Evaluation of Shear-relative Hurricane Structure from the 2012 HWRF Baseline Model

Paul Reasor, HRD/AOML/NOAA

April 24th, 2013

Background

Zhang and Tao (2013, JAS) found that with increased vertical wind shear comes increased uncertainty in the intensity forecast.

Reasor et al. (2013, MWR) recently documented the shear-relative structure of hurricanes using airborne Doppler-radar composites from NOAA P-3 flights into 18 storms.

As an initial step towards understanding the HWRF model's challenges in predicting sheared hurricane intensity, a shear-relative analysis of structure, similar to that in Reasor et al., is performed using the 2012 Baseline model.

Methodology

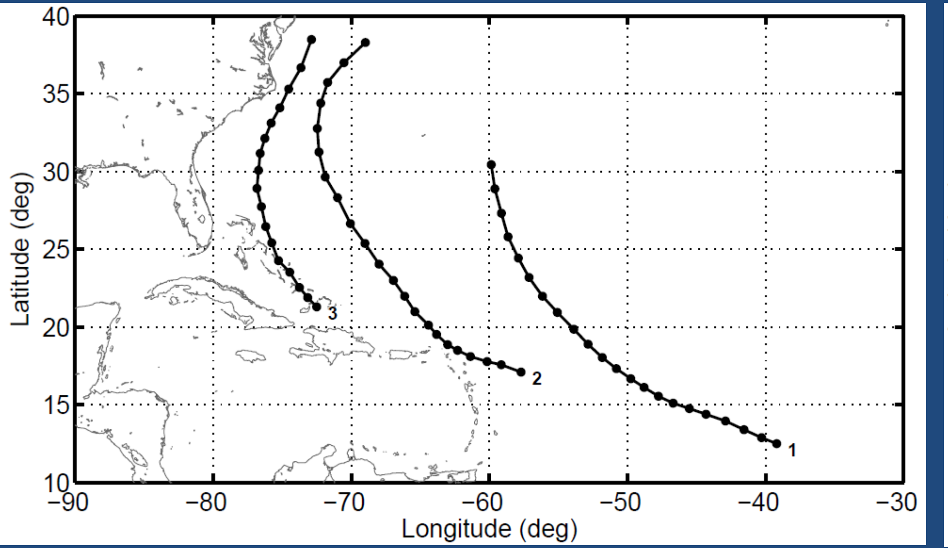
Following Reasor et al. (2013):

- Map storm-relative winds to a cylindrical coord. system centered on the low-level vortex (here, HWRF surface pressure centroid)
- Normalize radial coord. by the 2-km symmetric RMW
- Rotate fields such that the large-scale 850-200-hPa shear vector points due east
- Construct shear-relative structure composites

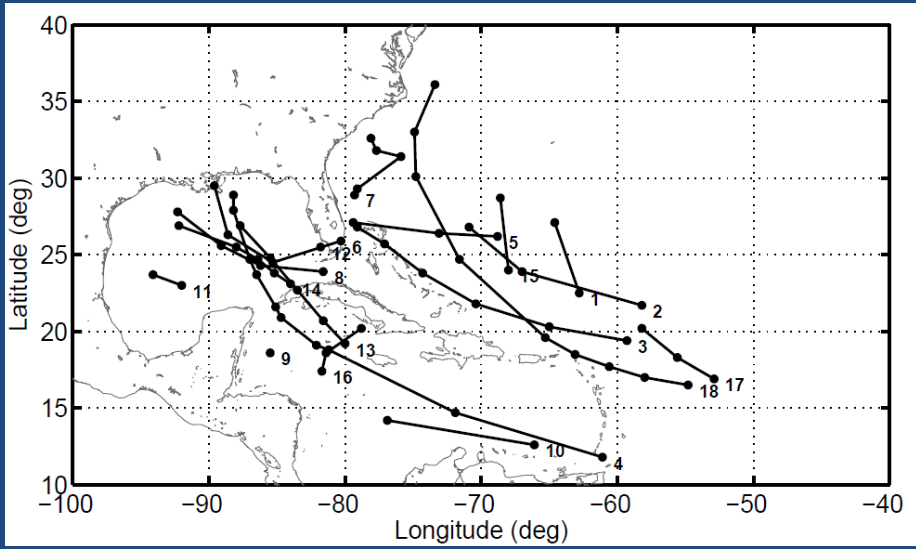
Focus here only on the domain represented by the radar analyses

