An Observational Analysis on Quantifying the Distance of Supercell-Boundary Interactions in the Great Plains

UNC CHARLOTTE

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INTRODUCTION

Boundaries are well-known to enhance horizontal and vertical vorticity, wind shear, and helicity, strengthening mid-level rotation in supercells (e.g., Maddox et al. 1980; Markowski et al. 1998b; Rasmussen et al. 2000). Additionally, it has been shown that tornadoes are most likely to occur within a range of 10 km to 200 km from the boundary (e.g., Markowski et al 1998b; Gagne II et al. 2012). However, these distances have yet to be assessed for a larger number of cases. It is also unknown whether these distances are valid for all types of mesoscale boundaries, as well as all types of severe weather. The goal of this study is to gain a better understanding of the nature of supercell-boundary interactions, and use this knowledge to promote more timely and accurate watches and warnings.

METHODOLOGY

1. Locate supercell cases in Great Plains from March 2004 – June 2016 using the Storm Prediction Center Severe Weather Event Archive (SPC SWEA)
2. Download Level II and III radar data from National Center for Environmental Information (NCEI) Radar Archives and use the Weather & Climate Toolkit for MDL to confirm whether or not the storm is a supercell
3. Assess the presence of a boundary (outflow, stationary, or warm front) using the Weather Prediction Center's Surface Analysis Archives (WPC SAA)
4. Download ASOS archives from Iowa Environmental Mesonet
5. Load ASOS archives and Level II radar data in IDV, use the drawing tool to measure distance from supercell's hook echo or storm centroid to nearest point on boundary
6. Record the supercell-boundary distance every 20 min, and capture the image to make a loop for a time-series approach
7. Collect associated storm reports for each case and use the recorded distances to linearly interpolate the distance of the supercell to the boundary for each report

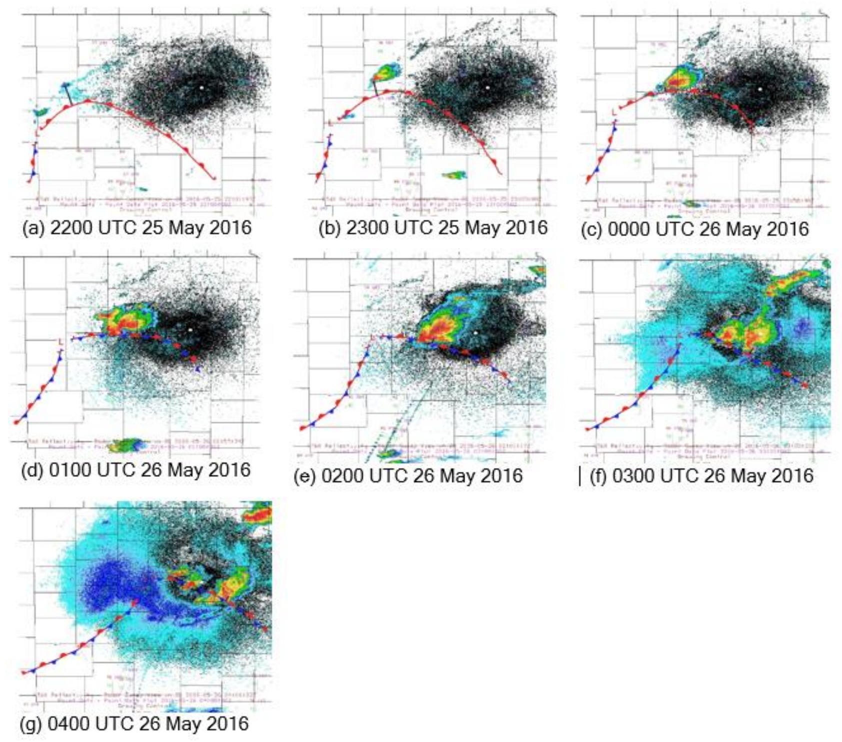

Fig. 1: Interaction of the May 25, 2016 Kansas supercell with the warm/stationary front from 2200 to 0400 UTC, as analyzed in IDV.

