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A TURN OF EVENTS FOR A LONG-LIVED CONVECTIVE SYSTEM

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1. INTRODUCTION

In a recent radar-based climatological study of warm season precipitation events over the continental United States, Carbone et al. (2002, hereafter CEA) found a high frequencey of long-lived coherent rainfall episodes. Many of the events were of longer duration than normally associated with mesoscale convective systems and exhibited propagation speeds in excess of the phase speeds of synoptic scale forcings or the steering level winds. It was speculated that density currents and other wave-like mechanisms were responsible for the longevity of many of the systems. Here we report on the 14-15 July 1998 event, one of the long-lived systems included in the statistics of CEA. We investigate the environmental factors that led to this system lasting about 50 hours and traveling over 2800 km.

2. DATA

The primary data used in this study is the WSI Corporation NOWrad national composite radar reflectivity product. The properties of this product include a ~2 km latitude/longitude grid with 15 minute temporal resolution and 16 levels of radar reflectivity at 5 dBZ intervals. RUC (Rapid Update Cycle) model analyses, soundings and satellite are used to describe the large scale environmental conditions.

Figure 1 shows a swath of the radar reflectivity (data are plotted at one hour intervals) and a time history of the area enclosed by various dBZ levels over about a 48 hour time period. The convection initiated over the higher terrain of southwestern Montana on July 13 at about 21:00 (all times are UTC, subtract 6 hours for local time), near the time of maximum solar heating. As the convection moved eastward onto the plains of eastern Montana, it became weakly organized into a N-S line and gradually increased in intensity and areal coverage, reaching an initial peak at about 8:00 in western North Dakota. After a 6 hour period of decay the convection began a second intensification period at about 14:00. Initially the intensification was gradual, but then accelerated at 0:00 on July 15. After remaining at peak intensity for 6 hours the storm rapidly decayed at it moved southward into Missouri. At its peak intensity in Minnesota and northern Iowa the storm produced local flooding, strong winds (up to 35 m/s), large hail (10 cm diameter) and two F0 tornadoes. While the

