3.3 THE RESEARCH AIRCRAFT COMPONENT OF THE BOW-ECHO AND MCV EXPERIMENT (BAMEX)

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1. INTRODUCTION

The *Bow-Echo and MCV Experiment* (BAMEX) will rely heavily on mobile platforms to provide high-resolution observations of mesoscale convective system (MCS) three-dimensional structure and airflow. Both aircraft and ground-based mobile systems will be employed in a coordinated fashion (e.g., Biggerstaff 2002). The aircraft operational base is proposed to be Lambert International Airport in St. Louis, MO. Weather forecasting and facilities coordination will be from the St. Louis weather service office (WSFO).

2. REQUESTED FACILITIES

We propose to use three research aircraft to document the mesoscale evolution of long-lived MCSs including the convective line and the development of mesoscale vortices and rear-inflow jets. Two of the aircraft will be long range turboprops (~10 hour endurance) equipped with pseudo-dual Doppler radar capability. These two aircraft are P-3s operated by the National Oceanic and Atmospheric Administration (NOAA) and the Naval Research Laboratory (NRL). The NRL aircraft will utilize the *Electra Doppler Radar* (ELDORA) provided by the National Center for Atmospheric Research (NCAR). The third proposed aircraft will be a high flying jet equipped to deploy dropsondes. Dropsondes will be the primary means of documenting environmental structure, thermodynamic structure of the stratiform region (where rear-inflow jets and mesoscale convective vortices reside (MCVs; Davis 2002). The combination of aircraft and ground-based measurements is important for understanding the coupling between boundary layer and free-tropospheric circulations within MCSs, and, in particular, how the rear-inflow penetrates to the surface in nocturnal severe wind cases (e.g., derechoes).

Table 1. Proposed aircraft platforms.

Facility	Flt hrs	Primary Use
NOAA P-3	167	Within stratiform region to the “rear” of convective line
NRL P-3	180	Ahead of the convective line
High altitude jet	200	Dropsondes (600 requested)

3. OBSERVATIONAL STRATEGIES

The primary means of documenting MCS precipitation and airflow structure will be by the airborne Doppler radars (Jorgensen et al. 1983). The scanning methodology of the NOAA P-3 and ELDORA radars (Figure 1) is similar in that they both utilize the fore/aft scanning technique (Jorgensen et al. 1996). However, the scanning rate of ELDORA’s antenna is about double that of the NOAA P-3. Additionally, ELDORA transmits both fore and aft beams simultaneously, whereas the P-3 alternates scanning a single beam between the fore and aft scans. These ELDORA enhancements result in a decrease in horizontal data spacing to ~300 m compared to the P-3’s data spacing of ~1.4 km (Figure 2). Both radars are X-band, vertically scanning radars (NOAA’s use the French-built “flat plate” antenna) that uses a batch-mode “staggered pulse-repetition frequency (PRF)” technique to extend the unambiguous radial (Nyquist) velocity using two PRFs (Jorgensen et al. 2000; Wakimoto 1996).

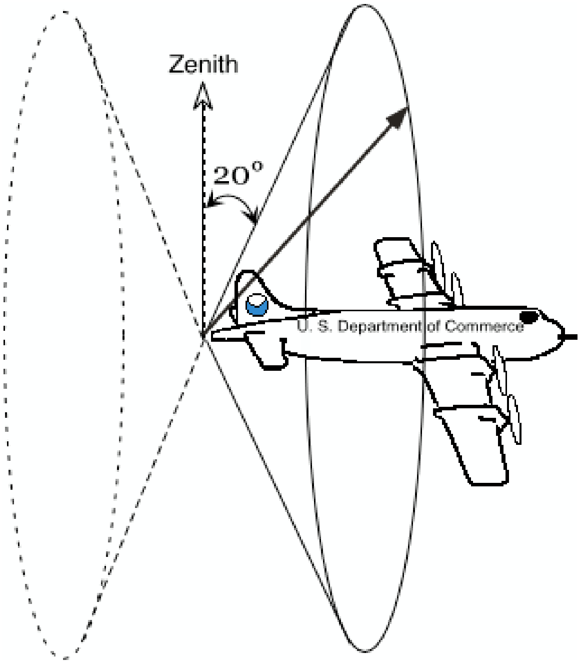

Figure 1. Scanning geometry of the NOAA P-3 and ELDORA Doppler radars. The antenna scans are about 20° forward and aft from the aircraft’s track.

