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THE TORNADIC SUPERCELL OF 8 APRIL 1998 ACROSS ALABAMA AND GEORGIA

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1. INTRODUCTION

During the early evening hours of 8 April 1998, a supercell formed within a line of thunderstorms over east-central Mississippi. This thunderstorm became tornadic shortly after moving east into Alabama. Although several supercells affected the states of Mississippi, Alabama, and Georgia with a variety of wind and hail damage on this particular day, it was this lone supercell that produced a family of six tornadoes across north-central Alabama and northwest Georgia (see Fig. 1). Thirty-four people were killed by the Alabama tornadoes, and there was one tornado-related fatality in northwest Georgia. Parts of western Jefferson County, AL, just west of Birmingham, were hardest hit as an F5 tornado struck the area between 7:52 and 8:28 PM CDT, and resulted in 32 fatalities and 258 injuries. More than 1,100 permanent homes were destroyed by the Jefferson County tornado.

This study focuses on three elements: a mesoscale boundary that the supercell traveled along as it traversed to the east; a northward moving radar-detected boundary that merged with the supercell over western Jefferson County; and the dramatic evolutions of the supercell as depicted in the radar reflectivity data. The supercell produced damage over a five-hour period.

2. SYNOPTIC PATTERN

An unstable and highly sheared environment was in place over the Deep South on 8 April 1998. The southern stream of the westerlies was very active, as an upper-level cyclonic vortex over Iowa moved northeast over southern Minnesota during the day on the 8th. The associated, trailing short-wave trough to the southwest moved east from western Texas to eastern Texas during the same time period. Wind speeds in the upper-level (200-300 mb) southwest flow were in excess of 62 m s^{-1} (120 kt) over north-central Texas on the evening of the 7th, and these strong wind speeds propagated over the lower Mississippi Valley by the evening of the 8th. Strong frontogenesis was evident in the mid troposphere (700-500 mb) over the southern plains during the morning of the 8th and progressed eastward over the lower Mississippi Valley by evening. Upper-air data depicted a "dry punch" in the southwest flow over south Louisiana to southwest Alabama by evening. In the boundary layer, a south wind was advecting warm, moist air northward from the Gulf of Mexico. Temperatures and dew points at 850 and 925 mb rose several degrees (°C) over the southeastern U.S. during the day on the 8th.

Upper-air soundings taken at the Shelby County Airport (BMX - Calera), about 50 km south of Birmingham, at 1200 and 1800 UTC on the 8th and 0000 UTC on the 9th (hereafter all times in UTC) indicated the air mass over Alabama became increasingly unstable during the day. The convective available potential energy (CAPE) was 1300 J kg^{-1} at 1800, and increased to 2370 J kg^{-1} at 0000. Very dry air above 700 mb resulted in a steep lapse rate between 700 and 300 mb (generally around 7.0 °C km^{-1}), and was indicative of the potential instability over the area. The 0-3 km storm-relative helicity values increased from 55 to 220 m^2 s^{-2} between 1800 and 0000. The 0000 Eta model run on the 9th analyzed 0-3 km helicity values of 360-440 m^2 s^{-2} over north Alabama. The 0-3 km vertical wind shear increased at BMX from 18 to 26 m s^{-1} (35 to 50 kt) between 1800 and 0000. The Storm Prediction Center outlooked a high risk of severe thunderstorms across the northern half of Mississippi, Alabama, and northwest Georgia.

