18.3 EVOLUTION OF THE MESOSCALE ENVIRONMENT PRIOR TO THE 12 MARCH 2006 MISSOURI OZARKS TORNADO OUTBREAK

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1. INTRODUCTION

During the evening hours of 12 March 2006, several supercell thunderstorms moved across the Missouri Ozarks region producing more than a dozen tornadoes, including five significant long-track tornadoes with damage rated as F2 or greater. Figure 1 shows the tracks of the various tornadoes across the Missouri Ozarks. In the National Weather Service Springfield, Missouri (KSGF) County Warning Area (CWA), the tornadoes caused an estimated 62.25 million dollars in damage, and left more than 670 homes either damaged or destroyed. In addition, two fatalities and more than four dozen injuries were attributed to the tornadoes.

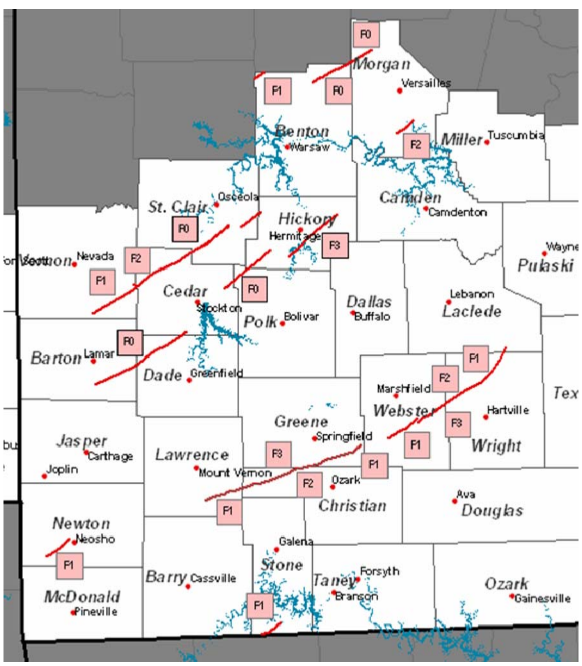

Fig. 1. Track map of the tornadoes that touched down in the KSGF CWA during the evening of 12 March 2006.

During the afternoon and evening hours of 12 March 2006, the majority of the KSGF CWA was located within the warm sector of a well developed mid-latitude cyclone. The environment within the warm sector endured significant modifications during the course of the event, providing a challenge to forecasters in assessing the rapidly changing tornado threat. Initially, conditions within the warm sector were only marginally favorable for tornadoes. However, as the event progressed, conditions quickly became markedly more favorable not only for tornadoes, but for long-lived and potentially significant tornadoes.

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Typically, sunset, and the resultant loss of solar insolation, leads to a reduction in the threat of severe weather from surface based thunderstorms. During the 12 March 2006 event, not only did the loss of solar insolation not lead to a reduction in the threat of surface based severe thunderstorms, but it actually appears to have been at least partially responsible for conditions becoming even more favorable for tornadic supercells.

This paper will briefly examine the synoptic environment leading up to the outbreak of tornadoes. The evolution of the mesoscale environment will be the primary focus of this study; with an emphasis on the changes in the environmental conditions that resulted in an increased threat of long lived tornadoes.

2. SYNOPTIC OVERVIEW

A classic mid-latitude cyclone moved eastward across the Plains and toward the Mississippi Valley region during 12-13 March 2006, characterized by an intensifying surface cyclone, warm front, and dryline. During th+e time period from 1800 UTC 12 March to 0300 UTC 13 March, the surface low pressure system tracked from northwestern Kansas eastward to northeastern Kansas, deepening from 998 hPa to 994 hPa as shown in Figure 2. During the same time period, the associated surface warm front, initially located just south of and parallel to Interstate 70 across Kansas and Missouri, moved northward approximately 110 km into northern Missouri and northeastern Kansas by early evening.

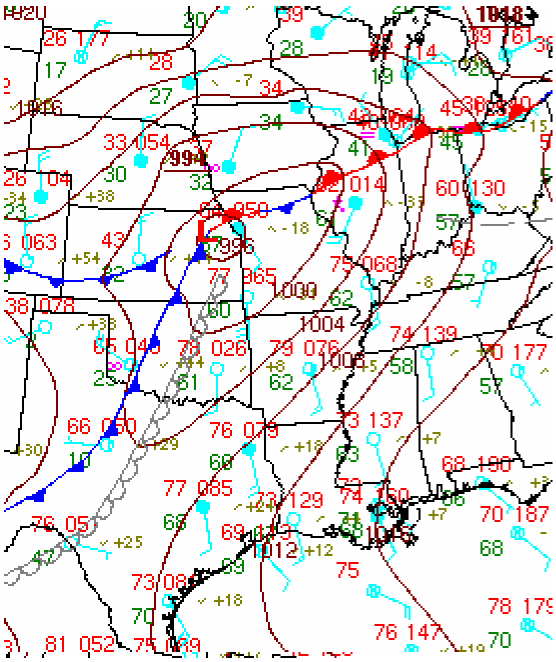

Fig. 2. 0300 UTC 13 March surface map depicting strengthening surface low over northeast Kansas with dryline extending southward across eastern Kansas and Oklahoma.

