A Synoptic Climatology of Severe Weather in the Charlotte Metropolitan Region

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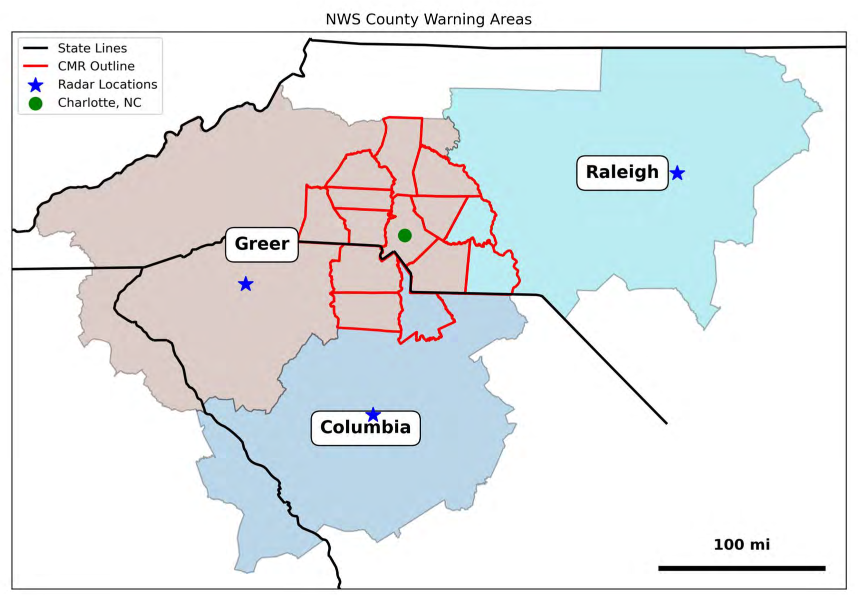
Introduction

Severe thunderstorms are identified by generating either: hail >1 inch, winds >50 knots, or a tornado. The National Weather Service (NWS) studies severe weather climatology by County Warning Area (CWA). Charlotte, NC is the 14th largest and the 6th fastest growing city in the country. However, the greater Charlotte Metropolitan Region (CMR) is split between three separate CWAs. This study investigates 70 years of CMR severe weather reports to develop a specialized climatology report for this rapidly growing urban region. *(See Figure 1 Below)*



Methods and Long-Term Trends

Data Acquisition

- All severe reports from the NCEI Storm Report Database within the CMR region from 1955-2024
- RAP weather model analysis data was downloaded for the pre-convective hour prior to each report from 2013-2024

Python Generated Visuals

- Differentiated reports by "severe" and "significant severe"
- Visualized storm report types by monthly and hourly distribution in local standard time (LST)
- Compared hail and wind locations to population density and land use maps

Composite Maps

- Averaged RAP model environmental variables spatially for each pre-convective hour of each storm event type

