

BAMEX Operations Plan

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1 Overview of BAMEX Operations

BAMEX is a study using highly mobile platforms to examine the life cycles of mesoscale convective systems. It represents a combination of two related programs to investigate (a) bow echoes, 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). MCVs can focus new convection and play a key role in multi-day convective events affecting a swath sometimes more than 1000 km in length with heavy to perhaps flooding rains. The main objectives regarding bow echoes are to understand and improve prediction of the mesoscale and cell-scale processes that produce severe winds. For MCV producing systems the objectives are to understand MCV formation within MCSs, the role of MCVs in initiating and modulating convection, the feedback of convection onto MCV intensity, and to improve the overall predictability of the vortex-convection coupled system. Further information on the science objectives of BAMEX may be found at <http://www.mmm.ucar.edu/bamex/science.html>.

BAMEX will use three aircraft, two equipped with dual Doppler radar capability, the third equipped with dropsondes, to map the mesoscale evolution of long-lived MCSs including the development of mesoscale vortices and rear-inflow jets. Dropsondes will be used to document environmental structure, thermodynamic structure of the stratiform region (where rear-inflow jets and MCVs reside) and to capture the structure of mature MCVs in the absence of convection.

In addition, a mobile array of ground-based instruments will be used to augment airborne radar coverage, document the thermodynamic structure of the PBL, including any existing convergence boundaries, probe the surface cold pool, and measure surface horizontal pressure and wind variations behind the leading convective line. 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.

2 Aircraft Operations

2.1 Aircraft Overview

Three research aircraft will be used during BAMEX, two “turboprop” aircraft and one “jet” aircraft. All aircraft will be based at the MidAmerica Airport about 23 miles east of St. Louis, MO (38° 32.71’N, 89° 50.11’W). The two turboprop aircraft will be used primarily to make Doppler radar observations of convective systems and in-situ observations of state parameters in low-to-mid levels in the vicinity of convective storms. The jet aircraft is equipped for mid-to-high altitude flights (26,000 ft to 40,000 ft) and will be used primarily to make global positioning system (GPS) dropsonde measurements ahead of (i.e., generally to the east of the convective system) and the rear of the convective line.

The minimum spacing of dropsondes is determined by the jet aircraft’s ground speed, altitude, fall rate of the sonde, and number of channels available (i.e., the maximum number of sondes that can be simultaneously tracked). For the NCAR’s 4 channel GPS dropsonde system, an aircraft ground speed of about 14 km/min. at 40,000 feet altitude, a fall speed of the GPS dropsonde is about 2,000 ft/min. resulting in a fall time of about 20 minutes, and amounts to a

maximum drop rate of 5 minutes or a spacing of ~50 km. Finer spatial separation can be achieved if drops are made from lower altitude or if the aircraft flies slower (or against the wind).

Observations by the turboprop aircraft will focus on the in-situ precipitation and cloud microphysical structure, and internal three-dimensional circulations of bow-echo and other mesoscale convective systems. Both turboprop aircraft possess basic in-situ sensors such as temperature, dewpoint, and position information.

The research aircraft flight hours available for BAMEX research are detailed in Table 2.1. The number of flights is consistent with the climatologically average number of eligible systems in the typical May 20 – July 6 period.

Table 2.1 Research flight hours available for BAMEX

<i>Resource</i>	<i># of missions</i>	<i>Dropsondes</i>	<i>Research Flight Hours</i>	<i>Endurance (hrs)</i>	<i>Max Altitude (ft)</i>	<i>Cruise Speed (knots)</i>
NOAA P-3	18	none	140	8.5	25,000	230-280
NRL P-3	18	none	135	8.5	28,000	230-280
Dropsonde Jet	18	450	100	4.5	43,000	450

2.2 Operational Domain

For convenience, the BAMEX aircraft operational domain is defined by the 1.5-hour ferry distance of the turboprop aircraft (~425 na mi). For a typical turboprop 9 hour maximum mission this domain implies an on-station time of at least 6 hours, roughly double the ferry time. This domain is shown in Figure 2.1 as a grey circle.

- Flights planned to use the maximum aircraft endurance may be limited by diversion fuel requirements, necessitating revisions in the daily flight plans after filing. This applies most directly to dropsonde aircraft operating over large areas.

Because flights are operated at a variety of levels within the domain it is essential that required target regions (including allowance for forecast error) be submitted to ATC and prior to takeoff. The operating area will normally be defined as the interior of a latitude/longitude polygon, usually a rectangle or combination of rectangles. The notification to ATC will also specify the times of possible first entry (by any aircraft) to, and final exit from, the area. If part of the specified area will only be used for a limited part of the total time ATC may request that notification be given when this part of the area will no longer be required. As part of the flight planning process locations of restricted zones will be identified and flight plans will avoid those areas.

The aircraft facility operators have well-established procedures concerning operations of their facilities to insure safe operations. These constraints assume a single crew for the turboprop aircraft.

BAMEX personnel in the operations of all three aircraft will observe the following operational constraints:

- A maximum crew duty day of 16 hours. A crew duty day is defined as when an aircrew member reports to their designated place to begin mission preflight and ends when he/she departs the work location after completion of the mission. Nominally, the pre-flight period is ~3 hours, and the post flight period, following block-in, is ~1 hour. These constraints imply that the maximum possible delay in take-off for a maximum duration mission (~9 hours) would be 3 hours. Delays longer than 3 hours would shorten the mission.
- A minimum crew rest period of 12 hours from the time the last person leaves the airplane to the time the first person reports for next mission pre-flight. A crew member cannot report for a subsequent preflight until the crew rest period is completed. This constraint implies a 16 hour period for consecutive flights between previous mission landing and next mission takeoff.
- 1 mandatory down day following 6 consecutive standby (i.e., alerts) or flight days.
- Takeoff times are set at least 12 hours in advance if the anticipated flight operations (i.e., alerts) are consistently in the same diurnal cycle, i.e., daytime or nighttime flights. If the takeoff alert is being shifted from predominately “daytime” to “nighttime” cycle or visa versa, then at least 24 hours notice is required.
- Following 3 consecutive maximum endurance missions the NOAA AOC facility manager for the NOAA P-3 or the NRL Commander in Chief for the NRL P-3 may authorize a 24-hour down period.

2.4 Aircraft Scientific Crew Duties

The successful execution of the flight missions depends on a few key scientists to direct the aircraft and supervise the data collection. The multi-aircraft missions will have an overall *Operations Director*, working at the Operations Center at MidAmerica Airport, who will be responsible for the overall coordination of the IOP including flight track suggestions for all aircraft and target selection. An Aircraft Coordinator who will monitor communications to insure products and reports easily flow between aircraft and the Operations Center normally

assists the Operations Director. Each aircraft will have a *Chief Scientist* responsible for the scientific flight execution and data collection of that aircraft as well as *Scientific Specialists* who will control and monitor various instrumentation. Each Chief Scientist is also responsible for collecting data summary reports from each of the Specialists and providing an overall flight summary to the Operations Director following each flight mission.

2.4.1 Operations Director

This individual will identify the initial targets of interest consistent with the overall objectives of the particular experiment that will normally be defined by the BAMEX Science Director before takeoff. He/she monitors the regional radar composite plots and chooses the initial target during the aircraft ferry, coordinate with the Chief Scientists on all aircraft to select the appropriate flight patterns, and monitor the progress of all aircraft in the mission. The Operations Director will also monitor the email messages from the aircraft to coordinate information, and arrange for imagery, such as NEXRAD composite maps and satellite pictures, to be transmitted to the aircraft. During the mission he/she will continue to monitor the exercise to ensure that the data gathering is proceeding smoothly and will resolve problems that arise such as choice of alternative patterns and the selection of alternative weather targets. He/she will also work with the Chief Scientists to suggest optimum flight pattern orientation and leg lengths. This individual has final responsibility for initiating, altering, and terminating aircraft scientific operations following takeoff. He/she will also normally lead the scientific de-briefing following the completion of the mission and provide a written summary of the operation and its accomplishments to the BAMEX web catalog.

2.4.2 Aircraft Coordinator

This individual will assist the Chief Scientists in preparation of flight plans before takeoff, and assist the Operations Director with compiling suggested way-points for the aircraft as well as communications to/from the aircraft during the IOP. This individual will also notify air traffic control (ATC) and alert crews of flight restrictions.

2.4.3 Chief Scientists (P-3s and jet)

Each aircraft will have a designated individual that will be responsible for the overall scientific execution of the flight. This person will work with the operational flight crew to set up and execute the appropriate flight patterns, supervise the scientific instrument specialists to insure proper data gathering (e.g., setting the proper scanning strategies for the Doppler radar), and act as the primary point of contact for the Operations Director. This individual will keep a detailed “event log” of significant aircraft activities (e.g., starting/ending times of flight leg segments, altitude changes, significant weather, dropsonde locations etc.), as well as keep the Instrument Specialists and Operations Director informed of problems. He/she will collect all relevant data logging and reporting forms from each of the instrument specialists (e.g., radar, dropsonde, cloud physics, and observers), and provide a written report about the mission accomplishments, problems, and equipment status to the Aircraft Coordinator following completion of the mission. He/she conducts pre-flight and post-flight briefings/debriefings of the aircraft’s crew.

2.4.4 Doppler or ELDORA Scientist (P-3s)

This scientist monitors the performance of the radar systems (lower fuselage and/or Doppler radars), ensuring optimal operation for the selected mission. He/she works with the Chief Scientist in the design of the optimal flight patterns and scanning strategies for the radars, and operates the radar control computers to change operating modes (e.g., scanning strategies). This person also interprets the radar displays to ensure proper operation of the radars and keeps a detailed written log of significant meteorological events, interesting data, problems encountered with system performance, and radar configuration changes to aid in subsequent scientific analyses. This person also takes the lead in examining data on the computer workstations at the Operations Center following the flights to prepare products for debriefings and to ensure proper equipment operation and recording. He/she prepares sample imagery for transmission via the internet satellite link to the Operations Center when requested (NOAA P3 only).

2.4.5 Cloud Physics Scientist (NOAA P-3)

The cloud physics scientist is responsible for the scientific data collection from the cloud physics sensors (i.e., PMS 2-D probes). He/she monitors system performance and recording. He/she keeps a detailed log of the cloud penetration events, significant weather, and sensor or data recording problems, and provides a written summary to the Chief Scientist following the flight mission. This person also monitors and interprets the particle image displays in real time to ensure system operation and to note interesting weather events.

2.4.6 Dropsonde Scientist (Jet or at the Ops Center)

The Dropsonde scientist is responsible for choosing the drop locations during the flight. This person monitors and interprets the regional network radar composite charts and notes interesting weather events. If possible, he/she monitors the dropsonde data for quality assurance. He/she keeps a detailed log of the significant wind events, sensor or data recording problems, and provides a written summary to the Ops Director following the flight mission.

Dropsonde operations support staff consist of a dropsonde operator and assistant on the jet and a dropsonde coordinator in the operations center. Double-crewing the dropsonde jet will require approximately double the number of dropsonde operations support staff. The Dropsonde Operator will

- Prepare and deploy the sondes from the jet and verify that sondes are functioning
- Keep a dropsonde log
- Perform post processing of dropsonde data (mainly while on the ground)

The drop points will be given to the Operator by the Dropsonde Coordinator. However, the pilot or co-pilot will give explicit permission for each deployment. Among the reasons that deployment may be delayed or canceled are that the jet is 1) over a populated area, 2) near other aircraft, 3) banking during a turn, and 4) nearing a landing.

