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5.4

THE LONG-LIVED MCV OF 11-13 JUNE 2003 DURING BAMEX

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1. INTRODUCTION:

The Bow Echo and Mesoscale Convective Vortex Experiment (BAMEX) was conducted from 18 May to 7 July 2003 out of Mid America Airport (BLV) located approximately 40 km east of St. Louis, Missouri. The period 5-14 June 2003 was noteworthy for the strong subtropical jet (STJ) that dominated the large-scale flow pattern. The STJ was positioned from southeast of Hawaii east-northeastward to the Mississippi Valley, then northeastward to the North Atlantic. The STJ provided a freeway for embedded disturbances to propagate over the central US, triggering multiple convective modes, including several mesoscale convective vorticies (MCVs).

MCVs have been documented to develop in the stratiform region of mesoscale convective systems (MCSs; e.g., Jorgenson et al. 1997). Although most MCVs dissipate as the parent MCS decays, in some cases MCVs can last long after the parent MCS has decayed (e.g., Bartels and Maddox 1991). Davis and Weisman (1994) suggest that the longevity of MCVs may be controlled by vertical shear. Weak but well-defined shear confined to low levels appears to optimize longevity, whereas moderate shear extending throughout the depth of the vortex weakens the MCV. Knievel and Johnson (2002) showed in a case from 1 August 1996 that deepening of an MCV may be reflected in changes of the vertical wind shear near the vortex's center. Long-lived MCVs, which can last through several diurnal heating cycles, can be responsible for reorganizing convection (e.g., Menard and Fritsch 1989), which can produce extensive rains over large regions (e.g., Bosart and Sanders 1981; Fritsch et al. 1994). The reorganized convection can provide a positive feedback mechanism by sustaining or reinvigorating the MCV (e.g., Trier et al. 2000).

On 0000 UTC 10 June 2003, a disturbance embedded in the STJ triggered convection over eastern New Mexico and western Texas. A mesoscale convective vortex (MCV) developed from the remnants of this convection over central Oklahoma at 0600 UTC 11 June 2003, and matured as it traveled northeastward. The uniqueness of this MCV lies in it longevity and its transition into a baroclinic system. The purpose of this presentation is to document the evolution and structure of this MCV in terms of vertical shear, dynamical structure, thermodynamic profiles, surface observations, and convective reorganization as it propagated northeastward to Ohio.

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2. DATA SOURCES:

The data used in this study were obtained from the BAMEX field catalog (http://www.ofps.ucar.edu/bamex/catalog/) and archives at the University at Albany/SUNY. Global 1.0° x 1.0° National Centers for Environmental Prediction Global Forecast System (NCEP/GFS) grids, available four-times daily, were used for all diagnostic calculations.

3. RESULTS:

(a) Dynamic and thermodynamic structures:

The large-scale flow pattern is shown in Figs. 1a and 1b. Figure 1a shows the 200 hPa height and isotachs for 1800 UTC 9 June. Note the 60-80 knot STJ situated from southeast of Hawaii stretching east-northeastward to the Mississippi Valley, where a coupled jet is present. This figure is representative to the period of 5-14 June in which the STJ dominated the large-scale flow pattern over the southern US. Within the STJ, transient disturbances propagated from the east-central Pacific, across the central US, to the northern Atlantic.

Figure 1b shows the 500-200 hPa thickness and 300 hPa absolute vorticity, and shows clearly four quasi-regularly spaced disturbances within the STJ. The three-day time-mean flow satisfies the necessary condition for barotropic instability (not shown). Simple Sutcliffe reasoning though $-\vec{V}_T \bullet \nabla(\zeta + f)$ would suggest that these disturbances should propagate eastward along the thickness gradient. These disturbances were not associated with any convection over the eastern Pacific, likely due to their small Rossby penetration depth in a stable atmosphere which can be seen when comparing Fig. 1b with the GOES-10 infrared image (Fig. 2a), both from 1800 UTC 9 June. Figure 2a clearly shows the lack of convection associated with these disturbances. These transient disturbances failed to trigger and organize convection until they reached the eastern side of the Rockies (Fig. 2b) where unstable high θ_e air was prevalent, thus increasing the Rossby penetration depth (not shown).