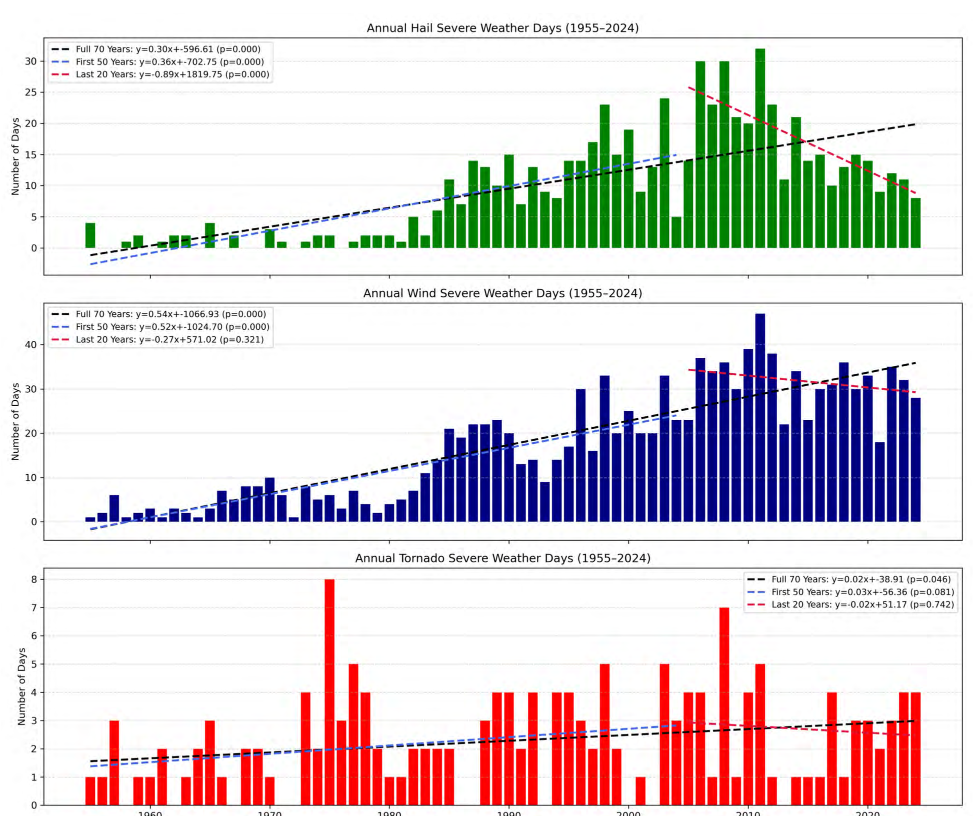


Figure 2: Annual severe weather days for each storm type from 1955-2024 and trend lines for all 70 years, first 50 years, last 20 years.

Temporal and Spatial Results

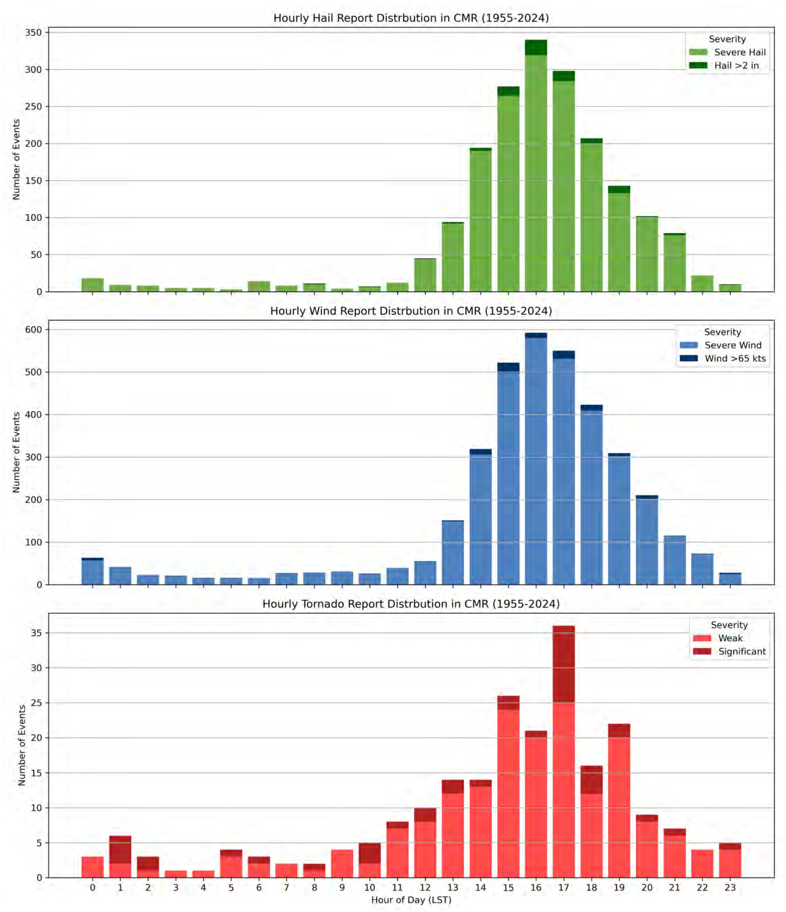


Figure 3: Hail (green), wind (blue), and tornadoes (red) reported in CMR from 1955-2024 by the hour the event was recorded- severity indicated by darker shades.

