Analysis of the High-Resolution Mobile Mesonet Observations Collected during the 24 March 2023 Rolling Fork, Mississippi, Tornadic Supercell

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Case Overview and Background

- High-end EF-4 tornado that impacted Rolling Fork, MS
  - 195 mph maximum estimated wind speeds
  - $83 million in property damage, 17 deaths, and 165 injuries (NOAA NCEI 2023)
- Observed during the 3rd Intensive Observing Period (IOP 3) of the 2023 Propagation, Evolution, and Rotation in Linear Storms (PERiLS) field campaign by:
  - National Severe Storms Laboratory (NSSL) Mobile Mesonets (MMs) (Waugh 2023)
  - University of Illinois at Urbana-Champaign (UIUC) C-band on Wheels (COW) (Wurman and Kosiba 2023)
  - Texas Tech University (TTU) StickNets (Weiss and Ostaszewski 2023)
- Goal: Provide a storm-relative (S-R) perspective of NSSL MM and TTU StickNet observations to identify and characterize features within the Rolling Fork, MS, tornadic supercell

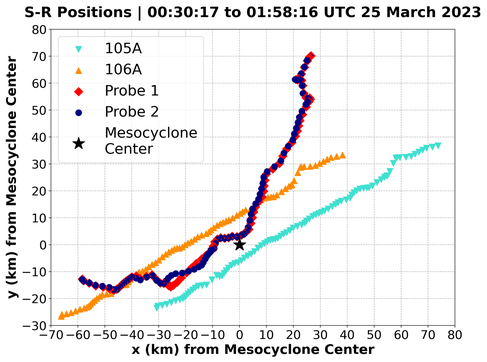


Fig. 1. Storm-relative (S-R) positions of the MMs (Probe 1 and Probe 2) and the StickNets (105A and 106A) with respect to the mesocyclone center (star).

Features of Interest

Forward-Flank Convergence Boundary (FFCB)
- Extends northeast from the mesocyclone with similar equivalent potential temperature (θ_e) values and weak gradients (Beck and Weiss 2013)
- Located along the eastern edge of the density (ρ) anomalies (Schueth et al. 2021)

Left-Flank Convergence Boundary (LFCB)
- Extends northwest from the mesocyclone with a strong eastward-pointing gradient (∇) in θ_e (Beck and Weiss 2013)
- Located along largest ρ anomaly (Schueth et al. 2021)

Streamwise Vorticity Current (SVC)
- Flows along forward-flank cold pool towards the mesocyclone (Orf et al. 2017)

Rear-Flank Gust Front (RFGF)
- Extends south from the mesocyclone with a sharp boundary in perturbation pressure and distinct wind shift (Beck and Weiss 2013)

Methods

- Identified the location and time of the low-level mesocyclone from the Jackson, MS, WSR-88D radar (KDGX) with Gibson Ridge 2 Analyst
- Quality controlled Probe 1 (P1) and Probe 2 (P2) data
- Conducted 5s averaging to P1, P2, 105A, and 106A
- Computed the mesocyclone relative location for each platform
- P1 fast temperature correction of -1.52°C
- Computed θ_e, virtual potential temperature (θ_v, acting as ρ), and horizontal baroclinically generated vorticity
- Vorticity calculation: $\frac{\Delta t}{\rho^2}\ \Delta\rho\ \Delta p$

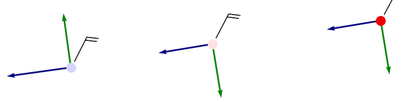


Fig. 2. Sample MM path vector (blue) and associated horizontal baroclinically generated vorticity vector (green). Note that the vorticity vector is always normal to the MM motion.

Results

FFCB
- ~1.4 km W of mesocyclone center
- Eastern edge of the $\nabla\theta_v$
- Streamwise baroclinically generated vorticity
- Identical θ_e on either side of the boundary

LFCB
- ~2.4 km W of mesocyclone center
- Largest $\nabla\theta_v$
- More streamwise and baroclinically generated
- Eastward pointing $\nabla\theta_e$

RFGF
- ~7 km S of mesocyclone center
- S-R wind direction change of ESE → NE
- Boundary in Mean Sea Level Pressure

SVC
- Peak generated vorticity within LFCB

Diffluent Signal
- ~0.8 km W of mesocyclone center
- Abrupt S-R wind direction change
- NNE → NE

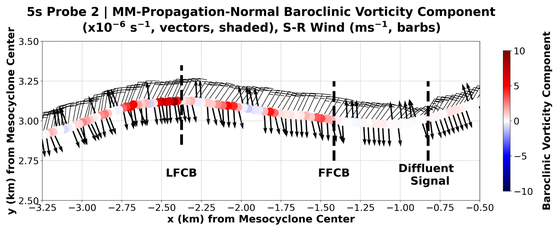


Fig. 3. Horizontal baroclinically generated vorticity magnitude and vectors, storm-relative wind, and approximate boundary locations.

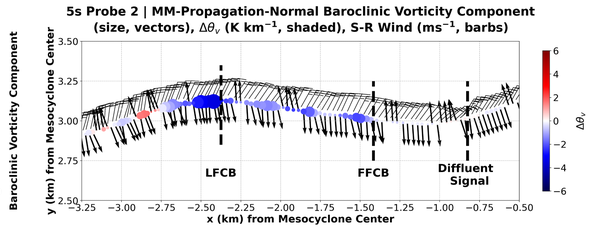


Fig. 4. Change in virtual potential temperature, horizontal baroclinically generated vorticity vectors, storm-relative wind, and approximate boundary locations.

