P4.3 EVOLUTION AND MAINTENANCE OF THE 22-23 JUNE 2003 NOCTURNAL CONVECTION DURING BAMEX

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1. INTRODUCTION

In the central Great Plains mesoscale convective systems (MCSs) account for a large fraction of the precipitation that falls in the warm season (Fritsch et al., 1986). The heavy precipitation associated with these MCSs typically occurs during the overnight hours. Convection that is initiated overnight in the central Great Plains is often elevated (i.e. feeding on air parcels from above the boundary layer). Elevated convection may arise when radiative cooling stabilizes the planetary boundary layer (PBL). In such cases, the low-level jet (LLJ) may be important in transporting moist, conditionally unstable air into the convective region. Trier et al. (2006) found that the LLJ is the most likely source of moisture that helps maintain the convection. However, since the majority of meteorological observations occur at the surface, it is difficult to determine the forcing and propagation mechanisms of elevated convection. Without this understanding, and lacking frequent and dense upper air observations, forecasting elevated convection remains difficult. Few studies of the evolution, maintenance and propagation of elevated systems have been undertaken.

In an attempt to better understand these processes the case of 23 June 2003 will be examined. In a nocturnal environment on 23 June 2003, two different modes of convection coexisted in very close proximity. Isolated cells, which appeared to be elevated, occurred near a large squall line in which the convection appeared to be surfaced-based. 22-23 June 2003 is remembered for both the Aurora, Nebraska supercell that produced the record breaking hailstone and the Superior, Nebraska supercell that produced the strongest measured mesocyclone in history (Wakimoto et al., 2004). These storms were sampled by the Bow Echo and MCV Experiment (BAMEX) over parts of southeastern Nebraska and northern Kansas. However, their subsequent nocturnal evolution of has received little attention.

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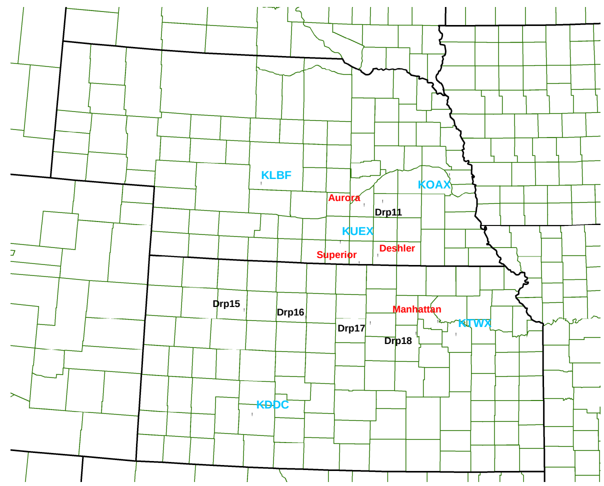


Figure 1: Locations of interest discussed in this paper. Radars and NWS sites (blue), Cities (red), and Dropsondes (black)

2. DATA

WSR-88D NEXRAD Level-II radar data from multiple sites were utilized, (Fig.1) to depict the storms' initiation, structure, and motions. Twenty-four dropsondes were also released during the event as a part of BAMEX (Davis et al., 2004). Several key dropsondes (Fig.1) provide an excellent temporal and spatial resolution of the environment near the convection.

3. BACKGROUND ENVIRONMENT

During the morning hours on 22 June 2003, convection moved through northern Kansas, eastern Nebraska, and Iowa. Outflow from this convection, slowly moving westward, persisted into the late afternoon hours over a large section of eastern Nebraska, northeastern Kansas, western Iowa and southeastern South Dakota (Fig.2). The western outflow boundary was aligned roughly from north to south. In addition a stationary boundary extended southward from central Nebraska and a dry line existed in western Kansas (Fig.2).

