Assessing tornadic potential in nonsupercell storms by quantifying the separation of Z_{DR} and K_{DP} enhancement regions

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1. Introduction

There is a significant gap in tornado warning performance between supercell and nonsupercell tornadoes: warning performance is worse for the latter, warranting further attention to these storms. Previous polarimetric radar studies have revealed hydrometeor size sorting through the separation of K_{DP} and Z_{DR} enhancement regions in tornadic storms. The goal of this study is to quantify the separation distance and orientation leading up to, during, and after a tornadic event in a large number of nonsupercell storms to reveal any characteristic features that may aid in the warning process.

2. Data and Methods

Only nonsupercell cases within 60 km of the closest WSR-88D radar were chosen for analysis to ensure sufficient data quality. Level-III radar data were used for analysis. To quantify the separation between enhancement regions, the enhancement regions must be defined. First, an area of interest, the "analysis box", is chosen (Fig. 1a,c). Enhancement regions are defined by all radar gates within the analysis box that exceed a K_{DP} or Z_{DR} threshold in addition to a ρ_{hv} threshold. The median x-and y-coordinates of the enhancement region determine its centroid (Fig. 1b,d).

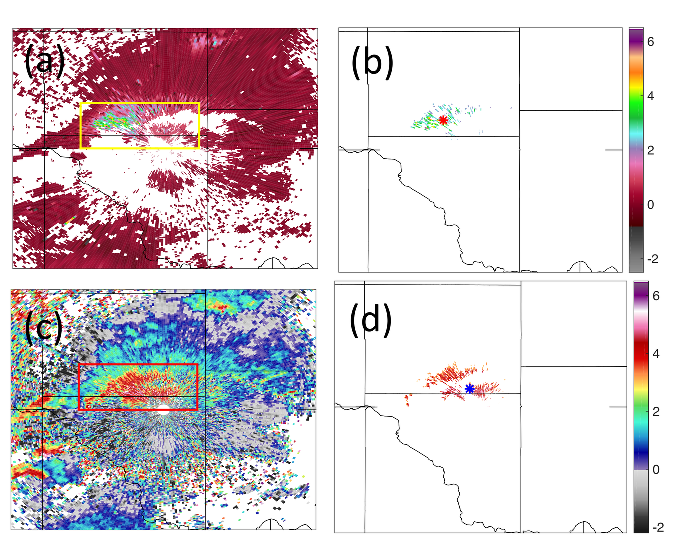

Figure 1. (a) K_{DP} (deg km^{-1}) scan with analysis box in yellow, (b) K_{DP} enhancement region with centroid in red, (c) Same as (a) but for Z_{DR} (dB) with analysis box in red, (d) Same as (b) but for Z_{DR} with centroid in blue.

The separation vector points from the K_{DP} to the Z_{DR} centroid. The distance and orientation clockwise from storm motion defines the separation vector (Fig. 2).