Database of Cases

HWRF (<u>6-hourly</u> sampling)

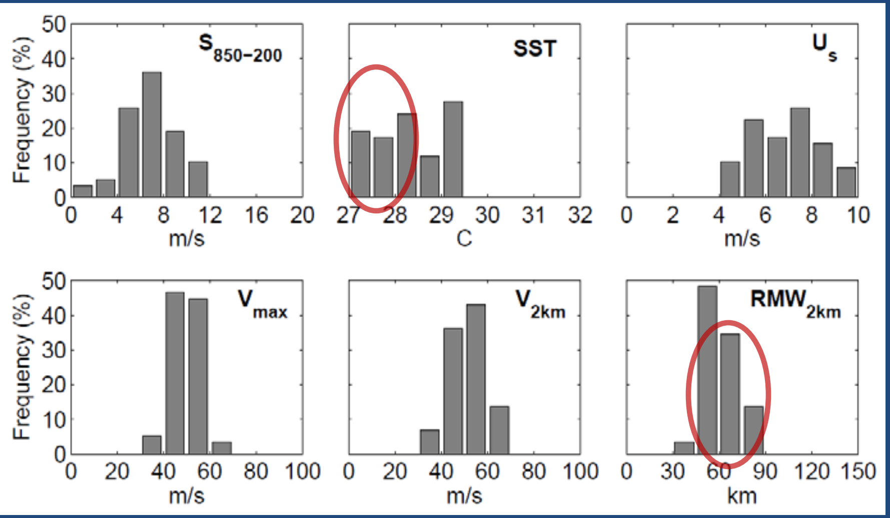


Radar-based

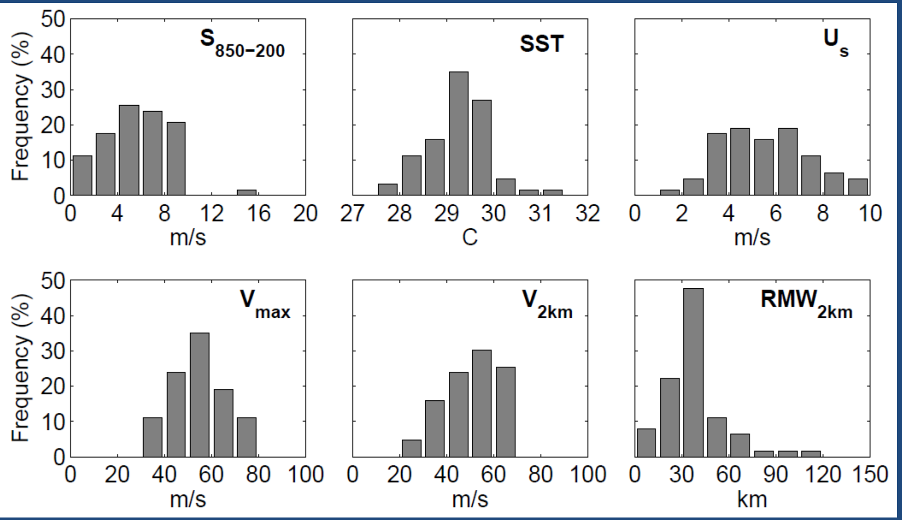


Environment and Vortex Properties

HWRF database



Radar database

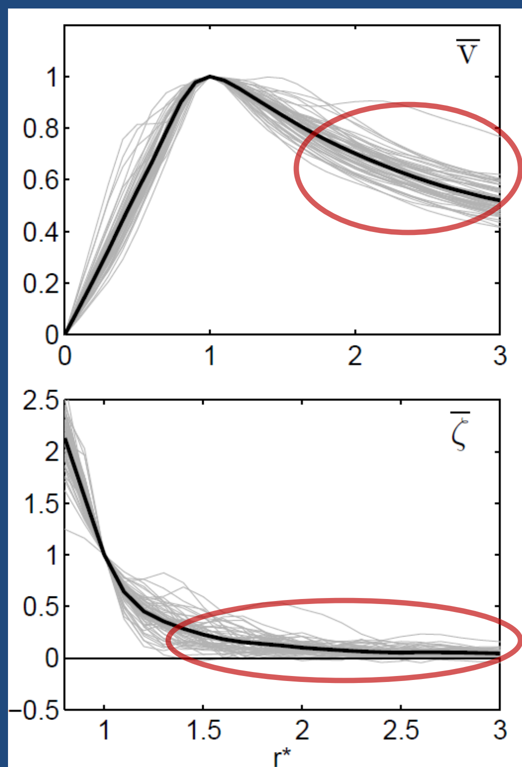


$S_{850-200}$ = SHIPS deep-layer shear   SST = Sea surface temperature U_s = Storm motion
