# A Multiscale Analysis of the Rainband and Cellular Structure in Hurricane Irma (2017) Using the NCAR Ensemble

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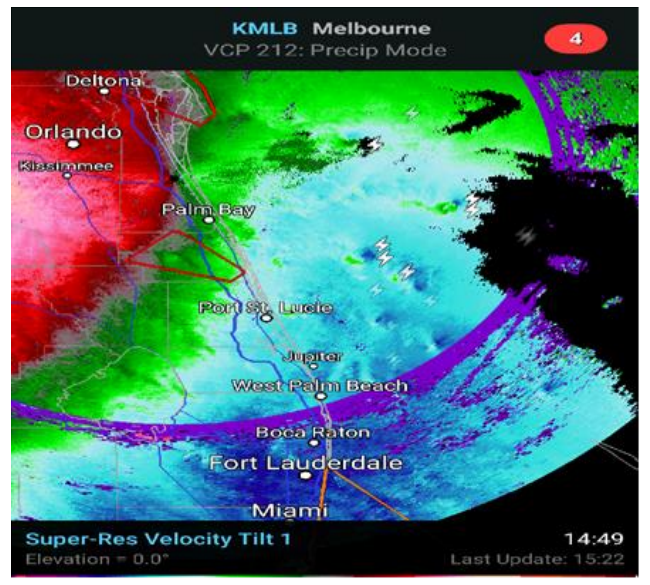
## Motivation:



- Tropical cyclones exhibit many severe weather hazards as they make landfall, such as storm surge, strong winds, flooding rains, and tornadoes from supercells in the rainbands.

*Fig. 1. 1449 LT 11 September super-res base velocity from Melbourne, FL (KMLB) during the landfall of Hurricane Irma (2017) .*

## Model and Storm:

- The NCAR Ensemble is a 10-member, single-physics, EPS with a 3-km convective allowing domain over the CONUS, initialized once a day at 0000 UTC, and run for 48 h.
- Both ensembles run on 10 and 11 September produce storms of similar track and intensity to the observed Hurricane Irma.

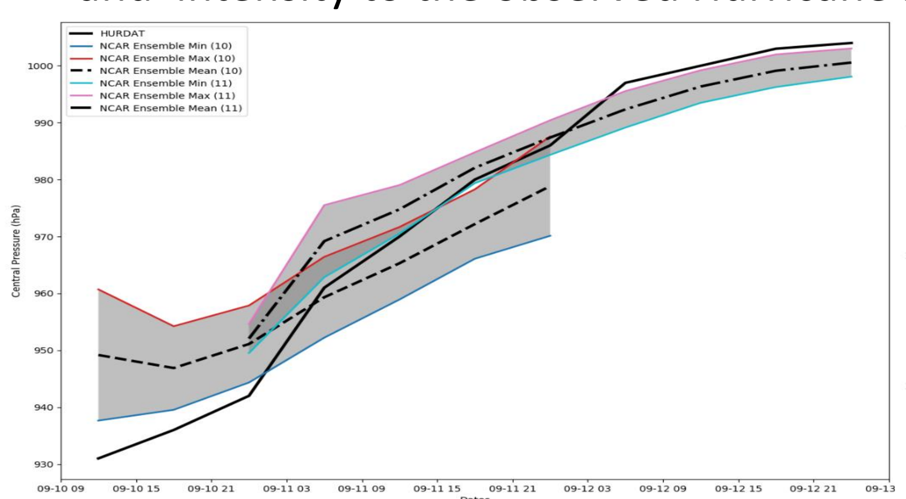


*Fig. 2. Minimum sea level pressure (hPa) initialized at 0000 UTC 10 and 11 September 2017.*

