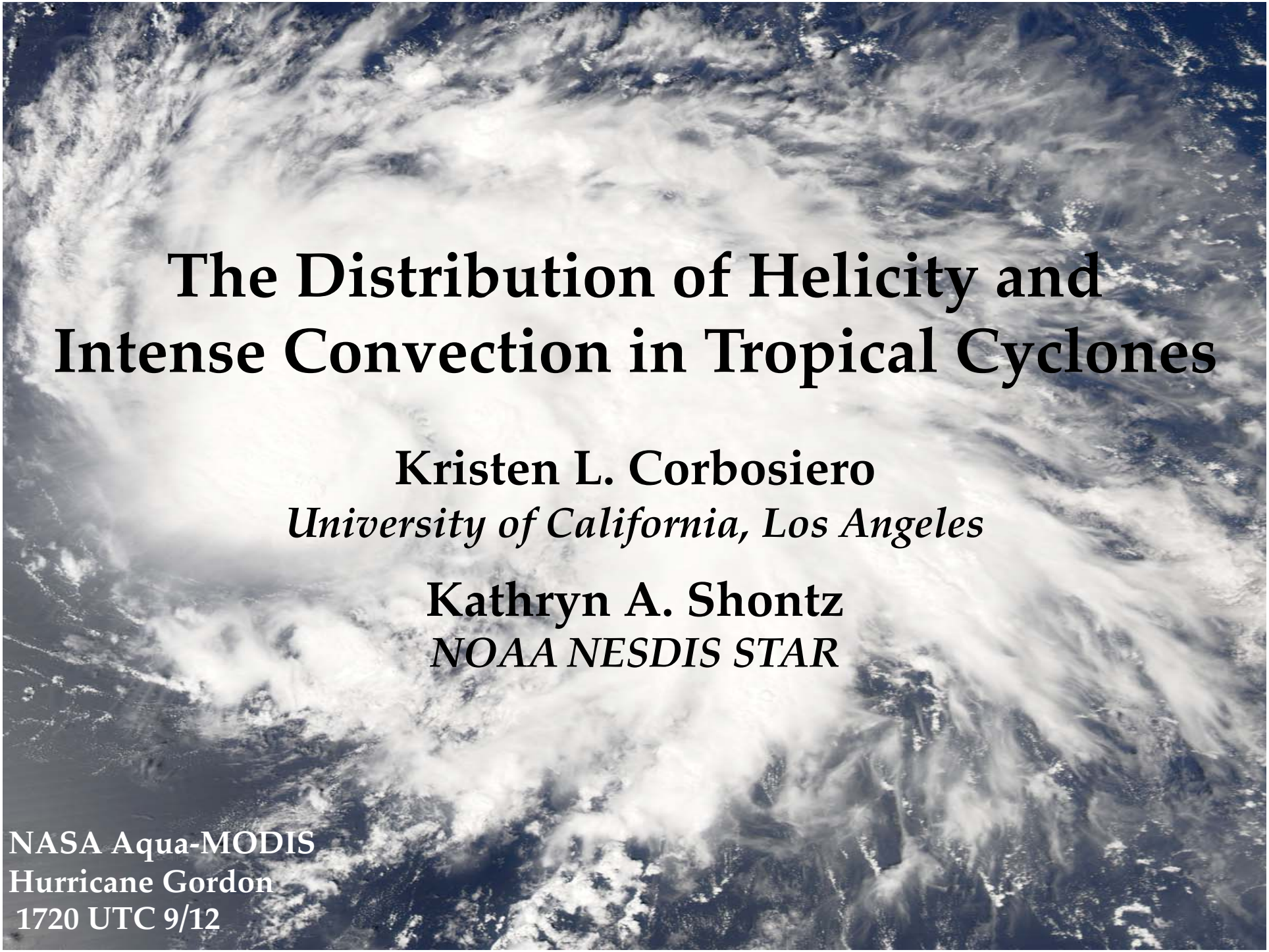

The Distribution of Helicity and Intense Convection in Tropical Cyclones

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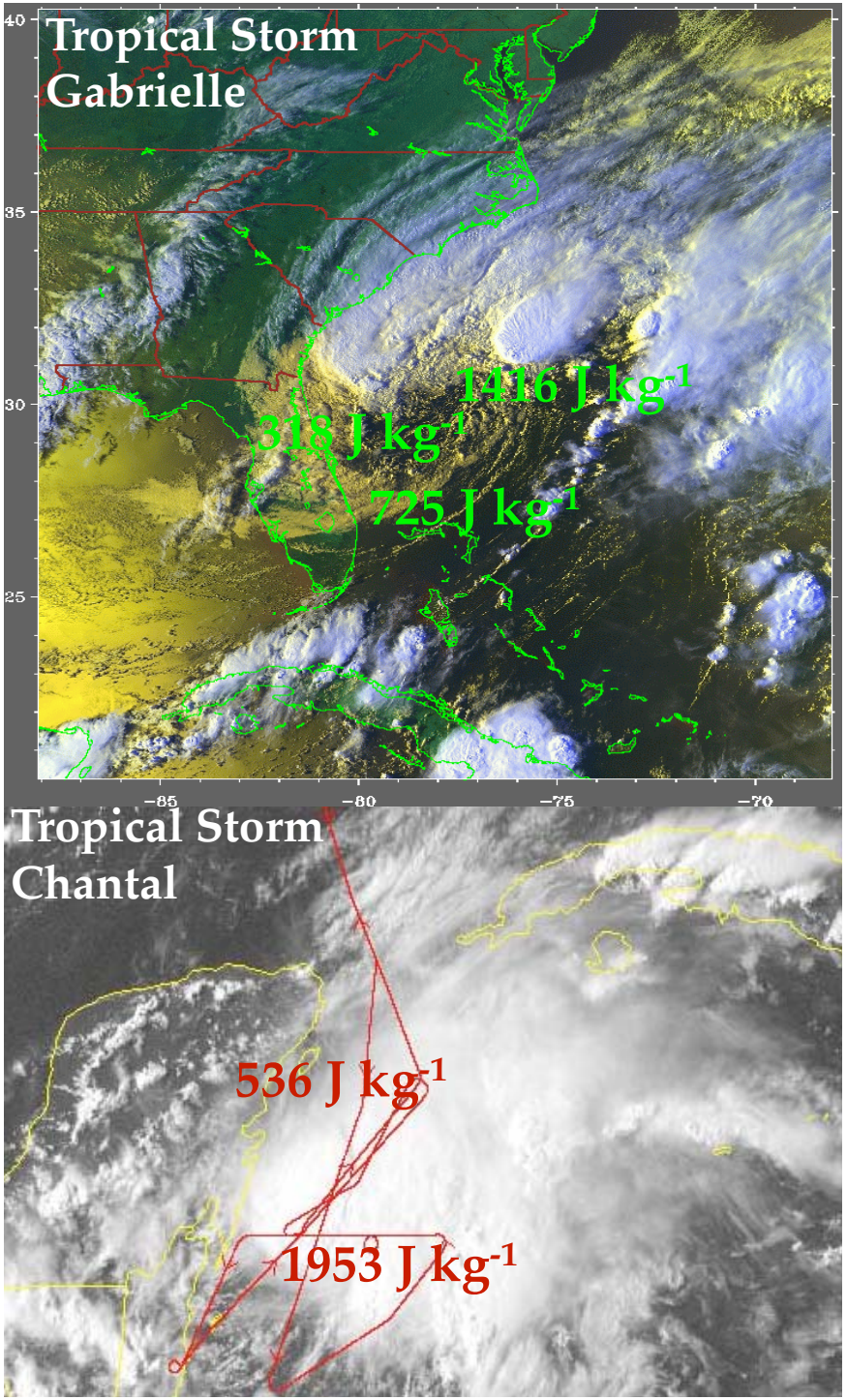
NASA Aqua-MODIS
Hurricane Gordon
1720 UTC 9/12

Motivation

- Fall 2001 Morris Weisman convection class project examining CAPE and shear in two highly sheared, but intensifying, convectively active CAMEX4 TCs.

- Hendricks et al. (2004) called buoyant updrafts possessing strong vertical vorticity "vortical hot towers" (VHTs) and linked their axisymmetrization and preconditioning of the environment to the development of nascent TCs.