V_{max} = Peak 10-m wind V_{2km} = Max. 2-km symm. tang. wind RMW_{2km} = Radius of V_{2km}

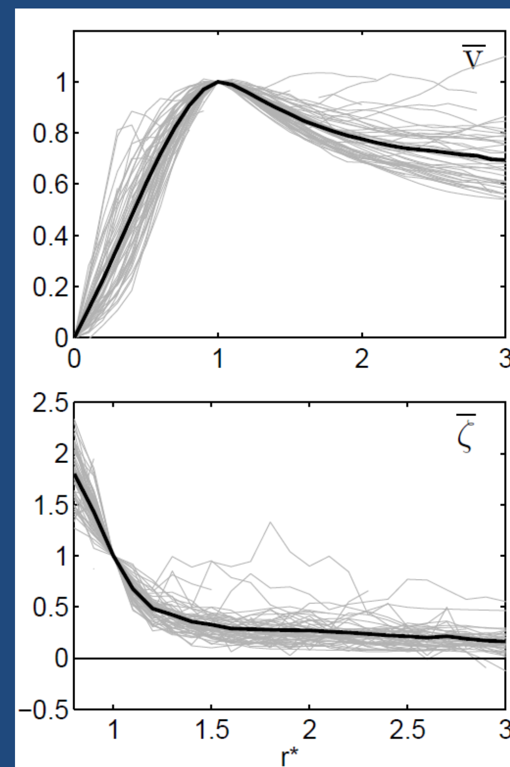
- More low SST cases in HWRF database (higher latitude)
- HWRF-simulated hurricanes have larger eyewalls → *Does this enhance resilience?*

2-km Symm. Tang. Wind and Vorticity
($r^* = r/RMW_{2km}$)

