18.5. A CASE STUDY OF A LONG-LIVED SUPERCELL IN THE 12 MARCH 2006 SEVERE WEATHER OUTBREAK

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1. Introduction

While many features distinguish supercells from ordinary thunderstorms, one of the most notable differences is the lifespan of such storms. Typically, ordinary convection develops and dissipates over a span of 30 to 90 minutes, whereas supercells can persist for many hours. While many supercells last for a few hours, there are cases of some which have maintained supercell structures for as long as 12 hours. There are several reasons a supercell can lose its definitive characteristics including a loss of diurnal heating, crossing a frontal boundary, or tracking into an area of decreased vertical wind shear. Because of the many reasons a supercell can dissipate or transition to a thunderstorm of a different type, those that maintain supercell structure for close to 12 hours are relatively rare. The purpose of this study is to investigate a long-lived supercell which occurred on March 12, 2006 and determine the environmental factors which enabled it to persist as a supercell for approximately 12 hours.

During the afternoon of March 12, 2006, several supercells developed along a dryline in Northern Oklahoma and Southern Kansas and rapidly tracked eastward into the Mid-Mississippi Valley. Many of these supercells produced very large hail for the duration of their life span. A couple of these cells also produced tornadoes which were primarily in Missouri and Illinois. While many of the supercells tracked north of the warm front over northern Missouri and transitioned to multicell thunderstorms, two cells maintained supercell characteristics across Missouri. However, near the Mississippi River, the northern of the two cells weakened and merged with the southern supercell. The remaining supercell produced tornadoes in Illinois and remained severe over Indiana. Eventually, it too transitioned to a multicell thunderstorm, but not before exhibiting supercell characteristics in four states for approximately 12 hours. The purpose of this study is to investigate the reasons why this long-lived supercell developed, lost supercell characteristics, and why it was able to sustain supercell characteristics for as long as it did.

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2. Methodology

In order to investigate the supercell of interest, radar data from several sites near the path of the cell were obtained from NCDC. Radar loops can be used to detect when thunderstorm cells gain and lose supercell characteristics through observation of cell motion (Zietler and Bunkers, 2006). A supercell deviates to the right or left of the mean wind over a deep layer of the troposphere whereas ordinary convection follows the mean wind closely. To determine the mean wind over a deep layer of the troposphere, Rapid Update Cycle (RUC) model output was obtained from NCDC and examined using NSharp. The netssap algorithm in WDSS was used to determine a motion vector for the cell of interest. A nearby surface observing station was identified at each hour and a model vertical wind profile was examined for the station the cell was nearest to. The surface to 6km mean wind obtained from NSharp was compared to the motion vector obtained from the Storm Cell Identification and Tracking (SCIT) algorithm in netssap. The comparison between the two vectors was used to determine when the cell of interest exhibited supercell characteristics.

To examine the synoptic-scale features of the cyclone which spawned the smaller scale circulations of several supercells, archived upper air charts were acquired from Storm Prediction Center (SPC). To determine the position of features such as the dryline, archived mesoanalysis images were downloaded from SPC. Additionally, surface and upper air observations were acquired from Iowa State University to aid in precisely determining the location of features such as the warm front and the dryline.

At the station which was determined to be nearest to the cell at each hour, model soundings were examined and several environmental parameters were recorded, most of which measured vertical wind shear over a layer. These parameters were compared with the known activity of the cell at times throughout its lifespan to attempt to identify trends in parameters relating to observed cell behavior. A qualitative comparison of the thermodynamic environment experienced by the cell was also examined at times close to when the cell gained and lost supercell characteristics.

To diagnose the forcing in the warm sector, archived GOES satellite imagery was acquired through the CLASS system. In particular, visible satellite images were used to examine cloud features which might indicate forcing in areas where the cap had been broken and convection is occurring but also in areas where the cap was not broken.

