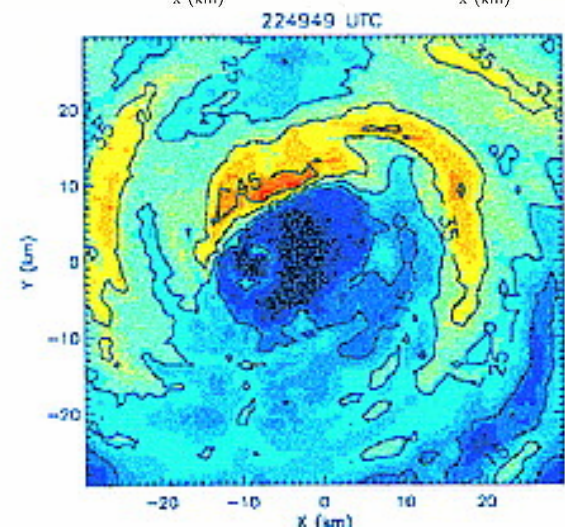


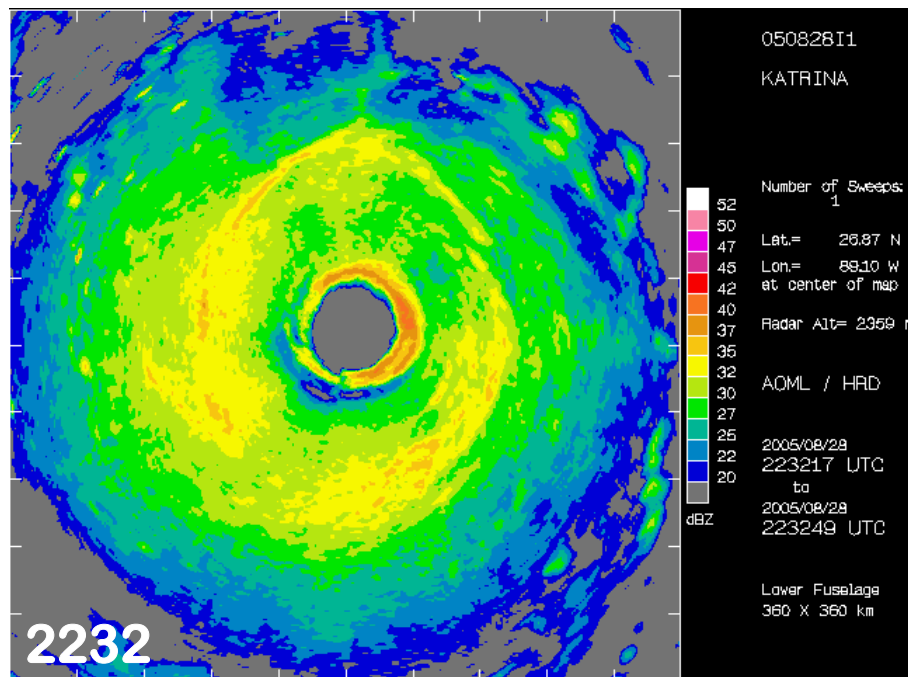
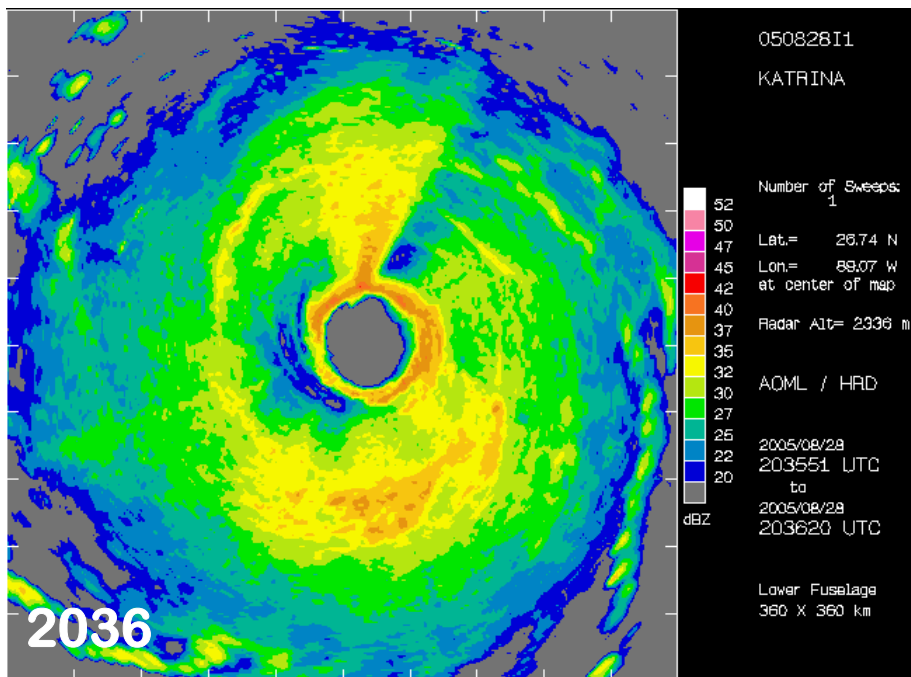
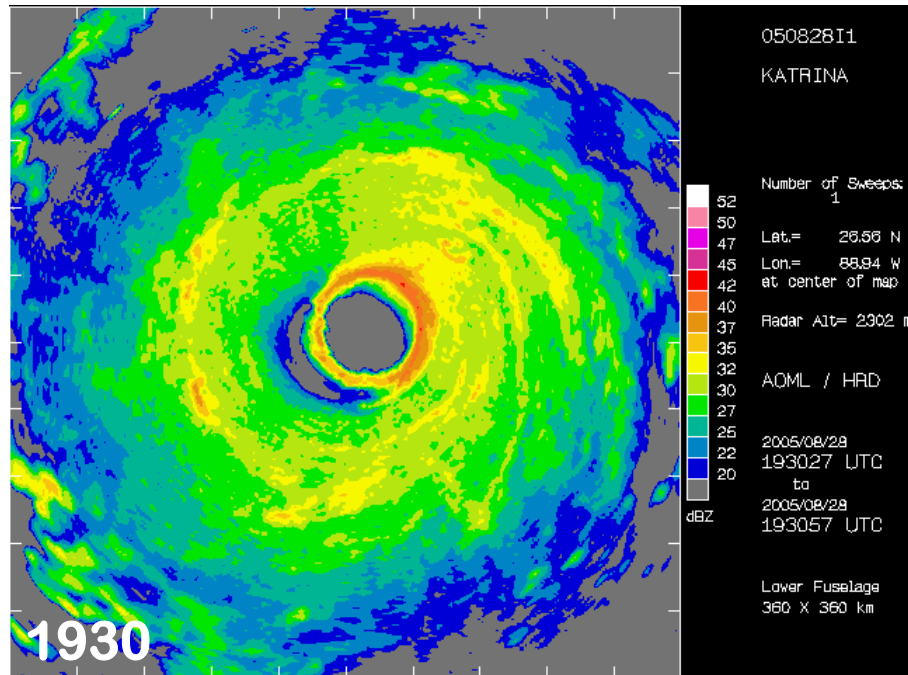
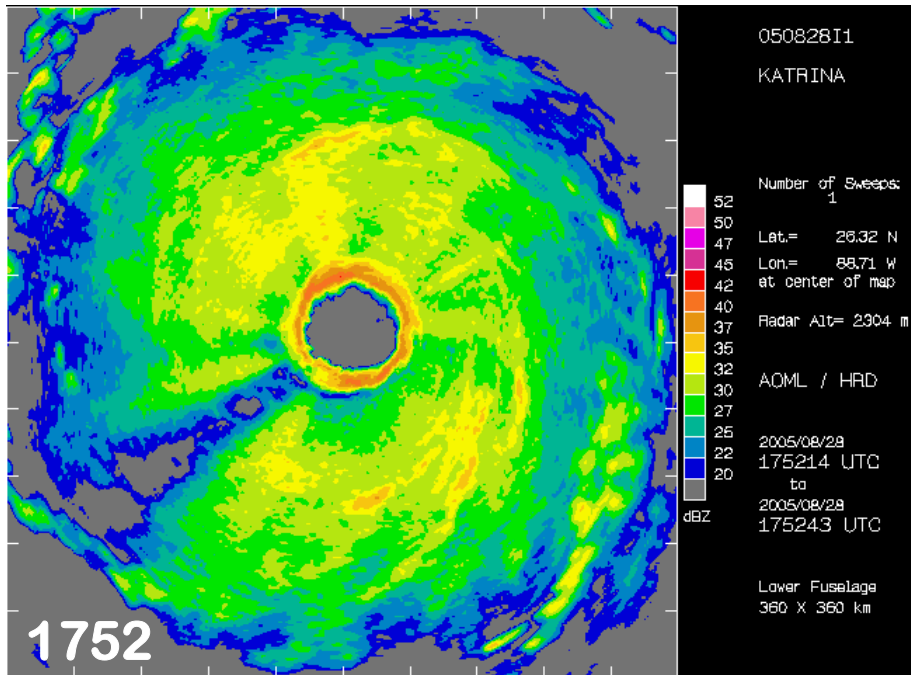
Corbosiero et al. (2006)

