P12.4 Early Cell Evolution and Resultant Isolation of Two Long-Lived Supercells During the 12 March 2006 Tornado Outbreak

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1. INTRODUCTION

On 12 March 2006 a major tornado outbreak occurred across the lower Missouri River and mid-Mississippi River regions with scores of tornado, large hail and high wind reports. While this date was marked with two distinct outbreaks of severe storms, this paper is concerned with the first of these episodes. Of particular interest within this first episode was the early evolution of two long-lived supercells that eventually produced numerous tornadoes across Missouri and Illinois. The remarkably long-lived southernmost of the supercells formed along the Kansas-Oklahoma border southeast of Wichita at approximately 1726 UTC and traveled to northeastern Illinois before losing its supercellular character 10.5 hours after cell formation. A relatively small number of past studies have documented the sometimes very complex early evolution and interaction of numerous cells forming within a short period along a common boundary which resulted in one or more isolated supercells. This case provides an ideal opportunity to investigate this supercell isolation process. In particular, 23 cells are tracked from formation to dissipation with an emphasis on cell evolution and interaction in the first 1-3 hours of this event, after which only three isolated supercells remained from the original 23. A foundational objective of this research is to identify early cell characteristics and interactions that can help focus nowcaster attention on the cells with the greatest downstream potential to be a severe. In many cases these severe weather producers are isolated supercells as in this 12 March 2006 tornado outbreak.

2. SYNOPTIC/MESOSCALE ENVIRONMENT

During the early morning hours of 12 March 2006, an upper level trough covered the western third of the U.S. with southwest flow at mid and upper levels extending over the central portions of the country. By 1200 UTC, a strong upper level shortwave was located over the desert southwest, and through the day the shortwave propagated northeastward over the southern High Plains. This shortwave was associated with a 125 kt jet streak at 300 mb (100 kt at 500 mb) which supported strong pressure falls at the surface in the Central Plains throughout the day.

At the surface at 1200 UTC, an area of low pressure was located in eastern Colorado with a diffuse warm front extending eastward through central Oklahoma into central Arkansas, and a dryline extended southward along the eastern OK and TX panhandles. By 1800 UTC, the surface low intensified and moved into northwest Kansas as shown in Fig. 1, with a developing warm front extending eastward into central Missouri, and a strong dryline extending from central Kansas into central Texas. The initial storms that eventually evolved into two long-lived supercells formed south and east of Wichita, Kansas, along a

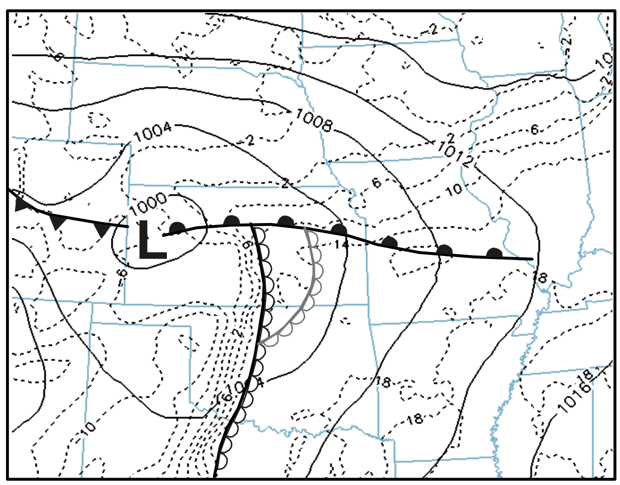

Fig. 1. Surface analysis at 1800 UTC 12 March 2006. Solid contours are isobars (contour interval 4 mb), dashed contours are isodrosotherms (contour interval 4°C). The positions of the surface fronts and dryline are shown in black. The position of the developing double dryline structure is shown in grey.

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developing double dryline structure (see Fig. 1) around 1730 UTC.