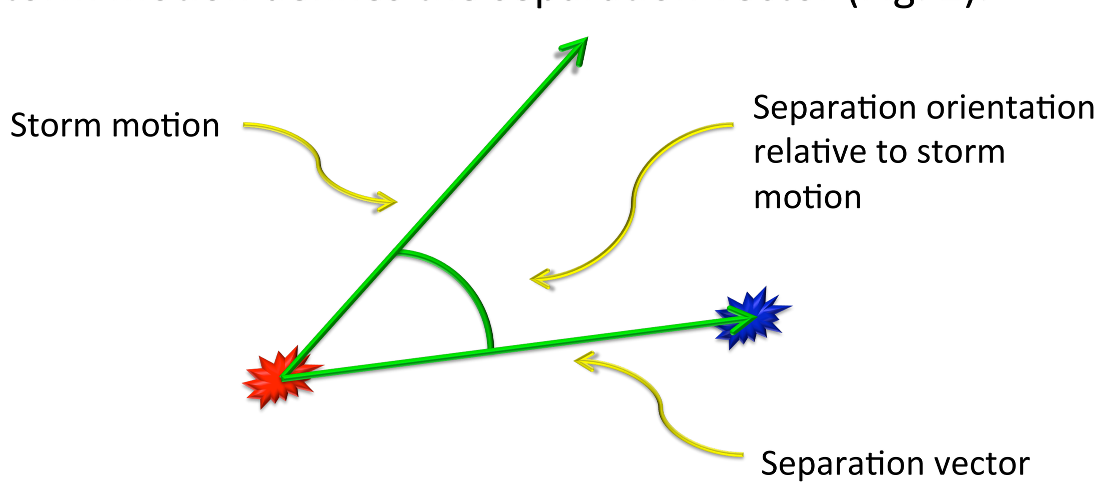

Figure 2. Depiction of the separation vector.

3. Results

A qualitative assessment of 70 nonsupercell tornadic storms revealed the repeatable signature of the separation of low-level K_{DP} and Z_{DR} enhancement regions in 30 cases. The separation vector was assessed at every volume scan during the analysis period. An example of this analysis from 1 March 2016 near the KBMX radar is shown below.