The environment on the warm side of the outflow was very unstable. At 0000 UTC 23 June 2003 the Topeka,

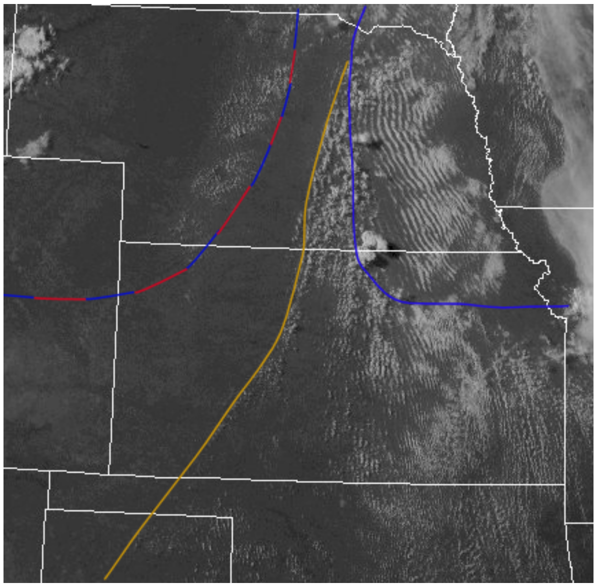


Figure 2: Analysis of the Surface Boundaries valid at 2200 UTC 22 June 2003, Outflow (blue), Dry Line (brown), and Stationary Front (blue/red)

Kansas (KTOP) sounding, representative of the warm side of the outflow, had a convective available potential energy (CAPE) of 5245 J kg^{-1} with minimal convective inhibition (CIN) around 800 hPa (Fig.3a). This unstable environment was also supportive of supercell development with a curved hodograph and a 0 to 6 km shear vector magnitude of 19 ms^{-1} (Fig.3b). Supercells were initiated on the western edge of the outflow in south central Nebraska around 2200 UTC 22 June 2003.

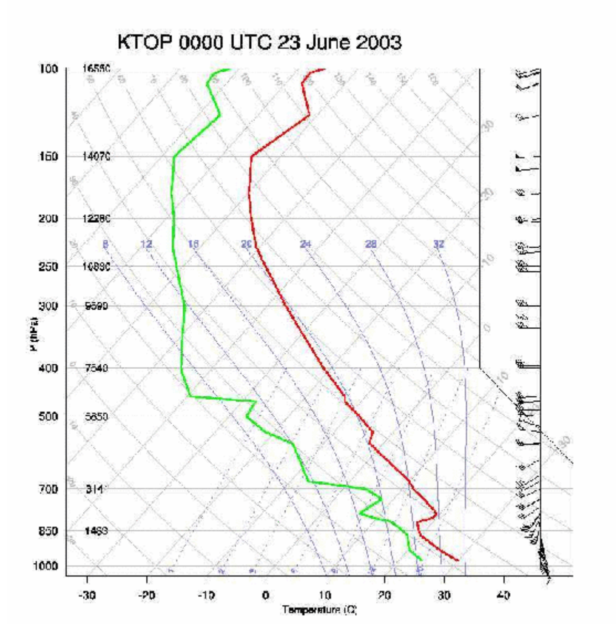
4. STORM STRUCTURE AND EVOLUTION

4.1 Initial Supercells

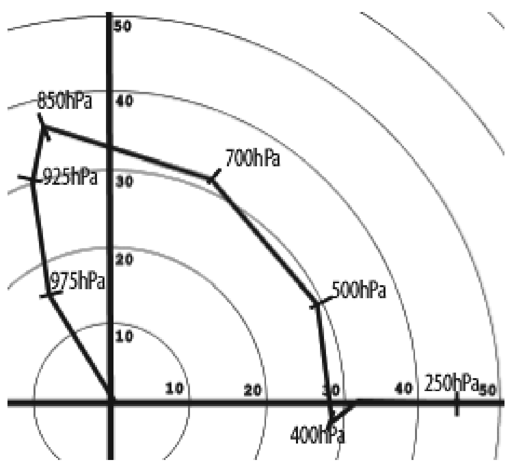
The storms that were initiated on the north-south oriented outflow boundary quickly matured into supercells (Fig.4a,b). The supercell located over Aurora, Nebraska dropped the record breaking hailstone at approximately 0005 UTC 23 June 2003 based on the National Weather Service (NWS) storm reports. A second strong supercell remained quasi-stationary near Deshler, Nebraska. The NWS storm reports document tornadoes near Deshler, Nebraska between 2340 UTC 22 June 2003 and 0030 UTC 23 June 2003.

