Tornadoes in close proximity to a major winter storm event over East Central Colorado

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1. Introduction

On 24 April 2007, eleven tornadoes developed over the eastern sections of the Palmer Divide in east central Colorado, from near the town of Boyero in Lincoln county, east to the Colorado/Kansas border west of the town of Sharon Springs, KS (Fig. 1). Most of the tornadoes were short lived, but a couple were on the ground for several miles and lasted tens of minutes (Table 1).

2. Synoptic Background

At 1200 UTC, 24 April 2007, a 500 mb upper level low was located over the Colorado/New Mexico border north of Albuquerque (Fig. 2). At the surface, a strong surface low was located over southeast Colorado in the vicinity of La Junta. A sharply defined occluded front extended to the east of the surface low to a triple point located near Hill City, Kansas. By 18 UTC, the surface low was located in the vicinity of Lamar, Colorado with the occlusion still extending well into Kansas. Surface winds across Colorado north of the occlusion were from the east-northeast at 7 to 13 ms^{-1} (15 to 25 mph), with temperatures in the 50s and dewpoints in the 30s and 40s. South of the occlusion, winds were from the west-southwest at 7 to 13 ms^{-1} (15 to 25 mph) with temperatures in the upper 50s and dewpoints in the 30s. Behind the surface low, over the western Palmer Divide, strong north to northwest winds of 10 to 20 ms^{-1} (20 to 40 mph) were occurring along with heavy snow at elevations generally above 6000 feet. Figure 3 shows the surface map just prior to 18 UTC.

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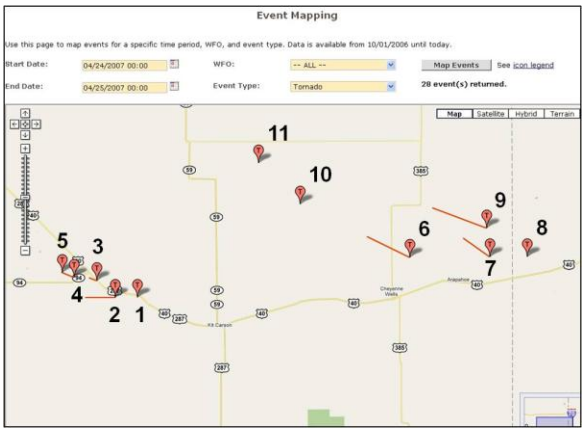

FIG. 1. Location of the 11 tornadoes which occurred on 24 April 2007 across the greater east central Colorado region. Note that the tornadoes in this case moved in a generally westerly direction.

TABLE 1. Time, EF#, length and width of the 11 tornadoes. The numbers below represent the tornadoes shown in FIG. 1. LST = UTC - 7

#	*Time (UTC)*	*EF#*	*Length (mi)*	*Width (yds)*
1	1758-1759	EF0	0.5	10
2	1815-1825	EF0	4.0	25
3	1838-1842	EF0	1.0	25
4	1842-1846	EF0	1.0	50
5	1858-1858	EF0	0.1	50
6	1926-1936	EF1	4.5	25
7	1937-1945	EF0	4.0	25
8	1948-1949	EF0	0.5	25
9	1955-2014	EF0	5.0	50
10	2000-2001	EF0	0.5	10
11	2000-2001	EF0	0.5	10

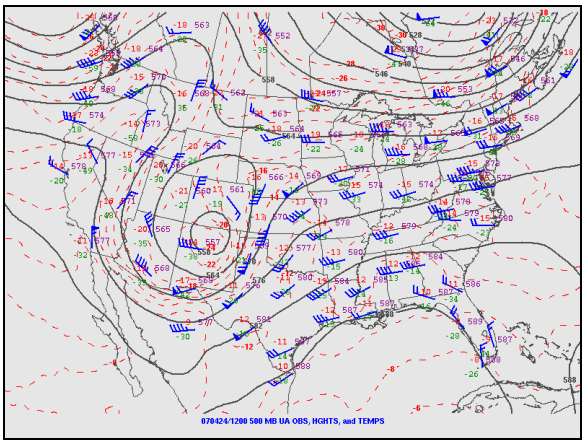

FIG. 2. 500 mb pattern over the Continental United States at 12 UTC 24 April 2007.

