Insights from Composite Environments of High-Shear, Low-CAPE (HSLC) Severe Convection

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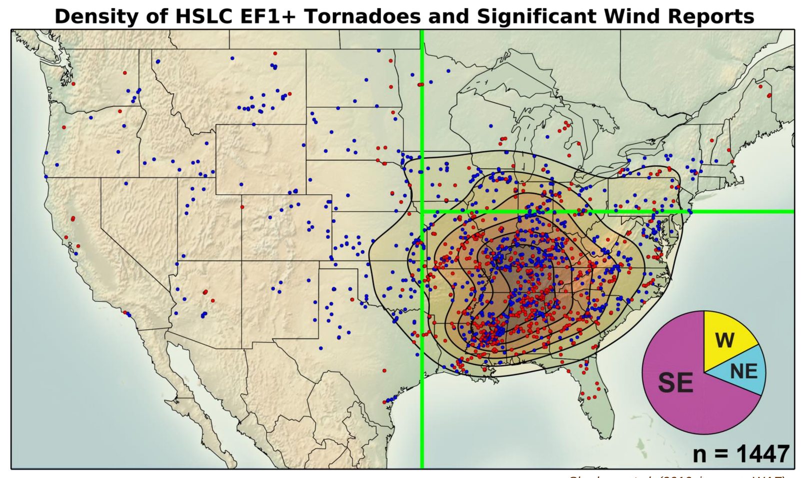
Background

Climatology

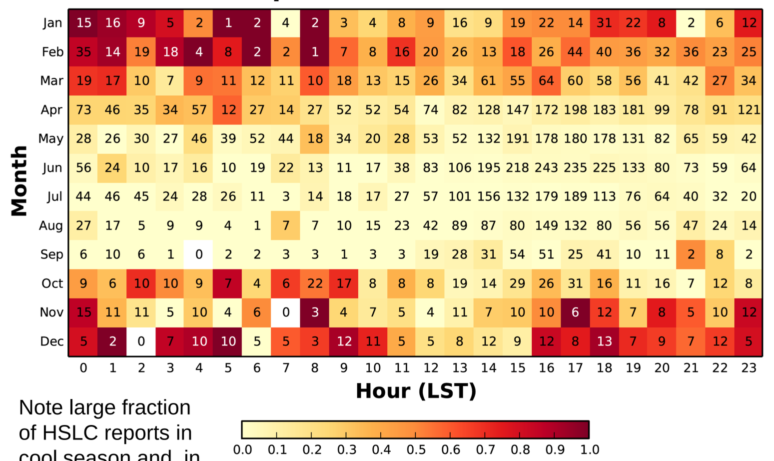
Density of HSLC EF1+ Tornadoes and Significant Wind Reports



(2006-2011) Red: HSLC EF1+ tornadoes, blue: HSLC significant wind reports; shading and contours show density

Sherburn et al. (2016, in press, WAF)

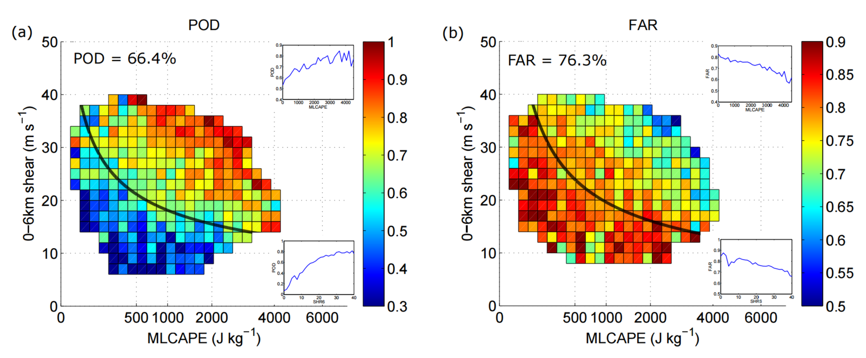
Fraction of EF1+ tornadoes and significant wind reports in HSLC environments



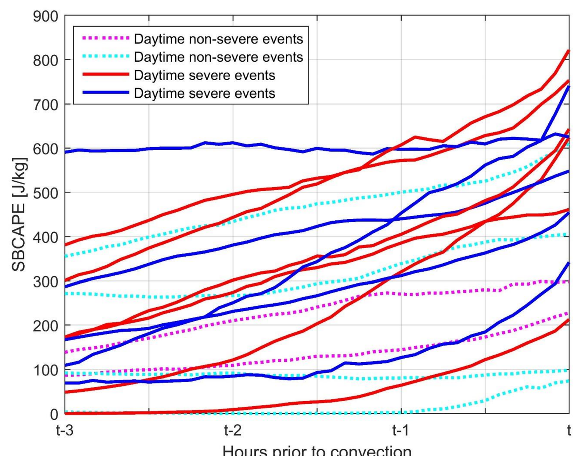
Note large fraction of HSLC reports in cool season and, in particular, overnight