4.2 Consolidation into a Squall Line

Between 2200 UTC 22 June 2003 and 0200 23 June 2003 six storms were initiated to the southwest of the Deshler supercell and moved northeastward. The collisions of these storms with the Deshler supercell ap-



(a)



(b)

Figure 3: Topeka, Kansas (KTOP) (a)Skew-t and (b)hodograph at 0000 UTC 23 June 2003.

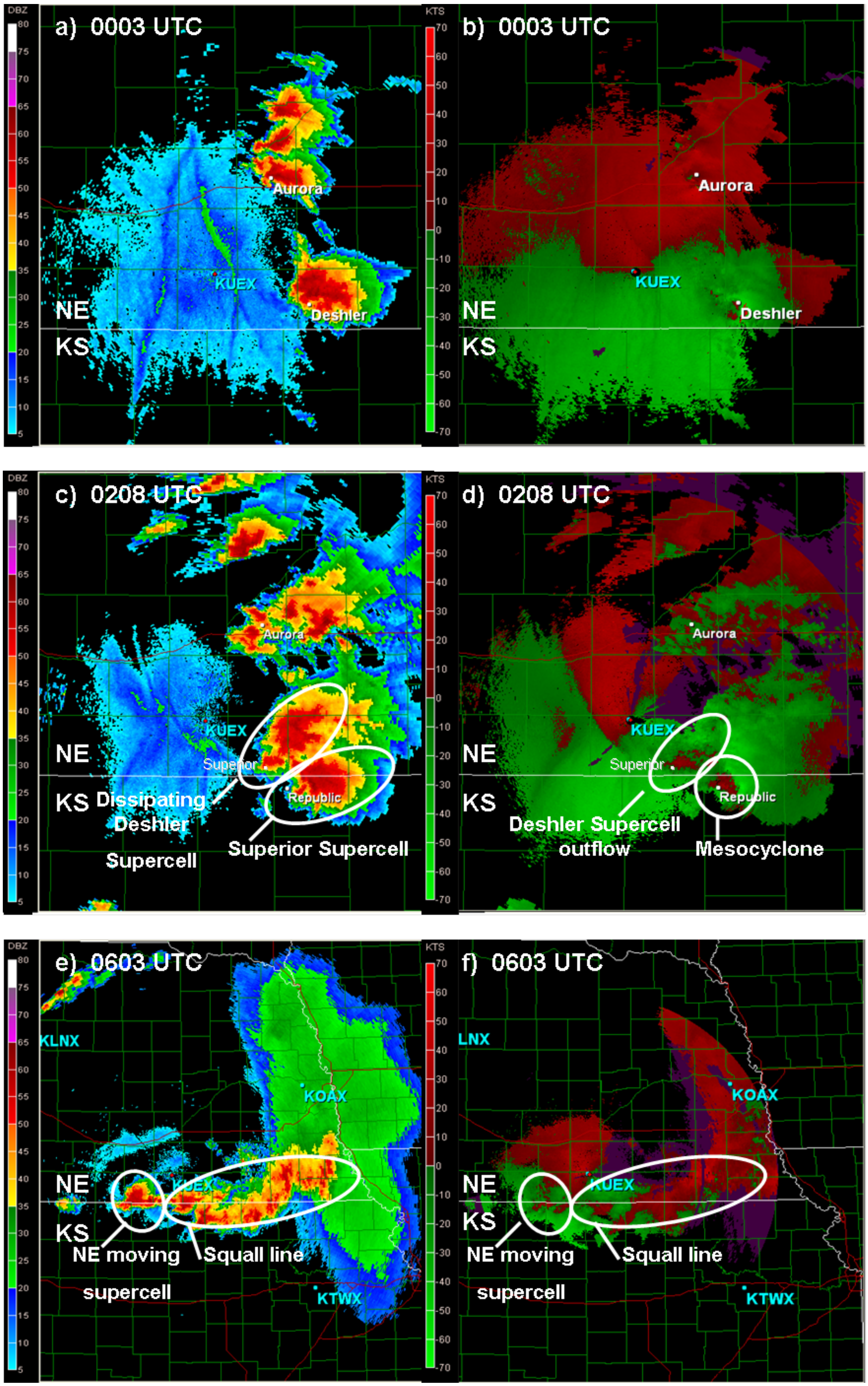


Figure 4: WSR-88D 0.5^o Radar reflectivity(left) and radial velocity(right) scans from KUEX at (a,b) 0003 UTC 23 June 2003, (c,d) 0208 UTC, and (e,f) 0603 UTC. Ovals signify areas of interest. The location of the radar is shown in Fig.1.

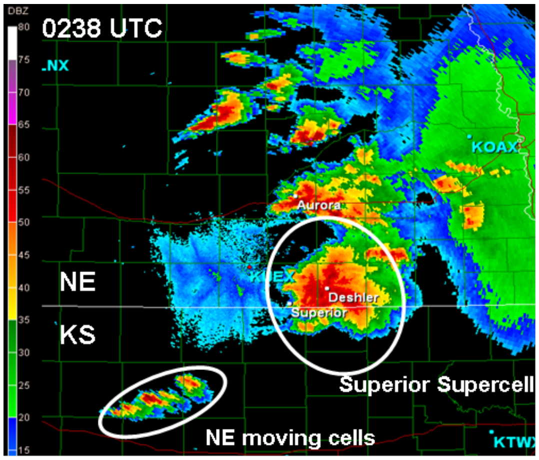


Figure 5: Radar reflectivity at 0238 UTC 23 June 2003 from the WSR-88D located at UEX. Ovals signify areas of interest.

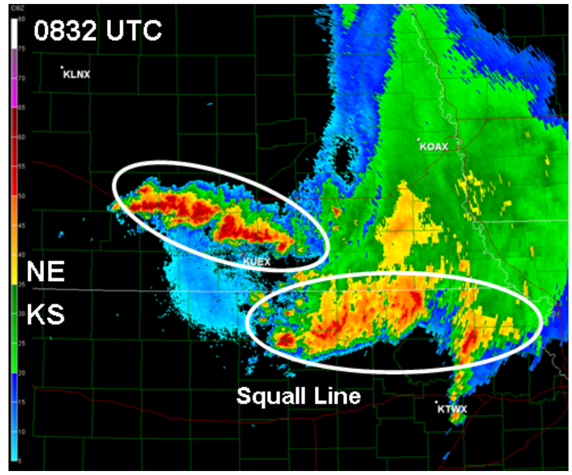


Figure 6: Radar reflectivity at 0832 UTC 23 June 2003 from the WSR-88D located at UEX. Ovals signify areas of interest

peared to change its character. Based on Doppler velocity data from Hastings, Nebraska (KUEX), by 0210 UTC the original Deshler supercell was not rotating and was predominated by low- level outflow (Fig.4c,d). The outflow was close to a mesocyclone that was associated with a supercell near Superior, Nebraska (Wakimoto et al., 2004). In turn, the Superior supercell then collided with the Deshler supercell. We hypothesize that these collisions enhanced the total precipitation mass which in turn led to a stronger cold pool. Near 0330 UTC the mesocyclone in the Superior supercell had dissipated, with only a strong outflow and elongated reflectivity core remaining. The outflow appeared to be the dominant forcing for new convection between 0330 UTC and 0800 UTC, during which time the orientation of the convection evolved into an east-west quasi-stationary squall line (Fig.4e,f).