Time (UTC)	Distance (km)
2200	29.34
2220	27.00
2240	25.44
2300	21.92*
2320	19.59
2340	12.23
0000	5.84**
0020	2.27**
0040	0.96**
0100	4.49
0120	13.96**
0140	12.23
0200	9.29**
0220	5.13
0240	7.28*
0300	10.72*
0320	8.32*
0340	7.75
0400	7.83

Table 1: Distances over time between the supercell and warm/stationary front on 25-26 May 2016. Negative distances signify the cool sector, positive distances are in the warm sector.
*Tornado report **Significant tornado report

CLIMATOLOGY

Figure 2

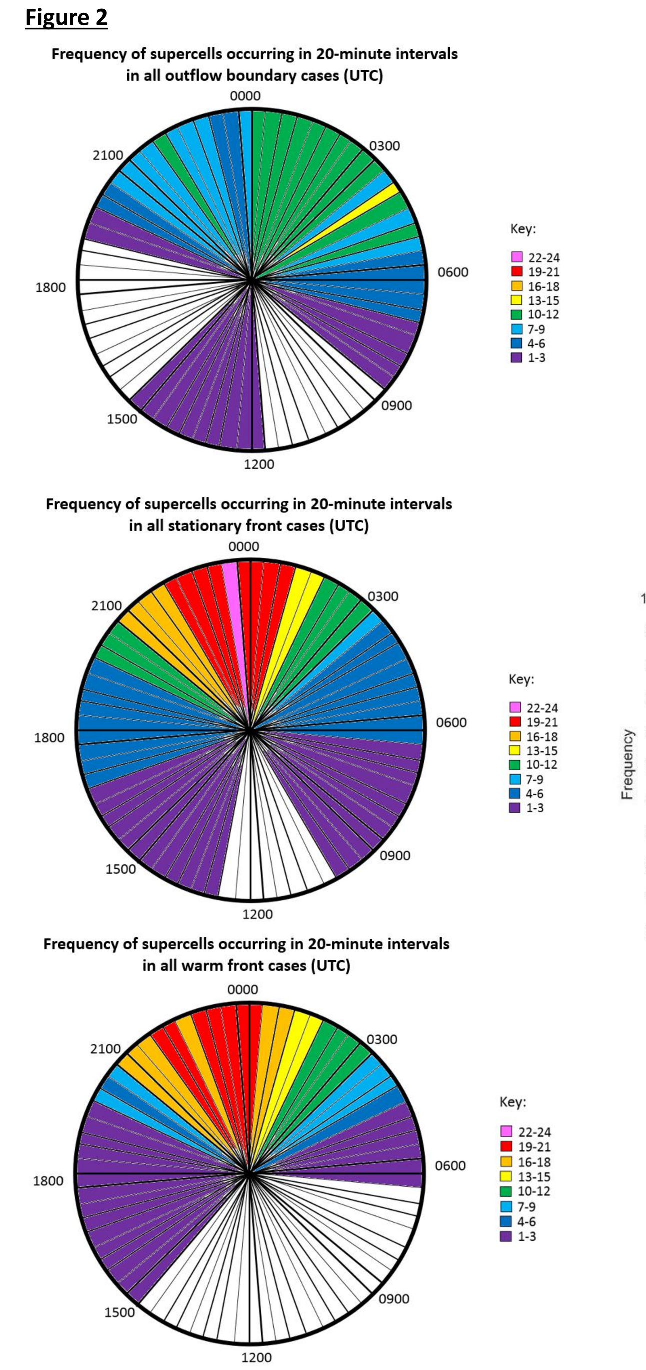

Figure 3

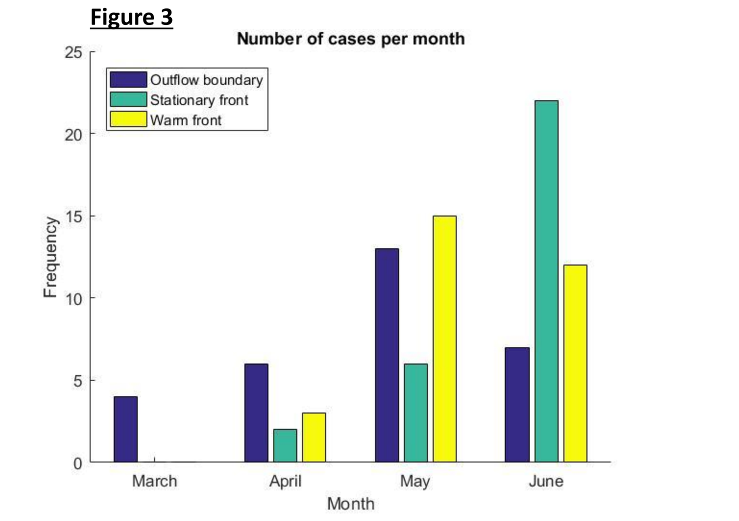