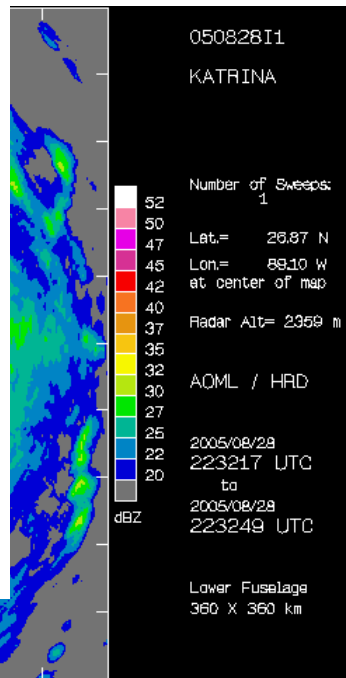
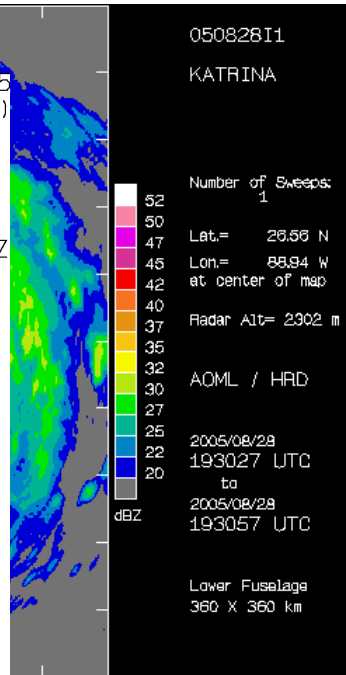
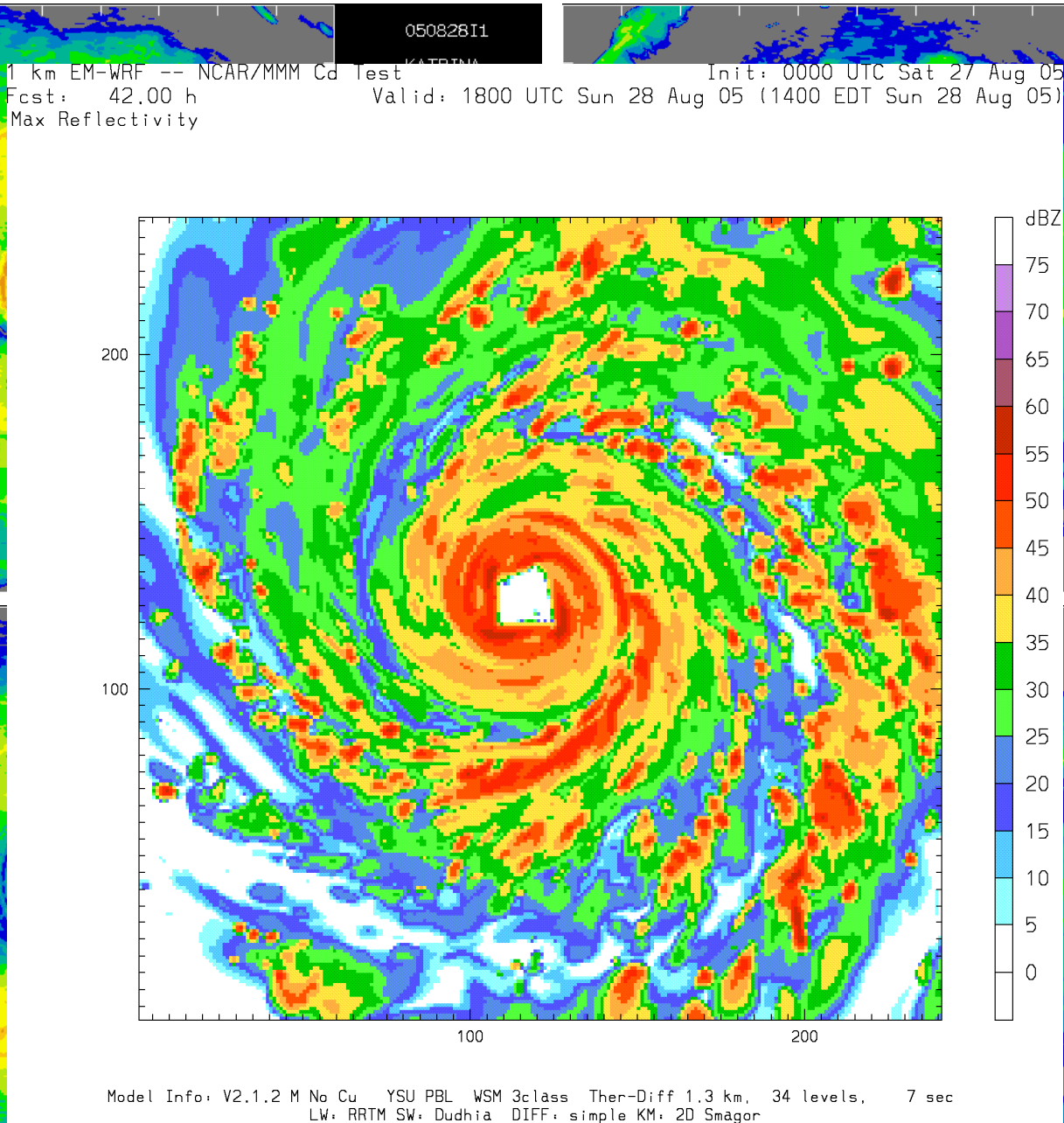
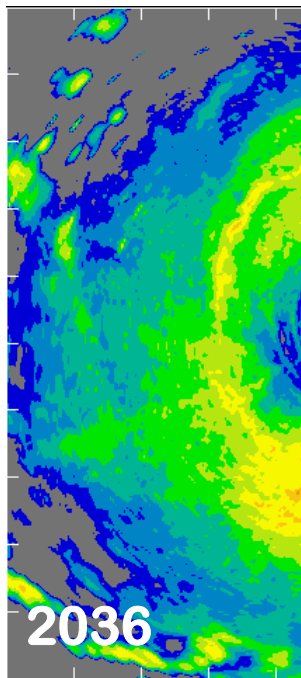
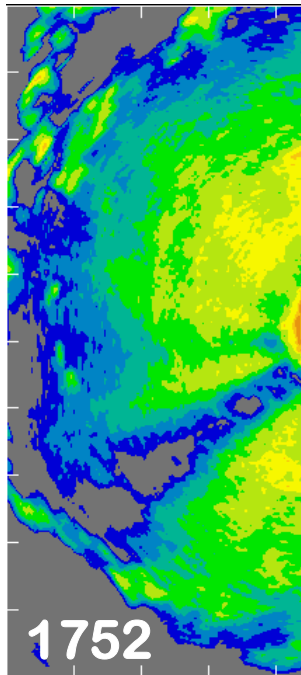
Schubert et al. (1999)

