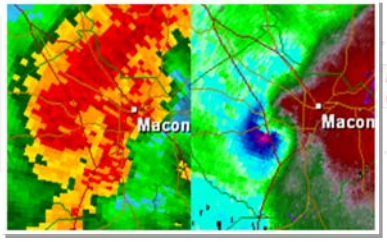
Characteristics and Estimated Warning Success Rates of Significant Tornadoes from QLCS and Supercells in the Southeast U.S.

Steven E. Nelson – NOAA/NWS Atlanta/Peachtree City, GA
Garrett D. Combs – Lyndon State College, Lyndonville, VT



Motivation

Two tornadoes, rated EF-3 and EF-1, caused $15M in damage and injured 2 people in Carroll County, Georgia on 26 February 2008 around1100 UTC. These tornadoes developed from a Quasi-Linear Convective System (QLCS) in an environment characterized by low instability, low convective inhibition, and strong vertical wind shear. None of the NWS outlooks, discussions, or warnings issued preceding the event indicated a risk for tornadoes.

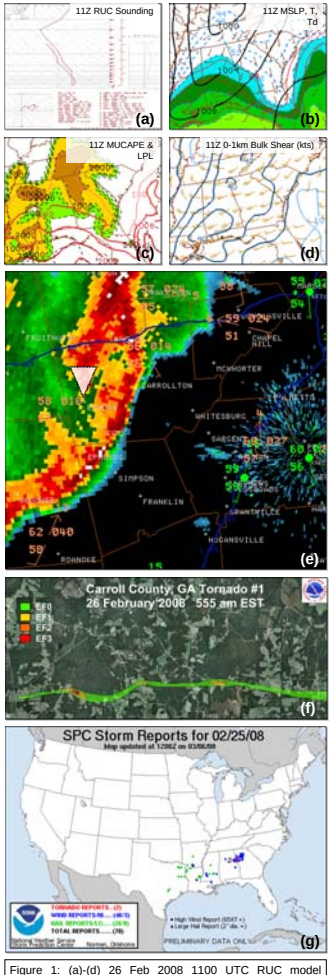


Figure 1: (a)-(d) 26 Feb 2008 1100 UTC RUC model sounding and analyses showing limited instability and unidirectional, strong low-level shear. (e) Radar reflectivity showed a comma-head feature on the north side of a bow echo where the EF3 tornado developed (white triangle) and tracked east for 6 miles (f). The two tornadoes were the only tornadoes that day (g). (*Images courtesy NWS*)

Comparison of Supercell and QLCS Tornadoes

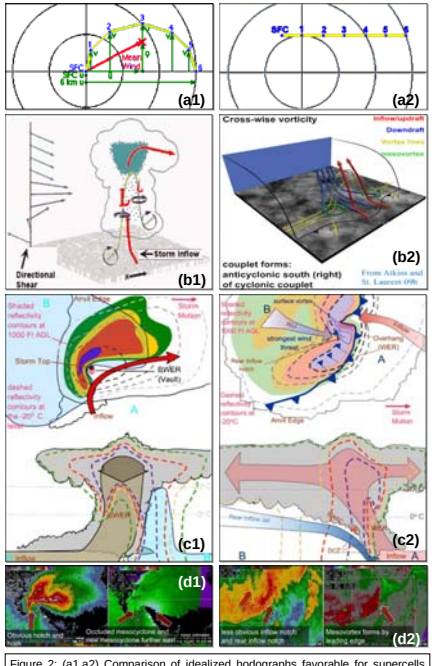


Figure 2: (a1,a2) Comparison of idealized hodographs favorable for supercells and QLCS (*images courtesy COMET*). (b1,b2) 3-D schematics of cyclonic-anticyclonic mesovortex formation (*images courtesy COMET and Atkins and St. Laurent*). (c1,c2) Plan-view and vertical cross-sections of idealized supercell and QLCS. (d1,d2) Comparison of radar reflectivity and velocity of a supercell and QLCS (*images courtesy NWS WDTB*).