Sherburn et al. (2016, in press, WAF)

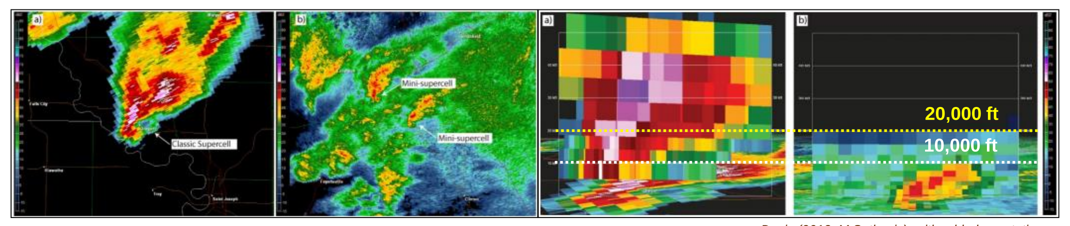
Operational Challenges



Anderson-Frey et al. (2016, in press, WAF)



King et al. (2016, in review, WAF)



Davis (2013, M.S. thesis), with added annotations

Examples

Top Left: Low POD/High FAR for tornado warnings

Bottom Left: Compressed convective scales compared to high-CAPE

Above: Rapid environmental evolution and destabilization

Data and Methodology

Dataset

North American Regional Reanalysis (NARR; Mesinger et al. 2006) fields associated with 2006-2014 high-shear, low-CAPE (HSLC) EF1 or stronger tornadoes and significant wind reports, in addition to false alarm tornado/severe thunderstorm warnings

HSLC criteria:

1. SPC mesoanalysis fields: SBCAPE ≤ 500 J kg^{-1}, MUCAPE ≤ 1000 J kg^{-1}, and 0-6 km bulk wind difference ≥ 18 m s^{-1}
2. NARR check: SBCAPE and MLCAPE ≤ 1000 J kg^{-1}

NARR details:

Horizontal resolution of approximately 32 km (0.3°)

