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ANALYSIS OF 11 JUNE 2003 MESOSCALE CONVECTIVE VORTEX GENESIS USING WEATHER SURVEILLANCE RADAR – 1988 DOPPLER (WSR-88D)

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1. INTRODUCTION

Long-lived MCVs can produce as much precipitation as a landfalling hurricane and lead to catastrophic flooding. The number of studies using multi-Doppler radar observations for validation of the kinematics, or three-dimensional (3D) wind structure of MCV genesis is limited. While mesoscale convective system (MCS) organization is common, previous published observations of MCVs have lacked the spatial and temporal data coverage to verify basic vorticity generation mechanisms (Scott and Rutledge 1995).

To gain a better understanding of MCVs, the Bow Echo and MCV Experiment (BAMEX) sampled numerous MCSs at high spatial and temporal resolution (Davis et al. 2004). The 11 June 2003 case provides an ideal opportunity to verify the proposed vorticity generation mechanisms of a long-lived MCV. However, during the time of initial formation, airborne Doppler radar platforms were not available to collect data so it is necessary to rely on two radars from the WSR-88D network to determine the 3D wind structure. The precursors to the MCV were two nocturnal MCSs which occurred on consecutive nights, both triggered by a short-wave disturbance embedded within the subtropical jet (Galarneau and Bosart 2005). The first MCS formed over eastern New Mexico on the evening of 9 June and produced an MCV over western Texas in the early morning hours of 10 June (Fig. 1). This vortex moved northeastward over western Oklahoma and new convection developed northwest of Norman, OK around 0000 UTC June 11 and evolved into another MCS overnight. Cyclonic rotation was evident through subjective analysis by 0600 UTC as the new circulation associated with the 11 June 2003 MCV developed.

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Also unique to this case is the fact that vorticity at mid-levels was able to penetrate the boundary layer and create cyclonic circulation at the surface. This MCV rapidly generated in approximately 1 hour, suggesting convective rather than planetary rotation (i.e., Coriolis force) influence on the time scales of MCV genesis. The time period of interest is 0000 to 0300 UTC on 11 June 2003 during which a convective line with little stratiform rain evolved into an organized MCS with an MCV located within its trailing stratiform rain region.

2. DATA AND METHODS

The data used in this study are from the Oklahoma City (KTLX) and Tulsa, Oklahoma (KINX) WSR-88D. The baseline between the two radars is 180.7 km, which is long by conventional methods but works well for this case to document mesoscale development of the MCV. The REORDER software program (Mohr et al. 1986) was used to convert level-II WSR-88D data from polar (radar) coordinates into a Cartesian coordinate system. The Cartesian grid was given a horizontal and vertical resolution of 3.0 km and 0.5 km, respectively. The horizontal radius of influence was set to 6.0 km while the vertical radius of influence was set to 3.0 km. A three-dimensional Cressman weighting scheme was used to derive Cartesian grid points from polar radar data. The analysis domain was a 450 km by 450 km box centered on the KTLX radar. Dual-Doppler analyses were performed using the NCAR CEDRIC (Custom Editing and Display of Reduced Information in Cartesian Space) software package (Mohr and Miller 1983). Analyses of reflectivity, wind magnitude and direction, and vertical vorticity were performed every fifteen minutes during the 0000 to 0300 UTC time period to allow a detailed examination of the MCV evolution.

3. RESULTS AND DISCUSSION

Figure 2 shows the rapid development of the 11 June 2003 MCV from 0000 to 0230 UTC. At 0000 UTC, the system was dominated by a leading convective line with a small region of stratiform rain. There is a suggestion of circulation in the rearward notch of 40 dBZ reflectivity located at x=0.0 km, y=80.0 km extending back from the leading line of convection. However, two hours later at 0200 UTC the system evolved into a mature MCS with a leading convective line and a larger trailing stratiform region. Within this stratiform region an MCV clearly exists with a closed circulation diameter of approximately 70 km. The early circulation evident in the leading convective line, which is followed by the development of a circulation center by 0045 UTC (not shown) and then a well defined MCV by 0200 UTC, qualitatively supports the idea that vorticity is generated on convective time scales.

Figure 3 shows the rapid development of vertical vorticity at 1.0 km. Although maximum vertical vorticity at 0000 UTC was $5.19\times10^{-3}\ s^{-1}$, it is entirely associated with the convective line. In the next hour, the region of vertical vorticity expanded and moved rearward relative to the leading convective line. In the next three hours as the MCV propagated to the east, the area of vertical vorticity expanded as did the diameter of the closed circulation associated with the MCV (not shown).