HWRF database



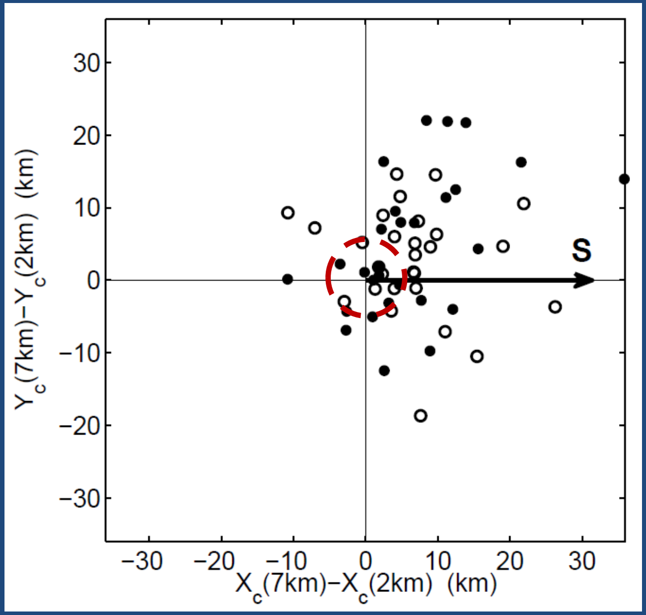
Radar database



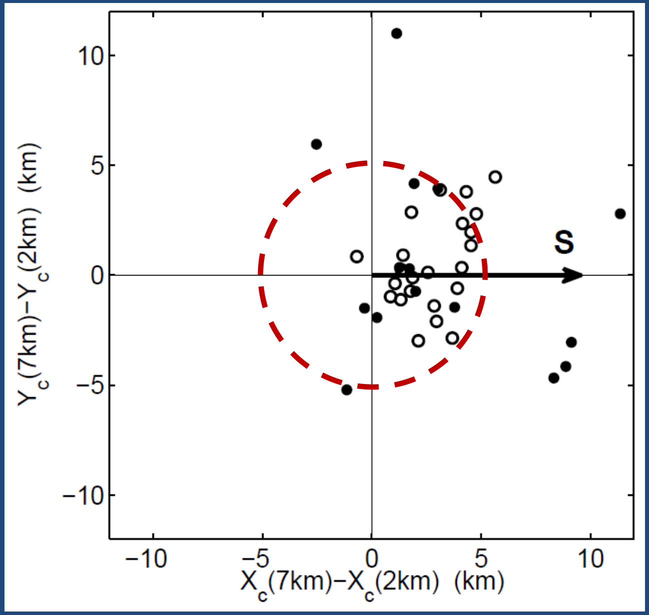
- On average, the HWRF-simulated hurricanes have less (normalized) vorticity at 1.5-3 RMW, but a larger radial *gradient* of vorticity → *Net impact on resilience?*

2-7-km Vortex Core Displacement

HWRF database



Radar database

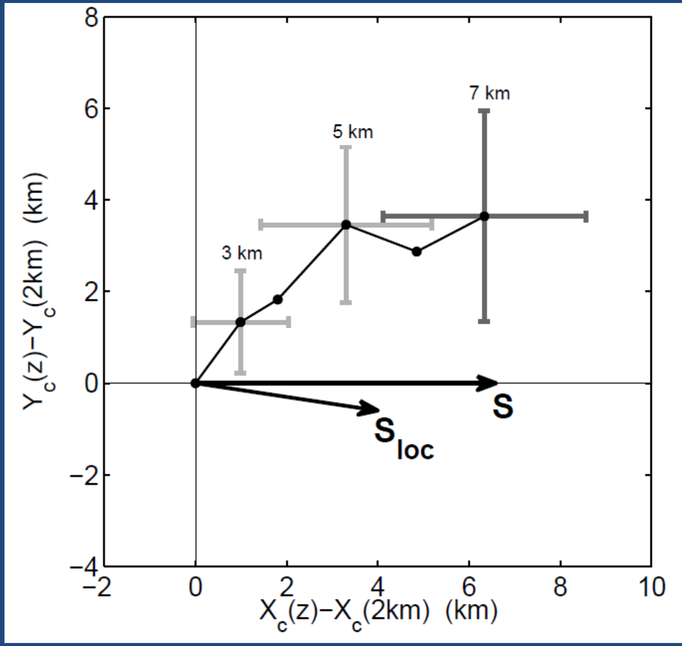


Solid (open) circles represent intensity less (greater) than mean intensity of database

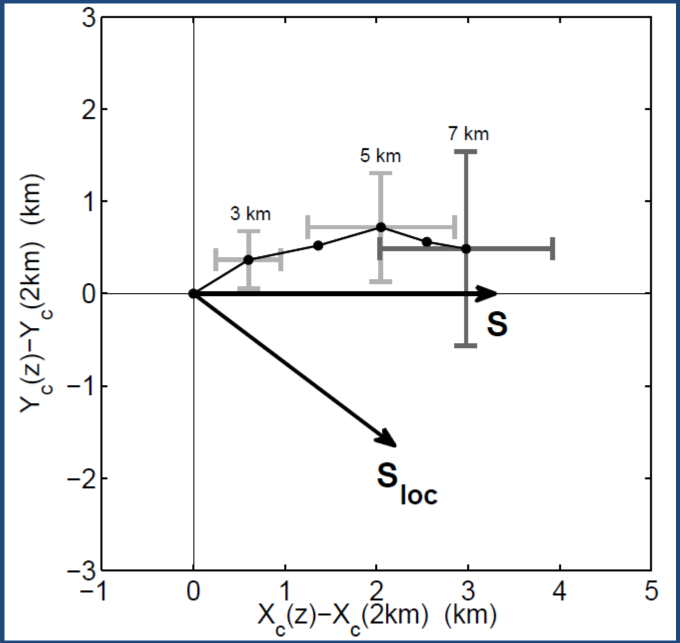
- Downshear to downshear-left preference for hurricane core tilt
- HWRF database reveals a higher frequency of core tilt values > 5 km → *Is this difference an artifact of a bias in the radar database sample?*

