P2.28 LEARNING FROM A NULL DERECHO EVENT—THE CONVECTIVE FORECAST FOR 08 JULY 2003

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1. INTRODUCTION

Shortly after 2300 UTC the evening of 07 July 2003, a number of supercells that had already formed in northeast Colorado began to advance in a more organized manner. By 0000 UTC 08 July, the storms had merged into a linear bow echo pattern and quickly moved east to cross the Colorado-Nebraska border. Reports of severe winds (see Fig. 1 for a complete plot of all reports) began at 0027 UTC with news of a 65 mph gust 2 miles south of Merino, CO, in Logan County.

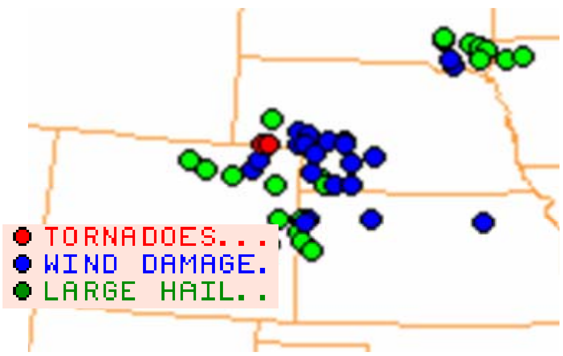

Fig. 1) Plot of preliminary severe weather reports, Storm Prediction Center, Norman OK.

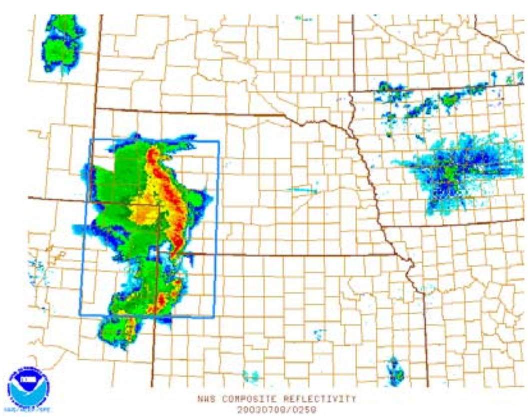

Fig. 2) NWS Composite Reflectivity radar image from 0258 UTC on 08 July 2003.

The complex continued (see Fig. 2) producing numerous damaging wind reports, including a 99 mph gust at 0059 UTC at Big Springs (Deuel county), Nebraska and an 80 mph gust in Keith and Lincoln counties, Nebraska, at 0235 UTC and 0319 UTC respectively. Severe reports ended at 0410 UTC with a 65 mph gust in Cozad (Dawson County) Nebraska.

All told, this resulted in a total of 18 severe wind reports along a path length of 178 miles. Essentially, this storm began in conditions from which derecho development would not be unlikely, and, until 0600 UTC, acted like a derecho. Yet it persisted only until reaching Grand Island, Nebraska, dissipating shortly after 0600 UTC (see Figs. 3a and 3b).

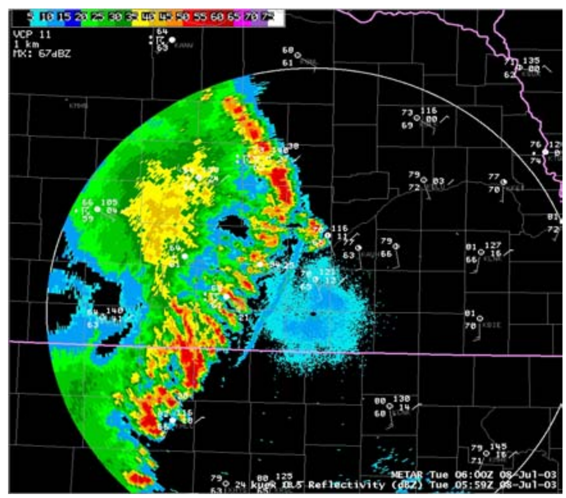

Fig. 3a) Hastings (KUEX) 0.5 Reflectivity at 0600 UTC. Note how the echo has begun to fall apart; also note the new convection forming north of Hastings on the outflow boundary.

This paper, by examining the environmental characteristics surrounding both the initiation point and the downwind path, hopes to deduce just why the "null event" did not evolve as anticipated. Parameters for development given by previous researchers will also be compared.

2. SYNOPTIC OVERVIEW

2.1 *Upper Levels*

As of 00 UTC 8 July, a large ridge was in place across the western portion of the continental United States. As a consequence, upper-level westerly flow could be found over the initiation point and much of the state of Nebraska. A shortwave trough existed over the Nebraska panhandle and northeast Colorado in both the

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250 mb and 500 mb 00 UTC RUC analyses, as displayed in Fig. 4.