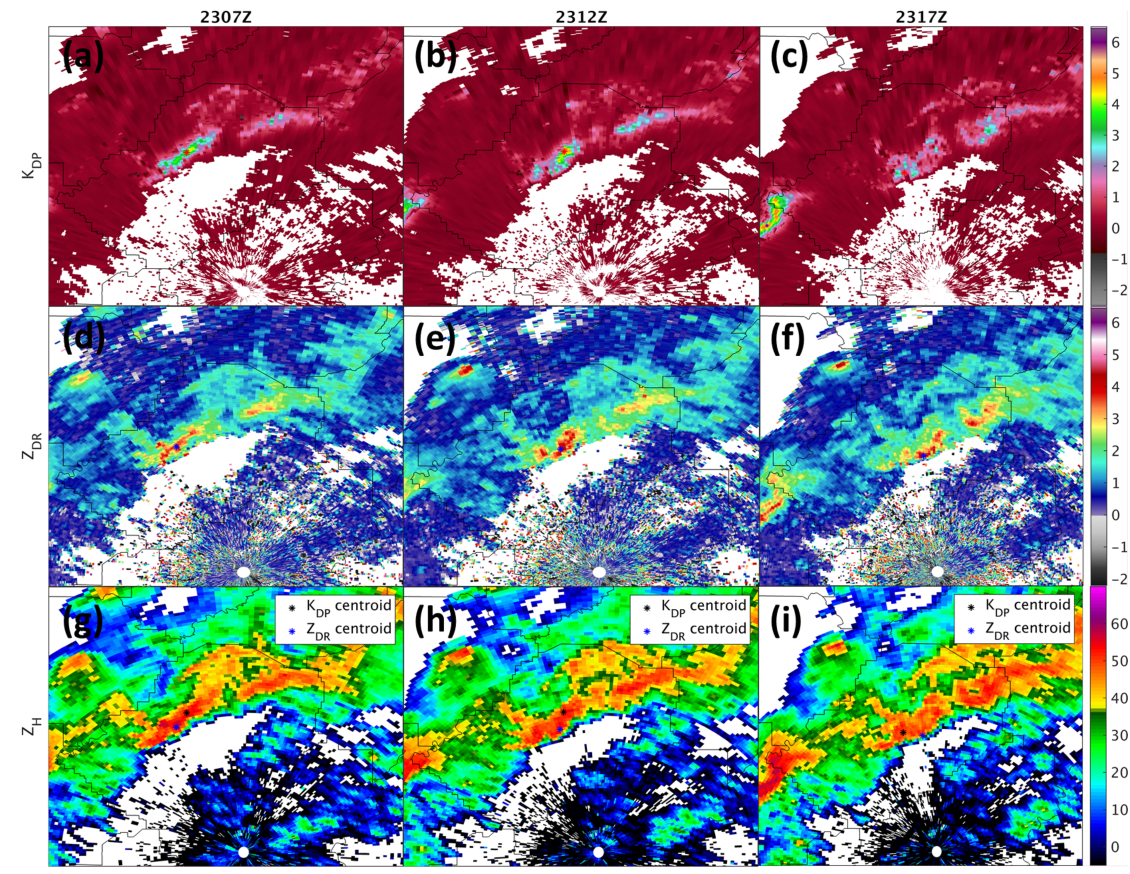

Figure 3. (a)-(c) K_{DP} scans at 0.5° at 2307Z, 2312Z, and 2317Z, respectively. Centroid in red. (d)-(f) Same, but for Z_{DR}. Centroid in blue. (g)-(i) Same, but for Z_H (dBZ). K_{DP} (Z_{DR}) centroid in black (blue). LSR was at 2312Z.

Scans of K_{DP} and Z_{DR} show their respective enhancement regions as well as the locations of the centroids (Fig. 3). The separation orientation before and at the time of the LSR is roughly orthogonal to the west-northwest to east-southeast storm motion.

This can also be seen in the time series of separation orientation (Fig. 4b). The separation orientation values are close to 90° at the time of the LSR as well throughout most of the analysis period. The time series of separation distance (Fig. 4a) shows values around 5 km for most of the analysis period with a peak separation around 10 km occurring 12 minutes prior to the LSR.

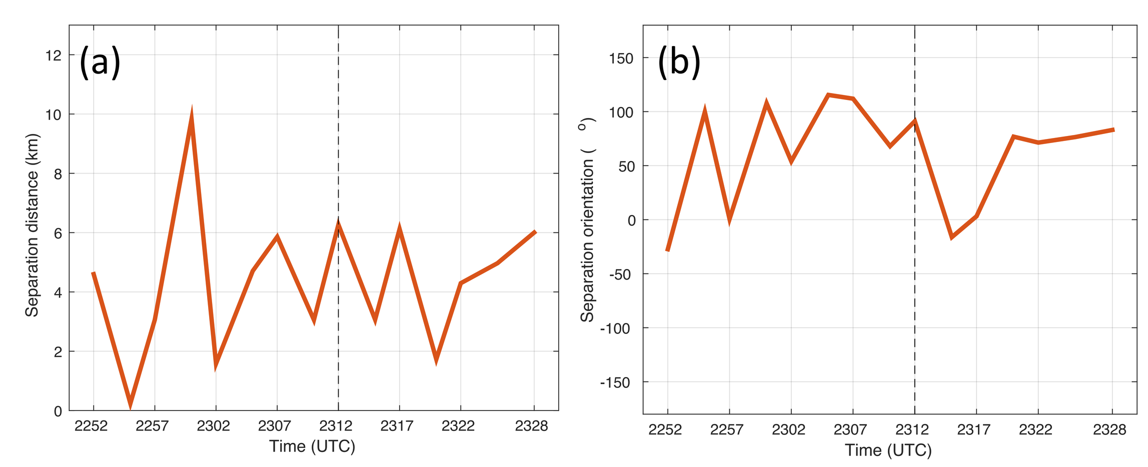

Figure 4. Time series of (a) separation distance and (b) separation orientation for 1 March 2016 near KBMX. LSR time noted by vertical dashed line.

The distribution of separation distances from all volume scans across all 30 cases (Fig. 5a) shows a right-skewed distribution with a peak around 4 km. The distribution of separation orientation (Fig. 5b) shows a large portion of measurements in the quadrant from 0-90° to the right of storm motion.

The distribution of the time relative to the LSR at which the separation distance peaks (Fig. 6) shows that the separation distance tends to peak close to the time of the tornado itself, compared to a uniform distribution if it was a random occurrence.

