P 12.6 THE 10 MAY 2004 LIMON, COLORADO TORNADIC EVENT: AN EXAMINATION OF A CYCLIC TORNADIC SUPERCELL IN A WEAK UPPER LEVEL FLOW ENVIRONMENT

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1. INTRODUCTION

On 10 May 2004, a tornadic supercell thunderstorm developed over the Palmer Divide region of east central Colorado, just to the west and northwest of Limon. A total of 7 tornadoes occurred with this storm over a ~2.5 hour time period (Fig. 1). During the Spring, it is not uncommon for tornadic supercells to develop over the higher terrain of east central Colorado. What makes this case atypical is that the upper level storm relative flow was weak, yet the supercell produced a large number of tornadoes over an extended period of time. This paper will examine the meteorological conditions associated with this event.

2. METEOROLOGICAL ANALYSIS AND FORECAST FIELDS PRIOR TO STORM DEVELOPMENT

Meteorological conditions for rotating convection were favorable across the eastern Plains of Colorado during the late afternoon and evening of 10 May 2004. On the large scale, a 500 mb trough was located over the western United States, and this feature was causing moderate surface cyclogenesis (993 mb surface low) over east central Nevada. This in turn was causing enhanced low level southeasterly flow over the eastern Plains of Colorado. In addition, during the previous night, an MCS developed over the Kansas/Colorado border and moved east. An outflow boundary from this MCS developed and moved westward towards the higher terrain of eastern Colorado during the late morning and afternoon of the 10th. This outflow boundary brought moist low level air (dewpoints into the 50s F° (10-13C°))into the eastern plains. Skies across east central Colorado during the early afternoon remained clear, which permitted the low level atmosphere across the Palmer Divide region to become moderately unstable.

The 18 UTC 10 May 2004 RUC analysis indicated flow at mid levels was modest, with southwest winds 10 m s^{-1} over the eastern Plains of Colorado (Fig. 2)). This 500 mb flow was forecast to not strengthen during the remainder of the afternoon or evening. Although flow at mid levels was modest, deep layer shear was forecast to be sufficient for supercell thunderstorms, as the 0-6 km shear was forecast to be 20 m s^{-1} . In the upper levels, flow aloft at jet stream level was forecast to be rather weak, with 10 - 15 m s^{-1} southwest winds

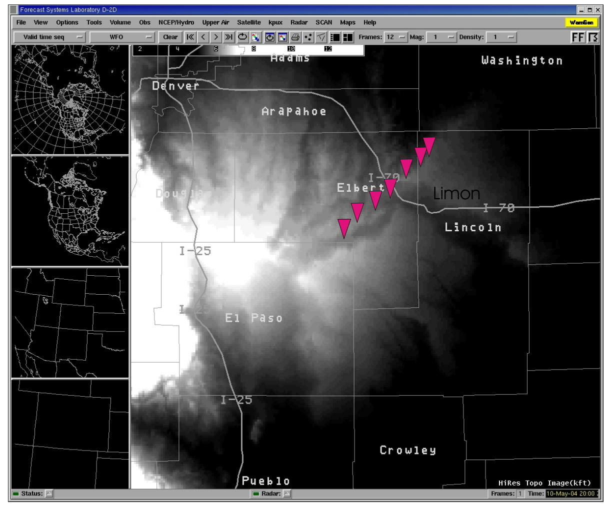

***Figure 1**. Topographical map of the Palmer Divide in east central Colorado. Areas between 1524 m (5000 ft) and 2134 m (7000 ft) emphasized. General track of tornadoes shown with triangles. Counties are labeled along with interstate highways.*