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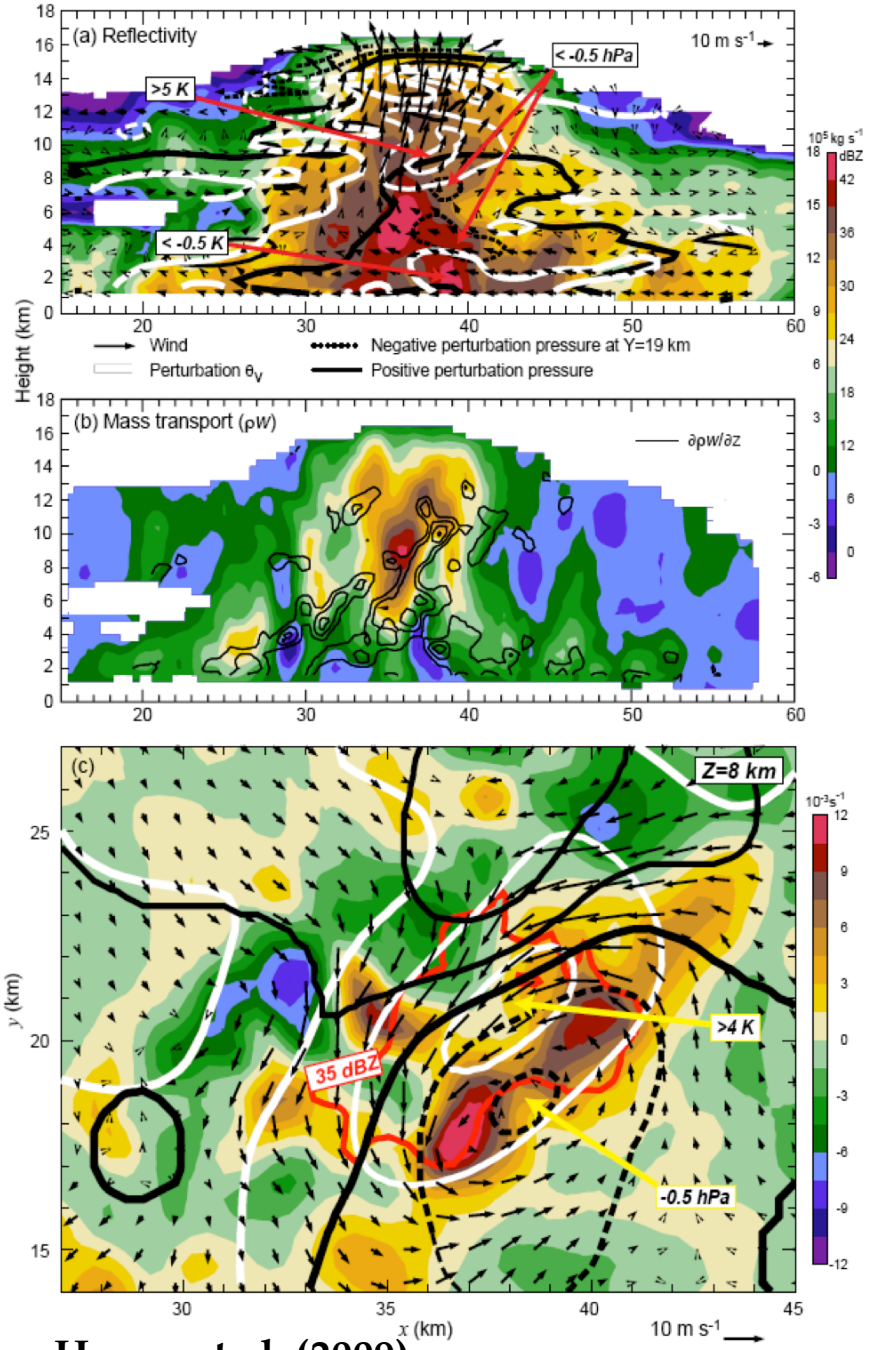
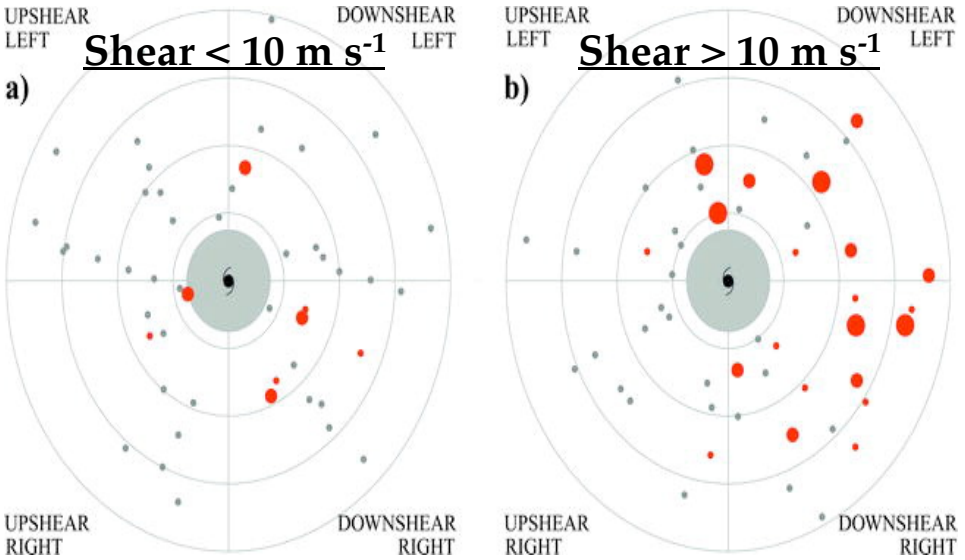


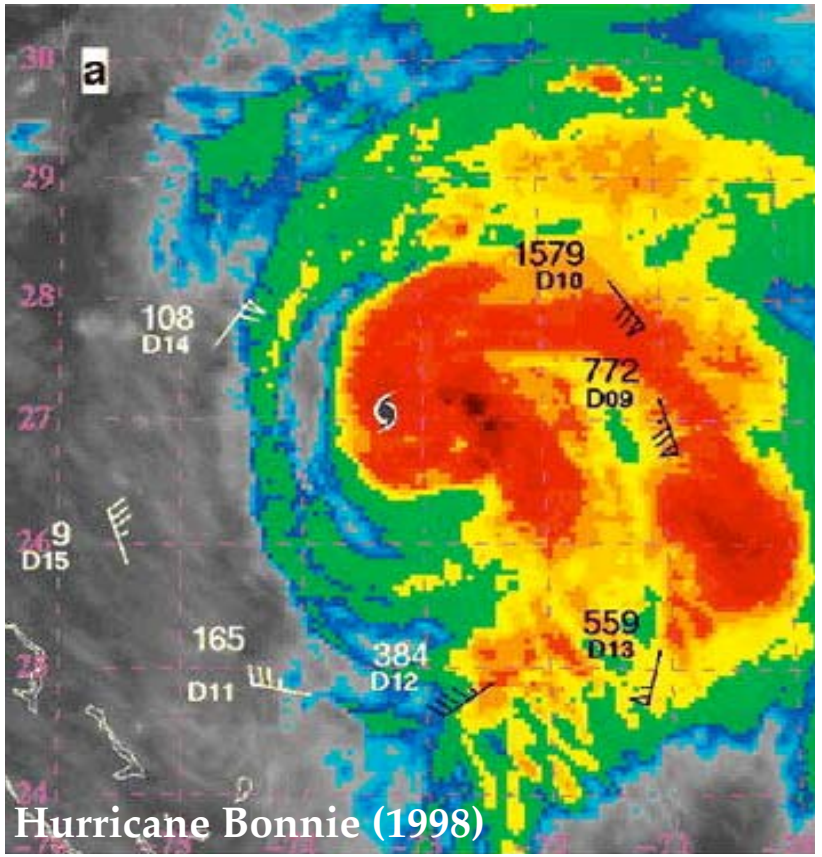
Houze et al. (2009)

Motivation

- Molinari & Vollaro (2008, 2010) found significant azimuthal asymmetries in CAPE and helicity in strongly sheared (> 10 m s^{-1}) CAMEX TCs.



- They hypothesized that the 30% larger CAPE and double the helicity found in strongly sheared storms lessen the negative impacts of shear on the vortex, but they were lacking inner core (< 75 km) dropsondes and three-dimensional, mesoscale data to fully explore their hypothesis.

