P10 AN OBSERVATIONAL EXAMINATION OF SUPERCELL AND SQUALL LINE THUNDERSTORM INTERACTIONS

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1. INTRODUCTION

Widespread severe weather outbreaks often contain multiple storm organizations, with supercells and squall lines generally producing most of the severe weather hazards (large hail, damaging winds, and tornadoes). Countless studies have researched supercells and squall lines independently, but very few have analyzed cases where the two convective modes are present in the same environment. When these two storm organizations occur in close proximity to one another, it is unclear how they may affect each other, particularly in terms of altering storm intensity and severity. The present paper seeks to address the question *how does a squall line affect the intensity of a nearby supercell thunderstorm?* This will be accomplished by using the Dodge City, KS (KDDC) WSR-88D radar data from 23 May 2008 to identify common changes to the structure and intensity of several supercells as a squall line approaches.

A number of studies have focused on the supercell and squall line merger process, where the evolution of the squall line is altered by the supercell (e.g. Goodman and Knupp 1993; Wolf et al. 1996; Sabones et al. 1996; Wolf 1998, French and Parker 2012). However, few studies have focused on how the squall line affects a supercell prior to the merger. Some limited observations of supercells and squall lines in close proximity have suggested increases in echo size and in the radar reflectivity factor (Przybylinski 1995), along with enhanced low-level rotation, and changes to the severe weather reports (French and Parker 2012) as the supercell draws close to a squall line. Previous squall line research has identified squall line-induced perturbations modifying the environment ahead of the approaching line (Fovell et.al 2002; Bryan and Parker 2010), including changes to the vertical wind shear, CAPE, CIN, and precipitable water. These parameters are well known to affect supercelluar structure (Doswell 2001). This past work leads us to hypothesize that the presence of a nearby squall line and its perturbations may be sufficient to alter supercell structure and intensity. In particular, we expect to observe an increase in the low-level rotation and increases in radar derived metrics related to updraft strength, such as maximum estimated hail size (MESH) and echo top heights (ET).

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2. METHODOLOGY

Archived KDDC WSR-88D data were obtained from the National Climate Data Center (NCDC). These data were ingested into the Warning Decision Support System–Integrated Information (WDSS-II) software, which converted data into netcdf format, dealiased Doppler velocities, and performed quality control. The WDSS-II software was then used to create derived fields that included azimuthal shear, vertical integrated liquid (VIL), hail detection algorithms (HDA), and echo top height above the 50 dBZ contours. Radar products were displayed at constant heights, instead of observing scan elevations.

3. SYNOPTIC OVERVIEW OF 23 MAY 2008

An upper-level omega blocking pattern was present over the CONUS throughout 23 May 2008 event. This favored a strong upper-level jet, with differential cyclonic vorticity advection and diffluence over the KDDC area providing upper-level dynamics supportive of severe weather (Figure 1a). At the surface, a low pressure system was located over southwestern Kansas, with a warm front extending across Kansas and the cold front extending south through the panhandles of Oklahoma and Texas. A dryline extended from eastern Colorado to the Texas Panhandle ahead of the cold front. Warm temperatures, and ample moisture, with dewpoints between 15°C and 20°C, were present ahead the dryline (Figure 1b) creating favorable low-level conditions for severe weather. In the early afternoon, storms formed along the warm front in northwestern Kansas, where by 2100 UTC supercells began to develop along the dryline and by 0044UTC the squall line formed west of the supercells.

