121 RELATING CONVECTIVE MODE INFORMATION TO SPC TORNADO OUTLOOK VERIFICATION

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1. INTRODUCTION

The Storm Prediction Center (SPC) has developed a comprehensive forecast verification database, which includes SPC forecasts (watches and convective outlooks), storm reports, and environmental information from observed soundings and objective mesoanalyses (Dean et al. 2006). A parallel effort at SPC is the development of a convective mode database, which includes subjective determinations of parent storm mode for a large number of tornado events from the period 2003-2017 (Smith et al. 2012). For this project, we have combined these two databases to assess SPC tornado forecast performance based onf convective mode, examining verification aspects such as probability of detection (POD) as a function of mode. Reliability of SPC probabilistic tornado outlooks is also discussed below.

2. CONVECTIVE MODE ANALYSIS

The convective mode for a filtered subset of tornado reports from 2003-2017 was assigned according to the methodology in Smith et al. (2012: see Fig. 1 for a graphical example). As a result of the filtering process and other factors, 76% (16 147 out of 21 170) of tornado county segments received a mode classification. Supercell and quasi-linear convective system (QLCS) modes are of primary interest in this analysis.

Fig. 2 and Fig. 3 show time series of the annual counts and fraction, respectively, of filtered tornado reports for supercell (red) and QLCS (blue) events. Supercells represent the majority of tornado events, though recent years have seen an increase in the number and relative fraction of QLCS tornado events. The largest annual total of QLCS tornadoes was 430 in 2017 (the most recent year in the analysis), which is more than double the count of any other year from 2003-2017, except for 2011.

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Damage intensity ratings (using the F/EF-scales) tend to be distributed differently for QLCS events compared to supercells, as shown in the stacked barplot in Fig. 4. The largest relative fraction of QLCS events (compared to supercells and other modes) occur at F1/EF1 intensity, while other (generally disorganized) modes are mostly F0/EF0 events. Supercell modes comprise an increasing fraction of events rated F2/EF2 and above.

3. SPC PROBABILISTIC TORNADO OUTLOOKS

SPC issues outlooks depicting the probability of a tornado within 40 km of a point (see Fig. 5) for the current convective day (i.e., Day 1). Since 2006, the set of probability thresholds for tornado outlooks has been: 2%, 5%, 10%, 15%, 30%, 45%, and 60%. An area defining a 10% (or greater) probability of significant (EF2+) tornadoes also may be drawn. Typical verification metrics include reliability and POD (for tornado events) within various probability thresholds. For reliability calculations, an aggregate areal coverage is computed at each forecast threshold, then divided by the total area covered at each threshold to get an areal coverage fraction value, which is then compared to the forecast probability. It should be noted these are considered true probability forecasts, not deterministic forecasts of areal coverage, so individual forecasts are not necessarily expected to verify with a coverage equal to the probability value.

3.1 *Tornado Outlook Verification Results*

Fig. 6 is a modified reliability diagram for SPC Day 1 tornado outlooks (for all issuance times) from 2006-2017. The mean areal coverage (filled dots) within each probability threshold lies relatively close to the perfect reliability (dashed) line, indicating generally good reliability. The percentile boxplots show the distribution of areal coverage for individual forecasts at each threshold.

The distributions for 2% and 5% thresholds are skewed toward values lower than the forecast probability, indicating a tendency for most forecasts to verify below the probability threshold, with a few forecasts verifying significantly above the threshold. For larger probability thresholds (10% and above), the distribution of areal coverage is more evenly distributed around the forecast probability value.

3.2 *Verification in the Context of Convective Mode*

SPC has begun to examine tornado outlook verification in the context of convective mode. Such an analysis is rather complicated, since forecasts are made for all tornado events, not just for a particular mode, and only preliminary results are shown below. Probability of detection (POD) for different modes at the various probability thresholds for the period 2006-2017 is shown in Fig. 7. At 2% or greater (the lowest threshold), POD for both QLCS and supercell events is generally at or above 0.8, with some interannual variability noted. At higher thresholds ($\geq$ 5% and $\geq$ 10%), there is tendency for the POD to be greater for supercell events compared to QLCS events. POD at 10% or greater has shown a decreasing trend for both supercell events and QLCS events in recent years.

Fig. 8 shows the distribution of QLCS and supercell tornado events within the various SPC probability thresholds, for the entire 2006-2017 period. QLCS and supercell events are equally likely to have been missed (<2% probability). Compared to supercell events, QLCS tornadoes are more likely to fall within 2% and 5% tornado risk areas, but less likely to be captured at higher probabilities (10% and above).

Fig. 9 incorporates environment information with the verification and mode data, using the effective-layer significant tornado parameter (STP; Thompson et al. 2012) as a proxy for the favorability of the near-storm environment for producing tornadoes. A clear increase in STP is noted for supercell events as forecast probability increases. STP values are consistently higher for supercell events compared to QLCS, even at higher-end forecast probabilities.