29 full vertical levels

3-hour time step

Based on 2003 Eta model

Methodology

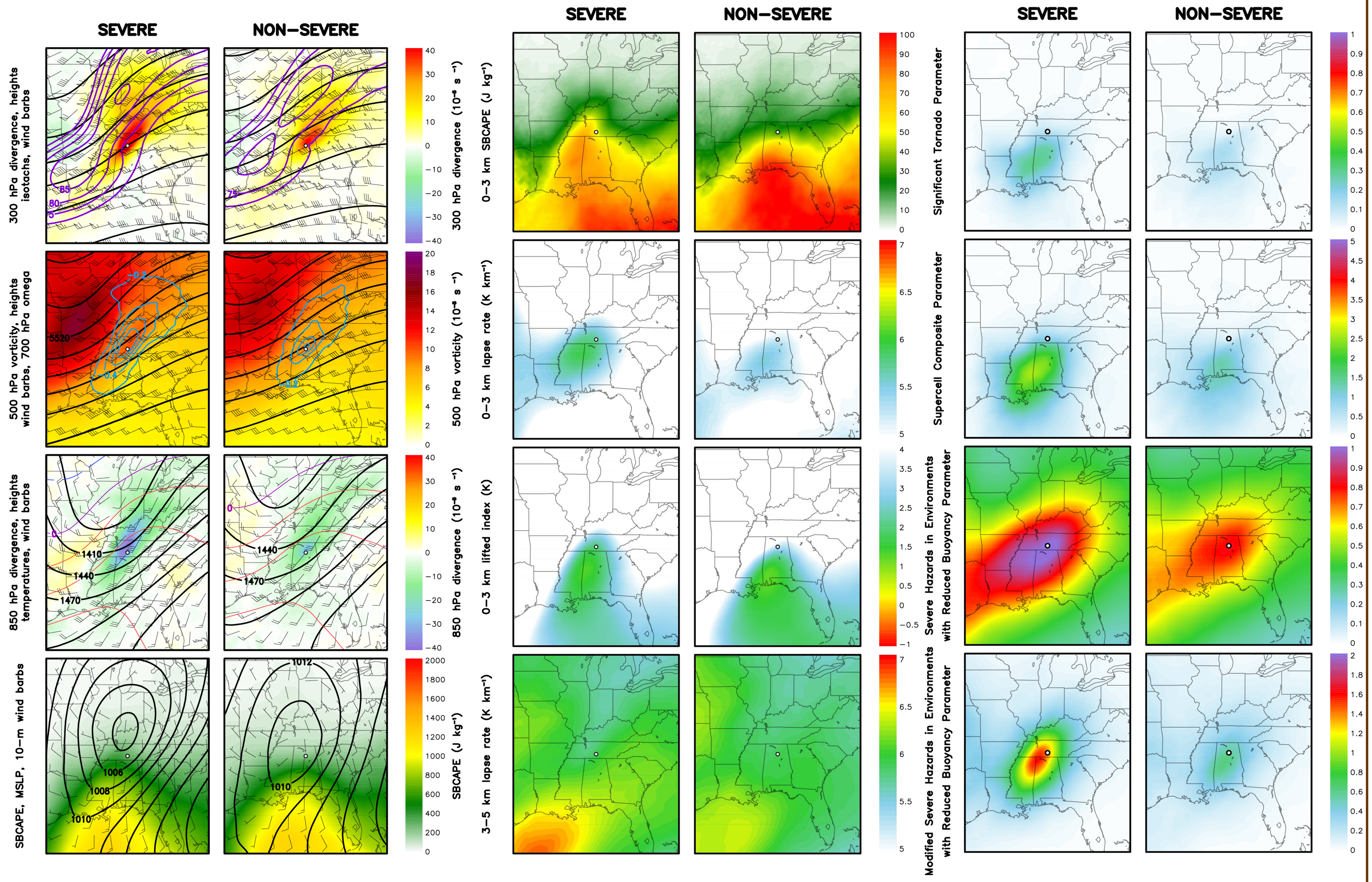
Composites were created in an event-relative sense; in other words, the center of the composite represents the *mean* report or null location in a given subset, and associated fields are plotted relative to this position.

In addition to overall severe reports versus nulls, several subsets were analyzed (those explored here in **bold**):

1. Seasonal (Spring, Summer, Autumn, Winter)
2. Diurnal (Daytime vs. Nighttime)
3. Regional (green lines in figure at top left; **Southeast**, Northeast, West)
4. **Report and warning type** (Tornado vs. Severe Thunderstorm)
5. **Convective mode** (Discrete supercells, hybrid supercells, and QLCS; subjectively determined; 2006-2011 only)
6. Event efficiency (i.e., number of reports)

