J5J.1

Keynote Talk: BAMEX Observations of Mesoscale Convective Vortices

Christopher A. Davis and Stanley B. Trier
National Center for Atmospheric Research
Boulder, Colorado 80307

1. Introduction

The Bow Echo and Mesoscale Convective Vortex (MCV) Experiment (BAMEX) is a study of life cycles of mesoscale convective systems using three aircraft and multiple, mobile ground-based instruments. It represents a combination of two related programs to investigate (a) bow echoes (Fujita, 1978), principally those which produce damaging surface winds and last at least 4 hours and (b) larger convective systems which produce long lived mesoscale convective vortices (MCVs) (Bartels and Maddox, 1991). The project was conducted from 20 May to 6 July, 2003, based at MidAmerica Airport in Mascoutah, Illinois. A detailed overview of the project, including preliminary results appears in Davis et al. (2004). The reader wishing to view processed BAMEX data should visit http://www.joss.ucar.edu/bamex/catalog/.

In this keynote address, I will focus on the study of MCVs, based particularly observations from airborne Doppler radar and dropsondes and wind profilers. This article will present results from the last case of the project, the bow echo and formative MCV of 5-6 July, 2003. This case has been studied in detail in a companion set of papers by Wakimoto et al. (2005a, 2005b).

2. Facility Deployment

Three aircraft were used in BAMEX: one of the P-3s from the National Oceanic and Atmospheric Administration (NOAA), the Naval Research Laboratory (NRL) P-3 and a Lear jet leased from Weather Modification Inc. (WMI). Mobile Ground-based facilities included the Mobile Integrated Profiling System (MIPS) from the University of Alabama (Huntsville) and three Mobile GPS-Loran Atmospheric Sounding Systems (MGLASS) from NCAR. The MIPS and MGLASS were referred to as the ground based observing system (GBOS). The two P-3s were each equipped with tail Doppler radars, the Electra Doppler Radar (ELDORA) being on the NRL P-3. The WMI Lear jet deployed dropsondes from roughly 12 km AGL.

For MCSs, the objective was to sample mesoscale wind and temperature fields while obtaining high-resolution snapshots of convection structures, especially those

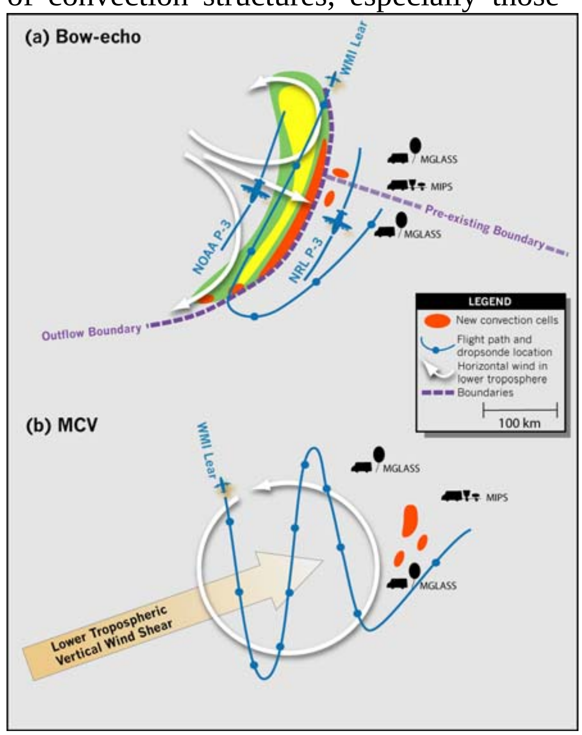

Figure 1. Schematic of BAMEX facility deployment.

linked to damaging surface winds. The ideal deployment (Fig. 1a) featured the Doppler aircraft on either side of the convective line with the Lear jet sampling environmental conditions ahead of the system as well as mesoscale circulation features. The NOAA P-3 was also equipped with cloud and particle imaging probes to quantify the microphysical composition of the stratiform region. The GBOS was focused on boundaries ahead of the MCS and measuring boundary evolution both ahead and within the MCS (i.e. measuring cold pool characteristics).

For mature MCVs (sampled after the decay of the spawning MCS), the lack of significant precipitation implied no need of the Doppler-equipped aircraft (except IOP 1). The Lear jet flew legs across the MCV (Fig. 1b) to cover the circulation of the MCV as well as some of the region outside the circulation. The MGLASS augmented sounding coverage, especially on the downshear side of the vortex.