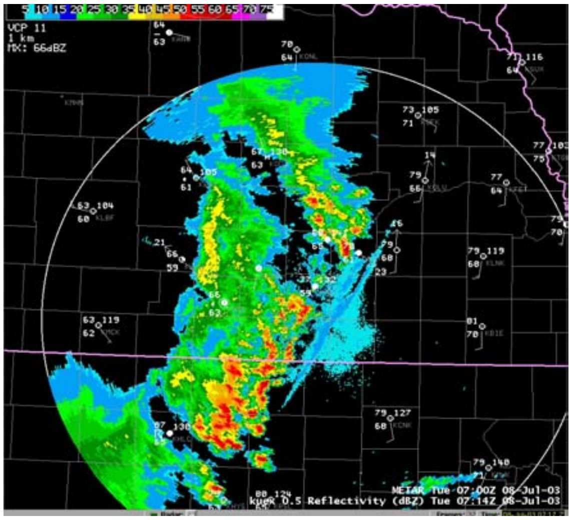

Fig. 3b) Hastings (KUEX) 0.5 Reflectivity at 0700 UTC. The storm has lost its "bow" shape and has dissipated into scattered showers and thunderstorms.

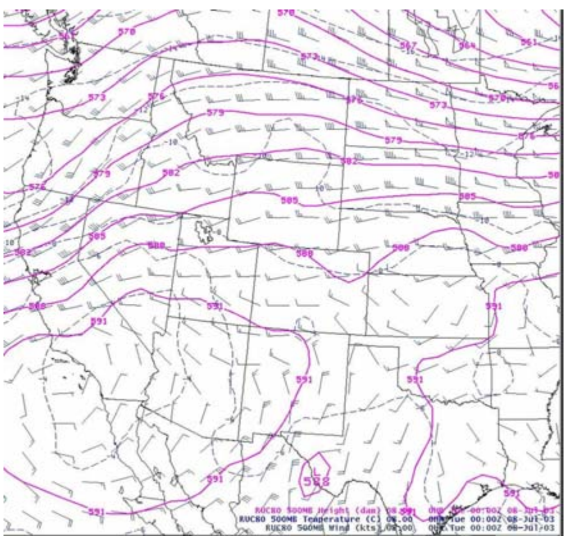

Fig. 4) 00 UTC 8 July 500 mb RUC analysis. Heights in fuchsia, temperature in dark blue, winds in black.

The 12 hour 500 mb height falls from upper air data in the vicinity of this trough are quite telling. None of the 00 UTC, nor the following 12 UTC soundings reported a height fall of greater than 40 m. Hence, this synoptic situation can be classified as providing "weak" forcing (Johns & Hirt, 1987).

Examination of the strength of the 250 mb and 500 mb winds further supports this conclusion. Wind speeds at 500 mb were as low as 10 kts at 00 UTC; speeds at 250 mb were not much better, with the 00 UTC analysis indicating values of 25 kts. Temperature advection was weak at these levels as well, as demonstrated by Fig. 4.

2.2 *Lower Levels*

On the other hand, warm air advection (WAA) seemed omnipresent in the lower levels of the atmosphere. The 00 UTC RUC analysis indicated 700 mb WAA values were approximately .5 K/hr near northeast Colorado, while values at 850 mb were as high as 1.8 K/hr. This temperature advection at 850 mb produced a large area of warm air north of a warm front, which was noted by a wind shift (see Fig. 5) from the south to the southeast just north of the Kansas-Nebraska border.

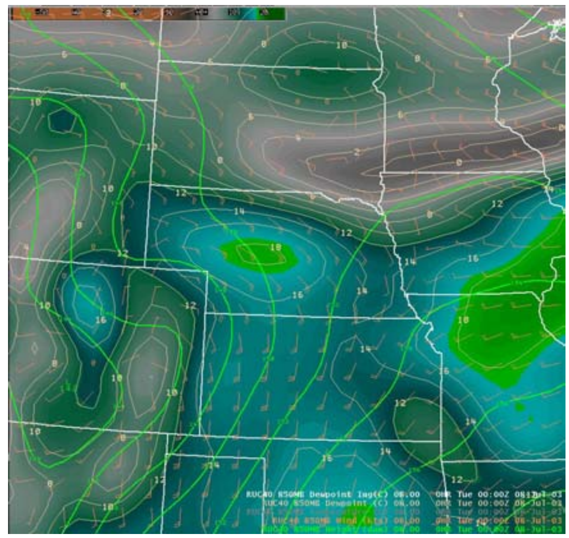

Fig. 5) 00 UTC 8 July 850 mb RUC analysis. Heights in green, winds in orange, dewpoint imaged.

Very obvious in Fig. 5 is the dewpoint pool north of the aforementioned boundary. The center of the pool contains dewpoints as high as 19°C. Consequently, there is a corresponding region of high moisture advection centered over western Nebraska, the same area the bow echo would soon be entering.

2.3 Surface Conditions

This synoptic situation has considerable thermodynamic potential, but little kinematic forcing. An examination of the surface conditions continues to bear out this premise. The quasi-stationary warm front, along with its associated surface low located over southeast Colorado, can be seen in Fig. 6.

Also apparent in the surface analysis is the moisture axis stretching across the state of Nebraska north of the warm front. Associated with a maximum dewpoint of 79°F, this axis contributed to an axis of most unstable CAPE (MUCAPE) greater than 4500 J/kg stretching from northeast Colorado into central Iowa. In essence, one can see how this situation has all the earmarkings of a progressive derecho situation.