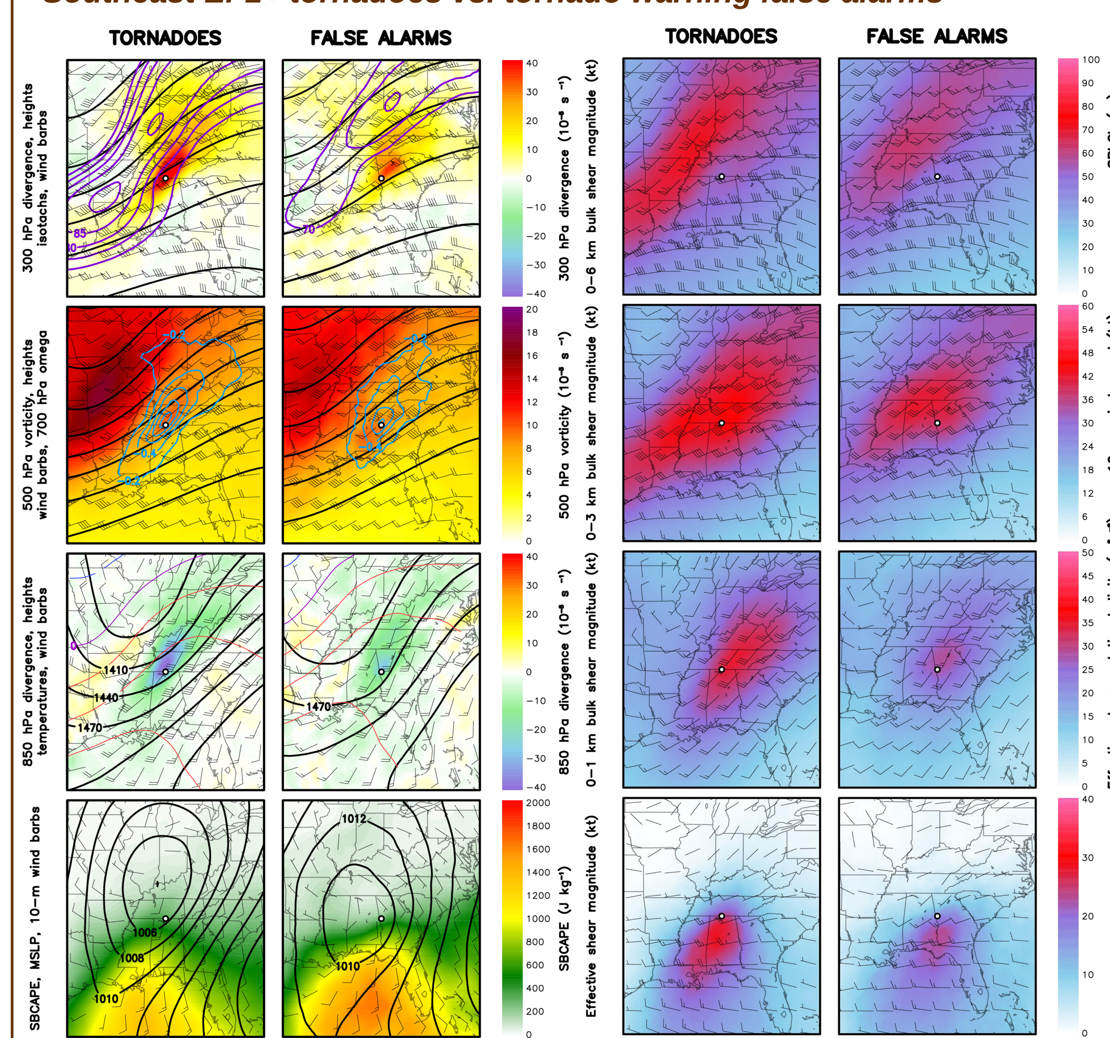
Composite Results

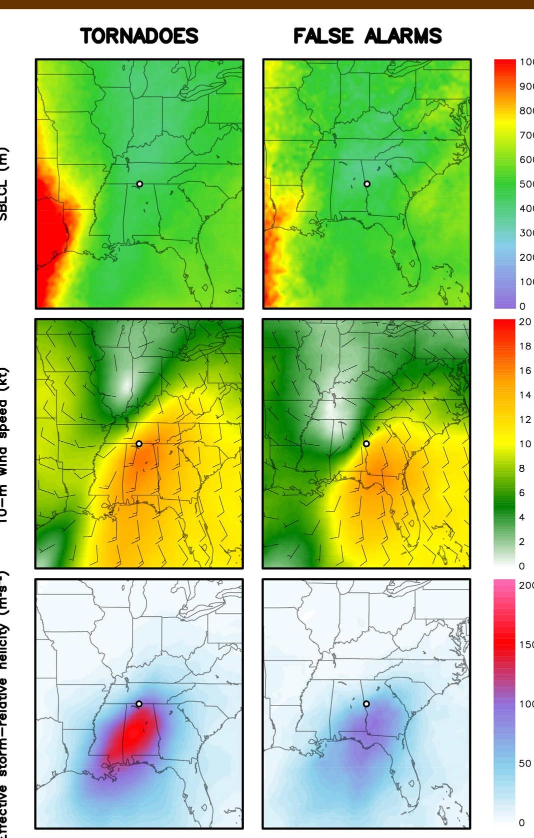
Southeast severe vs. non-severe events



Composite Results (continued)

Southeast EF1+ tornadoes vs. tornado warning false alarms





Number of cases in each composite

(Bottom left panel)