Convection began over the higher terrain of New Mexico at 0000 UTC 10 June in response to daytime heating (not shown), and subsequently organized into an MCS by 0300 UTC 10 June on the leading edge of disturbance "A" (Fig. 2b). As this MCS propagated southeastward, remnant mid-level vorticity associated with the aforementioned convection traveled northeastward into Oklahoma where it triggered new convection at 0000 UTC 11 June. This retriggering of convection was followed by a reintensification of the mid-level vorticity maximum and resulted in an MCV by 0600 UTC 11 June. This convective retriggering supports the positive feedback mechanism suggested by Trier et al. (2000a).

The remnant vorticity/MCV track is shown in Fig. 3 and is based upon the 600 hPa absolute vorticity field. Mid-level vorticity is first evident at 0600 UTC 10 June over eastern New Mexico in association with a squall line and trailing stratiform region (not shown). The vorticity maximum travels eastward with its associated squall line, then turns northeastward immediately after 1200 UTC 10 June as the squall line turns southeastward. The remnant vorticity retriggers convection, as mentioned above, and moves east-northeastward, then northeastward towards Lake Erie.

West to east cross sections of potential vorticity (PV), potential temperature (θ), and wind are shown on Fig. 4. At 1200 UTC 10 June (Fig. 4a) an upshear tilt configuration of the mid- and upper-level disturbances is evident and are connected with a small PV filament of approximately 1.0 PVU. At 0600 UTC 11 June, the mid-level disturbance is located over central Oklahoma and has strengthened (Fig. 4b). The mid-level PV anomaly is showing classic structure of an interior PV anomaly seen in Fig. 21 of Hoskins et al. (1985), with uplifted (downlifted) θ surfaces beneath (above) the disturbance. At 1800 UTC 11 June, the PV anomaly has grown further while a secondary anomaly has developed at 800 hPa. At this point, the MCV is in its mature stage, is growing upscale and is retriggering convection. Upshear tilt is evident in the wind field. At 0000 UTC 13 June, the upper-level PV disturbance has moved ahead of the mid-level PV disturbance, resulting in a forward tilt, and subsequent weakening of the MCV.

MCV-relative winds and pressure on the θ=310 K surface were generated from Lear-Jet dropsondes taken during intensive operations period 8 (IOP 8) conducted at 1600-1900 UTC 11 June (not shown). The center of circulation on the θ=310 K surface is to the southwest of the surface position, thus supporting evidence that the MCV tilted upshear. A broad tongue of ascent is positioned east of the MCV amidst broad southerly flow. The MCV was retriggering convection in the aforementioned region of ascent and farther east. Figures 6a-b shows examples of dropsondes during IOP 8 surrounding the MCV. A deep moist layer is present east (not shown) and north (Fig. 5a) of the MCV, and drier air and associated subsidence west (Fig. 5b) and southwest (not shown) of the MCV. Upshear tilt is apparent in the wind field seen in Fig. 5b, which supports previous evidence that the MCV was an upshear tilted system.

(b) Surface and radar observations:

Figures 6a-b document the evolution of the surface and radar features associated with the MCV. At 0000 UTC 11 June (not shown), a surface trough oriented south-southwest to north-northeast is positioned over central Oklahoma with a surface pressure deficit of approximately 2 hPa with respect to the surrounding environment. A squall line, triggered by remnant mid-level vorticity seen in Fig. 4b, has developed within this surface trough. The squall line develops a trailing stratiform region in which an MCV develops by 0600 UTC 11 June (not shown).

At 1800 UTC 11 June (Fig. 6a), the MCV is now in the mature stage with a surface pressure deficit of approximately 3-4 hPa. The MCV, while in Missouri and Arkansas, existed in a weak θ gradient region. Convection is redeveloping in the inflow region of the MCV. A wind shift boundary lies over central Illinois to the north and east of the MCV and extends northeastward to the southern edge of the Great Lakes. At 0000 UTC 12 June (not shown), the MCV's circulation area has grown, and surface pressure has dropped to almost 1004 hPa. Precipitation has shifted to the northern side of the MCV, in response to a shift in the main ascent region to the northwest side (not shown) and the aforementioned boundary over central Illinois. The MCV is beginning to interact with this boundary and is transitioning into a baroclinic system.