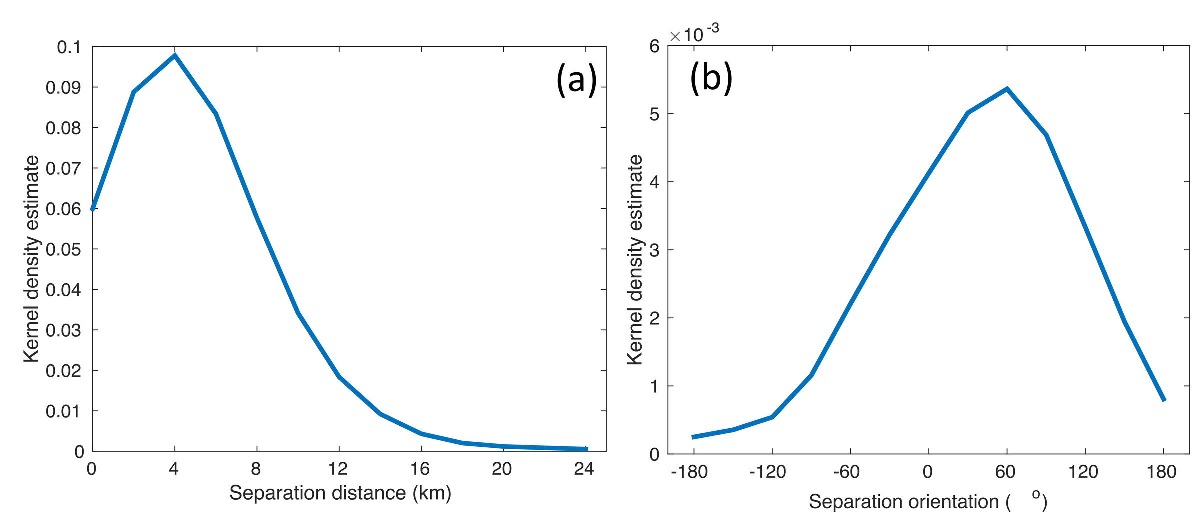

Figure 5. Distributions of (a) separation distance and (b) separation orientation

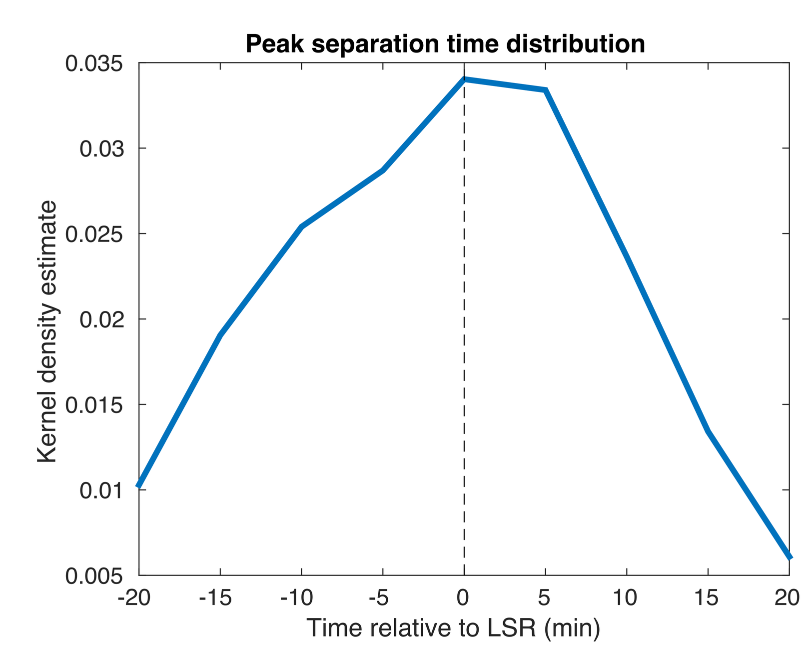

Figure 6. Distribution of times relative to LSR when peak separation distance occurs

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4. Separation vector and storm-relative helicity

Previous studies (e.g., Kumjian and Ryzhkov 2009; Dawson et al. 2014, 2015) have linked the presence and strength of the Z_{DR} enhancement region (or "Z_{DR} arc") to storm-relative winds and storm-relative helicity (SRH). Distance and orientation values for each case are compared with 0-1 km SRH from SPC mesoanalysis data (Fig. 7).

