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 tornado 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 $R_p$ threshold. The median x-and y-coordinates of the enhancement region determine its centroid (Fig. 1b,d).

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).

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.

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.

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.

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 ZDR enhancement region (or “Zdr 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).

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 = $D \times \sin(A)$). Data are subdivided by distance (Fig. 8). Though the SSP and 0-1 km SRH shows little correlation ($r^2 \approx 0.001$), the 3.5-7 km (red) group does show a moderate positive correlation ($r^2 = 0.43$).

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.

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