Figure 4

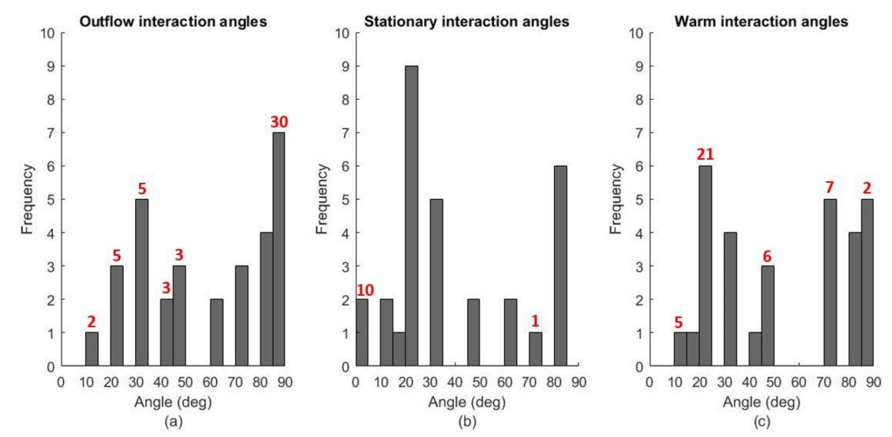

Fig. 2 (left): The number of cases (out of 30) per boundary type that were active for the specified time (UTC) for outflow boundaries (a), stationary fronts (b), and warm fronts (c).

Fig. 3 (top-right): Total number of cases per boundary type in each Spring month.

Fig. 4 (bottom-right): Angle of supercell motion relative to the boundary for outflow boundaries (a), stationary fronts (b), and warm fronts (c). Red numbers represent the number of significantly severe tornadoes (> F/EF2) occurring within that angle range.