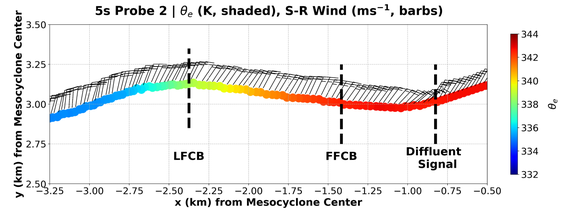


Fig. 5. Equivalent potential temperature, storm-relative wind, and approximate boundary locations.

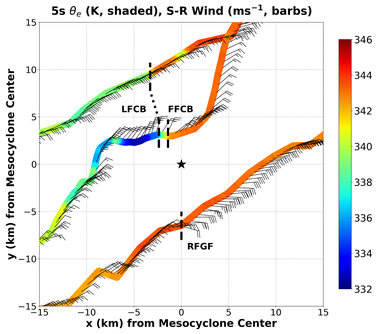


Fig. 6. Equivalent potential temperature, storm-relative wind, and approximate boundary locations.

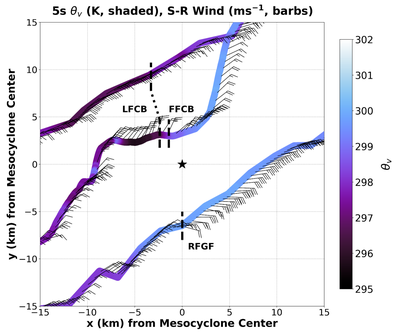


Fig. 7. Virtual potential temperature, storm-relative wind, and approximate boundary locations.

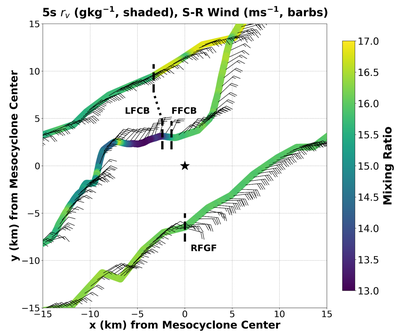


Fig. 8. Mixing ratio, storm-relative wind, and approximate boundary locations.

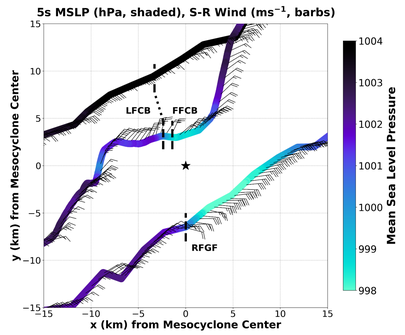


Fig. 9. Mean Sea Level Pressure, storm-relative wind, and approximate boundary locations.

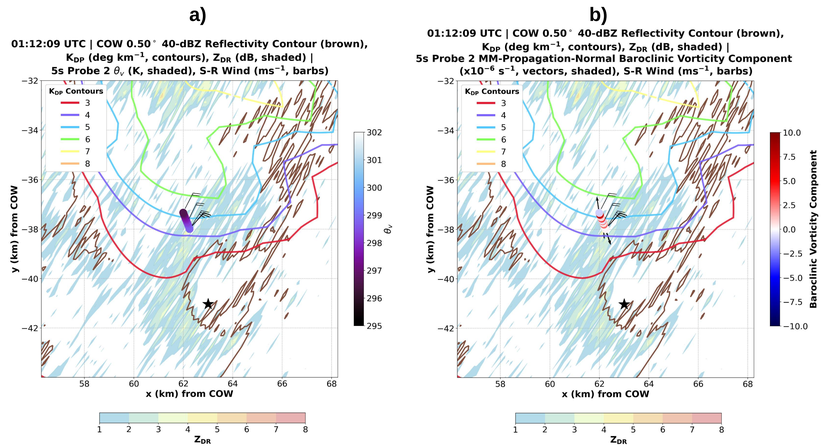


Fig. 10. a) COW 40-dBZ reflectivity contour, Differential Reflectivity (Z_{DR}), Specific Differential Phase (K_{DP}) contours, and a two-minute window of MM virtual potential temperature and storm-relative wind observations.
b) Same as in (a), but with horizontal baroclinically generated vorticity magnitude and vectors.

- Observations are in regions with high Liquid Water Content along the edge of a Differential Reflectivity (Z_{DR}) arc
- Hydrometeors are small raindrops
- Raindrops fall into the subsaturated air and will evaporate and cool
- Decreases θ_v and increases the ρ of the air
- Increases the ∇ρ along the MM path
- Results in a greater magnitude of baroclinically generated vorticity

$$\theta_v \propto \rho$$

$$\downarrow \theta_v \propto \uparrow \rho$$

$$\uparrow \Delta\rho$$

$$\uparrow \left[\frac{\Delta t}{\rho^2}\ \Delta\rho\ \Delta p\right] \propto \uparrow \left[\frac{dt}{\rho^2}\ \nabla\rho \times \nabla p\right]$$

Fig. 11. Connection between MM observations and COW observations.

Conclusions

- The FFCB, LFCB, SVC, and RFGF were identified in a storm-relative perspective of the Rolling Fork, MS, tornadic supercell via Mobile Mesonet and StickNet observations
- Results raise additional questions for future research to answer:
  Is there a difference between an SVC and LFCB at the surface?
  What are the differences in SVC characteristics at the surface versus aloft?
  Could the identification of high K_{DP} values along the edge of a Z_{DR} arc help identify LFCBs, FFCBs, and/or SVCs?
  Are these features driven by microphysical processes?

Acknowledgments

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References

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