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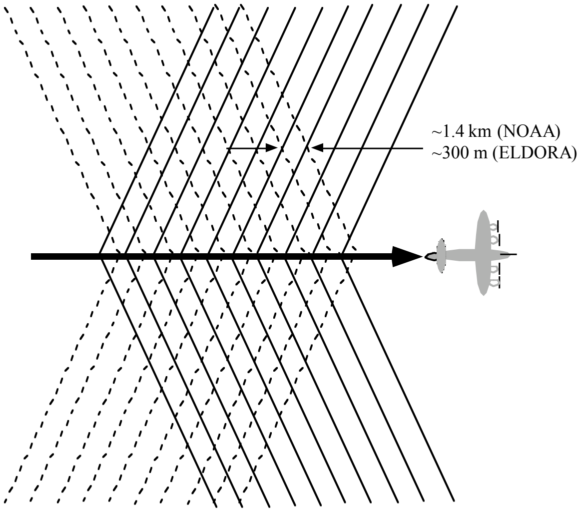

Figure 2. Diagram of the horizontal projection of the fore and aft airborne Doppler radar beams. A horizontal wind estimate can be made at the beam intersection points. Horizontal data spacing is a function of antenna rotation rate and aircraft ground speed, which for the ELDORA and NOAA P-3 radars is ~300m and ~1.4 km, respectively. Vertical velocity is estimated by integrating the continuity equation.

The maximum useful dual-Doppler range of the airborne radars is about 40 km, which represents a maximum time displacement between intersecting fore and aft scans of about 4 minutes. During that time, as well as for the duration of each flight leg that comprises the complete "volume scan", the weather within the analysis domain is assumed to be "stationary". The typical flight leg length is about 10-15 minutes, which represents about 80-120 km in horizontal distance.

During the approximately 6-week field phase from 20 May to 6 July 2003, we anticipate up to 16 convective systems will be observed. Therefore, we are requesting flight time (plus ferry from their base of operations) for the turboprop aircraft to operate in tandem for 16 flights of about 10 research flight hours each (Table 1). The high-altitude jet aircraft will be used to investigate both bow-echo MCSs and MCV systems, so the requested flight time is larger. The use of the turboprop aircraft will be limited to precipitating systems because their Doppler radars don't detect clear-air targets well, hence, unless there is significant regeneration of precipitation in an MCV under investigation, MCVs will be investigated using the jet aircraft alone. There is usually a time displacement between bow-echo maturity and appearance of MCVs (Johns 1993, Davis 2002), the jet requires double crewing permitting back-to-back flights into a bow-echo system and an MCV. If the jet has limited endurance (4 hour endurance in the minimum requirement), then the jet could be used twice on a single MCS.

