Analysis of MYRORSS Azimuthal Shear Observations of the Morning QLCS Mesovortices of 27 April 2011

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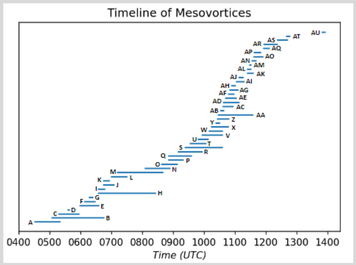
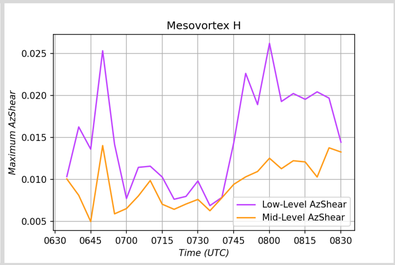
Background

- First QLCS of 27 April 2011 Super Outbreak
- Formed around 11:30 p.m. CDT on 26 April (0430 UTC on 27 April)
- Morning QLCS produced EF-0, EF-1, EF-2, and EF-3 tornadoes (58 total analyzed in this study)
- States Impacted: Louisiana, Mississippi, Alabama, Tennessee, Kentucky, Georgia, and Ohio



Timeline of the 47 morning QLCS tornadic mesovortices from 27 April 2011 labeled alphabetically in order of formation.



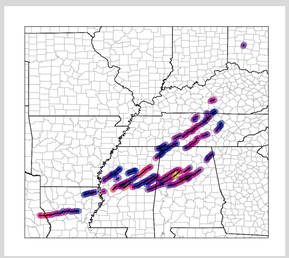
Comparison of low-level (0–3 km) and mid-level (3–6 km) azimuthal shear observations in Mesovortex H (longest-lived mesovortex and produced two EF3 tornadoes).

Methodology and Hypotheses

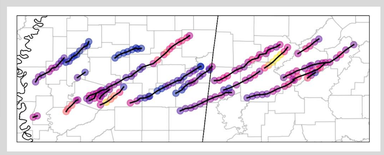
Methods: The Multi-Year Reanalysis of Remotely Sensed Storms (MYRORSS; Williams et al. (2022a)) dataset was used to study mesovortex evolution with azimuthal shear (AzShear) values. MYRORSS uses the Weather Surveillance Radar 1988-Doppler (WSR-88D) network archived data in the Multi-Radar Multi-Sensor (MRMS) framework and created a dataset of merged radar data from 1998–2011 in 5-minute increments (Williams et al. 2022b). The corresponding times of the MYRORSS merged AzShear observations were applied for both the low (0–3 km) and mid (3–6 km) levels of the mesovortices.

Hypotheses:

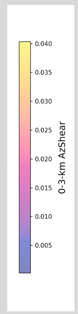
1. Values for low-level AzShear are higher than or equal to the midlevel AzShear during a tornado.
2. AzShear values are higher for the supercell mesocyclones than for the QLCS mesovortices.



QLCS mesovortex tracks plotted using mean latitude and longitude with associated low-level (0–3 km) azimuthal shear observations at each point.

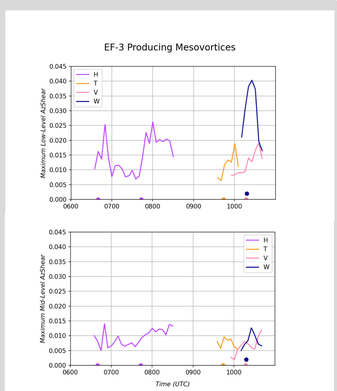


Close-up of morning QLCS mesovortex tracks group in Mississippi and Alabama plotted using mean latitude and longitude with associated low-level (0–3 km) azimuthal shear observations at each point.



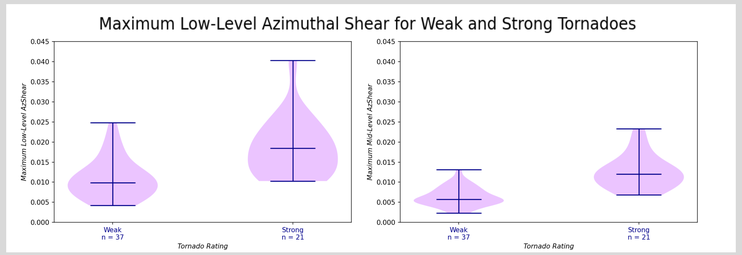
EF-3 Tornadoes of QLCS

- Range of AzShear: 0.0019 s^{-1} through 0.04033 s^{-1}
- Lowest value of AzShear found in mid-level observations (Range: 0.0019 - 0.01404 s^{-1})
- Highest value of AzShear found in low-level observations (Range: 0.00634–0.04033 s^{-1})
- Results show that peaks in AzShear happened either immediately after or shortly following tornadogenesis. A similar pattern was also observed by Lyza et al. (2019) for the Kankakee Valley mesovortices.



Comparison of low-level (0–3 km) azimuthal shear (top) and mid-level (3–6 km) azimuthal shear (bottom) observations in the four mesovortices that produced EF-3 tornadoes (H, T, V, and W) with tornadogenesis times plotted along the bottom of the plot, color-coded to the associated mesovortex.

Weak vs. Strong Tornadoes of Mesovortices



Comparison of maximum low-level (0–3 km) azimuthal shear (left) and mid-level (3–6 km) azimuthal shear (right) observations between weak (EF0 and EF1) and strong (EF2 and EF3) tornadoes from the morning QLCS.