Southeast Severe: **1330**

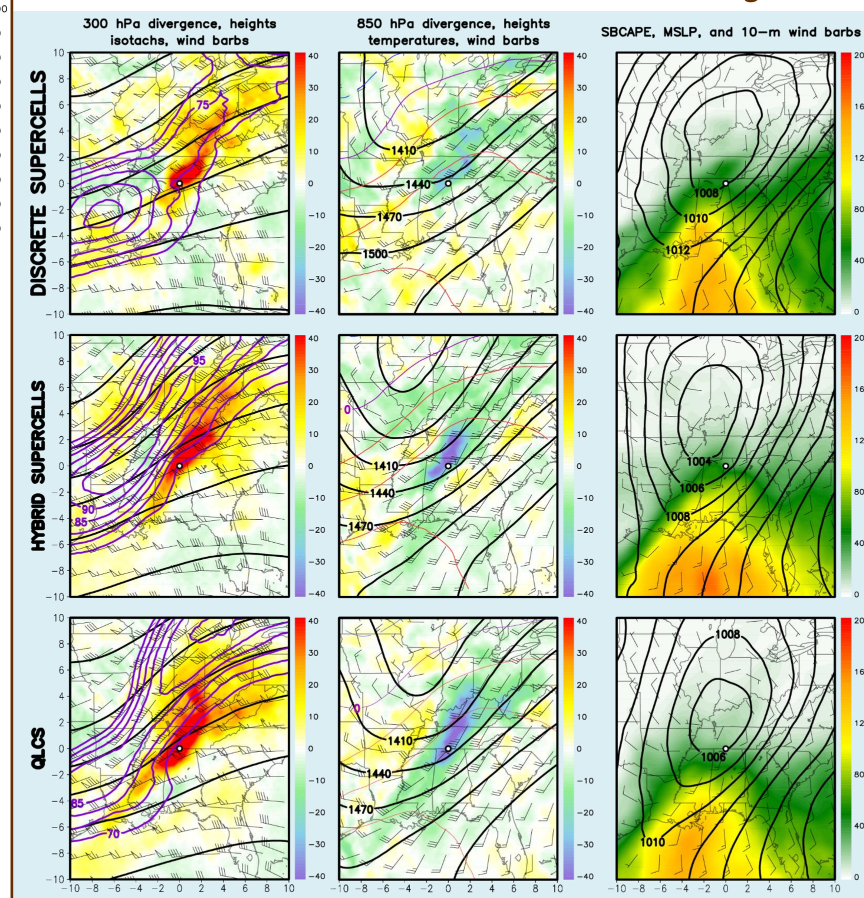
Southeast Non-Severe: **754**

(This panel)