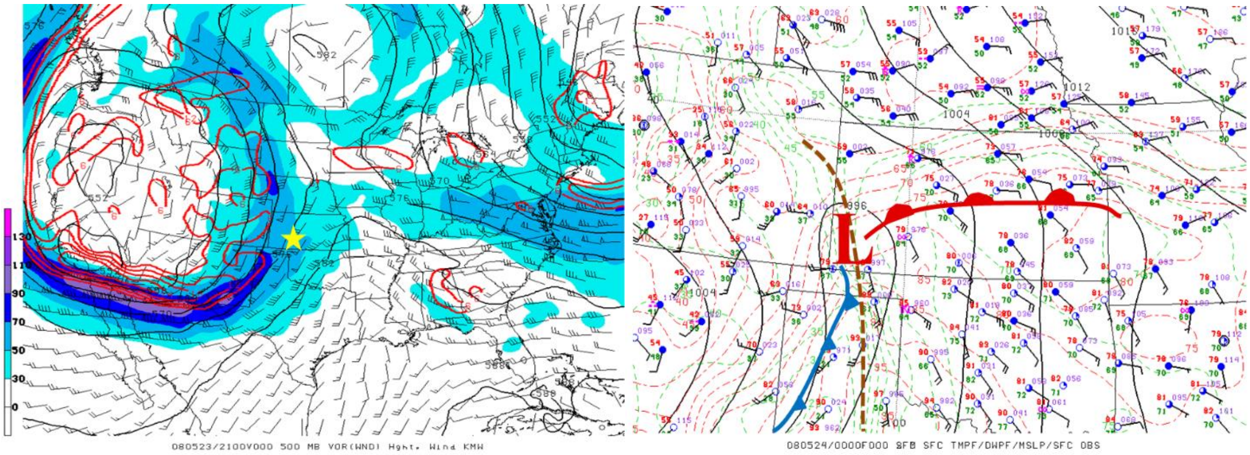

Figure 1: (a) 23 May 2100 UTC RUC 500mb heights, winds, & vorticity. (b) 24 May 0000 UTC surface observations & RUC MSLP, temp, & dewpoints

4. 23 MAY 2008 KDDC WSR-88D OVERVIEW

The main focus of this paper will be on the three supercells near the KDDC radar (Figure 2a). The supercells are labeled in order of their development (SC_A, SC_B, and SC_C). Each supercell formed and merged with the squall line at different times, which made this case ideal for observing how supercells at different levels of maturity may be impacted by a squall line.

a. Supercell A (SC_A)

SC_A formed at 2219UTC along the dryline on the KS/OK border and moved on a northeastward trajectory. It formed about two hours before the squall line and underwent a split before maturing. On KDDC radar (Figure 2a-e), the size of the SC_A echo can be seen to increase with time along with its intensity. By 0044UTC, when the squall line formed to the west, SC_A was well into the mature stage of its lifecycle. Shortly after the squall line's development, SC_A's radar reflectivity factor diminished and the size of the echo began to decrease as well. By 0244UTC SC_A along with the northern portions of the squall line began to weaken in intensity. This may be a result of the two most southern supercells cutting off SC_A and the northern portion of the squall line from the more favorable environment. SC_A maintained its supercellular features for greater than 4 hours categorizing it as a long lived supercell (Bunkers 2006), but it weakened before it merged with the squall line at 0330UTC

Looking at SC_A using other radar-derived metrics, increases in azimuthal shear, maximum estimated hail size (MESH), and echo top heights (ET) were observed before the development of the squall line. In general, the ET and MESH were observed to decrease in strength as the squall line approaches SC_A (Figure 4a & 5a). Azimuthal shear also weakened throughout the depth of the storm until about 80 minutes prior to the merger, but then briefly increased again in the low-levels (0-4km) beginning 40minutes prior to the merger (Figure 3a).

b. Supercell B (SC_B)

SC_B developed beginning at 2334UTC along the dryline on the TX/OK border and continued into KS on a northeastward track. It formed about an hour before the squall line developed and underwent a split. As the squall line approached the maturing SC_B (Figure 2a-e), its radar reflectivity factor increased in intensity and echo size, but by 0144UTC it began to decrease. A few radar scans later by 0258UTC, SC_B began to re-intensify in echo size just before the merger. As the squall line approached, SC_B maintained supercellular features for greater than 4 hours and had a longer track than the previous supercell. SC_B was the last supercell to merge with the squall line, at 0421UTC, before the line evolved into a bow echo.

The azimuthal shear, MESH, and ET for SC_B increased as the squall line developed to its northwest. As the squall line approached, ET (Figure 4b) and MESH (Figure 5b) values decreased. A noticeable decrease in azimuthal shear (Figure 3a), 110 minutes prior to the merger was also observed. By 80 minutes before the merger, an increase in low-level azimuthal shear and ET observed, while the general weakening trend in MESH continued until the merger.

