5.6 SYSTEM-RELATIVE DISTRIBUTION OF ATMOSPHERIC SOUNDINGS OBTAINED DURING BAMEX

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1 INTRODUCTION

The Bow echo And MCV Experiment (BAMEX) was the first large-scale effort to obtain high frequency atmospheric soundings within and near bow echo mesoscale convective systems (MCSs) and mesoscale convective vortices (MCVs). Over seven weeks from May to July 2003, about 450 dropsondes and 120 rawinsondes were launched from a Lear jet and mobile ground-based platforms (M-GLASS) ahead of, behind, and within mesoscale circulations associated with severe bow echo MCSs and MCVs. In order to address outstanding scientific questions the investigators targeted specific regions of the MCS and MCV by actively directing the Lear jet and M-GLASS units from a central operations center at Mid-America airport east of St. Louis. While air traffic and ground-based limitations sometimes hampered the sampling process, overall, the investigators enjoyed unprecedented access to the mesoscale systems for several hours at a time, and a great number of atmospheric soundings were obtained in critical regions of the storm. This paper describes the system-relative distribution of soundings with respect to the apex of the mature bow echo or the center of the MCV.

2 METHODOLOGY

2.1 BOW ECHOS

In order to explain the term "system-relative," we must first explore the basic anatomy of a bow echo. In its simplest rendition, one can define two separate zones: ahead of and behind the bow-shaped convective band (see Fig. 1). Usually the convective line precedes a more extensive area of stratiform precipitation, however in its initial stages there may be little or no stratiform precipitation at all. To simplify matters, our coordinate system is based solely on the configuration of the convective line. We first define the primary x-dimension such that x=0 always lies directly on the convective line or its extrapolated position (see Fig. 2 where the x=0 line extends beyond the precipitation echo). Positive x-values are ahead of the line and negative values are behind the line.

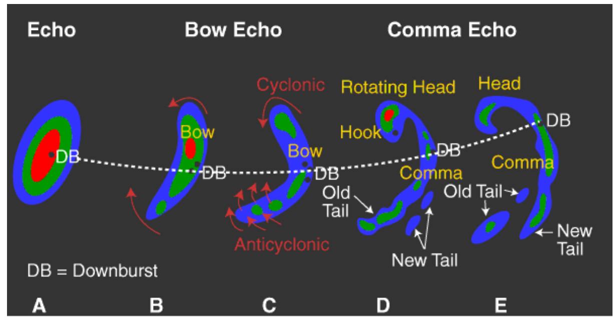

Fig. 1. Typical morphology of radar echoes associated with bow echoes that produce strong and extensive downbursts (from Fujita 1978).

Second, we define a y-axis nearly perpendicular to the x-axis with y=0 on the apex of the bow echo. The y-value corresponds roughly to the along-line distance from the apex. Points to the left of the bow echo motion vector acquire positive y-values while points to the right are negative. The apex of the bow echo was subjectively located in radar reflectivity loops by carefully tracking the point along the bow echo with the greatest curvature (see http://locust.mmm.ucar.edu/bamex/IOPloops20040625 for examples). Theoretically, the origin (x, y)=(0, 0) of our coordinate system coincides with the most damaging downburst winds (denoted with DB in Fig. 1), although no effort was made to correlate actual wind reports with the perceived apex of the bow echoes in this study.

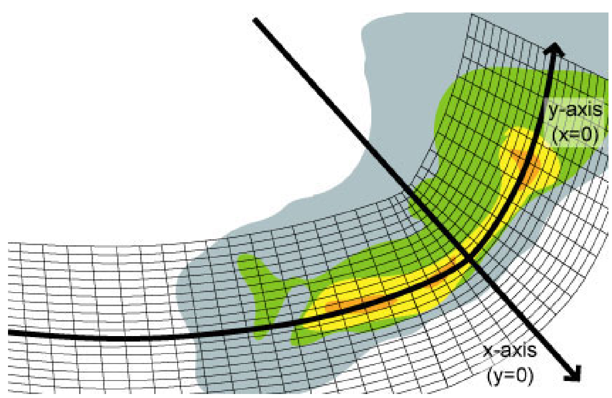

Fig. 2. Generic radar reflectivity pattern associated with a bow echo (solid colors) overlaid by its system-relative coordinate system (curvilinear grid). The origin (x, y) = (0, 0) coincides with the apex of the bow. See text for additional details.