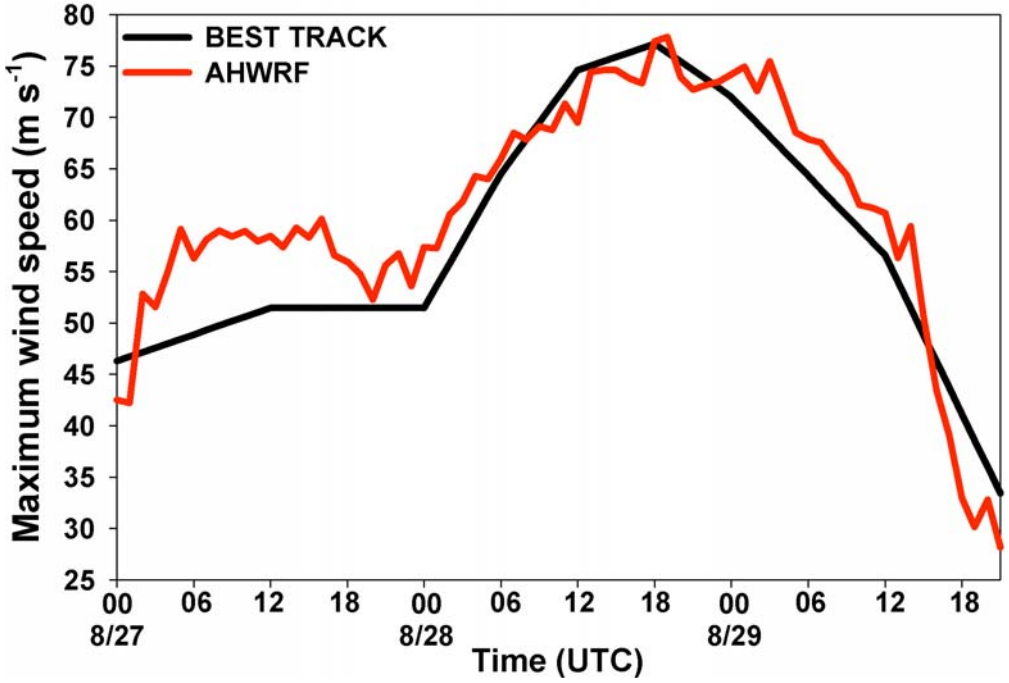


Data & Methodology

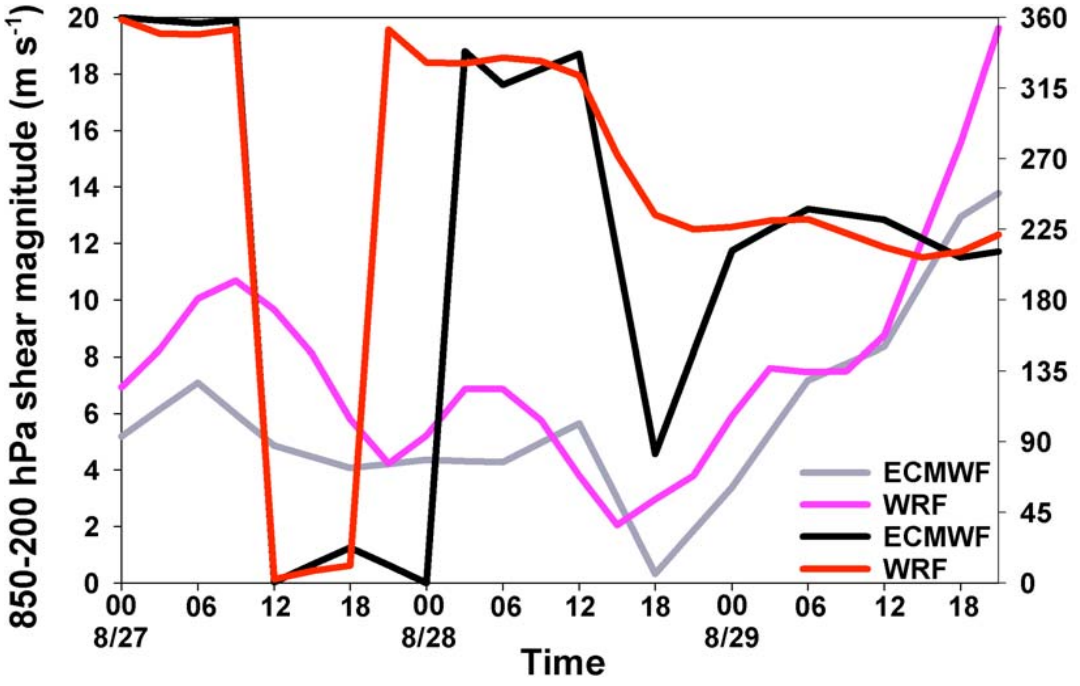
- **NCAR Advanced Hurricane WRF (AHWRF) model initialized from the GFDL model with three, two-way moveable nests at 12, 4 and 1.33 km resolution**
- **Kain-Fritsch cumulus parameterization (12 km grid only), WSM3 (5) microphysics, YSU planetary boundary layer scheme, drag (Donelan) and surface enthalpy coefficients (Carlson-Boland) for TCs**
- **Examine fields of most unstable CAPE (MUCAPE), calculated over the 300 hPa layer closest to the ground using virtual temperature, and storm relative helicity:**

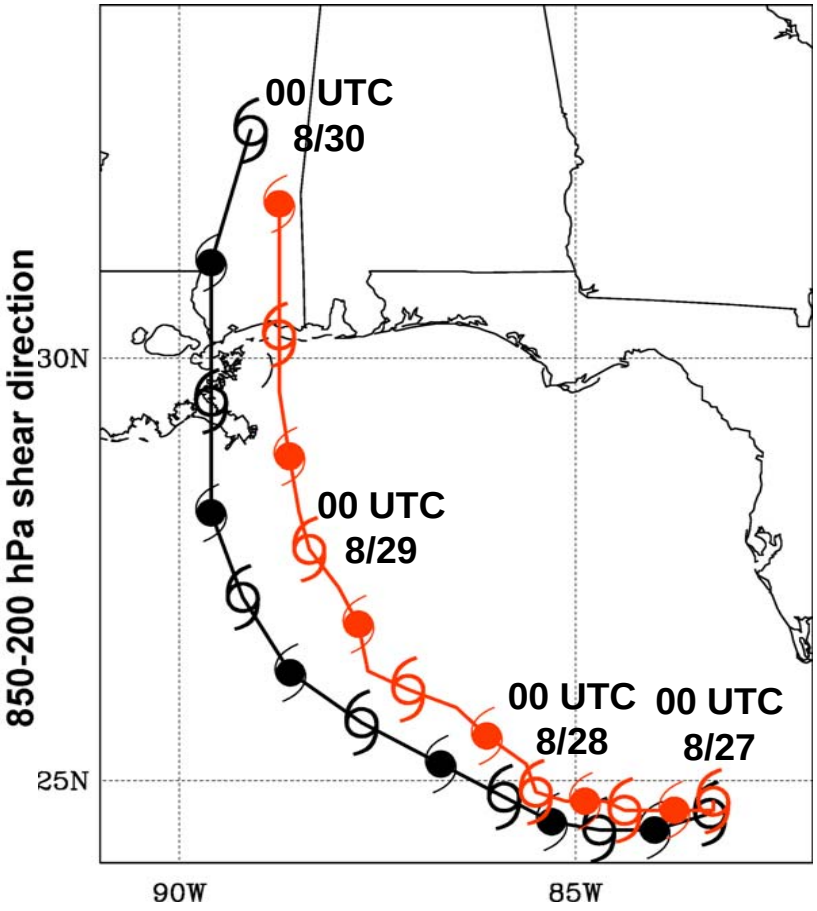
$$SRH = \int_0^h \left[\left(\vec{V} - \vec{c} \right) \bullet \left(\hat{k} \times \frac{\partial \vec{V}}{\partial z} \right) \right] dz$$

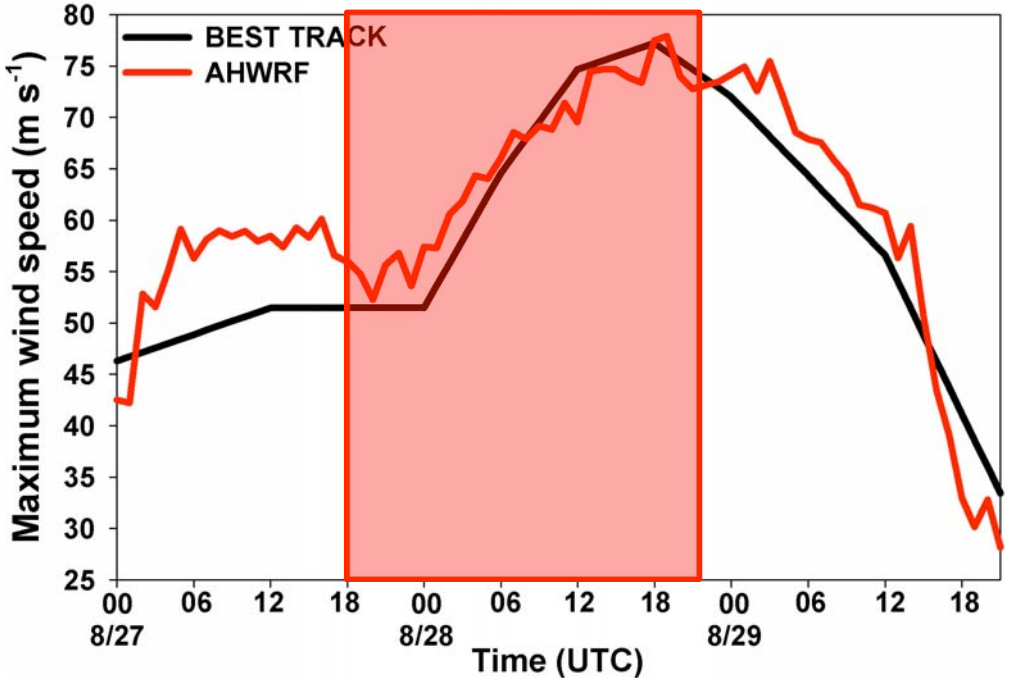
with h=6 km and cell motion ($\vec{c}$) estimated following Ramsay and Doswell (2005).