When a sonde fails and the jet is still acceptably close to the intended drop point, the Operator will deploy a replacement sonde as quickly as possible. If a sonde fails only well after being released, or if dropping another sonde would jeopardize drops at subsequent points, the Operator will not attempt a replacement drop.

The Operator’s duties also will include reporting to the Coordinator any problems with equipment. The reports may be made during or after flights at the Operator’s discretion.

The Dropsonde Assistant will

- Relay communications between the Dropsonde Coordinator and personnel aboard the aircraft
- Help the Operator deploy the sondes
- Assist in keeping a dropsonde log.

During long missions, especially those with multiple flights, the Dropsonde Assistant and Dropsonde Operator may exchange duties if necessary.

The jet’s flight crew will comprise a pilot and co-pilot. Two crews will likely be available during the project. Each crew is restricted to 14 h per mission. After two consecutive missions, a 24-h rest is required. A mission includes 2 h of pre-flight and 1 h of post-flight activity, which are included in a crew’s official duty day.

The jet’s flight crew always make the final decisions about their aircraft and flights, including the deployment of sondes. Scientists such as the Dropsonde Coordinator only make suggestions and requests.

ATD crew duty limits as described in Table (#) will apply to all dropsonde operators. Official duty days include 1.5 hr of pre-flight and 1 h of post flight activity.

Any 24 hour period (hotel to hotel), maximum number of hours worked	14 hours
Any 24 hour period, maximum number of hours flown	10 hours
Any consecutive 7 day period - Maximum number of work days	6 days
Any consecutive 7 day period - Maximum number of work hours	60 hours
Any consecutive 7 day period – Maximum number of flight hours	35 hours
Any 30 day period - Maximum number of flight hours	110 hours
Notice of duty cycle swap (day to night time ops)	36 hours
Minimum crew rest period (hotel to hotel)	12 hours
Maximum field deployment period	4 weeks
Minimum home turn around between field assignments	3 weeks
Table 2.2 Crew Duties for ELDORA and other Flight Crew	

2.4.7 Visiting Scientist Seats (P-3s)

A number of vacant seats usually exist on the NOAA P-3 aircraft. Those seats can be allocated to scientific observers, students, visitors, dignitaries, press reporters, and agency administrators who wish to observe, first hand, the BAMEX operations. Normally, the Operations Director in consultation with the Chief Scientist of the aircraft, and the appropriate aircraft Facility Manager and pilot, performs the responsibility for seat allocation.

On the NRL P-3, however, observers will be restricted to those individuals who have passed the Navy’s NP4 Survival and Physiology training course and are on NRL’s list of certified project specialists. One time waivers need to be requested no later than a month before the start of the program, i.e., no one-time waivers will be issued in the field.

On the Lear Jet, it is anticipated that there will not be extra seats for visiting scientists. Should an extra seat be added, priority for an additional passenger will be given to candidate dropsonde operator assistants to facilitate training. Any other visitors must be approved by WMI and the BAMEX Operations Director.

2.4.8 Candidate Personnel

Table 2.2 details possible experienced personnel who have indicated a desire to fill some of the required jobs during BAMEX. Other candidates are possible, particularly following the completion of the first few missions that will provide an opportunity for on-the-job training. There are several additional seats available on each aircraft for trainees, usually the same seats allocated for visitors, students, and trainees.

Candidate Personnel

Table 2.2 Dropsonde Coordinators

Name	Affiliation	Dates
David Ahijevych	NCAR MMM	7 June-22 June 28 June-6 July
Diana Bartels	NOAA NSSL	2 June – 7 July
George Bryan	NCAR ASP	18 May – 7 June
Dan Hawblitzel	Texas A&M	18 June – 1 July
Jason Knievel	NCAR MMM	18 May – 4 June
Richard James	Penn State	7 June-22 June 28 June-6 July

Table 2.3 Possible BAMEX flight crew members.

Job Title	Name
NOAA P-3:	
Chief Scientist	Jorgensen, Smull, or Ziegler
Radar Scientist	Jorgensen, Smull, or Ziegler
Cld Phy Scientist	McFarquhar or Rauber
NRL P-3:	
Chief Scientist	Wakimoto, Lee, or Jorgensen
ELDORA Scientist	Lee, Bell or Keeler
Jet	
Dropsonde Operator	Korn, Wheeler

2.5 Aircraft Communications

Rapid bow-echo evolution and limited aircraft horizontal radar coverage limits the ability of the aircraft Chief Scientists to prepare timely flight tracks to meet mission requirements. The complexity of the BAMEX flight patterns requires strong communications links to assure proper

execution of aircraft missions. Satellite based internet will be critical to the execution of BAMEX aircraft missions. All aircraft will be equipped with modern satellite communications systems (GlobalStar) to enable a 9600 baud PPP internet link to be established (NOAA P-3: Global Star 9600 baud, NRL P-3: Iridium 4800 baud, WMI Learjet: two Iridium 2400 baud). These links will enable limited transmission and reception of email, ftp of imagery, and periodic transmission of aircraft position information. A schematic diagram of the BAMEX aircraft data and information flow is shown in Figure 2.2. Timely reception of the position of suggested targets and start/end points of flight legs from the Operations Director by the airborne Chief Scientists will be required based on analysis of regional radar, sfc observations, and model forecasts. Opinions can also be sought from the nowcasters at the Ops Center and NWS St. Louis office. The Chief Scientists will periodically send in email reports of mission progress.

BAMEX Aircraft Data & Information Flow

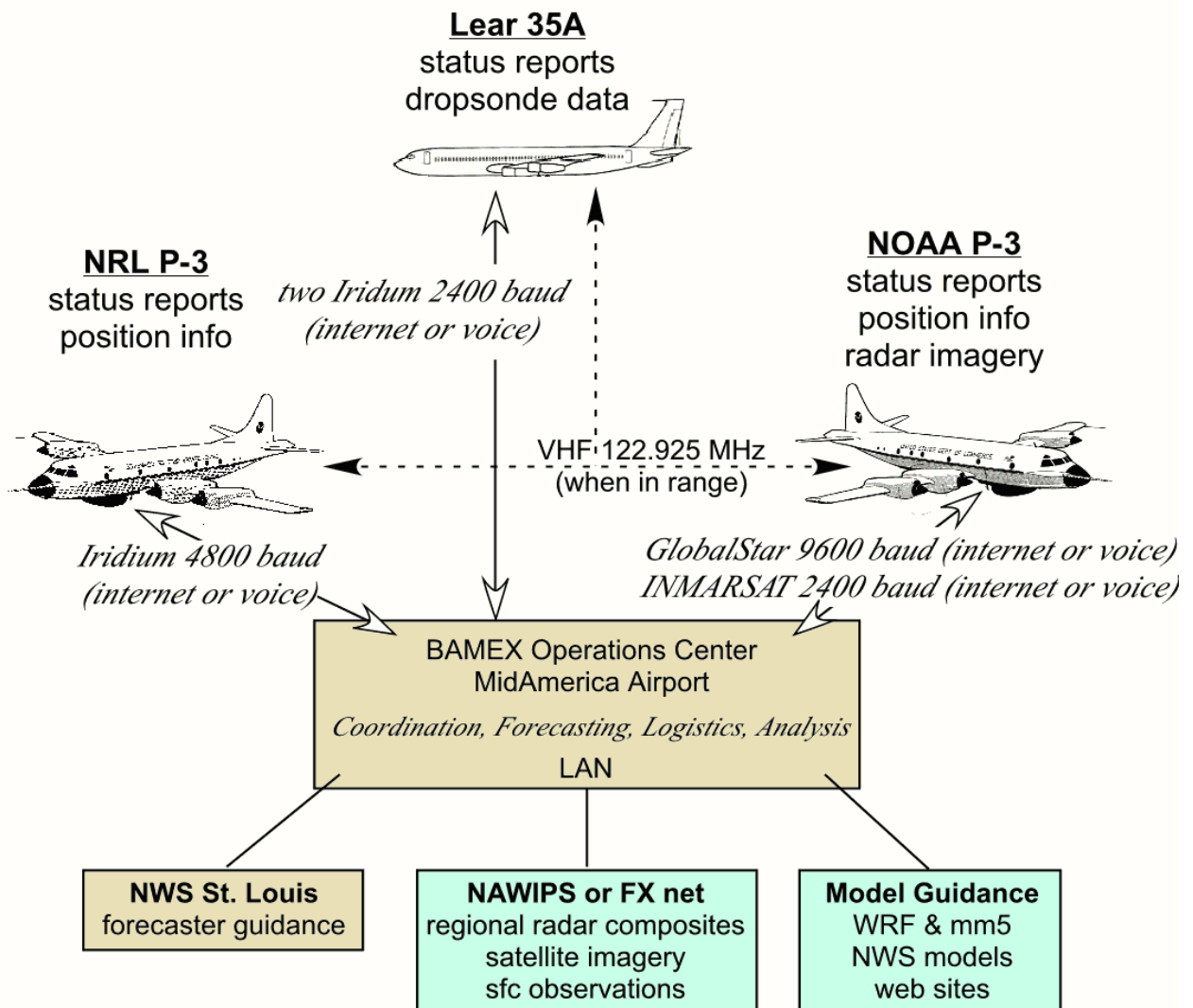


Figure 2.2 Schematic of aircraft data and information flow during BAMEX operations.

2.6 Post-Flight Procedures

2.6.1 Debriefing

Immediately upon the termination of each research flight, a scientific debriefing will be held of each aircraft chief scientist, all aircraft scientists, and observers. This debriefing will be led by the Operations Director or Aircraft Coordinator and may be held as a group meeting or with individual flight crews, depending on aircraft landing times and future operations. These debriefings will be carried out to ensure:

- Completion and receipt of flight forms and logs.
- Collection of all hard copy data.
- Documentation of interesting scientific aspects of the flights.
- Documentation of operations of all research systems.
- Documentation of aircraft status and instrument problems.
- Identification of any problems in coordination that hampered the mission (e.g., within the plane, between planes, or between the planes and the Ops Center).
- Provide an alert to all aircraft personnel and scientists concerning possible future missions.

This information will provide input to the Operations Director's report to the next days planning meeting and status reports posted to the BAMEX web catalog.

2.6.2 Data Processing, Data Checking, and Product Generation

Within a few days of the completion of an IOP involving aircraft flights, a concerted effort will be made to produce certain standard products such as flight tracks, time series of meteorological variables during interesting parts of the flights, radar reflectivity time composites, etc., to ascertain the data quality and coverage. These "quick-look" plots will be posted to the web catalog. For the NOAA P-3 aircraft this activity will be coordinated by the NOAA data manager who will also make available, via ftp, flight track files in ASCII format from the NOAA workstation to interested scientists. For the NCAR ELDORA, the ELDORA data manager will coordinate this activity. The raw ELDORA data (in sweepfile format), sample images, flight track, and the aircraft in-situ data (in netcdf format) will be made available via web access on the field network in the operation center. The dropsonde jet scientist will provide plots of selected dropsonde data to the data catalog. Other facilities will coordinate the data processing activities with the Chief Scientists and other PIs. Based on the results of this data examination a subsequent report could be made to BAMEX leadership that could lead to amending the IOP "scorecard" of mission accomplishments.