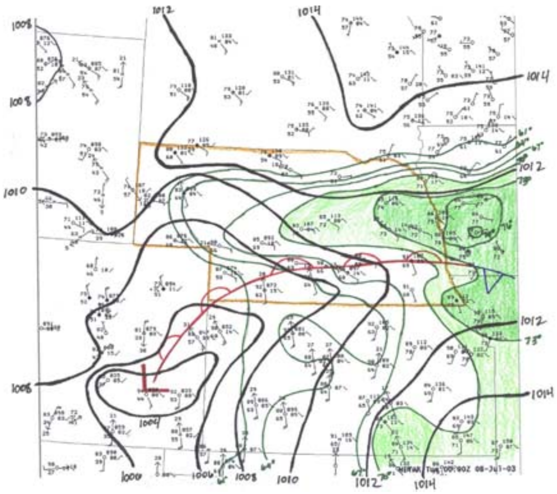

Fig. 6) 00 UTC 8 July Surface analysis. Pressure in black, dewpoint in green.

3. INITIATION CONDITITIONS

3.1 *Conditions Specific to Initiation Point*

The 00 UTC Denver sounding was modified to reflect conditions more similar to those near the initiation point. Utilizing METAR data, a representative surface temperature and dewpoint of 87°F and 60°F, respectively, was decided upon. These conditions resulted in MUCAPE values of 4363 J/kg, a Mean Layer CAPE (MLCAPE) of approximately 2000 J/kg, and, most notably, Downburst CAPE (DCAPE) around 1800 J/kg. The SELS Lifted Index value was -10. Bulk shear values were passable, with 0-6 km shear of 40 kts, and 0-2 km shear of 20-30 kts. However, the wind speeds reported within the sounding are quite noteworthy. Calm winds were reported at 575 mb; no winds greater than 10 kts could be found between 700 and 500 mb.

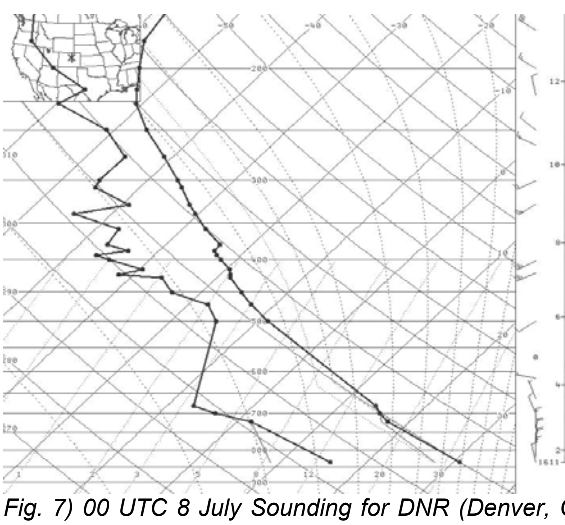

Fig. 7) 00 UTC 8 July Sounding for DNR (Denver, CO) with modified surface temperature and dewpoint to represent airmass over northeast CO where storms initiated.

3.2 *Comparison of Initiation to "Ideal" Conditions*

Johns's and Hirt's 1987 paper (hereafter referred to as J&H 87) presents a checklist of parameters to aid in being attentive to possible derecho development. A quick comparison of the environment in this situation to their checklist results in the following:

1) 500 mb flow direction greater than 240°? Yes
2) Quasi-stationary boundary nearly parallel to 500 mb flow? Yes
3) 850 mb warm advection within 200 nm? Yes
4) 700 mb warm advection within 200 nm? Yes
5) ELWS (Estimated Lower Midtropospheric Wind Speed) 25 kts or greater? No

Johns and Hirt delineate quite explicitly between weak forcing and strong forcing derecho events. However, as one can glean from the above, they are still of the opinion that at least some wind profile support is always necessary for development. Consequently, their checklist would not have even predicted this event to initiate.

Overlooking that fact for a moment, Johns and Hirt do recognize that if an abundant amount of thermodynamic instability is present, than less dynamic forcing is needed. Thus, they created a special checklist for such situations.

1) SELS Lifted Index -8 or lower? Yes
2) ELRH (Estimated Lower Midtropospheric Relative Humidity) less than 80%? Yes

J&H 87 also keys in on the need for these conditions to extend downstream (specifically, 250 nm downstream), in order for the derecho to sustain itself.

1) ELRH less than 80%? Yes
2) SELS Lifted Index -8 or less? Yes-0Z; No-6Z
3) ELWS 25 kts or greater? No

Accordingly, one can see that the J&H 87 checklist would also have predicted the storm's demise before it would have been able to propagate 250 nm.

4. CONVECTIVE FORECAST

At 0330 UTC (10 minutes after an 80 mph gust was reported 4 mi. south of North Platte, Nebraska) the NWS forecast office in Valley, Nebraska issued a Hazardous Weather Outlook calling for "a line of thunderstorms with very strong winds…to move into eastern Nebraska late tonight…at 40 to 50 mph [with] winds gusts of 50 to 80 mph." The Storm Prediction Center in Norman, OK, called for a similar event. Mesoscale Discussion (MCD) 1680, issued at 2052 UTC on 7 July, specifically remarked on the severe thunderstorm potential in eastern Colorado. MCD 1681 at 2116 UTC went into greater detail, highlighting the warm front stretched across northeast Colorado and Nebraska as a focus for development. (See Figs. 7a, b, c for the graphics associated with the MCDs.)