The warm sector of this mid-latitude cyclone was characterized by surface dewpoints around 15°C. A dryline stretched southward from the surface low and moved eastward into eastern Kansas by the early evening hours of 12 March 2006, resulting in a tightening surface moisture gradient. Dewpoints behind the dryline fell to around -10°C, or more than 25°C lower than the warm sector.

Aloft, a very strong mid-level jet streak with winds in excess of 50 ms^{-1} at 500 hPa moved across the central plains during the afternoon; with a large swath of 25-30 ms^{-1} winds at 500 hPa covering much of the warm sector. Surface winds in this region remained slightly backed as the surface cyclone deepened. The backing surface winds in conjunction with the strong southwesterly mid-level flow created a large region of 0-6 km bulk shear in excess of 25 ms^{-1}, leading to an environment well suited for supercell thunderstorms.

3. AFTERNOON

Nearly the entire KSGF CWA was located south of the warm front and well within the warm sector of the cyclone during the afternoon hours of 12 March 2006. The environment within the warm sector was strongly sheared and moderately unstable. The 2100 UTC KSGF sounding indicated 100 hPa Mean Layer Convective Available Potential Energy (MLCAPE) had increased to just over 1500 Jkg^{-1}. The same sounding sampled 0-6km bulk shear vectors over 25 ms^{-1}, which is more than sufficient for supercells which typically require 15-20 ms^{-1} of 0-6 km bulk shear (Bunkers 2002).

Sky cover across the KSGF CWA was generally partly cloudy through the morning and into the afternoon on 12 March, allowing temperatures to warm to around 26°C. While the sunshine led to an increase in surface based instability, it also caused the depth of the well mixed boundary layer to increase. The 2100 UTC KSGF sounding (Figure 3) showed that the well mixed boundary layer had increased to over 1600 m deep with surface dewpoint depressions increasing to 10-12°C. Finally, the increasingly deeply mixed boundary layer resulted in an overall decrease in 0-1 km shear as the winds throughout the mixed layer became increasingly homogenous.

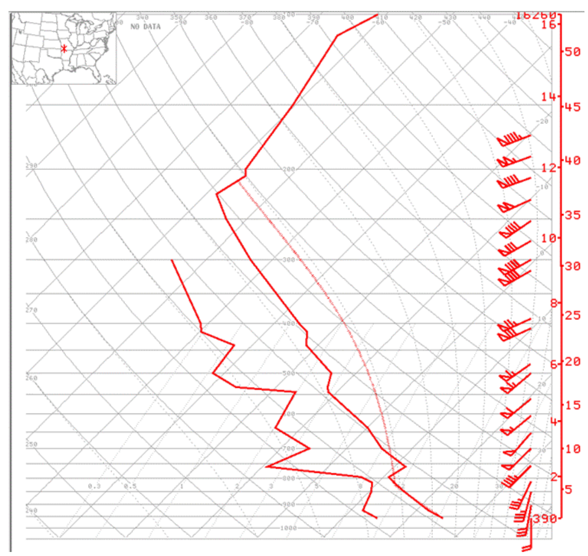

Fig. 3. 2100 UTC KSGF Sounding depicting an increasingly deep boundary layer and moderately large surface dewpoint depressions.

The increasing depth of the boundary layer also resulted in a decrease in the magnitude of 0-1 km storm relative helecity (SRH) values, which tend to be an excellent discriminator between torandic and non-tornadic supercells (Rasmussen 2003). The more deeply mixed boundary layer also resulted in an increase in lifted condensation level (LCL) heights. Lower LCL heights tend to allow less evaporation of precipitation falling from the updraft, which allows for warmer, more buoyant downdrafts and increases the potential for tornadoes (Rasmussen 1998). When assessing the tornado risk for the region at this time, the moderate instability and very strong deep layer shear were supportive of tornadoes. However, increasingly high LCL heights, due to the increasing surface dewpoint depressions, and the decreasing magnitude of the 0-1 km shear, were not particularly supportive of tornadoes, particularly significant tornadoes.

