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1. INTRODUCTION

On April 19, 1996, an outbreak of tornadic supercells struck portions of Illinois and adjacent states (Storm Data, 4/96). In Illinois alone, 36 tornadoes were documented, setting a single day record while additionally exceeding the average number of tornadoes for an entire year. An estimated \$30 million in damage was reported in 31 counties in Illinois with 1 fatality. Most of the tornadoes on this day were short-lived, but a few persisted for over 20 min and had damage paths of nearly 25 km with peak intensity rated at F3. To underscore the scope of this outbreak, Iowa, Indiana and Missouri reported 2, 13 and 5 tornadoes, respectively.

A fascinating aspect of this case involves the early evolution, interaction and merger of cells that initiated along the dry trough (Martin et al. 1995) just west of the Mississippi River in Missouri and the warm front that was located along a northwest-southeast line from southern Iowa to east central Illinois (Fig. 1). Radar analysis of this evolving convection presented in section 3 reveals a complex pattern of storm splits and mergers. Tornadic supercells simultaneously occurred along both fronts on this day. Of particular interest, from more than a dozen cells initiating along the dry trough in northeast Missouri and western Illinois, only 2 large long-lived supercells remained that tracked across central Illinois, spawning numerous tornadoes. We will investigate whether a relationship exists between cell mergers and supercell intensification and the timing of tornadogenesis. A companion presentation by the authors (P2.4) will present modeling results that address the role of the prominent boundaries on this day in terms of their local environment influence on storm intensity, structure and organization. It is hoped that studies such as this will better our understanding of thunderstorm interactions and local environment effects as they influence the evolution of supercell thunderstorms and related phenomena.

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2. SYNOPTIC ENVIRONMENT

The surface synoptic environment for 2100 UTC shown in Fig. 1 is dominated by an intensifying surface cyclone (992 mb) in southwest Iowa that is positioned under the left exit region of an approaching 65 m s^{-1} upper-level jet streak. The primary boundaries for storm initiation on this day were the warm front and dry trough. A tongue of dew points in excess of 18°C had advected northward on strong south-southeast winds in the morning and early afternoon hours in advance of the dry trough. In northeast Missouri the dry trough represents the leading edge of a 16°C drop in dew point. Moderate instability existed in the warm sector with 2300 J kg^{-1} of CAPE and an LI of -7°C at Lincoln, IL based on the 0000 UTC sounding. Strong 3 hr pressure falls of about 6 mb in western Illinois and northeast Missouri kept "backed" winds through mid-afternoon in the warm sector, sustaining strong vertical shear. The moderate instability, coupled with the strong low-level vertical shear and triggering presence of the major boundaries set the stage for a significant severe storm outbreak. Not shown on Fig. 1 is the presence of a cold front aloft that may have played a role in deep convection initiation. This additional factor is being studied by the authors.

Numerous storms initiated along both of these boundaries primarily between 2000 and 2100 UTC with the exception of a small cluster of storms that initiated about an hour earlier northeast of St. Louis, MO. This small cluster would gradually amalgamate to become the largest supercell of the day, travelling isolated down the warm front through eastern Illinois and across central Indiana. The first severe thunderstorm warnings were issued at about 2100 UTC.

3. RADAR ANALYSIS

To understand the supercell differentiation and organization processes active on this day, cells developing along or near the key boundaries were tracked and plotted in Fig. 2 using level 2 radar archive data from Davenport, IA, Lincoln, IL and St. Louis, MO. To construct this tracking map of peak reflectivity centroids, cells initiating between 2000 and 2250 UTC were plotted and tracked until 0100 UTC. Only cells that reached and maintained at least a reflectivity of 30