2-7-km Vortex Core Displacement (Composite)

HWRF database



Radar database

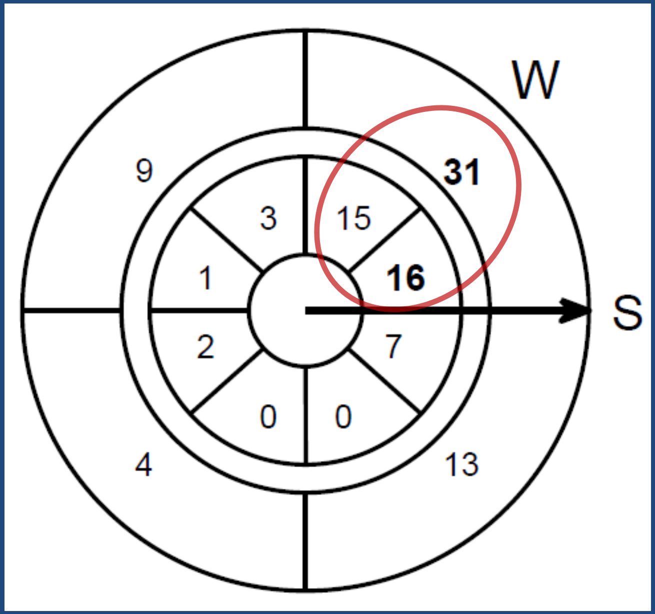


Note:

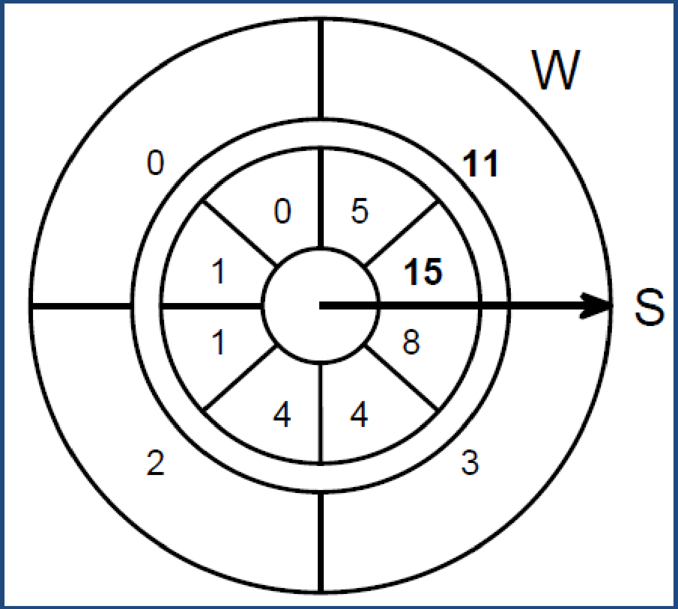
- On average, HWRF-simulated hurricane tilts more to the left of large-scale shear
- HWRF-simulated local 2-9-km shear (120-km radius with vortex “removed”) more closely aligns with the large-scale shear

Maximum Convective Area Location

HWRF database



Radar database



Number of cases in which the peak convective area (defined by the region with 5-km Inner (outer) band W > 2-2.5 (1-1.5) ms^{-1}) falls within a given octant or quadrant.

Inner band: $0.8 < r^* < 1.2$ Outer band: $1.5 < r^* < 2.5$

Wind, Divergence, and Vorticity
(Composite)