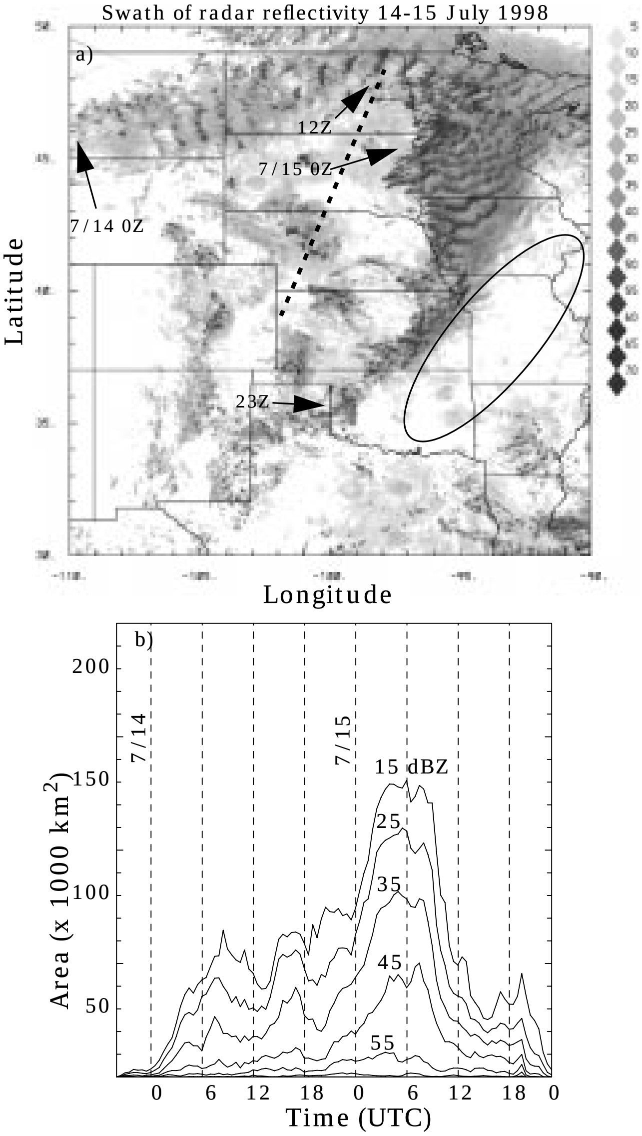

Fig.1 a) Swath of reflectivity plotted at one-hour intervals. Storm position at selected times is indicated by arrows. Dashed line shows location of trough line at 0Z on July 15 and elipse shows deformation/suppressed zone, b) time history of storm area enclosed by various dBZ contours.

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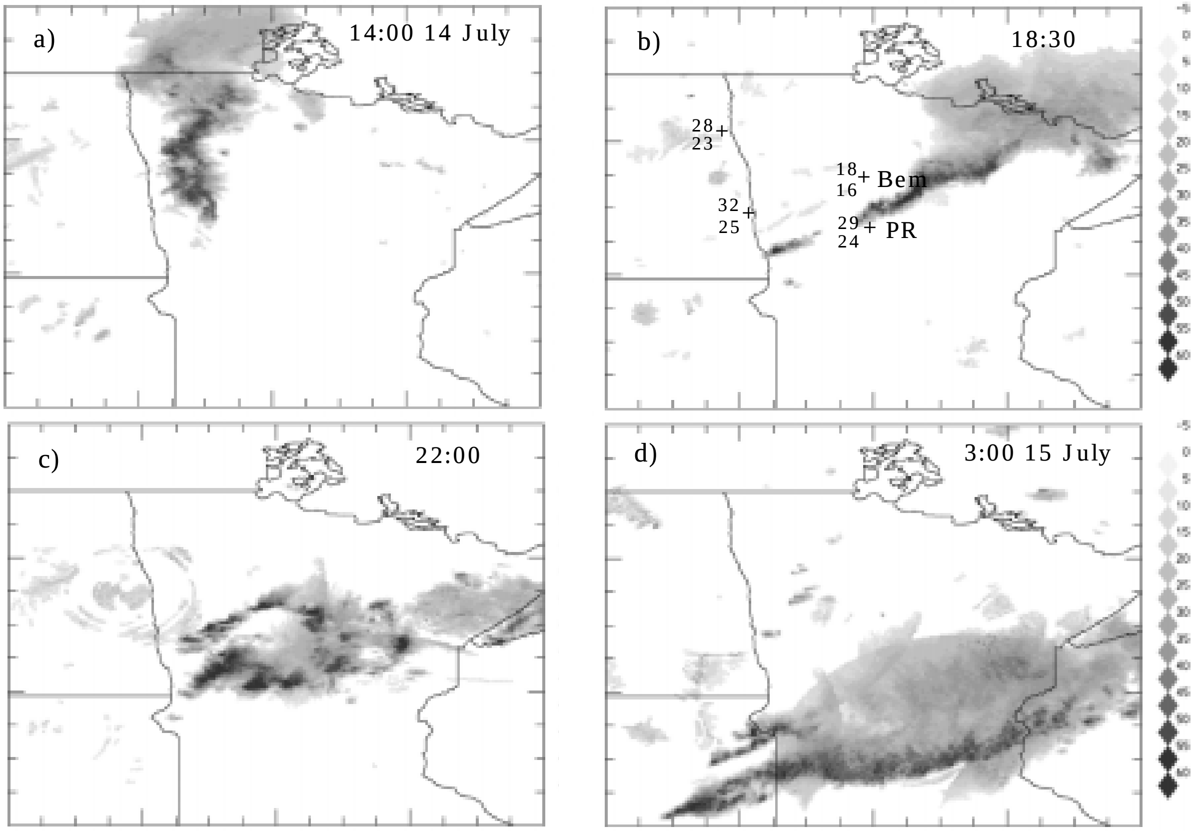

Fig. 2. Time series of radar reflectivity shown on a 4^o longitude by 3^o latitude grid. Surface temperature and dewpoint measurements are shown at selected sites at 18:30..

severe weather is noteworthly, the most interesting aspect during the second intensification phase was an abrupt change in the storm's orientation and propagation vector.