An idealized schematic of flight plans for the BAMEX aircraft investigation a bow-echo MCS is shown in Figure 3. Although the diagram depicts an MCS with a length of ~300 km, the flight track design philosophy is the same for smaller system, the patterns would simply be completed quicker allowing for more repeats. BAMEX will emphasize *coordinated* observations from all platforms. Flight tracks will be adjusted by the respective aircraft Chief Scientists in real time to insure that the Doppler radars observe as much of the MCS as possible. The NRL P-3 will focus on convective line structure with flight patterns *ahead* of the line from low level, because of the decreased horizontal data spacing of ELDORA compared to that of the NOAA P-3s Doppler radar. The NOAA P-3 will focus primarily on documenting the circulations to the *rear* of the convective line, within the stratiform rain region particularly of the rear inflow jet and line-end vortices. It will perform that task with two to three parallel flight legs, parallel to the convective line, each separated by ~70 km *relative to the line motion*. This spacing would produce slightly overlapping Doppler analysis regions (dashed boxes in Figure 3) that would cover the majority of the stratiform rain region. Additional flight legs could be added if the precipitation extending farther to the rear. For example, if the line is moving at 36 km hr^{-1} (10 m s^{-1}), and each NOAA flight leg take a half hour to complete, the leg mid points would be separated by 46.6 km, to maintain a system relative separation of 70 km, assuming the aircraft speed is ~8 km min^{-1}. Thus construction of the NOAA P-3 flight legs will require knowledge of the systems motion, which is difficult to determine using the airborne radar alone. An Aircraft Coordinator, working at the St. Louis Operations Center, examining WSR-88D imagery could provide the suggested flight tracks if the communications to/from the aircraft is reliable. The jet aircraft will deploy dropsondes both ahead of the convective line to document inflow characteristics, and to the rear to document the thermodynamic structure of the rear inflow. As in the case of the NOAA P-3 flight legs, the jet legs and dropsonde spacing should in a grid relative to the moving system, so line motion needs to be known to adjust the leg lengths and drop locations.

The NRL P-3 flight altitude would be as low as safety permits ahead of the line to observe the near-surface divergence and any strong surface winds associated with the leading edge (~1 km AGL). The NOAA P-3 would fly at ~3 km MSL to be near the level of strongest rear inflow and yet be remain below the melting level. At flight altitudes of 0° C and colder the P-3 faces an increased risk of lightning strikes on the aircraft. The jet altitude would be high as practical, ~12 km. Deploying sondes over the Midwest United States has not been a problem for NCAR, based on earlier experience in field projects, as long as heavily populated cites are avoided.