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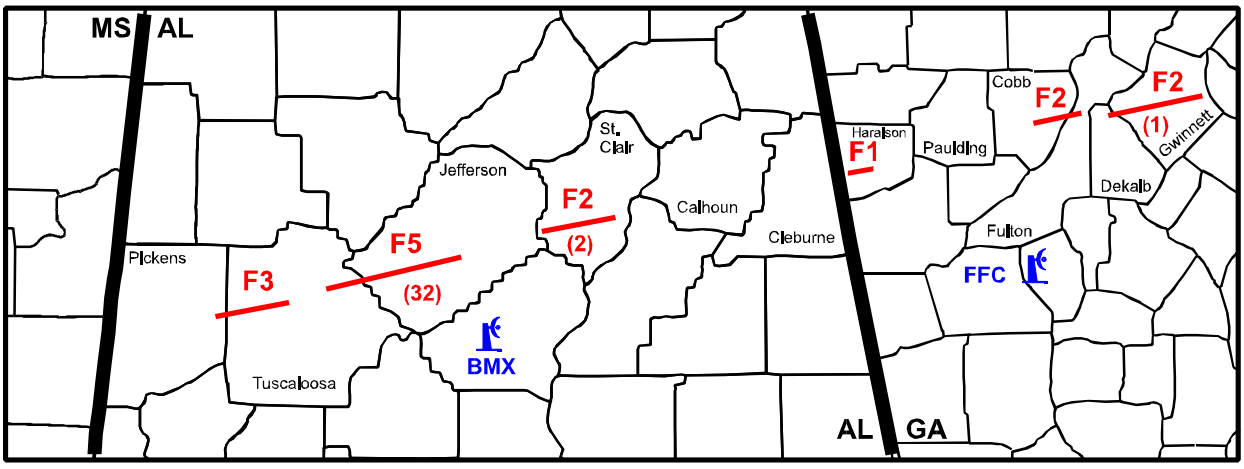

Fig. 1. Tornado tracks over north-central Alabama and northwest Georgia on 8 April 1998. F-scale intensities are plotted above tracks. Numbers in parenthesis are number of deaths. Location of BMX and FFC are plotted.

3. MESOSCALE FEATURES

During the predawn hours of 8 April 1998, surface temperatures and dew points were above 15 °C (60 °F) across the southeastern U.S. and above 21 °C (70 °F) along the immediate gulf coast. There were several surface reports of light rain and drizzle, especially near the gulf coast. Fog was also prevalent, with a few locations reporting a visibility less than 3 km. By 1600, showers and thunderstorms had developed over south Alabama and south Georgia. The main surface low was located over southwest Arkansas, with an associated cold front stretching southwest across eastern Texas. By 1800, surface dew points of at least 21 °C (70 °F) stretched from southeast Louisiana across south Mississippi to southwest and west-central Alabama. Extensive low cloudiness covered most of Mississippi, Alabama, and Georgia at this time. Temperatures were in the upper 20s °C (lower 80s °F) in those areas receiving plenty of solar radiation.

A surface dew point gradient became increasingly apparent during the afternoon along and northwest of a line from southwest Mississippi to north-central Alabama. Dew points immediately southeast of this line ranged from 20 to 23 °C (68 to 73 °F), while immediately northwest dew points ranged from 14 to 18 °C (58 to 64 °F). Visible satellite imagery depicted a concentrated area of cloudiness along this moisture gradient, and a short line of convection developed on this gradient over east-central Mississippi around 2200. The tornadic supercell of this study developed within this squall line. Several other boundaries, or lines of weak convection, over the area may have formed in response to differential heating along the edges of cloud fields.

At 2029, WSR-88D data depicted a southwest to northeast oriented line of weak reflectivity. This "fine line" may have originated with earlier severe thunderstorms that moved across all of southern Alabama. The fine line moved to the north at less than 10 m s^{-1} (20 kt). This radar-detected boundary was generally 8 to 16 km wide and was estimated to be 2.4 to 3.7 km deep. Figure 2 shows the locations of the boundary up until the time it merged with the eastward moving tornadic supercell over western Jefferson County. The fine line was about 50 km south of Birmingham as the supercell crossed the Mississippi-Alabama state line. Before the supercell and fine line merged, the supercell had produced tornado #1, and tornado #2 had been on the ground for approximately 18 km. Interestingly, tornado #2 was producing a narrow path of F0 damage prior to interacting with the fine line between 0053 and 0058. Coincident with the supercell and fine line merger, the tornado widened dramatically to at least 1 km and damage immediately increased to at least F3 intensity.

Shortly after this, the tornado became deadly over western Jefferson County. Population density increases over western Jefferson County as you approach Birmingham. As devastating as this killer tornado was, it was fortunate the tornado dissipated when it did since it was on a course to cross portions of downtown Birmingham and the Birmingham International Airport. The core of the supercell and its mesocyclone did pass over the Birmingham International Airport at 0137. The barograph at the airport registered a pressure fall of 3 mb in 30 minutes as the storm approached the airport. After storm passage, pressure rose 5 mb during the ensuing 8 minutes. A special surface observation at the Birmingham International Airport reported a wind gust of only 10 m s^{-1} (20 kt) as the mesocyclone passed overhead.