Fig. 2 shows a times series of radar reflectivity data covering the reorientation period of the storm. At 14:00 the storm was a weakly organized N-S line over NW Minnesota propagating eastward at about 22 m s^{-1}. By 18:00 the system was in NE Minnesota (still propagating eastward), but new development can be seen stretching southwestward from the original system. Surface observations showed a 11^oC temperature drop across the newly developing line (Fig. 2b, 29^o at Park Rapids to 18^o at Bemidji) indicating the presence of a strong cold pool. Note that surface reports to the west and north of Bemidji had temperatures much warmer suggesting that the cooling at Bemidji was local cooling due to a cold pool and not a synoptic scale cold front. At 22:00 intense convection was formed into a rather diffuse E-W line that by 3:00 on July 15 was highly organized into an intense E-W line that was starting to bow southward. It was during this phase that most of the severe weather reports occurred.

The radar data of Figs 1 and 2 are rather dramatic showing strong temporal changes in storm structure. Are these changes the result of strong synoptic forcing or are they the result of cold pool interactions with the environmental air following the arguements of Rotunno et al. (1988)? We proceed now to investigate in some detail the enivromental factors that led to the observations.

Fig. 3 shows the 0 Z July 15 300 mb chart. The upper level flow is dominated by two anticyclones, one centered over northwest Mexico and the other over the southeastern U.S. Between the anticyclones an axis of deformation is evident stretching northeastward from northwest Texas, across Missouri to northern Illinois. Associated with the deformation zone and slightly to the NW were high potential vorticity values in the upper levels, warm water vapor channel temperatures (>-20^oC), and CAPE values near 0. This is likely the result of a tropopause fold and is a region of suppressed conditions. The location of the suppressed zone is indicated by the elipse in Fig. 1. The polar jet was located north of the Canadien-U.S. border. The surface conditions (not shown) were typical of midsummer, having weak gradients and no strong thermal boundaries anywhere across the U.S. Strong baroclinic zones were located well to the north in central Canada. The one feature of note was an N-S trough line (moving eastward at 10 ms^-

^{1}), the position of which at 0:00 on July 15 is denoted by the dashed line in Fig. 1. Ahead of the trough strong southerly flow brought warm, moist unstable air into Iowa and Minnesota (dewpoints and CAPE values as high as 25^{0}C and 3500, respectively). Behind the trough winds were from the NW and the air slightly drier.