Sustained moisture convergence and decreasing convective inhibition, due to strong surface heating, allowed convection to develop along the dryline over southeast Kansas during the early afternoon hours of 12 March 2006. The convection quickly evolved into discrete supercells as shear vectors were favorably oriented with respect to the dryline to favor discrete cellular convection.

The southernmost storm developed quickly and took on supercellular characteristics, exhibiting the classic “flying eagle” reflectivity signature as well as a persistent mid-level mesocyclone. As the storm tracked northeastward across southeast Kansas and into west-central Missouri, the storm remained south of the warm front and within the warm sector. While several tornado warnings were issued for this storm, subsequent damage reports indicated that it failed to produce a tornado while in the warm sector.

Surface winds near the warm front were backed to a more southeasterly direction increasing the low level shear. In addition, moisture was pooling near the surface warm front with surface dewpoints approaching 20°C. The higher dewpoints and slightly cooler temperatures resulted in significantly lower LCL heights and the potential for warmer, more buoyant rear flank downdrafts. Thus, conditions were considerably more favorable for not only tornadoes, but potentially significant tornadoes in a narrow corridor along the warm front.

As this southern most supercell tracked northeastward into central Missouri, it encountered the warm front and began to exhibit a slightly more deviant eastward motion. It generally tracked very near the surface warm front, in a much more favorable environment for tornadoes. As a result, the first tornado from this supercell touched down in Henry County in central Missouri. The storm then intermittently produced several more tornadoes as it moved across central Missouri, including an F2 tornado near Sedalia, MO. The supercell continued to propagate along the warm front into eastern Missouri and central Illinois producing several more tornadoes, including an F2 and F3 tornado.

3. EVENING

While conditions during the afternoon were not particularly favorable for significant tornadoes in the warm sector, the environment across the warm sector became more favorable during the evening. Forecasters would normally anticipate a stabilizing boundary layer after sunset and, subsequently, a reduced risk of tornadoes. However, in this particular case, the loss of solar insolation seemed to be offset by strong positive low level theta-e advection and turbulent mixing of the boundary layer that limited the amount of boundary layer stabilization.

During the early evening hours of 12 March 2006, surface temperatures began to cool

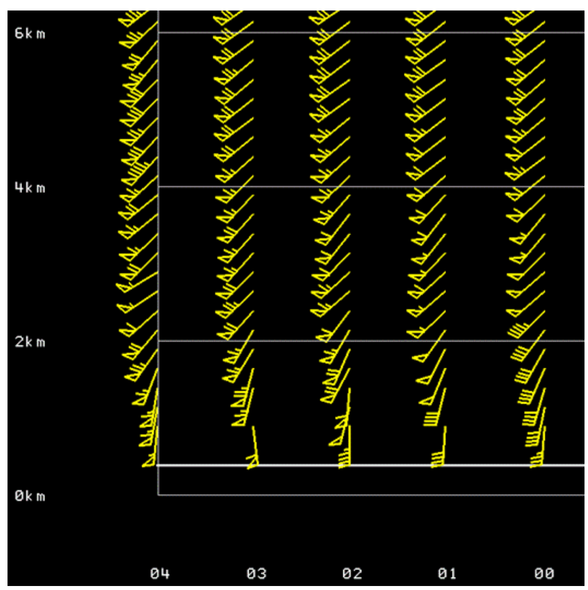

Fig. 4. Conway, MO Wind profiler from 0-6 km during the 0000 UTC to 0400 UTC time period showing a significant increase in 1 km AGL winds (kt).

0000 UTC 13 March and 0300 UTC 13 March, subsequent KSGF soundings indicated that LCL heights fell from over 1500 m at 0000 UTC to around 1000 m AGL at 0300 UTC.

While the lowering LCL heights were certainly creating more favorable conditions for tornadoes, the most dramatic change to the mesoscale environment was the significant increase in 0-1 km SRH values as an intense low level jet developed during the early evening. Figure 4, the Conway, Missouri wind profiler from 0-6 km between 0000 and 0400 UTC, shows an increase in 1km AGL winds of around 12.5 ms^{-1}. The substantial increase in 1 km AGL wind caused 0-1 km SRH to increase from around 100 $m^{-2}s^{-2}$ at 2100 UTC 12 March to over 600 $m^{-2}s^{-2}$ at 0300 UTC. Figure 5, a partial 0300 UTC 13 March 2006 sounding from KSGF, demonstrates the extremely strong and veering low level wind fields, with 25 ms^{-1} winds evident within 0.5 km of the surface.