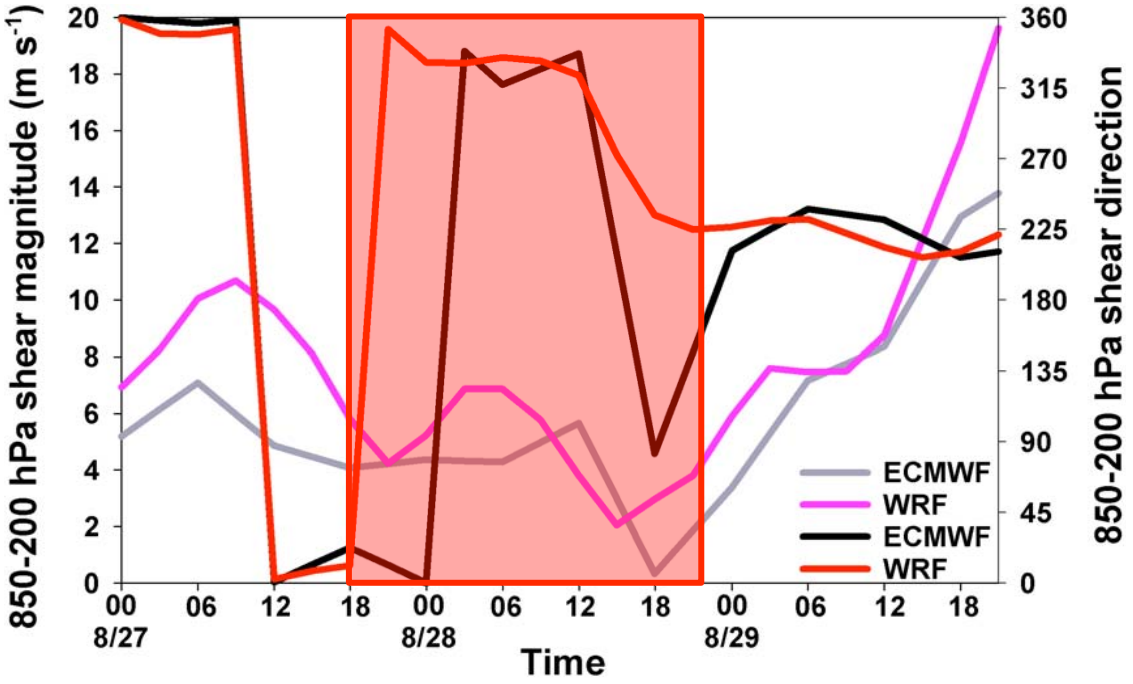


All aspects of Katrina's evolution (intensity, track, and vertical wind shear) were well handled by the AHWRF (V2.2 WSM5 6d)



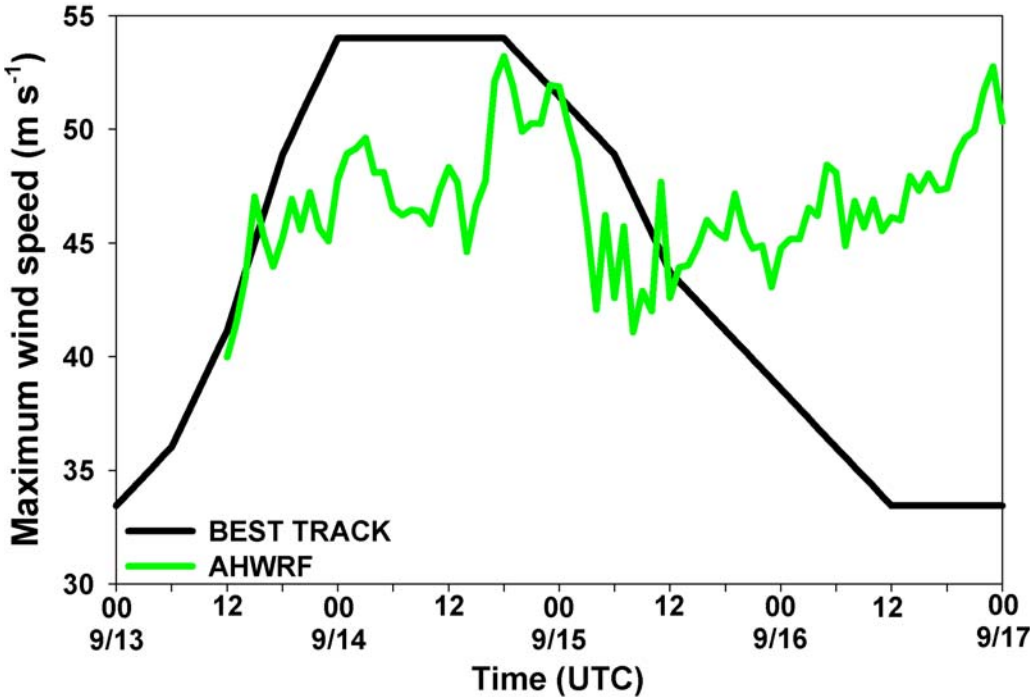




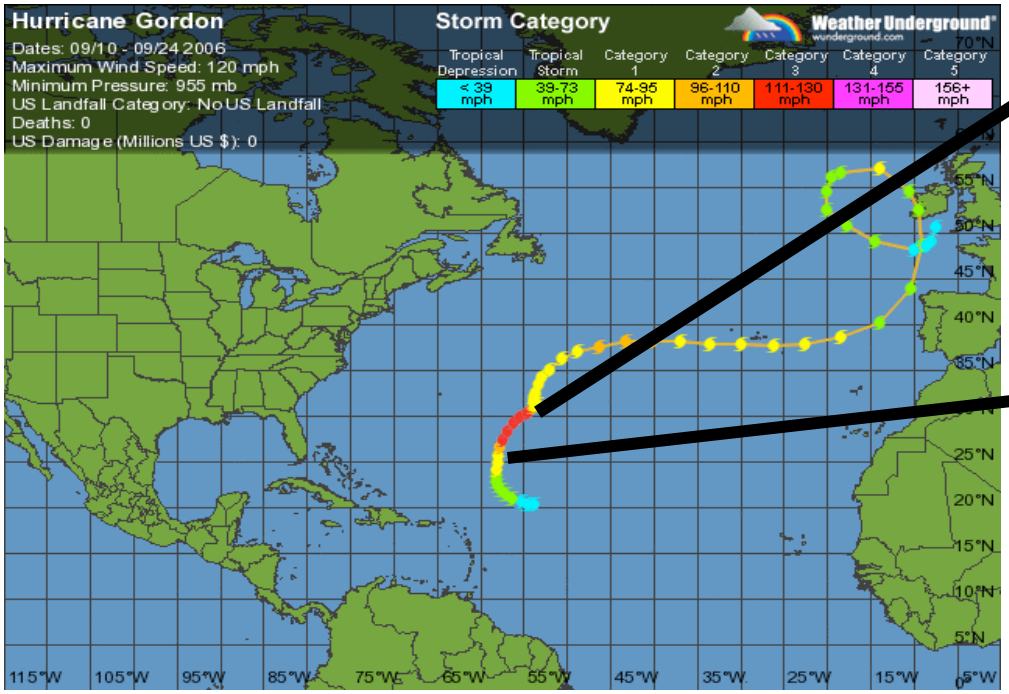


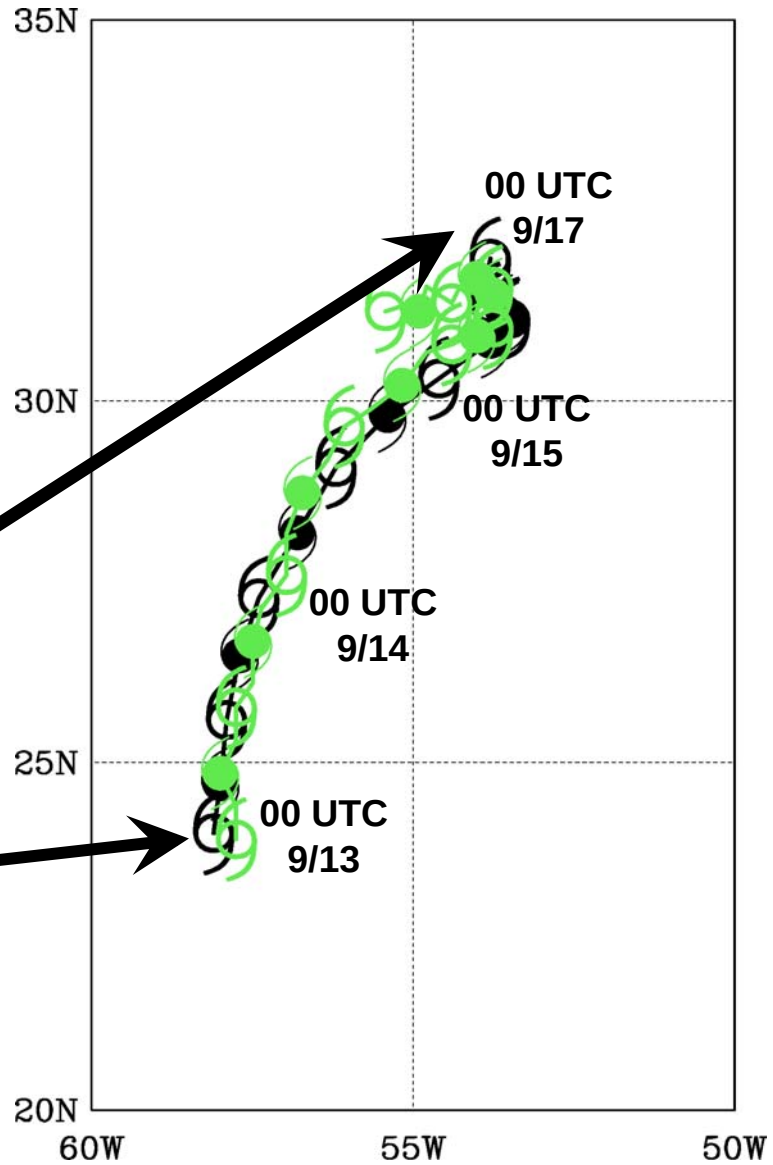
All aspects of Katrina's evolution (intensity, track, and vertical wind shear) were well handled by the AHWRF (V2.2 WSM5 6d)