To make this analysis as objective and reproducible as possible, the authors try to use simple rules and standard meteorological conventions. However,

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subjectivity enters the picture. For example, distinguishing between a bow echo and a non-bow echo MCS is sometimes difficult and subject to human interpretation. Different people may come up with different interpretations of the same radar sequence. A similar dilemma applies to finding the bow echo apex and orienting the system-relative y-axis. These types of ambiguities are unavoidable when classifying natural phenomena. On the other hand, certain aspects of this analysis are quite robust, such as the sign of the x-coordinate. If a sonde is assigned a positive x-value, it very likely resides in the zone ahead of the convective line, and conversely, if a sonde has a negative x-value, it is clearly behind the convective line. Additionally, a small x-value is always closer to the convective line than a larger one.

The authors believe y-values should be interpreted with more caution, but are also meaningful. When pre-existing boundaries are present ahead of the convective line, the y-values may be used to help discriminate soundings on either side of the boundary. Behind the convective band, positive y-values will be strongly associated with the cyclonic circulation that typically resides in the northern end of the MCS and negative y-values with the weaker anti-cyclonic circulation to the south.

2.2 MCVS

In the case of MCVs, defining the system-relative coordinates is simpler. The MCV center is subjectively determined from animated sequences of radar reflectivity and/or satellite images. At any instant, the x-axis is tangent to the path of the MCV. In terms of mesoscale dynamics, it may make sense to align the x-axis with the low- to mid-level wind shear vector rather than the MCV motion vector, but this analysis is not finished at the time of this publication. Since the shear vector and the motion vector are often quite similar, we do not expect drastically different results from this additional analysis. Similar to the bow echo coordinate system, the y-axis is always normal to the x-axis and positive y-values are to the left and negative values to the right of the MCV motion vector. However, unlike the bow echo coordinate system, one does not need to skew the y-axis to account for a curvilinear convective line.

2.3 CAVEATS

All together we identify 21 bow echoes and 5 MCVs among 18 intensive observation periods (IOPs). If multiple bow echoes or MCVs are present at one time, and it is unclear which system a particular sonde is sampling, then the system-relative sonde coordinates are calculated separately for each potential system. In this way, one sonde may appear multiple times in the final composites.

Both bow echoes and MCVs occur across a spectrum of spatial scales ranging from a couple dozen to several hundred kilometers. It may prove useful to scale the system-relative coordinates to account for this variability--perhaps by using the linear extent of 40-dBZ echoes (in a bow echo) or the radius of maximum wind (in an MCV) as a scaling factor. However, for simplicity, these composites do not account for the size of the system.

3 RESULTS

Figures 3 and 4 show system-relative sounding locations +/-250 km from the bow echo apex and MCV center. There were several points outside this range, but they are probably not relevant to the feature in question. The sounding density about bow echoes is much greater because 1) some soundings were counted twice (when multiple bows were present), 2) there were more MCS missions than MCV missions and 3) a greater density was required to capture the smaller-scale features in a bow echo system.

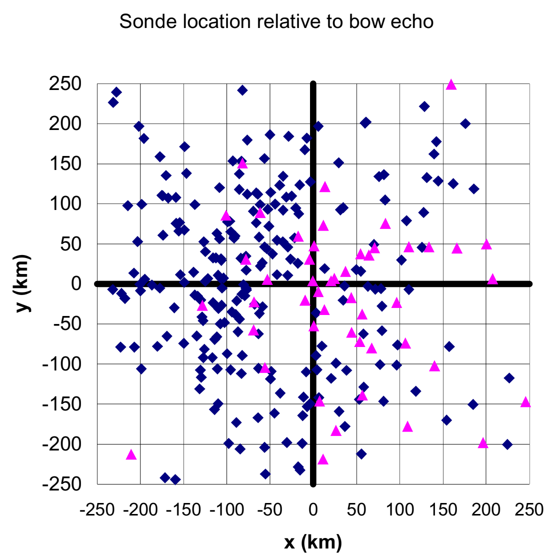

Fig. 3. Dropsonde and M-GLASS launch locations (diamonds and triangles, respectively) relative to apex of the bow echo (x, y) = (0, 0). In this coordinate system, the y-axis (x = 0) corresponds to the convective line, and bow echo motion is to the right towards positive x-values.