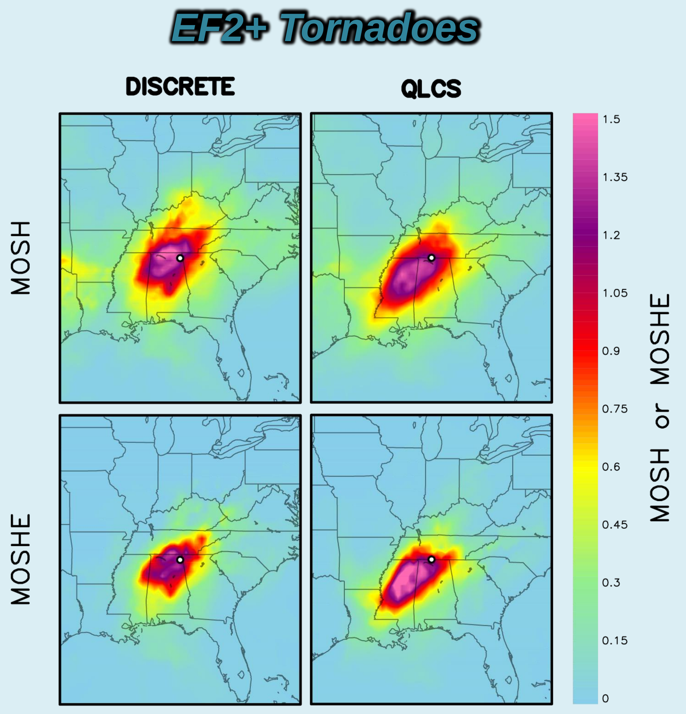
Southeast EF1+ Tornadoes: **719**

Southeast Tornado False Alarms: **147**

Southeast EF2+ tornadoes vs. tornado warning false alarms, by convective mode



EF2+ Tornadoes

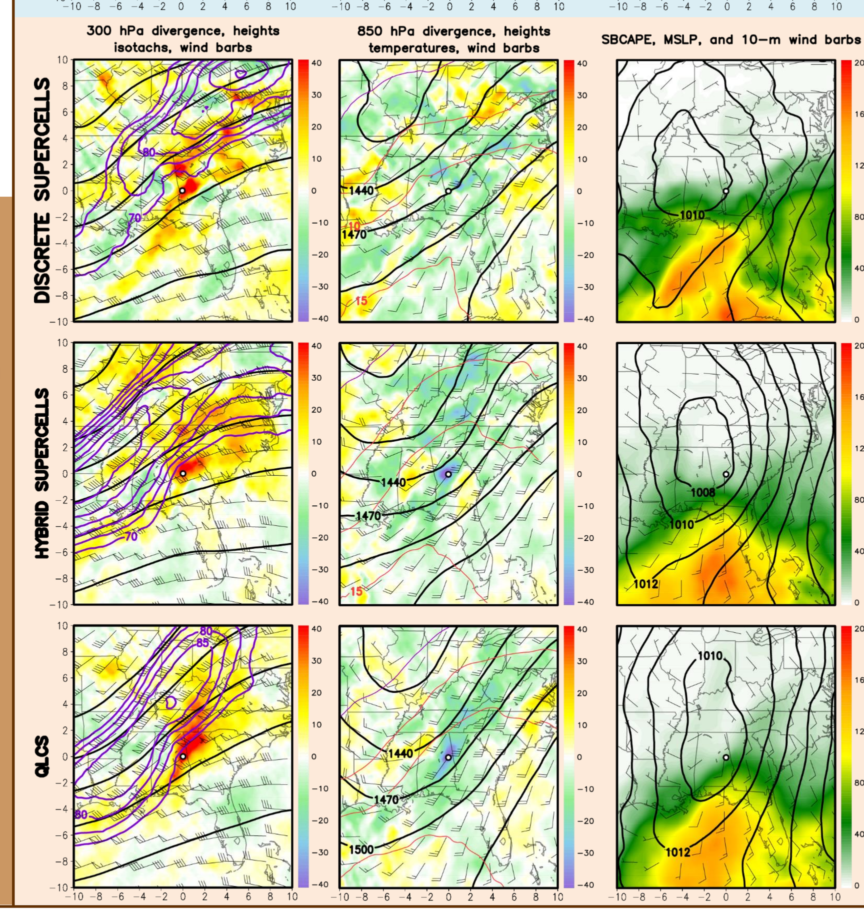


Number of cases in each composite

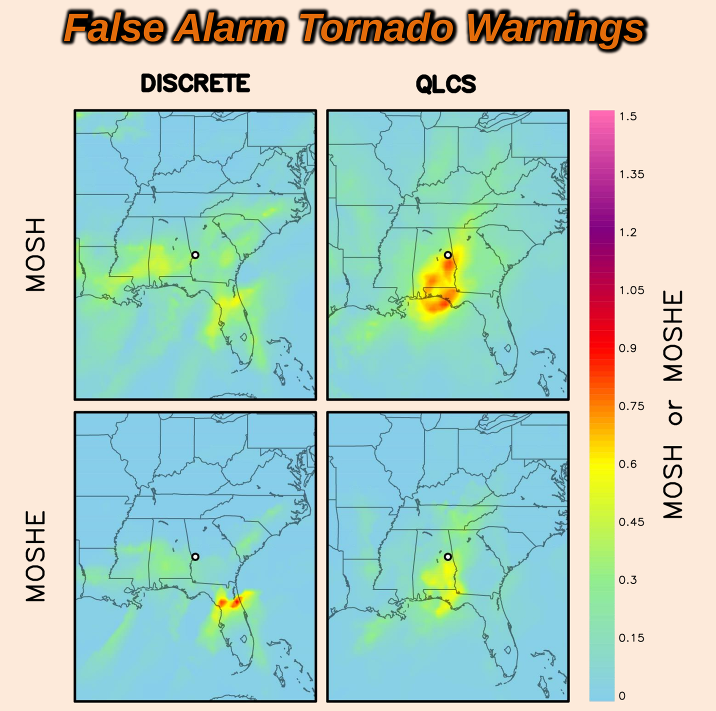
Discrete Supercells: **19**

Hybrid Supercells: **37**

QLCS: **44**



False Alarm Tornado Warnings



Number of cases in each composite

Discrete Supercells: **7**

Hybrid Supercells: **15**

QLCS: **25**

Modified Severe Hazards in Environments with Reduced Buoyancy parameter (MOSH)

The MOSH builds upon work by Sherburn and Parker (2014, *WAF*), who introduced the Severe Hazards in Environments with Reduced Buoyancy parameter (SHERB). The SHERB was originally a product of the 0-3 km lapse rate, the 700-500 hPa lapse rate [although the 3-5 km lapse rate is recommended by Sherburn et al. (2016, in press, *WAF*) to eliminate overlapping layers], and a shear vector magnitude, most commonly the 0-3 km shear vector magnitude or effective shear magnitude. Despite improving the detection of potentially severe HSLC environments, the SHERB sometimes suffered from high false alarm rates and large false alarm area, particularly in areas where convection was not expected (e.g., behind cold fronts).