Figure 4 shows a north-south and east-west transect through the center of the MCV at 0130 UTC. Interestingly, at this time vertical vorticity has nearly penetrated to the surface and the diameter of the MCV is approximately 70 km when including all vertical vorticity contours above $1\times10^{-4}\ s^{-1}$ connected to the center of the MCV. There is also a large region of $1.1\times10^{-3}\ s^{-1}$ vertical vorticity that extended from near the surface to approximately 7.0 km centered on the MCV.

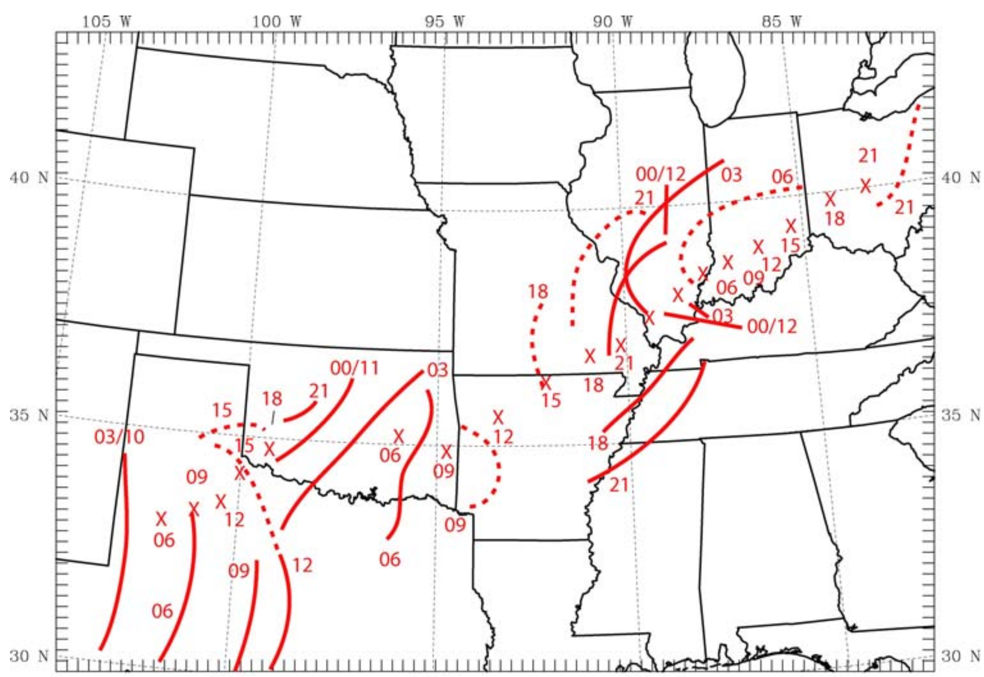

Figure 1. Isochrones of leading convective lines (solid = solid line of reflectivity > 40 dBZ, dashed = broken line consisting of cells with reflectivity > 40 dBZ) and positions of MCV (X's) at 3 hour intervals for the 11 June 2003 MCV. Two digit numerical labels refer to time (UTC), while the first symbol of the day is marked by both hour and day (HH/DD).