4. DISCUSSION

Explaining why the number of QLCS tornadoes has been increasing in recent years, and whether or not that increase will continue into the future, is beyond the scope of this analysis. Regardless, QLCS tornadoes will continue to pose a forecast challenge for the SPC into the future. While POD at the lowest probability threshold (2%) has been nearly identical for QLCS and supercell tornadoes, capturing QLCS tornadoes within higher probability thresholds (10% and above) will likely remain a challenge, given the differing intensity distributions and environmental characteristics noted with QLCS tornadoes. The question of whether or not there is value in attempting to capture QLCS tornadoes at higher thresholds will need to be examined. Future work along these lines will include an analysis of the areal coverage and density characteristics of QLCS tornadoes, in order to determine whether higher probability thresholds are appropriate for these events.

5. REFERENCES

Dean, A.R., R.S. Schneider, and J.T. Schaefer, 2006: Development of a Comprehensive Severe Weather Forecast Verification System at the Storm Prediction Center. Preprints, *23nd Conf. Severe Local Storms*, St. Louis MO, Amer. Meteor. Soc., 2.3.

Smith, B.T., R.L. Thompson, J.S. Grams, C. Broyles, and H.E. Brooks, 2012: Convective modes for significant severe thunderstorms in the contiguous United States. Part I: Storm classification and climatology. *Wea. Forecasting*, **27**, 1114–1135.

Thompson, R.L., B. T. Smith, J. S. Grams, A. R. Dean, and C. Broyles, 2012: Convective modes for significant severe thunderstorms in the contiguous United States. Part II: Supercell and QLCS tornado environments. *Wea. Forecasting*, **27**, 1136–1154.