2.7 Bow-Echo Flight Patterns

2.7.1 TurboProp Aircraft (NRL & NOAA P-3s)

2.7.1.1 Airborne Doppler Radar Scanning Methodology

BAMEX turboprop aircraft flight patterns are determined largely by the scanning methodology of their Doppler radars. The characteristics of the NOAA P-3 and ELDORA (mounted on the NRL P-3) radars are listed in Table 2.4. Both radars are X-band systems. ELDORA transmits up to 4 frequencies during a sampling period to increase the number of independent samples in each range sample to allow for a faster antenna scan rate (to $\sim 144^\circ \text{ s}^{-1}$) without sacrificing measurement accuracy. The NOAA P-3 transmits only a single frequency and consequently is restricted to a maximum antenna rotation rate of $\sim 60^\circ \text{ s}^{-1}$ (~ 10 RPM). Both systems employ a multiple PRF (pulse repetition frequency) scheme to extend their respective radial velocity Nyquist intervals to $> 50 \text{ m s}^{-1}$, greatly easing the work required to dealias (or unfold) radial velocity data sets.

Table 2.4. Radar parameters for the NOAA P-3 and ELDORA radars.

<i>Parameter</i>	<i>NOAA</i>	<i>ELDORA</i>
Scanning Method	Vertical about the aircraft's longitudinal axis; fore/aft alternate sweep methodology	Vertical about the aircraft's longitudinal axis; fore/aft simultaneous sweep methodology
Wavelength	3.22 cm (X-band)	3.2 cm
Beamwidth:		1.8°
Horizontal	aft: 2.07°, fore: 2.04°	
Vertical	aft: 2.10°, fore: 2.10°	
Polarization (along sweep axis):	Linear horizontal	Linear horizontal
Sidelobes:		
Horizontal:	aft: -57.6 dB, fore: -55.6 dB	-35 dB
Vertical:	aft: -41.5 dB, fore: -41.8 dB	
Gain:	aft: 34.85 dB, fore: 35.9 dB	40 dB
Antenna Rotation Rate	Variable 0-60° s ⁻¹	Variable: 5-144 deg s ⁻¹
Fore/Aft Tilt:	aft: -19.48°, fore: 19.25°	±15-19 deg, depending on frequency
Pulse Repetition Frequency	Variable, 1600 s ⁻¹ – 3200 s ⁻¹	Variable: 2000-5000 /sec
Dual PRF ratios	Variable: 3/2 and 4/3, typical	Variable
Pulses Averaged per Radial	Variable, 32 typical	Variable
Pulse Width	0.5 μsec, 0.375 μsec, 0.25 μsec	0.1-3 μsec
Rotational Sampling Rate	Variable, 1° typical	1-2°
Peak Transmitted Power	60 kW	25-50 kW
Unambiguous Range with Interlaced PRT technique	38-92 km	20-90 km

Unambiguous Radial Velocity with Interlaced PRT technique	13-71 m/s	13-110 m/s
Number of transmitted frequencies	NA	4
Along track beam spacing	~1.4 km	~300 m
Range resolution	150 m	375 m – 1200 m

Figure 2.3 illustrates the scanning methodology. Both ELDORA and the NOAA P-3 Doppler radar antennas are mounted in the tail of their respective aircraft. They utilize the fore/aft scanning technique to sweep out a three-dimensional volume during the aircraft's flight track. For the NOAA P-3 alternative sweeps are scanned forward then aft by about 20° from a plane that is normal to the aircraft's longitudinal axis. ELDORA transmits both fore and aft looking beams simultaneously. At intersection points of the fore and aft beams a horizontal wind estimate can be made. The horizontal data spacing of those intersection points depends on the antenna rotation rate and the ground speed of the aircraft. For typical values of ground speed the differences in antenna rotation rate lead to a ~300 m horizontal data spacing for ELDORA versus about a 1.4 km spacing for the NOAA P-3. For that reason the BAMEX flight patterns have the NRL P-3 usually ahead of the convective line where its higher horizontal data spacing can observe the characteristics of the intense convection. The NOAA P-3 will observe in the rear of the line where more horizontally homogeneous rainfall (i.e., stratiform) is usually observed.

Airborne Doppler Radar Scanning Geometry

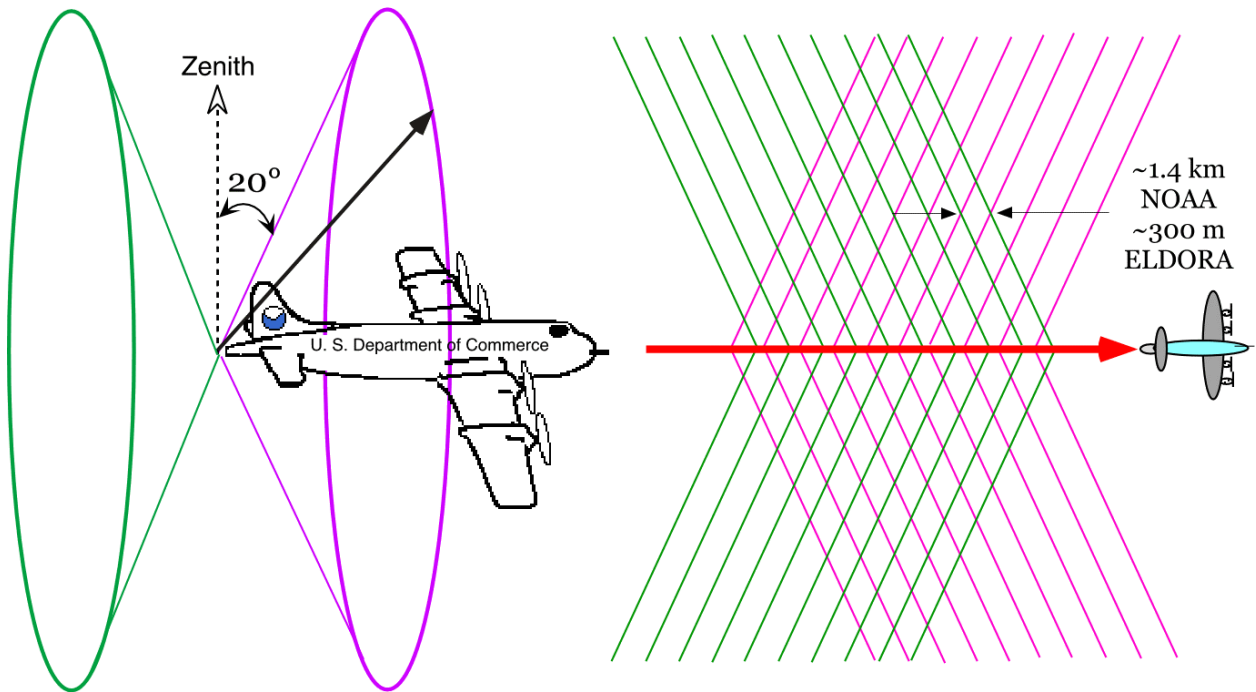


Figure 2.3 Tail radar scanning geometry. The left plot shows a schematic of the antenna scanning methodology. A horizontal projection of the beams is shown on the right.

Observations of the convective line will need to encompass the entire vertical extent of the storms in order to adequately derive three-dimensional motions from the pseudo-dual-Doppler technique. To avoid the deleterious effects of vertical hydrometer velocity (plus vertical motion)

it is desirable to contain the viewing to $\pm 45^\circ$ from the horizontal (Figure 2.4). A good rule of thumb is that R (the distance from the center of the intense precipitation core) should be greater than the distance the storm top is above the aircraft's altitude (or the surface is below the aircraft's height). For example, if the echo top, h , is 10 nmi (50,000 ft) and the aircraft altitude is 5 na mi (25,000 ft) then R is 5 na mi. If h is 50,000 ft and the aircraft altitude is 1 na mi (5,000 ft) then R is 9 na mi.

The exception to the $\pm 45^\circ$ rule is when the two turboprop aircraft are executing coordinated parallel patterns on each side of the convective line (termed "quad-Doppler" patterns). Those flight patterns produce 4 beams of data at each Cartesian point and allows for a triple Doppler solution for the three-dimensional wind. In that case the beam angles should be as high as possible to directly examine the echo top vertical motion.

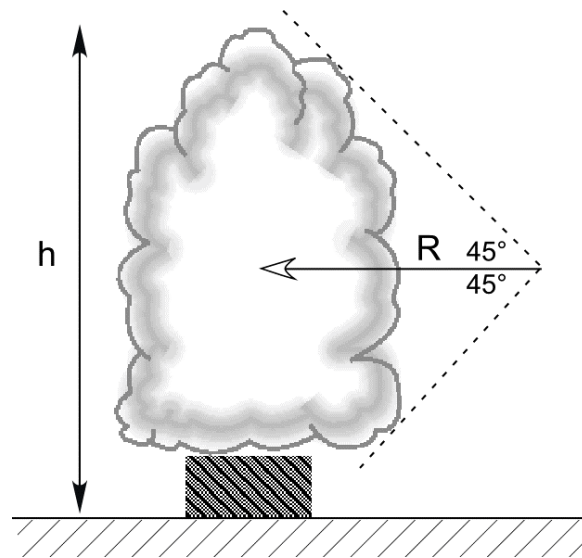


Figure 2.4. Schematic of desirable single aircraft airborne Doppler radar scanning at range R from the reflectivity maximum. Ideally the target is within the $\pm 45^\circ$ elevation angle to minimize the deleterious effects of vertical fall velocity on the measured radial velocity.

2.7.2 Flight Patterns

2.7.2.1 Basic Aircraft Strategy for Bow-Echoes

The objective of the multiple aircraft coordinated flights of a mature bow-echo MCS is to map as much of the MCS circulation and structure as possible in the shortest time. The basic flight strategy for all three BAMEX aircraft is shown in Figure 2.5. The flight strategy for each aircraft is:

- **NRL P-3:** The rapid scanning capability of ELDORA, relative to the NOAA P-3 tail radar, makes it most suitable to observe the convective cores within the line. To ease navigation and minimize attenuation near the leading edge the NRL P-3 will remain ahead of the line (i.e., generally to the east of an eastward moving line) and fly patterns roughly parallel to the line. Leg lengths are 20-40 na. mi to allow for multiple repeats of a small section of the line, or long enough to encompass most of the leading edge. Altitude will be as low as practical (~3,000-5,000 ft) to maximize viewing of surface divergence along the leading edge. Where

practical the legs of the NRL P-3 will be synchronized with the legs of the NOAA P-3 when it is near the back side of the leading edge to maximize the opportunity for collecting “quad-Doppler” data or simultaneous observations of common points.

- NOAA P-3: The primary responsibility of the NOAA P-3 is to map the region to the rear (i.e., to the west) of the convective line. Two flight legs, roughly parallel to the convective line, separated by about 38 na. mi in system relative space, will accomplish mapping the circulations from the convective line to near 50 na. mi into the stratiform region. Basic altitude is 10,000 ft, but other altitudes are possible if microphysics data sets are desired particularly in well-developed stratiform regions. Typical microphysics altitudes would be (-10oC, 0oC, 3oC, and 10oC). The flight leg lengths typically will encompass the entire convective line and cloud head region, but could be shortened to allow for a more rapid pattern completion period.
- Dropsonde Jet: Basic altitude for the dropsonde jet will be as high as allowed by air traffic control (26,000-40,000 ft). Initially the jet will deploy a sonde to the east of the convective line to document the environment inflow structure. The jet then proceeds to the rear of the line from the south and flies parallel to the line deploying a series of sondes with a spacing of about 50 na. mi. Each flight leg approaches the line by about 50 na. mi in system relative space.