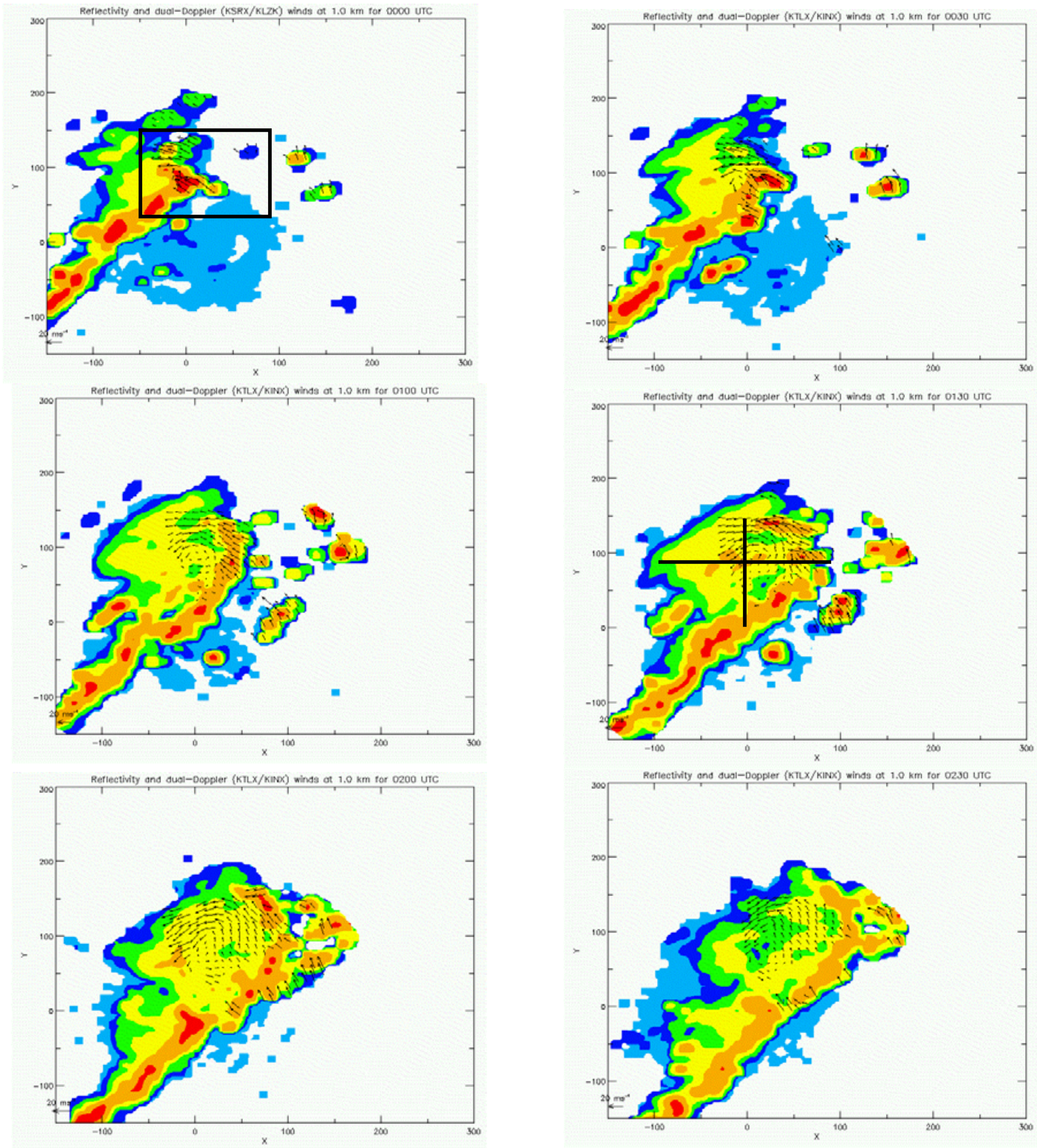

Figure 2. Reflectivity and wind vectors at half hour intervals between 0000 and 0230 UTC at 1.0 km altitude. Reflectivity scaled in 10 dBZ increments from 0 dBZ (light blue) to 50 dBZ (red). The box located in the 0000 UTC figure is the domain used for horizontal cross-sections of vertical vorticity in Figure 3. The two lines located in the 0130 UTC figure are for the vertical cross-sections located in Figure 4.