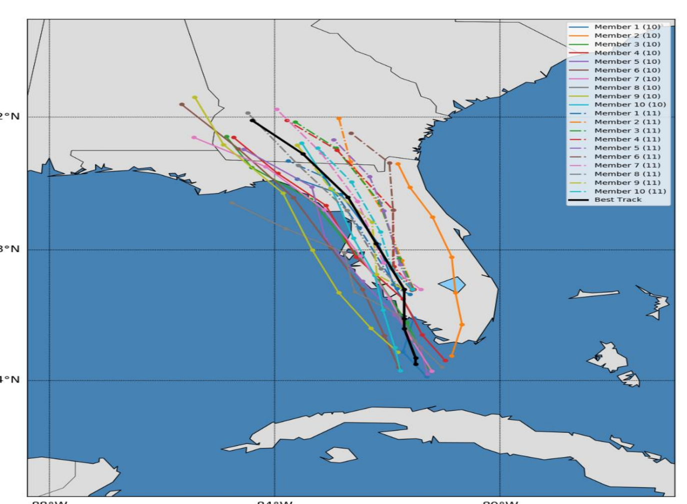


*Fig. 3. Track forecasts initialized at 0000 UTC 10 and 11 September 2017.*

## Structural Similarity (SSIM) and MET:

- **Radar reflectivity >=20 dBZ was** used to compare the ensemble members and observations.
- **SSIM** shows the **ensemble members are highly similar to the radar**, though **similarity decreases over time** as the storm undergoes extratropical transition.
- **MET-MODE area ratio** shows the **ensemble members are of similar size to the observed radar**, though this **ratio becomes smaller over time, as does the Critical Success Index.**

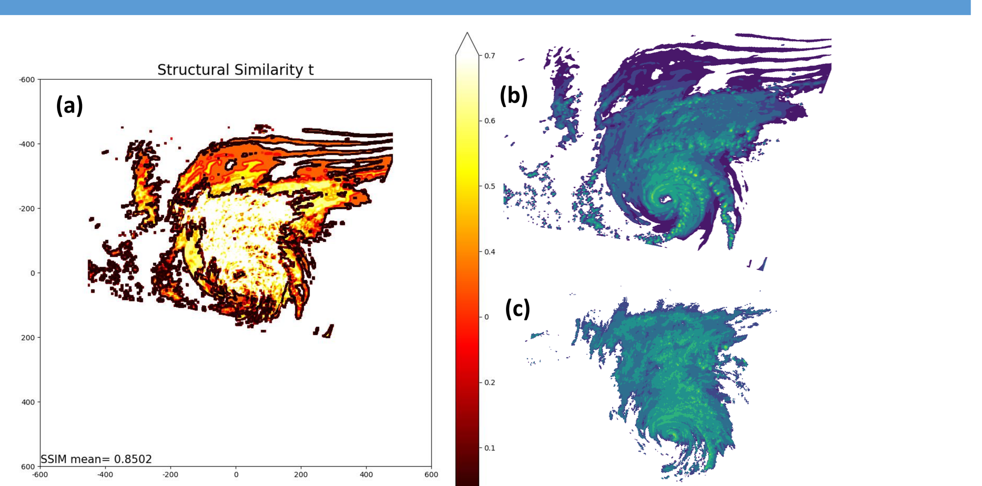


*Fig. 4. (a) Sample Structural Similarity Index plot for NCAR ensemble member 7 created from the model (b) and observation (c) reflectivity fields. Reds show regions where there are large differences between the ensemble member and the observed reflectivity.*

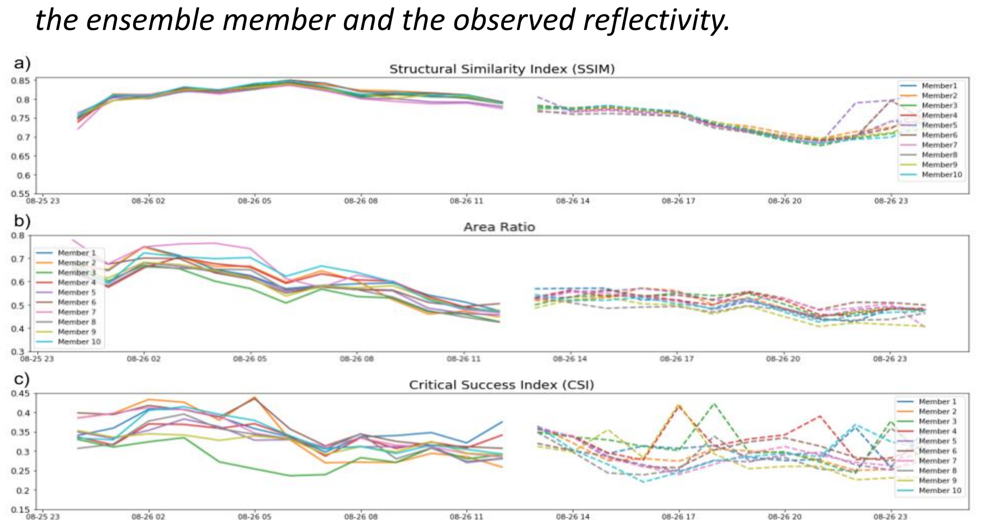


*Fig. 5. (a) Structural Similarity Index, (b) MET-MODE Area Ratio, and (c) Critical Success Index from 1200 UTC 10 September to 0000 UTC 12 September 2017.*