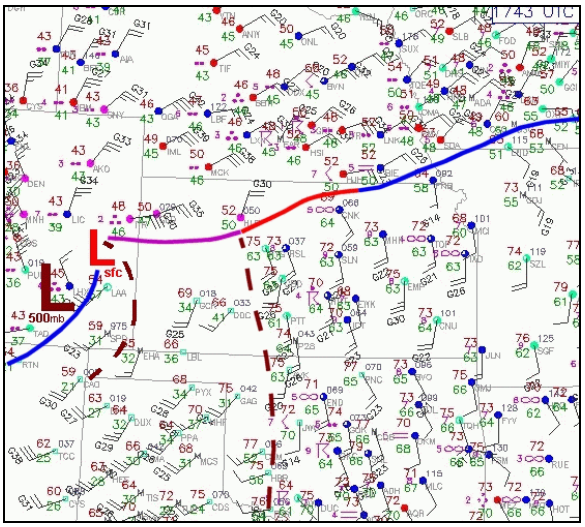

FIG. 3. Surface chart at 1743 UTC across the High Plains. Image courtesy J. Davies.

3. Radar Analysis

Figures 4a-c shows the 0.5 degree regional radar data from KPUX along with all available surface observations at 1800, 1900 and 2000 UTC respectively. These images show the heavy snow (and heavy rain below elevations of ~6000 feet), along with the small tornado producing supercells. At all three times tornadoes were in progress (see Table 1 and Fig. 1). The tornadoes were occurring along the occluded boundary which extended east-west across east central Colorado. Surface observations in the

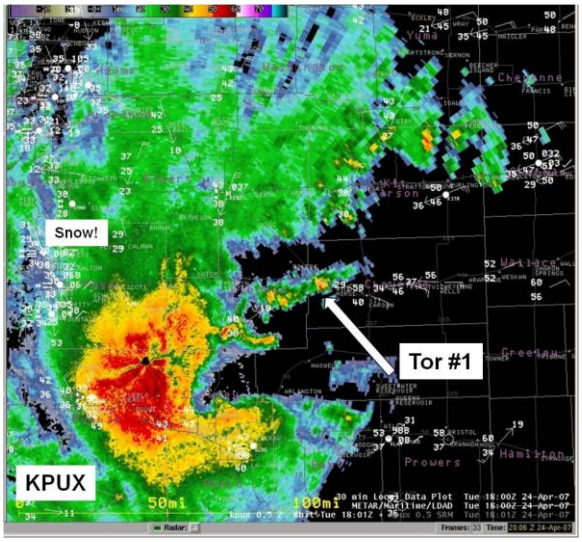

FIG. 4a. KPUX 0.5 reflectivity and surface observations at 1800 UTC. Tornado producing mini supercells are annotated (see FIG. 1 and TABLE 1).

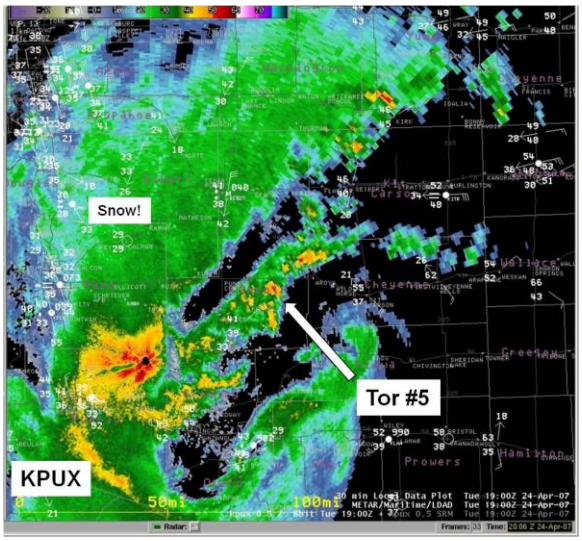

FIG. 4b. Same as FIG 4a except 1900 UTC.

vicinity of the tornadic storms indicated temperatures were generally in the 50s while dewpoints were in the 30s and 40s. Interestingly, heavy snow was noted to be occurring ~100 km (~60 miles) to the west of where the tornado activity was occurring.