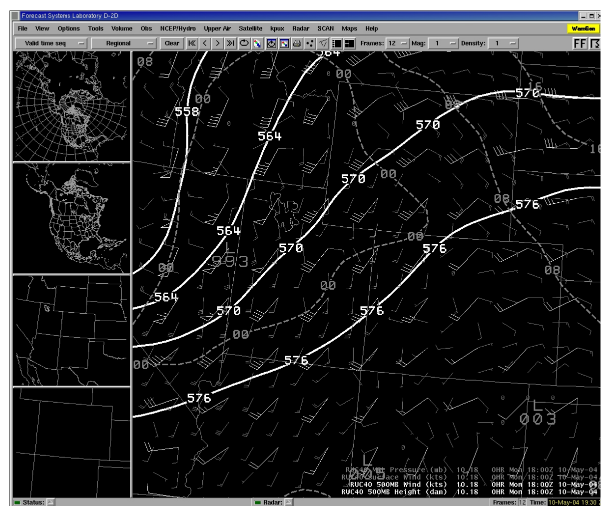

***Figure 2**. RUC-2 analysis at 1800 UTC 10 May 2004. Thick white lines are 500 heights, large wind barbs are 500 mb winds (knots), dotted lines are surface pressure, and small wind barbs are surface winds (knots).*

forecast at 00 UTC 11 May 2004 over the region. Any deep convection which would develop and move northeast with the mean flow would be in a weak storm relative anvil flow regime. This storm relative anvil flow

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would favor any rotating convection to transition to high precipitation supercells (Rasmussen and Straka, 1998), and become more of a large hail and damaging wind threat. At 3 pm MDT (2100 UTC), the NOAA/Storm Prediction Center issued Severe Thunderstorm Watch #179 for the eastern Plains of Colorado.

3. RADAR EVOLUTION

The outflow boundary which developed from the Kansas MCS the night before arrived over the Palmer Divide (El Paso and Elbert counties, CO) around 2000 UTC (Fig. 3). An area of cumulus clouds over this region prior to the arrival of the outflow boundary developed into a north-south line of broken convection after the boundary arrived. Once developed, the activity moved to the north-northeast at 7 m s^{-1}. Interestingly, as the convection moved northeast over the lower terrain north of the Palmer Divide (Fig. 1), it weakened and dissipated as it moved into a more stable airmass. Meanwhile, new convection developed over the south side of the Palmer Divide. This process continued on for the next ~2 hours.

Around 2145 UTC, one storm in the broken line of convection over northeast El Paso county became stationary. This storm remained motionless for approximately 2 hours and gradually took on marginal supercellular characteristics (weak to moderate mid level rotation). At 2330 UTC, a new storm developed to the to the southwest of the stationary storm and moved north-northeast, colliding with the stationary cell. After this interaction, both storms congealed and the convection took on classic supercellular characteristics, with the mesocyclone intensifying. It was shortly after this time (0033 UTC) that the storm began to produce the first tornado. As this cell moved to the northeast across Elbert county west of Limon, it produced an additional 6 tornadoes through 0249 UTC. This tornadic supercell storm also eventually weakened as it moved northeast over the lower terrain north of the Palmer Divide.

4. DISCUSSION

Why was this supercell so efficient at producing tornadoes over an extended period of time when the storm relative flow aloft was weak (Fig. 4)? Although meteorological conditions were quite favorable for supercells, the flow at upper levels of the troposphere did not support a classic, long lived, cyclic, tornadic supercell. Given the upper level storm relative wind flow pattern for this event, any supercell should transition to HP mode (Rasmussen and Straka 1998; Fig. 5). Storm chasers who were observing the storm from an early stage indicated it was initially an LP supercell, which gradually transitioned into a classic supercell. It was after the storm transitioned to classic that tornadogenesis occurred. All of the tornadoes were clearly visible, except for the first which became rain wrapped. During the last long lived tornado, the storm took on visual characteristics of a “dry end” classic supercell.

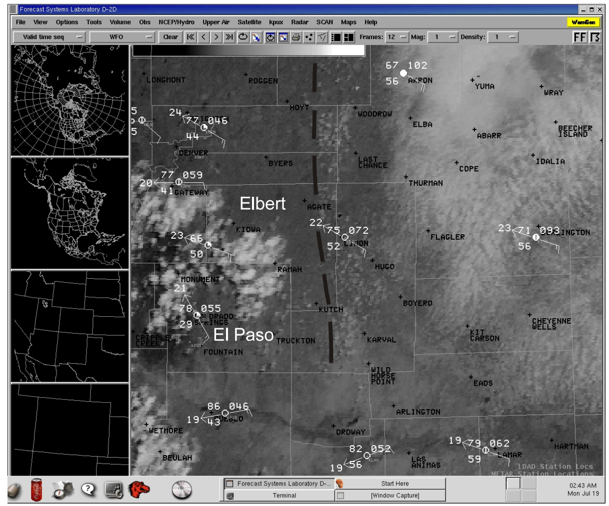

Figure 3*. 1930 UTC 10 May 2003 visible satellite image with 1900 UTC METAR observations over east central Colorado. Dashed black line represents leading edge of westward moving outflow boundary. Elbert and El Paso counties are labeled. Wind barbs in knots.*