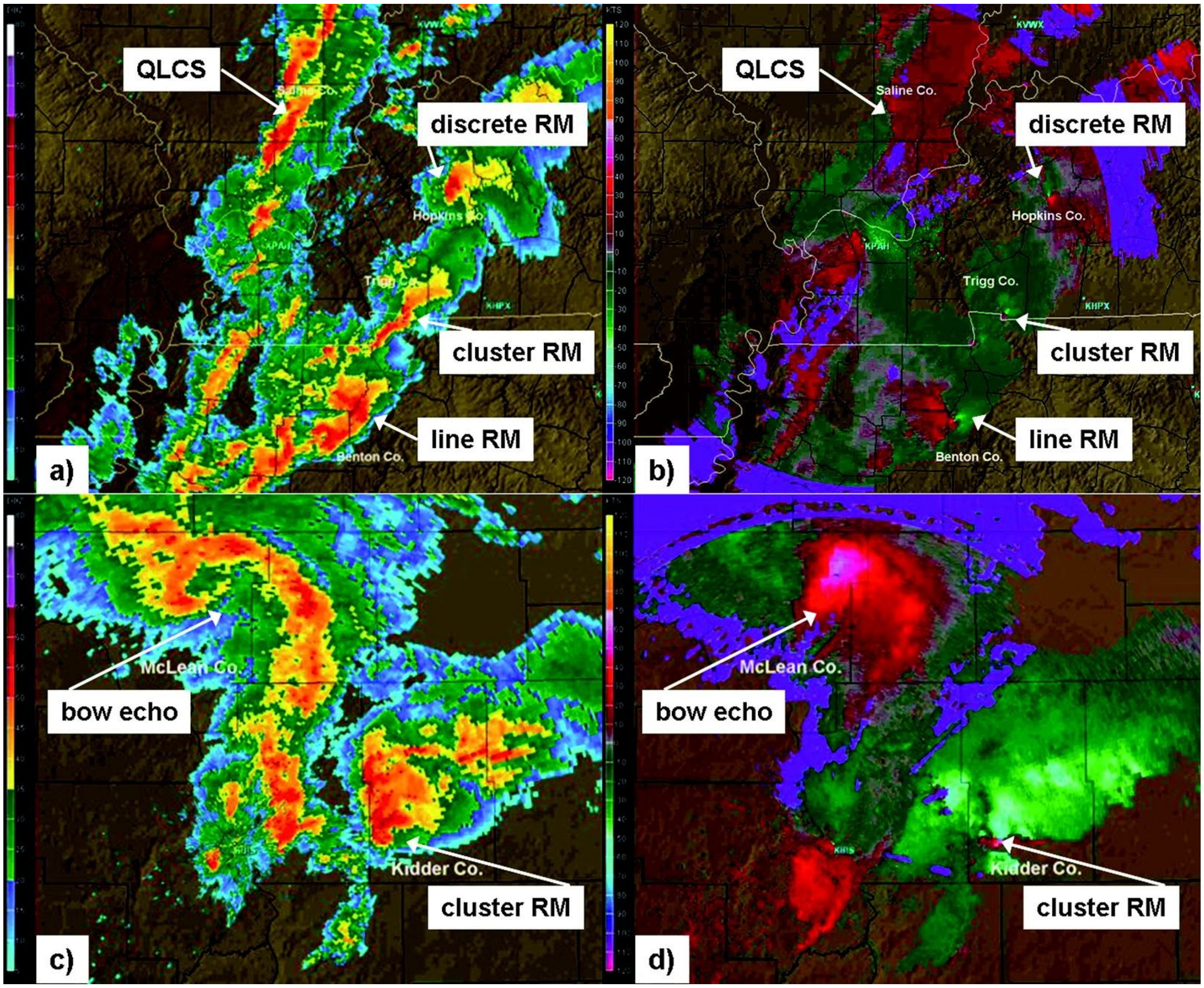

Fig. 1: Example of convective mode classification, taken from Smith et al. (2012).

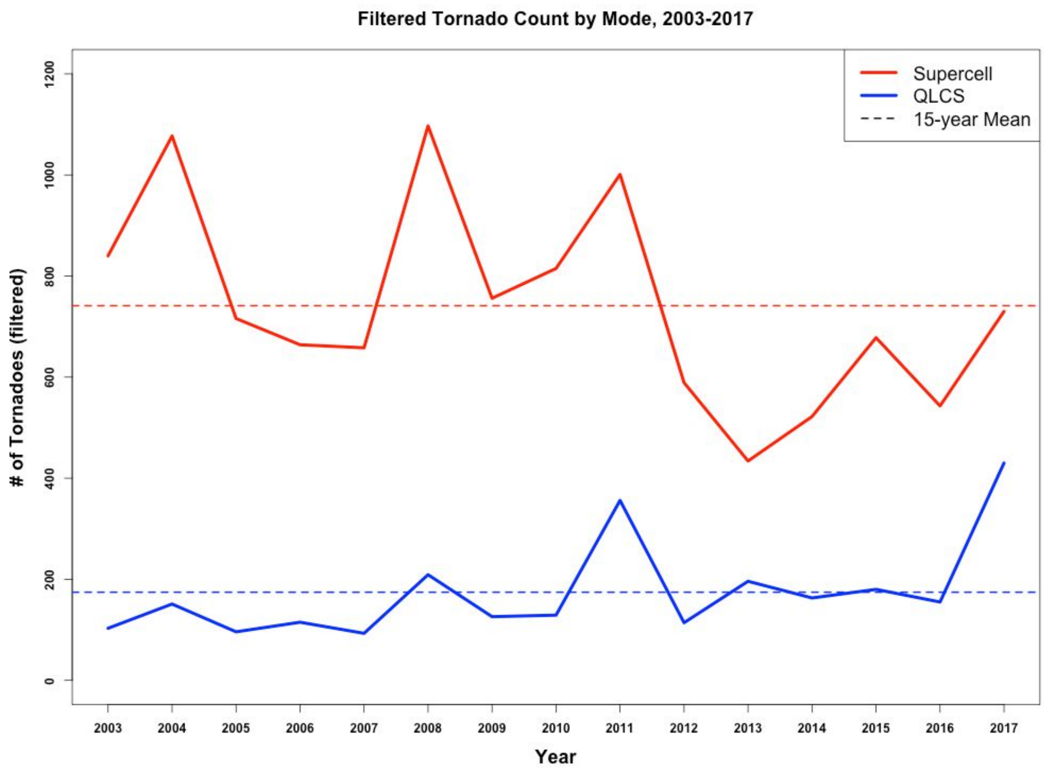

Fig. 2: Annual count of filtered tornado reports by mode, 2003-2017. Dashed lines represent 15-year mean. Supercell mode in red and QLCS mode in blue.