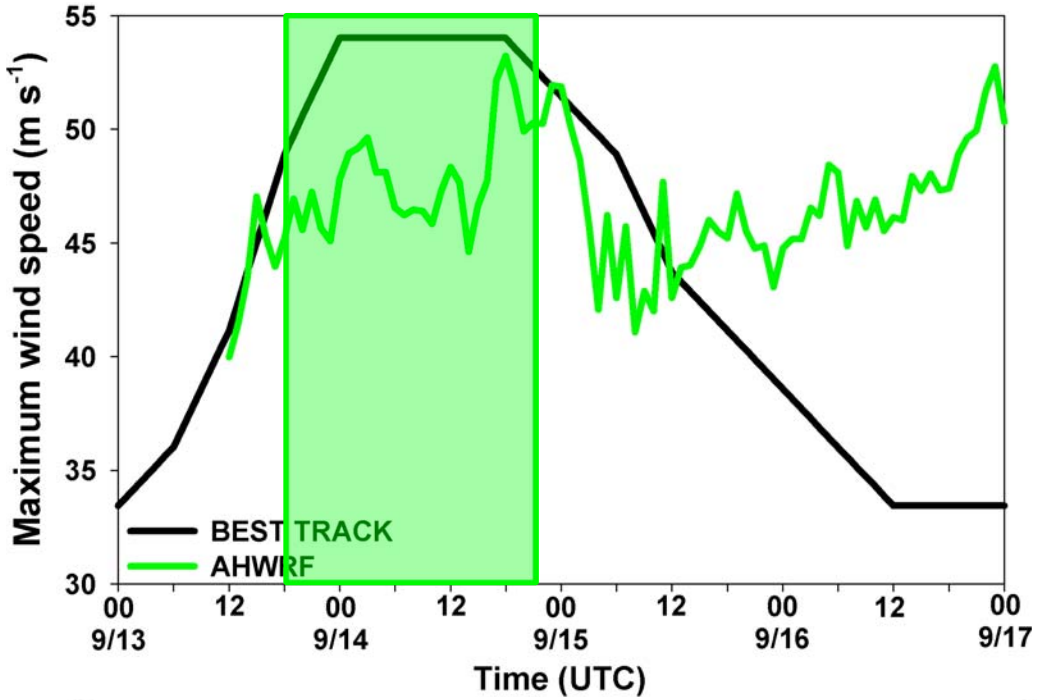
Katrina rapidly intensified in an environment of weak vertical wind shear and will be compared with the strongly sheared Hurricane Gordon.

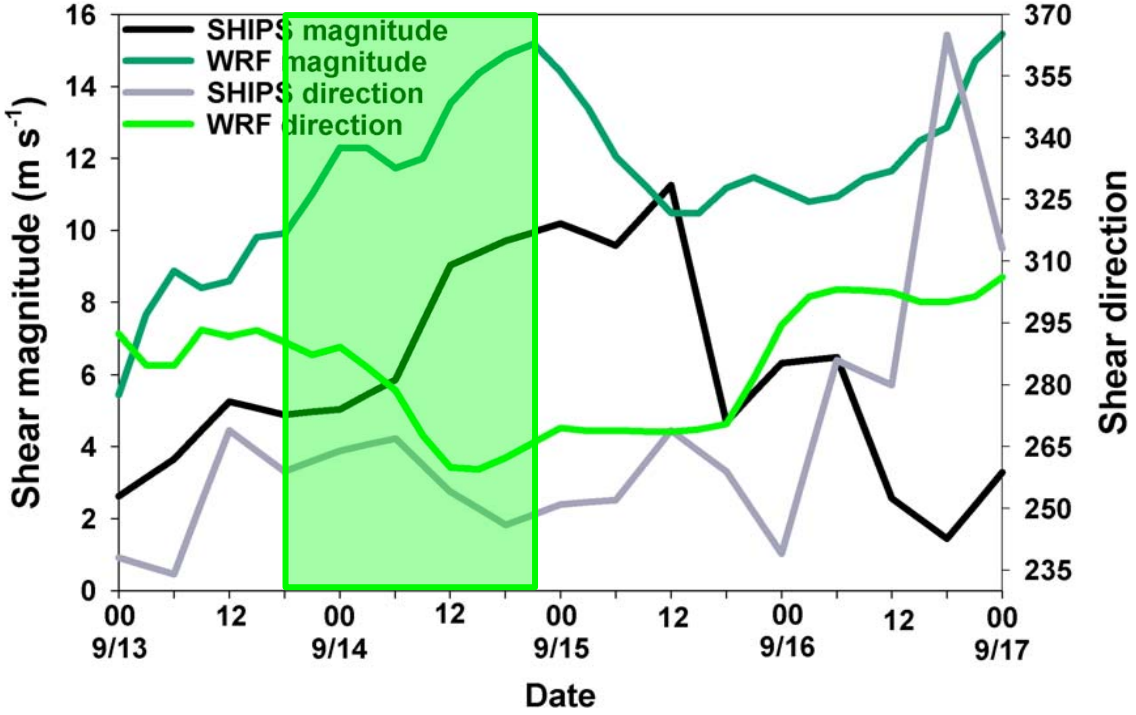


The same cannot be said for Hurricane Gordon…









The same cannot be said for Hurricane Gordon…

While the direction of the AHWRF vertical wind shear was consistent with the SHIPS model, the AHWRF shear magnitude was consistently 6-7 m s^{-1} greater than the true value.

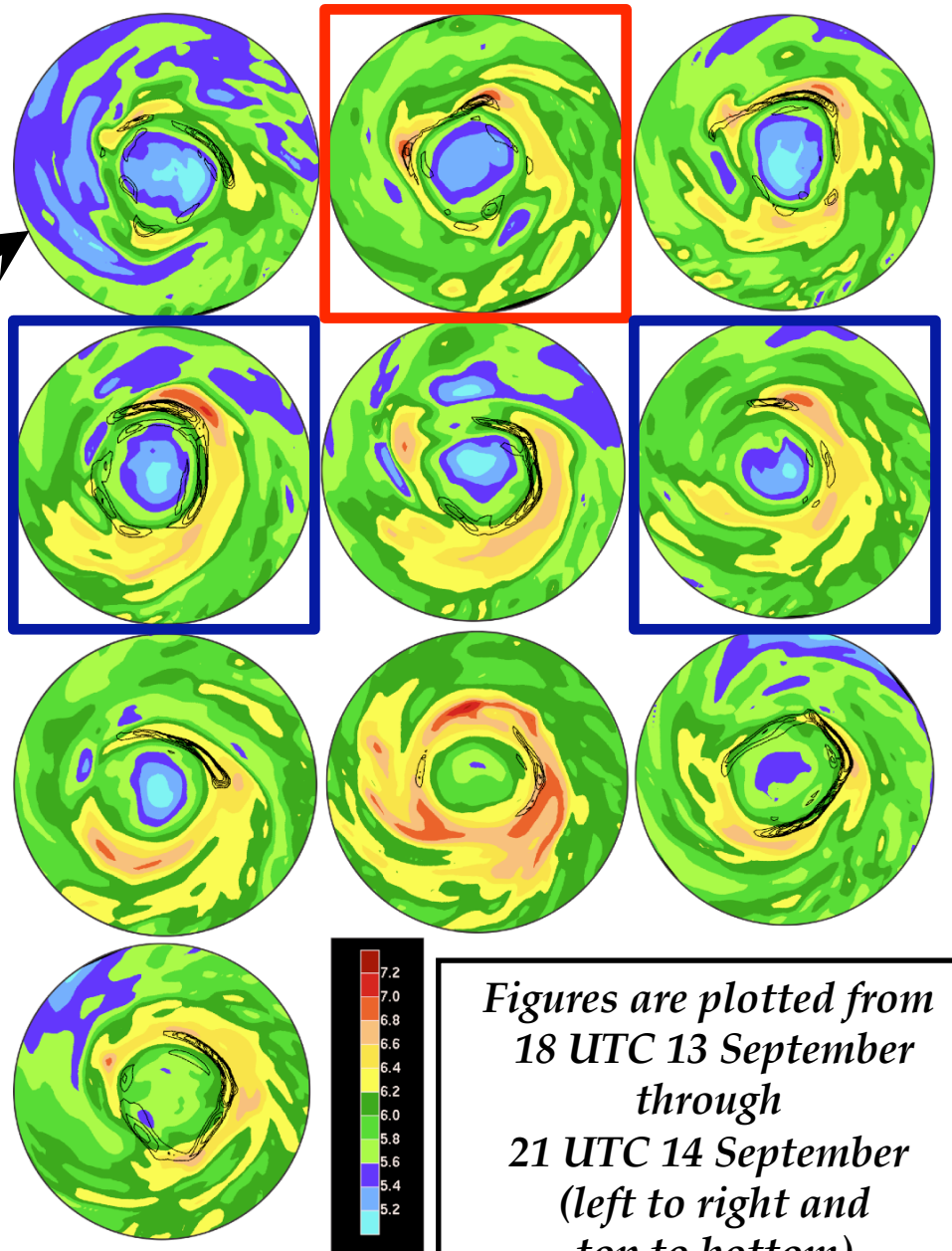
Gordon will thus be considered a strong shear case for study.