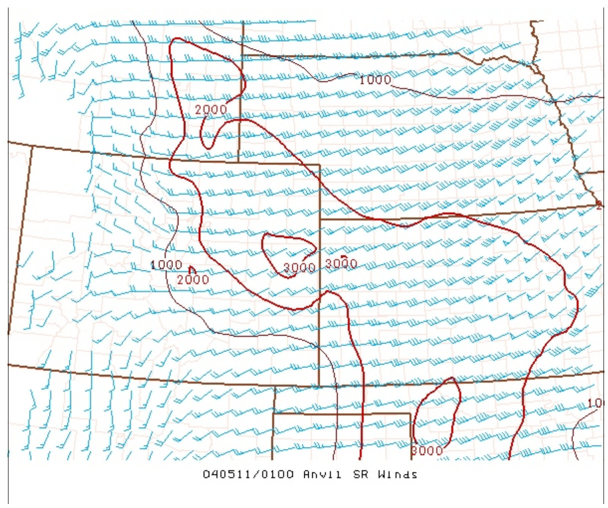

Figure 4*. Storm Prediction Center RUC-2 analysis of storm relative anvil flow and surface based CAPE at 0100 UTC 11 May 2004. Wind barb in knots.*

Why this storm was tornadic is now discussed. An examination of the 01 UTC 11 May 2004 RUC2 sounding in the vicinity of Limon CO indicates low level meteorological variables typically associated with tornadogenesis were quite favorable, including 0-1 km SRH of 200 $(m\ s^{-1})^2$, 0-1 km shear of 10.5 m s^{-1}, and 0-1 km EHI of 3.0 (Davies, J. M., 2004, Thompson et. al., 2003, Markowski et. al.,1998, Fig. 5). KDEN 00 UTC 11 May 2004 sounding is also shown for comparison (Fig. 6). Surface observations from Limon (24 km from the storm), indicated the temperature/dewpoint spread was also quite low (69 F^o/55 F^0 at 0100 UTC)), indicating a favorable moist boundary layer with LCLs at 1600 meters, and this too has also been shown to be favorable for tornadogenesis (Davies, J. M., 2004, Rasmussen and Blanchard, 1998).

Although it is beyond the scope of this paper, an important question which needs to be answered is why did this storm, given the weak storm relative flow aloft, remain a classic supercell and produce many tornadoes over a significant period of time (Fig. 8)? Although the NOAA/SPC correctly anticipated significant rotating convection on this day over east central Colorado, significant tornado activity was not anticipated. An informal literature review has documented other cyclic tornadic storms which have developed in weak upper flow environments in Colorado, but these storms were observed to be "anchored" to a low level boundary while tornadogenesis occurred. (Hodanish and Davies 2002, Hodanish 2000). This storm in this case, although initiated by a boundary, did not appear to be anchored to the boundary when the tornadoes were ongoing.

5. ACKNOWLEDGMENTS

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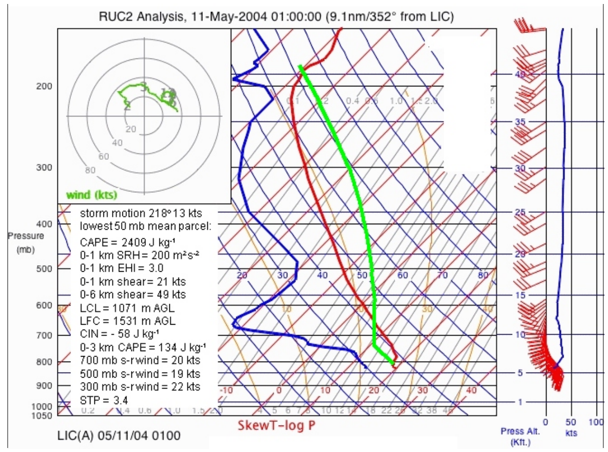