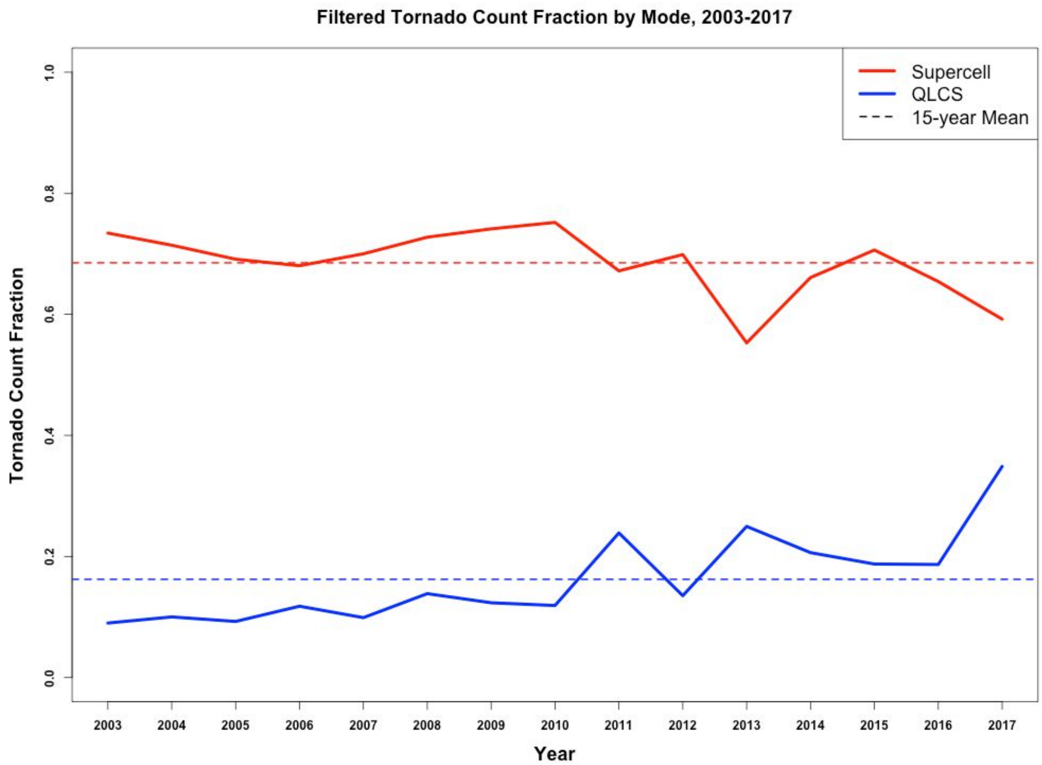

Fig. 3: Annual fraction of filtered tornado reports by mode, 2003-2017. Dashed lines represent 15-year mean. Supercell mode in red and QLCS mode in blue.

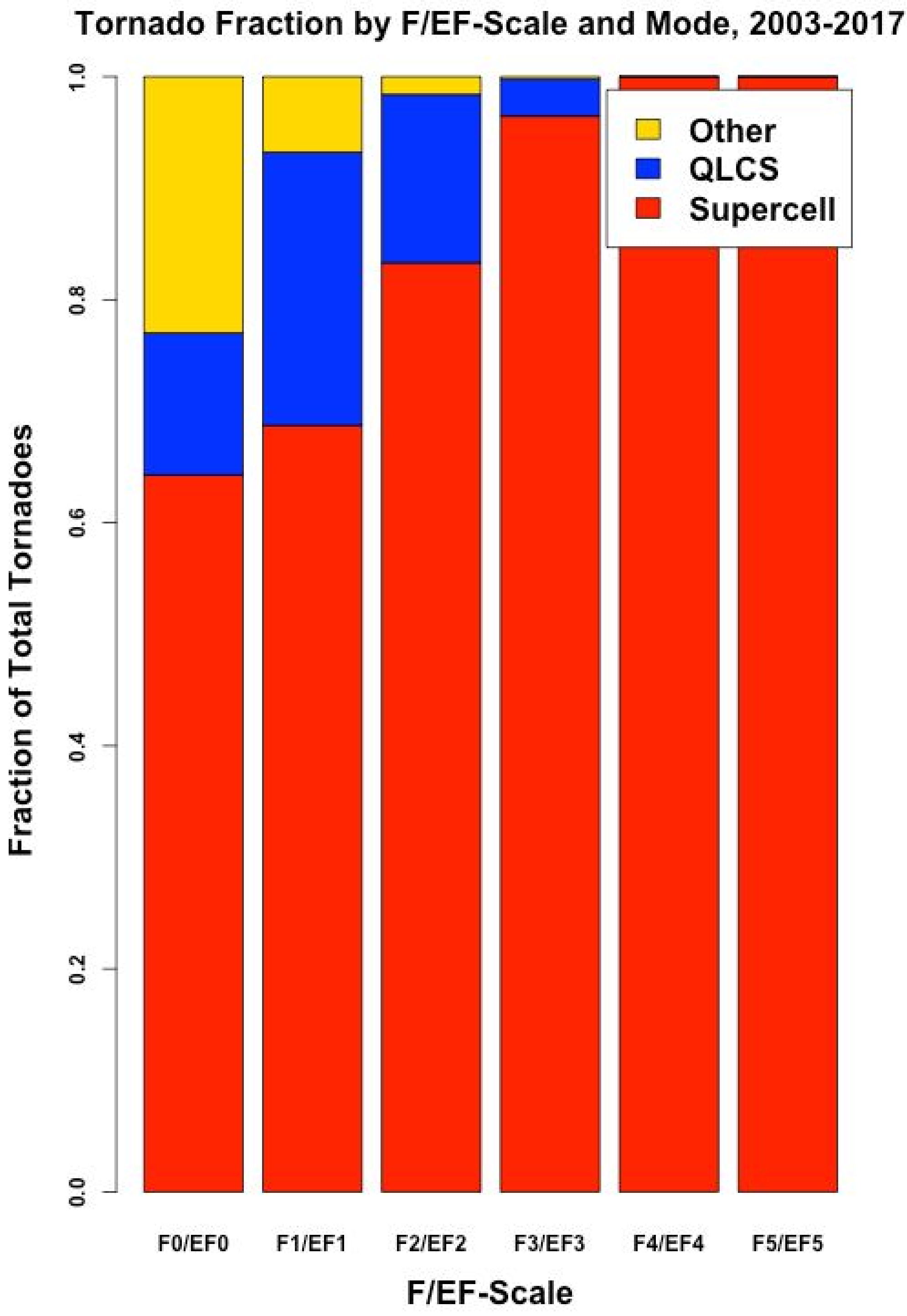

Fig. 4: Stacked barplot showing distribution of tornadoes by intensity and mode.

