P15R.10 OBSERVATIONS OF SUPERCELL MERGER AND TORNADOGENESIS FROM MAY 4, 2003

William T. Gilmore * and Neil I. Fox
University of Missouri - Columbia,
Columbia, Missouri

1. Background

On May 4, 2003, a record outbreak of tornadic supercells struck portions of the central United States. In Missouri alone, 38 tornadoes were documented, setting not only a new single day record, but a new monthly record of tornadoes. Approximately $270 million in damage was reported with 160 injuries and 19 fatalities.

An interesting feature of this outbreak was the evolution, interaction and merger of cells that produced a tornado in Southwest Missouri that devastated the town of Pierce City. A similar scenario occurred just hours earlier in northern Kansas City. These events present scientific questions about tornadogenesis that are not well studied. Does the merging of supercells cause tornadogenesis? Does the interaction between merging supercells produce stronger, longer-lived tornadoes than a single storm? This research will compare two instances where powerful, long-lived tornadoes developed following the merger of two separate supercells. The research will also investigate what relationship exists between cell mergers and supercell intensification and the timing of tornadogenesis.

Why did the two supercell thunderstorms of interest have two completely different velocities? The answer to this question is found in a hodograph or vertical wind profile. When the vertical wind profile is plotted and the result is a straight-line hodograph, mirror-image, left and right moving supercell thunderstorms are possible (Weisman and Klemp, 1986). Also, the left-moving cell typically has a higher speed than its right-moving counterpart. Observed vertical wind profiles on the day of interest, from Springfield, Missouri (KSGF) National Weather Service (NWS) Forecast Office, resemble a straight-line hodograph. This explains the different velocities associated with the two cells.

There does appear to be a relationship between tornadogenesis via squall line and supercell interaction (Goodman and Knupp, 1993), but the exact correlation between two supercells is relatively unknown. The idea of this study was to investigate whether the merger of two supercells intensifies rotation, and increases the dynamics and energy of a storm. Also to see if the changes that occur during mergers enhance tornadogenesis.

2. Procedure

WSR-88D radar data from the Tulsa, Oklahoma (KINX) and KSGF NWS Forecast Offices on May 4th was analyzed. By using WATADS radar data analyzing software, it was possible to quantify increases and/or decreases in thunderstorm intensity and rotation, before, during, and after the supercell thunderstorm merger associated with the Pierce City tornado using the metrics described below.

Specifically, WATADS NSSL cell, mesocyclone, and tornado algorithm output was analyzed. After the initial analysis, it was determined that the cell algorithm output was neglected because the data was too broad, not depicting smaller scale features of interest. The tornado algorithm output was also neglected because the data was too sparse. In addition, only mesocyclone algorithm output calculated for mesocyclones located in the southwestern, rear flank of the northern thunderstorm were used. This location was chosen since this is the most favorable location for tornadogenesis in right-moving, severe thunderstorms in the northern hemisphere (Rotunno 1986). Max Gate to Gate (MX GTG) shear was analyzed in this case. MX GTG shear is the maximum velocity differential between data points on the Doppler radar display. The larger the difference of velocities between data points, the larger the MX GTG shear. The larger the MX GTG shear, the more intense is the circulation associated with the mesocyclone.

3. Results

The Doppler radar analysis showed increased intensity and rotation of the main cell prior to the merger

**Corresponding author address* William T. Gilmore, Univ. of Missouri, Department of Soil, Environmental, and Atmospheric Sciences, Columbia, MO 65211; e-mail: wtgkb8@mizzou.edu

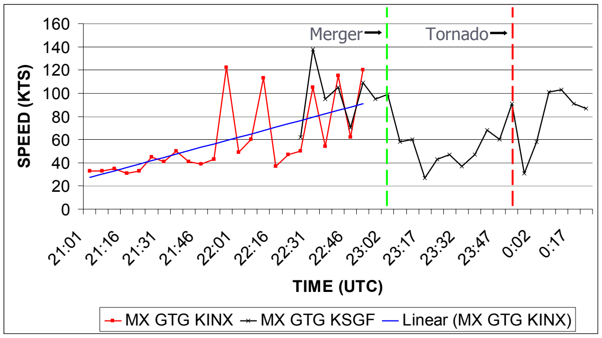

Figure 1. Graph of MX GTG shear from 21:01 UTC on May 4 to 00:27 UTC on May 5, 2003. Also plotted are the timestamps of the collision of the thunderstorms and the time of the powerful tornado. A trend line showing a gradual increase in GTG velocity difference slope prior to the merger is plotted in blue.