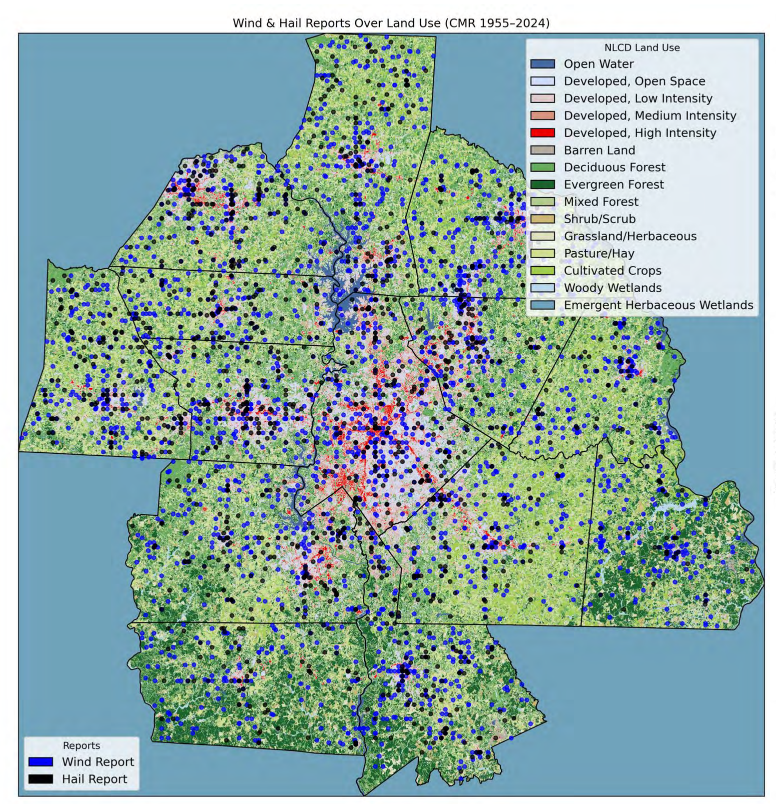


Figure 4: Wind (blue) and hail (black) reports in CMR plotted over land use data from the National Land Cover Database (NLCD) for events from 1955-2024.

