P12.6 Multiple Modes of Convection in Moderate to High Wind Shear Environments

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1. INTRODUCTION

A principle element of a severe weather forecast is the determination of the mode that the convective storms will take upon initiation, as differing modes will tend to result in different severe weather threats. Supercells tend to be producers of large hail and possibly tornadoes, while more linear modes tend to be favorable for damaging winds. Determining the mode storms will take allows forecasters to better anticipate the threats they will be facing and as such better alert the public to such threats (Doswell and Evans, 2003). In this vein, much research has been focused on the factors that determine convective mode. To date many of these studies, both observational and numerical, have focused on the relationship between vertical wind shear and convective modes, essentially concluding that different modes of convection are the result of different environmental vertical wind shear profiles (e.g. Bluestein and Parker, 1993, Weisman and Klemp 1982, Bluestein and Weisman, 2000).

This convention, however fails to account for occurrences of multiple modes of convection being observed in a fairly localized area that contains a uniform shear profile, namely cases of high shear wherein supercells would be expected, however linear modes are present as well. One such case took place during the afternoon of 30 March 2006 across central and eastern Kansas (Fig. 1). This paper looks to examine the forcings that resulted in multiple modes of convection across this fairly localized area, wherein morning radiosonde observations suggested generally uniform shear. An observational case study of the event will be discussed to set the stage for future numerical simulations of the event.

2. METHOD

In order to better understand the problem of multiple modes of convection in high-shear environments the case of 30 March 2006 was examined using available observational datasets. The synoptic conditions were determined using 1200 and 1800 UTC radiosonde observations from the operational observing network. Regional ASOS surface observations provided insight into surface features including key boundaries. WSR-88D Doppler radar observations from KICT and KTWX provided base reflectivity and Doppler velocity observations covering the scope of the storm. Finally, the radiosonde wind profiles were supplemented by hourly observations from local sites in the NOAA Wind Profiler network. The observations were analyzed to ascertain key surface and upper air features, as well as storm structures and evolution resulting in a detailed picture of the storm from 1700 UTC initiation through weakening at 2200 UTC.

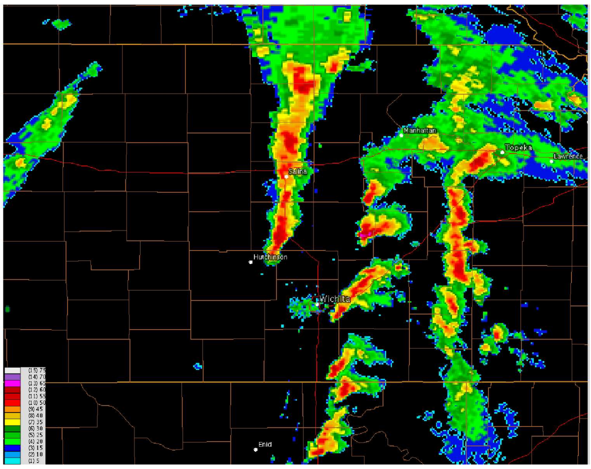

Figure 1: Long range base reflectivity from KICT at 1931 UTC 30 March 2006.

3. RESULTS

3.1 Overview of event

The synoptic conditions present at 1200 UTC on the morning of 30 March 2006 were indicative of an atmosphere primed for severe storms. An 850 hPa trough with a slight negative tilt was present over the central CONUS, with warm air advection occurring across

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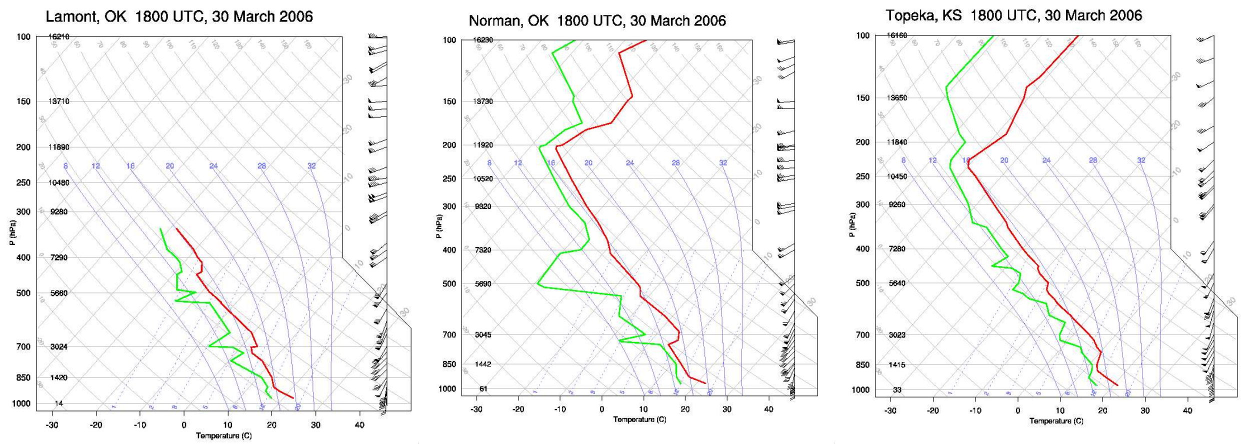