For Mesovortex Data:

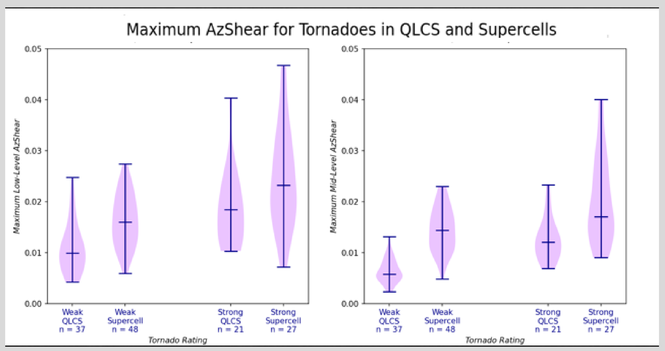
- Median for Weak Low-level: 0.00991 s^{-1}
- Median for Weak Mid-level: 0.00574 s^{-1}
- Median for Strong Low-level: 0.01843 s^{-1}
- Median for Strong Mid-level: 0.01202 s^{-1}

P values:

- Low-level weak vs. strong= 0.0002
- Mid-level weak vs. strong= 0.000001

According to Welch (1947), p-values of 0.05 or lower indicate that there is a 95% confidence that the means of two different populations are different from one another

Weak vs. Strong Tornadoes Compared between Mesovortices and Mesocyclones of Outbreak



Comparison of maximum low-level (0–3 km) azimuthal shear (left) and mid-level (3–6 km) azimuthal shear (right) observations between weak (EF0 and EF1) and strong (EF2 and EF3) tornadoes from the 27 April 2011 morning QLCS and supercells.

To compare the AzShear observations from the QLCS to those of the supercell outbreak on 27 April (Fig.10), 48 weak tornadoes and 27 strong tornadoes from the supercells were analyzed using the dataset from Lyza et al. (2022).

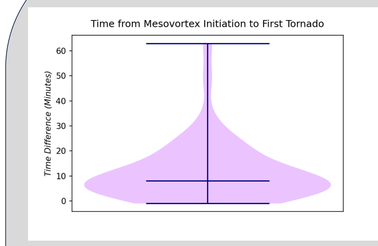
For Supercell Data:

- Median for Weak Low-level: 0.016 s^{-1}
- Median for Weak Mid-level: 0.01439 s^{-1}
- Median for Strong Low-level: 0.02321 s^{-1}
- Median for Strong Mid-level: 0.01704 s^{-1}
- Differences between median values of QLCS and Supercell AzShear is labeled on the figure above.

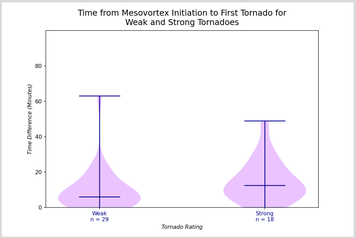
P values:

- Low-level weak = 0.000004
- Mid-level weak ≈ 0
- Low-level strong = 0.02
- Mid-level strong = 0.0002

Time Until Tornadogenesis



Median time difference (minutes) between mesovortex initiation and formation of a mesovortex's first tornado.



Comparison of the median time difference (minutes) between mesovortex initiation and the formation of a mesovortex's first tornado analyzed for weak (EF0 and EF1) and strong (EF2 and EF3) tornadoes from the morning QLCS.

All Tornadoes:

- Average: 11.7 minutes
- Median: 8 minutes
- Maximum: 63 minutes
- Minimum: -1 minute

The minimum time difference is negative because some tornadoes formed before their associated mesovortices were detected by radar.

Weak vs. Strong Tornadoes:

- Average for Weak Tornadoes: 9.7 minutes
- Median for Weak Tornadoes: 6 minutes
- Maximum for Weak Tornadoes: 63 minutes
- Average for Strong Tornadoes: 15.1 minutes
- Median for Strong Tornadoes: 12.5 minutes
- Maximum for Strong Tornadoes: 49 minutes
- P value= 0.143 (about 85% confidence)

Currently around a 15-minute lead time for tornadoes warned in advance (Brooks and Correia 2018)

Future Work

- Some of the start times for tornadoes had to be approximated as those records of the outbreak's tornadoes were inaccurate. These made it where tornadogenesis occurred before radar-detection for those mesovortices. The start times used in this study need correction should accurate information be made available.
- The comparison (p-value) found between tornado lead times for weak and strong tornadoes is determined substantial enough to provoke further study using a larger data set of multiple cases.
- According to Mitchell and Elmore (1998), Miller et al. (2013), and Newman et al. (2013), the LLSD method used in this study to derive AzShear, may possibly underestimate values. Further work could be done to analyze AzShear by other methods.
- Due to time, this study did not include information about a mesovortex's distance from the nearest WSR-88D radar. As this information is important when analyzing AzShear, it should be accounted for in future studies.

Key Findings

I. During both weak and strong tornadoes, low-level > mid-level

II. On average, strongly-rated tornadoes are associated with higher AzShear values.

III. Mesovortex W had highest recorded AzShear value: 0.04033 s^{-1}

IV. Noticeable peaks in AzShear immediately after/closely following tornadogenesis

V. Overall, mesocyclone AzShear > mesovortices AzShear (Excluding low-level observations in strong tornadoes)

VI. Mid-level observations contained largest difference in values between mesocyclones and mesovortices overall

VII. Time until tornadogenesis:

- Average: 11.7 minutes
- Median: 8 minutes
- Time difference is longer for strong tornadoes

Acknowledgements

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