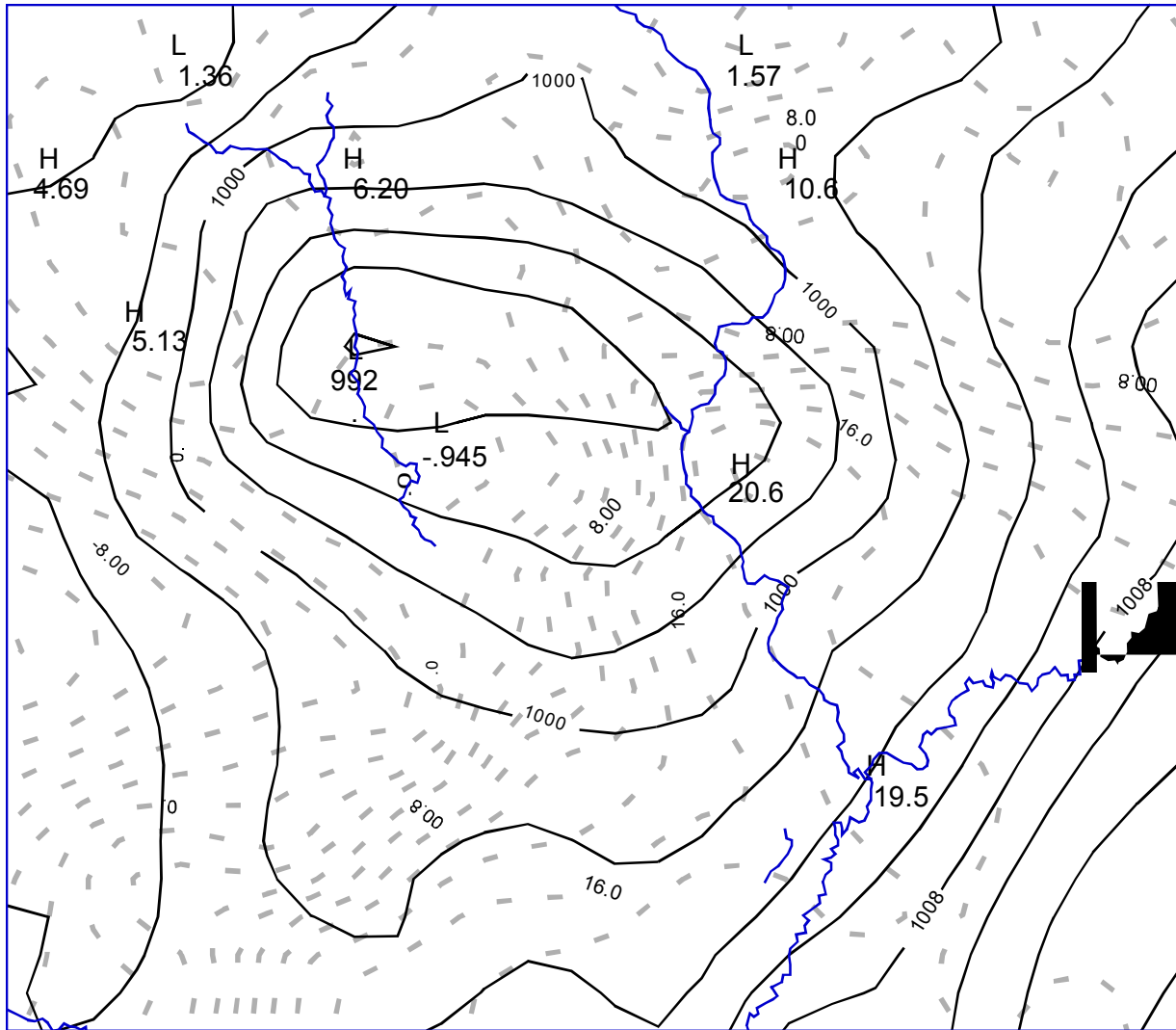


Fig. 1. Surface analysis for 2100 UTC on 19 April 1996. Solid lines are isobars and dashed lines are isodrosotherms.

dBZ for a 12 min. period were plotted. In order to focus on the heart of the outbreak, no cells initiating west of Des Moines, IA or south of Lebanon, MO after 2210 UTC were plotted. Two prominent flanking line cells (gray tracks) that initiated at 2350 UTC, which were deemed very important to the evolution of the 2 central Illinois supercells, are also included. In all, 81 cells are tracked.