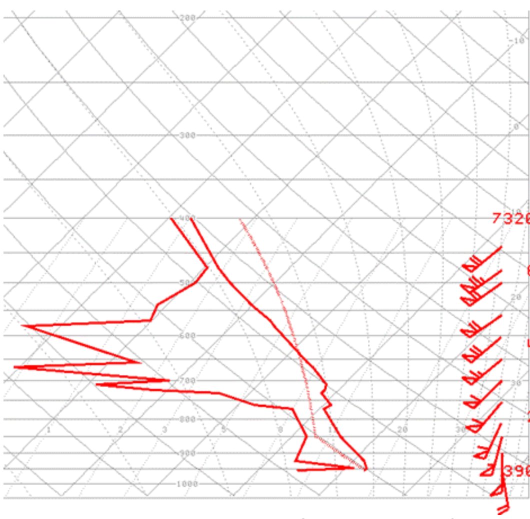

Fig. 5. Partial 0300 UTC sounding from KSGF showing an extremely strong and veering wind profile in the lowest 1 km AGL.

During the early evening hours of 12 March, additional convection developed along the dryline over southeast Kansas and northeast Oklahoma. Deep layer shear vectors were favorable for this convection to remain discrete and propagate away from the dryline. Consequently, the initial convection quickly evolved into discrete supercells. However, the National Weather Service WSR-88D data suggest that the mesocyclones were primarily located in the mid-levels within the first 2 to 3 hours of initiation. As each supercell moved farther into Missouri, and into an increasingly more favorable environment for intense and sustained low-level mesocyclones, each supercell matured and began to exhibit strong low-level rotation, taking on more classic supercell characteristics as seen in Figure 6.

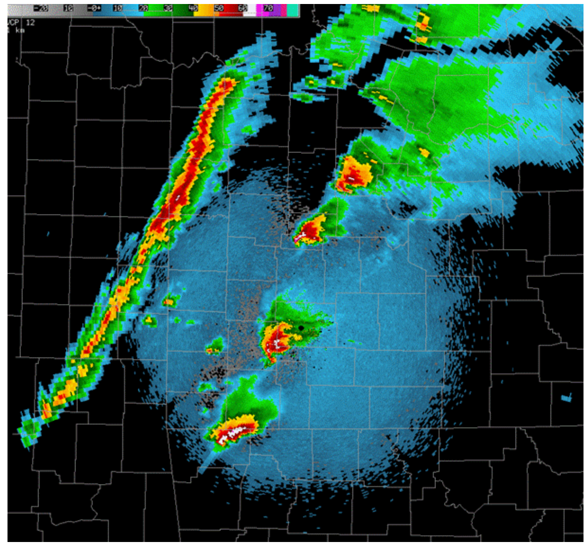

Fig. 6. KSGF WSR-88D Reflectivity image depicting the four discrete supercells tracking across the Missouri Ozarks.

In all, four supercells moved across the KSGF CWA from southeast Kansas, northeast Oklahoma, and extreme northwest Arkansas. Three of the four supercells produced significant (F2 or greater) tornadoes in the KSGF CWA that evening, with the fourth supercell producing an F1 tornado. The strengthening low-level rotation within the storms correlated well with the onset of the tornadoes across the Missouri Ozarks that evening.

3. SUMMARY

The severe weather and tornado outbreak of 12 March 2006 was a particularly difficult event to forecast, even in the 0-6 hour time frame. The significant modifications that took place in the near-storm environment were difficult to anticipate. The mesoscale environment evolved rapidly from one that was only marginally favorable for tornadoes to one that was extremely favorable for potentially significant and long-track tornadoes.

Close examination of the mesoscale environment during the afternoon hours of 12 March revealed some of the deficiencies in the necessary ingredients for significant tornadoes in the warm sector. The rapid evolution of the mesoscale environment to one extremely conducive for significant tornadoes during the evening hours was not fully anticipated due to the inherent uncertainties of whether convection would be able to remain rooted in the boundary layer after sunset.

Once discrete supercells with strong low level mesocyclones were detected on radar, it became clear the convection was rooted in the boundary layer and the tornado threat had increased. Indeed, the supercells were able to remain rooted in the boundary layer well into the night as they moved across the Ozarks taking full advantage of the extreme low-level environmental shear. The supercells ultimately produced more than a dozen tornadoes across the Ozarks that evening, including five tornadoes of F2 or greater intensity.

6. ACKNOWLEDGEMENTS

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