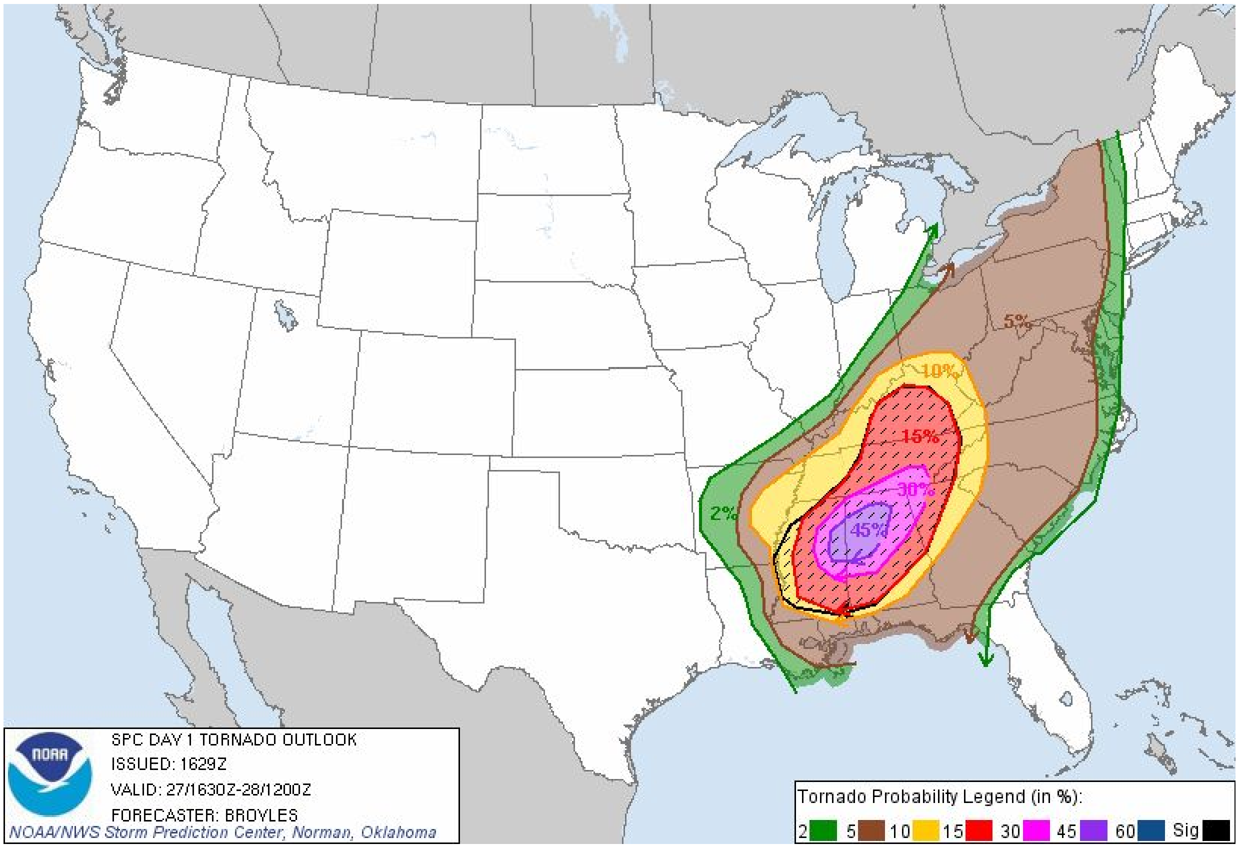

Fig. 5: Example of an SPC tornado outlook, taken from 27 Apr 2011.