(a) (b) (c)

Figure 2: 18 UTC Skewt diagrams for a) Lamont, OK, b) Topeka, KS, and c) Norman, OK

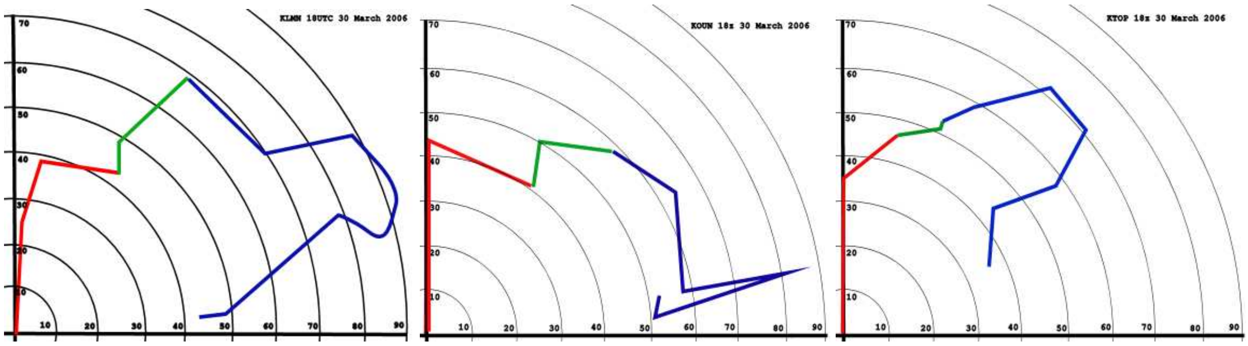
much of the central and southern plains. A 25 m/s low level jet extended from north central Oklahoma into northeast Kansas, enhancing low level wind shear as well as moisture and temperature advection into the central plains. A neutrally tilted cold-core trough over the eastern Rocky Mountains was the key feature at 500 hPa, with temperatures of -25°C over parts of Colorado and Utah. A negatively tilted trough was present at 250 hPa across the west-central CONUS with attendant 54 m/s jet over New Mexico, which was entering the central plains over Kansas and Oklahoma. Morning soundings across the central plains indicated a wide area of 500-1000 J/kg of CAPE across much of Oklahoma and Kansas extending southward into Texas, along with CIN values less than 100 J/kg over the same area and 0-6 km shear magnitudes 12-16 m/s. By the time special 1800 UTC soundings were taken across the region, the maximum CAPE values were still near 1000 J/kg, however the area of this instability had shifted to the east, spanning from north-central Oklahoma into northeastern Kansas (Fig. 2). There was little CIN across central Oklahoma with a maximum of -88 J/kg in eastern Kansas. The shear magnitude in the lowest 6 km was between 18-25 m/s over the region, maximized over central Oklahoma, where there was also a maximum in 0-1 km helicity of approximately 200 m^2/s^2 (Fig. 3)

Key features at the surface in the southern plains included a cold front that extended from southwestern Nebraska into the Texas panhandle, which progressed eastward throughout the day, a deepening low pressure center located along the Kansas/Nebraska border, and a strong dryline that stretched from northern Kansas southward through Oklahoma and progressed eastward during the course of the day.

The first storms of the event were a pair of cells that were initiated in north central Oklahoma at approximately 1630 UTC as part of a line of isolated cells that formed along the dryline across Oklahoma (Fig.4a). These initial cells moved northeastward into Kansas and eventually dissipated in northeast Kansas at approximately 2030 UTC. However new cells had developed to the southwest of these initial ones and were still well organized at this time. The western most line of convection was initiated along the dryline at approximately 1730 UTC and progressed eastward while expanding toward the south-southwest (Fig.4b). It eventually dissipated in northeast Kansas at approximately 0000 UTC 31 March. The final element to be initiated was the eastern most line that developed ahead of the supercells at approximately 1915 UTC in eastern Kansas (Fig. 4c) and progressed eastward while expanding to the north and south, eventually dissipating in northwest Missouri around 2230 UTC. Thus by 2000 UTC there were both isolated cellular and linear modes of convection present over a rather small geographic area in eastern Kansas (Fig.4d). Each of these events will be discussed in detail in the following sections. This storm system resulted in severe weather in all its forms, including several tornadoes, numerous hail reports, some over 5cm in diameter, and, to a lesser extent, severe winds, across much of central and eastern Kansas as well as surrounding states.