BAMEX Schematic Flight Patterns

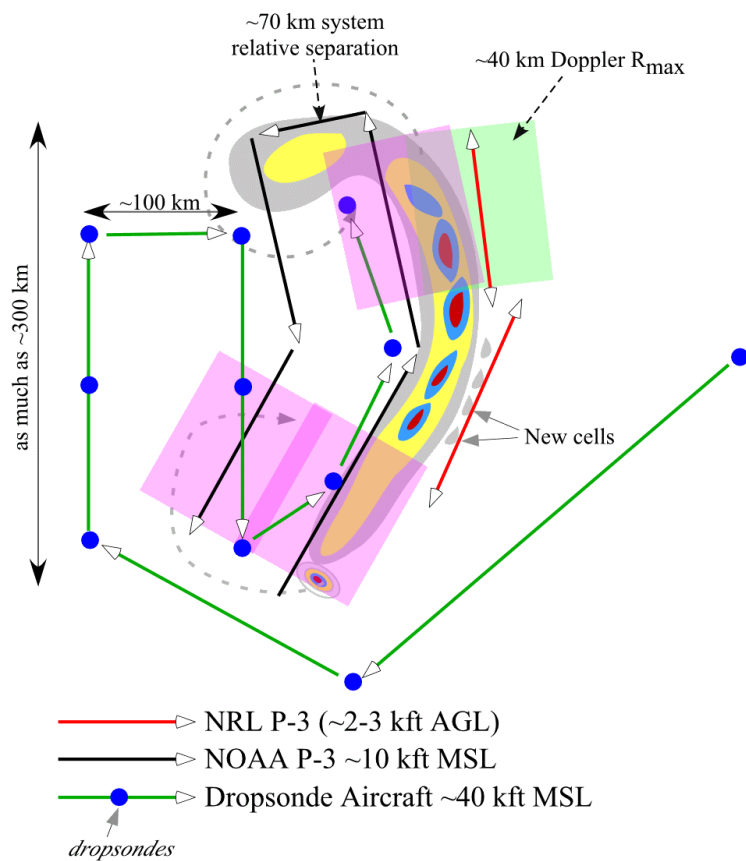


Figure 2.5 Schematic depiction of idealized flight patterns for the NRL P-3 (red lines with arrows), NOAA P-3 (black lines with arrows), and the dropsonde jet (green lines with arrows). Background field is radar reflectivity based on observations of bow-echoes. Shaded regions illustrate typical coverage by the tail Doppler radar systems of ELDORA (green area) and the NOAA P-3 system (magenta areas). Dashed lines with arrows indicate typical mid-level line-end vortices sometimes seen with bow-echoes.

2.7.2.2 *Microphysics Flight Modules*

From time to time during an IOP it would be advantageous to execute special flight modules to more closely examine the interactions of the rear inflow with the hydrometeor microphysics to examine hypotheses related to the role that evaporative cooling plays driving high mid-level winds down to the surface. Specifically, these modules have the objective:

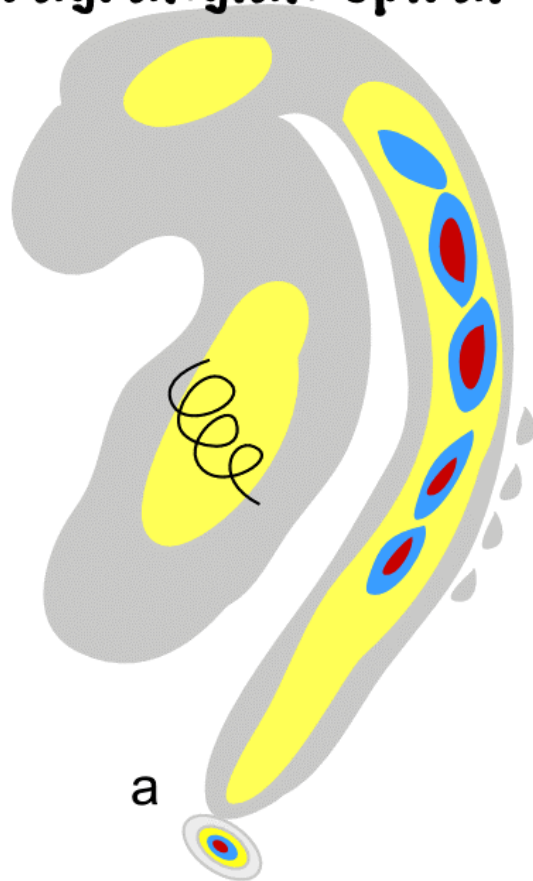
- Map vertical profile of hydrometeor sizes, shapes, and phases above, within, and below the melting layer.
- Generate database of hydrometeor properties for verification of remote sensing retrieval algorithms.
- Document sublimation, melting and evaporation processes occurring within regions of potential downdraft formation.
- In combination with thermodynamic observations and modeling studies, estimate cooling rates within these stratiform regions.

The NOAA P-3 will be the aircraft that will be best configured to make these special microphysical modules. That aircraft will have the NCAR PMS 2D-C and 2D-P Particle Measurement Systems (PMS) probes. A Lagrangian spiral is the best strategy for an *extensive and strong stratiform region* (i.e., a region that is several times larger than the P-3's typical turning radius of ~ 1.2 nautical miles and is very evident on the aircraft's LF and on ground based radars). The schematic illustration for the Lagrangian spiral is shown schematically in Figure 2.7a. The spiral strategy consists of:

- Descent in circles (~ 1.2 nautical miles is the typical radius of standard 2-minute turn in the coordinate system of the aircraft) so that P-3 stays within stratiform region at all times.
- P-3 descent rate equal to approximate terminal velocities of particles, ~ 1 ms⁻¹ above freezing layer, ~ 5 ms⁻¹ below freezing layer.
- Start descent from -10°C (~ 6 km) through melting layer (~ 4 km) to ~ 500 m above the surface (or as low as air traffic control permits, representing total flight time of ~ 45 minutes).
- Block off region between 6 km and ground with a radius of 20 miles. Hence, will most likely have to avoid this profile near any major airport or approach/departure corridors.

Ideally, four such descents should be performed during BAMEX to give a good statistical sample. However, the Doppler radar data collected during these spirals will not be very useful in the construction of three-dimensional wind fields because the forward and aft looking beams do not intersect in a regular fashion. Vertical profiles of divergence, vorticity, and vertical air motion can easily be derived using a modified VAD approach (the "purl" flight pattern used extensively in TOGA/COARE).

Lagrangian Spiral



Racetrack

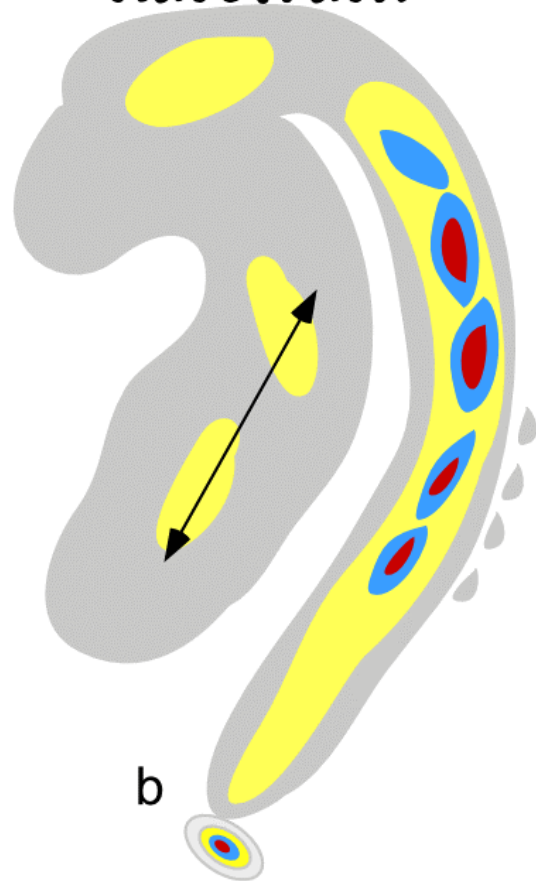


Figure 2.6. Schematic illustration of the microphysics modules. The left illustration (a) is of a “Lagrangian spiral” through a well developed stratiform rain region to the rear of the bow-echo convective line. The right illustration (b) shows an alternative plan for a less well developed stratiform region.

If the stratiform region is not as well developed, then an alternative pattern consisting of straight-line racetracks could be used (Figure 2.6b). This pattern would be executed as:

- Fly racetrack patterns approximately 50 km long parallel to the squall line at altitudes above, within, and below the melting layer (-10oC, 0oC, 3oC, and 10oC).
- With 4 flight altitudes, should take approximately 45 minutes to complete.
- Specify endpoints of racetracks based on position of squall line from ground-based or LF radar. Modify these endpoints based on movement of squall line.
- May be easier on air traffic control than requesting block out altitudes for Lagrangian spirals (only one altitude is requested at a time).
- Airborne Doppler data collected during the racetracks could be used to construct three-dimensional wind fields.

One of the potential drawbacks of the microphysical modules is the hazard of lightning strikes on the aircraft as the plane traverses the mixed phase region between about 0° C and -5° C. The P-3 has a tendency to become highly electrically charged in this temperature region due to impact with ice crystals. The charging has been known to completely block VHF radio

transmission and reception, making contacting air traffic control problematic. It is not known if the charging has an appreciable effect on satellite communications. Static electric discharges (i.e., lightning strikes on the aircraft) are another known hazard and those discharges have been known to damage radar antennas and radar transmitters/receivers (not to mention holes drilled in the skin of the aircraft by the discharge). *Therefore, to minimize damage to the aircraft the Chief Scientist should carefully monitor the environmental conditions and be prepared to abort the spiral or racetrack if lightning strikes threaten scientific equipment or block communications with air traffic control.* Dropping below the melting level is usually sufficient to bleed off the charging.

2.7.3 Dropsonde Jet

The design of the dropsonde jet bow-echo flight patterns are driven by the observational requirement to document the environment of the inflowing air ahead of the system and the circulations to the rear of the system. Some missions will be flown on developing MCSs in anticipation that the systems may eventually produce an MCV or evolve into a bow echo that delivers damaging wind. These missions have the potential to become the longest of any, because takeoffs will be at the earliest stages of developing systems. Fortunately, the speed of the dropsonde jet will often allow it to be the last of the aircraft to takeoff for an anticipated target, so dropsonde missions may suffer from relatively few unnecessary missions.

If an anticipated target does grow into a long-lived phenomenon of interest, these missions will likely be broken up into multiple flights when possible, sometimes involving both crews. It will occasionally be useful to separate flights by a few hours in order to ensure that there is available flight time toward the end of a target's lifetime, should something important occur, such as an MCV fostering new moist convection.

The archetypal flight tracks are designed based on the following constraints. The jet will release sondes from 40,000 ft (12 km) while flying at roughly 400 kts (200 m/s). GPS dropsondes fall 2,000 ft/min (10 m/s), so descents take 20 min. Because there are 4 channels to the dropsonde receiver, data from no more than 4 sondes can be recorded simultaneously. Therefore, sondes cannot usefully be deployed at a rate of more than one per 5 min. In practice, the steps required to prepare and release sondes make a deployment rate of 8 per hour more realistic than 12 per hour. This translates to 7.5 min and roughly 50 nm (90 km) between each drop.

When fully fueled, the jet's missions cannot exceed approximately 4.5 h, which gives it a range of 1,600 nm (about 2,500 km). The BAMEX domain is roughly 650 km in radius, so the dropsonde jet will have a typical on-station time of 3-3.5 h. For longer missions, like those in which long-lived MCVs are the target, the jet's high cruising speed will allow the crew to land and refuel at Mid-America or another airport, then fly the target a second time, if the restrictions to crew duty allow it. Double-crewing will permit missions to be extended even longer.