as shown in Fig. 1, and a very intense resulting thunderstorm with very strong rotation signatures. Increasing radar reflectivity values and Doppler velocity differentials are indicative of increasing strength and rotation. In this case, the intensity of the cell decreased slightly during the merger. This can be deduced from the high resolution satellite images gathered from AWIPS. A more pronounced overshooting top, shown in Fig. 2, was seen prior to merger. This is directly related to the strength of the storm's updraft. During the merger, the overshooting top appears to collapse somewhat as seen in Fig. 3, indicating a decrease in intensity. These storm strength fluctuations can be explained by a change in updraft strength. A simple conceptual model can be posited as to how the outflow of one storm can influence the updraft of warm, moist air into another developed storm. The increase of vorticity caused by storm interactions with boundaries has been shown to affect tornadic development in both observations (e.g. Markowski et al. 1998) and modeling studies (e.g. Atkins et al. 1999).

The outflow in this case is evident in the radar images shown in Fig. 4. The additional development is depicted by the enhanced reflectivity just north of the southern storm. A cross-section through the cells along the line in Fig. 4 gives a more detailed view of the reflectivity enhancement in Fig. 5. This enhanced precipitation shows the presence of an outflow boundary, forcing warm, moist air vertically, resulting in additional precipitation ahead of the southern storm.

A comparison of these results with a case from the Kansas City area on the same day revealed similar results. Doppler radar data showed increased circulation in the northern storm prior to the merger, then a slight weakening during the merger. However, the Kansas City case involved strong tornadoes throughout the time of interest, whereas the Pierce City case only involved a weak tornado at the time of merger that quickly dissipated. It was after 35 minutes that the deadly tornado touched down west of Pierce City.

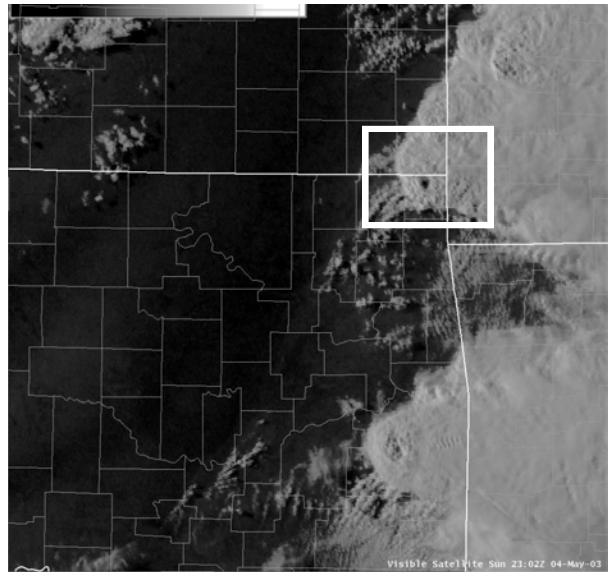

Figure 2. High resolution visible satellite image taken at 23:02 UTC on May 4, 2003. A very pronounced overshooting top can be seen in the center of the white box. This is evidence of a strengthening updraft just prior to the merger.

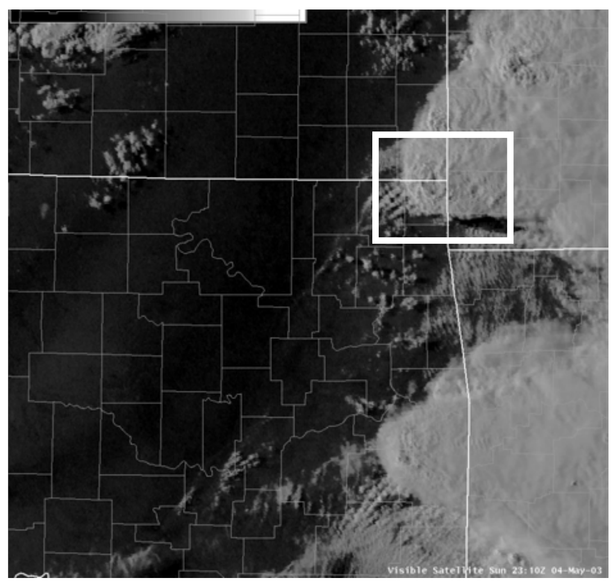

Figure 3. This image is a high resolution satellite image taken at 23:10 UTC May 4, 2003. Notice that the pronounced overshooting top visible in Fig. 2 is not present in the center of the white box. This is one signature of a weakening thunderstorm.