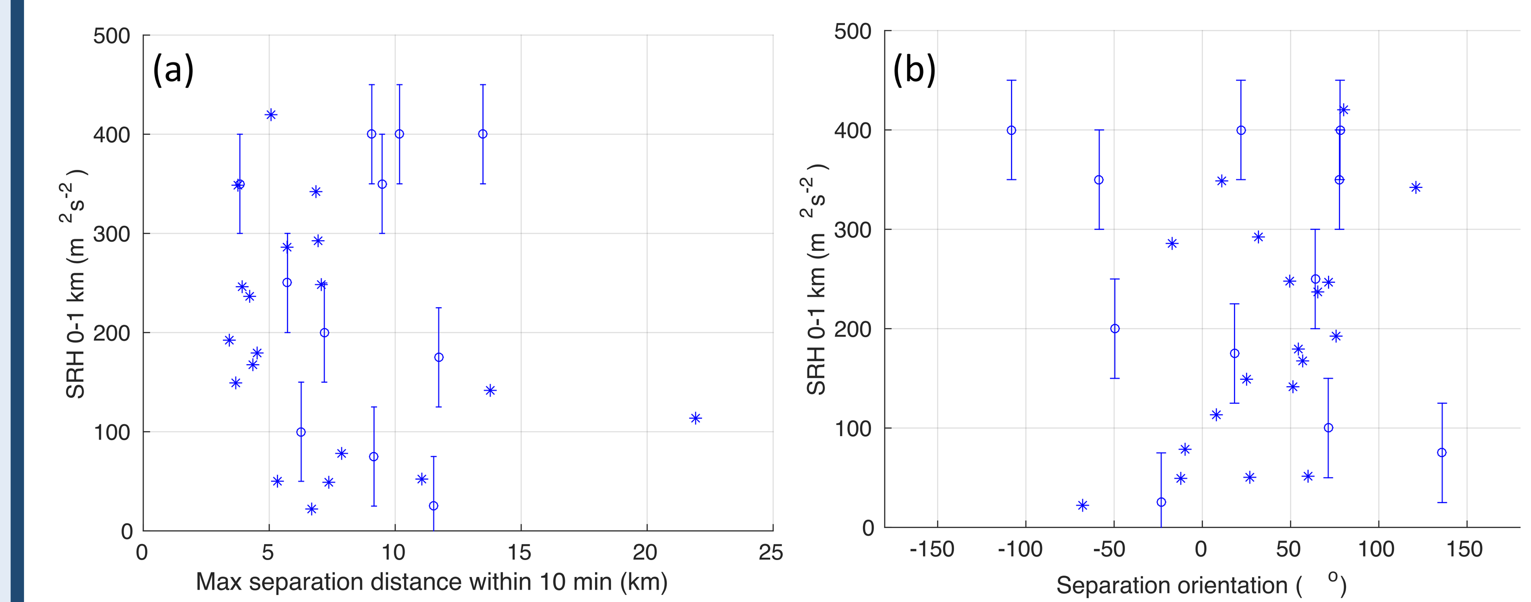

Figure 7. 0-1 km SRH vs. (a) max separation distance within 10 minutes of the LSR and (b) median separation orientation within 10 minutes of the LSR.

Neither distance nor orientation show a correlation with 0-1 km SRH (r^2 = 0.02 and 0.01, respectively) or 0-3 km SRH (not shown). A "size sorting parameter" is developed to incorporate both distance and orientation (SSP = D×sin(A)). Data are subdivided by distance (Fig. 8). Though the SSP and 0-1 km SRH shows little correlation (r^2 = 0.001), the 3.5-7 km (red) group does show a moderate positive correlation (r^2 = 0.43).