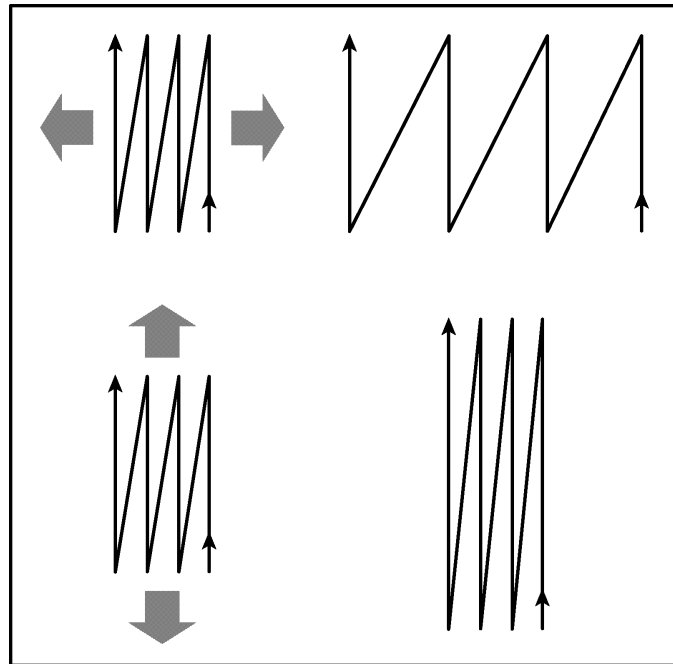


Figure 2.7. Scalability of flight tracks.

Because the diameters of target phenomena will range from roughly a few tens to many hundreds of kilometers (i.e., small bow echoes to large MCV-containing MCSs), it is important that flight tracks be scalable. A sawtooth pattern suits this purpose well (fig. 2.7). A sawtooth pattern also has the advantage of simplifying the pilot's navigation because tracks will comprise long, straight legs followed by single turns to a new, fixed heading. (The sawtooth pattern is in the Lagrangian sense; for the fastest targets, corrections to the longest legs may be needed to adjust for the target's translational motion.) When the target is an MCS, each leg will be roughly in the direction of the major axis of the convective line (fig. 2.8), which will make it easier for the pilot to avoid unintentionally leaving the stratiform region and penetrating the tops of dangerous, active cumulonimbi. The sawtooth pattern can be easily adapted to targets of different sizes by adjusting the lengths of the legs and the acute angles at their vertices. Even so, the smallest targets may require some modification to the sawtooth pattern in order to avoid unnecessarily continuing legs well beyond the target and desired drop zones. In this case the points of the sawtooth may be squared off with a pair of turns, as long as the modification does not prohibit releasing sondes in key parts of the target (fig. 2.8b). The Dropsonde Coordinator and Operator should be aware that extending some flight legs beyond the immediate drop zone might be necessary to establish the best timing for subsequent drop points.

All flight tracks will have certain commonalities, no matter the target. For most missions, drop points will be set to produce a roughly even distribution across the target (avoiding large gaps and dense clumps), which may not necessarily maximize the number of sondes deployed during a mission. The first and last soundings of each mission will be in a target's environment, well away from any active moist convection. Precisely how many environmental soundings are made will vary from mission to mission.

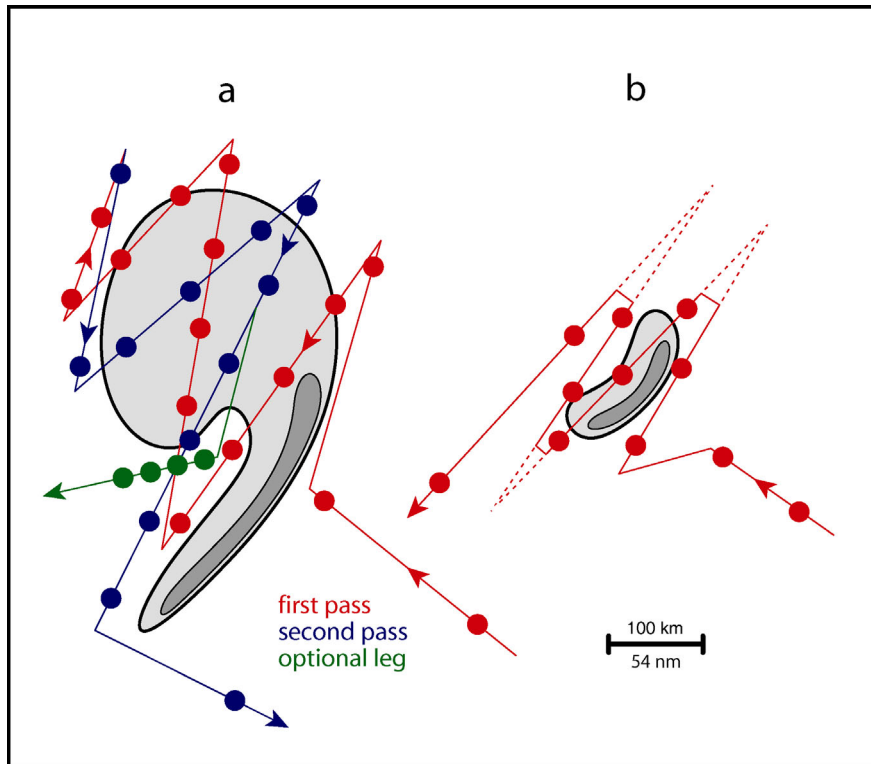


Figure 2.8 Archetypal Lagrangian flight tracks for small and large MCSs. The thin line is the flight track; black circles are the release points for the dropsondes. The shaded regions are schematic depictions of radar reflectivity of 20 dBZ (outer region) and 45 dBZ (inner region).

In mature MCSs, dropsondes will be concentrated in the stratiform region, especially on the northern half of the system, where the MCV is located. The flight strategy near the MCV will be nearly the same as that for a lone MCV without active moist convection.

Three regions away from the MCV will also be specifically targeted. The first two are immediately ahead of and behind the convective line (fig. 2.8a), where the sondes should be able to sample the inflow and outflow of the line's cumulonimbi. The third region is any dry notch(es) that may develop in the stratiform region (fig. 2.8a). Notches can mark the location of a strong mesoscale inflow.

Because they are small, fast, and quick to develop, bow echoes will be the most challenging targets. The foci of the drops will be in the environment ahead of the bow echo and in its stratiform region, especially immediately behind any part or parts of the line that are deformed into a concave shape (as seen from behind). These concavities tend to occur when a bow echo is particularly well developed (fig. 2.8b), and they mark the strongest inflow. Some bow echoes will be small and long-lived enough to allow the jet to fly multiple sets of tracks through the stratiform region. In this case a few sondes will be deployed at the same positions (relative to the system, not the ground) of previous deployments in order to assess the system's evolution.

Because the high cruising speed of the dropsonde jet, it is feasible for some missions to have multiple targets. Among the considerations in prioritizing among multiple targets are: 1) the distance to each target, 2) the longevity and steadiness of each target, and 3) the successes of previous missions flown during the experiment. Priority will generally be given to the target that is closest, shortest-lived, least steady, and least well-observed by that point in the experiment.

The Dropsonde Coordinator will issue the list of longitudes and latitudes of potential drop points. A preliminary list will be made available to the flight crew during the pre-flight briefing so the pilot and co-pilot can determine a flight plan. Depending on what the flight crew prefers, the preliminary list may only need to include the location(s) of the initial environmental sounding(s) and the locations of the first few drops near the target. Once the jet is on station, the Coordinator will revise the preliminary list if necessary and add additional drop points. Revisions and additions will be communicated either via satellite phone or a short email to the Dropsonde Assistant. The assistant will then relay the information to the flight crew and Dropsonde Operator.

The most important considerations in determining drop points are

- Avoid urban areas
- Avoid other aircraft, such as the P-3s
- Avoid organizing the drop points in a way that would take the dropsonde jet through dangerous weather, such as active cumulonimbi; the pilot will almost certainly veto such tracks. *(The real time location of the dropsonde aircraft will either be provided by Flight Explorer or by providing aircraft position updates in 1 minute intervals through one of the Iridium satellite systems to the BOC.)*
- Assign drop points when the jet is expected to be flying level with the horizon, not rolling through a turn
- Emphasize the stratiform regions of MCSs
- Obtain environmental soundings at the beginning and end of each mission

The easiest method of defining drop points is to specify a heading and the starting time for an initial drop on that heading, then to simply instruct the Dropsonde Operator to deploy sondes at a regular period (every 8 min, for example). This will obviate any need for the Operator to know precisely the latitude and longitude of the jet at all times. Of course, Coordinators and Operators should be mindful that some points will need to be adjusted at the last minute if the structure or location of a target has changed significantly, or if the jet is over a region where deployment is prohibited.

The Dropsonde Coordinator's station, from which he/she will determine the drop points, will be located in the lower floor of the Mid-America Airport and will consist of one PC on a local network that includes access to the Internet, and an adjacent station at which a laptop may be connected to the network. The PC will be running FX-Net, which will be the primary source for the real-time weather data that the Coordinator will use to lay out flight tracks and drop points. Also at the Coordinator's station will be a map that depicts the regions within the BAMEX domain in which dropsondes are restricted or prohibited.

2.7.4 Pattern Coordination

It is essential that ground-based coordination be available to help each aircraft set up the end points of each flight leg in the moving coordinate system of the MCS. The limited range of the

horizontally scanning Lower Fuselage (LF) radar on the NOAA P-3 will not allow flight track planning for all the BAMEX aircraft to reliably occur. The Operations Center can access regional NWS radar low-level composite reflectivity charts which can be used for this purpose.

2.8 MCV Flight Patterns

The goal of the jet MCV flight pattern is to document the circulation of the remnant circulation remaining from an MCS. The basic flight pattern for the dropsonde jet aircraft is shown in Fig. 2.9.

MCVs are the only target that may be unaccompanied by active moist convection or, in some cases, even clouds. The flight tracks and drop points may be hard to determine without any precipitation (as depicted by radar reflectivity) to mark an MCV's vortical circulation. The advantages of this kind of mission is that the target will move and evolve slowly, and the dropsonde jet will be less constrained about where to fly.

The most critical soundings in MCVs that lack, and are not expected to trigger, active moist convection are 1) at the center of the vortex, 2) near the radius of maximum wind in the vortex's quadrants, and 3) in the vortex's environment. In order to insure at least one sounding near the center of an MCV, drops may need to be concentrated in a smaller area than is typical of other missions (fig. 2.9). A clump of soundings near the center will also help to define a vortex's tilt. The radius of maximum wind will be difficult to determine, but the real-time transmission of data to the Operations Center should aid diagnosis. In the case of the environmental soundings, it is important that sondes be deployed away from active moist convection.

If the MCV is expected to destabilize its local environment and foster new moist convection, then the regions that will be emphasized are the center and the down shear perimeter, where new convection is most likely, as well as the vortex's environment ahead of the down shear perimeter. Accordingly, a second set of soundings may be dropped in these regions after the initial flight legs (fig. 2.9) are completed, either in an abbreviated form or in their original form, if time allows.