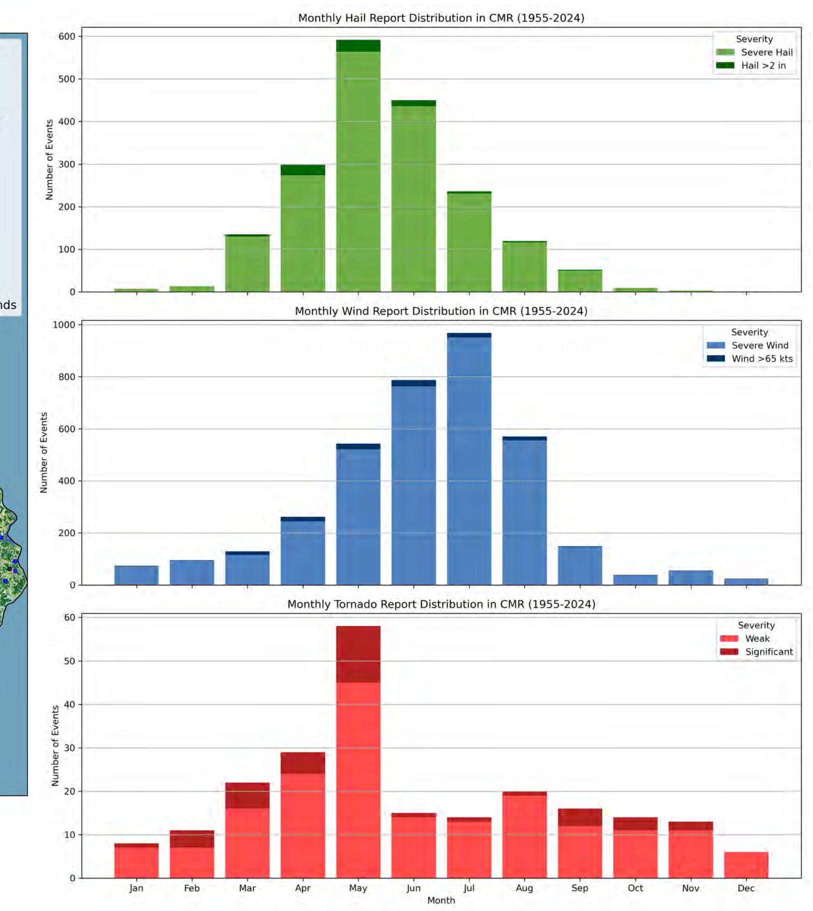


Figure 5: Hail (green), wind (blue), and tornadoes (red) reported in CMR from 1955-2024 by the month the event was recorded- severity indicated by darker shades.

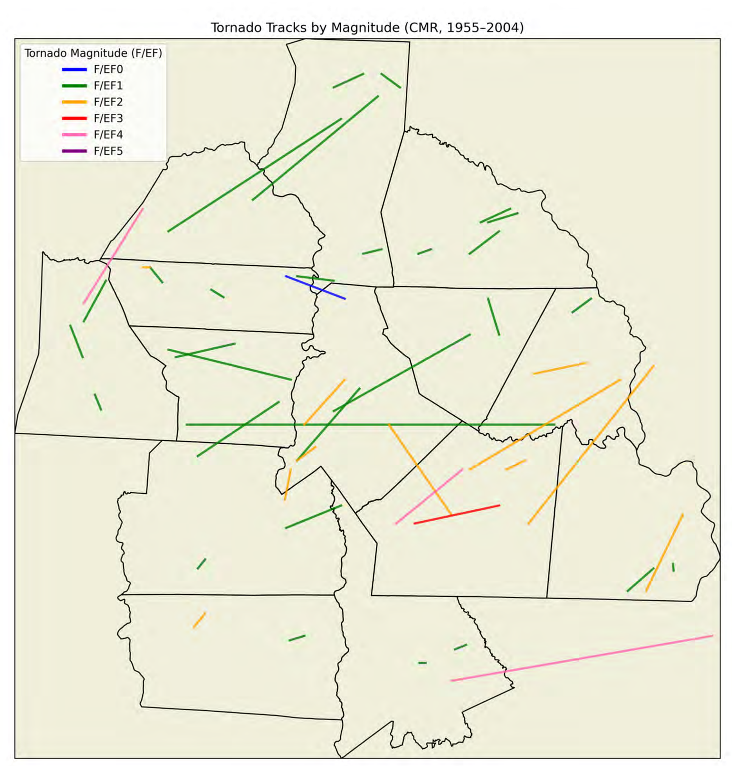


Figure 6: Tornado tracks from 1955-2004 color-coded by maximum F/EF rating.