With respect to the frontal configuration noted in Fig. 1, it is easy to pick out the convective initiation zones, mainly along the dry trough and warm front. In some large outbreaks such as this, a large degree of complexity is involved as the number of surviving cells, is reduced to a subset of primarily supercells. Note that the thunderstorms designated as supercells (bold tracks) in Fig. 2 demonstrated persistent mesocyclones and moved to the right of the mean wind shear. The tracking analysis shows this complexity through an

intricate pattern of mergers ($M=14$), storm splits ($S=16$) and other interactions ($I=2$). Considering the storms initiating near the dry trough in eastern Missouri, after the first 2 hours, only a small percentage of the storms have survived. Many storms initiated in the region of high moisture convergence near the dry trough, moved off the trough, and within about 20 - 40 min. simply died in an environment that apparently was not conducive to further growth. Other storms are involved in mergers (Westcott 1984) and the most intense of these early storms undergo storm splitting (Klemp and Wilhelmson 1978). The splits then interact and, in several cases, merge with right moving supercells to their immediate north. By 2300 UTC, of the numerous cells initiating along the dry trough north of St. Louis, MO, or warm front east of Ottumwa, IA, 9 supercell storms remain with few other ordinary (non-rotating) thunderstorms.

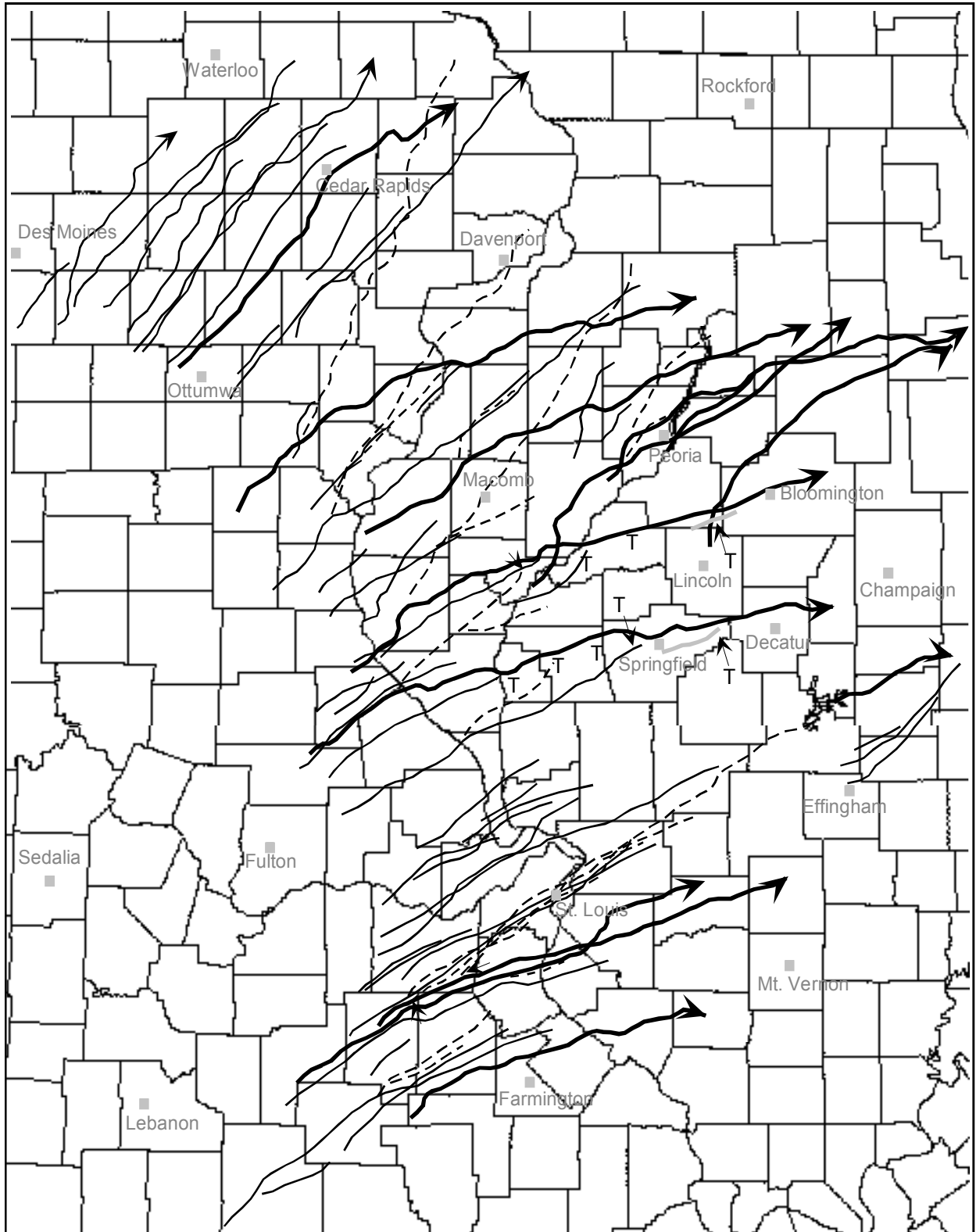


Fig. 2. Cell centroid tracks for the 19 April 1996 outbreak. Bold tracks represent cyclonic supercell storms and dashed tracks designate storms produced from splitting. S, M, I and T represent a storm split, merger, other interaction, or tornado report, respectively. Tracks with arrows designate storms that were still underway at 0100 UTC. See text for further details.

It appears differential storm motion was responsible for some of the merger events whereby a more mature cyclonically rotating thunderstorm moving to the right of the mean shear interacts with a younger cell (Klemp et al. 1980). Another mode of merger, also based on differential motion, resulted from the previously mentioned splitting process whereby a left moving anticyclonically rotating cell intersects a right moving cyclonically rotating supercell. A third mode of merger involved significant new convection generated along the flanking line of a supercell that ultimately merges with the parent cell.

All three modes of merger may be seen by following the west-east evolution of the 2 central Illinois supercells (Bloomington and Springfield cells). The Bloomington storm experiences 3 merger events while the Springfield storm experiences 4 merger events. Thus, numerous cells are gradually consolidated into just 2 supercells.