## Environment and Rainband Structure:

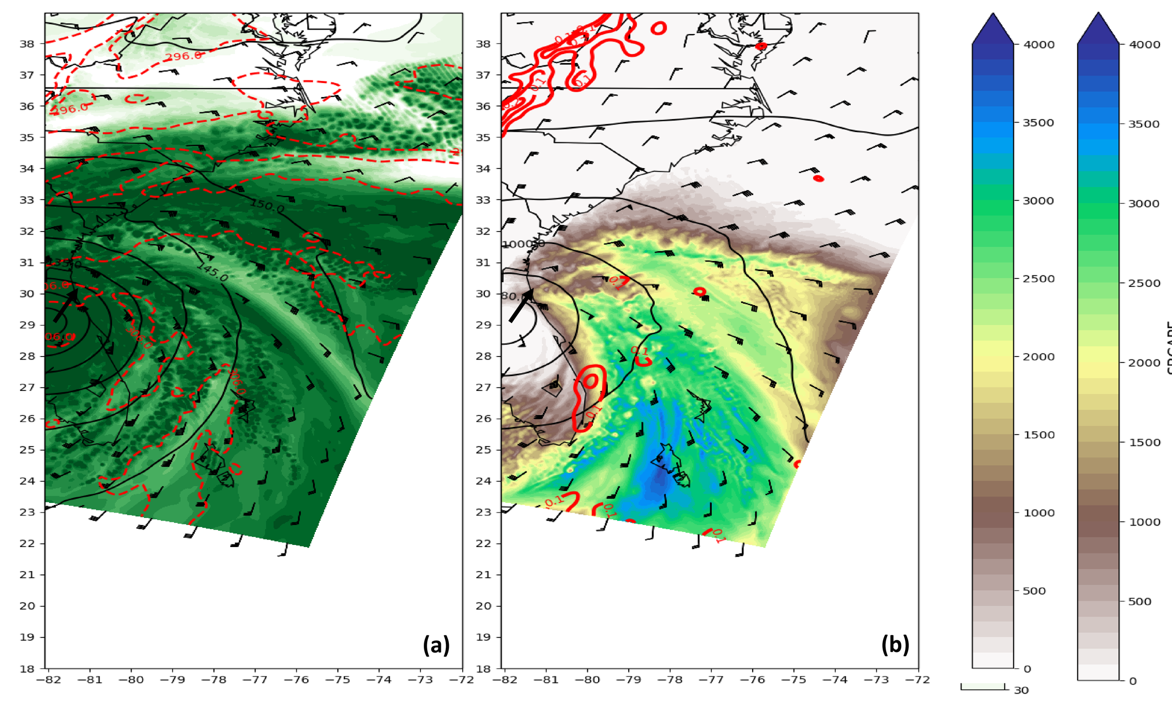


*Fig. 7. NCAR ensemble member 5 at 1200 UTC 11 September. (a) 850-hPa relative humidity (filled) and potential temperature (dashed), (b) surface based CAPE (filled) and 10-m wind convergence (solid). Arrows show the environmental shear vector.*