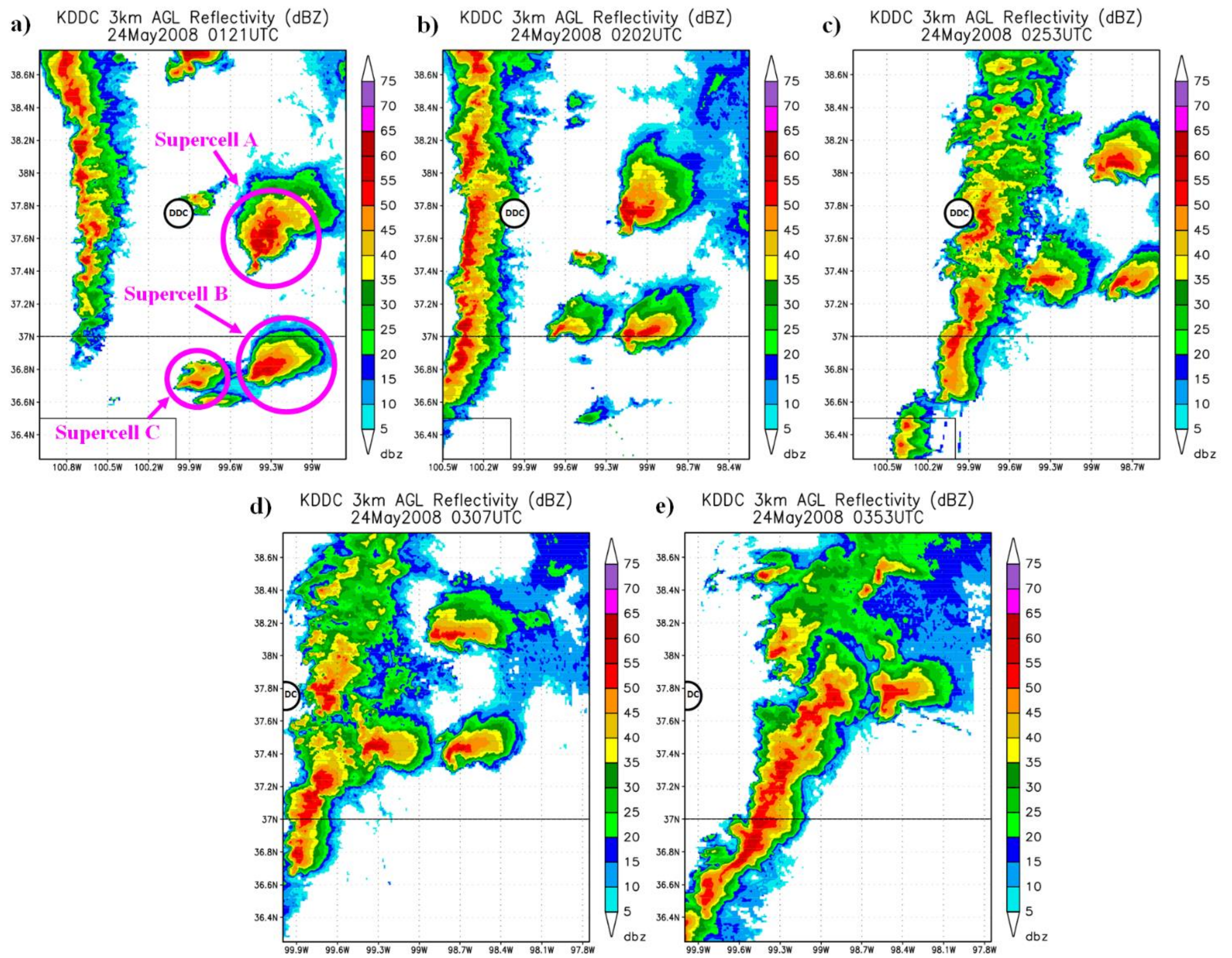

Figure 2: 3 km AGL Reflectivity from Dodge City, Kansas WSR-88D from (a) 0121UTC, (b) 0202UTC, (c) 0253UTC, (d) 0307UTC, and (e) 0353UTC on 24 May 2008. Supercell A was in its mature stage as the squall line forms and as the squall line approached, its intensity decreased along with the northern portion of the squall line by 0253UTC. Supercell B was in the developing stage when the squall line formed. As the squall line approached, the intensities

c. Supercell C (SC_C)