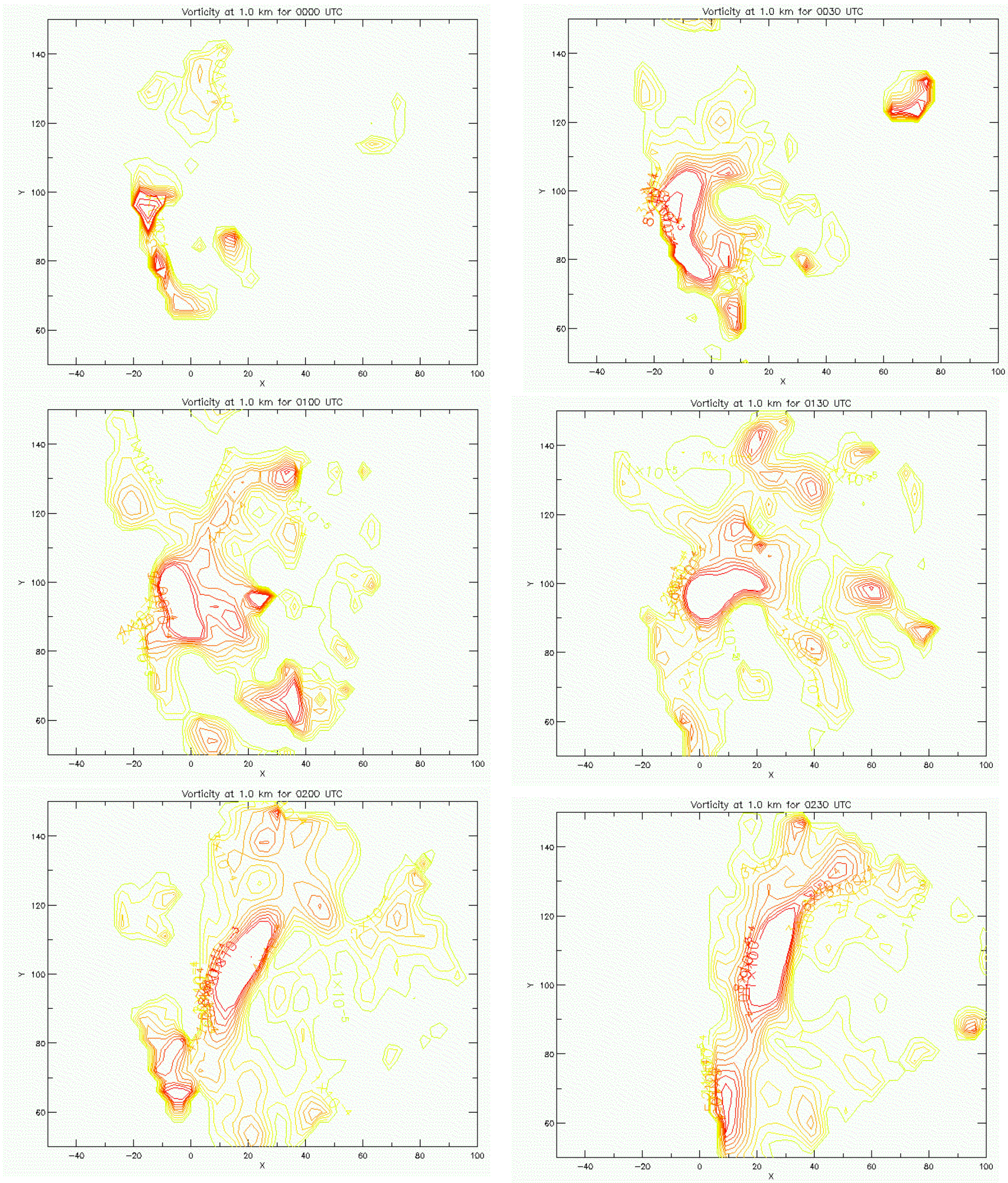

Figure 3. Horizontal cross-sections of vertical vorticity at an altitude of 1.0 km for half hour intervals between 0000 and 0230 UTC. The first contour level is $1x10^{-5}$ s^{-1} (green). The next contour level is $1x10^{-4}$ s^{-1} (yellow) with a $1x10^{-4}$ s^{-1} increasing interval thereafter.

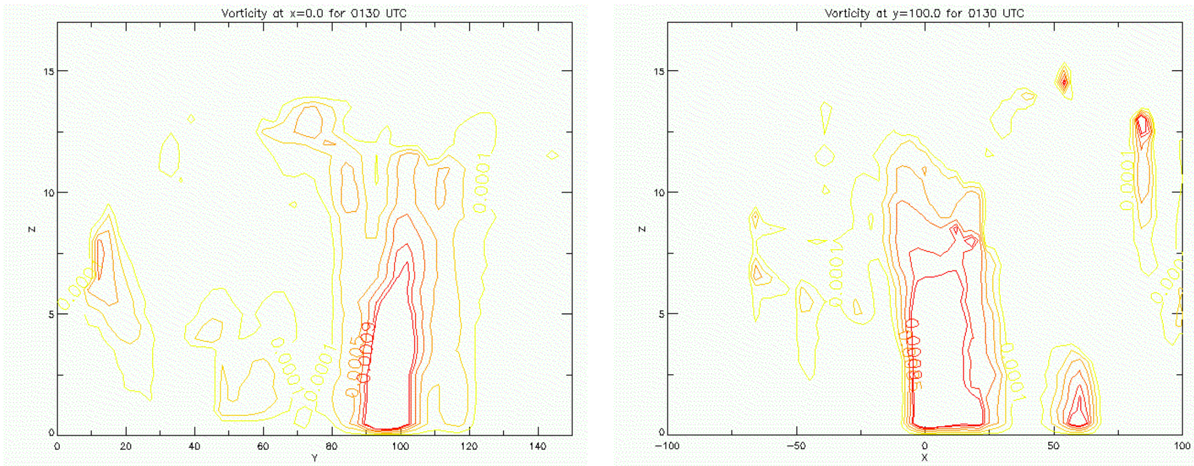

Figure 4. Same as Fig.3 except vertical cross-sections for North-South (left) and East-West (right) transects (see Fig. 2).

4. CONCLUSIONS

The results of this study have shown that the 11 June 2003 MCV rapidly generated from 0000 to 0230 UTC, increased in size both horizontally and vertically, and likely benefited from the rearward advection of vertical vorticity generated by the leading convective line. A maximum vertical vorticity of $5.19 \times 10^{-3}\ s^{-1}$ did exist at 0000 UTC, but was entirely located within the convective line before the appearance of an organized stratiform rain region or MCV. It appears that the rapid generation of the 11 June 2003 MCV occurred at convective, rather than planetary, timescales. Future work will include cumulative frequency with altitude diagrams to obtain a better understanding of the 3-dimensional evolution of this rapidly generating MCV. In addition, a vorticity budget will be performed to determine exactly how the MCV was able to generate.

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