Reasor et al. (2000)

Kossin & Schubert (2004)







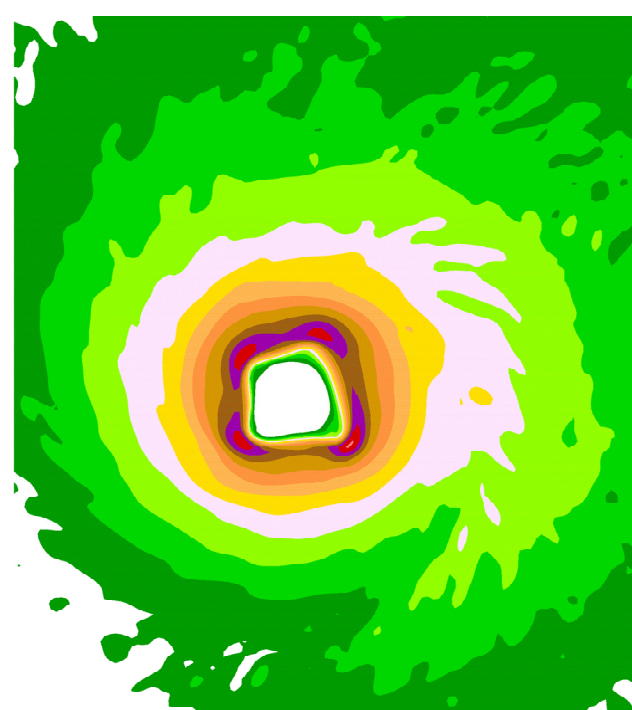
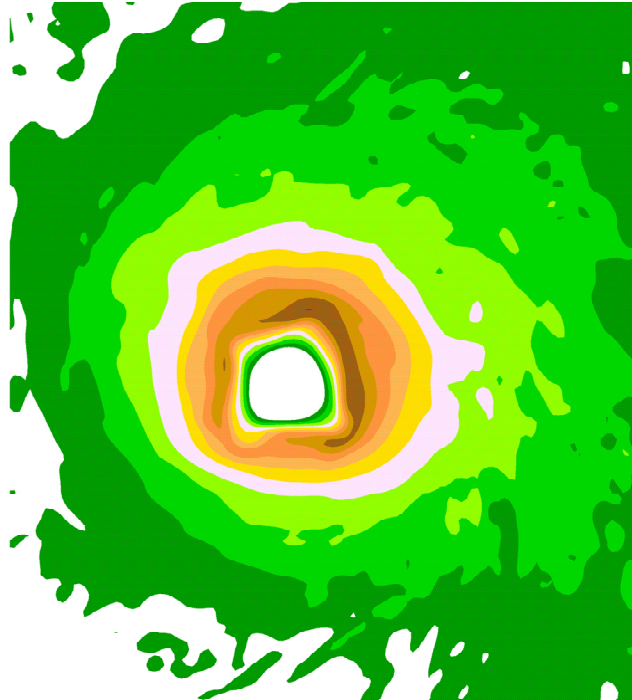
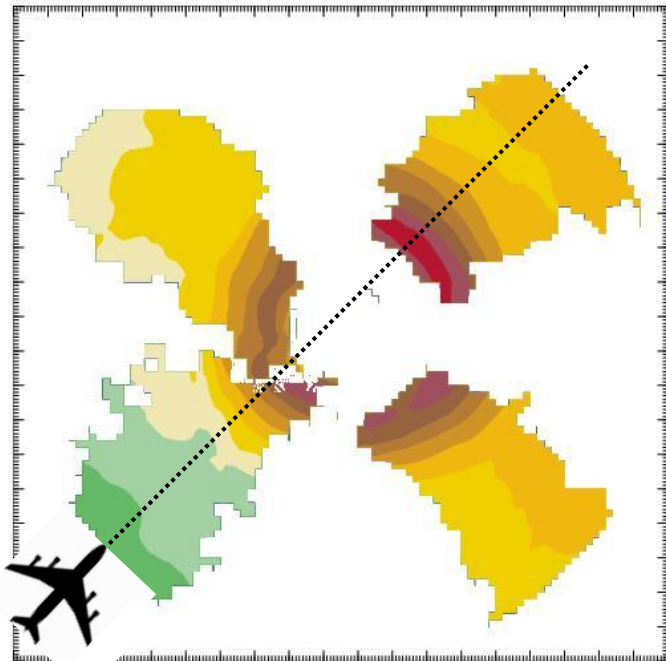
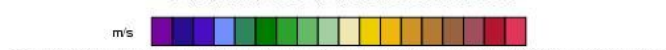
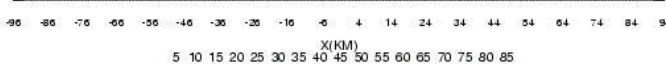
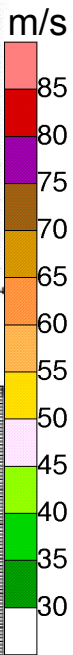
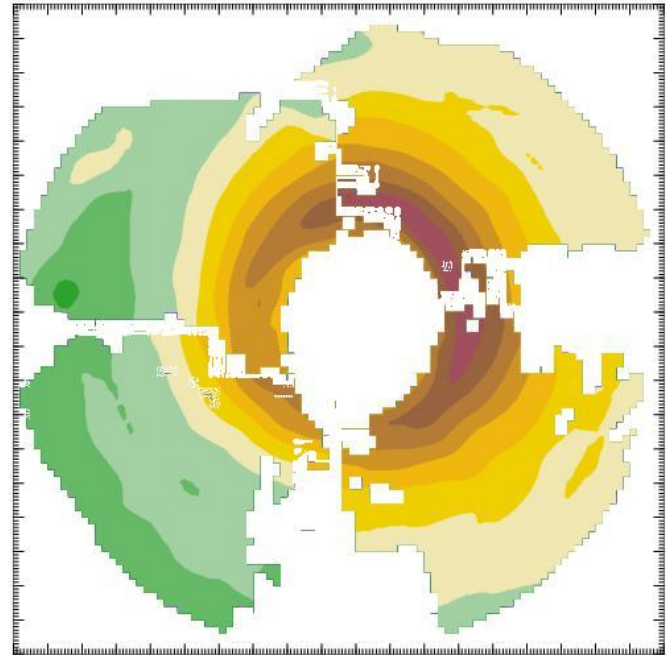
050828I1
KATRINA
Number of Sweeps: 1
Lat.= 26.56 N
Lon.= 88.94 W
at center of map
Radar Alt.= 2302 m
AOML / HRD
2005/08/28
193027 UTC
to
2005/08/28
193057 UTC
Lower Fuselage
360 X 360 km