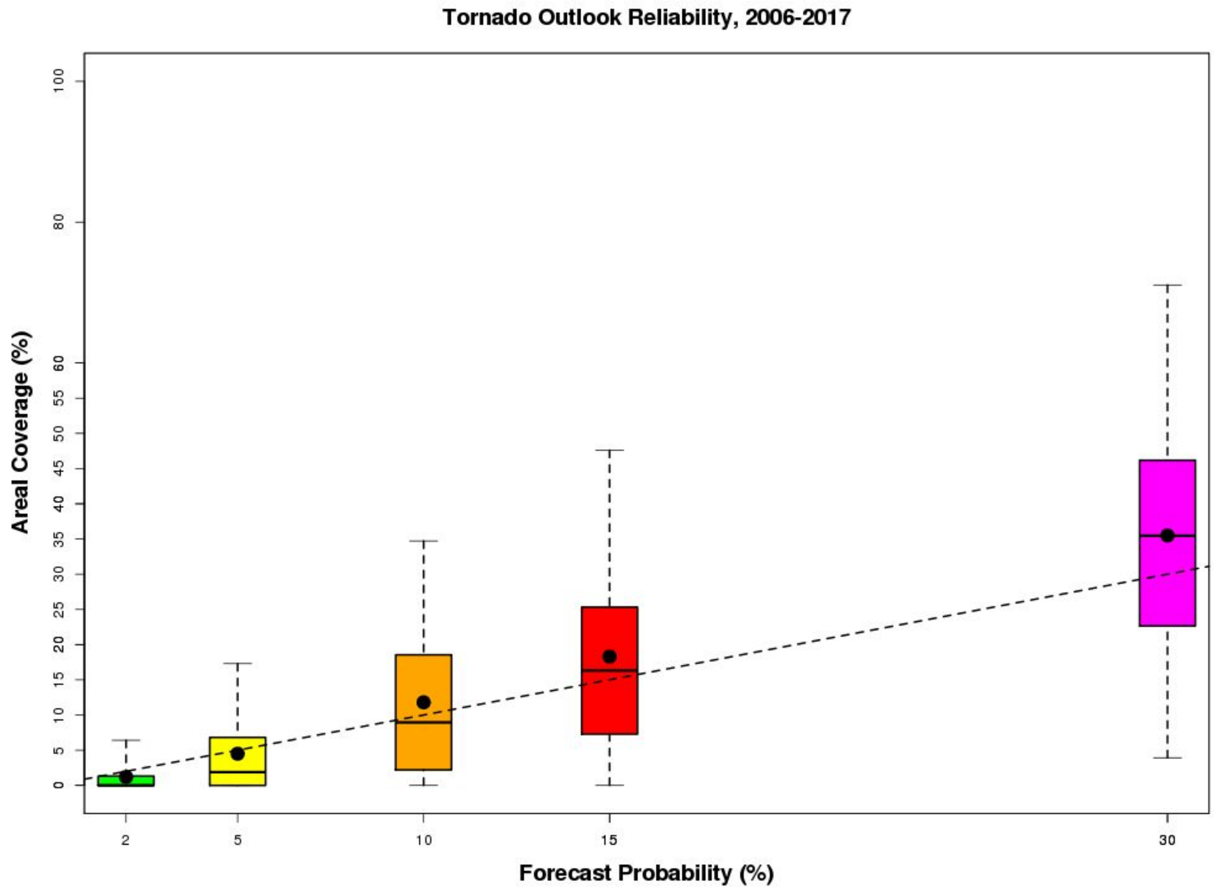

Fig. 6: Modified reliability diagram for SPC tornado outlooks for 2006-2017. Dots indicate mean areal coverage, while the solid lines indicate the median areal coverage. Boxes are drawn from 25th-75th percentiles, with whiskers extending to 5th-95th percentiles of areal coverage. Dashed line indicates perfect reliability.