An 1800 UTC special sounding was launched from KOUN on this day due to the enhanced severe convective risk. This sounding was modified with 1800 UTC ASOS data and RUC-2 upper-air analyses to produce a representative sounding for the region just ahead of the surging dryline in southeastern Kansas. Given that peak convective initiation was between roughly 1730 and 1830 UTC, we have some confidence that this sounding approximately characterizes the pre-dryline environment. At this time moderate conditional instability existed with a convective available potential energy (CAPE) based on the lowest 50 mb layer mean parcel of 1600 J kg^{-1} and a lifted index of -6.1˚C. The convective inhibition was 5 J kg^{-1}. The 0-6 km shear was 32 m s^{-1} with a generally unidirectional shear profile. Storm relative helicity over the lowest 3 km was 139 m^2s^{-2} and the Energy Helicity Index was 1.4. Given the stated environmental parameters, the pre-dryline environment was supportive of storm splitting and an eventual supercell storm mode. Worth noting is that as the supercells became more isolated and moved northeast well off the dryline, they moved into an environment near the warm front where the low-level wind profile was much more conducive to strongly rotating tornadic storms. Coupled with lower lifted condensation levels near the warm front, the environment over Missouri and Illinois was favorable for tornadic supercells.

3. METHODOLOGY

Level II Weather Surveillance Radar-1988 Doppler (WSR-88D) data from Wichita, Kansas (KICT), Tulsa, Oklahoma (KINX), and Kansas City, Missouri (KEAX) were used in the intensive tracking analysis for the first 3 hours of convective evolution. The extended cell tracking for the three longest-lived storms included data from the WSR-88D at St. Louis, Missouri (KLSX), Lincoln, Illinois (KILX), Chicago, Illinois (KLOT) and North Webster, Indiana (KIWX). To make the analysis tractable and to concentrate on the ensemble of cells that characterized this event, only storms that formed between 1726 and 1826 UTC were tracked, along with new cells resulting from storm splits. This storm "formation window" included the first storms to develop and encompassed the episode of peak initiation frequency along the dryline in southeast Kansas and northeast Oklahoma.

Radar tracking was limited to cells displaying a 30 dBZ reflectivity core on four consecutive lowest elevation angle (0.5^o) base reflectivity scans for at least one radar. (Note: the period of one volume scan was 4-6 min for the datasets utilized) A cell meeting this reflectivity and longevity criteria was tracked until the cell core reflectivity dropped below 30 dBZ. For the tracking analysis, the approximate centroid of highest reflectivity was used to document the cell position. Note that we considered cells with a negative reflectivity time tendency and maximum reflectivity dropping below 30 dBZ to be dissipating. The nearest radar to the cell was used in the tracking analysis.

4. RADAR ANALYSIS AND CELL TRACKING

The ensemble of tracked cells for the extended tracking period is shown in Fig. 2. All cells developing in the 1726 - 1826 UTC formation window are tracked until dissipation. Twenty-three cells are tracked including 19 cells that formed on or near the dryline and four cells that are left members from storm splits. Cells are numbered in the order they formed. The southernmost tracks are representative of long-lived tornadic supercells. Specifically, from the embryonic supercell stage through the time where the cell no longer displayed supercell characteristics (Browning 1964, Rotunno 1993), cells 1 and 4 had life spans of 7.2 and 10.5 hr, respectively. The full cell life (including the post-supercell stage) of cell 4 was a remarkable 14.5 hr. For reference, of the 19 original cells, storms 1, 4, 5 and 13 were supercells.

A notable feature of Fig. 2 is the dramatic evolution of the ensemble of cells to three isolated cells by the time the cell array crosses the Kansas-Missouri border. The cell isolation process is initially quite rapid with only 9 cells remaining from the original 19 cells (not including left members from splits) after 1 hr from the start of cell tracking at 1726 UTC. Only three supercells remain from the original 23 cells after slightly more than 3 hours into the tracking analysis. The dramatic evolution of the ensemble of cells may be seen in Fig. 3 which depicts the cell organization at 1814 UTC from KICT and at 2046 UTC from KEAX. One might be challenged to discern one or both of the eventual longest-lived storms from looking at the cell distribution at 1814 UTC.