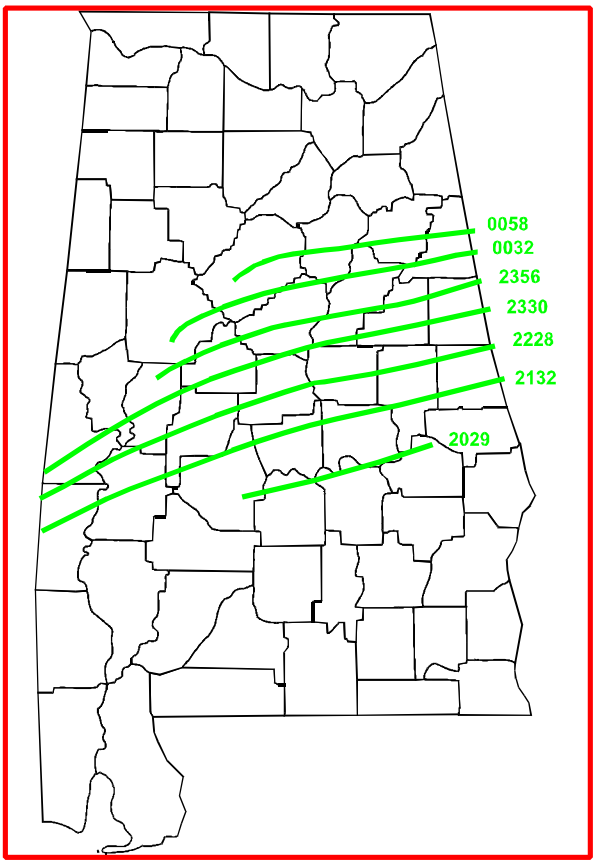

Fig. 2. Isochrones of radar-detected boundary, or fine line, in UTC.

4. SUPERCELL EVOLUTION

4.1 *Tornado #1 - HP Supercell*

At 2300 on 8 April 1998, a southwest to northeast line of thunderstorms developed between Jackson and Meridian, MS, and extended northeast to just northwest of Tuscaloosa, AL. Embedded in the center of this squall line, the thunderstorm took on the appearance of an HP supercell (Doswell et al., 1990) as it crossed the Alabama state line around 2320. The reflectivity core, with values greater than and equal to 50 dBZ, was concave to the southeast at the lowest two radar elevations. The storm's reflectivity tilted to the southeast in the next three elevations creating a weak echo region (WER), indicative of a strong updraft on the southeast flank. A mesocyclone (M1 - see Fig. 3) was well developed at this time, with rotational velocities greater than 18.5 m s^{-1} (36 kt) from 5.5 to 10.4 km. At 2335, the inflow notch at the lowest elevation (2.4 km) became very pronounced. Furthermore, the area of reflectivity greater than 55 dBZ

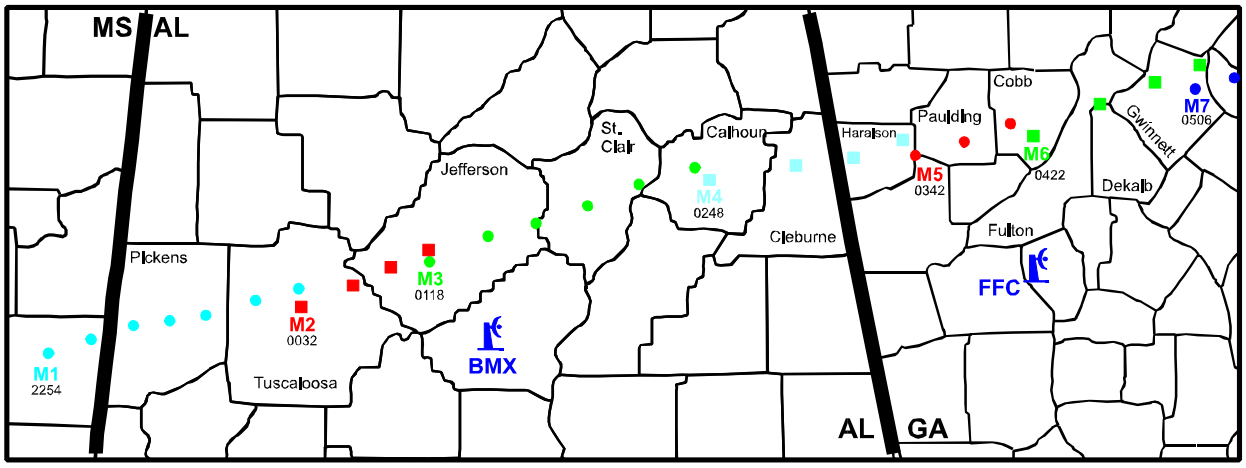

Fig. 3. Tracks of mesocyclones (M1-M7). Beginning times in UTC and 15-minute interval positions are plotted.

increased significantly from 4.8 to 6.9 km immediately above the inflow notch, indicative of strengthening updrafts.