RESULTS

Figure 5

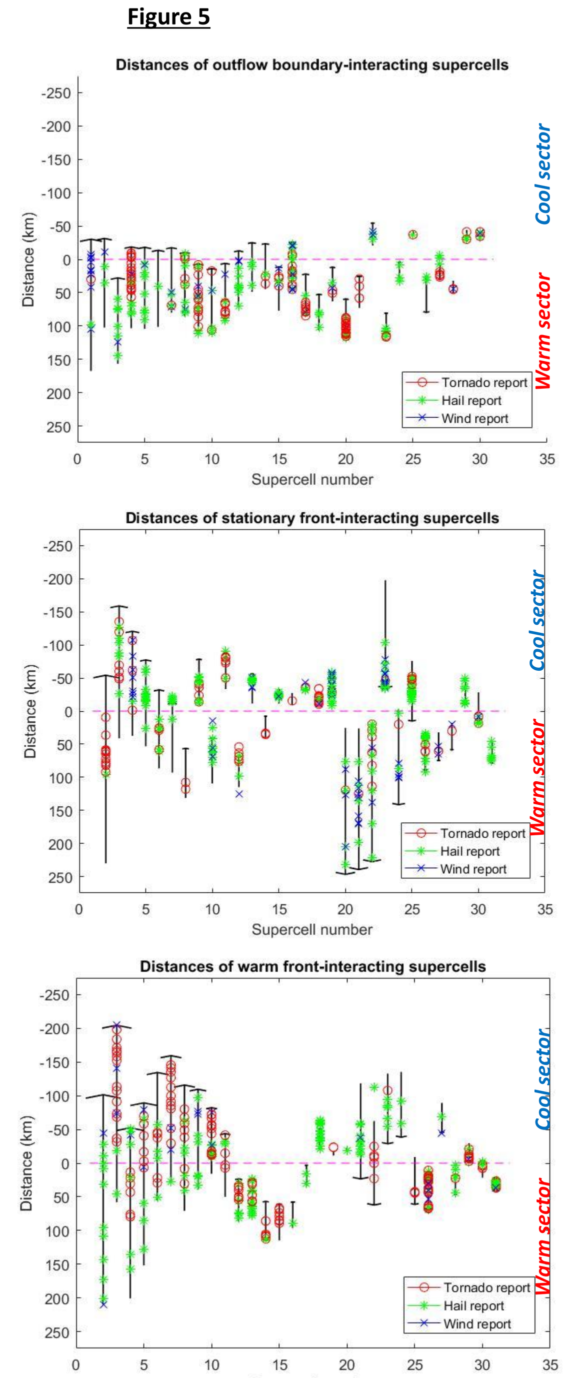

Figure 6

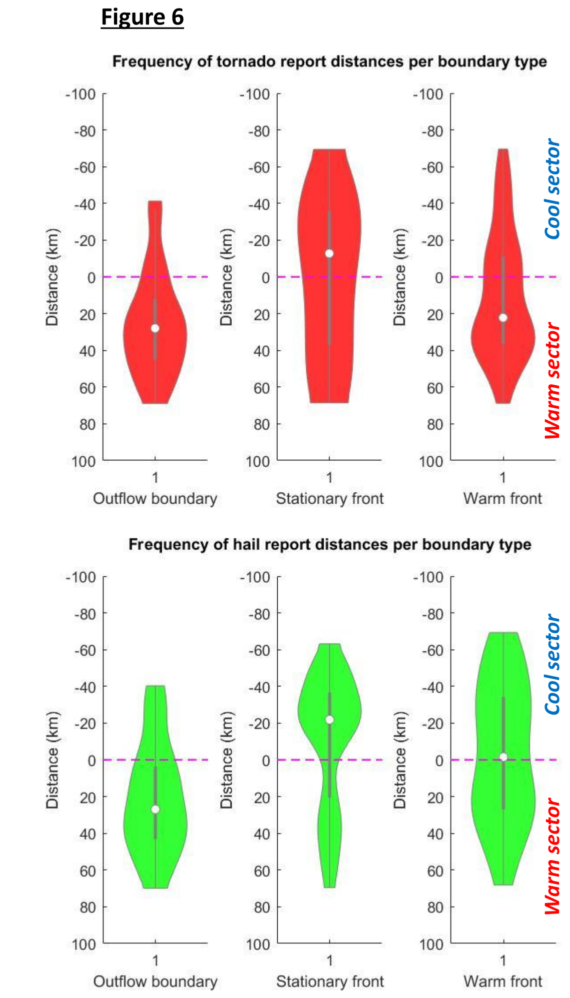

Fig. 5 (left): Supercell motion vectors starting at boundary distance at the beginning of the supercell's lifetime and ending at the end of the supercell's lifetime for (a) outflow boundary-interacting supercells, (b) stationary front-interacting supercells, and (c) warm front-interacting supercells. Wind reports omitted due to subjectivity of reporting (Edwards 2016).