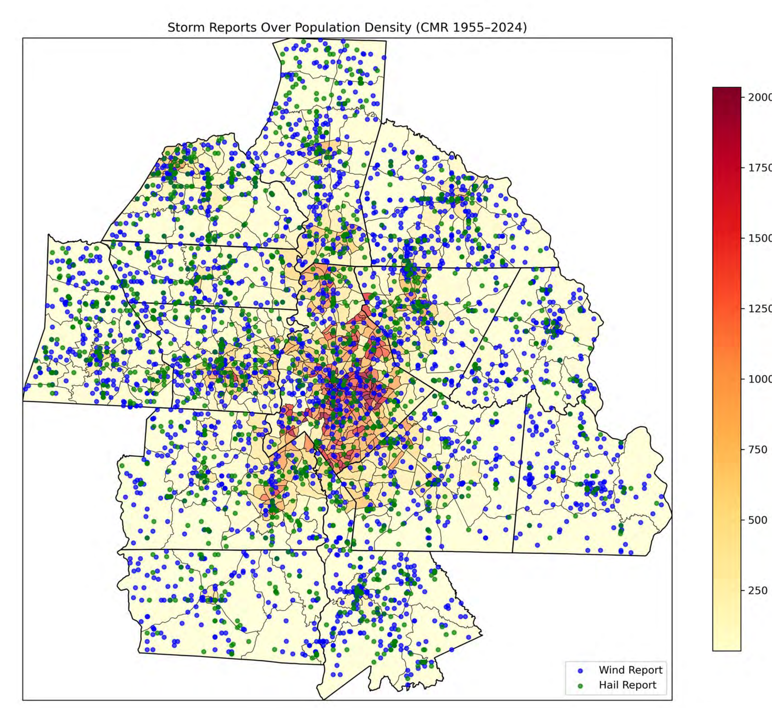


Figure 7: Wind (blue) and hail (green) reports (1955-2024) in CMR plotted over population density obtained from 2020 U.S. Census Records.

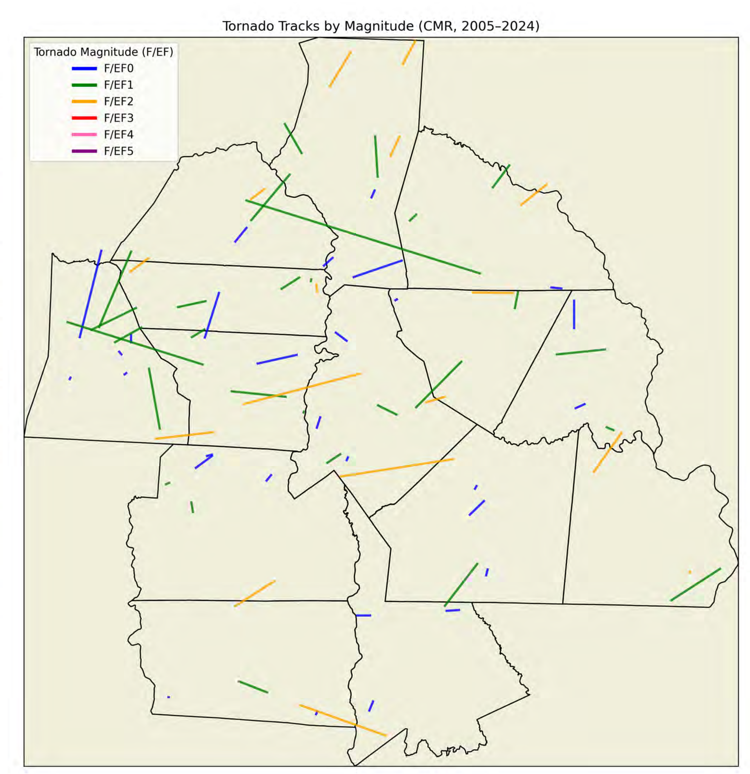


Figure 8: Tornado tracks from 2005-2024 color-coded by maximum F/EF rating.