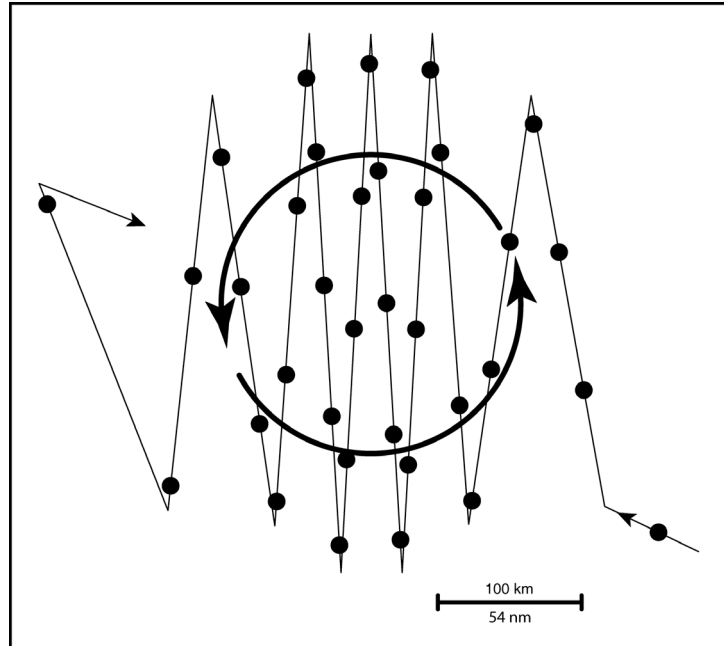


Figure 2.9. Archetypal Lagrangian flight tracks for an MCV without active moist convection. The thin line is the flight track; black circles are the release points for the dropsondes. The heavy line with arrowheads shows the maximum tangential wind. For dropsonde legs of ~ 200 na. mi, deploying sondes every 50 na. mi (\sim every 8 minutes) a six leg pattern could be completed in 3 hrs. With the jet endurance being 4.5 hr, a refueling break could be scheduled at an airport somewhere within the MCV domain.

2.8.1 General Mission Schedules

The two primary schedules for dropsonde missions during BAMEX will be *afternoon* and *night* (fig. 2.10). Afternoon missions generally will apply to bow echoes and mature, long-lived MCVs that are expected to foster new moist convection through destabilization of their local environments. Night missions generally will apply to developing and mature MCSs and developing MCVs. Takeoffs for afternoon missions will nominally be set for 1100 CDT (1600 UTC) when a second crew is available for a following night mission and 1400 CDT (1900 UTC) when a second crew is unavailable. Takeoffs for night missions will nominally be set for 2100 CDT (0200 UTC).

Because the flight crews' duty days are 14 h and each mission must include 2 h before the first takeoff and 1 h after the final landing, the flight window for a mission is 11 h following the takeoff time (figs. 2.10 and 2.11). Long missions will comprise two flights, each shorter than ~ 6 h (including ferry time), and one refueling. Short missions will comprise a single ~ 6 -h flight, which can occur any time during those 11 h. Once a takeoff time is set during the previous day's planning meeting, it cannot be moved up, only delayed, so setting a mission's takeoff time as early as might be needed provides the most flexibility, as long as the end of the 11-h flight window is not changed. It follows that delays can be up to 5 h without shortening the time on station.

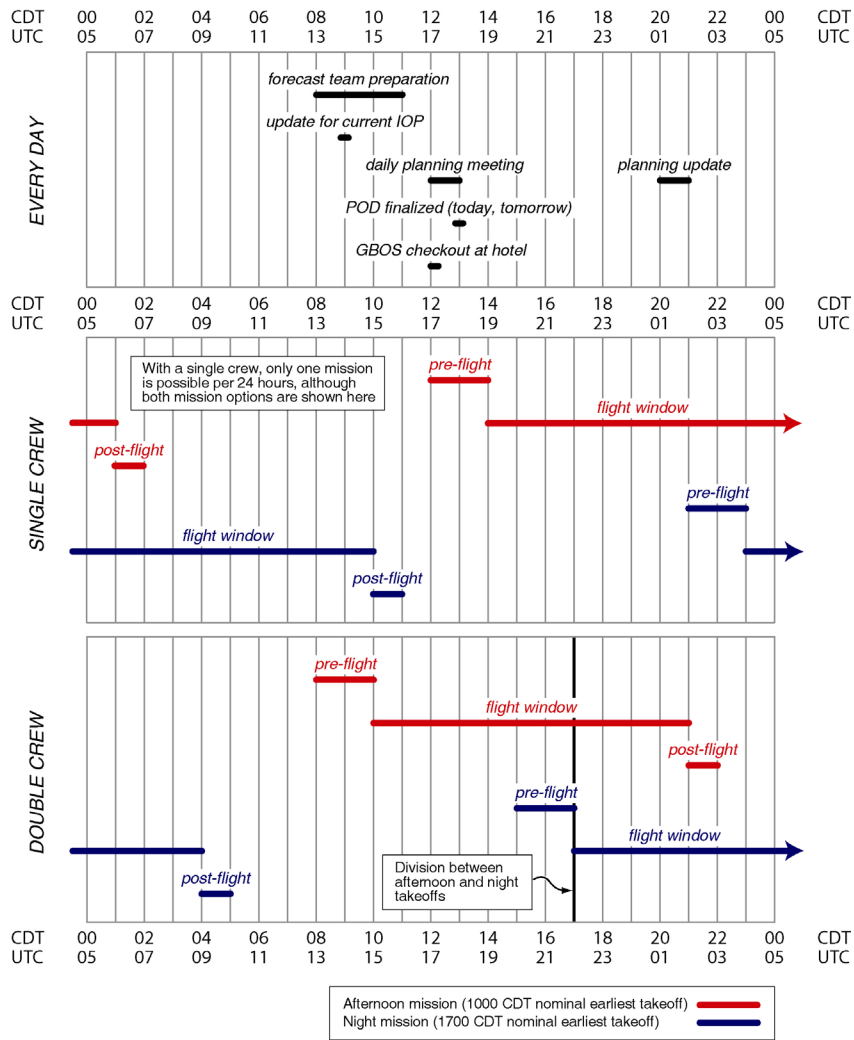


Figure 2.10. Timeline for dropsonde missions. See fig. 5 for details about the flight windows such as ferry times and refueling.

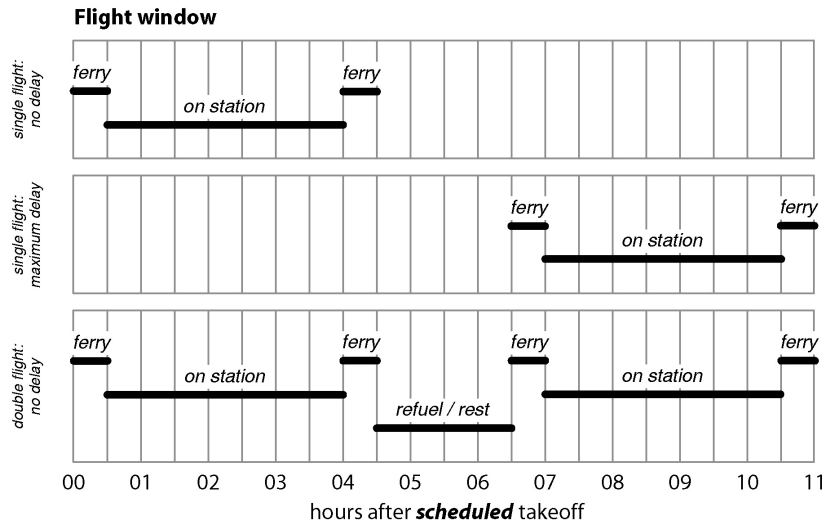


Figure 2.11. Details of flight window for dropsonde missions. See fig. 2.10 for a more general timeline.

2.9 Damage Surveys

Based on preliminary reports gathered by the SPC/participating NWS offices, ground and aerial surveys of storm damage will be conducted immediately following bow-echo events. Aerial surveys will be performed (on fair-weather days) with a Cessna-172 aircraft flying at 500-1000 feet AGL. It will be critically important to photo-document the damage extent, intensity, and patterns from the air, the latter allowing for the necessary discrimination of “tornadic” damage from that due to straight-line winds. The quality of the damage intensity estimates will be limited by the number of structures damaged and also by available vegetation. For example, corn and soybean plants that eventually cover much of the Midwest farmland are typically just emerging from the ground during the early scheduled weeks of BAMEX. More useful information during these weeks will thereby be revealed by damaged trees, utility poles, and structures.

Ground surveys will also be executed, to provide additional damage information and photo documentation that is not available from the air. Ground survey endeavors of volunteers and other interested BAMEX personnel will be directed by the Survey Coordinators, who will also work cooperatively with local NWS offices and the general public to collect as much damage information as possible. Such information could include approximate times, locations, and associated weather conditions of damage, and also any photographs or video taken of the event.

All aerial and ground survey information will be plotted onto high-resolution USGS topographic maps. Preliminary survey results will be posted on the BAMEX data website. Research quality survey results will be made available on CD or DVD, following the completion of the field phase.

3 GBOS Operations

3.1 Overview and measurement goals

The BAMEX program will deploy a modest number of mobile, Ground-Based Observing Systems (GBOS), consisting of:

- University of Alabama in Huntsville *Mobile Integrated Profiling System* (MIPS),
- two NCAR *MGLASS* sounding systems, and
- one *Mobile Probe* (MP) vehicle (UAH).

The GBOS will provide measurements of: (i) boundaries in the pre-storm environment, (ii) atmospheric boundary layer (ABL) and free tropospheric structure within and around bow echoes (BE) and MCS's; (iii) kinematic, thermodynamic, and microphysical properties of bow echoes and MCS's; and (iv) the environment and internal structure of MCV's. In several cases, sampling will continue for long time periods into the early morning hours, as late as 0200 CDT. A typical scenario would involve a pre-storm setup for 1-3 h prior to the BE arrival, sampling of the MCS passage, and then a short sampling time after the MCS leaves the GBOS domain. A flexible experimental design will facilitate a quick set up and redeployment if storms evolve or propagate differently than forecast over the 1-6 h time frame.

3.2 GBOS Descriptions and Personnel

Collectively, the GBOS consists of six vehicles (including trailers 24 and 14 ft long), and a minimum of 12 personnel. GBOS teams are defined in Table 3.1

Table 6.1. GBOS team descriptions

GBOS component	Personnel	Position descriptions
MIPS	4	GBOS Team Leader, MIPS Operator, Logistics Scientist, GLASS Operator, possible visitor (1)
MP	2	Driver, Navigator/Communicator, possible visitor (1)
MGLASS1	2	Driver, Navigator/Communicator
MGLASS2	2	Driver, Navigator/Communicator
MGLASS pickup	2	Driver, Navigator/Communicator
MGLASS Support Vehicle	2	Driver, Navigator (responsible for helium supply to MGLASS units)

3.2.1 Mobile Integrated Profiling System (MIPS)

3.2.1.1 Physical description

The MIPS includes a van with two personnel (driver, navigator), computers, electronics, and workspace. The van tows a 24-ft instrument trailer that carries the major instruments. In addition, a pickup (one driver, one passenger) and 14 ft utility trailer with a generator will usually follow the MIPS van and instrument trailer. Four helium canisters will be stored and secured in the pickup bed.