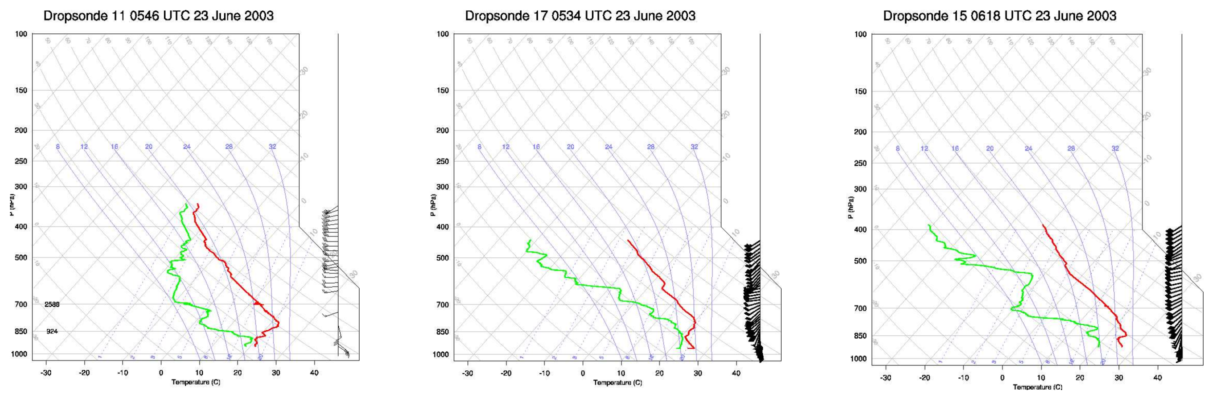
4.3 Subsequent Behavior

Around the same time that the cells in Nebraska and extreme northern Kansas were merging ($\sim$0130 UTC) additional isolated storms were being initiated along the dry line in western Kansas (Fig.5). The storms moved quickly toward the northeast. During a relatively long period of time ($\sim$0400 UTC - 0830 UTC), the storms that were initiated in Kansas and the squall line in southeastern Nebraska coexisted in close proximity to one another (Fig.4e, but exhibited different behaviors. The isolated cells appeared to be aligned with the primary squall line along the Nebraska-Kansas boarder for some time (Fig.4e). However,the western storms continued to move slowly northeastward while the squall line continued to move slowly southward. By 0830 UTC, the two complexes had moved away from one another (Fig.6).

5. IMPLICATIONS

Between 0400 UTC and 0800 UTC 23 June 2003 the two different modes of storms exhibited a nearly common leading edge, however, their forcing mechanisms were apparently different. Throughout the nighttime and early morning hours the environment experienced nocturnal radiative cooling, which would tend to stabilize the PBL and suppress “surface–based” convection. The Concordia (KCNK) and Manhattan (KMHK), Kansas surface observations reveal that the squall line continued to possess a surface cold pool well into the nighttime hours. At 0455 UTC the KCNK Automated Surface Observing System (ASOS) recorded a surface temperature of 27^{o}C with a southerly wind. Approximately ten minutes later the temperature decreased by 7^{o}C and the wind became northerly. KMHK, however, recorded a temperature of 26^{o}C with south/southeasterly winds, which did not change over the next hour. One possibility is that nocturnal convective systems with strong cold pools may continue ingesting low-level air and remain “surface–based”. This hypothesis is addressed elsewhere in this volume by Parker (2006).

