16B.8. THE SEVERE WEATHER OUTBREAK OF 10 NOVEMBER 2002: LIGHTNING AND RADAR ANALYSIS OF STORMS IN THE DEEP SOUTH

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1. INTRODUCTION

On the afternoon and evening of 10 November 2002, a major severe weather outbreak unfolded from Ohio and Pennsylvania southward through Mississippi, Alabama and Georgia. By the end of the event, some 80 tornadoes had been reported, the strongest being an F4 at Van Wert, OH. The NCDC publication *Storm Data* indicates 33 tornadoes from storms occurring in Tennessee, Mississippi, Alabama and Georgia, some of which were long-track F3s. These storms caused 26 deaths and 154 injuries. Hail up to baseball size was noted with some of the storms in Tennessee, and, because of echo training, more than 6" of rain fell locally there. Most of these storms were observed with National Weather Service (NWS) WSR-88D Doppler radars, and many passed near enough to Huntsville, Alabama, so that their lightning activity could be documented in detail with the North Alabama Lightning Mapping Array (LMA). This paper's purpose is to use LMA and WSR-88D data to describe the characteristics of this outbreak.

2. METHODOLOGY

The LMA consists of 10 stations distributed around Huntsville. These sites detect the radio-frequency radiation emitted by many of the individual segments of propagating lightning channels, and record their power and arrival time. By comparing arrival times among sites, the time and three-dimensional location of each source may be computed (Rison et al. 1999; Krehbiel et al. 2000). Later, after the raw source data have been compiled, a separate algorithm clusters the sources in both time and space to assign distinct flash numbers to each clustered collection of sources. Although the LMA network's ability to detect sources decreases with range, most flashes produce enough sources so that flash counts retain physical accuracy out to ranges beyond 200 km (Williams et al. 1999). However, because of radial position errors in source location that increase quadratically with range from the network (Koshak et al. 2004), we limit our analysis of the spatial structure of individual storms to ranges of 160 km or less. On 10 November 2002, numerous severe storms passed within analysis range of the LMA, and we have selected several of the most significant storms for detailed lightning and radar analysis. In this analysis, we also employ cloud-to-ground (CG) lightning data from the National Lightning Detection Network (NLDN, Cummins et al. 1998). In all analyses of NLDN CG data, we neglect all positive polarity CGs having peak currents less than 10 kA; such weak positive CG flashes have a high probability of being misidentified intracloud events.

The storms were well observed by WSR-88D radars, so we also examine radar data from Nashville, Tennessee (KOHX), Hytop, Alabama (KHTX), Columbus, Mississippi (KGWX), and Birmingham, Alabama (KBMX) to provide reflectivity and velocity structure data for comparison with the LMA data. In addition, regional radar mosaics provided by WSI Corporation were also used to follow the large-scale evolution of the outbreak, and to help assign severe weather reports to the echoes responsible for them. We also consult available surface and upper air data to characterize the environment in which the storms formed.

3. RESULTS AND DISCUSSION

The environment on 10 November was characterized by a broad, eastward-moving trough over the central United States, with jetstream flow of more than 60 m s^{-1} approaching Tennessee during the afternoon. At the surface, strong southerly flow had imported record-breaking warmth and high levels of humidity, with afternoon highs reaching 28C at Huntsville, and dewpoints exceeding 20C at some reporting stations. A strong capping inversion near 700 hPa suppressed active convection in the Deep South portion of the warm sector of the associated surface cyclone until late afternoon. Eventually, the cap was overcome, and storms developed in an environment having convective available potential energy (CAPE) in excess of 2000 J kg^{-1}. The first of the many isolated prefrontal supercells developed south of Nashville around 2100 UTC, followed shortly thereafter by a series of new supercells in far southern Tennessee. All these storms rapidly acquired severe character and raced quickly east-northeastward at 26 m s^{-1}, producing numerous tornadoes after sunset in the hills of eastern Tennessee. Meanwhile, other lines of prefrontal supercells developed near sunset in north central Mississippi, and moved at 22 m s^{-1} toward Alabama. The slightly slower forward speed of the southern storms is apparently associated with reduced jetstream-level flow there. All told, we have found that the outbreak consisted of 18 primary prefrontal supercells (many had multiple splits), some 13 of which were

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tornadic. In addition, a squall line with embedded supercells formed along the cold front, and triggered another two tornadoes.