050828I1
KATRINA
Number of Sweeps: 1
Lat.= 26.87 N
Lon.= 89.10 W
at center of map
Radar Alt.= 2359 m
AOML / HRD
2005/08/28
223217 UTC
to
2005/08/28
223249 UTC
Lower Fuselage
360 X 360 km

Katrina Wind speed

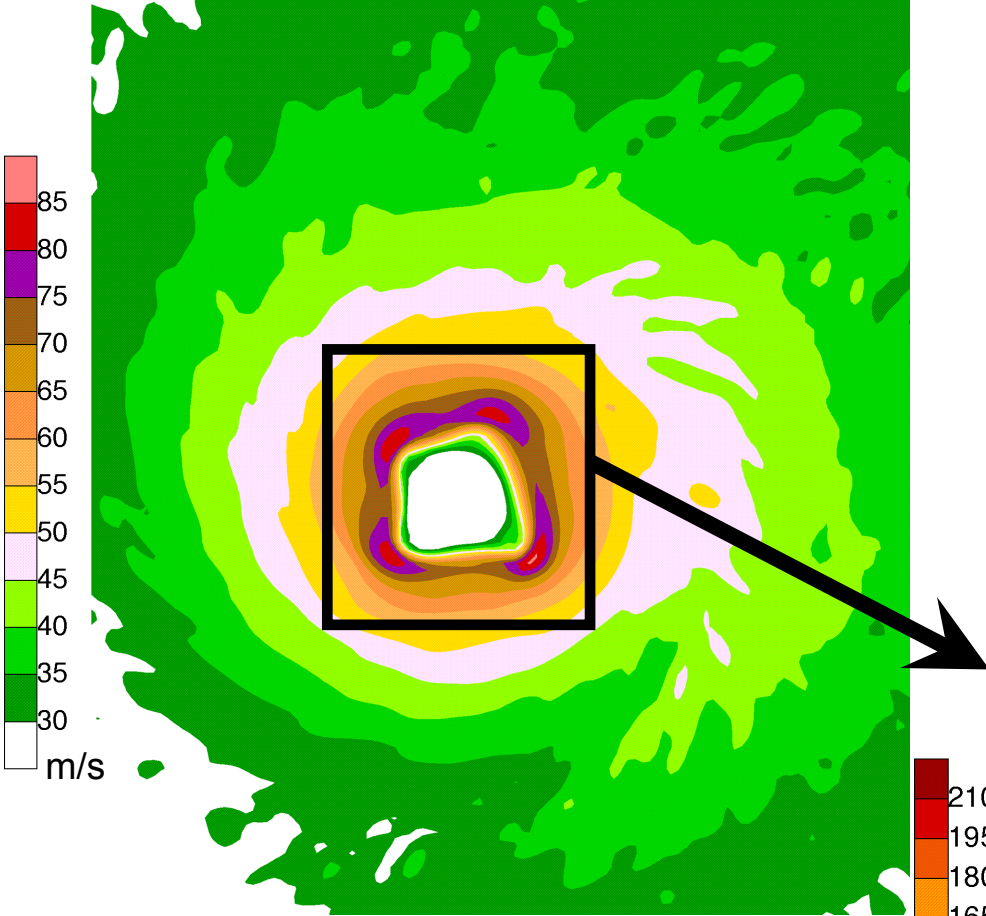
Left:
Dual Doppler
1725-1946 UTC
28 August

Right:
WRF 1.33 km
18 UTC
Top: 700 hPa
Bottom: 900 hPa

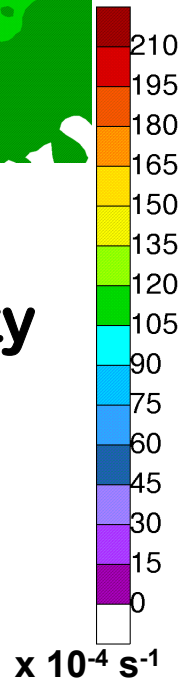
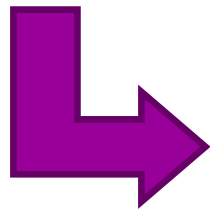