The MOSH, which also has an effective version (MOSHE), limits false alarm area through the inclusion of a term meant to approximate the release of potential instability. This term is a product of ω, or vertical velocity, and $d\theta_e/dz$. The maximum value over the layers from 0-2 km through 0-6 km in 0.5 km intervals (0-2 km, 0-2.5 km, 0-3 km, and so forth) is utilized for the MOSH.

Overall, the expressions for the MOSH and MOSHE are:

$$\boldsymbol{MOSH} = \frac{(\boldsymbol{LLLR} - 4\,K\,km^{-1})^2}{4\,K^2\,km^{-2}} * \frac{(\boldsymbol{S15MG} - 8\,m\,s^{-1})}{10\,m\,s^{-1}} * \frac{(\boldsymbol{MAXTEVV} + 10\,K\,Pa\,km^{-1}s^{-1})}{9\,K\,Pa\,km^{-1}s^{-1}}$$

$$\boldsymbol{MOSHE} = \frac{(\boldsymbol{LLLR} - 4\,K\,km^{-1})^2}{4\,K^2\,km^{-2}} * \frac{(\boldsymbol{S15MG} - 8\,m\,s^{-1})}{10\,m\,s^{-1}} * \frac{(\boldsymbol{ESHR} - 8\,m\,s^{-1})}{10\,m\,s^{-1}} * \frac{(\boldsymbol{MAXTEVV} + 10\,K\,Pa\,km^{-1}s^{-1})}{9\,K\,Pa\,km^{-1}s^{-1}}$$