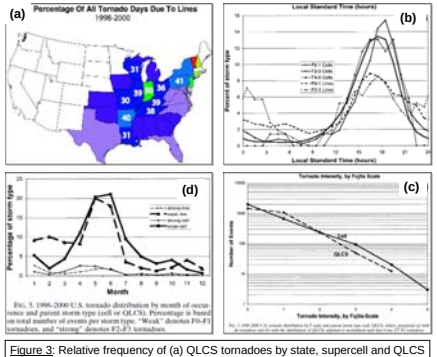


Figure 3: Relative frequency of (a) QLCS tornadoes by state, supercell and QLCS tornadoes by time (b), and by month (c). (d) Supercell and QLCS normalized frequency by intensity. (*charts from Trapp et al. 2005*)

Data and Methodology

Thirty tornado events were selected using these criteria:

Area: Alabama, Georgia, Mississippi, Tennessee*
Dates: 1 Nov 2008 to 31 May 2009 and
1 Nov 2009 to 30 April 2010*
Intensity: All significant tornadoes (F2/EF2 or greater)**
Source: NCDC Storm Data

For each of the 30 events, these datasets were obtained:

- WSR-88D Level II radar data analyzed with GR2Analyst
- NCAR/NCEP Regional Reanalysis (NARR) 3hr composites
- RUC mesoanalysis images from SPC
- NWS Outlooks, Watches, and Warnings

Level II radar data were obtained to classify each tornado as a supercell or QLCS event and to determine differences in the size, strength, and evolution of the mesovortices. NARR composite images were created to identify differences in mean mass, wind, moisture and instability fields associated with supercell and QLCS tornadoes. Similarly, RUC mesoanalysis images were used to compare derived fields, typically associated with favorable environments for tornadoes, between supercell and QLCS events. Finally, NWS outlooks, watches and warnings were used to estimate accuracy and lead time. Note that false alarm rates were not computed due to the lack of null events.

** The locations and dates were chosen to minimize the number of tornadoes from tropical cyclones. Also, May 2009 Storm Data was not available during the research phase.*
*** Significant tornadoes were used due to the higher reliability of the storm reports and their much larger impact on society.*

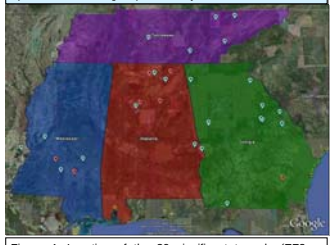


Figure 4: Location of the 30 significant tornado (EF2 or higher) events used in this study. Blue markers show 23 supercell tornadoes, red markers indicate 7 QLCS tornadoes.

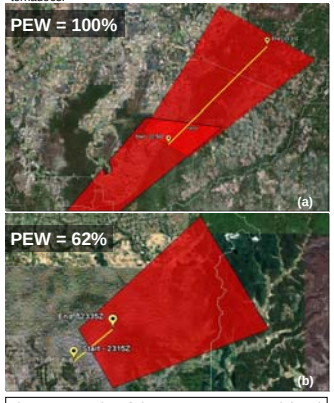


Figure 5: Examples of the Percent Event Warned (PEW) accuracy metric for (a) a fully-warned case (PEW=100%) and (b) a partially-warned case (PEW=62%).

Results

Radar

Of the 30 tornadoes analyzed, 23 (77%) were determined to originate from supercells and 7 (23%) from QLCS. The intensity of the tornadoes in this study from supercells were higher than those from QLCS (Figure 6). All of the QLCS tornadoes were rated EF2.

Rotational velocity was computed manually using storm-relative velocity data displayed with GR2Analyst. While manual interrogation of mesocyclones and mesovortices introduces some subjectivity into the results, it best reflects the procedures that operational meteorologists use to determine mesocyclone strength and the likelihood of a tornado.

Rotational velocity at 0.5° for significant tornadoes from supercells averaged 4-10 kts (2-5 m/s) higher than those from QLCS (Figure 7), which may be due to QLCS mesovortex rotational velocity decreasing with height and/or due to their smaller diameter (radar sampling issues). The trends of the velocity for each storm type were quite similar, which did not match that of other case studies which showed the QLCS mesovortex increasing more rapidly during and after tornado touchdown (Atkins et al. 2004).