At 2100 UTC 12 June (Fig. 6b), the MCV has continued moving northeastward and is now situated over northern Ohio. The area of cyclonic circulation associated with the MCV has strengthened and expanded as the MCV has now attached itself to the aforementioned surface baroclinic zone just south of Lake Erie, thus acquiring frontal structure. The surface θ gradient was likely enhanced in the warm frontogenesis region because of warm southerly flow ahead of the MCV interacting with air situated over the cool waters of Lake Erie.

At 0000 UTC 13 June, the upper-level disturbance has moved eastward of the MCV resulting in downshear tilt (Fig. 4d). Subsequently, the MCV dissipated, and the remnants can be tracked into southern Canada (not shown).

4. CONCLUSIONS:

The period 5-14 June 2003 during BAMEX featured a strong STJ from southeast of Hawaii, stretching across the southern US, then northeastward to the North Atlantic. Transient disturbances embedded within the STJ acted to trigger multiple convective systems across the US. These disturbances were unable to trigger convection until they crossed to the eastern side of the Rockies and tapped the moist unstable air thus increasing the Rossby penetration depth.

A long-lived MCV formed from a squall line triggered by remnant mid-level vorticity over Oklahoma on 0600 UTC 11 June. This MCV can be tracked northeastward to Ohio. It is noteworthy for tilting upshear, reorganizing convection, growing upscale, and acquiring baroclinic structure

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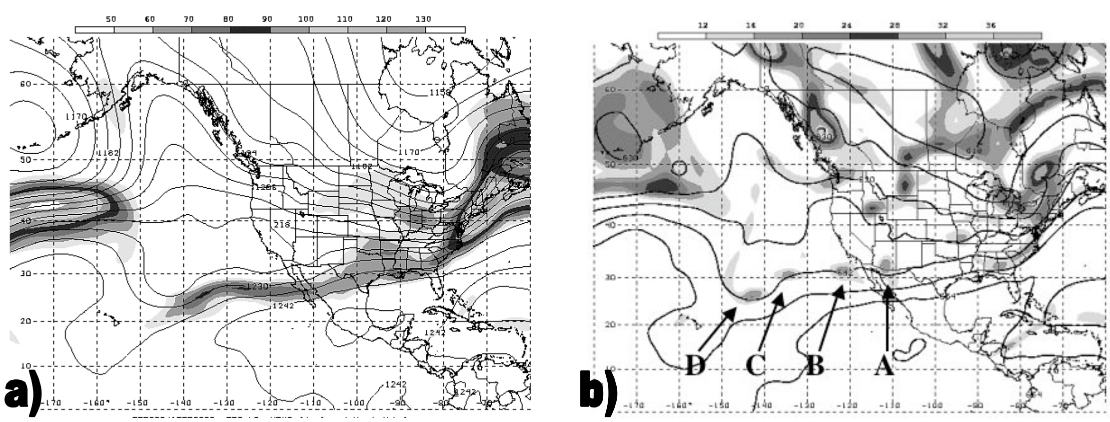
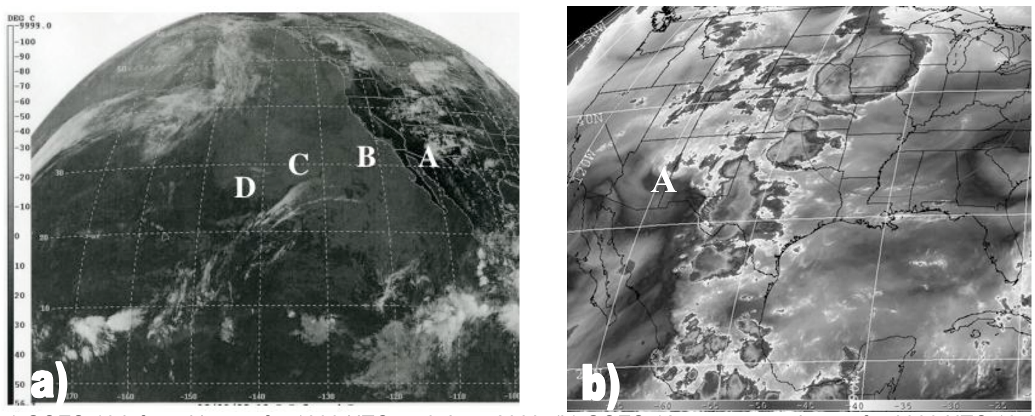