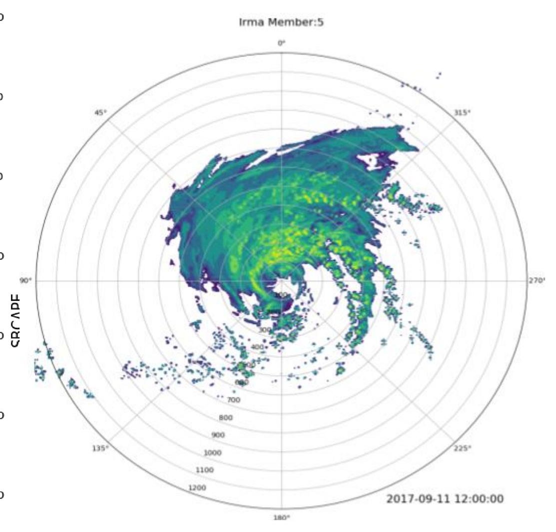


*Fig. 8. NCAR ensemble member 5 model reflectivity at 1200 UTC 11 September.*

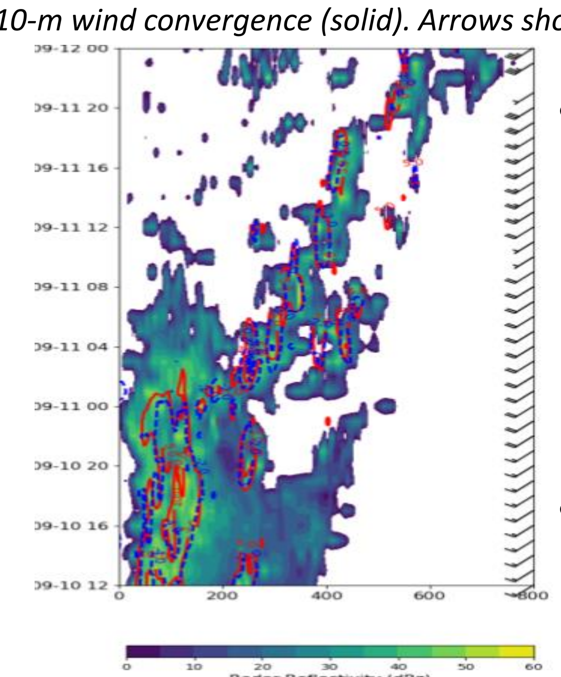


*Fig. 9. Hovmöller of model reflectivity (filled), updrafts (solid red), downdrafts (dashed blue), and shear (barbs).*

- There are regions of **lower relative humidity and higher temperature in between rainbands**, potentially associated with clearing resulting in increased surface warming causing **weak baroclinic forcing**.
- **SBCAPE is maximized to the right of the environmental shear vector**. Convergence of the 80-m winds can be seen on the leading edge of some convective cells.
- A reflectivity Hovmöller of member 5 shows multiple rainbands that move **outward over time**, and that the locations **updrafts (red) and downdrafts (blue) are collocated**.
- A cross section shows the rainband has **similar structure to observations and modeling studies.**
- A midlevel jet can be seen just below 4 km associated with the strong updraft of the convective line.