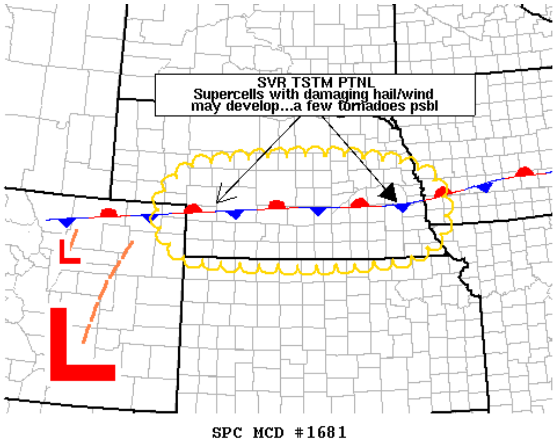

Fig 7a) SPC MCD #1681 graphic; issued 2116 UTC

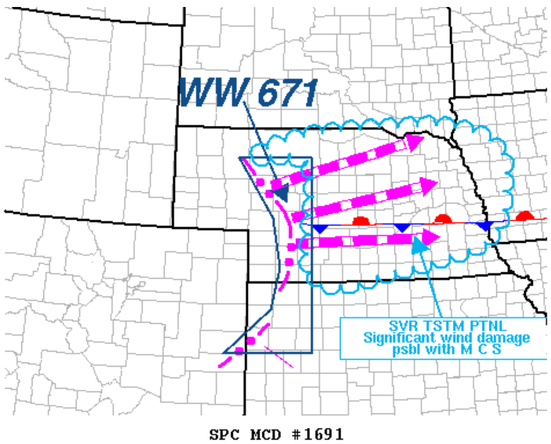

Fig 7b) SPC MCD #1691 graphic; issued 0315 UTC

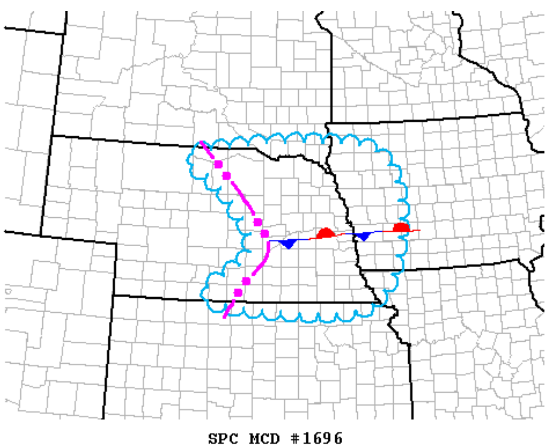

Fig 7c) SPC MCD #1696 graphic; issued 0634 UTC

MCD 1691, depicted by Fig. 7b, was the most explicit discussion about this event, predicting a "severe MCS" to travel into central Nebraska, remaining severe through at least 0600 UTC. This discussion also mentions the large east component to winds in the lower levels. This component, the discussion explains, is helping to increase storm-relative inflow (preventing the outflow boundary from progressing too far ahead of the storm), and thereby maximizing convergence along the bow echo. Severe Thunderstorm Watch #675, covering central and eastern Nebraska to the Missouri valley, is also issued.

Discussion #1696 continued in this vein, stating that a "well-defined large bow echo convective system…with a continuing threat for damaging wind gusts and hail" will maintain its strength and move along the warm front to past the Missouri river around 0900 UTC.

5. PATH CONDITIONS

Several factors supported derecho development during the early evening hours in northeast Colorado, as well as into western Nebraska. However, a close examination of the environmental conditions downstream of the storms, and in the six to eight hours after storm initiation, is necessary to ascertain the ingredients needed to sustain the convective line to determine whether it could eventually result in a derecho. As mentioned in the Introduction, the last severe wind report occurred at 0410 UTC in Cozad, Nebraska. By 0600 UTC, the storms had weakened considerably, despite new convective cells developing on the outflow. The identity of the convective line was rapidly diminishing by 0700 UTC as the convection weakened further. Conditions near Grand Island, Nebraska (GRI) were examined at 0600 UTC 08 July to represent the "path" conditions that the convective line was moving through. In addition, the wind profiler at Red Willow, Nebraska (near Mc Cook) was also studied for along-path kinematic characteristics.

5.1 Thermodynamics along the Path

No observed sounding exists for the GRI area at the time of interest (0600 UTC), so a RUC model analysis was generated from the 0600 UTC run of the RUC, and then modified for observed surface conditions (temperature of 78 F and dewpoint of 65 F). Figure 8 shows the RUC analysis sounding revealing a drastic increase in the surface-based convective inhibition value of 247 J/Kg. The surface-based CAPE value had dropped to 1108 J/Kg. Due to the low-level nocturnal inversion that is typical over the central plains, the storms had become elevated as they moved east. The most unstable parcel originated near the 850 mb level, and lifting that parcel resulted in a MUCAPE value of 1557 J/Kg, with a most unstable CIN value of 81 J/Kg. This is a decrease in CAPE of 2806 J/Kg, which is apparently significant.