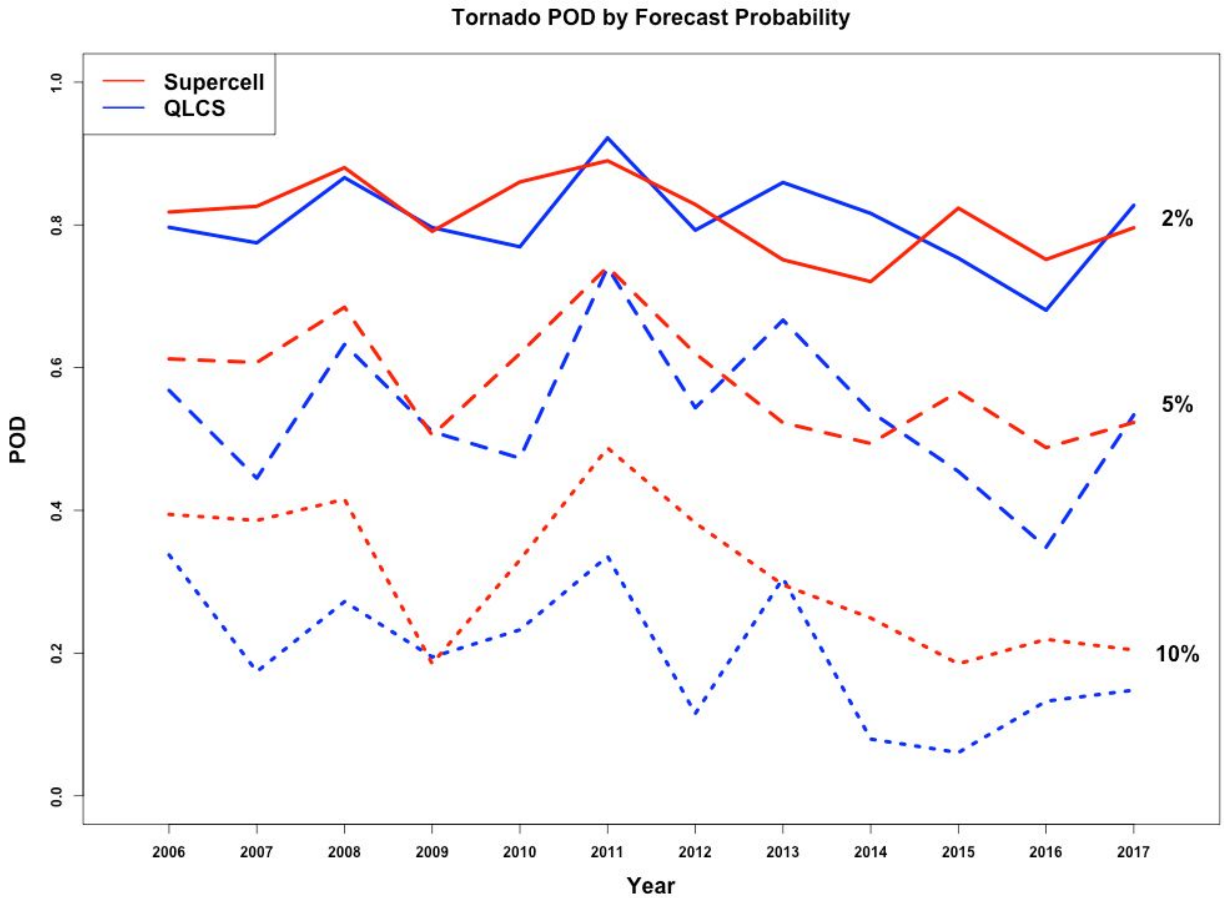

Fig. 7: POD for supercell (red) and QLCS (blue) tornadoes within various forecast probability thresholds, by year.