Synoptic Composite Maps

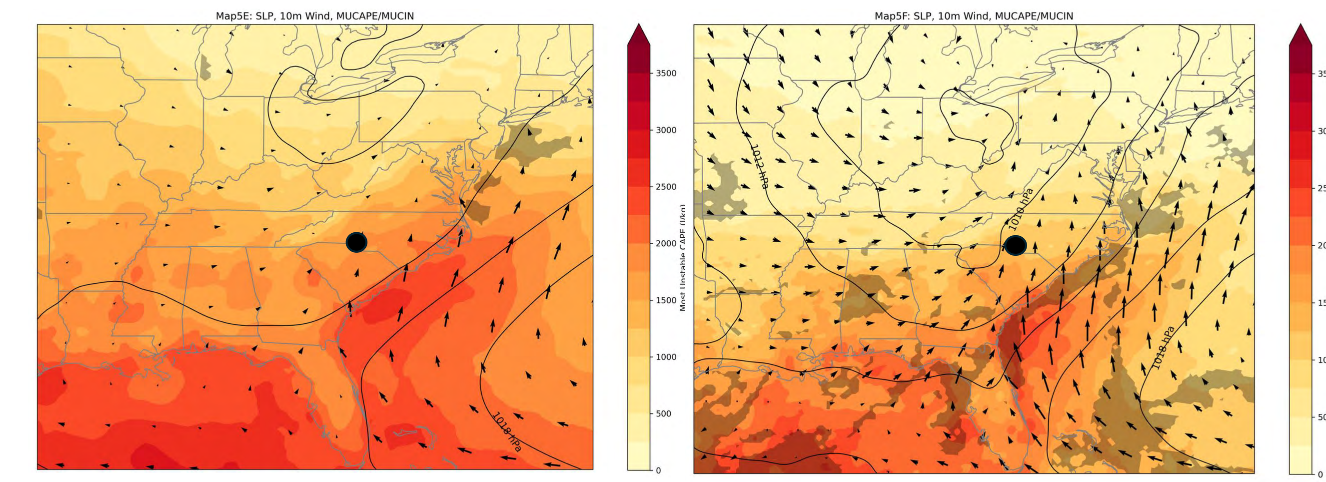


Figure 9: Most-Unstable Convective Available Potential Energy (MUCAPE) and Convective Inhibition (MUCIN-shaded) composite map of all severe wind report environments (left) and significant severe event environments (right).

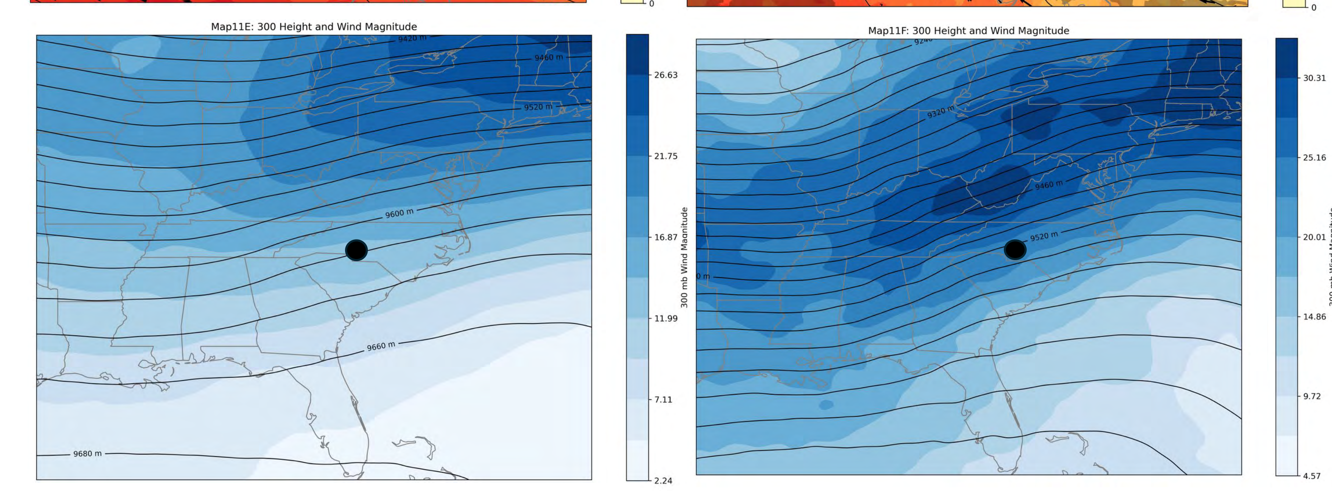


Figure 10: Upper-level wind magnitudes composited with 300 mb height contours for all severe wind report environments (left) and significant severe environments (right).