A rear-inflow notch, possibly associated with a rear-flank downdraft (RFD), was evident in the reflectivity data at 2345. The diameter of the associated mesocyclone appeared to shrink from roughly 9 km to 6 km. Tornado #1 began in eastern Pickens County at 0001 and lifted at 0029 over north Tuscaloosa County. The reflectivity data depicted a broad pendant to the immediate west of the mesocyclone over eastern Pickens County at 0001. According to the mesocyclone nomogram (Operational Support Facility, 1995), the mesocyclone increased from moderate to strong intensity between 0001 and 0006. At 0012, the rotational velocity increased to greater than 26 m s^{-1} (50 kt) at 1.6 km, and exhibited a cyclonic convergent pattern. By 0022, the pendant and inflow notch were not nearly as obvious in the reflectivity data.

4.2 *Tornado #2 - Classic Supercell*

At 0032, tornado #1 had already dissipated and the supercell started to show a new inflow notch and pendant in the reflectivity data. By 0037, a pronounced hook was evident from 1.2 to 2.4 km in the lowest two radar elevations. A bounded weak echo region (BWER) was present at 4.2 km. It became obvious by 0042 that the supercell had evolved into a classic configuration in the reflectivity data with a hook evident at the lowest three elevations and a BWER at the fourth elevation. The BWER was located directly over the area of weak reflectivity northeast of the hook. KBMX WSR-88D detected a tornado vortex signature (TVS) at the completion of this radar volume scan. Tornado #2 began over northeast Tuscaloosa County at this time and was on the ground for the next 46 minutes as it tracked into western Jefferson County. The thunderstorm continued to look like a textbook, classic supercell in the reflectivity data through 0113. At 0058, the BWER at 4.3 km was composed of a ring of 50 dBZ surrounding a weak reflectivity hole of 20 dBZ. A core of 62 dBZ at 9.4 km was located almost directly above the BWER. The strong mesocyclone (M2) was "maxed out" at this time, with rotational velocities greater than 28 m s^{-1} (55 kt) through the radar's lowest six elevations (0.6 to 5.5 km). The hook had virtually wrapped completely up, and the BWER was visible down to a height of 1.6 km by 0108. A well-defined inflow notch developed at 0113. At 0118, the inflow notch was quite evident, and another mesocyclone (M3) had formed to the southeast. This deadly tornado finally dissipated at 0128, after being on the ground for just under 50 km and 46 minutes.

4.3 *Tornado #3 - HP Supercell with a Bowing Pendant*

The reflectivity data at 0129 still looked very impressive, with a very large inflow notch and a BWER at 3.9 km. The supercell appeared to be transforming back to an HP. As the supercell approached St. Clair County at 0144, the 0.5° reflectivity data showed few pixels of 50 dBZ. The supercell still had a well-defined inflow notch on the southeast flank, and a rear-inflow notch on the southwest flank. M3 contained strong rotational velocities of greater than 21 m s^{-1} (40 kts) through the lowest 3 km. At 0154, a pendant to the south of the core of the storm bowed out to the east. M3 was located within the bowing pendant, and at 0156 tornado #3 touched down over southwest St. Clair County at the apex of the bow. The reflectivity data at 0205 indicated the most intense part of the supercell was the bowing pendant, not the so-called core of the thunderstorm. The bowing pendant was not evident at 0215, but the tightest reflectivity gradient was on the back side of the storm. Tornado #3 lifted at 0215.