Figs. 1a-b: (a) 200 hPa heights (solid contours, dam) and isotachs (shaded, knots) for 1800 UTC on 9 June 2003; (b) 700-300 hPa thickness (solid contours, dam) and 300 hPa absolute vorticity (shaded 10^{-5} s^{-1}) for 1800 UTC on 9 June 2003.



Figs. 2a-b: (a) GOES-10 infrared image for 1800 UTC on 9 June 2003; (b) GOES-12 water vapor image for 0300 UTC 10 June 2003.

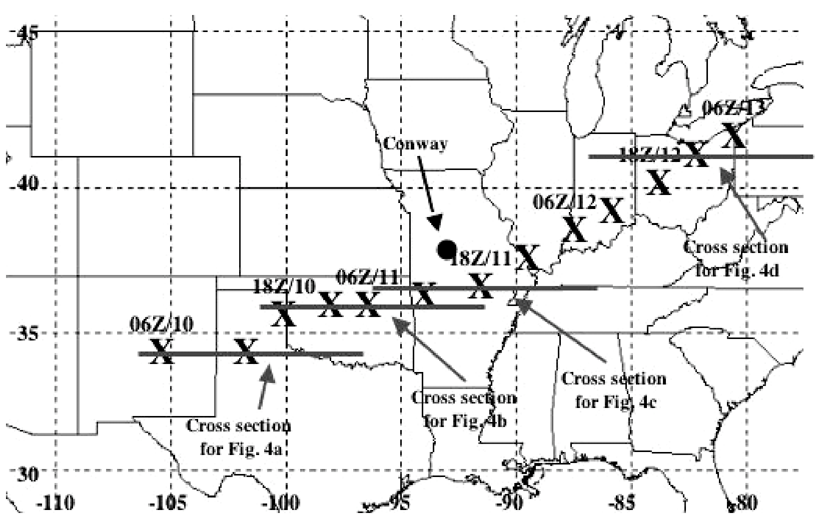
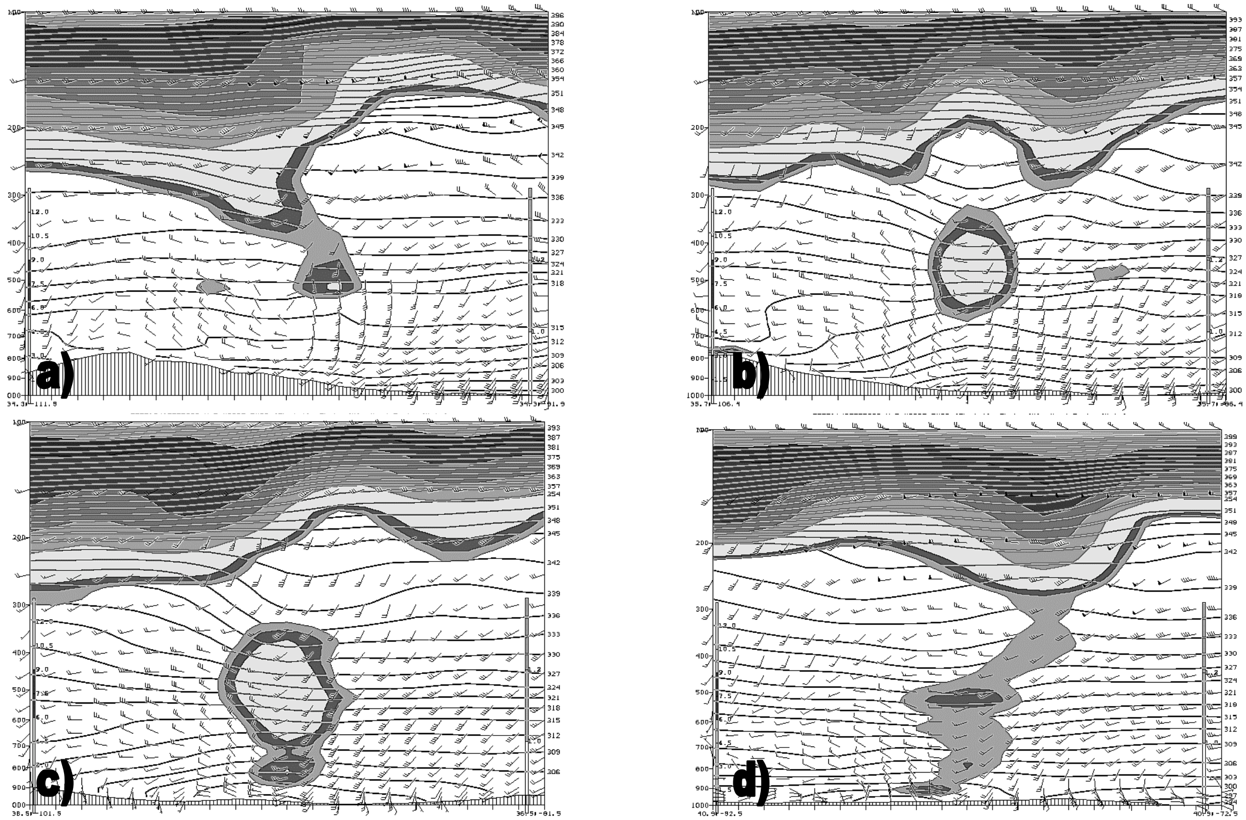