Through study of composite radar imagery, we were able to assign all severe weather reports to the echoes of the various storms. A regional radar image from 0100 UTC 11 November 2002 (Fig. 1) shows the array of prefrontal supercells as they were reaching peak intensity. Cells are labelled with alphabetic characters for identification purposes. Cells B, D, E and G in Tennessee were all tornadic, with cells B, D, and E spawning killer tornadoes. Cells I, J, K, L and M were also tornadic, with I, J, and L spawning long-track killer tornadoes. Killer tornadoes from cells E and I are in progress at the time of this image. Fig. 2 provides a concise history of the severe weather produced by each cell in the main prefrontal cluster; 28 of the tornadoes are represented. It is evident that the Tennessee storms tended to split often, while the Mississippi-Alabama cells split at most once. In addition, none of the Tennessee tornadoes, in spite of their intensity, were long-track, while further south, cells I, J and L all produced long-track tornadoes. It is suspected that the frequent splitting of the northern storms is indicative of more rapid mesocyclone cycling, likely associated with the stronger vertical shear present in Tennessee, which prevented the northern cells from producing long-track tornadoes.

The time series of LMA-derived total lightning flash rates for cells D and I are given in Fig. 3 using a time resolution that matches the KHTX radar volume scan interval (roughly 5 min). Also plotted are NLDN-derived CG flash rates. Cell D, which was typical of the Tennessee supercells, featured peak total flash rates of approximately 100 min^{-1}, and CG rates of about 30% of that. There are significant fluctuations in total flash rate with this cell, with both CG and total flash rates beginning to increase 25-30 min before the 2345 UTC touchdown of a killer tornado west of Manchester, Tennessee. While increases in flash rate similar to those seen in Fig. 3 generally indicate a strengthening of the storm updraft, not all such updraft increases lead to tornadoes or other severe manifestations at the surface.

In addition to the significant temporal structure seen in the LMA data, there were also some interesting spatial structures. In Cell E, the total lightning data map (Fig. 4) for the 1.5-min period beginning at 0026 UTC shows a "hole" at the southwest end of the source cluster. Radar data provides collateral evidence that this hole marks the location of the storm's principal updraft. This hole was visible for approximately 10 min, and occurred roughly 15-25 min before the beginning phase of a killer F2 tornado.

Cell I also exhibits a sizable increase in total flash rates, from about 50 min^{-1} to more than 130 min^{-1} during the 30 min period prior to the touchdown of a long-track killer tornado several min before 0100 UTC. In this case, CG rates also increase rapidly, reaching more than 40 min^{-1}, but this increase provides virtually no advance warning of the impending tornado. This tornado achieves F3 strength and remains on the ground for some 53 min. Of special interest is the very large subsequent increase in lightning rates, particularly the total, and by inference, the intracloud rate, that occurs before 0300 UTC 11 November 2002. Study of the radar and lightning data reveals that this surge in lightning activity, which features total flash rates of more than 800 min^{-1}, occurs in conjunction with the merger of a daughter cell, formed along Cell I's southwest flank during the long-track tornado, with the main cell. The phenomenal flash rate achieved by Cell I during this merger process is larger than the largest flash rate reported in Florida tornadic supercells by Williams et al. (1999). Remarkably, it is not directly associated with any reports of tornado activity, but only a funnel cloud near 0246 UTC.

4. SUMMARY AND OUTLOOK

The LMA total lightning data provide an intriguing new dimension to the characterization of the storms in the major tornado outbreak of 10 November 2002. While many of the prefrontal supercells generated peak total flash rates of approximately 100 min^{-1}, one cell in Alabama produced a peak flash rate of more than 800 min^{-1}. This latter flash rate is the largest yet seen by the North Alabama LMA, but it is ironic that no tornado could be documented in association with it. In many other instances, tornadoes followed total lightning flash rate jumps, but the flash rates following the jumps were not so remarkable. In at least two storms, maps of lightning sources revealed the presence of lightning-void "holes," and these occurred during or just prior to observed tornadoes. Further observations are needed to expand the data sample size, in order to draw reliable conclusions about the statistical significance of these lightning signatures.

