P12.3 # An Assessment of Supercell and Tornado Forecast Parameters with RUC-2 Model Close Proximity Soundings

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1. INTRODUCTION

In a preliminary investigation, Edwards and Thompson (2000; hereafter ET00) examined multiple sounding parameters related to supercell and tornado potential with a sample of 188 close proximity soundings derived from RUC-2 model hourly analyses. Building upon that initial work, we have expanded our sample to include 548 close proximity soundings associated with supercells, and a smaller set (75) of close proximity soundings for discrete non-supercell storms. A more detailed discussion regarding our sounding collection methodology can be found in Thompson et al (2002, this volume; hereafter T02).

Numerous studies have examined proximity sounding characteristics for severe, tornadic, and supercell thunderstorms. Several of the more recent studies, namely Rasmussen and Blanchard (1998; hereafter RB98) and Craven et al (2002; hereafter C02) have collected samples with thousands of individual soundings. While such large samples are desirable, these studies relied on relatively coarse proximity criteria in time and space. The hourly RUC-2 model analyses allowed relatively strict temporal resolution (within 30 minutes) in our proximity soundings, at roughly the spacing of the surface observing network (40 km horizontal resolution). To keep the sample size reasonably large, we considered the majority of discrete radar-identified supercells across the contiguous United States during a 27 month period from April 1999 through June 2001.

An adaptation of the original SHARP sounding analysis software (Hart and Korotky 1991) was utilized to calculate all variables.

2. THERMODYNAMIC PARAMETERS

From the box and whiskers plot of lowest 100 mb mean parcel (ml) CAPE shown in Fig. 1, it is clear that larger mlCAPE values tend to be associated with significant tornadic supercells, and lesser CAPE with nontornadic supercells and non-supercell storms. The significant tornadic and nontornadic supercells are offset by almost one quartile from the 25^{th} to 75^{th} percentiles. These results are similar to the findings of RB98, ET00, and C02.

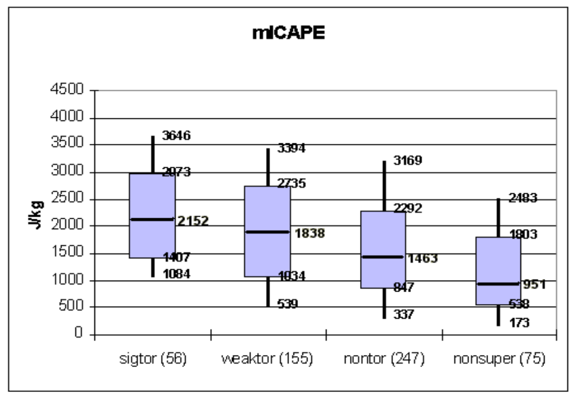

Figure 1. Box and whiskers plot of mlCAPE. The top and bottom of each shaded box denotes the 75^{th} and 25^{th} percentiles, respectively, and the heavy horizontal line is the median value. The heavy vertical lines extend upward to the 90^{th} percentile, and downward to the 10^{th} percentile. Groups of supercells are labeled, with sample size in parentheses.

Several recent studies (namely RB98, ET00, and C02) have identified lifting condensation level (LCL) height as an important discriminator between tornadic and nontornadic supercells. Our RUC-2 proximity sounding sample reaffirms these findings, with a substantial offset (more than one quartile) between significant tornadic and nontornadic supercells (Fig. 2). The lower LCL heights of the significant tornadic storms supports the hypothesis of Markowski et al. (2000) that increased low-level relative humidity may contribute to increased buoyancy in the rear flank downdraft, and an increased probability of tornadoes. The substantially higher LCL heights for the non-supercell storms may be misleading in that our sample is probably not representative of the full spectrum of storms. All soundings with a surface pressure greater than 999 mb were excluded because of a truncation error in our sounding analysis software. Thus, most thunderstorms from the moist coastal (low elevation) areas were not included in this sample.