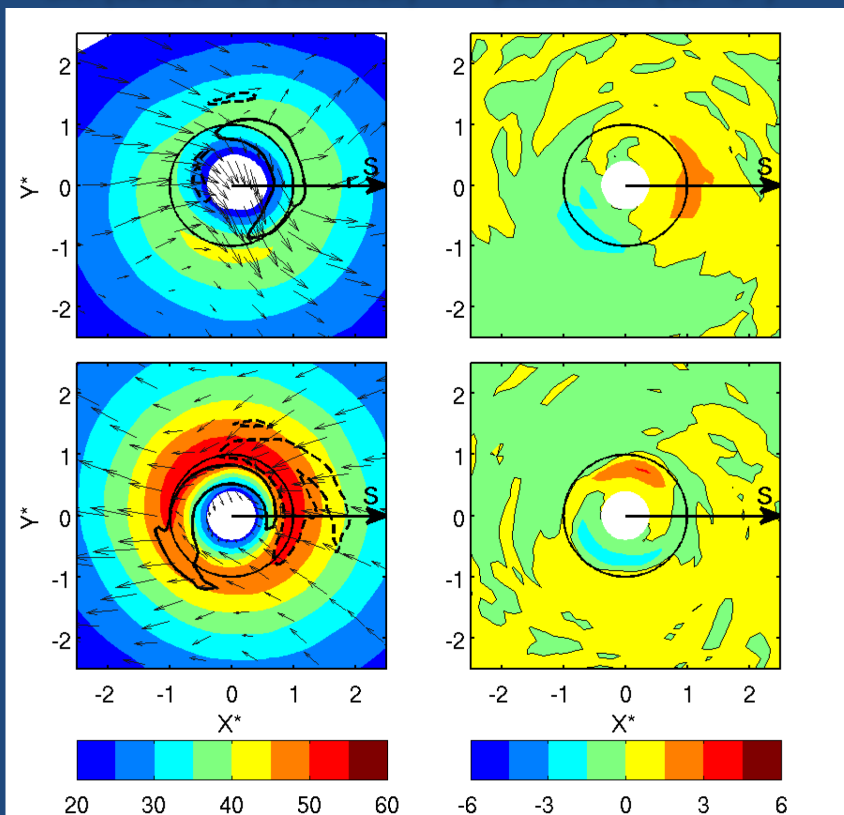
7 km

2 km

HWRF database

Windspeed (ms^{-1})+pert. vectors div. ($\pm 1x10^{-4}$ s^{-1}, contour)

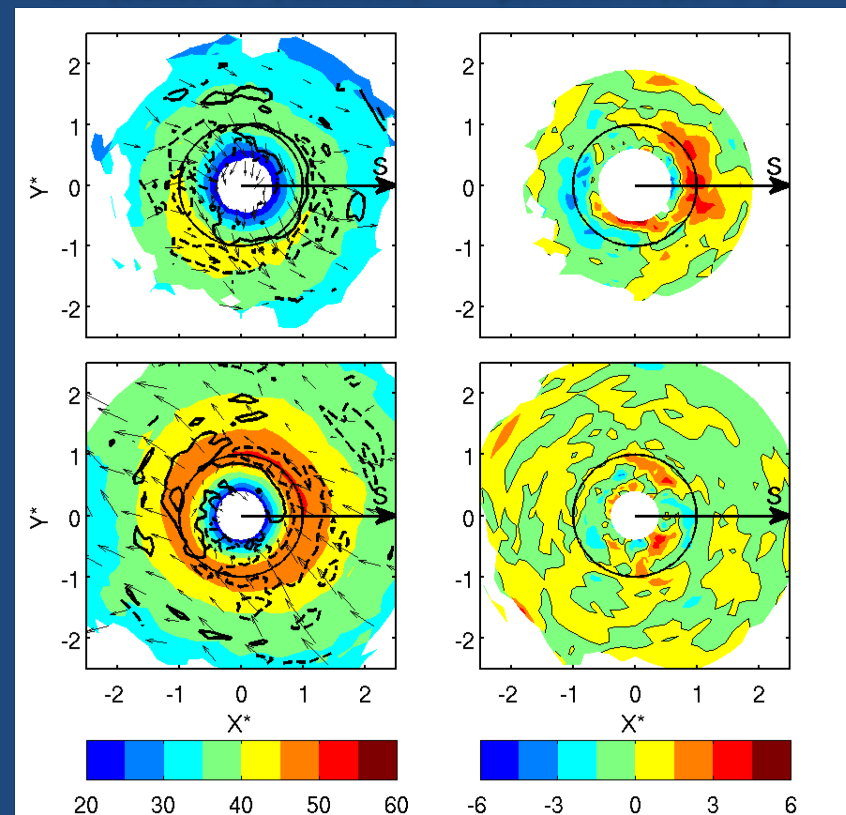
pert. vort. (10^{-4} s^{-1})