***Figure 5**. 01 UTC 11 May 2004 RUC-2 sounding in the vicinity of Limon, Colorado. Storm motion used was from 218 at 13 knots (6.5 m s^{-1}). Wind barb in knots. Data courtesy J. Davies.*

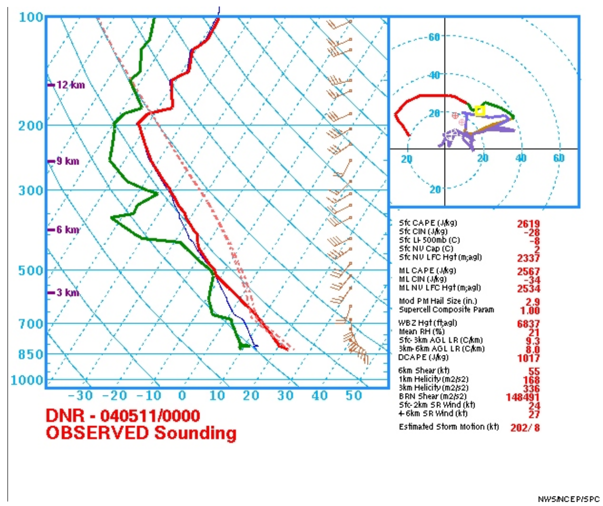

***Figure 6**. Observed KDEN sounding at 00 UTC 11 May 2004.*

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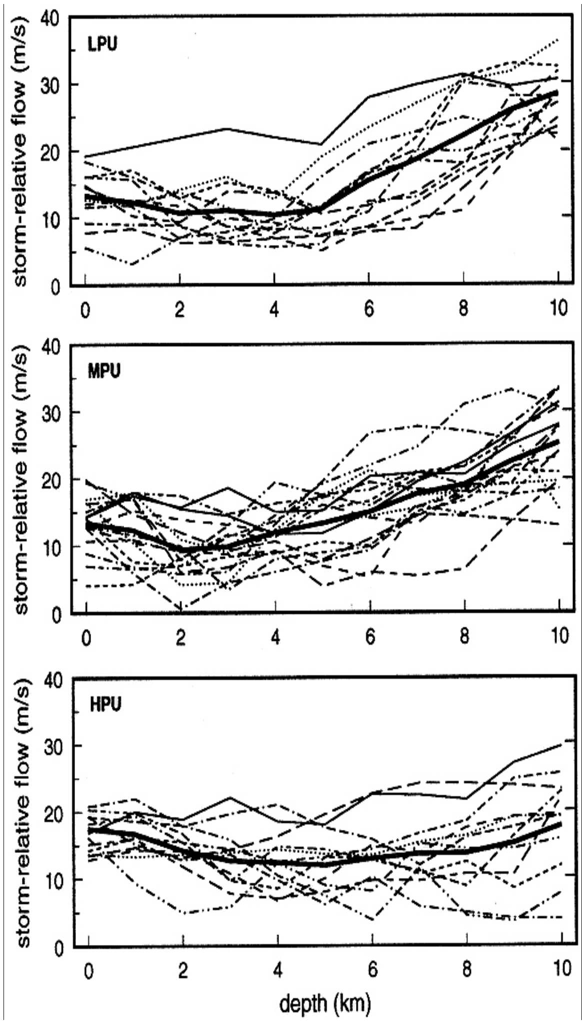

Figure 7. *Storm-relative (SR) wind speed (m s-1) for Low Precipitation (LP), Classic (CL) and High Precipitation (HP) Supercells. The top graph is for LP storms, the middle for CL storms, and the bottom for HP storms. Heavy curves represent the mean for each storm type. From Rasmussen and Straka, 1998.*

Figure 8. *One of the 7 tornadoes which occurred west and northwest of Limon, Colorado on 10 May 2004. Courtesy Patrick Burke.*