3.2 Evolution of Cells

The supercells in this case were initiated in a northeast-southwest line around 1645 UTC along a slight dry-



(a) (b) (c)

Figure 3: 18 UTC hodographs for a) Lamont, OK, b) Topeka, KS, and c) Norman, OK. Red denotes surface-850 hPa,green 850-500 hPa, blue 500-100 hPa

line bulge located in north central Oklahoma (Fig.4a). The storms progressed toward the northeast into central Kansas. While the cells were initiated fairly close to one another, they managed to remain isolated as they progressed northeastward, across central and eastern Kansas. The initial cells dissipated in eastern Kansas by 2030 UTC, however several strong cells were still ongoing across southeast Kansas and into north-central Oklahoma at this time and a final isolated, strong supercell was initiated along the Kansas/Oklahoma border south of Wichita at approximately 2100 UTC and proceeded to move towards the northeast much like its predecessors (Fig.4e-f). Not only did the initial cells maintain their cellular nature despite moving through a region characterized by linear modes of convection to the east and west, but a new supercell was able to develop in the region just south of the western line of convection. (Fig 4e).

3.3 *Evolution of Western Line*

Shortly after the initiation of the first cells in western Oklahoma, around 1715 UTC, a group of closely spaced cells in a north-south line developed in central KS (Fig 4b). These cells merged into a line that developed rapidly to the south just ahead of the dryline that was moving through west central Kansas. While the line developed to the south, it moved in a predominantly eastward fashion. It began to lose its linear structure over northeast Kansas by 2200 UTC, however it continued to progress eastward as a loose cluster of convection through the remainder of the event (Fig.4f).

While the aforementioned supercells appeared to move off of the dryline as it progressed to the northeast, the western line appears to have remained close to the dryline itself, as evidenced by the short time span between passage of thunderstorms and passage of the dryline seen in surface METAR reports (Fig.4b-e). Despite being initiated not long after the supercells, this line moved more slowly, such that eventually several of the northeastward moving supercells were directly in front of it (Fig.4d).

3.4 *Evolution of Eastern Line*

The final feature in this event was a line of convection that developed in eastern Kansas shortly after 1900 UTC (Fig 4c). This line developed ahead of the group of supercells moving through east-central Kansas and then moved eastward while developing both to the north and south in areal extent. It eventually moved into western Missouri, and significantly weakened by 2330 UTC. The exact means of initiation for this line remains somewhat mysterious given the dearth of observations in eastern Kansas. However, based on the appearance of the line on radar, especially during its initiation, it appears that it developed along an outflow boundary that originated from the line of supercells that was in east central Kansas by 1900 UTC, which may have interacted with another outflow boundary left by convection that moved through eastern Kansas earlier in the day.

4. DISCUSSION

Based on the observations described above, several possible explanations emerge as to why multiple modes of convection were possible over a very limited area on 30 March 2006. One key feature that stands out is that both the supercells and western line were initiated along the dryline, however they evolved as entirely different modes. The supercells were broadly spaced along the line, and upon initiation, they moved off of the dryline

