P1.7

A COMPARISON OF BULK SHEAR AND CUMULATIVE SHEAR AS A PREDICTOR FOR CONVECTIVE MODE

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1. Introduction

Supercell thunderstorms, while relatively rare, constitute a significant part of the high-impact events dealt with by the National Weather Service. The majority of large hail events (> 5 cm) and nearly all significant tornadoes (F2 or greater) in this area are associated with supercell thunderstorms, as well as a portion of severe wind events (> 25 m s^{-1}). As a result, the distinction between a non-supercell severe thunderstorm event and a supercell severe thunderstorm event can create different needs for office staffing, prediction, and warning coordination within the Weather Forecast Office (WFO). Determining the best way to differentiate between environments favorable for supercells versus non-supercell is necessary for helping forecasters improve the prediction of convective mode.

Wind shear has considered a primary ingredient for determining convective mode (Weisman and Klemp 1986). Initially bulk shear, the vector difference between the top and bottom of a layer (generally 0 to 6 km) was calculated. However, other researchers showed that helicity can be used to determine convective mode (Davies-Jones 1984). To calculate the helicity the wind profile within the entire layer, rather than the top and bottom, must be known. So, for two layers with the same bulk shear, the helicity can be much larger when there is a more curved hodograph. This implies that the cumulative shear would also be larger as it is more closely related to helicity. With mesoscale observations and data sets as well as increased computing power both calculations can be done and are currently used in the National Weather Service as a means of predicting convective mode. However, neither type is emphasized as more accurately predicting supercells or non-supercells. Since knowledge of storm mode is important prior to storm initiation, some method of differentiation in prediction should be developed. In this study, bulk and cumulative shear are compared in groups of supercell and non-supercell thunderstorms events in order to determine which computation of shear is the best predictor.

2. Data and Methodology

The data set initially chosen for this study was all days with severe thunderstorm reports in the Sioux Falls WFO County Warning Area (CWA) (Fig. 1) from 2001-2006, in the months of April through October. The data were initially sorted by the most significant severe report of that day in the following order: tornado, hail, and severe wind. The cases with hail size of 4.5 cm in diameter or greater or a tornado report were initially placed into the supercell category, and those with hail smaller than 4.5 cm in diameter or a severe wind report were placed into the non-supercell category. After this initial grouping, the non-supercell category contained over 100

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days, and the supercell category contained over 50 days.

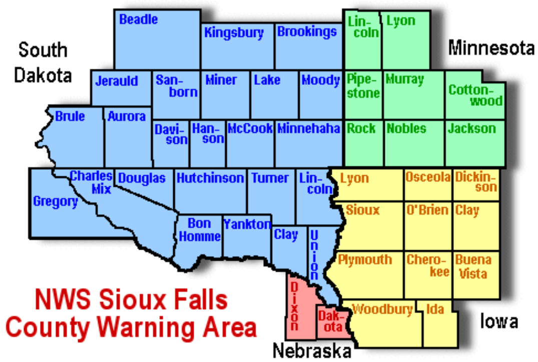

Figure 1. The National Weather Service Sioux Falls County Warning Area.

Radar data were then used to more accurately classify storm days. In order to do so, it was necessary to define what constituted as a supercell. The definition used in this study was based on Weather Surveillance Radar 88 Doppler (WSR-88D) data, and maintained that a supercell must exhibit at least 20 m s^{-1} of rotation on at least two adjacent levels, for at least four scans (approx. 15 min), and must deviate in motion from the mean storm motion. Although anything that did not meet these criteria was technically considered a non-supercell, cases that possessed a majority but not all of the criteria were not classified into either category in this study.

Archived WSR-88D reflectivity and velocity data were then used to determine into which category each severe thunderstorm day fit. Although many days began as a supercell case and quickly dissolved into a non-supercell case, no days were duplicated between the two categories, and all days which contained a supercell at any point were placed into the supercell category. Maps of the storm's initiation or entrance into the CWA, storm track, and dissipation or exit from the CWA were made for each case, noted with the time of initiation (entrance) and dissipation (exit), the latitude and longitude of the initiation (entrance), and closest surface observation. Any cases that were considered questionable were removed from the data set.