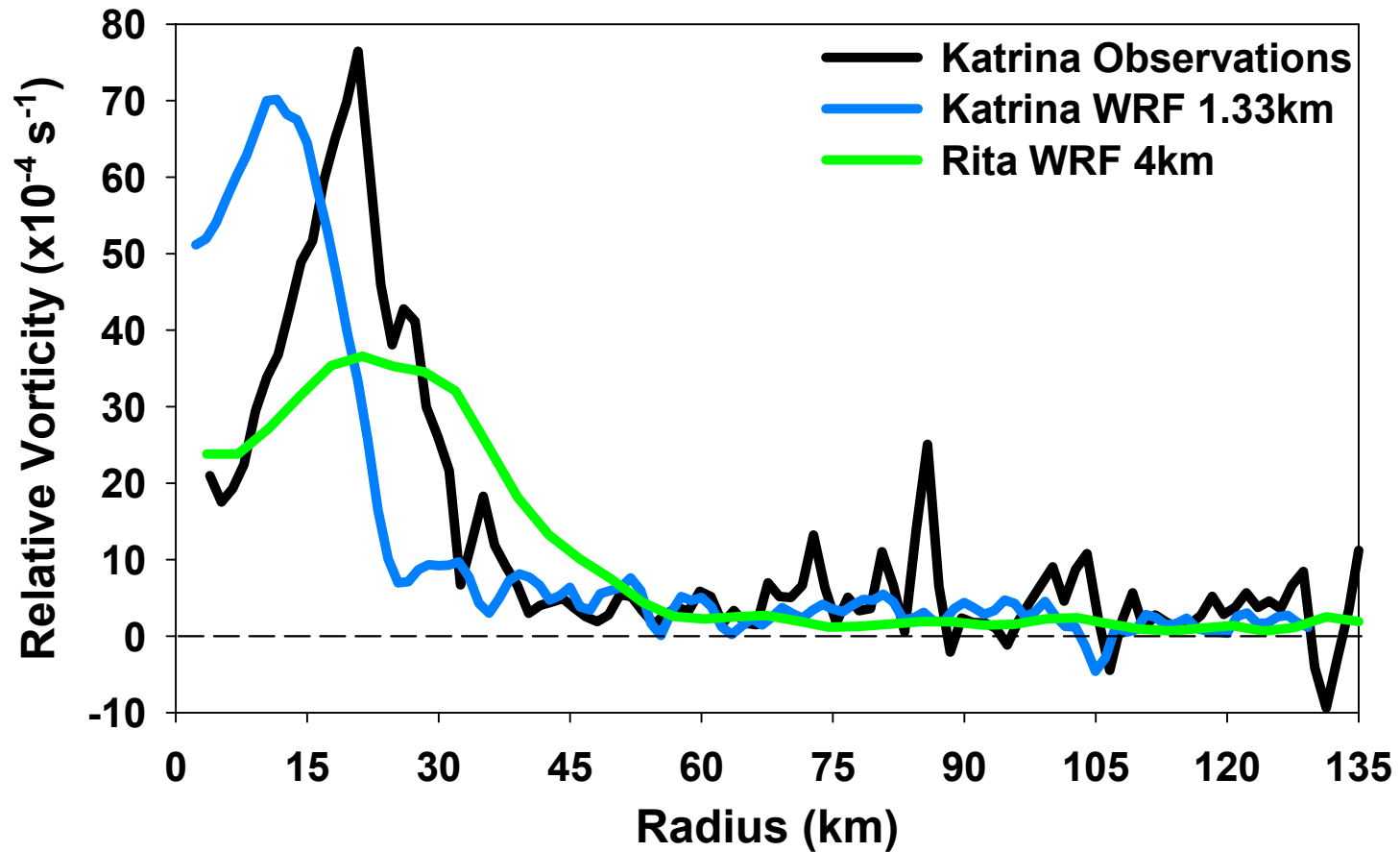
Katrina 1.33 km WRF

900 hPa wind speed



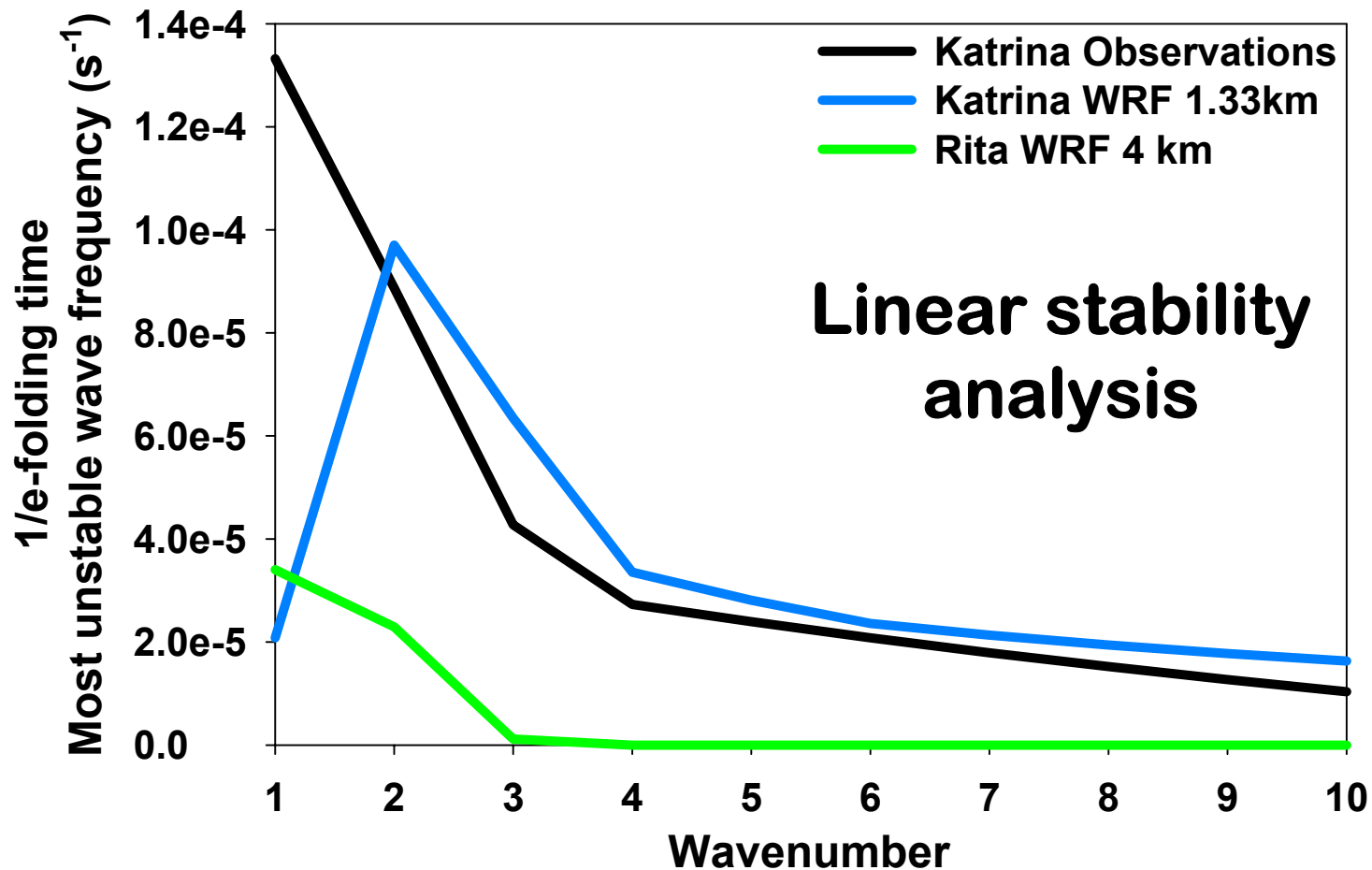
900 hPa relative vorticity





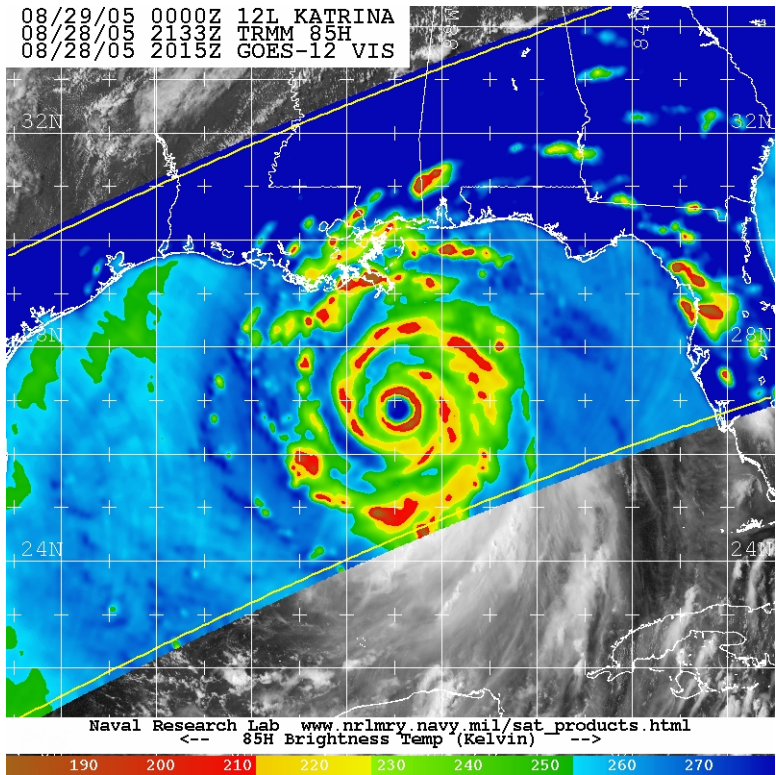
Both the real and WRF vorticity profiles exhibit sharp gradients of vorticity and changes in the sign of $\partial\zeta/\partial r$.

Such profiles satisfy the necessary condition for barotropic instability.