We summarize the temporal evolution of the storm and its environment with a series of time-longitude plots covering two days (ofter refered to as Hovmoller diagrams in climatological studies) where data have been averaged or summed in the latitudinal direction along constant longitude slabs (see CAE for details of the analysis techniques). Fig. 4a depicts the radar reflectivity where the numbers represent the number of 2 km data points greater than 25 dBZ in each longitude slab. Figs. 4b-d repeat the radar Hovmoller contours superimposed on the v-component of the low-level wind, mixing ratio and vertical shear vector in the lowest 2.5 km taken from the 3-hourly RUC model analysis. For the RUC Hovmollers the data represent a simple average of data in each longitude slab. For the eastward moving phase of the storm the latitudinal averaging window is set to 5^o centered on the storm. For the southward propagating phase, the window continues to move and is kept just ahead of the storm. These Hovmoller figures are representative of the environmental air just in front of the storm. The radar Hovmoller (Fig. 4a) shows the event entering the domain at -110^o, moving rapidly at about 22 m/s across the northern tier of states and entering Minnesota at 13:00. The system continued to move eastward before dissipating over Michigan (-87^o and 2:00 on July 15). However new development along the cold pool's leading edge led to a secondary system forming at about 17:00 (July 14) moving southward along about the -95^o longitude. The secondary nature of the convection is clearly evident in the Hovmoller depiction. The v-component plot (Fig. 4b) clearly shows the position and eastward propagation of the trough line (position of trough is denoted by dashed line passing through the approximate 0 m s^{-1} contour). Note the strong southerly flow ahead of the trough (up tp 12 m s^{-1}) . The convection initiated west of the trough, but moving at about twice the speed, overtook and passed ahead of the trough at around 6:00-8:00 Z. The initial peak storm intensity (Fig. 1b) occurred as the storm passed through the trough. Fig. 4c shows the moist plume of air being advected by the southerly flow ahead of the trough and that the convection entered the moist air at about 13 Z on July 14. The timing of the start of the second period of intensification is coincident with the storm entering the moist air. Fig. 4d shows the low-level shear vector where north is taken as directed toward the top of the page in the usual sense. During the eastward propagating phase the shear vector is somewhat noisy out ahead of the storm (at a given time ahead of the storm would be longitudes just east of the Hovmoller streak), but generally has an east to southeastward direction with a magnitude of 15 m s^{-1}. The combination of the trough line, location near the polar jet and the marginally favorable shear probably led to the longevity of the storm despite the moisture not being too impressive. During the southward propagating phase the shear increased to 25 m s^{-1} and assumed a N-S direction perpendicular to the line. Note that the storm path coincides perfectly to the zone of strong southerly shear. During and immediately after the reorientation phase there was a brief period when the storm was oriented parallel to the shear. Though the convection was intense, it was not very well organized. (Fig. 2c) It was only when the storm moved south into a more favorably sheared environment that it became highly organized. As the storm continued to move south into the region of suppressed conditions decay was rapid with erosion taking place on the eastern end of the line.

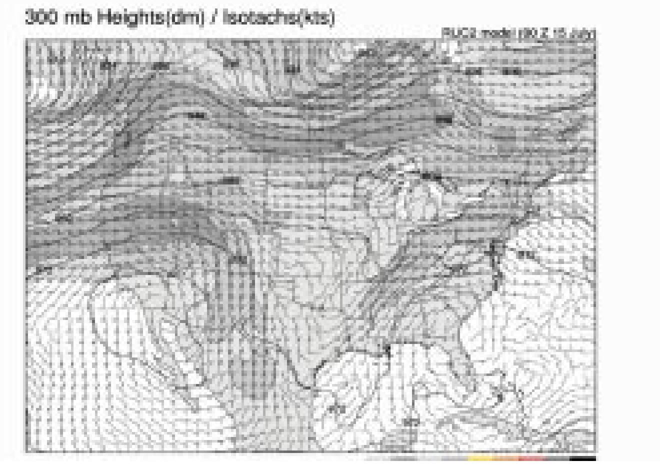

Fig. 3. RUC analysis 300 mb winds and heights at 0 Z on July 15. Isotachs of 30, 50 and 70 knots are shaded.

3. DISCUSSION

We have presented results for a long-lived convective episode (consisting of two MCSs) that lasted 50 hours and spanned 2800 km. The most dramatic feature of the event was an abrupt change from an N-S eastward propagating line to an E-W southward propagating line over northern Minnesota. The synoptic conditions were weak with no evidence of strong thermal boundaries that could account for the changes or the longevity of the storm. Instead the observed features arose primarily because of favorable interactions between the cold pool and the low-level environmental shear