Not surprisingly, the storms which produced the tornadoes were small both in vertical and horizontal extent (Davies 2006, Kennedy et. al. 1993, Markowski and Straka, 2000). The

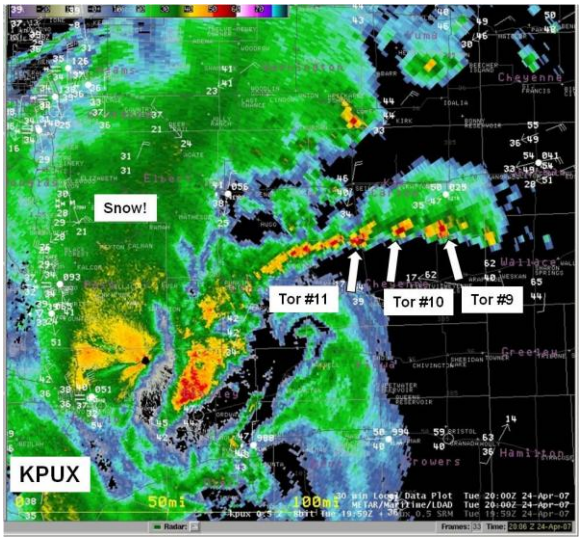

FIG. 4c. Same as FIG. 4a except at 2000 UTC.

mini-supercells were generally about 9 km (30 kft) deep and extended horizontally about ~6 km (4 mi). Radar velocity products did show weak persistent rotation with quite a few of the cells, but the velocity couplets were (obviously) small and were only observable in the lowest volume scans. Interestingly, these supercells showed characteristics of mini supercells which are found in the outer rainbands of tropical cyclones (Hodanish et. al, 1997, Spratt et, al, 1997) Figures 5a-c show close-in radar imagery of several of the supercells, with base reflectivity, reflectivity cross sections and storm relative velocity images shown.

4. Discussion

So why did so many tornadoes occur across east central Colorado? Although the ambient temperatures and dewpoints were quite low, temperatures aloft were very cold (500 mb T= -20C; 700 mb T= -3C, and favorable insolation (Fig. 6) allowed for the ambient temperatures to warm. This allowed for a favorable thermodynamic environment for low topped convection to develop. An examination of a RUC sounding in the vicinity of the tornadic supercells, using

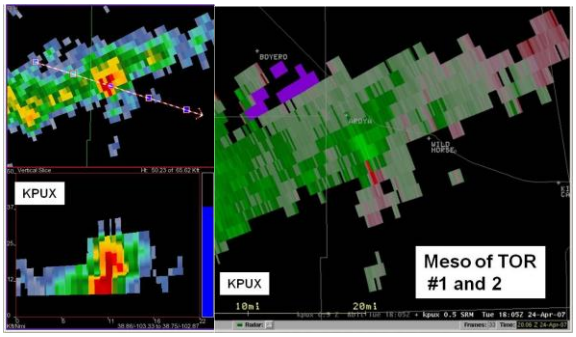

FIG. 5a. KPUX radar data at 1805 UTC. Low level (0.5) base reflectivity is shown (upper left), reflectivity cross section (lower left) and 0.5 SRM velocity (right). This mini supercell just produced tornado #1 and was about to produce tornado #2.

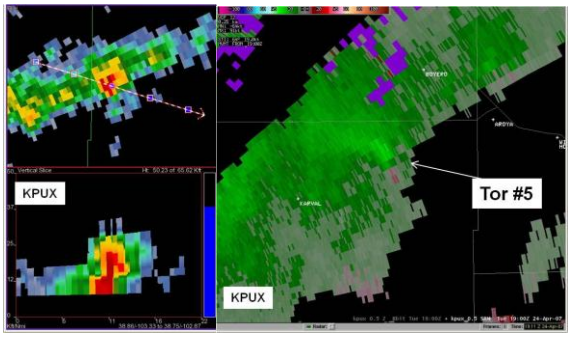

FIG. 5b. Same as FIG 5a except at 1900 UTC. The mesocyclone of tornado #5 is annotated.