5. REFERENCES

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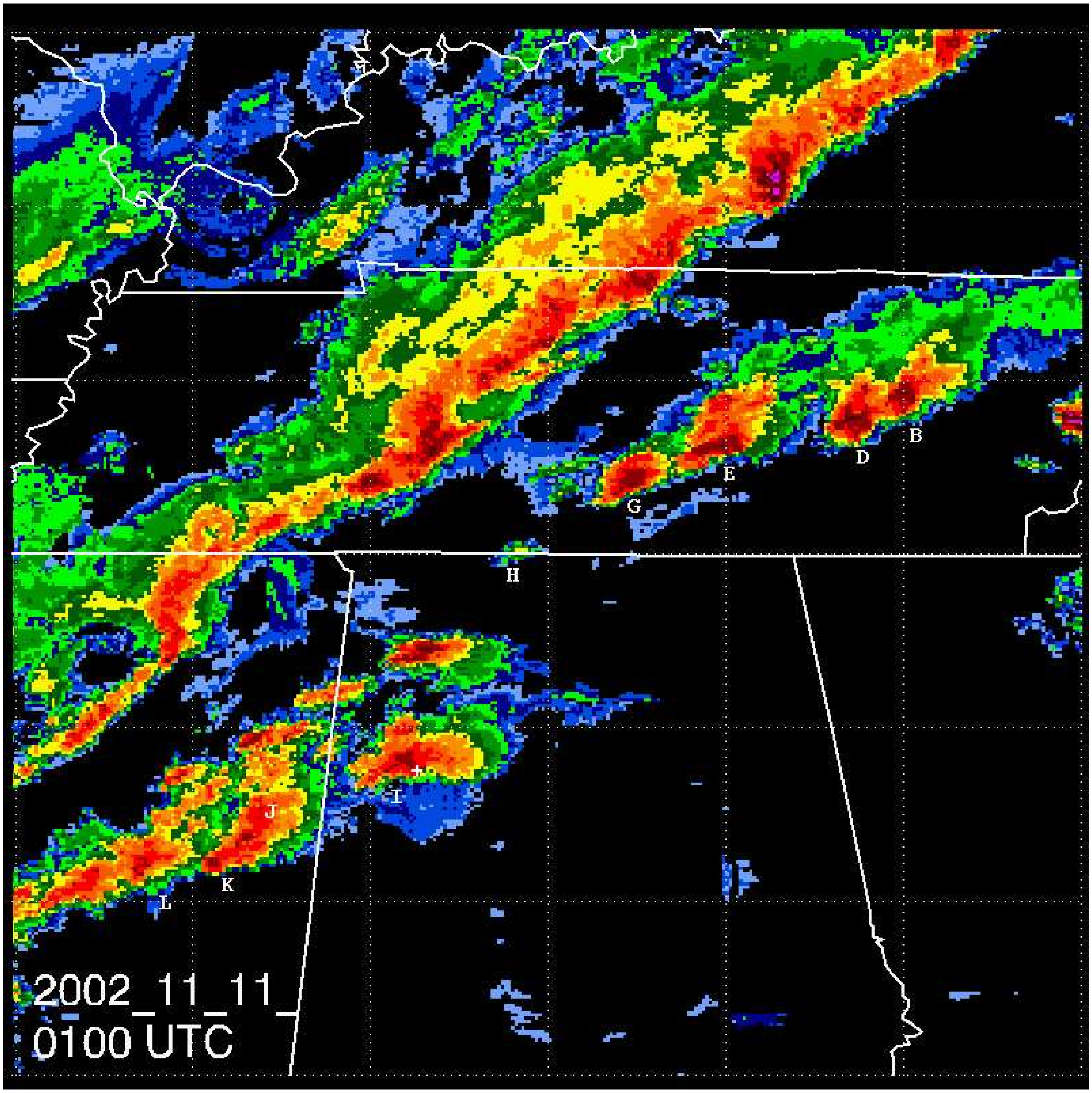

Fig. 1. Composite radar image of southern tornadic supercells at 0100 UTC 11 November 2002, provided by WSI NOWrad (TM). Cells are labelled on their southeastern flanks with alphabetic characters, as described in the text.