SC_C is different from the other two supercells because it developed after the squall line formation. As seen on KDDC radar (Figure 2a-e), SC_C originally developed as a left split, but eventually by 0102UTC became the dominant cell. As SC_C continued on its northeastward track, it continued to grow in intensity and echo size. Unlike the previous two supercells, SC_C was considered a short-lived supercell (≤2 hours) (Bunkers 2006) and once it had reached peak maturity, it merged with the squall line by 0307UTC.

A general increasing trend in ET and MESH values were observed throughout the lifecycle of SC_C, indicative of the storm maturing (Figure 4c & 5c). By 65 minutes prior to the merger, SC_C's azimuthal shear intensified, but unlike SC_A and SC_B, a short-lived decrease in azimuthal shear was observed around 15 minutes prior to the merger, followed by a rapid increase again before the storms merge (Figure 3c).

5. SUMMARY

Overall, all three supercells share similar trends in structure and intensity as seen on radar, but also have their differences. Each supercell was observed at various locations along the squall line and were in different stages of their lifecycles when they merged. Based on KDDC radar reflectivity, the long-lived supercells (SC_A and SC_B) tended to fluctuate in echo size and intensity, while the short-lived supercell (SC_C) had a steady strengthening trend as the squall line approached. One trend that is observed in all three supercells relates to azimuthal shear initially decreasing as the squall line approached, but then increasing immediately prior to the merger (Figure 3a-c). Echo top time series for SC_B and SC_C showed a general strengthening trend, while SC_A showed a weakening trend (Figure 4a-c).

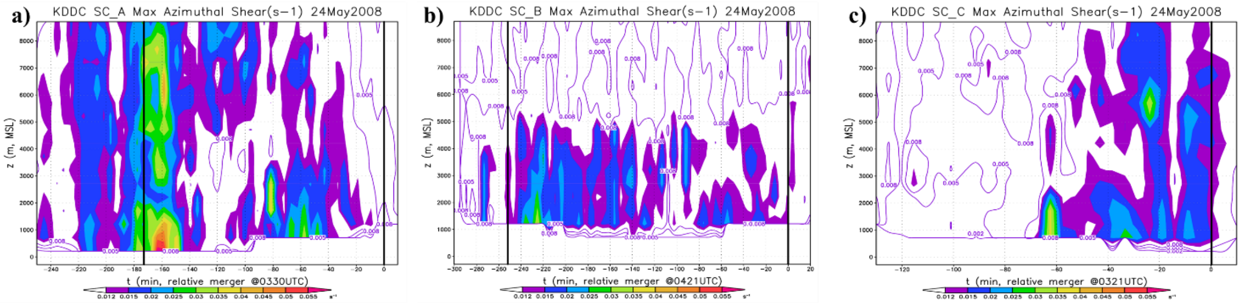

Figure 3: Time vs. height plots of maximum azimuthal shear (s^{-1}) associated with 24 May 2008 isolated supercells for (a) Supercell A, (b) Supercell B, and (c) Supercell C. Time (min) is relative to the supercell merging with the squall line with the line at t=0 indicating the merger for each supercell at (a) 0330UTC, (b) 0321UTC, and (c) 0421UTC. The lines at (a,) t= -166 and (b) t= -254 denotes the formation of the squall line by 0044UTC.