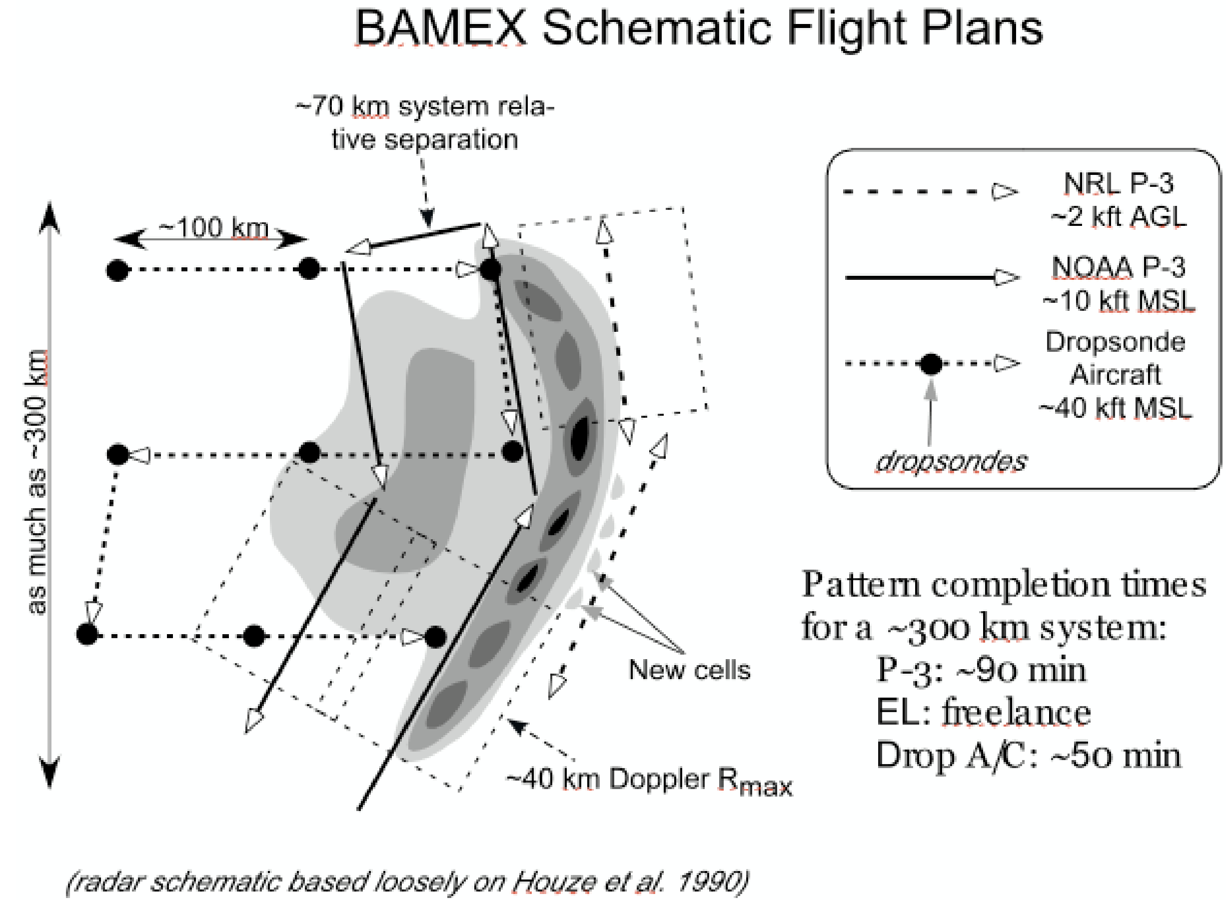

Figure 3. Schematic BAMEX flight plans for bow-echo MCS. The proposed flight tracks for the NOAA P-3 is shown as the solid line with arrows, the NRL P-3 as the dashed line with arrows, and the high-altitude jet as the dotted line with arrows. Dashed boxes centered on the NOAA and NRL tracks represent the approximate 40 km maximum range of their Doppler radars. Pattern completion times are for an MCS of ~300 km length. For smaller systems, the flight leg lengths are shortened to cover the system, but the leg separations are held constant (e.g., P-3 leg separation: ~70 km, dropsondes ~100 km apart) which will result in the basic patterns being completed faster.

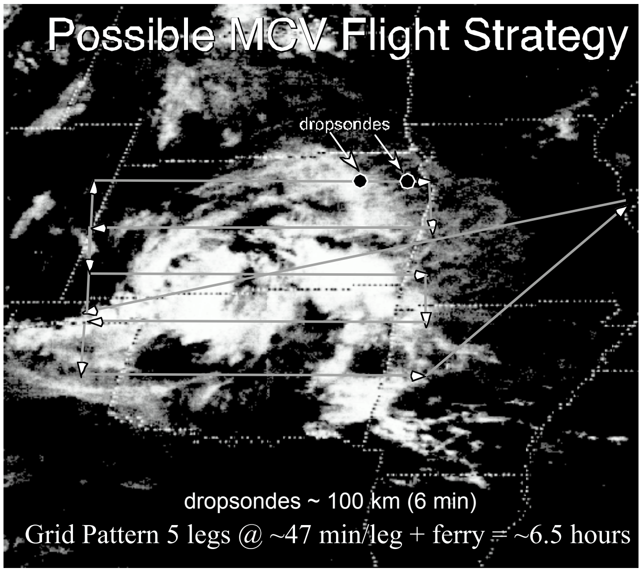

Figure 4. Schematic flight track for high-altitude dropsondes investigation of an MCV. Dropsondes are spaced ~100 km.. Background is visible satellite image.

A possible MCV dropsondes deployment strategy is shown in Figure 4. The dropsondes will be critical for documenting the structure of the MCV, including identifying regions of horizontal temperature advection, which are likely associated with mesoscale vertical motion. The dropsondes will also be examined for evidence of lapse-rate changes above the boundary layer induced by the MCV, which could indicate regions of likely convective regeneration. A grid pattern that has 5 legs of ~750 km length would require about 5 hours plus the ferry to/from St. Louis. Dropsondes would be deployed every 100 km, or 6 minutes of flight time. Total dropsondes per MCV mission would be 40.