Fig. 6 (above): Violin plots of distance of severe tornado (top panel, red) and hail (bottom panel, green) reports within 70 km of the boundary in the cool sector (negative distance) and warm sector (positive). Boundary signified by dashed purple line with positive values representing the warm sector and negative values representing the cool sector

DISCUSSION

- Temporal distribution throughout the day shows outflow boundary-associated severe reports most commonly occur from 00Z – 05Z, while stationary and warm front severe reports occur mostly from 22Z – 01Z (Fig. 2)
- In most cases, significant tornadoes occur more frequently with smaller angles of interaction between the supercell and boundary (Fig. 4)
- Storm report frequency often increases as the supercell nears or crosses a boundary (Fig. 5)
- Two-Way Kolmogorov-Smirnov Tests (KS-Test) indicate that all distributions are unique within each report type, and all but tornado and hail reports for outflow boundaries are unique within each boundary type (Table 2)
- The majority of storm reports occur within 70 km of the boundary. Using +/- 1 standard deviation for the normal distributions, ranges indicating the location of where severe weather is most likely to occur based on boundary and report type is shown in Fig. 7

I. Comparisons by Boundary Type	
Distribution Comparison	**P-Value**
Tornado-Outflow and Hail-Outflow	0.396
Tornado-Stationary and Hail-Stationary	***9.00E-04***
Tornado-Warm and Hail-Warm	***5.32E-02***
II. Comparisons by Report Type	
Distribution Comparison	**P-Value**
Tornado-Outflow and Tornado-Stationary	***1.76E-06***
Tornado-Outflow and Tornado-Warm	***1.35E-02***
Tornado-Stationary and Tornado-Warm	***1.30E-03***
Hail-Outflow and Hail-Stationary	***4.78E-12***
Hail-Outflow and Hail-Warm	***1.47E-04***
Hail-Stationary and Hail-Warm	***1.20E-03***

Table 2: List of distribution comparisons and associated p-values for all reports within 70 km of the boundary, regardless of warm or cool sector. A p-value less than 0.05 means that there is less than a 5% chance that the two distributions are from the same parent distribution, and is considered statistically significant; these values are indicated by bold italics.

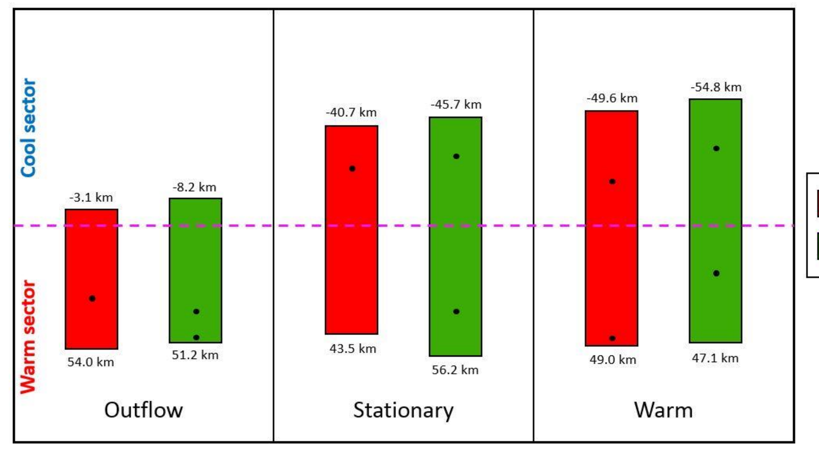

Figure 7: Visual representation of the distances that contain one standard deviation around the mean distance from the boundary (dashed purple line) for each storm report type per boundary type (outflow-tornado, outflow-hail, and stationary-tornado). One standard deviation around the mean for the warm sector and cool sector reports (stationary-hail, warm-tornado, warm-hail). Negative distances indicate distance is in the cool sector. Black dots indicate the mode of the distribution.

CONCLUSIONS AND FUTURE WORK

- Surface boundaries enhance supercell development and intensity by local baroclinicity increasing environmental wind shear, helicity, and vorticity
- Nearly all distributions of hail and tornado report distances were determined to be statistically different, both within report type and within boundary type (Table 2)
- Unique ranges for where tornado and hail reports are most likely to occur during supercell-boundary interactions should assist forecasters with watch and warning issuance (Figure 7)
- These distributions will be further broken down to account for angle of interaction between the supercell and boundary, as well as in which sector the supercell originates (warm or cool sector)