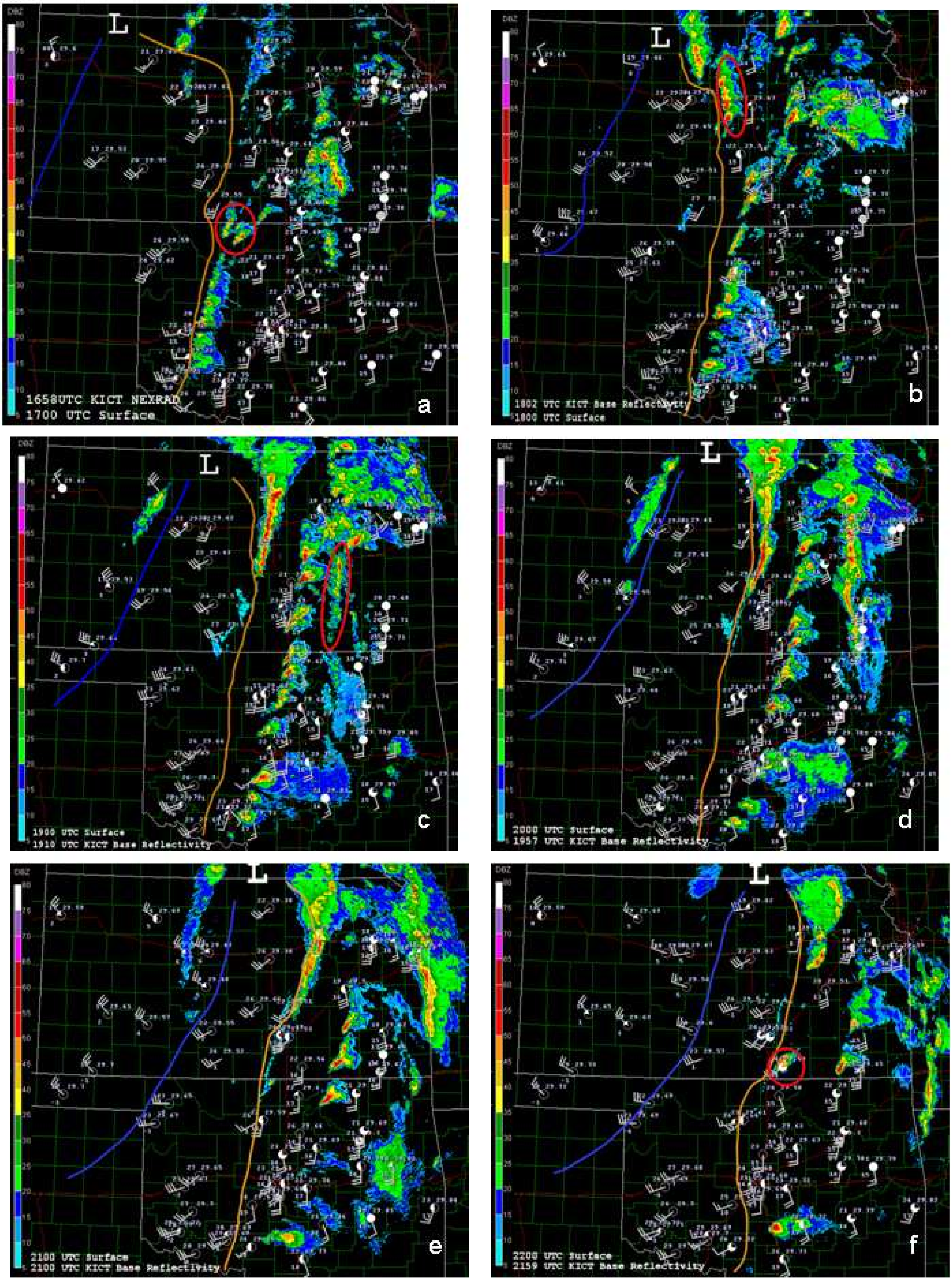


Figure 4: Composite of KICT Base reflectivity and surface observations. a)1700UTC Supercell initaition highlighted in red. b)1800 UTC, Western line initiation highlighted in red. c)1900 UTC Eastern line inititation highlighted in red. d)2000 UTC All three modes present, e)2100 UTC Initial supercells have dissipated, newer ones remain as well as both lines. and f)2200UTC Both lines and supercells have largely dissipated, new supercell forming highlighted in red. The blue line indicates the position of the surface cold front and the tan line the position of the surface dryline. The approximate location of the surface low pressure center is denoted by a bold L.

rather quickly, becoming independent of their forcing mechanism and taking on isolated cell characteristics. Meanwhile, the western line was initiated as a group of closely spaced cells along the dryline, and it failed to move very far off the line, remaining very close to this linear forcing throughout its lifetime. The ability of these storms to move off (or not move off) of the dryline appears to have played a role in their ultimate mode. This independence from the dryline may be due to the line being initiated along a fairly straight section of the dryline while the supercells were initiated in an area wherein there was a slight eastward bulge in the line. This bulge could orient the storms such that rather than interacting with each other, they are able to remain independent, and move off of the line (Bluestein and Weisman, 2000). The current evidence suggests that the orientation of initiation mechanism and the cell spacings may play a key role in the mode storms will eventually take, perhaps more so than the environmental wind shear.

This interpretation is partly reinforced by the appearance of the easternmost line, as said line appears to be initiated in a linear manner. As discussed earlier, the mechanism that forced the easternmost line remains a mystery. When viewed in a radar loop the origins of this line appeared to be tied to a boundary that moved off of the line of supercells (Fig.5). The new line of convection develops rapidly around the time when radar data suggest that this outflow from the supercells is interacting with some other pre-existing boundary. Thus a possible explanation for development would be due to an interaction or collision of outflow boundaries, as described by Intrieri, Bedard and Hardesty (1990). Unfortunately, the purported outflows are not obvious in the surface observations, so the question remains open.