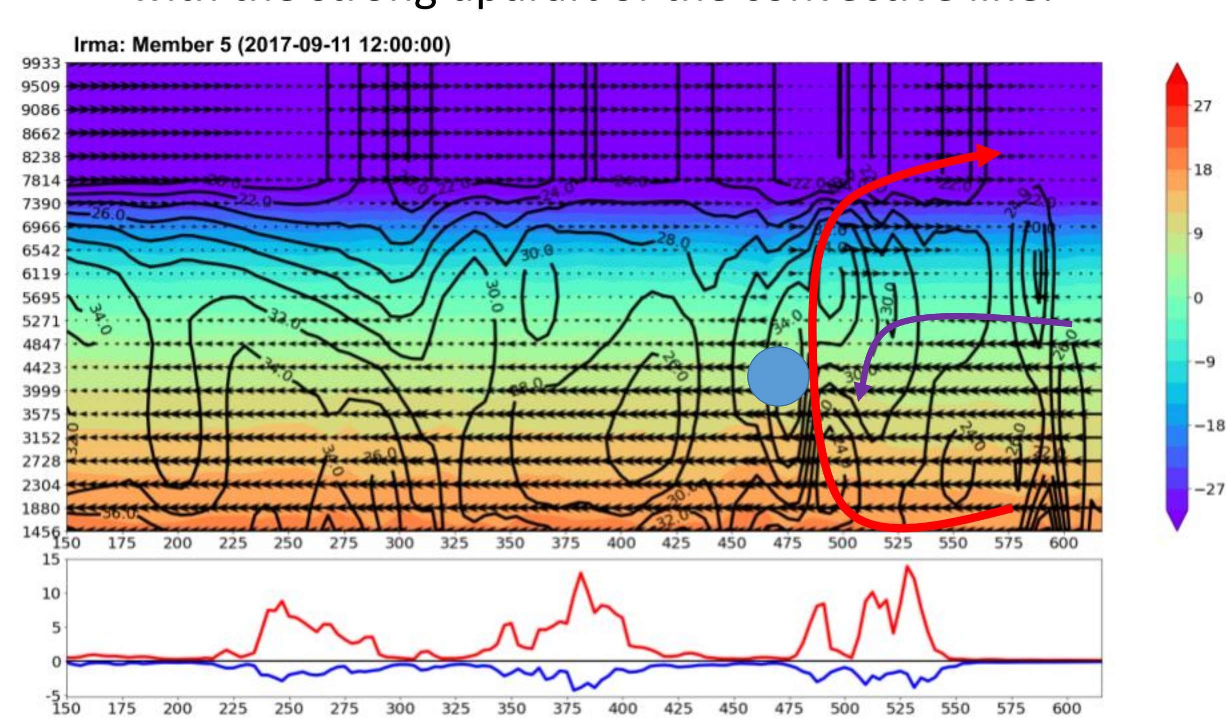


*Fig. 10. (Top) Vertical cross section of temperature (filled), tangential wind (solid), and radial wind (arrows). (Bottom) Upward (red) and downward vertical motion (blue).*

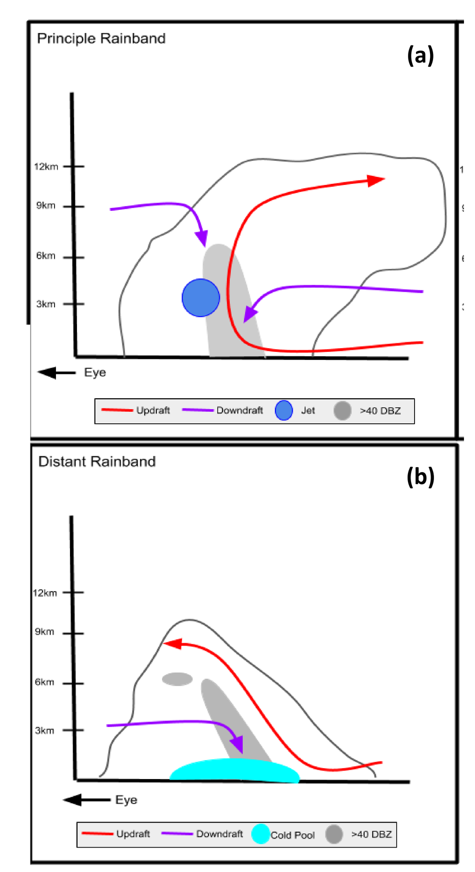


*Fig. 11. Schematics adapted from Houze (2010), Li and Wang 2012), and Moon and Nolan 2015) showing the vertical structure of the principle (a) and distant (b) rainbands.*