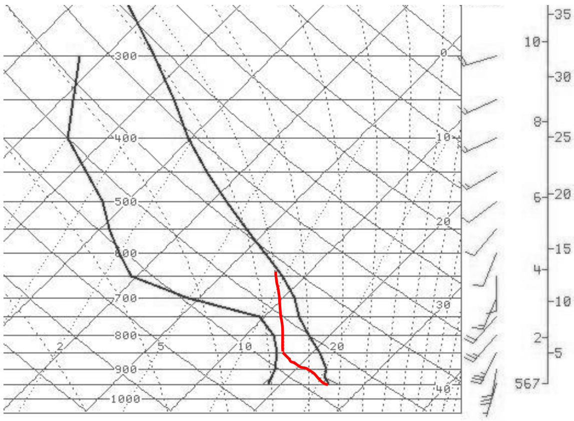

Fig. 8) 06 UTC 8 July 2003 RUC analysis sounding for GRI, modified for observed surface temperature and dewpoint. CINH is outlined in red.

5.2 Wind Shear along the Path

The wind profiler at Red Willow, Nebraska revealed rather weak winds in the 700 mb to 500 mb layer just ahead of the storms as they moved through western Nebraska (Fig. 9). In fact, wind speeds were approximately calm at some heights in that layer beginning around 0100 UTC, and persisting through 0300 UTC.

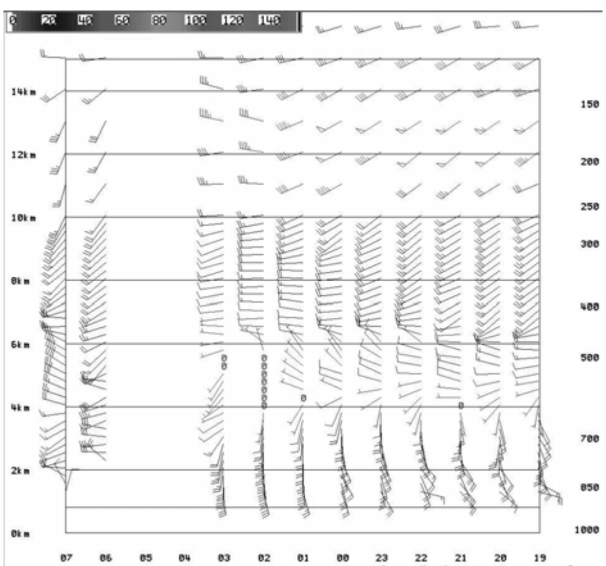

Fig. 9) Red Willow, NE wind profiler showing measured winds from 1900 UTC 07 July, through 0700 UTC 08 July, with missing values during the 0400 and 0500 UTC hours. Note the calm winds in the mid levels between 0100 UTC and 0300 UTC.

By 0600 UTC, the RUC model analysis sounding for GRI also indicated relatively weak winds in the mid levels of the atmosphere. Using the RUC model sounding and observed surface winds, a hodograph was constructed for the GRI vicinity (Fig. 10). The hodograph showed significant shear in the lowest 1 KM of the atmosphere, but much weaker shear in the middle levels.

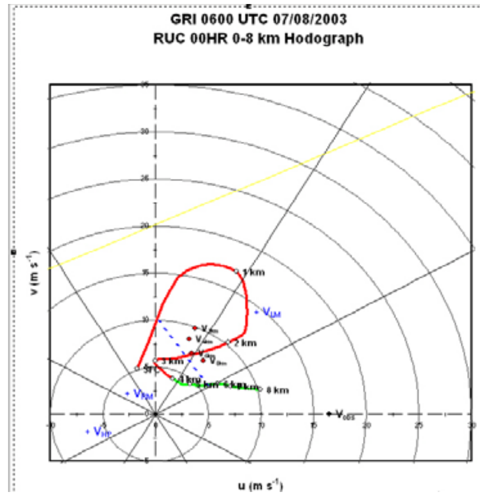

Fig. 10) 0600 UTC 8 July 500 mb hodograph for GRI, constructed using the 0600 UTC RUC analysis and observed surface winds.

From the hodograph in Figure 10, the 0-6 KM mean wind was calculated at only 16 m/s, and the 0-6 KM bulk shear value was 18 knots. The system speed, as determined using a sequence of radar images, was 32 knots.

The RUC model was also used to evaluate the low level thermodynamic advections at 0600 UTC over the region. Figure 11 shows the RUC model 850 mb winds, temperatures, and temperature advection. Although there was still positive temperature advection over the path, the temperature advection had weakened, with the maximum moving into northern Nebraska. The low level jet had strengthened to 40 knots in southwest Nebraska, but had veered to the southwest. This increase in wind speed and direction resulted in a significant change in the advections at 850 mb. Figure 12 shows the RUC model 850 mb advection of equivalent potential temperature, with negative values over most of Nebraska. This negative equivalent potential temperature advection at 0600 UTC was a result of the veering low level jet, advecting in drier air residing over the western high plains of western Kansas.