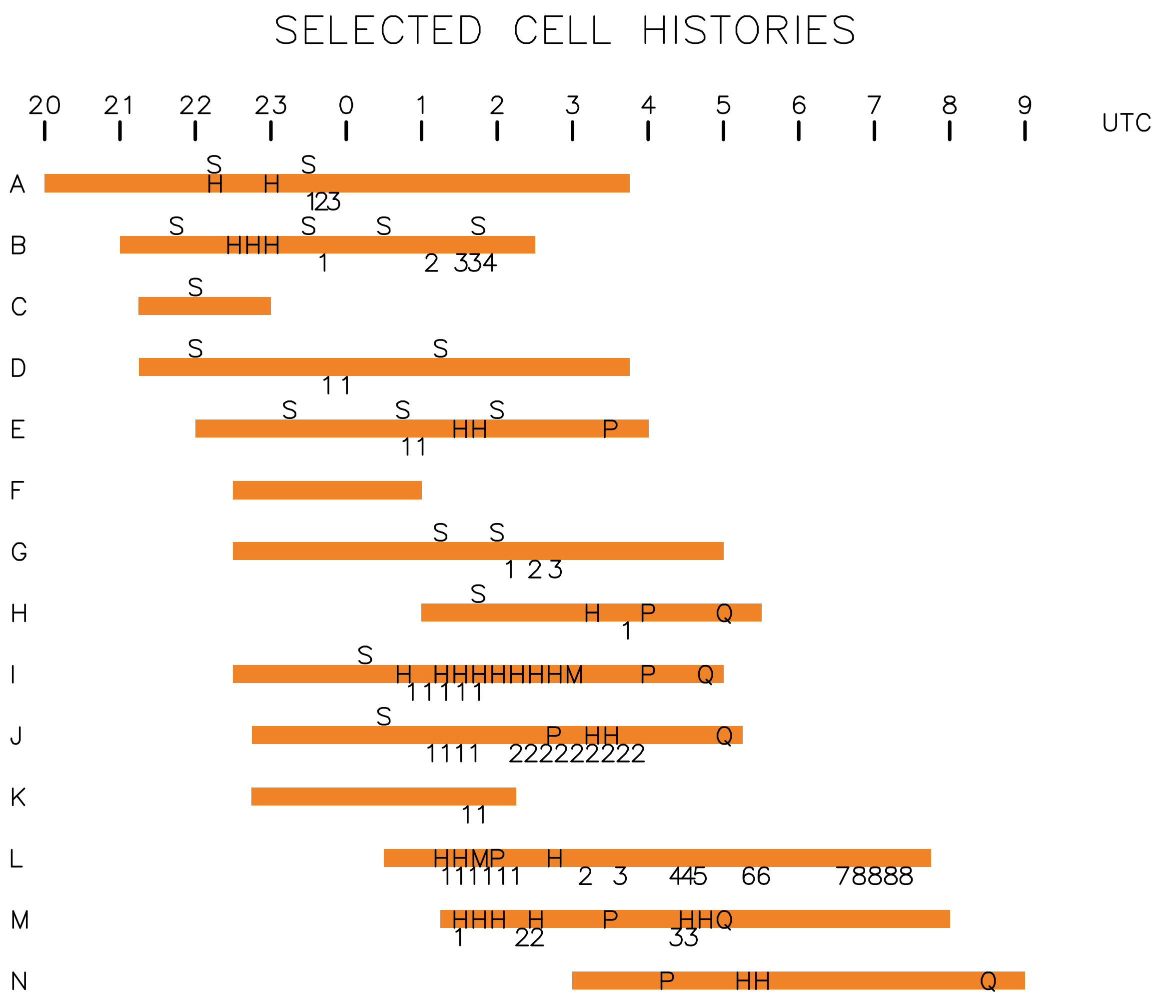

Fig. 2. Time histories of severe weather and other characteristics of the prefrontal tornadic storms comprising the Deep South portion of the 10 November 2002 outbreak. See Fig. 1 for locations of the cells. Cell IDs are listed at left, and tornado numbers are provided below each cell's time stripe. Above each cell stripe are indicators ("S") of times of radar-observed cell splits. Within each cell stripe are other indicators for features such as hook echoes ("H"), cell mergers ("M"), conversion to heavy-precipitation supercell morphology ("P"), and absorption by the frontal squall line ("Q").