Radar database

Windspeed (ms^{-1})+pert. vectors div. ($\pm 1x10^{-4}$ s^{-1}, contour)

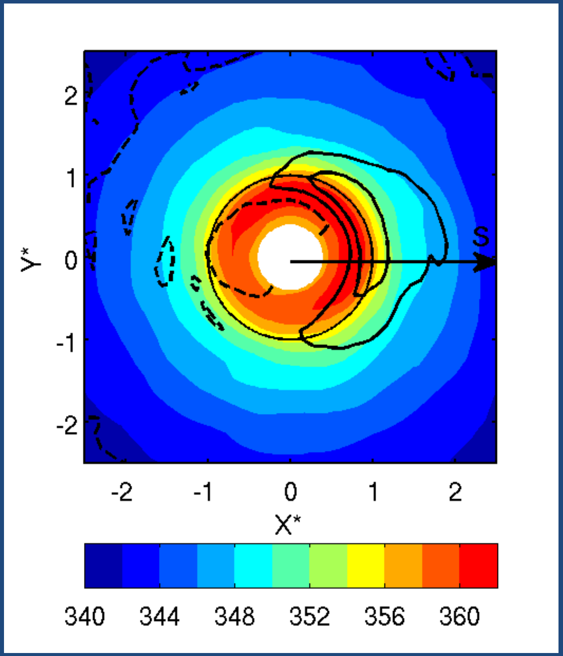
pert. vort. (10^{-4} s^{-1})



Vertical Velocity and θ_e/dBZ (Composite)

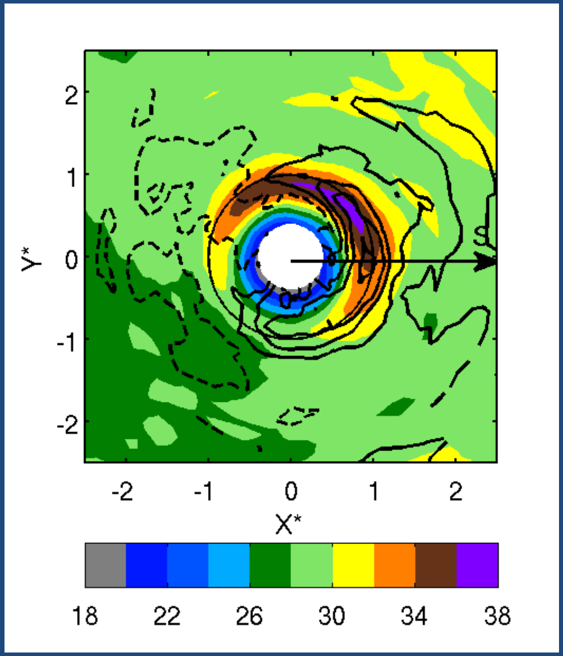
HWRF database

5-km W (contour) and θ_e (K, shaded)



Radar database

5-km W (contour) and 2-km Refl. (dBZ, shaded)