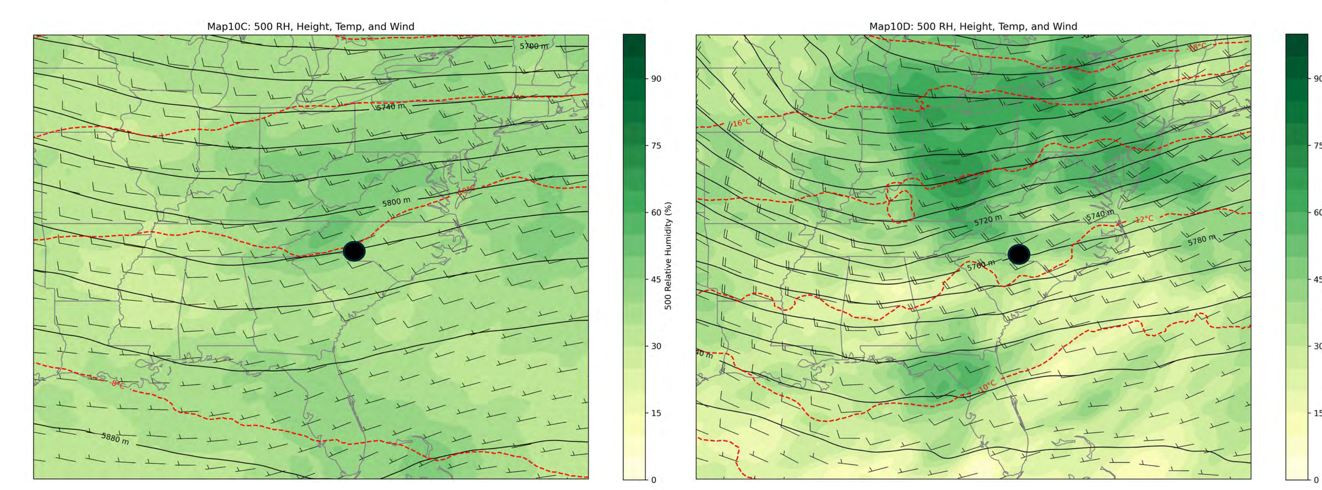


Figure 11: Mid-level atmospheric relative humidity, 500 mb height, wind, and temperature contours (red dashed lines) composited for all hail event environments (left) and significant severe hail environments (right).