Gordon: Precipitable Water and 850 hPa Positive Vorticity

- **Shear rotated**, 3 hour snapshots out to a radius of 50 km from the center.

Shear vector

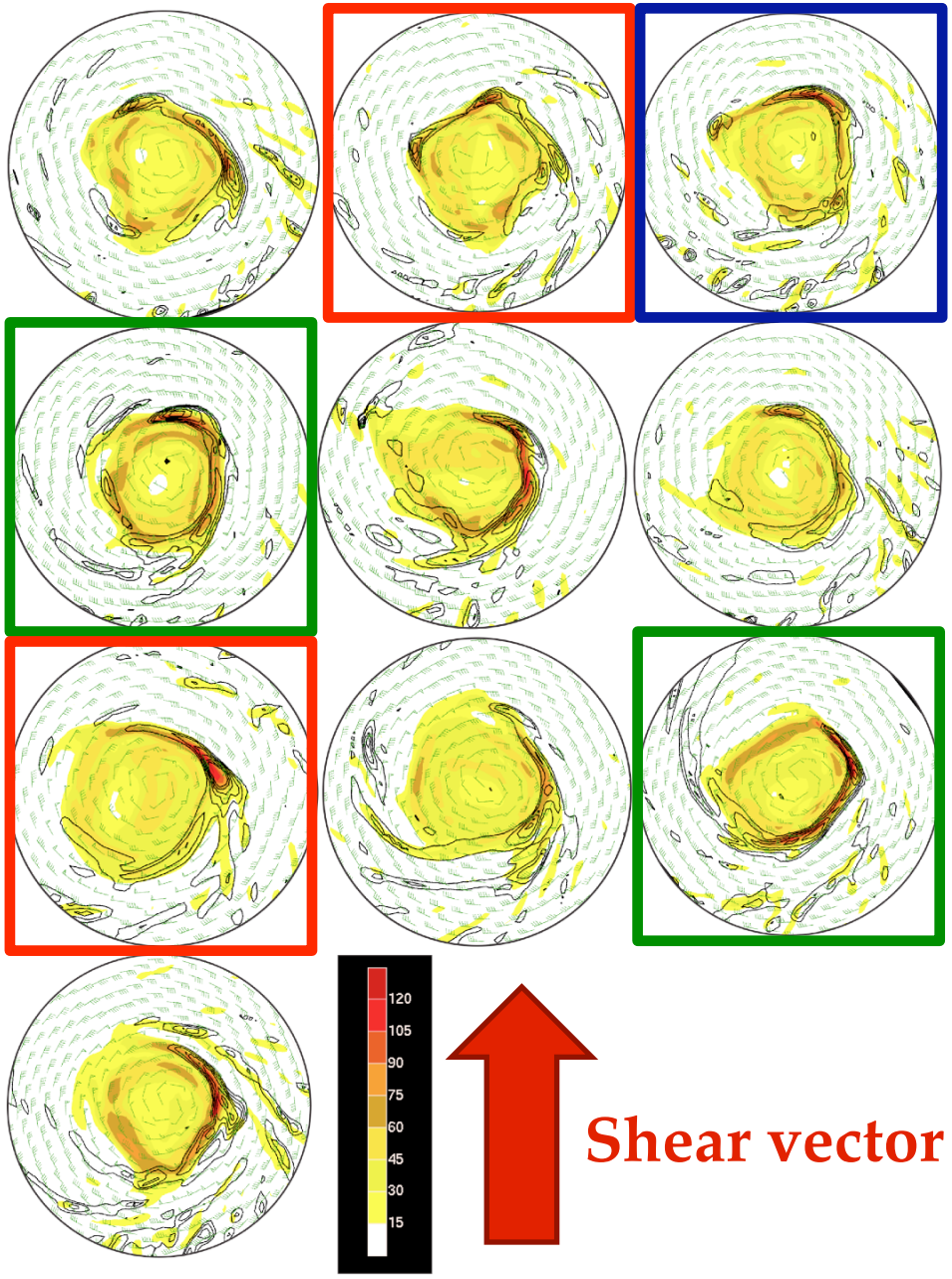
r = 50 km



Figures are plotted from 18 UTC 13 September through 21 UTC 14 September (left to right and top to bottom)

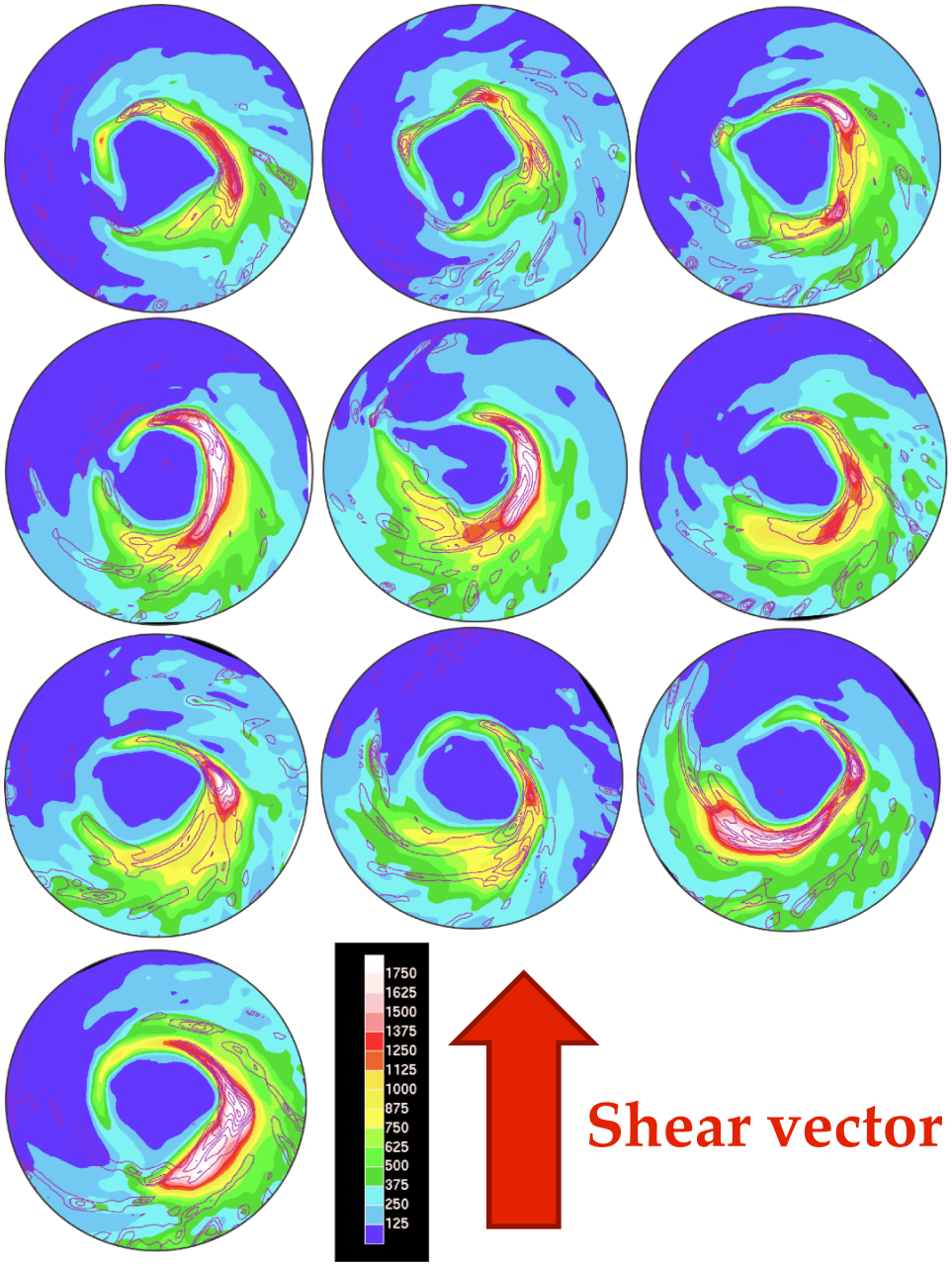
- The precipitable water and vorticity are highly variable, but exhibit distinct right of shear and downshear maxima with convective bursts both co-located with, and upstream of, eyewall vorticity maxima.