The main challenge for BAMEX was complicated coordination of aircraft and ground teams near areas of hazardous weather. The ground teams were based near the location where convection was anticipated, hence they often had to drive 300-500 km in a single day to be in position. The aircraft were restricted to roughly an area of 600 km surrounding MidAmerica Airport near St. Louis, the base of the project.

Real-time aircraft communication (plane-to-plane and plane-to-ground) used internet chat room capability as well as satellite phones. This worked very well and overcame some of the complications related to intermittency of weather displays for the NRL P-3 and complex direction of the Lear jet, which had only weather-avoidance radar on board. Effective communication allowed extensive simultaneous Doppler measurements from each P-3, known as quad-Doppler, where four beams sample approximately the same volume of air. Several successful quad-Doppler datasets were collected during BAMEX bow echoes, including the July 5-6 case.

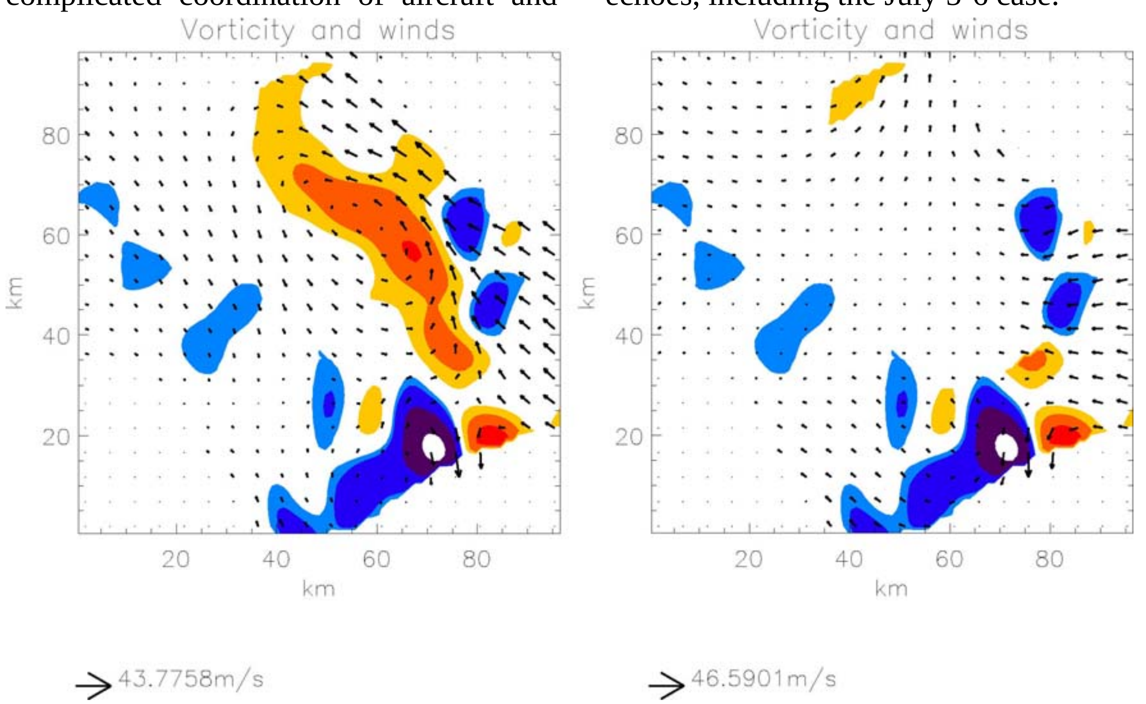

Figure 2. Relative vorticity at 1.6 km AGL for (a) full field and (b) field with line-end vortex removed. Cyclonic vorticity greater than 10^{-3} s^{-1} is yellow, and greater than $2.5x10^{-3}$ s^{-1} is orange.

3. 5-6 July Developing MCV

As summarized in Wakimoto et al., several synchronized passes of the P-3 aircraft were accomplished during the 5-6 July event (IOP 18). The MCS organized over northeastern Nebraska on the evening of 5 July, and rapidly propagated eastward. Damaging winds occurred in the Omaha Nebraska area just prior to 0600 UTC.

A quad-Doppler leg fortuitously passed near enough to the developing line-end vortex that a detailed snapshot could be obtained. Figure 2 shows the relative vorticity and wind at 1.6 km AGL just prior to 0600 UTC, while the convective system was still intense.