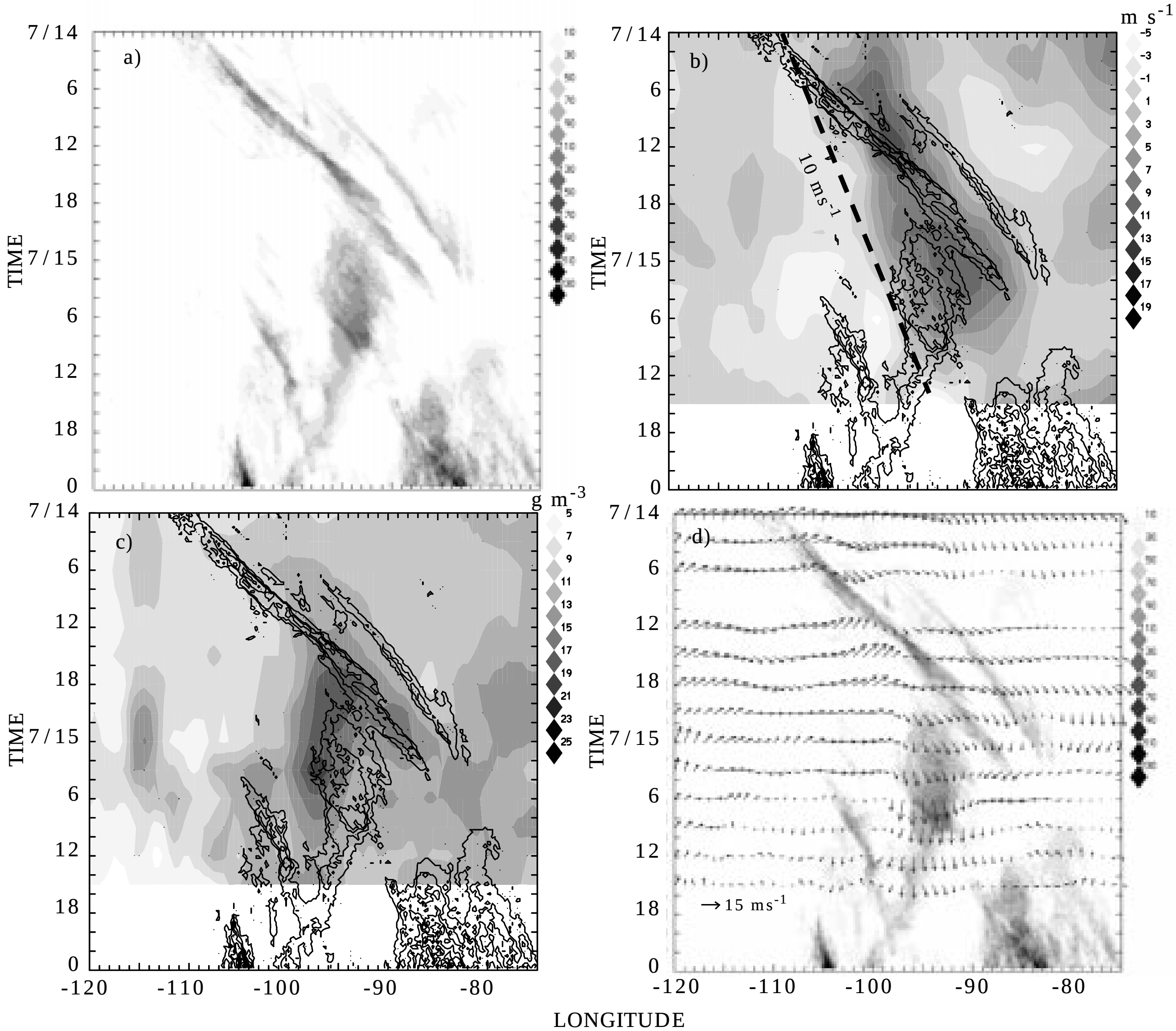

Fig. 4. Time-longitude (Hovmoller) plots of a)radar reflectivity, b) contours of reflectivity superimposed on RUC low-level v-component of wind (dashed line shows position and propagation speed of trough line, c)reflectivity superimposed on low-level mixing ratio and d)reflectivity superimposed on the low-level vertical wind shear vector over a 2.5 km depth.

and moisture. CAE observed many other long-lived system existing in conditions of weak synoptic forcing. Case studies of some of these episodes are ongoing, which along with more statistically based approaches, should provide opportunities for improvements in forecasts of warm season precipitation.

4. REFERENCES

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