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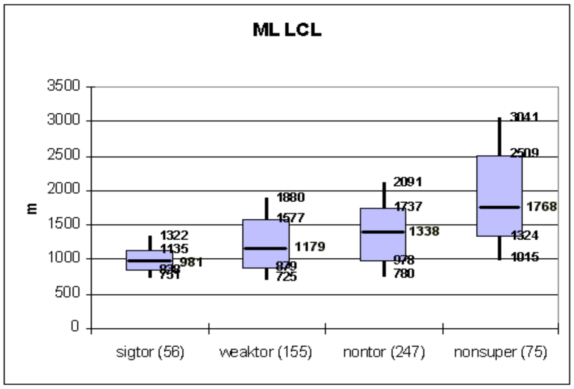

Figure 2. Same as Fig. 1, except for mlLCL height.

3. VERTICAL SHEAR PARAMETERS

Cloud model simulations by Weisman and Klemp (1982), along with observational studies by Markowski et al. (1998), RB98, and Bunkers et al. (2000; hereafter B2K) all present evidence that a vector shear magnitude of roughly 20 m s^{-1} over the lowest 6 km is necessary to support supercells. We have collected proximity soundings for both supercells and discrete non-supercell storms, as well as a small sample of storms with "marginal" supercell characteristics (see T02 for details). These sounding samples allow direct comparison between the various storm type groupings.

Based on our RUC-2 proximity sounding samples, 0-6 km vector shear magnitudes commonly exceeded 35-40 kt (17-20 m s^{-1}) for both tornadic and nontornadic supercells, with only a slight tendency for stronger shear in the significant tornado cases (Fig. 3). The 0-6 km shear magnitude clearly discriminates between all supercells and non-supercells, with no overlap in values between the 10th percentile values for supercells (29-36 kt) and the 90th percentile for non-supercells (28 kt). Storms with "marginal" supercell characteristics were associated with 0-6 km shear magnitudes in the transition region between supercells and non-supercells. Figure 3 suggests that supercells become more probable as 0-6 km vector shear magnitude increase from 30 to40 kt.

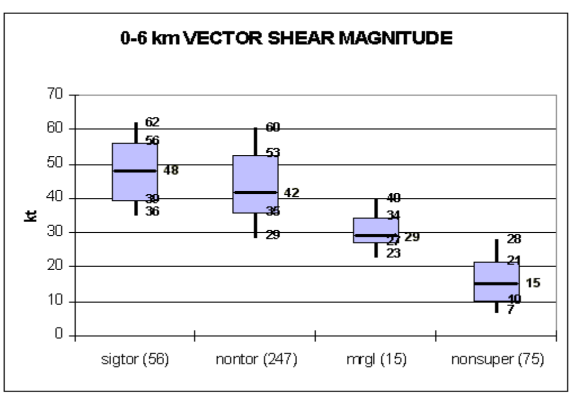

Figure 3. Same as Fig. 1, except for 0-6 km vector shear magnitude (kt), and with the addition of storms with marginal (mrgl) supercell characteristics.

Differences between significant tornadic and nontornadic supercells become more apparent when considering the vector shear magnitude in the lowest km (Fig. 4). Vertical shear in the lowest km tends to be about 5 kt stronger for the significant tornadic supercells, and much weaker for the marginal and non-supercell storms.

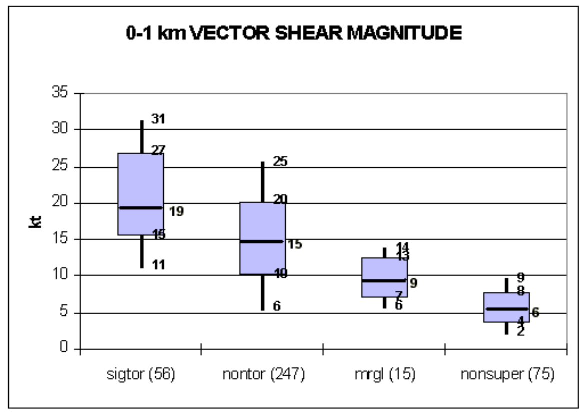

Figure 4. Same as Fig. 3, except for 0-1 km vector shear magnitude.