## Cellular Analysis:

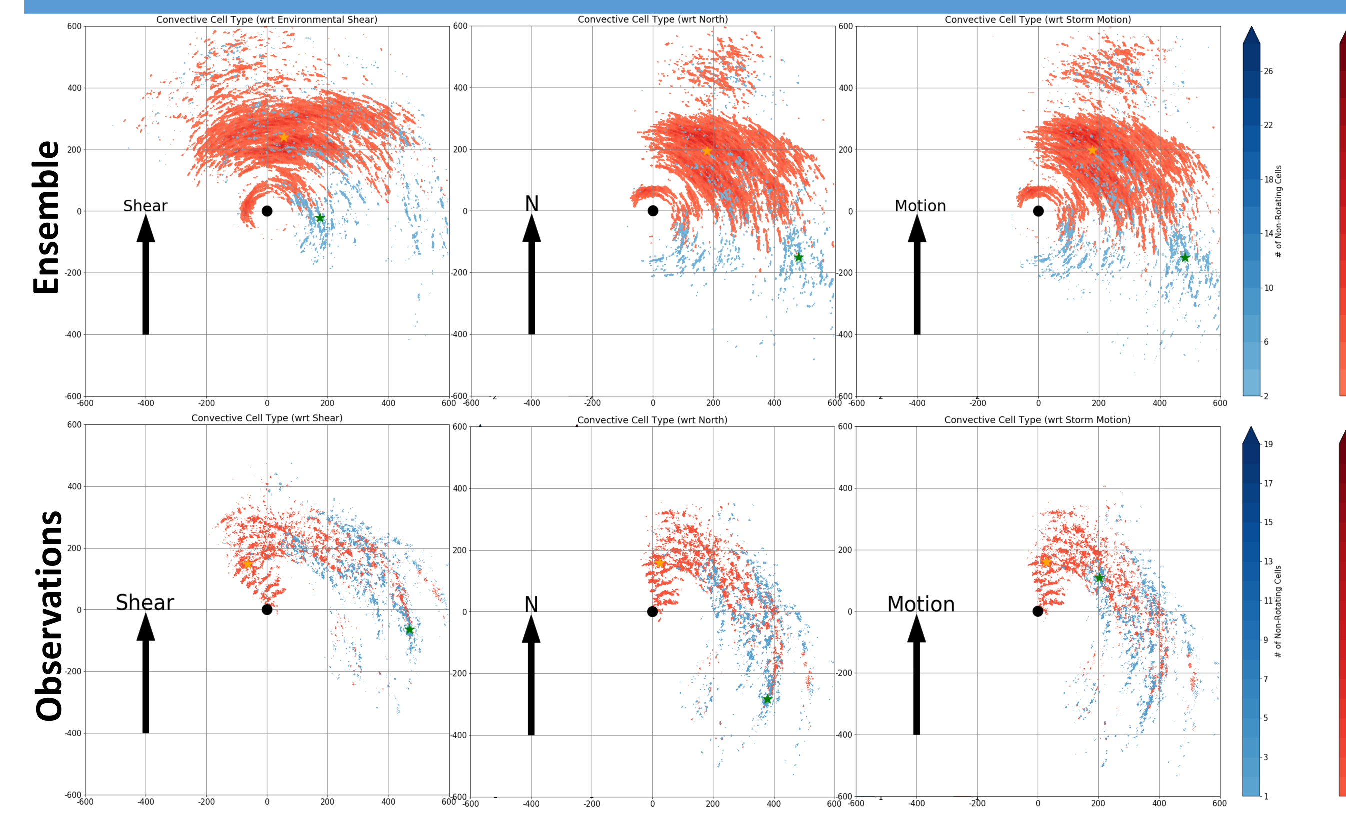


*Fig. 12. Heat map of rotating (red) and non-rotating (blue) cells with respect to shear, north, and storm motion. Centroid of rotating cells (orange star ) and centroid of non-rotating cells (green star).*

- **Rotating cells occur almost exclusively downshear**, while **non-rotating cells occur right of shear**.
- This separation suggests that **non-rotating convective cells form in the upshear-right quadrant** and begin to **rotate as they move downshear**.
- **Non-rotating convection peaks in the late afternoon.**
- **Rotating convection peaks in the morning hours** and decreases as the number of non-rotating cells increases.