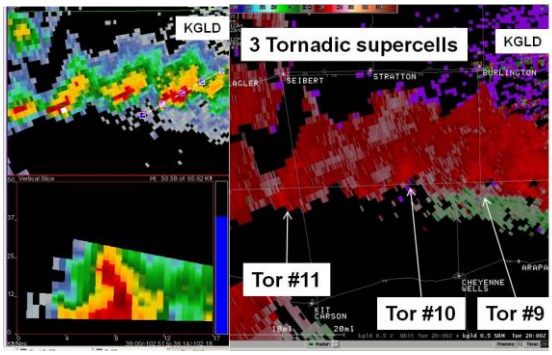

FIG. 5c. KGLD radar data at 2000 UTC. Low level (0.5) base reflectivity is shown (upper left), reflectivity cross section (lower left) and 0.5 SRM velocity (right). Three mini supercells are shown. All three were producing tornadoes at this time.

temperature and dewpoint values observed in the inflow region of the storms, indicated about 850 J/KG of mean layer CAPE was available (Fig. 7). Nearly all this CAPE was noted below 400 mb. LCLs, given the low

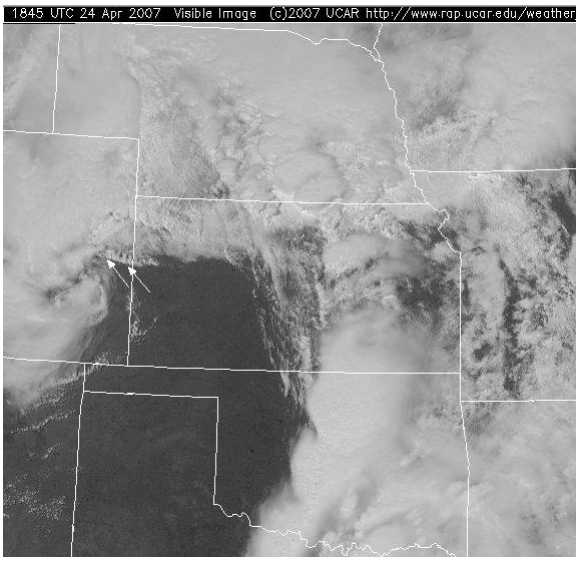

FIG. 6. Visibile image at 1845 UTC showing the low topped rotating convection (arrows) across east central Colorado. Note the clear skies south of the boundary. Image courtesy J. Davies.

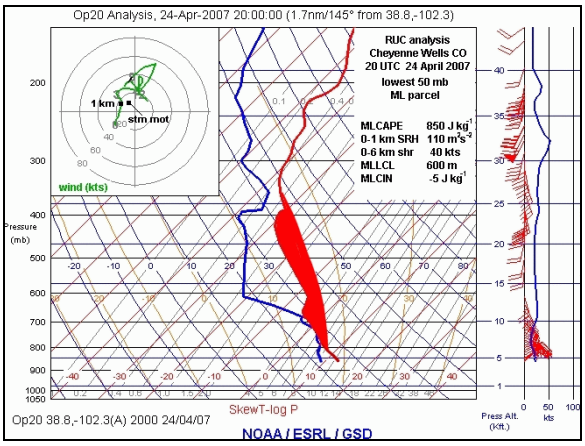

FIG. 7. RUC analysis in the vicinity of Cheyenne Wells Colorado at 2000 UTC 24 April 2007. Three tornadic supercells were in progress in the vicinity of Cheyenne Wells at this time (see FIG. 5c). Figure courtesy J. Davies.

T/Td spreads, were quite low. CIN was near zero. Wind fields favorable for tornadic storms were also present, as strong low level shear was indicated (0-1 km SRH 110 m^2s^{-2}, while deep layer shear was 20 ms^{-1} (40 knots). The occluded front acted as a favorable boundary (strong low level shear) for the rotating storms to form on.

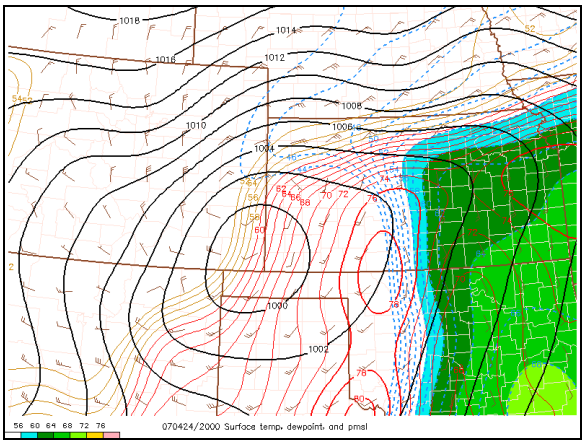

FIG. 8a. SPC RUC mesoanalysis Temperature and Dewpoint plot at 2000 UTC.