3. Results

3.1. Synoptic Conditions

The synoptic setup for the morning of 12 March 2006 was unusual, however, not unheard of for late Spring across the Central Plains and Mid Mississippi Valley (Hoch and Markowski, 2005). Using 12Z observed soundings from across the US, the state of the atmosphere can be obtained for the morning of March 12. A strong 300-mb jet on the order of 90 Kts stretched from the Desert Southwest up through the Upper Great Lakes region, with imbedded jet streaks at 125+ Kts. At the 500-mb level, a deep trough has dug its way into the West Coast and Intermountain West, with slight ridging occurring over the Southeast US. Strong southwesterly flow existed across much of the Central US, and a shortwave was entering into the Central Plains region. At 700 mb, low pressure was located over the Central Rocky Mountains and the general flow remains southwesterly. At 850 mb, Gulf moisture was being pulled into the Ozarks as denoted by dew point depressions less than 4ºC across Central and Northwest AR, Northeast OK, Southeast KS, and Southwest MO. Low pressure at this level was located over the Front Range of the Rockies and into the Western High Plains. The general flow over the Central US at the 850-mb level became more southerly. This shift in wind would help to produce enough directional shear to produce rotating supercells during the afternoon hours.

3.2. Convective Initiation

Just prior to 18 UTC, the first signs of convective initiation appeared on radar imagery. RUC model soundings and satellite observations of water vapor indicated an eastward surge of the dryline between the 17 UTC and 18 UTC hours over Northern Oklahoma and Southern Kansas. RUC model soundings showed strong downward motions west of the dryline in these regions in the 18 UTC RUC initialization along with a more westerly component of winds near the surface as compared with winds from previous model analyses and other locations farther southwest of the dryline. Due to stronger winds aloft with a greater westerly component than surface winds, downward mixing of momentum is a likely cause of the development of a dryline bulge over Oklahoma and Kansas (Schaefer, 1986; Peckham, et al, 2004; Auslander and Bannon, 2004). The eastward propagation of this part of the dryline provided the necessary convergence to break the cap and initiate convection. SPC mesoanalysis images also showed an eastward surge of the dryline in Northern Oklahoma and Southern Kansas between the 17 UTC and 18 UTC hours with the dryline becoming relatively stationary in later hours.

In conjunction with the eastward propagation of the dryline, convection rapidly developed over North Central Oklahoma and South Central Kansas. In very favorable thermodynamics and strong directional speed shear, thunderstorms quickly developed supercell structures. Prior to gaining supercell characteristics, the cell which is the focus of this study was observed to have a motion of approximately 220 degrees. This is very close to the mean wind over the surface to 6 km layer of 217 degrees. Around 1830 UTC, radar imagery shows a shift in motion to about 230 degrees suggesting that the cell had transitioned into a supercell.

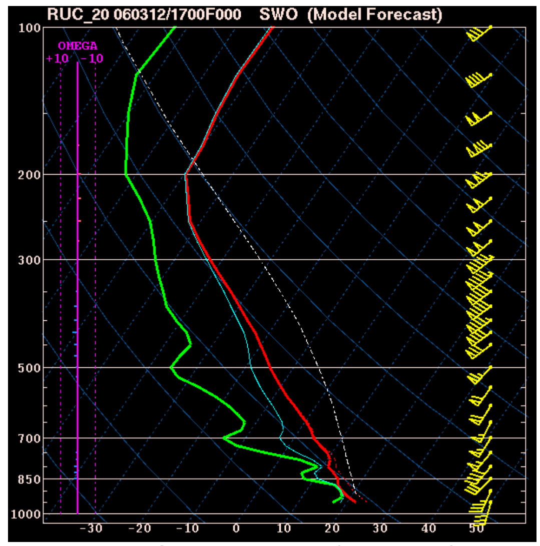

Figure 1: A RUC model sounding from 17 UTC on March 12 at Stillwater, OK in the vicinity of the dryline shows largely unidirectional winds but strong speed shear. The environment was favorable for development of supercells but not necessarily for tornadoes.

Over much of Southeast Kansas and extreme Western Missouri in the early afternoon hours of March 12, 2006, RUC model soundings, such as the one shown in figure 1, indicated surface to 2 km SRH values were approximately 200 m^2/s^2. Surface winds were primarily out of the south over much of the region. Despite strong deep layer shear and favorable thermodynamic profiles for surface-based convection, the environment experienced by the supercell was not particularly favorable for tornadoes. However, the strong deep layer shear along with low freezing levels, low wet bulb zero levels, and the destabilizing environment favored an increasing threat of very large hail as the day progressed.