Relatively large differences were also noted between the significant tornadic and nontornadic supercells in terms of storm-relative helicity (SRH, Davies-Jones et al. 1990). As with ET00, and work by Rasmussen (2002) with the RB98 sounding set, 0-1 km SRH discriminates more strongly than 0-3 km SRH between significant tornadic and nontornadic supercells (Fig. 5). The differences between the supercell groups are maintained when the storm motion algorithm

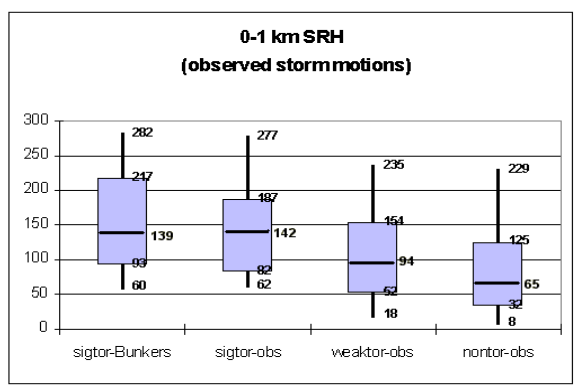

Figure 5. Same as Fig. 1, except for 0-1 km SRH. "Bunkers" denotes algorithm used to estimate storm motion, while "obs" are values calculated from radar-derived storm motions.

developed by Bunkers et al. (2000) is applied to the same soundings (Fig. 6), and the estimated SRH values using both storm motions were similar (compare Figs. 5 and 6).

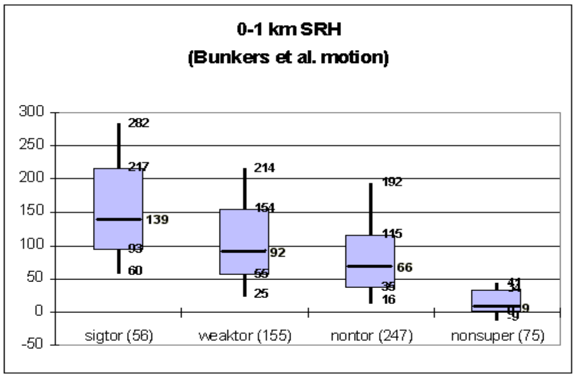

Figure 6. Same as Fig. 3, except all estimates of SRH were based on the Bunkers et al. (2000) storm motion algorithm.

The degree of low-level shear (e.g., 0-1 km SRH) and low-level moisture, in combination, can strongly discriminate between significant tornadic and nontornadic supercells. A large majority (77%) of the significant tornadic supercells were associated with 0-1 km mean RH >65% and 0-1 km SRH >75 m2 s-2, while 72% of the nontornadic supercells occurred with lesser values of either parameter (Fig. 7).

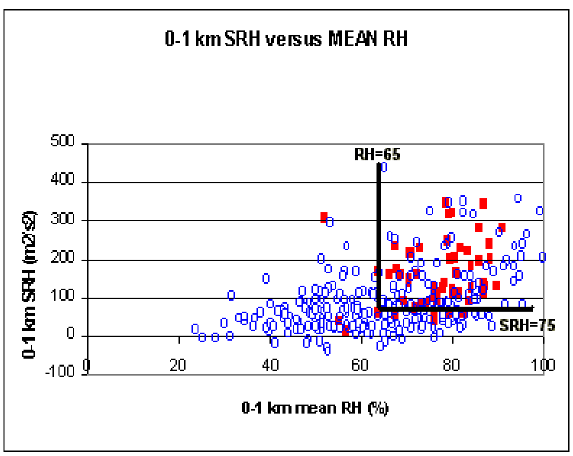

Figure 7. Scatter diagram of 0-1 km SRH and 0-1 km mean relative humidity (RH). Solid squares are significant tornadic supercell cases, and open circles represent nontornadic supercells. See text for discussion of the threshold values marked by the heavy lines.