where…

LLLR: 0-3 km lapse rate

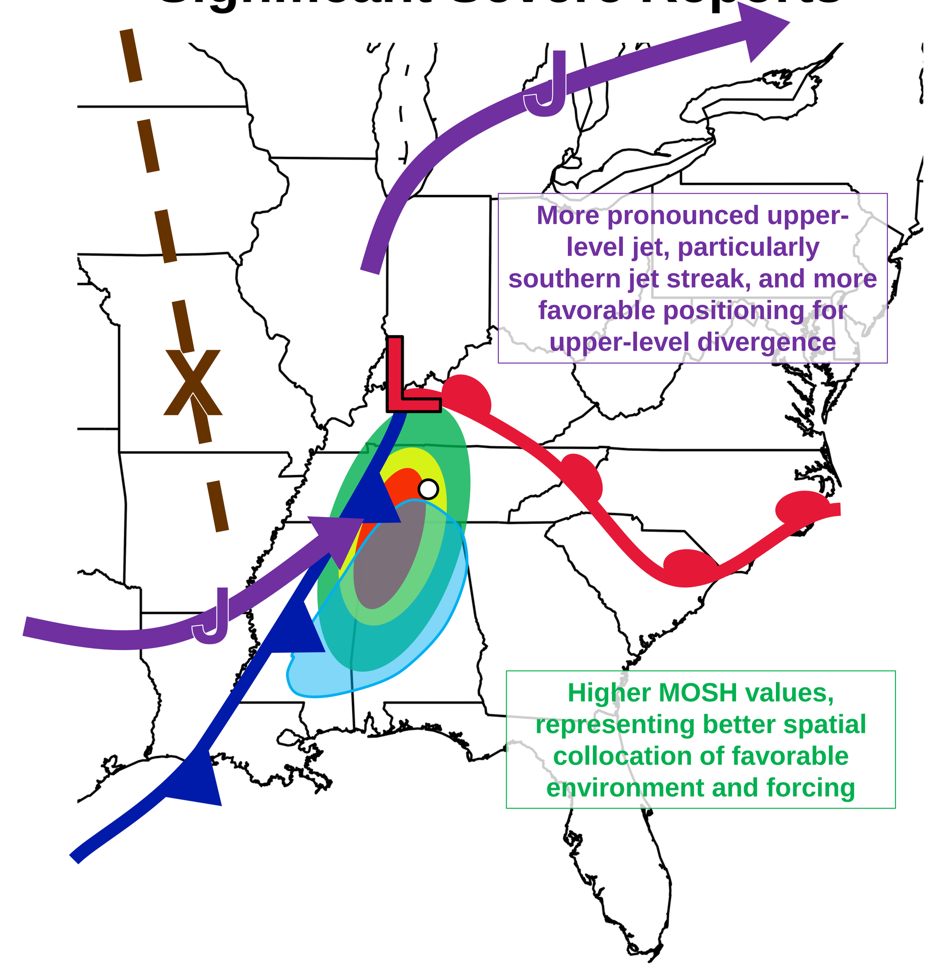
S15MG: 0-1.5 km shear vector magnitude

ESHR: Effective shear magnitude

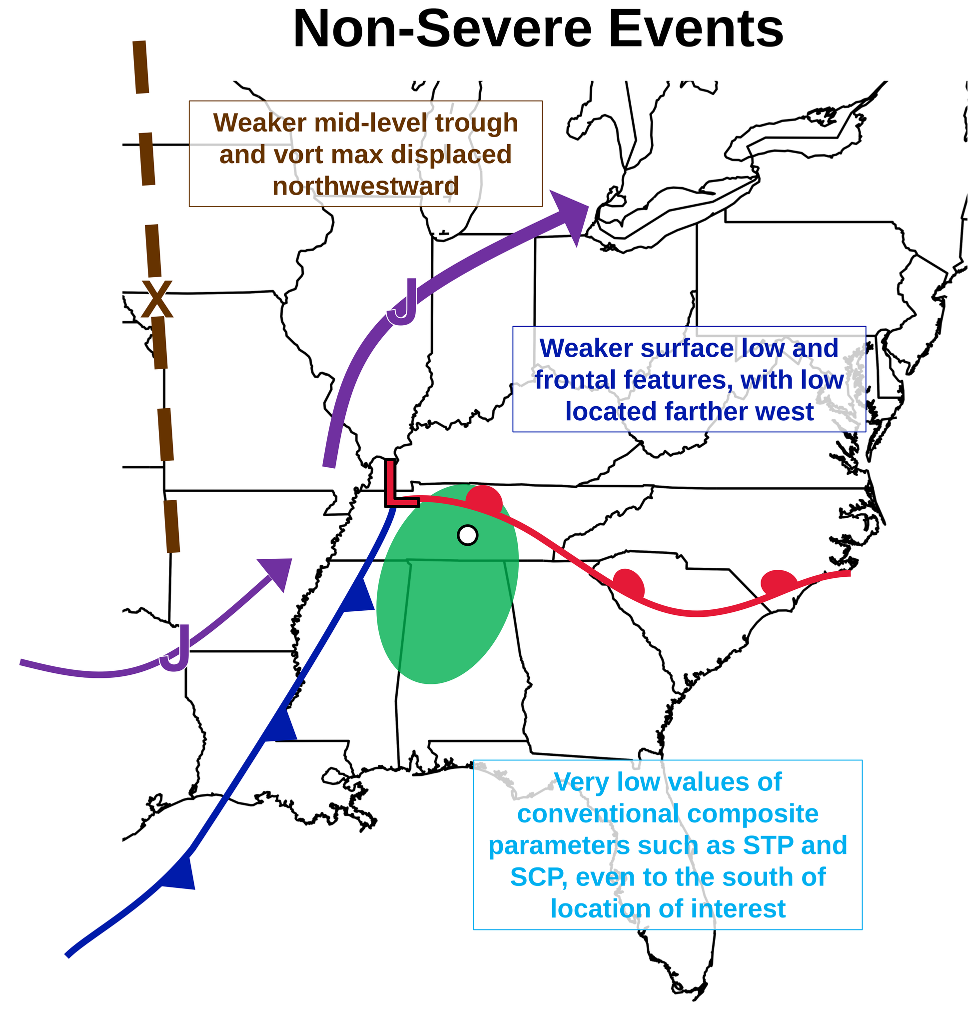
MAXTEVV: Potential instability product described above

Conclusions

Conceptual Diagram: Southeast HSLC Significant Severe Reports



Conceptual Diagram: Southeast HSLC Non-Severe Events



Key Points

- On the whole, synoptic-scale forcing for ascent and associated features are stronger in severe HSLC events compared to non-severe events.
- A Modified Severe Hazards in Environments with Reduced Buoyancy parameter (MOSH) improves the detection of potentially severe HSLC environments while limiting false alarms.
- A key feature of EF1 or greater HSLC tornadoes, particularly those associated with discrete supercells, appears to be an approaching upper-level jet streak from the west.
- Low-level shear vector magnitude tends to be stronger in HSLC tornado events when compared to environments of false alarm tornado warnings.
- Increased low-level convergence appears to be a key discriminator between discrete supercell and QLCS tornado environments.
- The *spatial collocation* of favorable forcing and environment appears critical in producing significant severe HSLC events.

Acknowledgements

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For more information

Sherburn, K. D., M. D. Parker, J. R. King, and G. M. Lackmann, 2016: Composite environments of severe and non-severe high-shear, low-CAPE convective events. *Wea. Forecasting*, in press.

If you have any questions, feel free to contact the lead author: kdsherbu@ncsu.edu