3.3. Intensification over MO

RUC model soundings and plan view analysis of RUC output from 20 UTC suggested that the warm front roughly extended from Kansas City, MO to Quincy, IL. Model soundings north of the warm front indicated elevated instability was present with a nearly isothermal layer from the surface up to a kilometer or slightly higher. Most of the veering of the winds was in the nearly isothermal layer near the surface. Model soundings from locations north of the warm front showed little CAPE for parcels lifted from the surface suggesting that any convection crossing the warm front would become elevated. With the inflow for any cells north of the warm front above the greatest veering of the winds, the effective shear would be reduced and the shear would primarily be speed shear. Despite the elevated instability, unfavorable shear profiles for supercells north of the warm front suggested a transition from supercells to multicell closers for any convection that crossed the warm front.

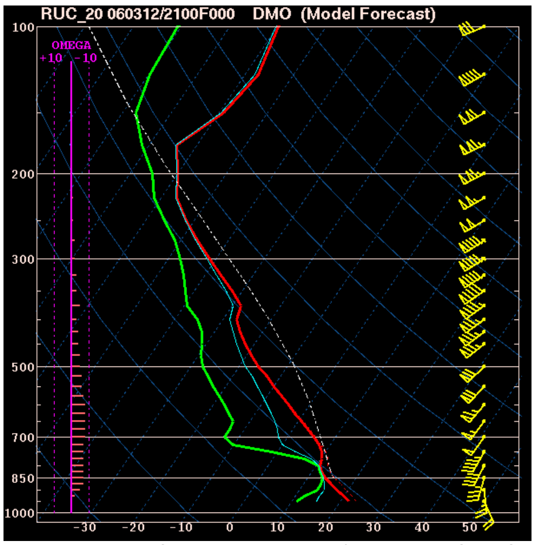

Figure 2: A RUC model sounding from 21 UTC at Sedalia, MO shows backed winds at the surface, strong veering, and a favorable thermodynamic profile for surface-based convection. Just prior to 22 UTC, tornadoes were reported in the vicinity of Sedalia, MO.

Radar imagery from Pleasant Hill, MO (KEAX) indicated that supercells moved north of the approximate location of the warm front and did indeed lose supercell characteristics. However, two supercells remained in the vicinity but south of the warm front as they tracked into Central Missouri. RUC model soundings, such as the one shown in figure 2, indicated backed winds at the surface and increasing storm relative helicity (SRH) values across Central Missouri favored an increased tornado threat for the supercells which moved across the region late in the afternoon.

Model soundings south of the supercells indicated a capping inversion across much of the warm sector. Despite strong anvil level storm relative winds favoring low precipitation supercells, radar imagery, as shown in figure 3, indicates that both supercells that tracked across Central Missouri were classic supercells. The supercells were not outflow-dominated and therefore were not providing a particularly strong lifting mechanism for developing convection to the south. Satellite imagery from the afternoon, such as the image in figure 4, showed waves propagating eastward through the warm sector suggesting that while forcing for upward motion was present, lifting mechanisms were not sufficient enough to break the cap.

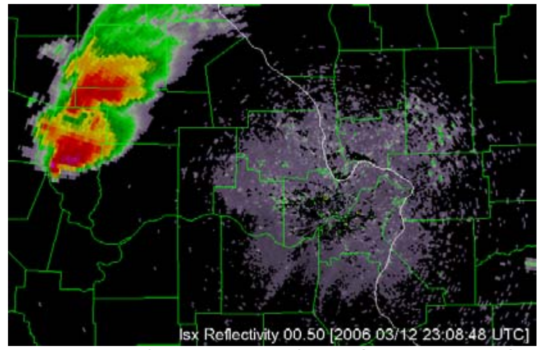

Figure 3: A reflectivity image from LSX at 2308 UTC shows the two supercells tracking across Central Missouri.