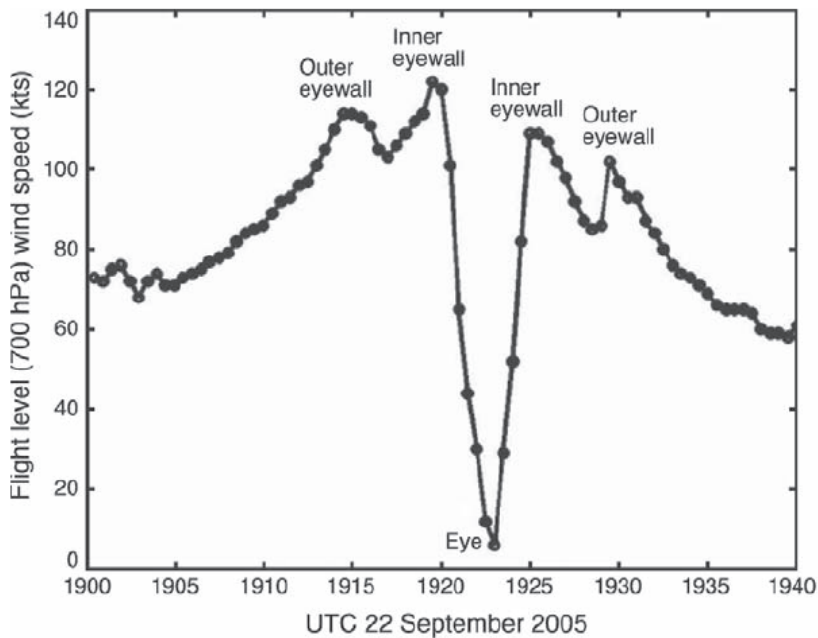
The 1.33 km WRF simulation is most unstable to wavenumber 2, with significant wavenumber 1-4 instability.

The 4 km WRF simulation is most unstable to wavenumbers 1 and 2, with very little instability at higher wavenumbers.

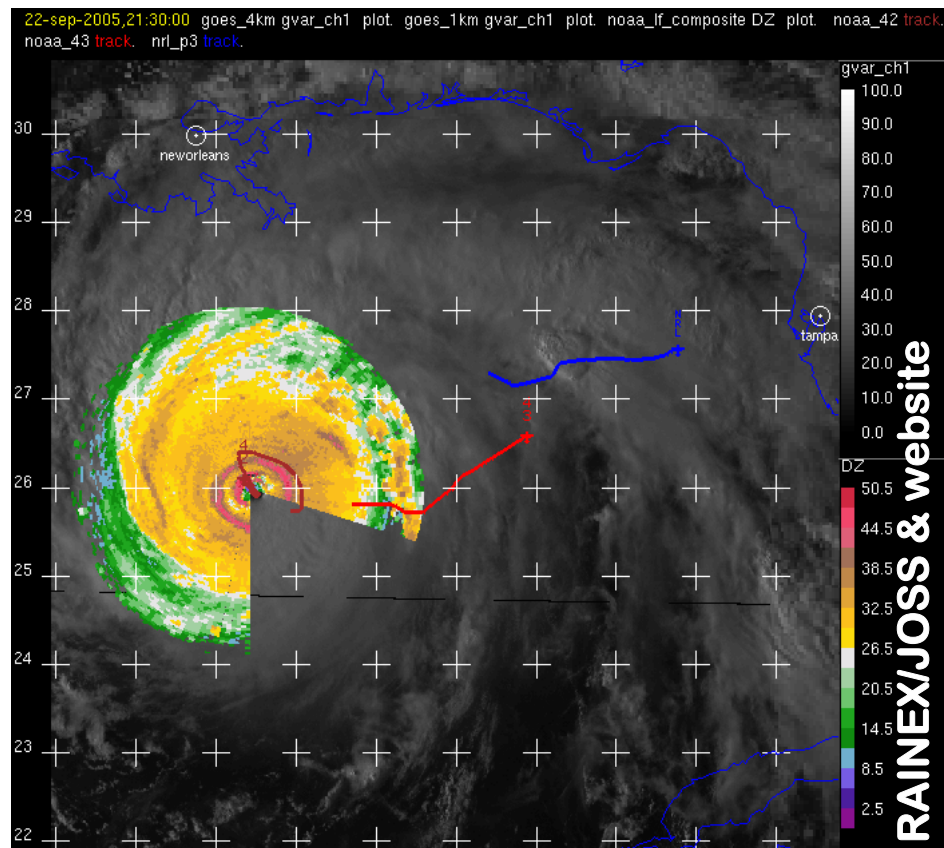


In 2005, both Katrina and Rita exhibited secondary eyewalls during the RAINEX field campaign.

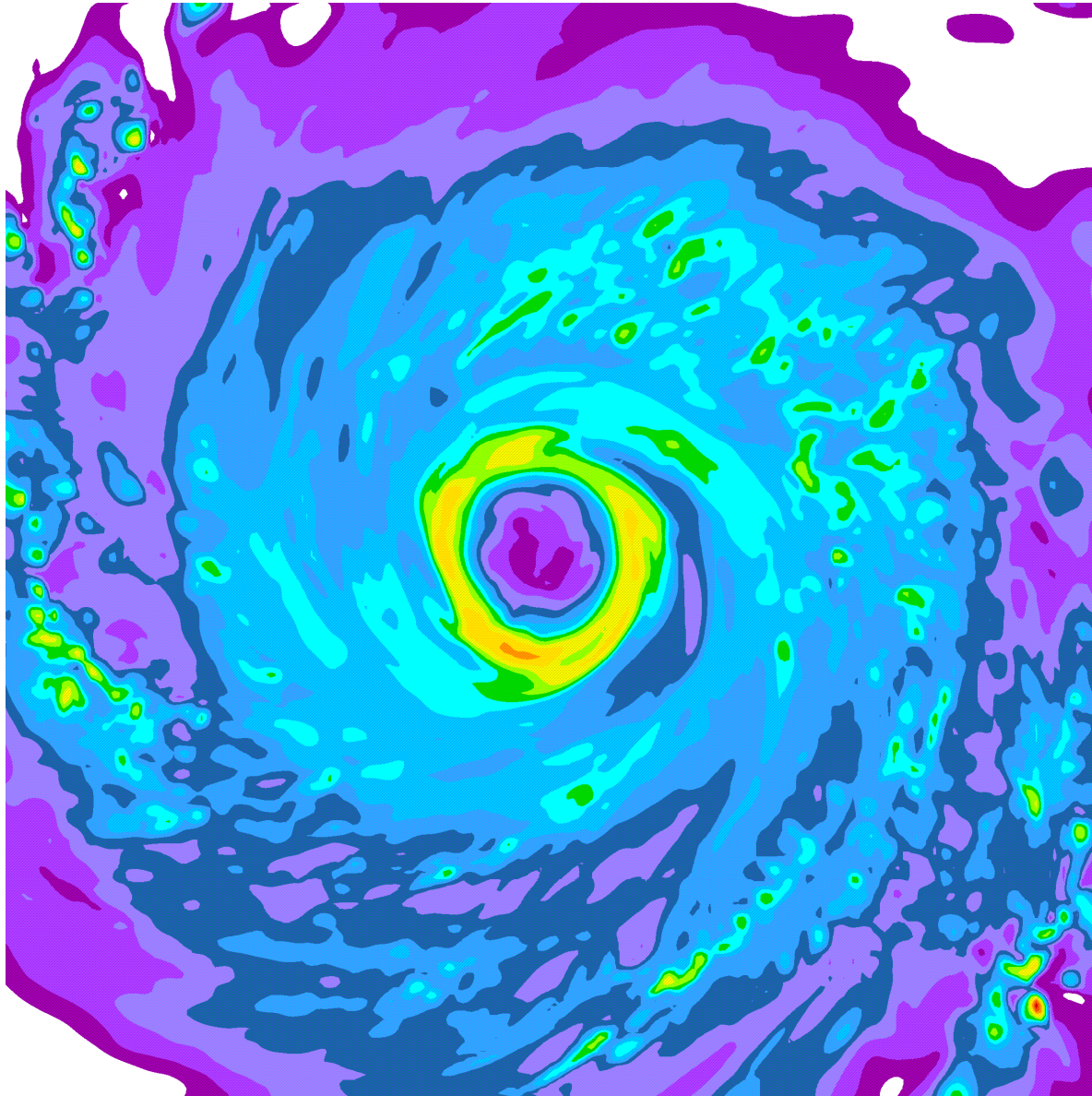
Were these events captured by the AHWRF?