A closer examination of the early stages of the ensemble cell evolution may be seen in Fig. 4. Apparent in this tracking analysis is the complexity in cell evolution and interaction, especially when many cells form in close proximity. For instance, cell 1 incurs four mergers within the tracking domain of Fig. 4 and cell 5 incurs two mergers and one non-merger interaction. In contrast, for cells developing in relative isolation such as cells 4 and 13, few mergers or non-merger interactions take place. In total, six of the 23 cells were subordinate members of a storm merger. Thus, one of the ways in which cell isolation ensued was through the process of weaker cells merging with more dominant cells. In most of these cases, the merger was caused by differential propagation (Lilly 1979) due to differences in cell rotation. The stronger storms were moving right of the mean wind and with

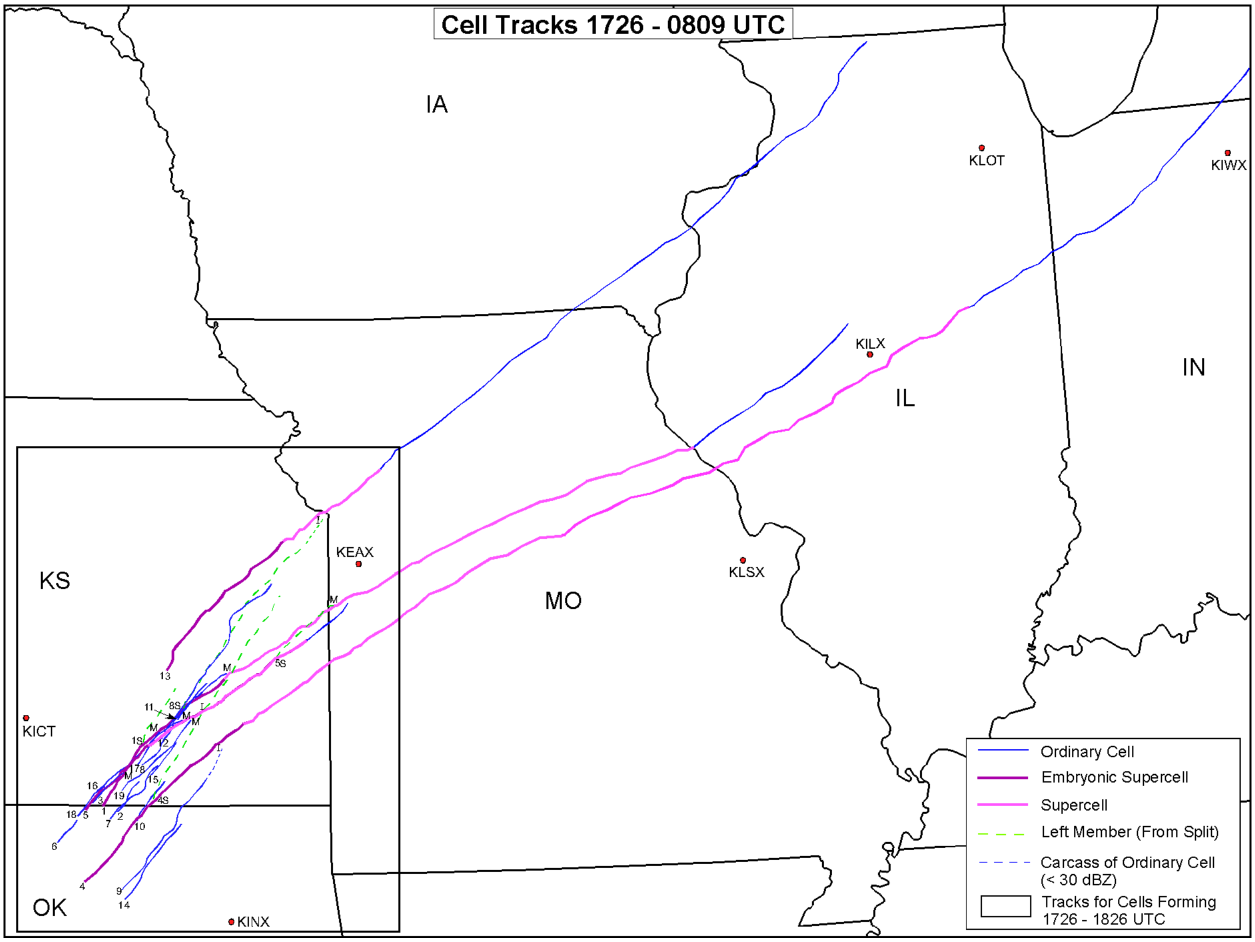

Fig.2. Cell maximum radar reflectivity centroid tracks at the 0.5° elevation angle for 1726 – 0809 UTC on 12-13 March 2006. See legend for cell track designations. M and I represent merger and non-merger interactions, respectively. Note the detailed region within the inset box is shown in Fig. 4.