Gordon: 850 hPa Positive Vorticity and Vertical Velocity



- Positive vorticity and upward vertical motion exhibit a clear wavenumber 1 asymmetry maximized to the right of the shear vector.
- Periods of increased symmetry correspond to relative peaks in intensity.
- Evidence for both VHTs and eyewall mesovorticies exist.

Gordon: Storm Relative Helicity and Precipitable Water

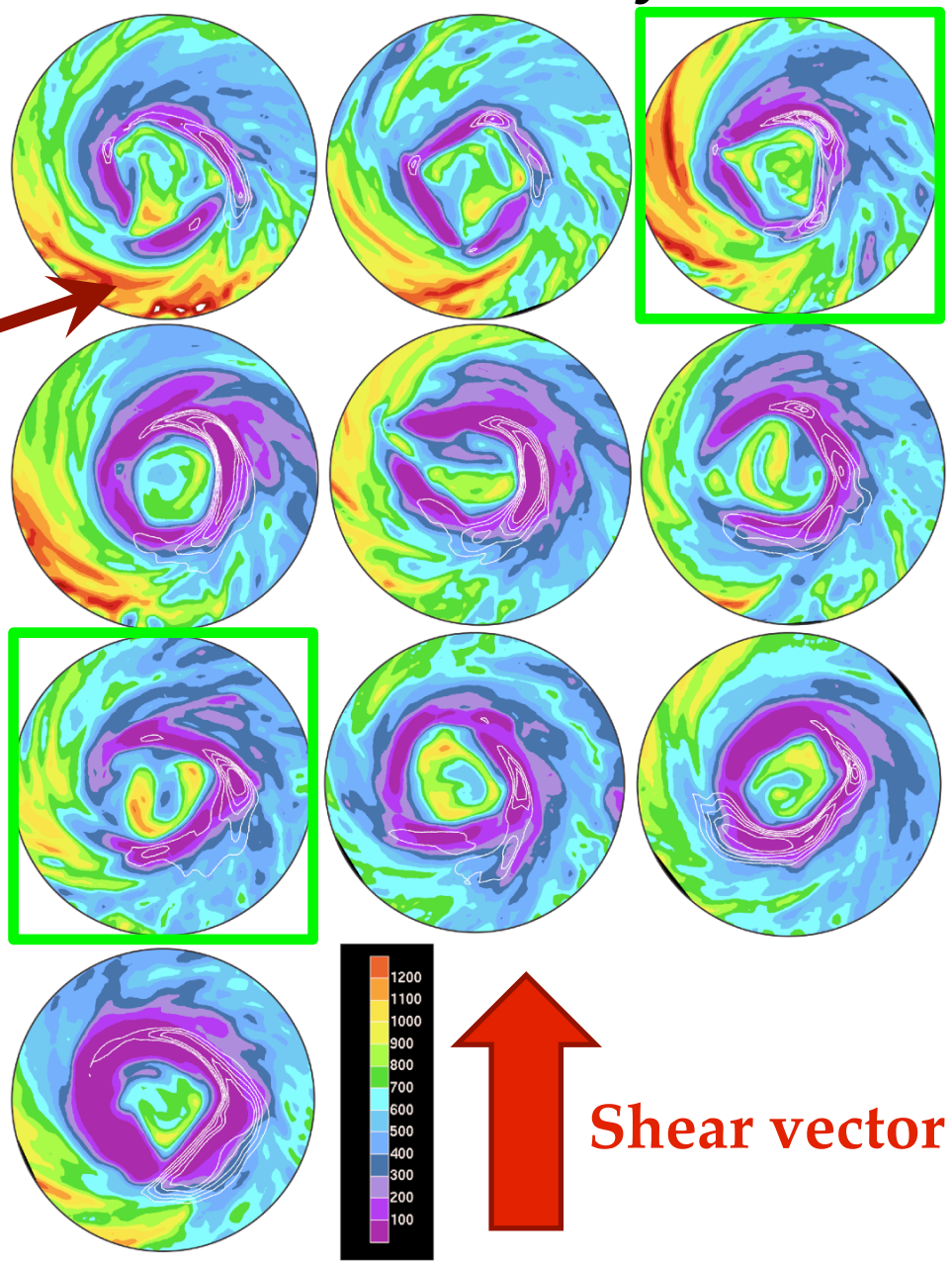


- Consistent with Molinari and Vollaro (2008, 2010) helicity values are an order of magnitude larger than in mid-latitude thunderstorms.
- PW and SRH maxima are located to the right of the shear vector.
- Convective cells never propagate into the left of shear semicircle and the simulated storm does not attain a symmetric structure.

Gordon: MUCAPE and Storm Relative Helicity

- **Large CAPE values are found to the left of shear and upshear of the center outside of the eyewall.**

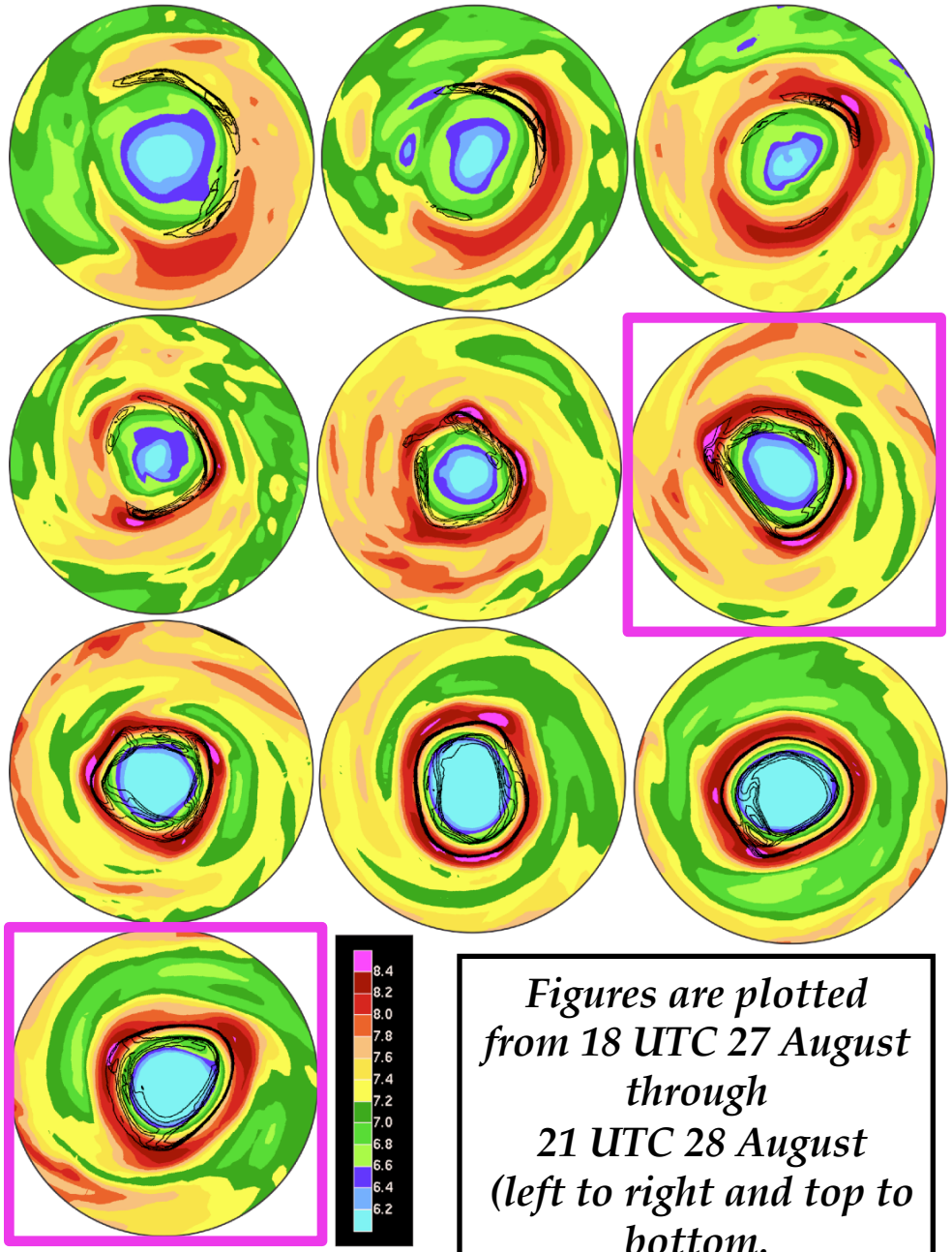
- **Modest CAPE values pool into discrete centers in the eye and appear to fuel the strong updrafts right of the shear vector via eye-eyewall mixing associated with mesovorticies.**