The supercell continued east-northeast across the two remaining Alabama counties (Calhoun and Cleburne) and produced no more known severe weather damage. The storm looked chaotic in the reflectivity data as it exited St. Clair County. Its areal coverage encompassed almost three counties, and it didn't have a tight reflectivity gradient on any flanks. It had a very round shape to it. M3 weakened over Calhoun County, while the fourth mesocyclone (M4) formed over southern Calhoun County. The supercell was becoming better organized again at this time. The strongest updraft appeared to be on the back, or west side, of the supercell at 0243 over Calhoun County in concert with the tightest reflectivity gradient.

4.4 *Tornado #4 - HP Supercell*

The supercell bowed to the east as it moved across eastern Cleburne County. A significant rear-inflow notch was depicted in the reflectivity data at 0308. M4 intensified on the south flank of the supercell over extreme eastern Cleburne County, and the rotational velocity increased to 21 m s^{-1} (40 kts) at 4.5 km at 0317. The southern flank of the storm crossed into Haralson County, GA, during the 0322 volume scan. KFFC WSR-88D (Peachtree City) detected a weak inflow notch, and a rotational velocity of 21 m s^{-1} (40 kt) at 1.4 km and greater than 23 m s^{-1} (45 kt) at 2.9 km over west-central Haralson County at this time. Tornado #4 began around 0322 and was on the ground for 6 km. The supercell had a linear shape to it and was oriented from the southwest to the northeast. Several weak bands of precipitation were moving northward across northern Georgia. One of these bands appeared to merge with the southern flank of the supercell at the time of tornado #4. The associated mesocyclone weakened rapidly over eastern Haralson County. The fifth mesocyclone (M5) developed at this point and traversed Paulding County before it weakened over Cobb County.

4.5 *Tornado #5 - HP Supercell*

Another mesocyclone (M6) formed rapidly over central Cobb County, as the rotational velocity at the lowest elevation was greater than 26 m s^{-1} (50 kt) at 0417. The reflectivity data depicted a well-defined inflow notch on the southeast flank, while a rear-inflow notch was also apparent at this time. The 3.4° reflectivity product (4 km) depicted greater than 55 dBZ echoes directly over the low-level inflow notch (WER). The rear-inflow notch appeared to be associated with a rear-flank downdraft, as the trailing pendant was bowing to the east. Tornado #5 dropped to the ground at 0420 over eastern Cobb County and was on the ground for 5 km. It tracked into northern Fulton County before lifting. A band of weak convection appeared to merge with the supercell over southern Cobb County at the time of the tornado.

4.6 *Tornado #6 - HP Supercell*

The final tornado in the family of six tornadoes associated with this killer supercell developed rapidly after tornado #5 dissipated. It touched down at 0435 over northern Dekalb County and tracked 31 km well into Gwinnett County. The 0436 scan from KFFC depicted a rotational velocity of greater than 26 m s^{-1} (50 kt) at 1.2 and 2.4 km. Once more, another band of weak convection merged with the southern flank of the supercell near the time of the beginning of the tornado. This F2 tornado resulted in the lone tornado-related fatality across north Georgia during this event. A seventh mesocyclone (M7) developed on the south flank of the supercell by 0506.

5. SUMMARY AND CONCLUSIONS

The tornadic supercell of 8 April 1998 produced six tornadoes; three over north Alabama and three over northwest Georgia. The long-lived supercell had HP characteristics for most of its lifetime. The major exception was when it became “classic” over northeast Tuscaloosa and western Jefferson counties. Similar to the HP supercell studied by Glass and Przybylinski (1998), this supercell went through rapid and often complex evolutions. These complexities of HP supercells have been documented and stressed previously (Moller, et al., 1990) and must be understood by warning meteorologists. Visual characteristics in the reflectivity depictions of the supercell varied substantially with each of the six tornado occurrences. The WSR-88D network performed well depicting velocity couplets and tornado potential throughout the life cycle of the supercell.

The supercell developed and propagated along a pre-existing boundary. This boundary was evident in the visible satellite imagery and produced a moisture gradient in the surface observational data. Four of the six tornado occurrences appeared to coincide with mergers between the supercell and radar detectable “fine lines” or bands of weak convection. The most noteworthy merger took place over western Jefferson County between 0053 and 0058. The classic-looking supercell was producing F0 damage prior to interacting with a northward bound fine line. To the best of our knowledge, limited by the temporal and spatial resolution of the data at our disposal, the tornado widened significantly and began to produce F3 to F5 intensity damage upon and after the interaction of the supercell and the fine line.

6. ACKNOWLEDGEMENTS

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