a slower propagation speed than the ordinary cells or left member cells. Cell dissipation was the other major factor in supercell isolation. Specifically, 8 of the 23 cells dissipated in isolation (≥ 10 km from a neighboring cell) while 4 cells dissipated in close proximity to a neighboring cell (≤ 10 km from a neighboring cell). Although this observational dataset is insufficient to clearly identify the mechanisms for cells dissipating in close proximity to a more dominant cell, one candidate would involve the dominant cell inducing sufficient deep tropospheric subsidence around it to inhibit the convective development of young nearby storms (Cunning et al. 1982). Another possibility is that the dominant cell produced low-level outflow that negatively influenced the inflow wind field to the weaker cell and/or reduced the CAPE in the inflow.

Cell formation times and cell intensity were examined to see if there were signals in the early stages of development that could lead to the early identification of the eventual isolated supercells. One can see from Fig. 4 that the lowest cell identification numbers (designated for the order of formation), were indeed generally associated with the prominent supercells. Specifically, the two long-lived supercells were the first and fourth (of 19) cells to develop. Only a 13 min time period separated the two formation times. The other prominent supercell (cell 5) "officially" formed one minute later than cell 4. Thus, embryonic supercells were among the first cells to develop. This is consistent with a similar tracking analysis in a much larger study from the 19 April 1996 Illinois Tornado Outbreak (Lee et al. 2006a). This "first to form" characteristic is likely quite important in regions where the density of developing cells is high such as the general region around cells 1 and 5.

Two tests of cell intensity were examined to investigate the hypothesis that the first cells reaching a certain intensity threshold would be favored to evolve into the isolated supercells. The first test involved identifying the order in which cells reached a reflectivity level of 50 dBZ. To standardize the methodology, the test was based on an examination of reflectivity at the base scanning level of 0.5^{o}. Of the 13 cells to reach 50 dBZ (excluding the left member cells), the eventual two long-lived supercells, cells 1 and 4, were the second and third earliest to reach the 50 dBZ threshold. Cell 5 (one of the triad of southern supercells) was tied for the third earliest to reach 50 dBZ with cell 4. The first cell to reach 50 dBZ was cell 3; however, this cell quickly merged with cell 1 after a short life span.

The second test of the relationship of cell intensity to survivability involved examining the order in which the 40 dBZ echo top height reached the 7 km level. The assumption is made that higher 40 dBZ echo top heights correspond to a stronger updraft and a more intense storm (Byers and Braham 1949, Browning 1965). Of the nine cells that had a 40 dBZ echo top height reach the 7 km level, cells 1 and 4 were the first and third earliest to reach that level. Cell 5 was the second earliest to reach that level. Thus, based on both measures of intensity, the cells that reach the reflectivity and echo top height thresholds the earliest were generally favored to be among the isolated supercells downstream.

5. DISCUSSION AND CONCLUSIONS

In the first episode of severe convection in the 12 March 2006 Tornado Outbreak, 23 cells were tracked with WSR-88D data from formation to dissipation. From the 23 original cells, only 3 supercells remained within just over 3 hours into the tracking analysis. Cell mergers and cell dissipation (either isolated or in close proximity to a dominant cell) were the main processes for supercell isolation. In most of these merger cases, the merger was caused by differential propagation (Lilly 1979) due to differences in cell rotation. The stronger storms were moving to the right of the mean wind and with a slower propagation speed than the ordinary cells or left member cells, thus setting the stage for cell mergers. The timing of cell formation also appeared related to the probability that a given cell would be among the isolated surviving supercells. In general, the long-lived supercells were among the first cells to form. We additionally found a relationship between the timing of certain intensity thresholds being reached and downstream cell survivability. In particular, the two long-lived supercells (cells 1 and 4) evolved from a group of cells reaching 50 dBZ the earliest. The other supercell in the southern triad of supercells (cell 5) also evolved from one of the earliest cells to reach 50 dBZ. An examination of the timing of the 40 dBZ echo top height reaching the 7 km level produced similar results. The southern triad of supercells all came from the small group of cells that exhibited the earliest 7 km echo top height.