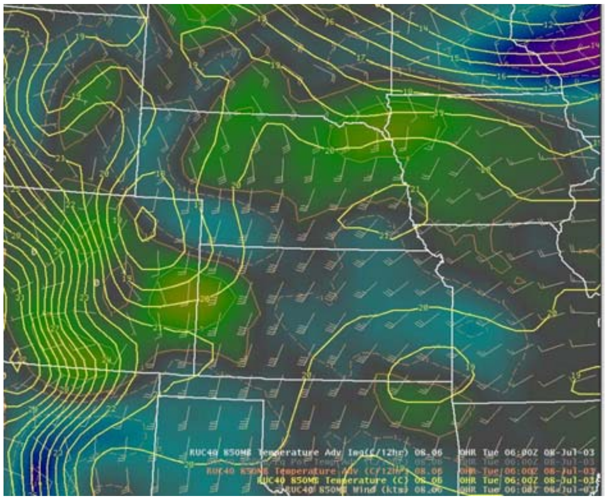

Fig. 11) 0600 UTC 8 July 500 mb RUC model 850 mb temperatures in yellow, wind barbs, and temperature advection in orange and imaged. From the 0600 UTC run of the RUC, 00 Hour analysis.

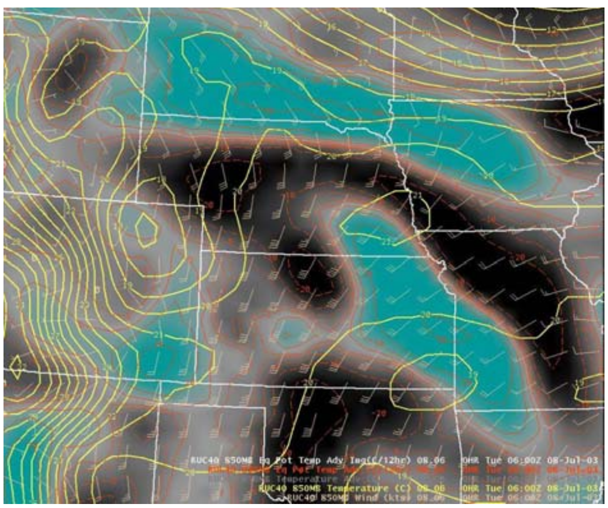

Fig. 12) 0600 UTC 8 July 500 mb RUC model 850 mb temperatures in yellow, wind barbs, and equivalent potential temperature advection in orange and imaged. From the 0600 UTC run of the RUC, 00 Hour analysis.

6. COMPARISON TO OTHER NULL EVENTS

In a 2001 paper by Evans and Doswell (hereafter referred to as E&D 01), 13 non-derecho events were compared to 30 weakly forced derecho events. To summarize their findings, non-derecho events had weaker system speeds and weaker deep layer mean winds than the weakly forced derecho environments. However, similar thermodynamic environments were noted.

A comparison of the event described in this paper with the statistics from the E&D 01 paper revealed the 08 July value for the 0-6 KM shear was close to the median value for their non-derecho events, but was below the 25th percentile for their weakly forced derecho environments. These results alone would point to a more likelihood of a non-derecho event. However, the 08 July mean wind was near the 75th percentile of their non-derecho events and near the 25th percentile of their WF derecho events. Finally, the system speed of the 08 July event was well above the 75th percentile of the non-derecho events, but near the 25th percentile of the WF derecho events. Drawing a conclusion from the later two parameters is less clear, although still somewhat supportive of a non-derecho event.

7. NWP PERFORMANCE

7.1 Conventional NWP Performance

To be consistent with operational practices, the performance of some of the more commonly used NWP models was evaluated.

One of the more misleading models was the NCEP eta model, using the Bettes-Miller-Janic convective parameterization scheme. Figure 13a and 13b show the 06 hour quantitative precipitation forecast (QPF) and the 12 hour QPF forecast, respectively, from the 00 UTC July 08 run of the eta. The model clearly indicted the rainfall would continue to move east into eastern Nebraska and western Iowa between 00 UTC and 1200 UTC, 08 July.

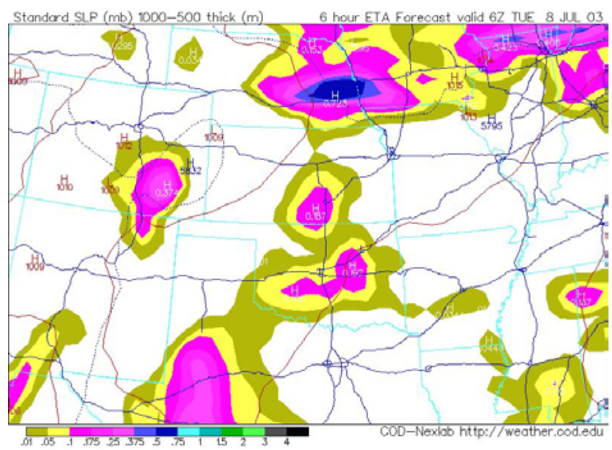

Fig. 13a) NCEP eta model QPF valid at 0600 UTC 8 July, from the 00 UTC 08 July model run. Purple contour is 0.1 inches, dark blue contour is 0.5 inches.