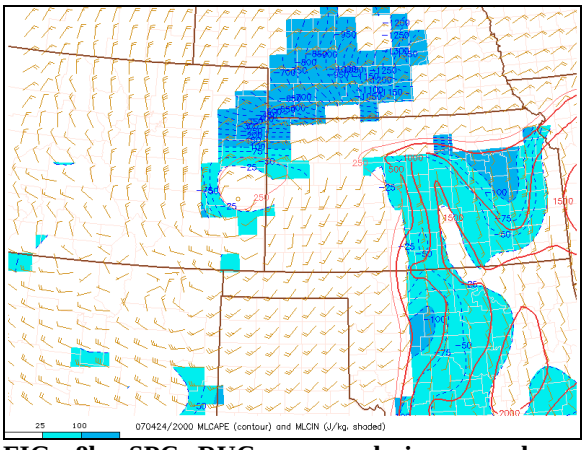

FIG. 8b. SPC RUC mesoanalysis mean layer CAPE plot at 2000 UTC. The mean layer CAPE was less than what was calculated in FIG. 7. The reason for this is the RUC analysis temperatures and dewpoints were actually lower than what was observed (See FIG. 4c for actual temperatures and dewpoints in the vicinity of the tornadic supercells).

An examination of SPC mesoananlysis charts around the time of the tornado activity indicated CAPE values lower than what was observed in Fig. 7. The reason for this is the lower temperature and dewpoint values in which the RUC model data was calculating. In reality, the temperatures and (especially the) dewpoint values were a few degrees higher than what was being simulated in the RUC analysis fields (Fig. 8a-b).

5. Summary

During the late morning and early afternoon of 24 April 2007, and localized tornado outbreak occurred across the greater east central Colorado region. A total of 11 tornadoes occurred during a two hour period (Fig 9). Several aspects of this event were unique. First, the ambient temperatures and dewpoints in the immediate vicinity of the tornadic supercells were quite low. Ambient temperatures were in the 50s while dewpoints were in the 30s and 40s. Second, during the time of the tornadoes, heavy snow was falling over the western sections of the Palmer Divide, only ~100 km (~60 miles) to the west (Fig 4a-c). Third, the tornadoes occurred quite early in the day, with the first tornado occurring around 11 am mst (18Z) while the last tornado ended around 1 pm mst (20Z; see Table 1). Fourth, the spatial dimensions of the storms were quite small, both in horizontal and vertical extent (storm height 9 km [30 kft], 6 km [4 miles] width; Fig 5a-c). Fifth, the mini supercells and associated tornado activity traveled from the east to the west. Sixth, the event was not well forecast in advance (Fig. 10).

Deep shear necessary for rotating convection combined with sufficient CAPE in the lower part of the atmosphere allowed for the low topped supercells to form on the occluded boundary. Low LCLs combined with strong low level shear and little or no CIN likely played a role in tornado formation

5 Acknowledgments

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6 Bibliography

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FIG. 9. One of the tornadoes that occurred on 24 April 2007. This was tornado # 9 in table 1. Photo taken at 2008 UTC. Photo courtesy of Al Pietrycha.

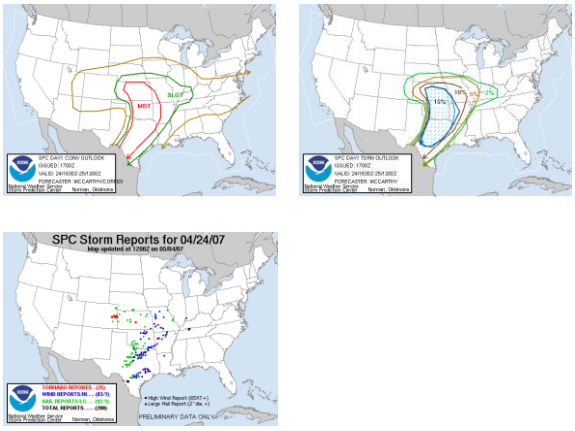

FIG. 10. SPC forecasts issued at 1700Z along with preliminary severe storm reports for 24 April 2007. The first tornado in east central Colorado occurred at 1758Z. Overall, from a national perspective, the severe weather event was well forecast, except for the localized tornado outbreak in the east central Colorado region.