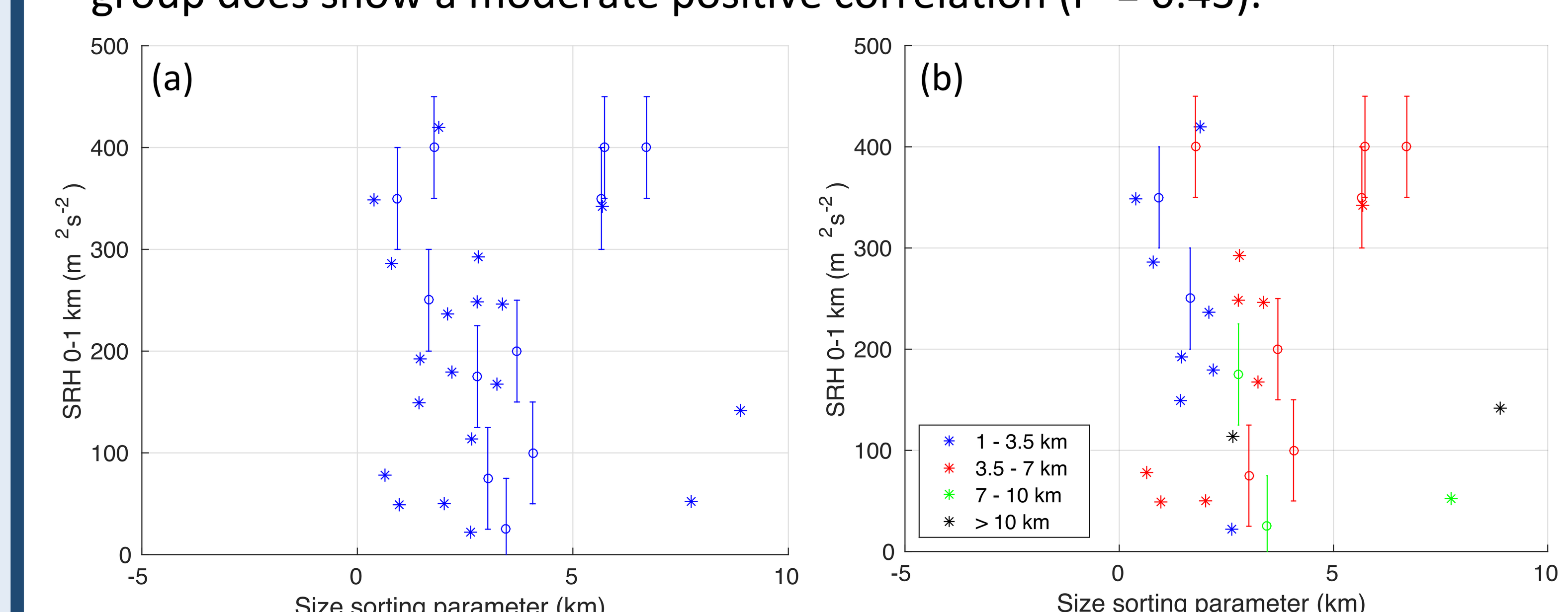

Figure 8. 0-1 km SRH vs. (a) size sorting parameter and (b) size sorting parameter subdivided by distance

5. Conclusions and Future Work

- Low-level separation of K_{DP} and Z_{DR} enhancement regions is quantified in 30 nonsupercell tornadic storms.
- Distributions of separation distance and orientation show characteristic values of separation distance around 4 km and a preferred quadrant for separation between 0-90° to the right of storm motion.
- For a given separation distance, SRH tends to increase with more orthogonal orientations.
- Next step is to analyze a large number of nontornadic cases for comparison. Preliminary results show less favorable (further from orthogonal) orientations in nontornadic cases.