The diameters of the supercell mesocyclone and QLCS mesovortices also showed similar trends, although the diameter of the QLCS mesovortices reached a well-defined minimum during tornado touchdown, while the supercell mesocyclone diameter bottomed out 1 scan after the tornado touched down.

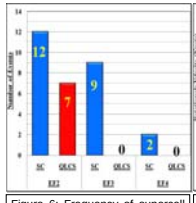


Figure 6: Frequency of supercell and QLCS tornadoes by intensity.

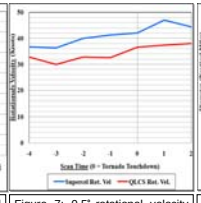


Figure 7: 0.5° rotational velocity for supercell and QLCS events.

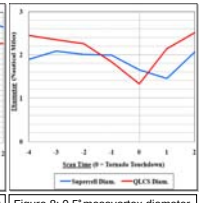


Figure 8: 0.5° mesovortex diameter for supercell and QLCS events.

Storm Environment

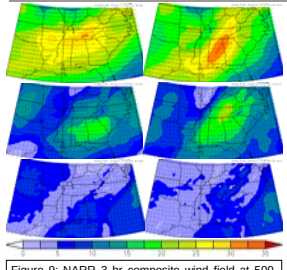


Figure 9: NARR 3 hr composite wind field at 500, 850, and 1000 hPa in m/s for supercell (left) and QLCS (right) tornado events.

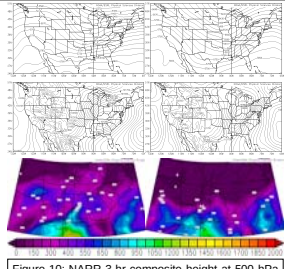


Figure 10: NARR 3 hr composite height at 500 hPa in m, MSL Pressure in Pa, and SBCAPE in J/kg for supercell (left) and QLCS (right) tornado events.

NWS Accuracy and Lead Time

Figure 10: SPC (a) Outlook category frequency and tornado watch relative frequency (b) and lead time (c), for supercell and QLCS events.

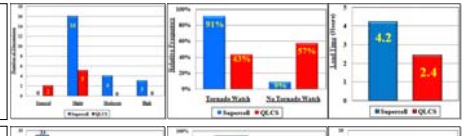
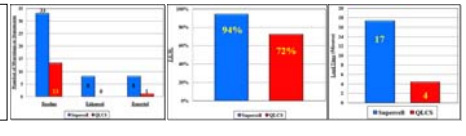


Figure 11: WFO tornado warning (a) wording comparison, (b) PEW and (c) lead time for supercell and QLCS events.



Conclusions

Recent literature suggests that tornadoes from QLCS storms are both dynamically and climatologically distinct from tornadoes originating from supercells (Trapp et al. 2005; Weismann and Trapp 2003). Until recently, training for NWS meteorologists has not accounted differences between QLCS and supercells tornadogenesis and what patterns and features precede a QLCS tornado, if any. There continues to be a misperception by many operational meteorologists that QLCS tornadoes can only be brief and weak events. This research shows that over 20% of all ***significant*** tornadoes were QLCS-based.

This study also not only confirms that there are differences between these two tornado-producing storm types, but shows that there are significant challenges to issuing accurate and timely warnings for QLCS tornadoes.

Tornado warning lead time for QLCS events averaged only 4 minutes, around 4 times less than the average lead time for supercell tornadoes. The PEW for QLCS tornadoes was also over 20% lower than that of supercell tornadoes.

While continued observational research and training on QLCS events will help this challenge to some extent, more thorough research must be done on the dynamics of QLCS events. A much larger climatological study encompassing all relevant regions of the U.S. should be undertaken. This study should use all recent advances to the WSR-88D, particularly superres data.

Future work on this regional study will further look at the environmental differences between QLCS and supercell events. It will also expand the number of cases to add greater confidence to the results. Warning thresholds for QLCS tornadoes will also be explored.

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Questions or Comments?

Steven.Nelson@noaa.gov
Science and Operations Officer
National Weather Service
4 Falcon Dr
Peachtree City, GA 30269
770-486-1133 x224