Another important product of these cell mergers involves thunderstorm intensification. The majority of the merger events for the 2 central Illinois supercells result in cell intensification as indicated by peak reflectivity and high reflectivity areal coverage. Moreover, these supercells generally display enhanced classic "hook" appendage reflectivity structure during or just after the cell interaction. An analysis of NEXRAD wind data to verify the inference from the reflectivity structure (i.e., that the mesocyclones are strengthened) is underway. Did the mergers enhance the existing mesocyclones or did they in fact prompt new mesocyclone development? Both the Bloomington and Springfield storms had persistent mesocyclone presence, but were they the same mesocyclone or new ones developing concurrent with the merger event? The first and second authors observed in the field that the low-level mesocyclone strength on the Springfield supercell was markedly cyclic. NEXRAD data appears to confirm this cyclic mesocyclone intensity for both central Illinois storms.

4. DISCUSSION

The first phase of this observational study has described the early convective complexity and cell interactive processes that produced, in a 2 - 3 hr period (from initiation), a subset of 9 - 12 supercell thunderstorms from a large number of initial cells. The common modes of merger included interactions resulting from: 1) differential motion created when a younger or weaker storm approaches a more mature or stronger cell that has already acquired cyclonic rotation and is moving to the right of the mean shear, 2) differential motion created from a left moving anticyclonically rotating cell intersecting a right moving cyclonically rotating supercell, and 3) prominent new cells generated along the parent cell's flanking line that

propagate into the parent supercell. Cell interaction resulting from the configuration of line orientation with respect to the vertical shear vector will also be explored and compared to the recent idealized simulations of Bluestein and Weisman (2000).

Further radar analysis will address what the merging process structurally represents in the 19 April 1996 outbreak. In some cases it appears that the dominant storm becomes stronger and better organized, and in other cases, it appears a new updraft and associated high reflectivity are produced near the point of merger. Recent model simulations of merging storms appear consistent with this latter scenario (Bluestein and Weisman 2000; Finley et al. 2000). On a related topic, do the mergers lead to enhanced rotation of a pre-existing mesocyclone or sponsor new mesocyclogenesis, especially at low-levels? It appeared visually (and the tornado reports verified) a pattern of cyclic intensification of the low-level mesocyclone. To see if there was any temporal relationship between merger events and tornado occurrence, tornado reports were plotted for the 2 central Illinois supercells up to 0100 UTC. The timing of tornadogenesis and merger events was striking. For the Bloomington supercell, 2 of the 3 tornadoes associated with this storm occurred near the location and time of a merger. Similarly, for the Springfield storm, 4 of the 5 tornadoes reported with this storm (up to 0100 UTC) occurred near a merger event. The relationship between merger events and tornadogenesis is very compelling.

6. REFERENCES

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