3.2.1.2 Measurement capabilities

The UAH Mobile Integrated Profiling System (MIPS) consists of the following components: (a) five-beam 915 MHz Doppler profiler, (b) 2 kHz Doppler sodar, (c) 0.905 m lidar ceilometer, (d) a 12-channel passive microwave profiling radiometer, (e) an electric field mill, (f) a vertically pointing imaging camera, (g) a Joss-Waldvogel disdrometer, and (h) standard surface instrumentation including solar radiation. The 915 MHz radar measures horizontal wind, vertical velocity and backscattered power profiles at 60 to 105 m vertical resolution. While average wind profiles (accuracy within $\sim 1 \text{ m s}^{-1}$) are generated in real time every 30-60 min, an independent wind vector is achievable every 90 s (in precipitation-free air) for linear wind fields. For the non-precipitating boundary layer, the dwell time along each beam is typically $\sim 30 \text{ s}$ and the vertical beam is sampled every other dwell cycle to provide information on vertical motion profiles (accuracy $\sim 0.25 \text{ m s}^{-1}$) every 60 s. Doppler spectra will be archived during BAMEX. Profiles of backscattered power obtained by the 915 MHz profiler contribute important information on atmospheric stratification, which is particularly useful for monitoring turbulence within the ABL, water vapor gradients, stable layers and the CBL depth. In the precipitation mode, the 915 MHz profiler will sample to 10-12 km AGL with shorter dwell times in the range 10-20 s.

The three-beam Doppler sodar will sample higher resolution wind profiles at 25-m vertical resolution, beginning at 50 m AGL. With a pulse repetition period of $\sim 6 \text{ s}$, vertical motion is measured at about $\sim 20\text{-s}$ intervals, up to maximum measurement heights of typically 200 to 600

m AGL. Both the 915 MHz radar and sodar will provide information on ABL turbulence using the mean velocity and spectrum width fields. The sodar also provides the acoustic source for profile measurements of virtual temperature (T_v) via the Radio Acoustic Sounding System (RASS) technique. Profiles of T_v will be acquired at time intervals of 30-60 min.

Cloud base, cloud thickness and visibility profiles (e.g., relative aerosol loading) will be obtained by the lidar ceilometer, which acquires measurements of backscattered power at 15-m intervals, beginning at 15 m AGL. Time resolution will be set at 15 sec. Cloud visual properties and coverage fraction will be documented (during daytime) by a vertically pointing camera (55 deg field of view) at 30-s time resolution.

The 12-channel radiometer will measure temperature, water vapor density and cloud water (at cruder resolution) profiles up to 10 km AGL (greatest vertical resolution at low levels) at 1 or 2 min intervals. In addition, the radiometer derives accurate estimates of column integrated water vapor and cloud water, also at 1 or 2 min intervals.

The electric field mill measures the E field at 50 Hz, and is therefore able to detect lightning flashes within relatively close proximity. The surface measurements (T, RH, p, wind direction/speed at 10 m and solar radiation) will be recorded at 1 Hz.

The disdrometer is a Joss-Waldvogel unit (RX-XX) unit manufactured by Disdromet, Ltd. It measures drop sizes at 127 intervals over the range 0.3 – 5 mm, with an accuracy of $\pm 5\%$. After processing, the drop-size distribution is estimated at 1 min intervals for 20 size classes that are distributed roughly exponentially. The corresponding moments of DSD (rainfall rate, liquid water content and reflectivity factor) are also output at 1 min intervals.

A wide-band satellite communication system (DataStorm) is a recent addition to the MIPS. This system will be used to obtain near real-time meteorological data (radar, satellite, profiler, sounding, surface, etc.) available from various web sites. More importantly, MIPS data, including GLASS soundings (if available on the MIPS) will be uploaded to a web server for utilization by BAMEX forecasters and scientists.

Data from the MIPS components are archived on computer hard disk and will be backed up daily on CD media. Displays of the data (time-versus-height sections of mean wind and moments from individual beams) are produced in near real time, and images of these displays will be generated for every IOP. More extensive analyses, including images of time-height sections and time series, will be posted to the BAMEX web site within one day of data collection.

3.2.1.3 Personnel

MIPS crew will consist of four core personnel who will have the job duties defined below. Additional personnel (e.g., students) may be added to assist with these activities.

GBOS Team Leader (TL) – Coordinates the GBOS and MIPS activities, communicates with BOC and aircraft, logs GBOS operations and notable weather events in the *GBOS Logbook*.

MIPS Operator – Helps with MIPS deployment; monitors MIPS data collection and analysis, summarizes MIPS measurements in the *MIPS Logbook*; takes photos of MIPS set up and cloud conditions; puts MIPS and GLASS data to web site on a regular basis.

Logistical Scientist (LS) – Helps with MIPS deployment; assists with communications (e.g., during MIPS transit and setup), provides continuous mesoscale analysis and nowcasting during deployment; maintains the *Nowcasting Logbook*; makes hard copies of radar images, etc; assures that satellite communication system is functional.

GLASS Operator – Helps with MIPS deployment; prepares, launches and analyzes GLASS soundings with support from the LS; maintains *GLASS Logbook*, including launch times and sounding properties.

3.2.2 NCAR Mobile GLASS (M-GLASS)

3.2.2.1 Physical description

The two M-GLASS systems will be mounted inside two GSA vans with all the hardware required to make atmospheric soundings, including three helium cylinders and equipment to make supporting surface meteorological observations. Each unit will be operated by two people. A third vehicle, also staffed with two people, will be responsible for providing adequate supply of helium bottles to the two MGLASS vans. Helium will be supplied by Praxair through a UCAR contract that allows for pick up and return to any office in the operational region.

Data communications from the truck to a central operations center can be managed in one of two ways. Data can be transmitted using a cellular phone or it can be sent using a packet radio communication system. Partial messages or pseudo-real time data can be sent during the sounding using a second computer and the cellular phone.

MGLASS Field Managers are Chamberlain, Lim, and Verstraete.

3.2.2.2 Measurements

The NCAR M-GLASS systems measure profiles of T and RH with a Vaisala RS80-15GH instrument package. Accurate winds (define error here) are derived from a GPS receiver located within the Vaisala instrument package. Soundings will be acquired at 1-1½ h intervals, or within targeted regions of bow echoes, MCS's, and MCV's. The M-GLASS units will also measure wind, p, T and RH at the 2 m level, at sampling periods of 10 s, during each deployment period.

During BAMEX, the first sounding of every IOP (20-s data in CLASS format) will be sent to the BOC via cell phone modem. The full set of 20-s data files for each IOP will be uploaded from the MIPS during the following morning. The full set of MGLASS files (~1 Mbyte per sounding) will be archived on each M-GLASS computer. Data are backed up on transferable media.

3.2.2.3 M-GLASS Operations

Occasionally a "nowcast" sounding will be launched before normal operations begin. These environmental soundings will aid the BOC in evaluating the potential for operations later in the day. Launches will be done at the hotel before departure.

The NCAR MGLASS units will be deployed north and south (for a generic linear MCS oriented north-south) of the MIPS within the Intensive Observational Domain (IOD, illustrated as two systems in Fig. 3.1). One MGLASS unit will operate on the cool/moist (most stable) side of the target boundary (if a boundary is present). The second MGLASS will be deployed on the

warm/moist side of the boundary, forming an approximately boundary-normal orientation with the first unit. The third GLASS unit (on the MIPS) will be deployed on the cool side of the boundary, roughly half way between the two MGLASS units. The two MGLASS units will launch balloons at intervals dependent on the experimental type. It is assumed that each MGLASS will, on average, release 5 radiosondes on each operational day for a total of 100 sondes from each of the two MGLASS systems. Balloon launches will be done every 1 - 1.5 hours.

Mobile sounding teams will maintain an adequate supply of sondes, balloons and helium in their vehicles. The M-GLASS minivans will hold three helium canisters, and the MIPS pickup will hold 4-5 (145 lbs each). The M-GLASS pickup will store extra helium canisters for the two NCAR M-GLASS units, and travel to designated cities to replenish He supplies. The MIPS pickup will do likewise on hard down days when required.

An aircraft flying either normal or parallel to the LMCS will typically deploy frequent dropsondes over the entire MCS domain. NCAR will assign MGLASS frequencies that will be spread over the 400-410 Mhz range to avoid interference. Tentative frequencies are provided in Table 3.2. The dropsondes, which use a narrow-bandwidth system, will operate at a frequency between those listed in Table 3.2.

Table 3.2: Mobile Balloon Frequencies

Instrument	Frequency (MHz)
M-GLASS1	405.00
M-GLASS2	401.25
MIPS GLASS	400.00

3.2.2.4 MGLASS Data

- Data will be transferred as an ASCII CLASS format file. This file will be a 20 second data file.
- Only the first flight of the day is required at the ops center. Other flight can be transferred if time allows.
- Files not transferred will be put on a floppy and MIPS will transfer them by the morning after the day of operations.
- Surface data will be logged while the mobile GLASS are stationary. The data will either be 10 second data or 1 minute averages with peak gust wind included.

All communications regarding position will be in the format of decimal degrees i.e. 40.43677 N and 105.28453 W.

3.2.3 Mobile Probe (MP)

3.2.3.1 Physical Description

The MP vehicle is a four-door sedan with a special roof rack supporting meteorological sensors. The MP will typically sample surface conditions within about 50 km of the MIPS. The MP will also serve as a scout vehicle that will often travel ahead of the GBOS caravan and

determine specific locations of boundaries, and optimum MIPS locations for various experimental configurations.

3.2.3.2 Measurement capabilities

The mission of the MP is to identify horizontal variability in surface wind, temperature, humidity, and pressure ahead of, around, and within evolving convective systems. When combined with other observations during the post-field-program analysis, the MP observations will be used to assess how horizontal variations in CAPE, vertical wind shear, surface cold pool, and other parameters affect overall bow-echo structure.

The UAH MP is similar to the MP units developed by the National Severe Storms Laboratory and University of Oklahoma (Straka et al. 1996). Measurements of pressure, temperature (slow- and fast-response), relative humidity, wind direction, and wind speed at 3 m AGL will be recorded at 1 Hz. In addition, the UAH MP will include a fast-response (1 s) Epply pyranometer for measurement of solar radiation.

Wind-tunnel tests have indicated that accurate wind measurements ($\sigma_v \sim 1 \text{ m s}^{-1}$) can be collected when a vehicle is moving at highway speeds, provided that blockage by trees and buildings is not substantial. Data quality is poor only when the vehicle is accelerating or decelerating. Since GPS locations of the vehicles will be recorded, an estimate of surface pressure at particular reference levels may be obtained using an accurate topographic database.

3.2.3.3 Personnel

A two-person crew consisting of a driver and a navigator will staff the MP sedan. The driver's sole responsibility is to make sure that the crew reaches their destination safely. The navigator has multiple responsibilities: communicating with the GBOS team leader or GBOS coordinator about observing strategies, executing the planned strategy (navigating), monitoring data quality, noting the presence of obstacles that block surface flow, and watching for signs of dangerous weather or other driving hazards.

3.2.4 Photography

Hand-held 35 mm and digital photographs at fixed focal length and known orientation will be obtained from the MIPS and MP. The azimuthal orientation of the digital camera will be determined and recorded. The camera will be operated at fixed focal length, eliminating the need for photogrammetric landmark surveys. The MIPS will also utilize a vertically pointing digital camera during daylight conditions. Hand-held photos will document MIPS set-up configurations and orientations.

3.3 GBOS Crew Duty Day

In order to prevent fatigue and remain within budget constraints, the GBOS units will be limited to three consecutive IOP days, with a total operational time (defined as motel check-out to motel check-in) of 42 h over three days. A rest period of at least 10 h (motel check-in to motel check-out) is required between each IOP. If three consecutive IOP days are completed, the fourth day will be declared a "hard down" day, which will include a two-night stay at the same motel.

Many alternate scenarios will emerge during BAMEX, such as a mission that is terminated due to unanticipated MCS demise, for example. Such cases will be handled individually in consultation with the MGLASS and MIPS lead personnel.