5. FUTURE WORK

While the observational case study provided a great deal of insight into the nature of the 30 March 2006 multimodal storm system across Kansas, it also inspired new questions that could not be answered by observations alone. A good way to answer these questions is through numerical simulations of this case. A real-world simulation of the case was attempted using the Weather Research and Forecasting (WRF) model and a variety of datasets and initiation times, however none of these attempts appeared to faithfully depict the key mesoscale boundaries that initiated the storms in the observed case. In light of this, a more idealized approach will be taken to test some of the hypotheses generated based on the observational study. Namely, the WRF model will be used to examine the sensitivity of convective mode to variations in the environmental shear and thermodynamic profiles, as well as variations in the trigger mechanism used to initiate storms. It is anticipated that these results will shed further light on how multiple modes of convection can be present over a rather small geographic area. Furthermore, it may answer some of the questions that remain about the dominant mechanisms in the observational study.

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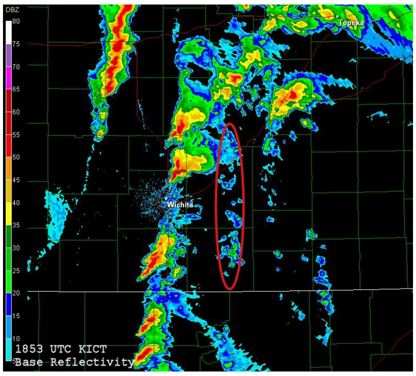

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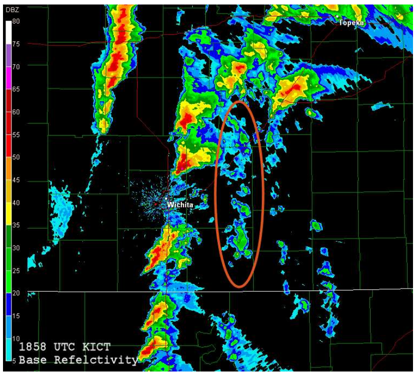
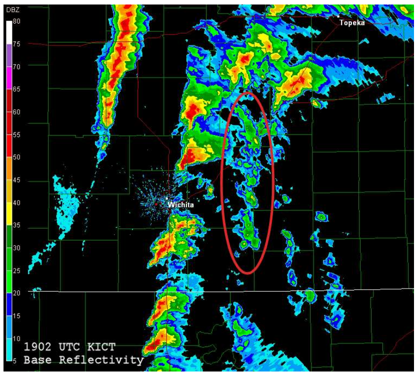
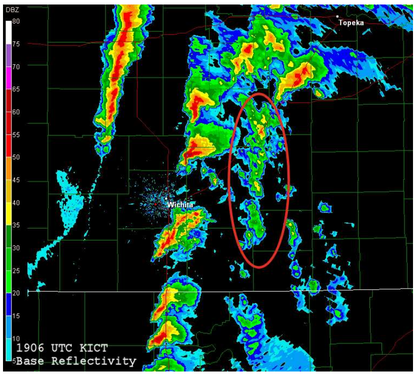


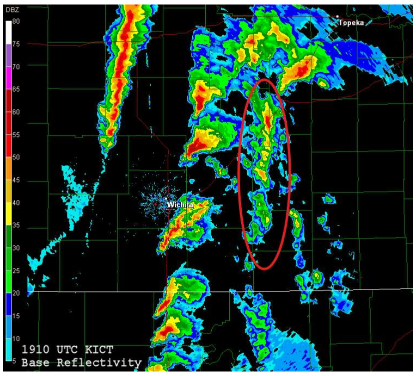
(b) 1858 UTC



(c) 1902 UTC



(d) 1906 UTC



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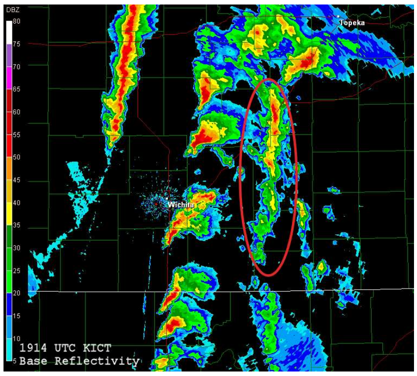

(f) 1914 UTC

Figure 5: Time series of base reflectivity from KICT showing the initiation of the eastern line. Times are noted under each figure. Area of interest is outlined in red.