From Fig. 2a, two cyclonic vortices are apparent. One is the small-scale (10 km diameter) feature that is at the edge of the data on the right side of the plot. This was the vortex responsible for focusing the damaging wind in the Omaha area, studied in detail by Wakimoto et al. The much larger vortex to the north is highly elongated northwest-southeast. The long axis is roughly 70 km in length. Strong southeast winds are evident on the east side (these winds are relative to the movement of the convective line). To the west and southwest of the maximum of cyclonic vorticity, northwesterly winds prevail, turning to westerly to the south (which is immediately to the west of the strongest convection at this time).

Data from other altitudes indicate that this vortex penetrated to within 400 m AGL between 0538 and 0548 UTC. The elongated nature of the vortex and the lobe of vorticity on the southeastern end, coupled with the isolated intense vortex further southeast suggest a string of large vorticity immediately behind the convective line. It is possible that mesovortices are continually forming and merging within the broad circulation on the northern end that defines the growing MCV. Further diagnosis is needed to determine the origin of this feature.

A diagnostic calculation was done in which the vorticity at 1.6 km AGL was removed from the remainder of the vorticity field. The difference between this modified vorticity (Fig. 2b) and the full vorticity (Fig. 2a) was inverted for a non-divergent streamfunction and a non-divergent wind as in Wakimoto et al. (2005b). This wind was subtracted from the full wind, yielding the resultant wind field in Fig. 2b. Of note is a nearly complete lack of a *storm-relative* rear inflow current without the line-end vortex. Thus, the propagation of the MCS matched the divergent rear-inflow current at this altitude. The developing MCV provided nearly all the storm-relative rear-inflow observed.

Within 1 hour of this time, the system decayed dramatically. One hypothesis is that the system encountered drier lower-tropospheric air farther east in the wake of a previous MCS in southeastern Iowa, based on the 00 UTC sounding from Davenport, Iowa. However, a 06 UTC sounding from the same location indicated that lower-tropospheric mixing ratios had nearly recovered to amounts favoring convection. Another possibility is that the MCV itself played a role in the MCS decay, perhaps by altering the shear in the vicinity of the leading-line convection. This possibility is being further evaluated.

Late that night, a well-defined MCV moved across northern Iowa into Wisconsin, as evinced by radar animations (not shown). The vortex was associated with new convection in Wisconsin during the following afternoon. This represents the first known case where the detailed structure of an MCV was observed during its formation.

4. Other Results

Mature MCVs were also examined extensively using dropsondes and wind profilers. The salient results of this analysis will be described at the conference, but the key findings are:

- MCVs can penetrate to the surface, but it typically takes two diurnal cycles to do so (with new convection each night). However, there is evidence that the July 6 MCV penetrated to the surface via a single MCS.
- MCVs are dynamically balanced – established from observations conclusively for the first time.
- New convection occurs primarily downshear from MCVs, but there are significant structural complications to the theorized dipole of quasi-balanced ascent theorized by Raymond and Jiang (1990).

References

Bartels, D. L., and R. A. Maddox, 1991: Midlevel cyclonic vortices generated by mesoscale convective systems. *Mon. Wea. Rev.*, **119**, 104--118.

Davis, C., N. Atkins, D.Bartels, L. Bosart, M. Coniglio, G. Bryan, W. Cotton, D. Dowell, B. Jewett, R. Johns, D. Jorgensen, J. Knievel, K. Knupp, W.-C. Lee, G. McFarquhar, J. Moore, R. Przybylinski, R. Rauber, B. Smull, J. Trapp, S. Trier, R. Wakimoto, M. Weisman, and C. Ziegler, 2004: The Bow-Echo And MCV Experiment (BAMEX): Observations and Opportunities, *Bull. Amer. Meteor. Soc.*, In Press: August Issue.

Done, J., C. Davis, and M. Weisman, 2004: The Next Generation of NWP: Explicit Forecasts of Convection Using the Weather Research and Forecasting (WRF) Model. *Atmos. Sci. Lett.*

Fujita, T. T., 1978: Manual of downburst identification for project NIMROD. Satellite and Mesometeorology Research Paper No. 156, Department of Geophysical Sciences, University of Chicago, 104 pp.

Wakimoto, R., H. V. Murphey, A. Nester, D. J. Jorgensen, and N. T. Atkins, 2005a: High Winds Generated by Bow Echoes. Part I: Overview of the Omaha bow echo 5 July 2003 Storm during BAMEX. *Mon. Wea. Rev.*, Submitted.

Wakimoto, R., H. V. Murphey, C. A. Davis, and N. T. Atkins, 2005b: High Winds Generated by Bow Echoes. Part II: The Relationship between the Mesovortices and Damaging Straight-Line Winds. *Mon. Wea. Rev.*, Submitted.