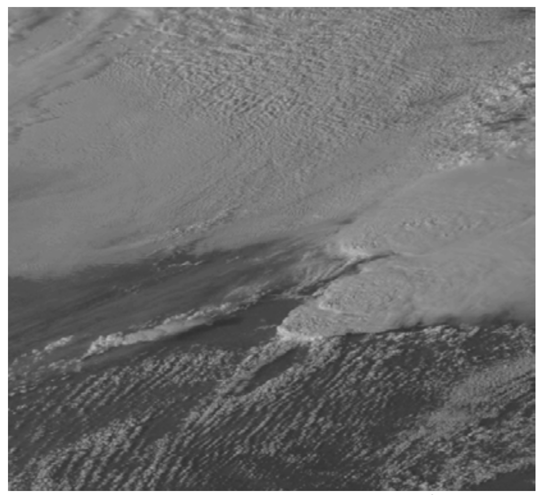
Figure 4 shows a visible satellite image from 2155 UTC showing the supercells tracking across Central Missouri and waves to the south indicating capping in the warm sector.

The contamination of supercell inflow by hydrometeors from a supercell to the south can cause a supercell to transition from an low precipitation (LP) or classic supercell to an high precipitation (HP) supercell (Rasmussen and Straka, 1998). However, because of the cap present throughout the warm sector, convection did not develop to the south, which allowed the supercells to retain classic supercell structures as they crossed Missouri.

3.4. Cell Mergers

At approximately 0030 UTC on March 13, the northern supercell showed signs of weakening in scans from the LSX radar. Also, 0030 UTC was the time of the final tornado report in Missouri from these two supercells for nearly an hour. Radar imagery in figure 5 shows the cells starting to merge, just prior to 0030 UTC. Shortly thereafter, the classic “hook echo” disappeared from reflectivity scans of the northern cell while radial velocity images still indicated two distinct large areas of rotation suggesting the continued presence of two rotating updrafts even after 0030 UTC. One explanation for this is the contamination of the inflow of the northern supercell with hydrometeors from the southern supercell causing the northern cell to transition to an HP supercell prior to losing supercell characteristics.

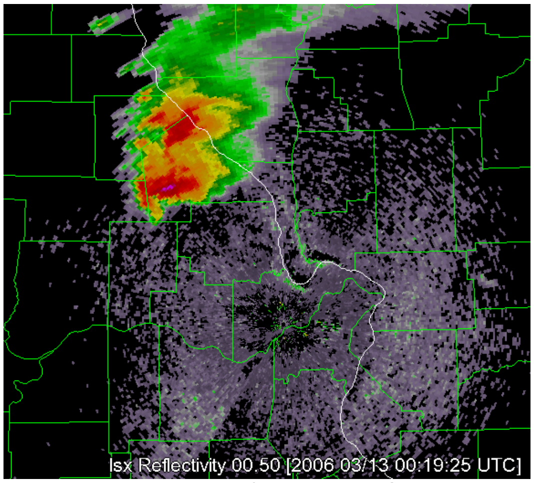

Figure 5: Radar imagery from 0019 UTC on March 13 from LSX shows the two cells beginning to merge over Pike County, MO.

A few scans after 0030 UTC depicted the northern cell no longer having a large area of weak rotation suggesting that a rotating updraft was no longer present or that the rotation was much weaker. This indicates that the northern cell was no longer a supercell. Reflectivity images appear to depict a merging of the two cells, however later scans eventually show multicell thunderstorms to the north of the merged cells. Figures 6 and 7 show reflectivity and radial velocity images, respectively, of the two cells shortly after the merging of the two cells. Both cells were in close proximity to the warm front, and it is possible that the warm front played a role in the northern cell losing supercell characteristics upon crossing the front. This would be consistent with multicell convection developing to the north of the merged cells.