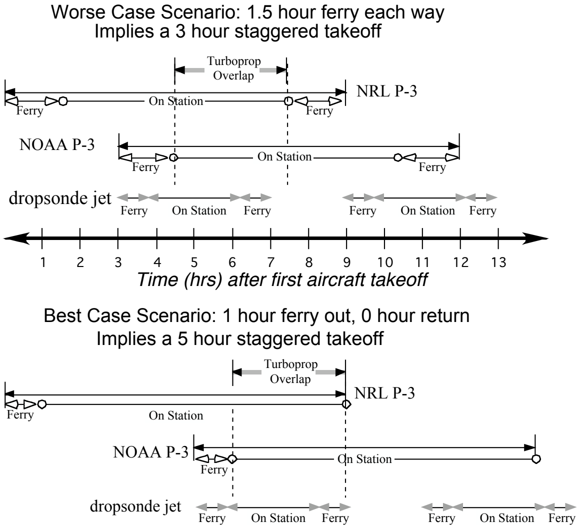

Figure 5. Two possible scenarios for staggered aircraft deployments into MCSs depending on the range from St. Louis. Horizontal axis is time relative to the NRL takeoff. The NRL P-3 timeline is shown at top, NOAA P-3 in the middle, and dropsondes jet at the bottom of each figure. In the top (worse case) scenario, the MCS is at extreme range from St. Louis (1.5 hours ferry or ~650 km), which necessitates a 3 hour staggered takeoff between turboprop aircraft to insure a 3-hour overlap of turboprop aircraft. In the best-case scenario (lower figure) the MCS is only a 1-hour ferry away from St. Louis and moving toward the base. This scenario would necessitate a 5 hour staggered turboprop takeoffs to insure a 3-hour overlap. The jet, if its double-crewed, could fly 2 missions into the MCS.

To cover as much of an MCS lifetime as possible, yet allow for some overlap of aircraft during the mature phase when documentation of overall system structure is desired, we suggest temporal staggering of the aircraft. Two scenarios for temporal staggering of the takeoffs of the three BAMEX aircraft are shown in Figure 5. Maximum endurance of the turboprops is assumed to be 9 hours, for the dropsonde jet, 4 hours. In the top scenario, the MCS is near the maximum ferry distance for the Doppler aircraft (1.5 hours or ~650 km). The requirement for a 3 hour overlap period for the two Doppler aircraft implies those aircraft need to stagger their takeoffs by 3 hours and produces an 10.5 hour observation period with at least one Doppler aircraft. With a system much closer to STL (bottom scenario) the Doppler aircraft can stagger their takeoffs by 5 hours and achieve about 14 hours of continuous observation by one aircraft and 3 hours of dual-aircraft observations. With double crews, the dropsonde aircraft could produce two flights into the MCS, assuming a 2 hour refueling time at STL and a 45 minute ferry. If the dropsonde aircraft's takeoff coincided with the P-3s, the dropsondes would coincide with the period of two Doppler aircraft overlap plus most of the dissipation stage with the single P-3.

4. COMMUNICATIONS AND COORDINATION

Successful execution of the research aircraft component of BAMEX will depend heavily on good communications between the aircraft and the Operations Center in St. Louis. The limited range of surveillance radars on the aircraft hampers the ability of their Chief Scientists to determine flight leg end points and accurate system motion. Fortunately recent installation of satellite communication systems on the NOAA P-3 has greatly improved the capability of sending and receiving e-mail and limited imagery to/from the Operations Center over a 9600 baud data link (GlobalStar satellite). We envision conducting flight operations with extensive direction from weather forecasters and nowcasters at the Operations Center. They will examine satellite imagery and WSR-88D products and assist the Chief Scientists in specifying flight legs relative to the moving convective line.

5. SUMMARY

The proposed BAMEX flight component has been described. The flight plans will likely continue to be refined as we learn more about the fate of our proposals. For more information about BAMEX, please see our web site at: http://www.mmm.ucar.edu/bamex/science.html.

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