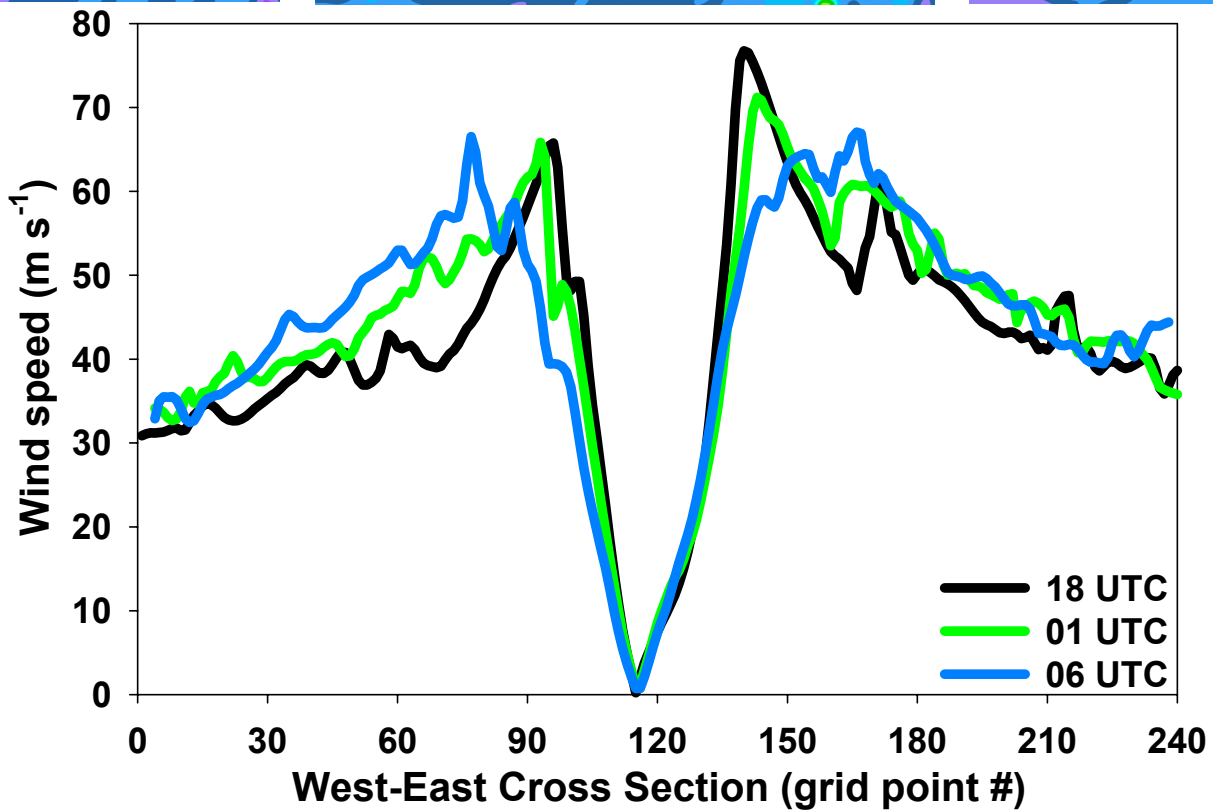
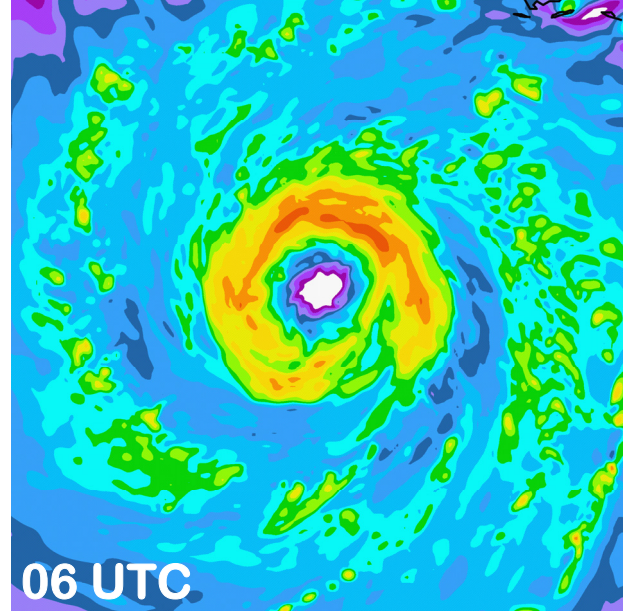
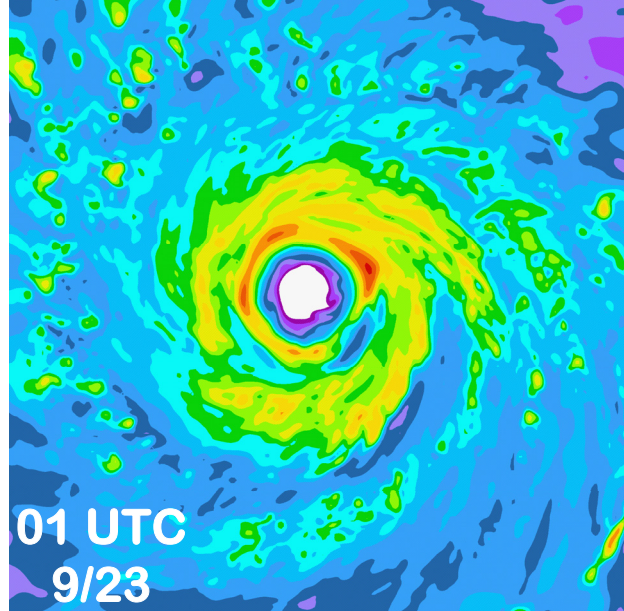
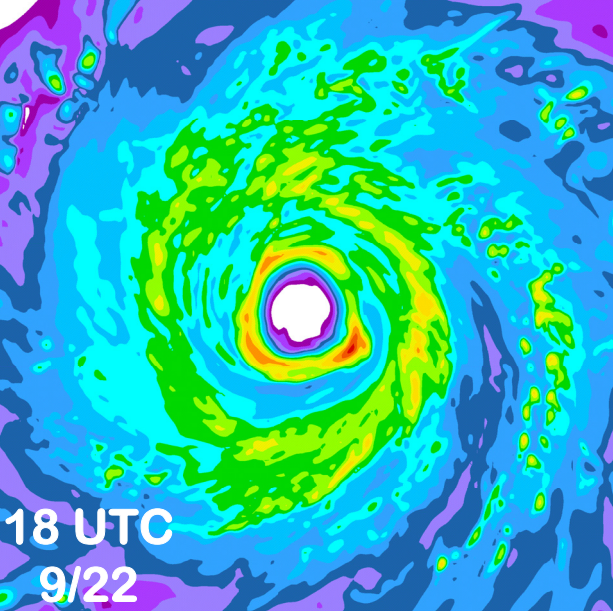