4. Summary and Conclusions

It is concluded that it was not the collision of the two supercell thunderstorms that enhanced the northern storm's strength and rotation, but actually the events leading up to the merger. Doppler radar data showed that the circulation intensified prior to the collision, then decreased during the collision. An outflow boundary from the southern storm shown in Fig. 4 appears to have increased the inflow of the warm, moist air necessary for thunderstorm development. Another aspect to note was the increased low-level shear present as the inflow changed from a southeasterly direction to a more easterly component. The effect of boundaries or convergence zones enhancing supercells leading to increased intensity and rotation is well known (e.g. Sills et al. 2004; Wilson and Schreiber 1986; Wilson and Megenhardt 1997). However the differentiation of the effects of the outflow boundary and cell merger is less well documented.

The weakening of the northern storm during the merger may have been caused by a lack of warm, moist inflow as the southern storm blocked the primary source for warm, moist, unstable air. At this time, the only explanation for intensity of the resultant thunderstorm is the storm was propagating into an extremely unstable, favorably sheared environment. Further research is necessary to better understand the microscale dynamics and thermodynamics during the merger of two separate supercell thunderstorms.

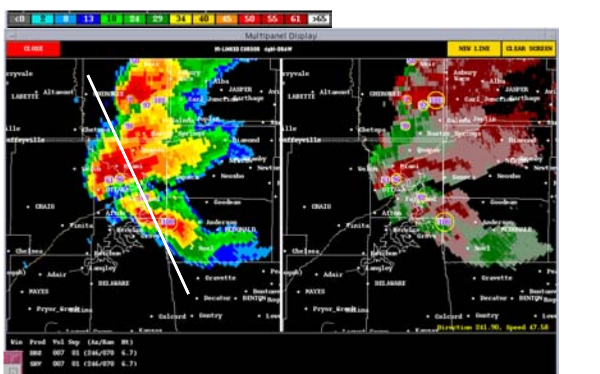

Figure 4. Reflectivity, on the left, and Doppler storm relative velocity data, on the right, at 22:57 UTC on May 4, 2003. At this time, there was an additional high reflectivity area on the northern edge of the southern storm. This denotes the location of the outflow boundary. The white line signifies the location of the cross-section shown in Fig. 5 below.

5. Continuing Research

Future research may include a more in depth Doppler velocity analysis of the storms using a compilation of multiple Doppler radar data sets. An interesting observation made was there were multiple examples of merging and splitting supercells that lead to violent tornadoes this specific day. Comparisons of these results with the many other similar events that have occurred that day, as well as new cases recently observed are planned.

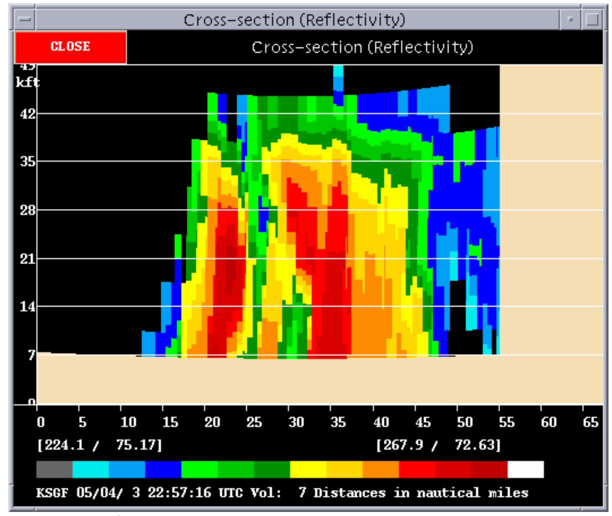

Figure 5. Cross-section along the white line in Fig. 4 above from South to North. The southern storm is located on the left, with the northern storm on the right. The enhanced reflectivity region between the two storms is strong evidence of an outflow boundary causing warm, moist air to ascend.

6. Acknowledgements

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