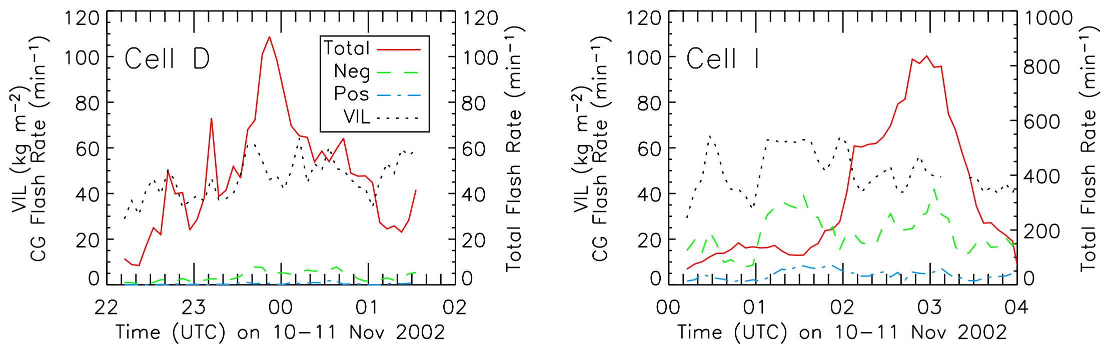

Fig. 3. Time series plots of lightning flash rates ("Neg" and "Pos" refer to polarity of CGs only) and KHTX-derived vertically integrated liquid (kg m^{-2}), from tornadic supercells D and I (see Figs. 1 and 2). Note that the total flash rate scales (right side of each plot) are different.

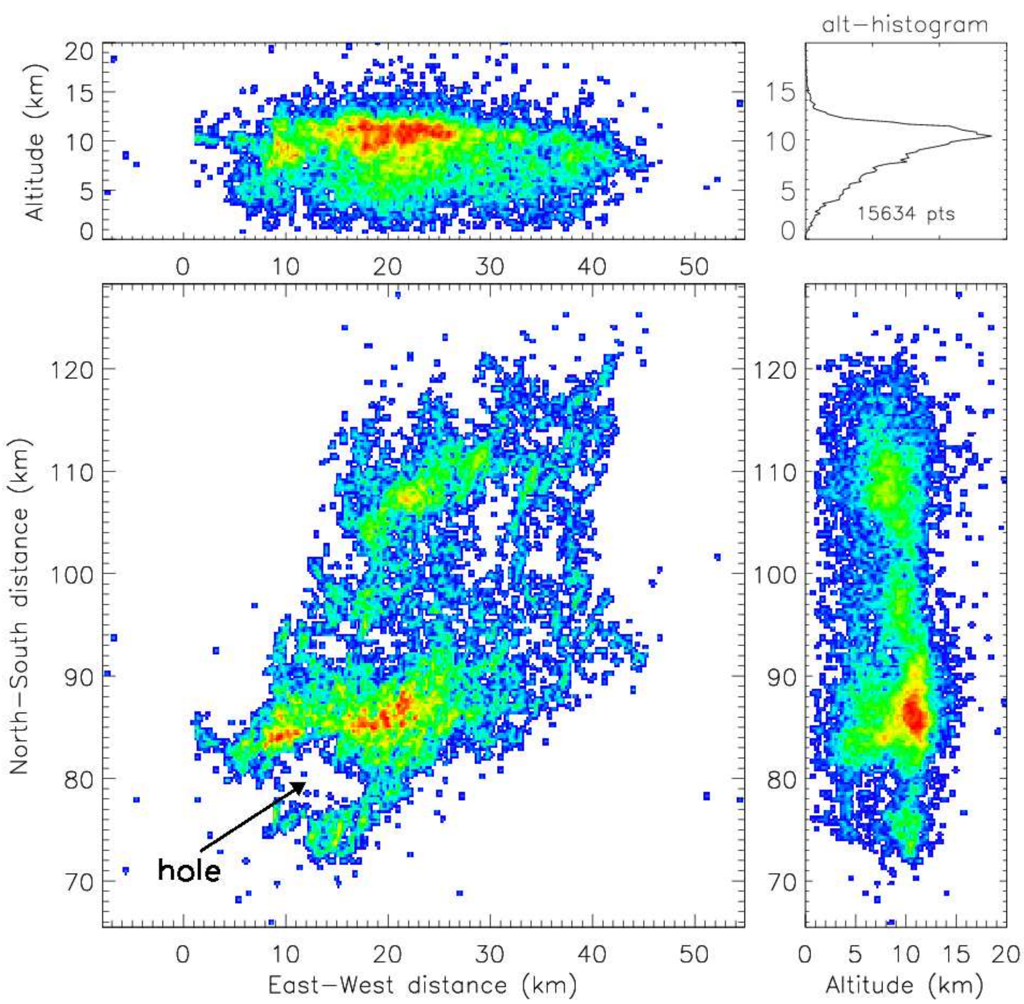

Fig. 4. Map, cross section projections, and altitude histogram of all LMA-detected sources in Cell E during 1.5-min period starting at 0026:00 UTC 11 November 2002. Note presence of lightning "hole" at southwest end of source cluster, near x = 12 km, y = 79 km. Source cluster near x = 22 km, y = 108 km, is associated with an earlier cell split.