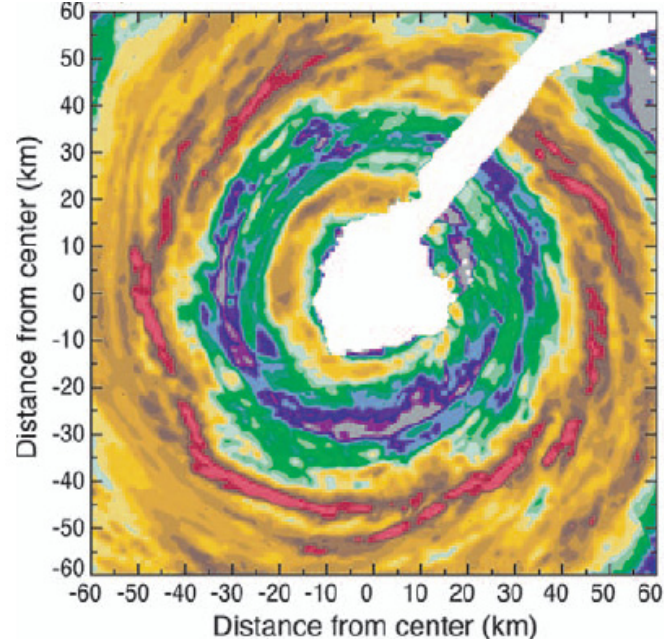
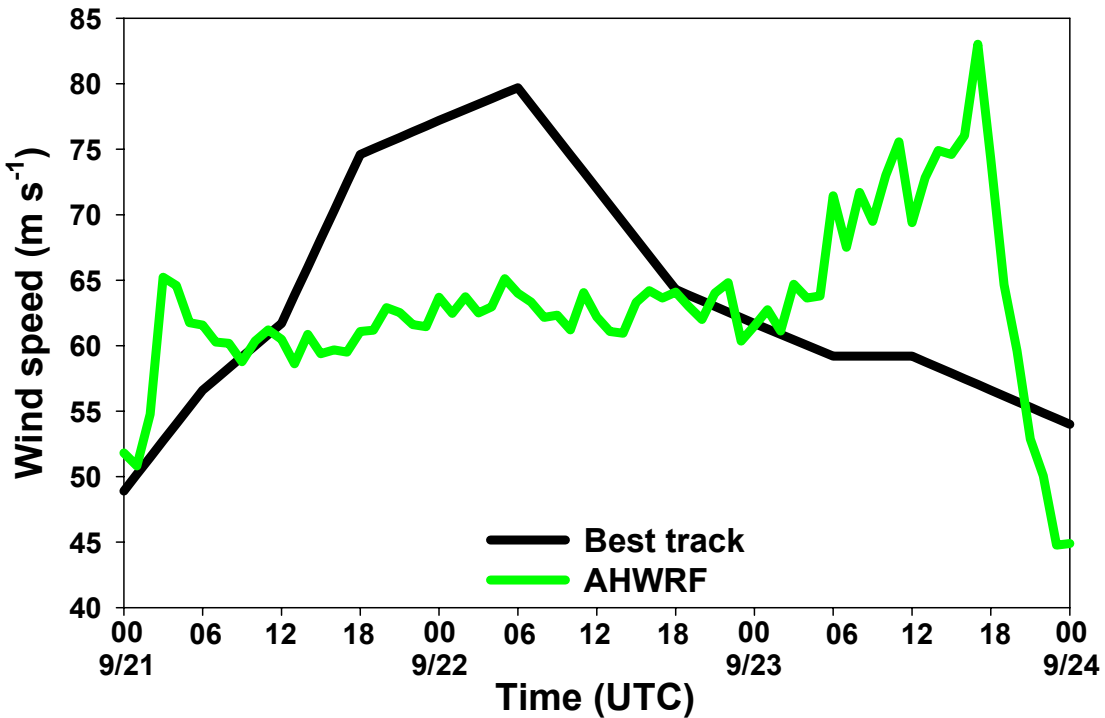
Houze et al. (2006)



**Rita 2005 1.33 km AHWRF Precipitable water
18 UTC 9/21 – 06 UTC 9/23 (every hour)**



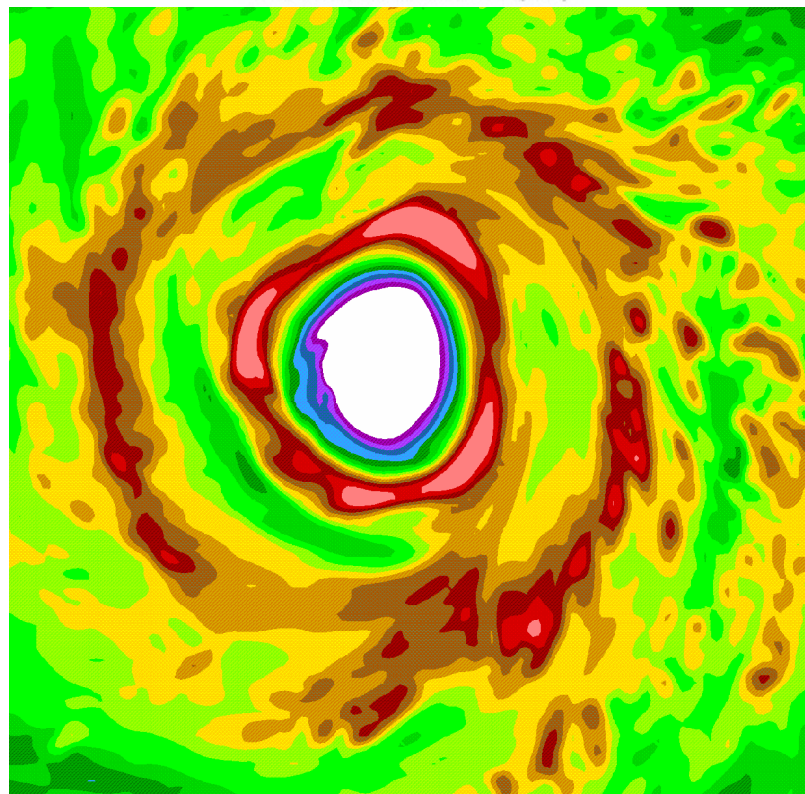




Houze et al. (2006)

ELDORA radar (top)
Radar reflectivity
17 UTC 9/22

1.33 km AHWRF (bottom)
Precipitable water
23 UTC 9/22



Questions, Unresolved Issues and Future Work

- Are model parameterizations playing a role in the abundance of unusually shaped eyewalls? (Fovell, UCLA)
- Will 1.33 km AHWRF TCs always be too weak due to an abundance of eyewall asymmetries, or can mixing of high entropy air between the eye and eyewall act as an offset?
- What are the mechanisms by which secondary eyewalls are formed in the 1.33 km AHWRF simulations? Do these match observations? (S. Abarca, UCLA)
- Does the AHWRF simulate rapid intensification? What is the role of convective instability, vertical wind shear and helicity in the intensification process? (Molinari & Vollaro, SUNY Albany; Shontz, UCLA)