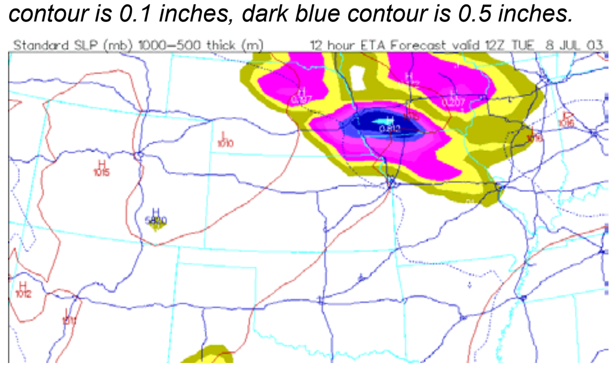

Fig. 13b) Same as Fig. 13a, except valid at 1200 UTC.

Figure 14 shows the 12 hour QPF from the Global Forecast System (GFS) model in cyan, and from the Nested Grid Model (NGM) in brown, valid at 1200 UTC 08 July. The GFS did indicate some rainfall over southwest and south central NE, but also showed rainfall over much of eastern NE and IA. The NGM failed to produce precipitation over western NE or southern NE, but showed significant rains from northeast NE into much of IA. The NGM in particular was rather misleading as it did not represent the convective rains over southwest Nebraska.

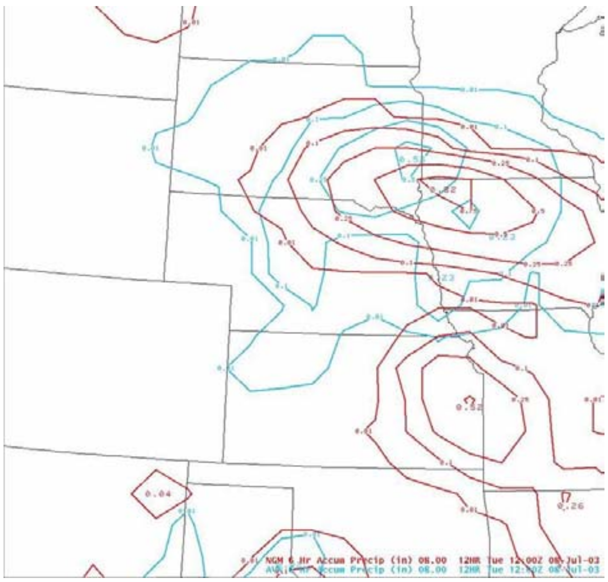

Fig. 14) NCEP GFS and NGM model QPF valid at 1200 UTC 8 July, from the 00 UTC 08 July model run

7.2 Weather Research and Forecasting Model Performance

The Weather Research and Forecast (WF) model was run by the National Center for Atmospheric Research (NCAR) on a domain that included the central plains during 08 July, 2003. This model was run at 4 KM horizontal resolution, which is a higher resolution than the conventional models. Most importantly however, the higher resolution allowed the model to represent explicit convective processes, as opposed to the convective parameterizations employed by conventional, courser resolution models. This explicit convection and high resolution has resulted in model simulations of convective mode, and convective system behavior. The model was run at 00Z 07 July, 2003, and the 27 hour forecast of reflectivity was quite accurate in representing the bowing convective line (Figure 15a and 15b).

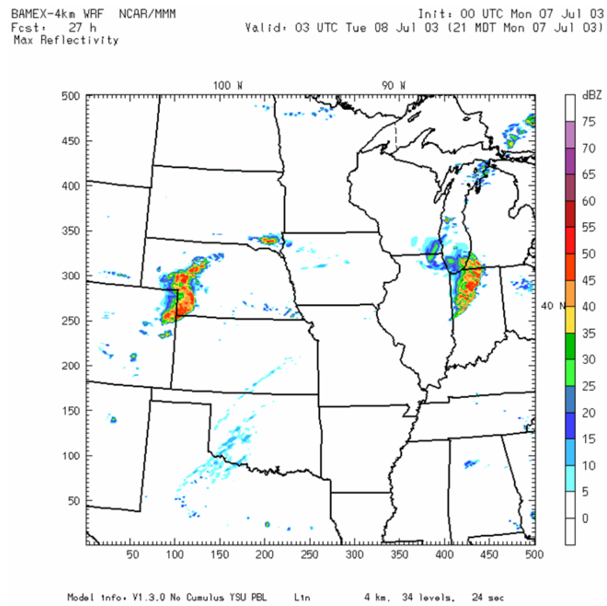

Fig. 15a) NCAR WRF model reflectivity valid at 0300 UTC 8 July, from the 00 UTC 07 July model run.

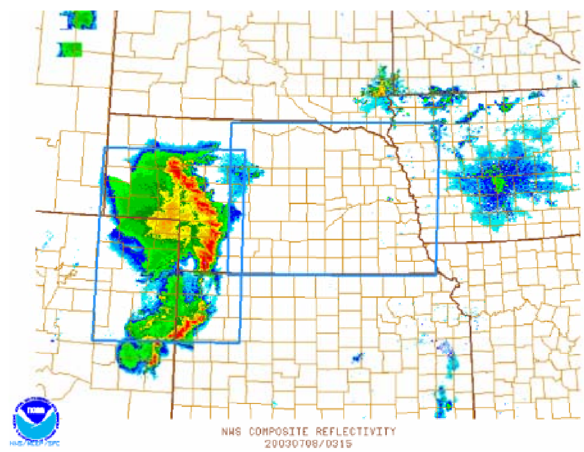

Fig. 15b) Composite radar reflectivity valid at 0300 UTC 8 July.