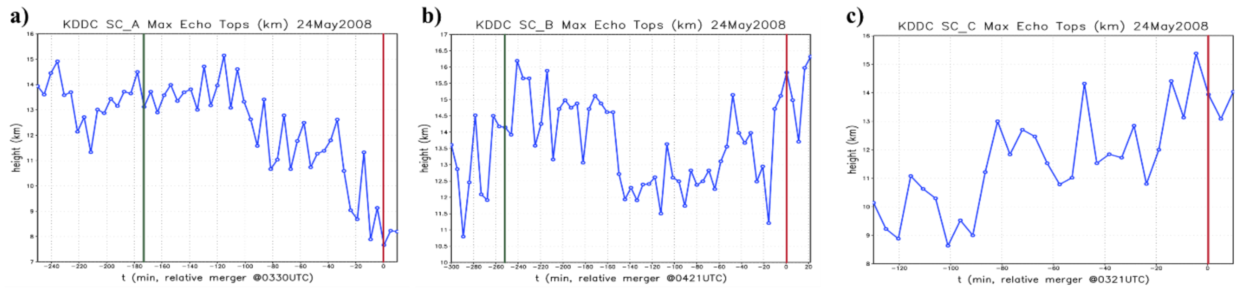

Figure 4: Time series of maximum 50 dBZ echo tops for 24 May 2008 (a) Supercell A, (b) Supercell B, and (c) Supercell C. Time is in a merger relative framework as in Figure 4.

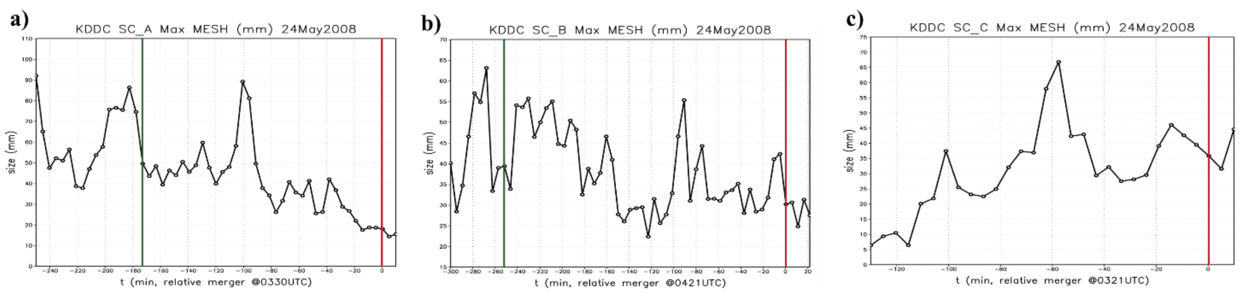

Figure 5: Time series of maximum value of maximum estimated size of hail (MESH, mm) associated with 24 May 2008 (a) Supercell A, (b) Supercell B, and (c) Supercell C. Time is in a merger relative framework as in Figure 4

SC_A and SC_C MESH time series share similar trends to the corresponding echo top time series, except for supercell B, where the MESH has a noticeable decreasing trend (Figure 5a-c). These preliminary results suggest that the presence of a nearby squall line may be sufficient to alter supercell structure and intensity.

Although the squall line may have played a role in the supercell's evolution, other environmental factors may also have had an effect on the supercells. Some influences from other isolated convection ahead of the squall line may have an impact, including restricting the availability of high CAPE inflow air. Other environmental changes, such as the developing low-level jet or diurnal effects on static stability could also have played a role in the supercells' evolution. Finally, errors involving the radar, such as attenuation from when the squall line passes over the radar, can impact the radar analysis of each supercell. With a variety of environmental influences present at the time of the 23 May 2008 event, the squall line may not have been the only influence on the supercells' evolution. Further analysis on more cases is necessary to obtain more information on the generality of these results.

6. Future Work

The results of this analysis will help to better define a conceptual model of how these two storm types interact when in close proximity, and provide observation-based "ground truth" with which to evaluate on-going numerical model simulations of similar interactions (Wipf 2014; French 2015). The analysis framework established in this paper will be implemented on other supercell and squall line cases, with different storm attributes and background environments in order to identify common features in the structural evolution of supercells. The variety of cases will help categorize the different types of events based on how many supercell thunderstorms are present and type of quasi-linear convection system (i.e. bow echo, derecho, cold front, etc.) More recent cases from 2013-2015 will be utilized to eventually incorporate the use of dual-polarization radar products. Ultimately, the combined results of these projects are intended to aid in the development of future forecasting techniques to help enhance severe weather warnings during these types of complex weather events.

Acknowledgments

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