The environment behind the squall line is characterized by dropsonde 11, released at 0556 UTC (Fig.7a). This environment is characterized by surface based CAPE (SBCAPE) values at 536 J kg^{-1} and surface based Convective Inhibition (SBCIN) of -467 J kg^{-1}; in short, this is the squall line’s cold pool. The environment ahead of the squall line is represented by dropsonde 17, released at 0634 UTC (Fig.7b) with SBCAPE of 2524 J kg^{-1} and SBCIN of -186 J kg^{-1}. The large SBCIN means that a deep cold pool would be necessary for the squall line to ingest the surface air. Preliminary results from radar and dropsonde analysis (Bryan



(a) (b) (c)

Figure 7: Dropsondes plotted on a skew-t/log-p diagram from:(a) 0546 UTC 23 June 2003, Drp11 (b) 0634 UTC 23 June 2003, Drp17 (c) 0618 UTC 23 June 2003, Drp15. Locations are shown in Fig.1.

et al., 2005) show that the cold pool depth was approximately 1.5 km. The surface based level of free convection (SBLFC) was approximately 2.5km AGL based on dropsonde 17. Particularly in strongly sheared evironments, it is quite possible to accomplish lifting of this depth at an outflow boundary (e.g. Weisman and Rotunno (2004)). We therefore surmise that the squall line remained cold pool – driven through the episode. The slowly southward moving cold pool explains the squall line's southward storm motion.

Some of the isolated northeastward moving storms evolved into a line by 0600 UTC. However, a supercell was also evident at the extreme western edge of the convective line (Fig.4e), and NWS storm reports document three tornadoes produced between 0600 and 0700 UTC by this supercell. The environment of this group of storms was sampled by dropsonde 15 released at 0618 UTC (Fig.7c), yielding SBCAPE of 2960 J kg^{-1} and SBCIN of -219 J kg^{-1}. The -219 J kg^{-1} SBCIN would likely supress surface–based convection. However, the most unstable air parcel located approximately 1 km AGL at 806 hPa had more CAPE (most unstable CAPE, of 3281 J kg^{-1}) and lower CIN (most unstable CIN of -31 J kg^{-1}). This preliminary evidence suggests that the isolated cells were likely elevated, although the tornado prduction remains curious.

Hodographs of dropsondes 15 released at 0618 UTC, 16 released at 0626 UTC, 17, released at 0634 UTC and 18 released at 0640 UTC (not shown), reveal that the northeastward moving cells and the slowly southward moving squall line existed in relatively similar vertical wind shear environments, suggesting that other factors are responsible for their differences. In general, the hodographs favored northeastward storm motion. Radar animations reveal that, within the squall line, individual storm motions were toward the northeast. However, propagation due to retriggering along the systems outflow boundary caused the line to move slowly southward. This reinforces the notion of a cold pool driven system, suggesting the interesting possibility that nocturnal convective systems may be surface–based despite large amounts of CIN.

6. CONCLUSIONS

On 22-23 June 2003 three different groups of storms existed in a relatively similar environment. Initially several stationary supercells developed, after which new storms rapidly moved northeastward and collided with the Deshler supercell. These collisions enhanced the total hydrometer content and thus the total precipitation mass leading to a colder, deeper, and overall stronger cold pool, that slowly propagated southward. The cold pool was responsible for the nocturnal evolution of the convection into a seemingly surface-based, east-west orientated, quasi-stationary squall line near the Nebraska-Kansas boarder. At the same time isolated storms to the southwest were moving northeastward. Large negative SBCIN values suggest that these cells were elevated, whereas there is evidence that the squall line was cold pool driven and may have continued to be surface–based.

Future studies will include using the Weather Research and Forecasting model to simulate this event. Preliminary model simulations show that the squall line evolution is well represented. With these simulations we hope to better understand how elevated and surface based convective storms might exist near one another. Studies will also include tests to better understand the initial quasi-stationary supercells observed on this day.

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ACKNOWLEDGMENTS

The research reported here is supported by the National Science Foundation under Grant ATM–0552154.