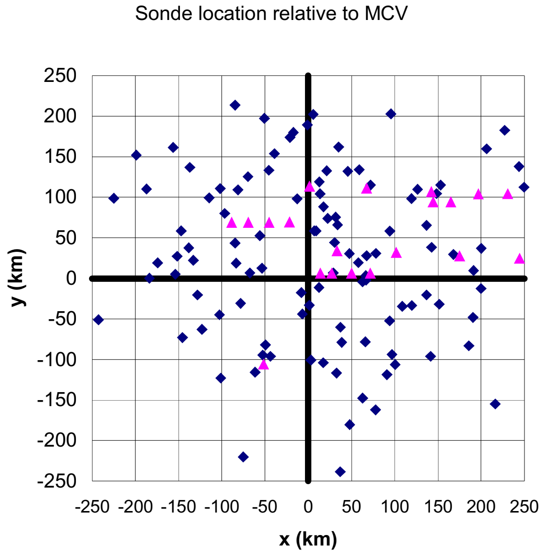

Fig. 4. Dropsonde and M-GLASS launch locations (diamonds and triangles, respectively) relative to center of MCV. The MCV motion is toward positive x-values.

4 SCIENTIFIC PERSPECTIVE

There were a great number of samples behind and within 150 km of the bow echo convective line (Fig 3). This is a scientific boon considering all the outstanding questions about the role of the rear-inflow jet and its lifecycle. Does it descend to the surface and how does it interact with the stable nocturnal boundary layer? With so many system-relative soundings, we should be able to reconstruct a fairly detailed three-dimensional picture of the rear inflow jet in several stages of development and in a variety of situations. The only potential problem is the sounding-sparse zone within 50 km but behind the convective line. For some reason, sonde launches were very sparse here (-50<x<0km, -150<y<0km).

Several M-GLASS launches were within 15 km of the convective line and 50 km to the left or right of the bow echo apex. M-GLASS successfully sampled regions close to the convective line where the Lear jet could not fly due to severe turbulence. These soundings are especially critical to fundamental studies of squall lines involving the balance of horizontal vorticity generated by cold pools and ambient shear (Rotunno et al., 1988).

Mesoscale variability sampled ahead of the convective line may hold clues to tornado formation along bow echoes. An intriguing property of bow-echo tornadoes is their tendency to be located from the apex of the bow northward. To date, there have been few studies or research-quality observations of such events (Tessendorf and Trapp, 2000).

Several other scientific questions may be addressed by the myriad soundings ahead of the convective line (x>0 in Fig. 3). For example, how does the vertical distribution of wind shear affect storm organization and evolution? What dynamical role does low-level shear play versus mid- or upper-level shear? What effect do preexisting surface boundaries have on the overall evolution of bow echoes and MCVs? We all know that the atmosphere is not static and homogenous, but past studies of MCSs have typically relied heavily on one or two soundings to characterize the pre-storm environment. This dataset will allow us to quantify spatial and temporal variability of soundings and investigate the appropriateness of using a single sounding to represent a diverse synoptic environment ahead of the storm.

Many of the bow echo soundings could apply to MCVs, especially the soundings to the rear and the left of the bow echo apex (x<0 and y>0 in Fig. 3). This quadrant is where most MCVs form. Mesoscale dynamics of mature MCVs such as vortex tilting in shear and isentropic lifting ahead of the vortex should be nicely resolved by plentiful soundings ahead of the mature MCV (x > 0 in Fig. 4). Interestingly, the sounding density is significantly lower in the right, rear quadrant. This quadrant is sometimes associated with a slot of subsiding, drier air wrapped in from behind the system—a region where there is often little or no precipitation. When the coordinators targeted the MCV, they may have naturally gravitated toward cloudier regions where the circulation was more easily traced in radar and satellite loops.

In summary, this analysis confirms that the sounding platforms in BAMEX succeeding in obtaining an unprecedented, high-resolution dataset. All quadrants of bow echoes and MCVs were sampled at some point during BAMEX, although some areas are comparatively less sampled. In particular, the right-rear quadrant of both bow echoes and MCVs had fewer measurements than the other quadrants. At the Conference, the authors will provide explanations for why these regions were less sampled, and will provide suggestions for future aircraft-oriented field projects.

5 REFERENCES

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