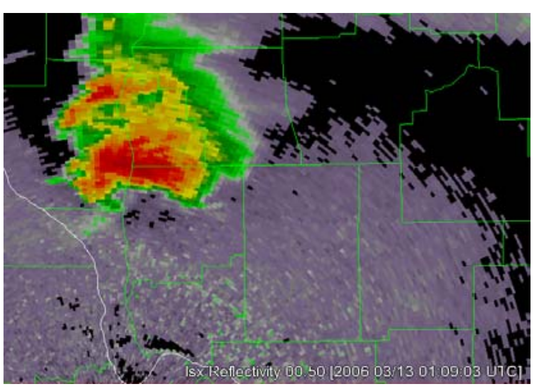

Figure 6: Radar imagery from 0109 UTC at LSX shows that the two supercells have merged and multicell convection is evident to the north of the supercell.

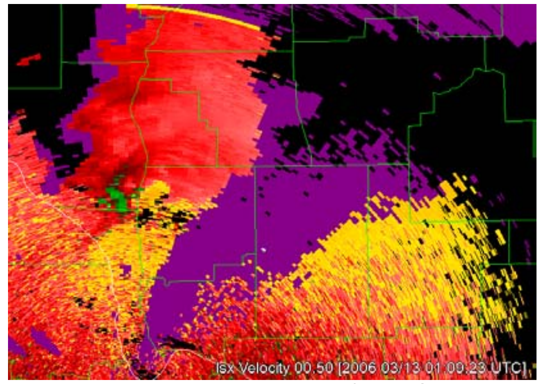

Figure 7: A radial velocity image from LSX at 0109 UTC shows that the cell to the north of the supercell no longer clearly has a couplet and suggests the northern cell no longer has supercell characteristics.

Around 0100 UTC, the merged cell appears less organized and the motion of the cell is much closer to the mean wind than what was observed when the two supercells clearly exhibited supercell characteristics, due to the merging of the cells as suggested (Lindsey and Bunkers, 2005). The resulting cell moved to the right of the mean wind by less than 10 degrees as opposed to the observed 15 to 30 degrees to the right of the mean wind observed previously with a distinct change in motion observed at approximately 0115 UTC.

3.5. Reorganization in Illinois

The first tornado report in Illinois occurred at 0120 UTC. Over the following couple of hours, several tornadoes were reported across West Central and Central Illinois. By 0130 UTC, reflectivity scans from the ILX radar show a much more organized appearance to the cell. Around 0200 UTC, the cell once again begins to move to the right of the mean wind by about 15 to 20 degrees suggesting that the reorganization of the cell is complete and the cell is clearly a supercell. Merging of a supercell with another supercell or even with ordinary convection can precede cell reorganization and tornadogenesis (Lee *et al*., 2006). Therefore it is possible that the merging of the two cells enhanced the tornadic nature of the reorganized supercell.

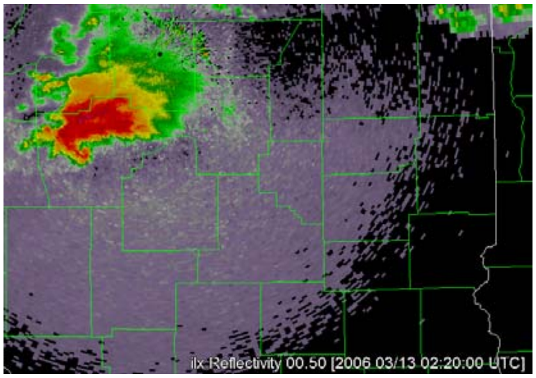

Figure 8: A reflectivity image from ILX at 0220 UTC shows a well organized supercell in the vicinity of Springfield, IL. A hook echo is apparent and a swirl is also apparent on the southern part of the hook. Radial velocity imagery (not shown) indicated strong rotation within the supercell and a secondary, shallower rotation where the reflectivity image shows a swirl at the end of the hook.

Analysis of the supercell while it was in the vicinity of Springfield, IL suggests that it had strengthened significantly after reorganizing. A large deep and strong circulation, several kilometers wide, is apparent in the cell. Additionally to the south of the circulation, a secondary shallower but strong circulation is also apparent at the southernmost point of the hook echo. Evidence of the secondary indication is also visible as a small swirl in reflectivity images. Figure 8 shows a reflectivity image of the supercell while it was in the vicinity of Springfield, IL and shows good structure along with a hook and a secondary swirl evident. An increase in lightning activity was also observed in the cell, with the greatest density of lightning flashes at any time while the cell was a supercell being observed at this time.