Fig. 3: Position of MCV from 0600 UTC 10 June-0600 UTC 13 June 2003 marked every 6 hours and position of cross sections for Figs. 4a-d (solid lines).



Figs. 4a-d: West to east cross section of potential vorticity (shaded, PVU where 1 PVU = 1×10^{-6} m^2 s^{-1} K kg^{-1}), potential temperature (solid contours, K), and wind barbs (knots) for (a) 1200 UTC 10 June, (b) 0600 UTC 11 June, (c) 1800 UTC 11 June, and (d) 0000 UTC 13 June 2003.

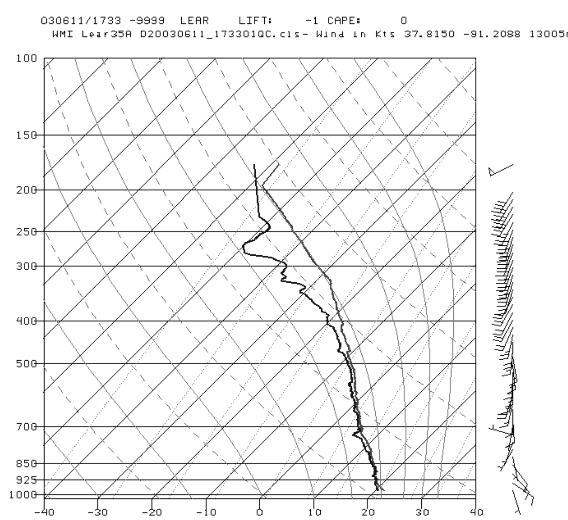


Fig. 5a: Lear-Jet Dropsonde for 1733 UTC 11 June 2003 north of MCV