After cases were separated into the two categories or removed, the data set consisted of 51 supercell cases and 40 non-supercell cases. In order to balance the category distribution and the monthly distribution between two categories, five non-severe cases were added into the non-supercell category, giving 51 supercell cases and 45 non-supercell cases, and a nearly equal monthly distribution (Fig. 2).

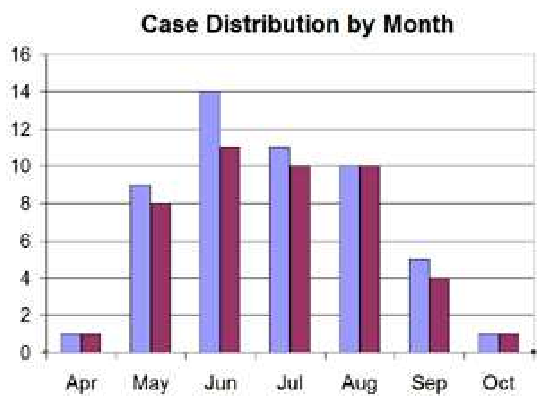

Figure 2. Case distribution by month, separated into supercell (blue) and non-supercell (purple).

The 32 km North American Regional Reanalysis data from the National Climatic Data Center were then used to extract proximity soundings for each case. The wind data were interpolated every 500 m from 500 m to 10 km, and archived surface obsrevation from the closest location were used for surface wind. The proximity sounding was taken three or less hours before storm initiation or entrance, and the surface data were taken from the same time. These data were then used to calculate both bulk and cumulative shear for 0-1 km, 0-2 km, 0-4 km, 0-6 km, 0-8 km, and 0-10 km. Effective shear was also calculated.

3. Results

Simple statistical analyses of the data were then done to compare the significance of the results. As 0-6 km shear is most commonly used in operational forecasting, this parameter, as well as 0-10 km shear, is used in the comparison between non-supercell and supercell cases. Table I shows values of bulk and cumulative shear for both data sets. The non-supercell cases had larger cumulative shear in the 0 to 6 km layer than supercell cases. The 0 to 10 km cumulative shear was slightly larger for supercell cases than non-supercell cases. In contrast, the average value for the 0-6 bulk shear was much larger for supercell cases than non-supercell cases was 15.75 m s^{-1}, and 20.02 m s^{-1} in the supercell cases. A similar result was seen in the 0 to 10 km bulk shear.

	0 to 6 km shear	0 to 10 km shear
Supercell bulk	20.02	28.34
Supercell total	28.61	41.39
Non-supercell bulk	15.75	21.74
Non-supercell total	30.75	40.93

Table I. Mean bulk and cumulative shear for supercell and non-supercell cases (m s^{-1})

To more clearly show the significance of the results, 95 percent confidence intervals were constructed with the data. The range of values for the 0-6 km cumulative shear in the non-supercell cases was 27.2 – 34.3 m s^{-1}, and 26.3 – 30.9 m s^{-1} in the supercell cases, while the range of the 0-10 km cumulative shear was 38 – 44.8 m s^{-1} in the non-supercell cases and 38 – 43.9 m s^{-1} in the supercell cases. The range of values for the 0-6 bulk shear in the non-supercell cases was 14 – 17.5 m s^{-1}, and 18.1 – 22 m s^{-1} in the supercell cases, while the range of the 0-10 km bulk shear was 19.1 – 24.4 m s^{-1} in the non-supercell cases and 25.2 – 31.5 m s^{-1} in the supercell cases.

4. Conclusions

The confidence intervals for the bulk shear at both levels show no overlap in ranges, while the cumulative shear overlaps almost completely. Although there is a little gray area that does not fall into the non-supercell or supercell categories, it can generally be assumed that a 0-6 km bulk shear value less than 17 m $s-^{1}$ indicates the development of a non-supercell thunderstorm, and a bulk shear greater than 18 m $s-^{1}$ indicates the development of a supercell thunderstorm.

There is little statistical significance in the difference between average values of cumulative shear and in the difference in range of the confidence intervals of cumulative shear. It is possible that the primary use of severe thunderstorm cases in the non-supercell category biased the wind data toward larger shear, which may have slightly affected the results. However, it is likely that the difference in bulk shear between supercell and non-supercell cases would increase, and the difference in cumulative shear would still not be large enough to be statistically significant. In either case, it is implied that bulk shear may be a better predictor of supercell versus non-supercell thunderstorms.

5. Acknowledgements

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6. References

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