As the supercell tracked east of Springfield, it still maintained a strong appearance on radar as it approached the Indiana border. A few tornadoes were reported to the northeast of Springfield but not nearly at the frequency as was reported when it moved through Springfield.

3.6. Loss of Supercell Characteristics

As the supercell tracked into Indiana, its east-north-easterly motion took it across the warm front. A RUC model sounding from 7 UTC on March 13 from South Bend, Indiana indicates a nearly isothermal temperature profile from the surface to approximately 850 mb. The most unstable parcel as indicated by NSharp is just above this layer and has approximately 750 J/Kg of CAPE. Figure 9 shows a similar sounding from Valparaiso, Indiana, which is just to the south of South Bend. The greatest veering of winds is below the lifted parcel level (LPL) of the most unstable parcel with winds at and above 850 mb veering only slightly from southwesterly to west-south-westerly. Most of the effective shear is speed shear with only slight directional shear (Thomson *et al*., 2004). Despite the strongly sheared environment, the environment north of the warm front favored a multicell linear mode of convection.

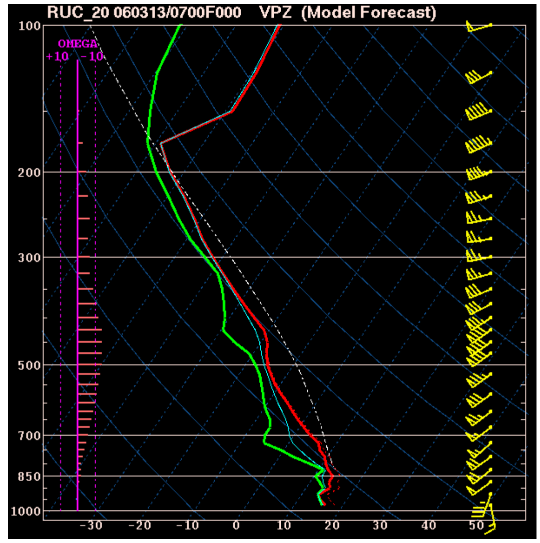

Figure 9: A RUC model sounding from Valparaiso, IN at 07 UTC shows a roughly isothermal layer from the surface to approximately 850 mb. The LPL of the most unstable parcel is at 825 mb, which is above the greatest veering of winds in this vertical profile.

Radar imagery confirmed this with several linear segments of convection observed over Northern Indiana at and shortly after 0700 UTC. After the supercell transitioned to a multicell structure, it merged with other convection north of the warm front creating a larger MCS.

4. Conclusion

The features at the synoptic scale on March 12 provided the necessary ingredients for supercells to develop over a wide area of the Plains and Mid-Mississippi Valley regions. Strong southwesterly winds aloft over brisk southeasterly winds near the surface provided the necessary shear for supercells. The very moist and unstable air of the warm sector was also very favorable for supercells. However, the warm sector remained strongly capped throughout much of the day preventing explosive development over the region due to synoptic scale forcing mechanisms. However, strong forcing over the Plains in association with a dryline bulge which developed early in the afternoon provided the necessary lift to break the cap which allowed supercells to develop.

Strong capping in the warm sector prevented convection from developing over Southern Missouri and areas farther south in the warm sector. As a result, thunderstorms did not develop to the south of the long-lived supercell and therefore the inflow to the supercell was uncontaminated by hydrometeors from other convection. Strong storm relative winds at the anvil level favored LP and classic supercell structures instead of a transition to HP supercells and eventually to a multicell mode of convection.

The reasons for the long lifespan of the supercell of interest in this study are due to the favorable environment for supercells over a wide area and the failure of convection to initiate to the south of the supercell forcing a transition to an HP supercell and eventually a loss of supercell characteristics. The positioning of the deep trough at 500 mb well west of the surface cyclone provided strong vertical wind shear and strong upper level storm relative winds favoring primarily LP and classic supercells. Strong capping in the warm sector prevented other convection from developing, thus allowing the cell to interact with the environment of the warm sector without contamination from hydrometeors.

5. References

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