In summary, at least in this study, the cells that formed first and were the earliest to intensify were more likely to develop into one of the surviving isolated supercells. It appears that this early formation and intensification give these cells a "competitive advantage" in subsequent cell interactions. These cells acquire storm rotation before later developing cells, which sets the stage for cell mergers and interactions due to rotationally induced differential propagation. These cells are generally the dominant component in mergers similar to the findings of Lee et al. (2006 a,b). One might also infer that in some cases, storms that intensify the earliest could induce an environment near them that would be inimical to other cells nearby thus enforcing cell isolation through nearby weaker cell attrition.

6. REFERENCES

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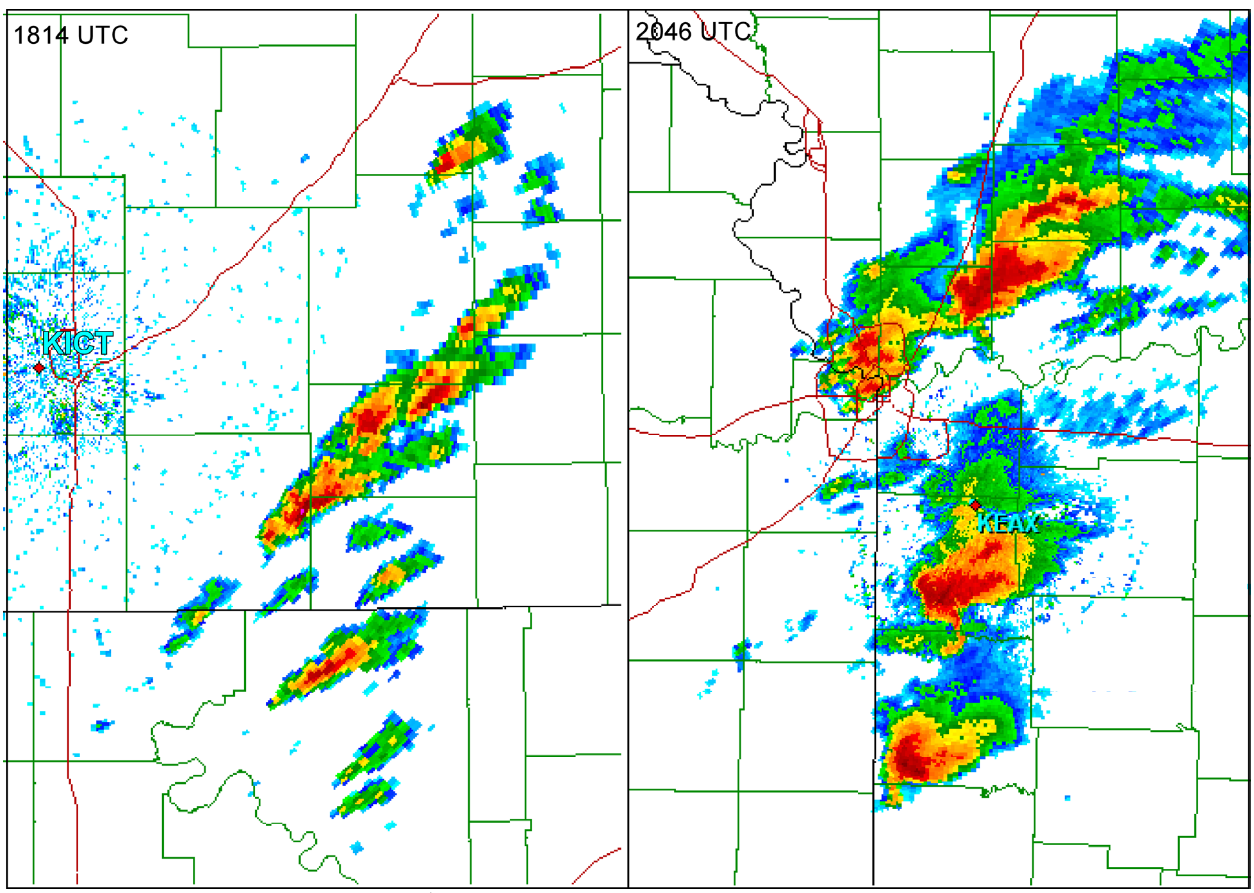

Fig. 3. WSR-88D base reflectivity (0.5°) from KICT and KEAX at 1814 and 2046 UTC, respectively.