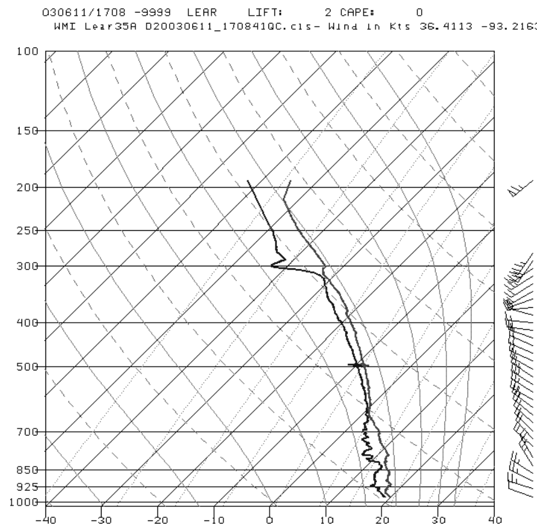
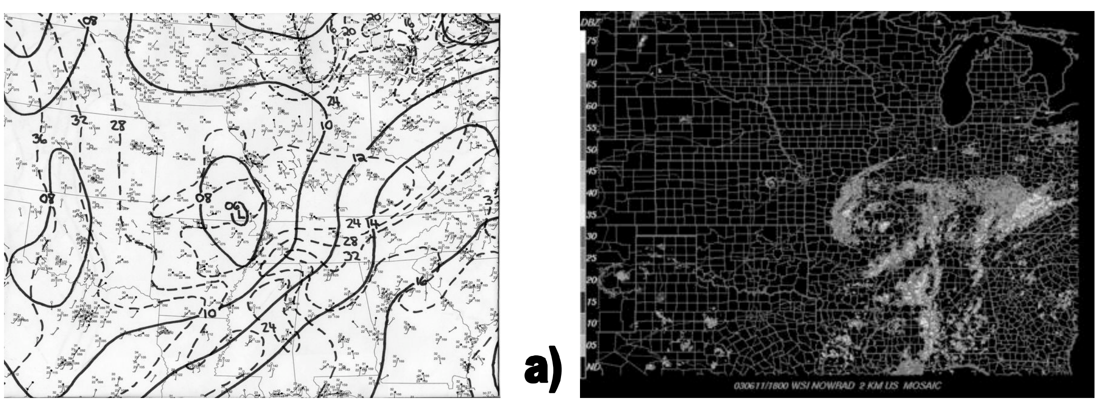
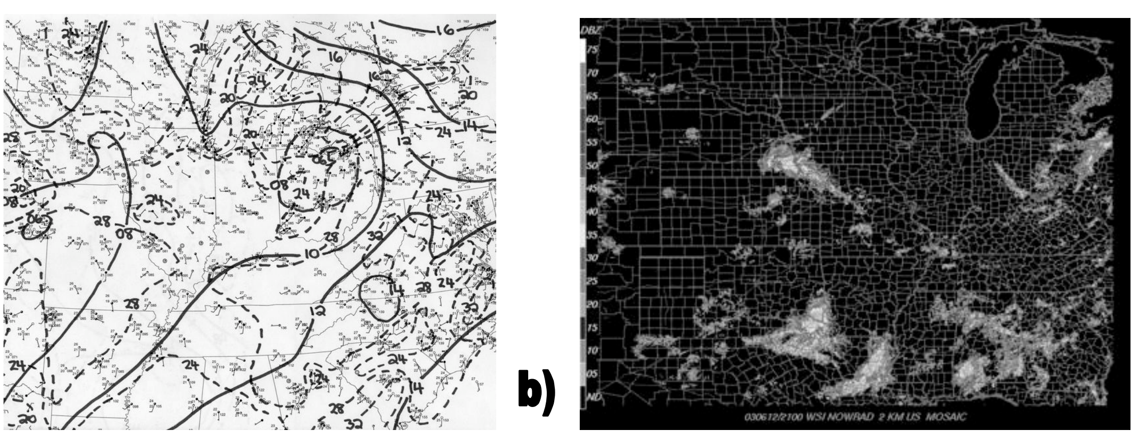


Fig. 5b: Lear-Jet Dropsonde for 1708 UTC 11 June 2003 west of MCV



a)

Fig. 6a: Surface pressure (solid contours, hPa), potential temperature (dashed contours, not plotted on stations, C), dew point (C), temperature (C), winds (knots), and present weather (left), and composite base reflectivity image (right) for 1800 UTC 11 June.



b)

Fig. 6b: Same as Fig. 6a, except for 2100 UTC 12 June 2003.