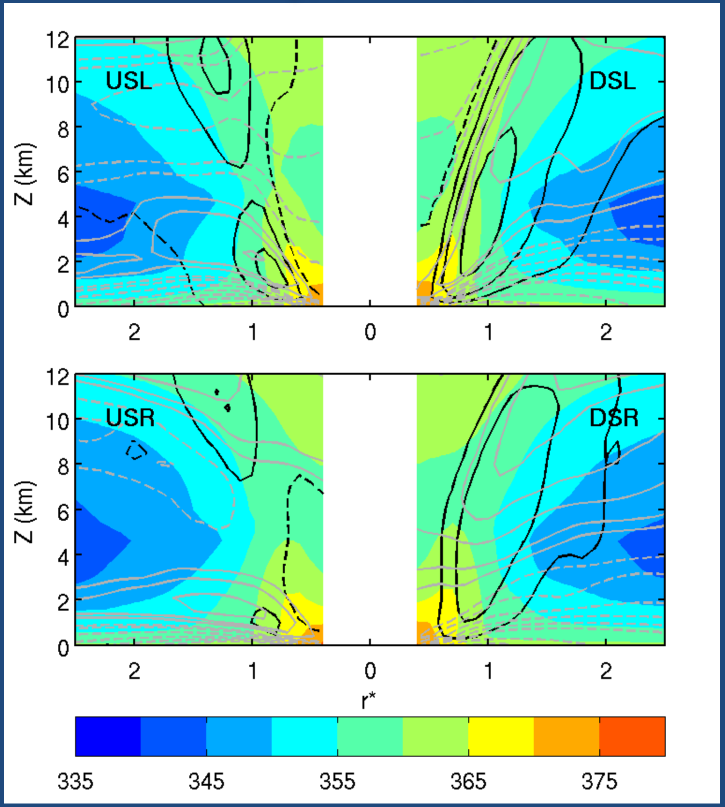


W contours: 0 (ms^{-1}, dashed); 0.5, 1, 1.5, 2 (ms^{-1}, solid)

Vertical and Radial Velocity and θ_e/dBZ (Quadrant-Mean Composite)

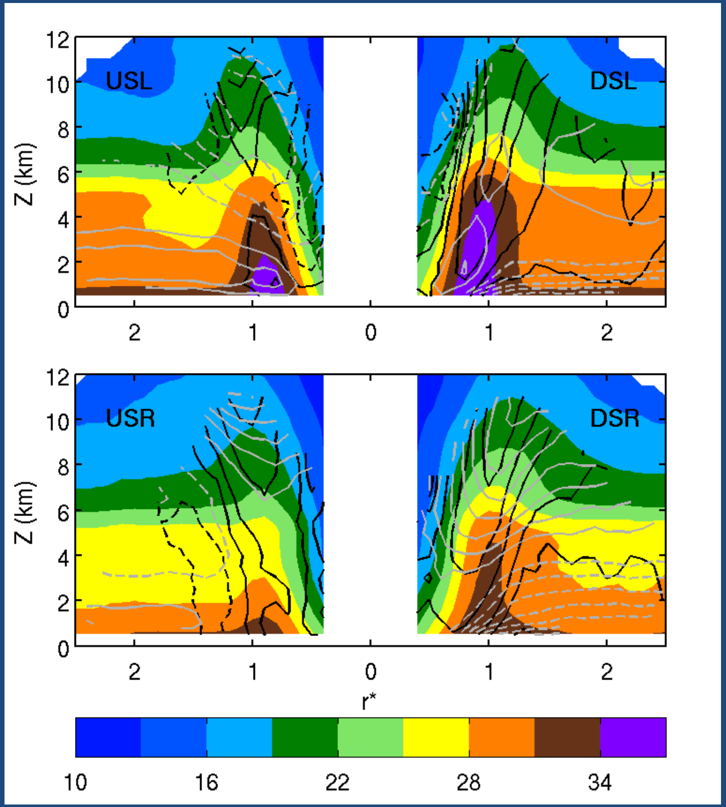
HWRF database

Vertical wind (-.25,0,.25,.5,1,1.5,2 ms^{-1}, black)
radial wind (±1,2,4,6,8,10,15,20 ms^{-1} gray)
θ_e (K, shaded)



Radar database

Vertical wind (-.25,0,.25,.5,1,1.5,2 ms^{-1}, black)
radial wind (±1,2,3,4,5,… ms^{-1}, gray)
Refl. (dBZ, shaded)



DSL = Downshear-left USL = Upshear-left USR = Upshear-right DSR = Downshear-right

Summary

Relative to the radar-based study of Reasor et al. (2013), the composite analysis of shear-relative hurricane structure from the 2012 HWRF baseline model reveals:

- Lower (normalized) vorticity outside the RMW, but a greater radial gradient of vorticity there
- Greater tilt of the core, on average, but still a preference for a downshear-left orientation
- Composite eyewall ascent that is more sloped than from observations
- A core-region kinematic asymmetry that is broadly consistent with observations. The pattern of core-region descent and the low-level flow/thermo. structure require further investigation.

Future Work

Include a greater number of storm cases to increase the diversity of the sample.

Extend HWRF diagnostic analyses to a larger domain, and focus more on processes involved in shear-induced intensity change (e.g., transport of low-θ_e air into HBL).

Recommendations:

1) Test existing and future configurations of the HWRF model within this shear-relative diagnostic framework to ensure consistency with observations.
2) Use the extended HWRF diagnostic analyses to guide future sampling of observed sheared hurricanes.