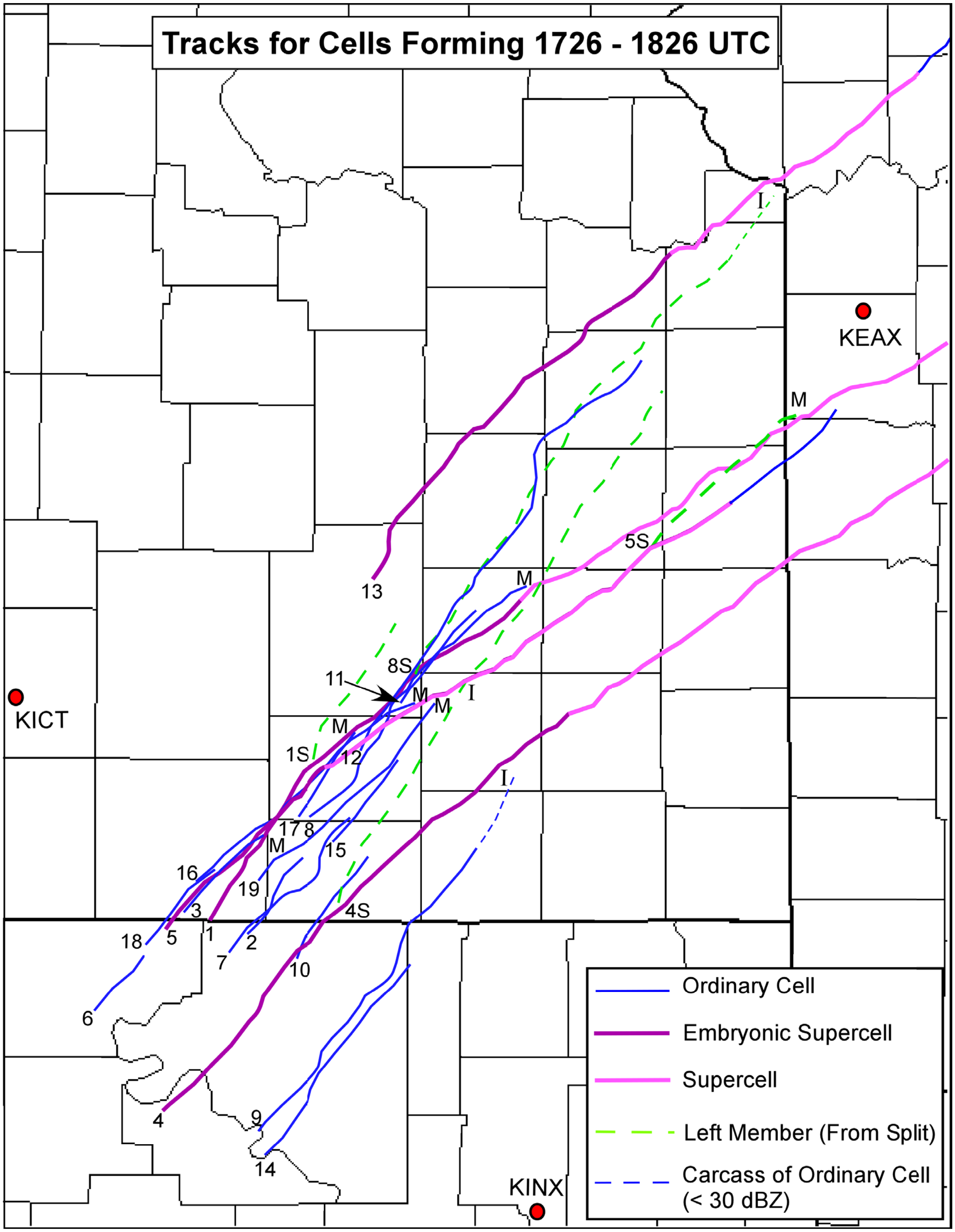

Fig.4. Cell maximum radar reflectivity centroid tracks at the 0.5° elevation angle for cells developing between 1726 and 1826 UTC on 12 March 2006. See legend for cell track designations. M and I represent merger and non-merger interactions, respectively.