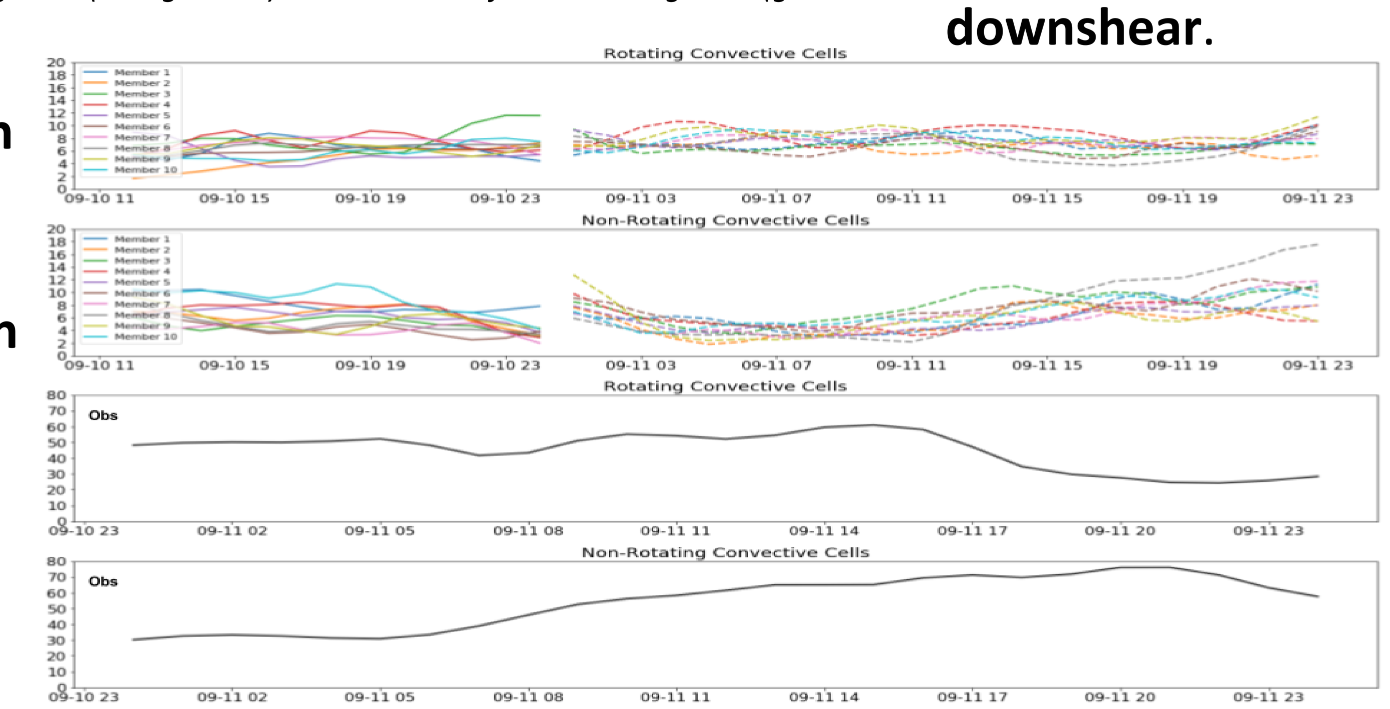


*Fig. 13. Hourly count of rotating and non-rotating cells in the NCAR ensemble and observations.*

## Conclusions and Future Work:

- The results of the structural similarity analysis are consistent with MET-MODE and may be a viable way to examine tropical cyclone structure.

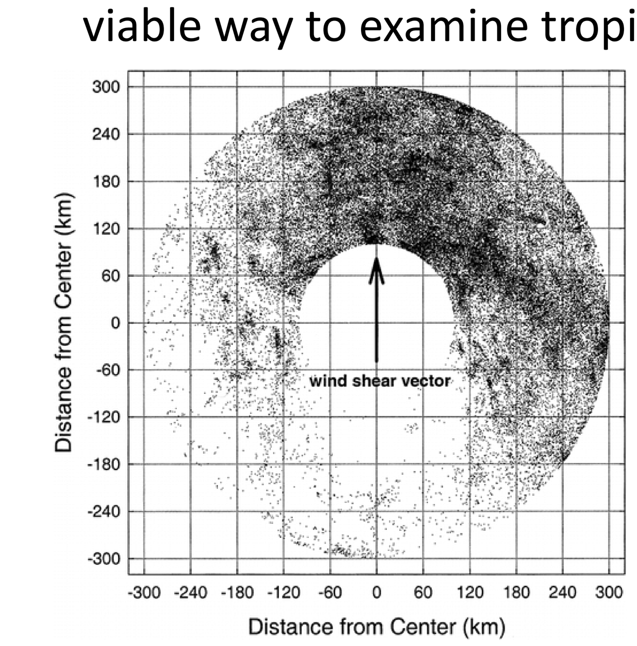


*Fig. 14. Lightning flashes occurring in tropical cyclones with respect to vertical wind shear. From Corbosiero and Molinari (2002).*

- CAPE is maximized downshear right consistent with observational studies.
- The structure of the principle rainband is well resolved in the NCAR ensemble consistent with observations and modeling.
- Most rotating cells occur downshear and most non-rotating cells occur right of shear.
- Non-rotating cells increase in frequency during the afternoon.
- Convection is oriented mostly downsehar right consistent with observational studies using lightning as a proxy for convection.
- Future work:
  - Repeat analysis for Hurricane Harvey (2017).
  - Further analysis to help predict supercells in the outer rainbands of tropical cyclones, including a high-resolution modeling study.