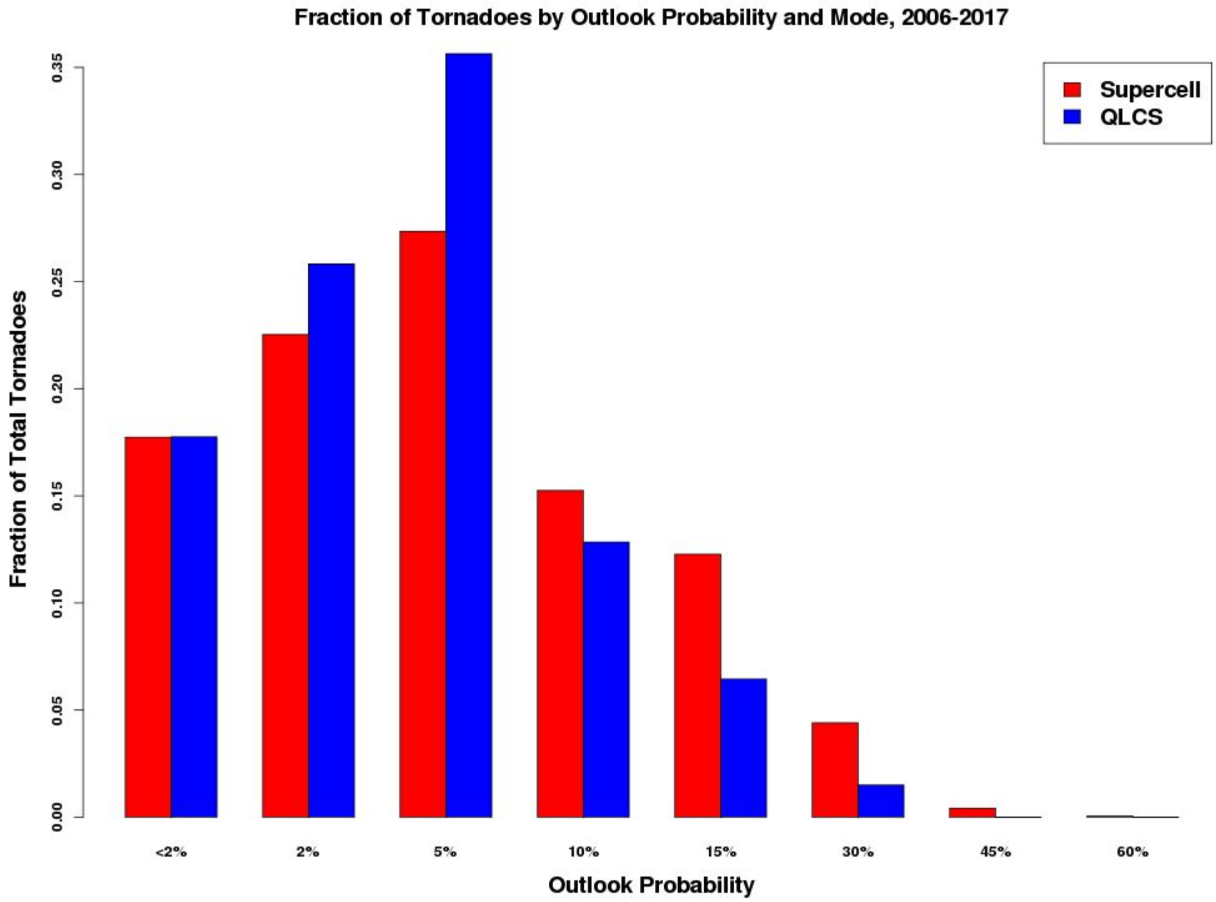

Fig. 8: Barplopts showing distribution of supercell (red) and QLCS (blue) tornadoes within the various tornado probability thresholds.

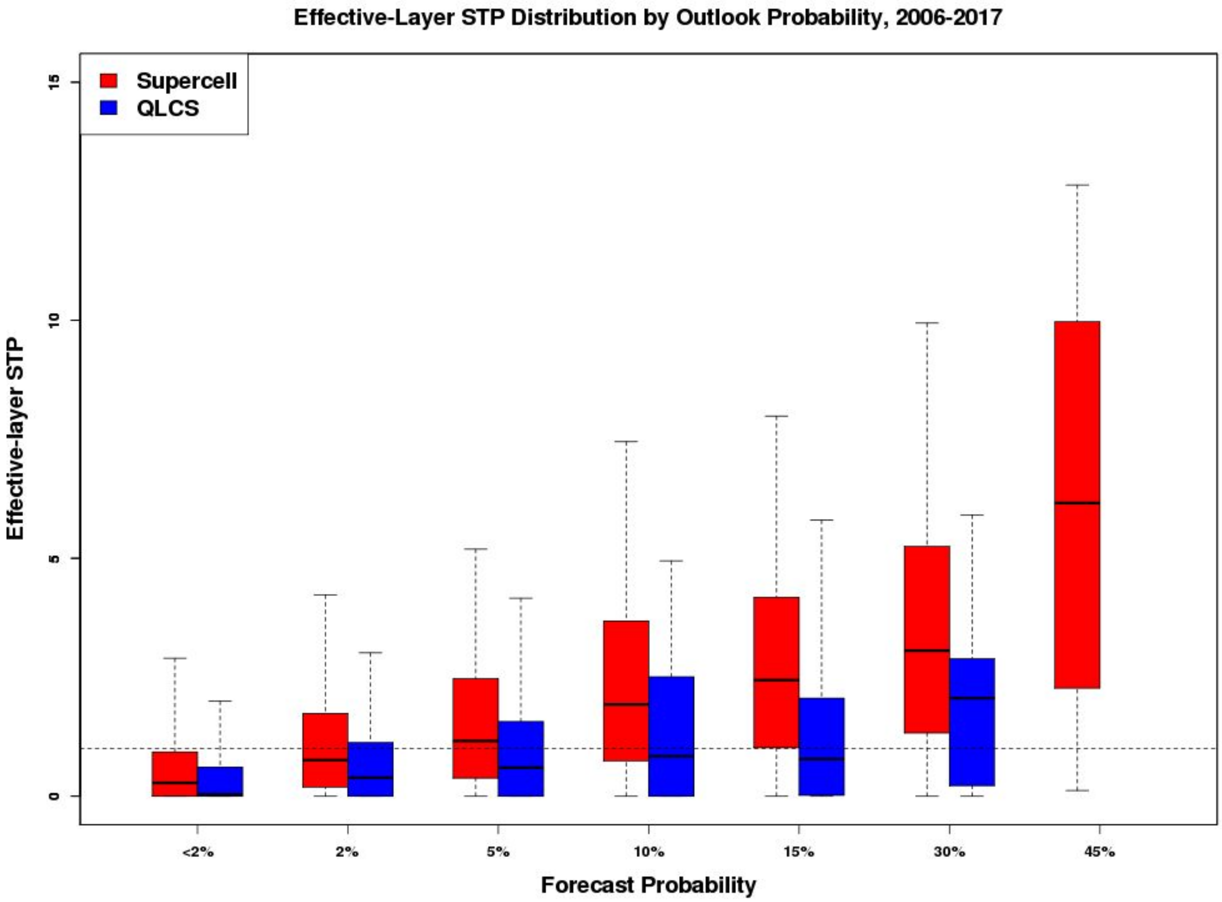

Fig. 9: Boxplots showing the distribution of effective-layer STP values for supercell (red) and QLCS (blue) tornado events, by forecast probability. The box shows the interquartile range, the whiskers extend to the 5th and 95th percentiles, and and solid line indicates the median value. The horizontal dashed line indicates where STP = 1.