4. MIDLEVEL STORM-RELATIVE WINDS

An original motivating factor for this work was to refine the ability to discriminate between tornadic and nontornadic supercells in operational forecasting, after Thompson (1998; hereafter T98). T98 found that storm-relative (SR) winds, derived from Eta model analysis grids, were larger at 500 mb for tornadic supercells, and weaker for nontornadic supercells. The means of each storm group were offset by one standard deviation, and application of a t-test confirmed that the difference in the means was significant at the 99% confidence level. An apparent threshold for tornadic supercells was noted at a 500 mb SR wind speed of about 15 kt (8 m s^{-1}) The 500 mb level was used for the calculations because only mandatory pressure level analyses were available, and the 700 mb level was used to estimate storm motion as part of a forecast test in T98. At the time, it was suggested that a more reliable method would be to calculate a layer average in the middle troposphere.

In spite of the increased horizontal resolution of the RUC-2 analyses compared to the Eta used in T98 (40 km versus 80 km), and more stringent temporal constraints, we have been unable to improve upon the findings of T98. Storm-relative winds were calculated in the 4-6 km layer (above RUC-2 ground level) for our entire supercell sample (Fig. 8). A comparison of SR wind speeds using observed storm motions reveals that the majority of significant tornadic supercells were associated with SR wind speeds greater than 8 m s^{-1}, and the significant tornadic values were about one quartile larger compared to the nontornadic values in the middle 50% of the distributions. While not an improvement, these results are consistent with the findings of T98 at a single pressure level for a smaller supercell sample.

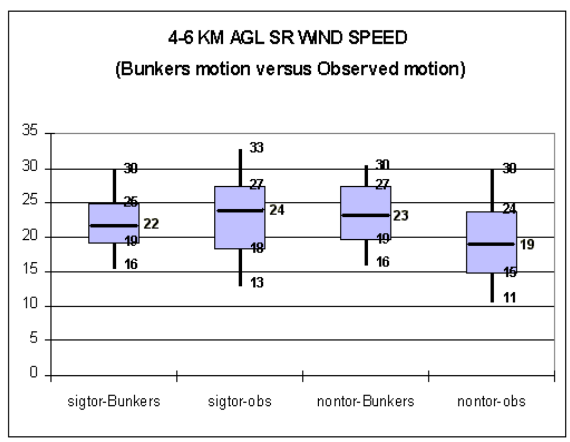

Figure 8. Box and whiskers plot (same as Fig. 1) of 4-6 km SR wind speed (kt). Storm motions are estimated in the "Bunkers" groups, and the "obs" groups use radar-derived storm motions.

The most reliable supercell motion algorithm available in forecast operations, the "ID Method" developed by Bunkers et al. (2000), was also examined. As can be seen in Fig. 8, the 4-6 km SR wind speed estimates were reasonable for the significant tornadic supercells. Unfortunately, the ID Method systematically over-estimated 4-6 km SR wind speeds for the nontornadic supercells. As a result, both groups of supercells occupied the same range of the parameter space, with no apparent ability to discriminate between the groups. The ID Method is apparently unable to replicate observed nontornadic supercell motion with enough precision to preserve any difference in 4-6 km SR wind speed between the two supercell groups. Therefore, the midlevel SR wind speed may not be a suitable parameter for such applications as the SPC hourly mesoscale analysis page described in Bothwell et al. (2002), given current storm motion estimate techniques.

5. SUMMARY

A number of common thermodynamic and kinematic sounding parameters were calculated for a set of 548 RUC-2 close proximity supercell soundings, as well as a small sample of discrete non-supercell storms. The RUC-2 analysis soundings revealed a tendency for greater CAPE and vertical shear to be associated with significant tornadic supercells, and lesser values with nontornadic supercells and non-supercell storms. It appears that the RUC-2 analyses retain the signals identified in previous and ongoing proximity soundings that utilize observed soundings, and that the RUC-2 analysis soundings are a suitable basis for objective guidance to operational forecasters.

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