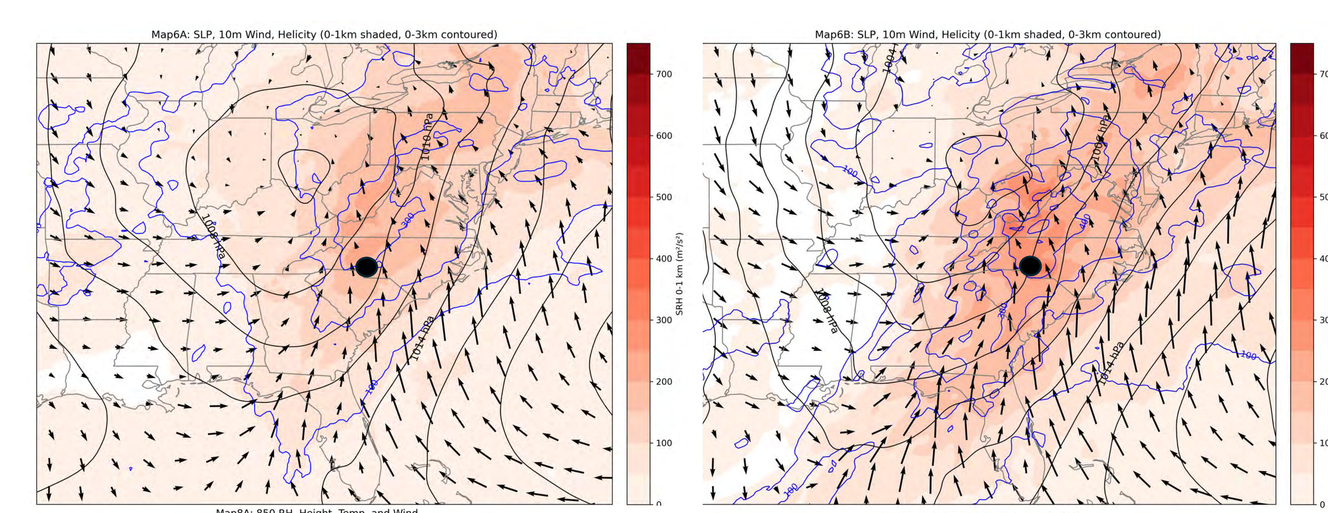


Figure 12: 0-1km (red shaded) and 0-3km (blue contour) with sea-level pressure and wind vector composite map for all tornadic environments (left) and significant tornado event environments (right).

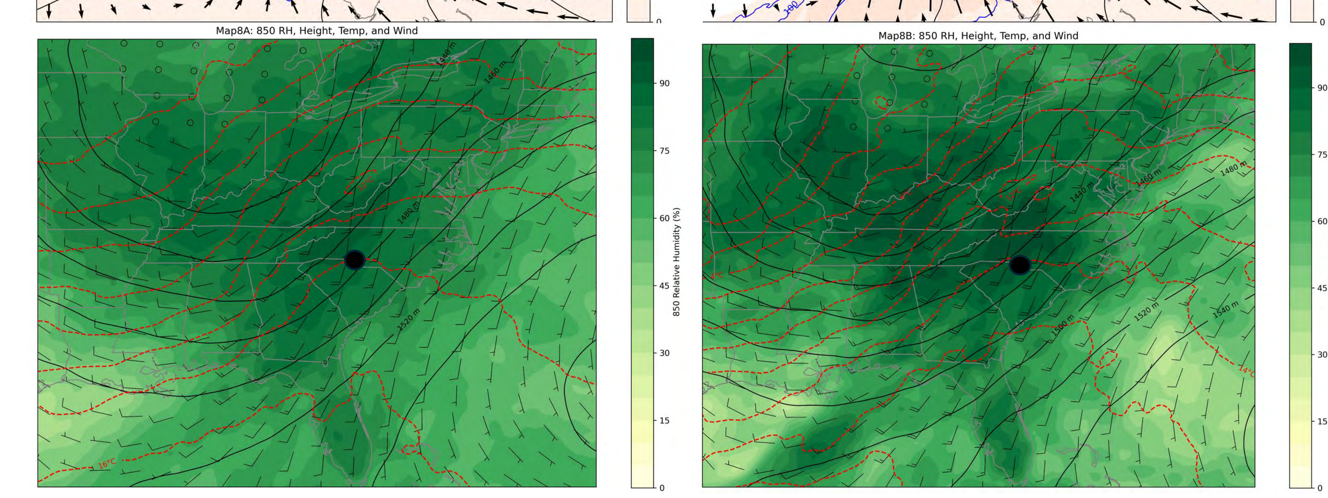


Figure 13: 850 mb relative humidity, temperature (red dashed contour), height contour, and wind barbs for all tornadic environments (left) and significant tornado event environments (right).

Discussion

Implications for Urban Systems

Enhanced understanding of the temporal and spatial distribution of severe weather across CMR is critical to providing effective emergency management and proactive urban planning strategies. Identifying large-scale weather patterns common through severe weather events can enhance the forecasting of hazardous and extreme events for this heavily populated region

Synoptic Pattern Analysis Highlights

- Most Unstable Convective Available Potential Energy (MUCAPE) decreased for more severe wind events while surface pattern intensified
- CMR more closely located under right entrance region of 300 mb jet streak for severe wind events
- Increased 500 mb Relative Humidity and Warm Air Advection (WAA) for significant hail events
- Enhanced helicity and 850 mb relative humidity for significant tornado events

Acknowledgements

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