Perhaps just as impressive, the 32 hour forecast of reflectivity from the WRF showed the convective system weakening, with a dissipating trend. Comparing the WRF forecast with the composite radar image shows the accuracy and utility of the WRF forecast with this system (Figures 16a and 16b).

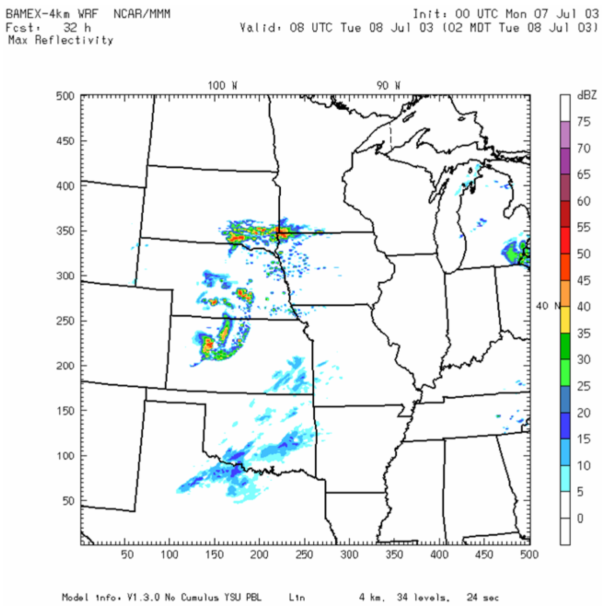

Fig. 16a) NCAR WRF model reflectivity valid at 0700 UTC 8 July, from the 00 UTC 07 July model run (27 hour forecast).

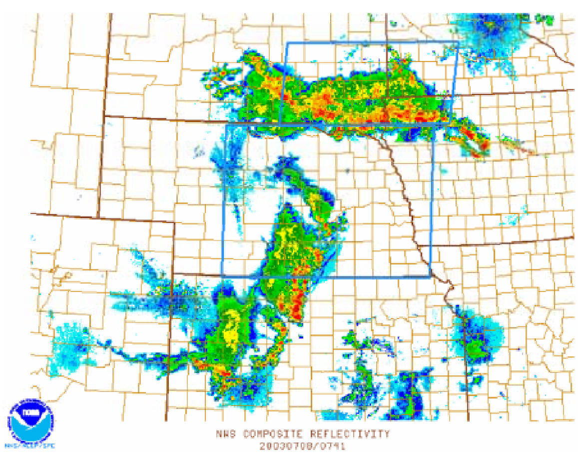

Fig. 16b) Composite radar reflectivity valid at 0700 UTC 8 July (32 hour forecast).

8. CONCLUSIONS

This paper described a convective weather event that initiated over northeast CO and demonstrated many signs of evolving into a mature, long-lived derecho event. These events have a great impact on the plains, causing widespread damage (J & H 87). Operational forecasters, including those at the Storm Prediction Center and at the National Weather Service office in Valley, NE, predicted this event to continue tracking across NE and eventually into IA during the early morning hours of 08 July, 2003. Several environmental parameters supported this reasoning, however some important atmospheric characteristics prevented the system from meeting derecho criteria, and the convection dissipated just a few hours after initiation.

As the convective line moved east from CO into NE, it encountered three primary changes in environmental conditions which appear to have led to the system's demise: 1.) very weak mid level winds, 2.) a SW low level jet which resulted in negative values of equivalent potential temperature advection, and 3.) increasing convective inhibition. The weak mid level winds decreased the deep layer shear, and slowed the system movement. The SW low level jet veered from the SE, and as a consequence the equivalent potential temperature advection changed from positive to negative. Increasing convective inhibition acted against new cell development as the nocturnal boundary layer continued to stabilize.

The checklist devised by Johns and Hirt (J&H 87) did catch the lack of supporting mid level winds. All other environmental parameters included in the checklist however did point to derecho development. When comparing this event to the 30 weakly forced derecho events and 13 non-derecho events studied by Evans and Doswell, there was slightly more similarity to the non-derecho events regarding the 0-6 KM mean winds, the 0-6 KM shear, and the system speed.

Conventional NWP models did a poor job in simulating the 0-12 hour rainfall with this system, and generally did not forecast the system dissipation. However the NCAR WRF model, with a 4 KM horizontal resolution and explicit convection, was able to simulate the development and the dissipation of the convective system remarkably well.

Forecasters studying this particular event may be able to glean a few lessons from the data presented. Special attention should be paid to the wind field in the mid levels for several reasons: supporting shear and system speed values, and advection potential. Other researchers have shown that weak shear and weak mid level winds may not support derecho development, making that an important parameter to diagnose (Ashley 2000, J&H 87, E&D 01). In the case of central NE convection, a veering low level jet may often result in negative advection of equivalent potential temperature, as occurred in this event. Finally, there appears to be potential in the NCAR WRF model with its ability to forecast the development and dissipation of convective systems. Although the authors recognize that conclusions can not be drawn from the verification of one event, the fact remains that this model run was extremely accurate in predicting sub-mesoscale features of this system, as well as the system's development and dissipation.

9. ACKNOWLEDGEMENTS

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