Katrina: Precipitable Water and 850 hPa Positive Vorticity

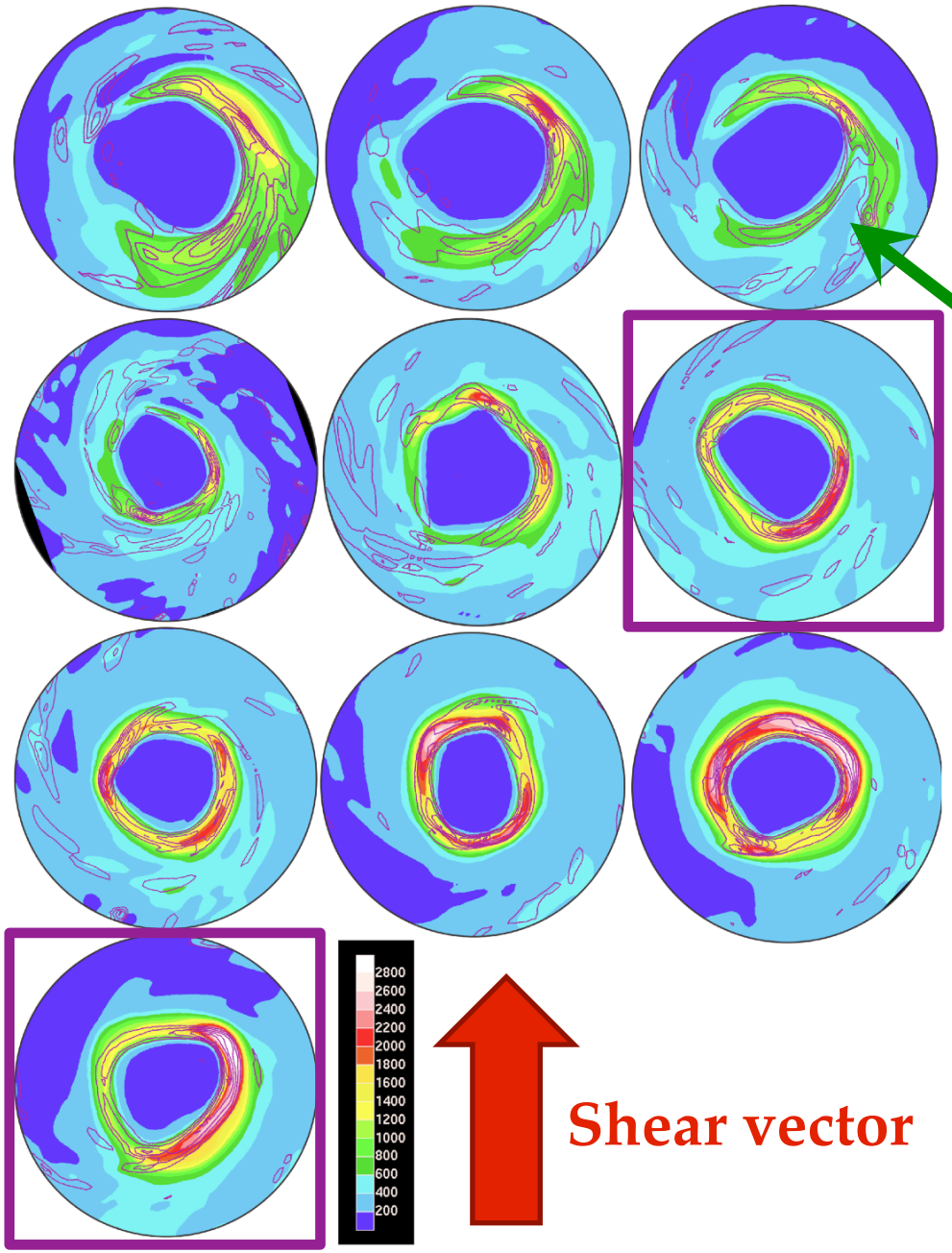
- Initial right of shear and downshear asymmetries in precipitable water and vorticity are quickly replaced by large wavenumber 3-5 eyewall mesovorticies with radially outward and upstream PW maxima.

- The mesovorticies propagate completely around the eyewall, consistent with the weak shear, leading to a more symmetric inner core.



Figures are plotted from 18 UTC 27 August through 21 UTC 28 August (left to right and top to bottom.

Katrina: Storm Relative Helicity and Precipitable Water

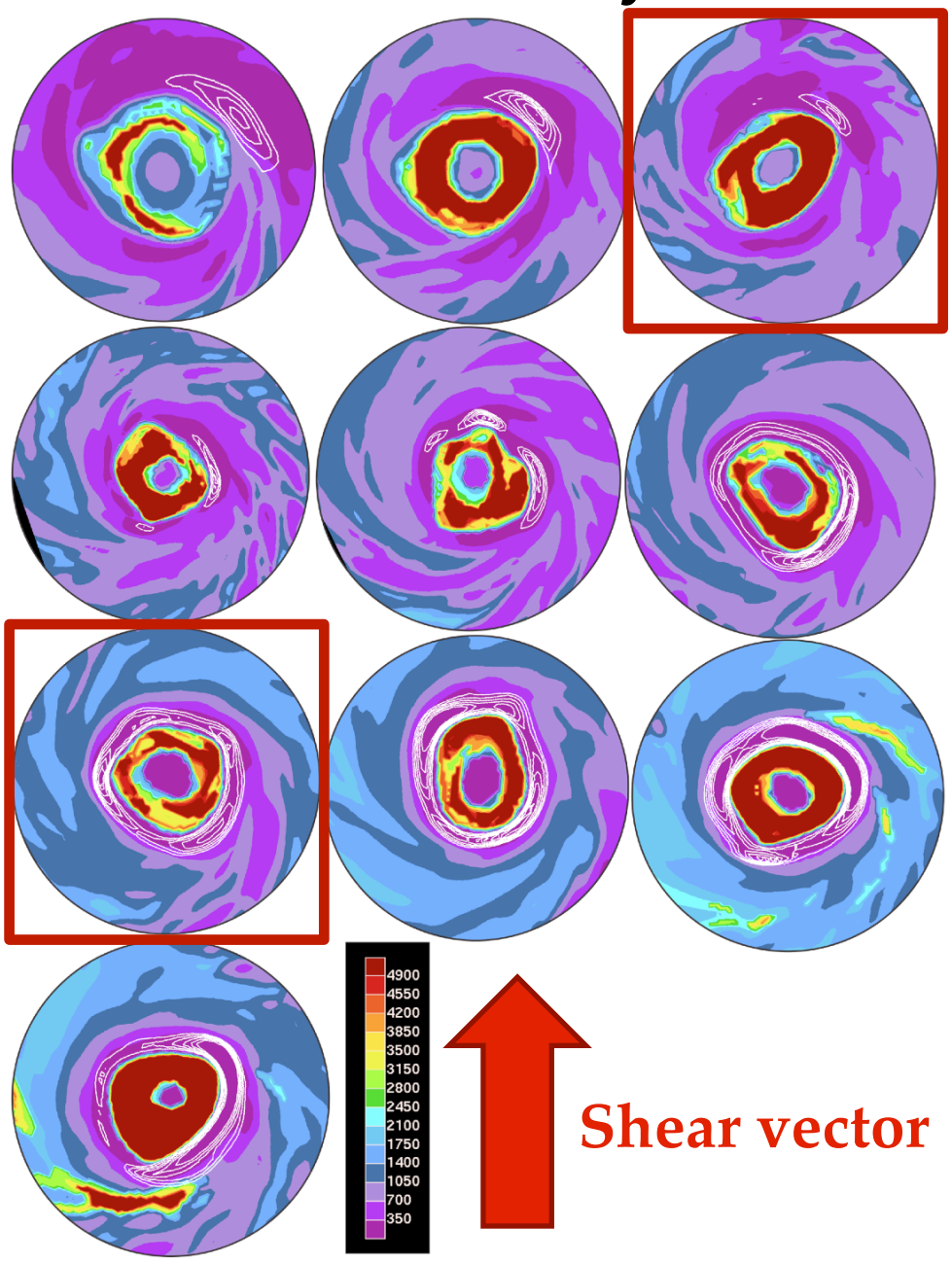


- A distinct right of shear asymmetry in helicity persists throughout the simulation.
- Extreme values of helicity are found within eyewall convective cells downshear and right of the center.

Katrina: MUCAPE and Storm Relative Helicity

- Very large values of CAPE are found in a 15 km wide ring located along the eye-eyewall interface.

- Distinct cyclonic wave breaking features appear along the interface, mixing high CAPE outward, temporarily reducing the eye CAPE, and fueling strong eyewall convection associated with the mesovorticies.



Summary & Future Work

- **Simulated values of CAPE and helicity within the inner 50 km of Hurricanes Gordon and Katrina are consistent with the observational results of Molinari and Vollaro (2008, 2010).**

- **Evidence of both vortical hot towers and eyewall mesovorticies exist in AHWRF high resolution, real data case simulations.**

- **Calculate radial profiles of MUCAPE and helicity in each shear rotated quadrant**

- **Examine a large number of storms embedded in a wide variety of shear environments with a consistent modeling framework, i.e. HFIP storms**