Definitions:

- Crew day is defined as hotel to hotel.
- Hard down day is defined as two nights at the same hotel.

Crew Duty Limits (for BAMEX GBOS operations only):

- Between each operational day there will be a mandatory 10 hours off, defined as from the time of arrival at the hotel until the time of departure. This will allow for three 10 am to midnight operational days.
- Total number of working hours during the “worst case” 3-day time frame cannot exceed 42 hours.
- The fourth day of the “worst case” sequence will be a hard down day to provide a thorough and complete rest day.
- Requests beyond the scope of the guidelines and other operational periods will be dealt with by the MGLASS Field Managers on an individual basis.
- The MGLASS Field Managers reserve the right to call for unscheduled down days to provide for proper crew rest and equipment maintenance if needed.
- In general, the guidelines outlined in the feasibility will be followed (see below).

3.4 GBOS Network Design and Operation Scenarios

3.4.1 Generic experimental setup

The proximity of WSR-88D radars or NOAA 404 MHz profilers will be considered in selecting the intensive operating domain (IOD). Figure 3.1 illustrates the general GBOS experimental setup. The deployment configuration and strategy is dependent on system orientation with respect to the road network. When MCS's are oriented 45° to the road network, the MP may conduct a zig-zag pattern (Fig. 3.1b), rather than a straight line pattern as in Fig. 3.1a. In all designed configurations for bow echoes and MCS's, the MGLASS units will define the end points of a linear array, with the MIPS placed approximately midway between the MGLASS units. The MP track will typically be 40-50 km long and centered on or near the MIPS site. In some circumstances, the MP sampling may be moved to locations, removed from the MIPS, where surface measurements are deemed important. The distance scale between MGLASS units will be in the range 100-200 km.

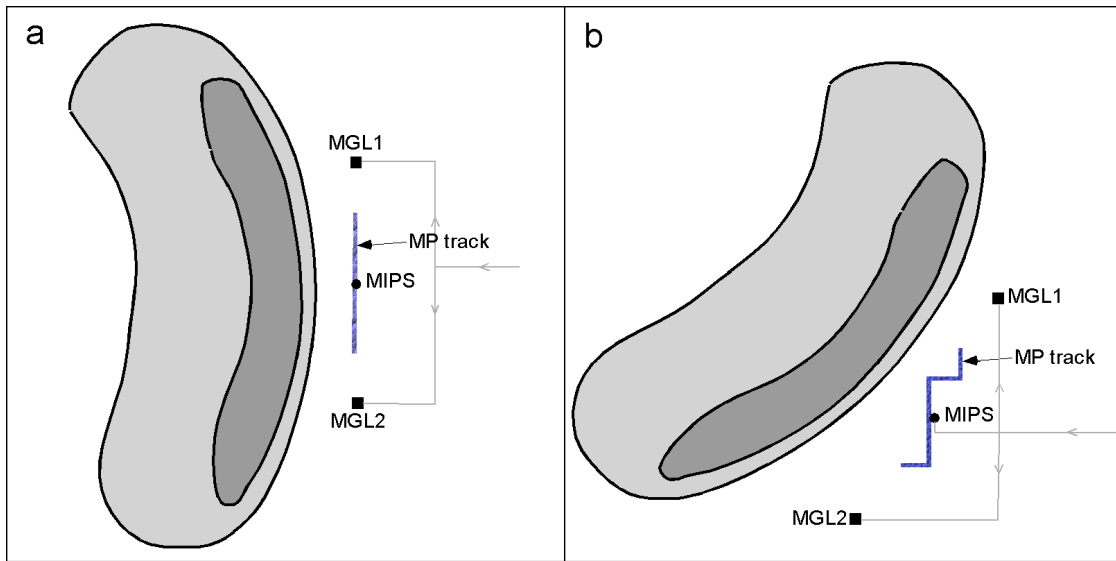


Fig. 3.1. GBOS experimental design for a linear MCS or bow echo whose major axis is (a) aligned parallel to roads, and (b) aligned at an angle of 45° ($30\text{--}60^\circ$ range) from the roads. The thin gray lines represent the paths followed by each GBOS unit during transit to their designated location. MGL1 and MGL2 represent M-GLASS1 and M-GLASS2, respectively. The MCS major axis is about 150 km in this case.

3.4.2 Pre-Storm (PS) or developing bow echo (Dev-MCS) network design

This experimental design applies to pre-storm conditions or to the region east of a developing MCS. Measurements of the pre-storm environment will be acquired whenever feasible, and for time periods as long as possible. The measurement period should begin around 1600-1700 LST in order to capture ABL evolution from convective (unstable) to nocturnal (stable) conditions. Given the time constraints for travel to a target region, this scenario is not expected to be common. However, in many cases, we expect to sample pre-storm conditions (the ABL in particular) for a 1-3 h period prior to MCS arrival.

Within the target region ahead of the developing (or anticipated) convective system, the GBOS will sample a linear domain approximately perpendicular to the expected system motion, or parallel to the bow echo major axis (Fig. 3.2). The MIPS will be positioned at a location close to the forecast maximum surface winds (e.g., the bow echo apex). If a surface boundary is identified, the MIPS will be located about 20 km north of the boundary. The M-GLASS units will be located 50-100 km north or south of the MIPS, forming a baseline 100-200 km long. This distance separation will be determined from the size of the bow echo or MCS. The MP vehicle will drive back-and-forth repeatedly along a leg 40-50 km long passing near the MIPS. The round-trip time necessary to complete each leg will be approximately 60 min at typical highway speeds of 55 mph.

During pre-storm conditions, M-GLASS balloon releases will be coordinated at $1\frac{1}{2}$ h time intervals.

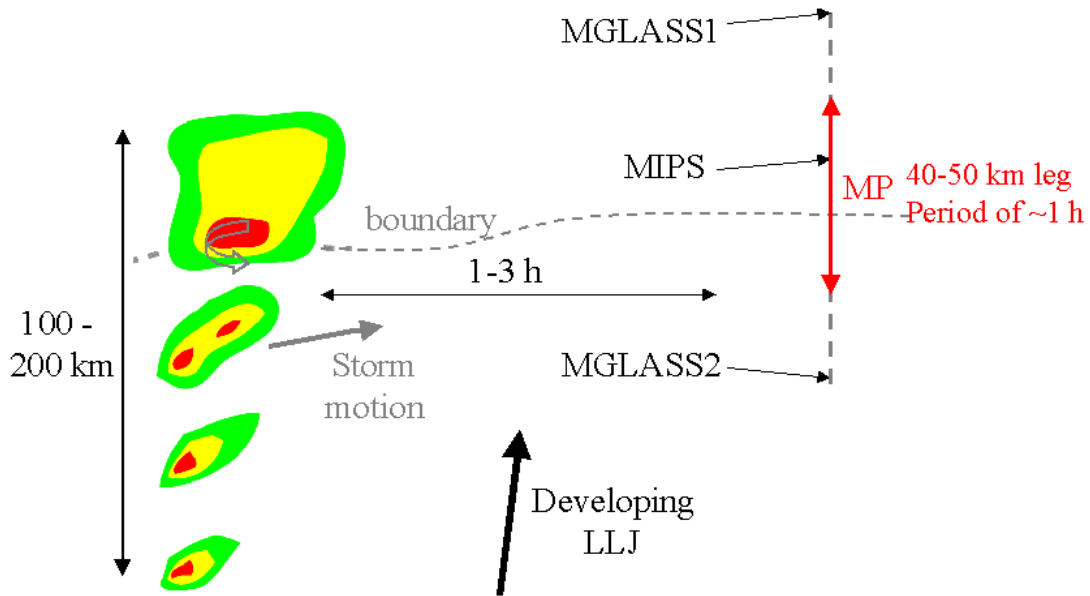


Fig. 3.2. Linear array fixed site configuration for sampling of the pre-storm atmosphere 1-3 h in advance of a developing MCS.

3.4.3 Bow Echo (BE) network design

a) Sampling of the Bow Echo or Mature MCS Convective Region

The design for BE experiments will be generally the same, but minor adjustments may be made to optimize measurements in strategic regions of the BE or MCS. The primary mission will be to (a) measure wind and thermodynamic profiles within and around bow echoes, and (b) MCS internal structure properties such as updraft/downdraft profiles, cold pool depth/strength, and rear inflow jet structure, thermodynamic and microphysical properties. When a mature bow echo approaches the target region, the MP crew will terminate the mobile sampling strategy and move to a location several kilometers up track of the MIPS (Fig. 3.3), while the BE convective region moves over the GBOS array. In some cases, the MIPS and MGLASS locations may be adjusted to sample preferred regions of the bow echo, provided that secondary sites are available. These fixed locations should be reached at least 30 min prior to the BE arrival. Since the MIPS and MGLASS have surface meteorological sensors, 4 surface measurement locations will be realized in this stationary network mode.

As the bow echo approaches, safety for the crews and instruments will be the top priority. Crews should be provided enough time to find a good location to “ride out” the storm. To minimize the chances that the vehicle will be hit by airborne debris when the bow echo arrives, each crew should park in an open area, away from power lines, signs, buildings, and trees. The deployment site should be along a road (paved or gravel, but not a dirt road), perhaps on the shoulder of the road or in a nearby parking lot. Flashing warning lights should be turned on so that other drivers are aware of the parked vehicle. The crews will remain stationary until the threat of severe weather has passed.

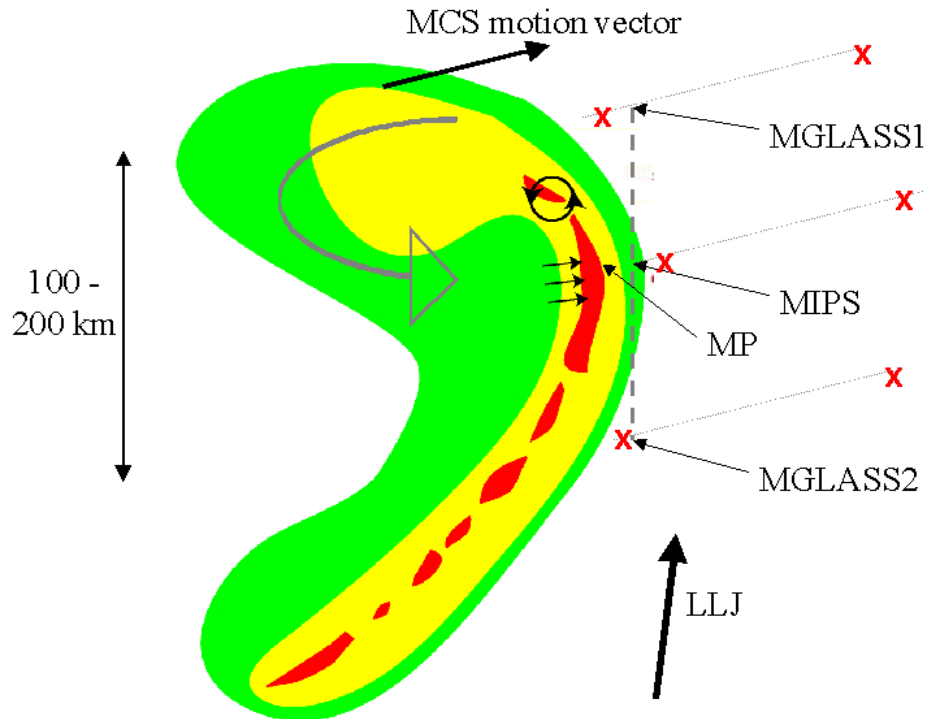


Fig. 3.3. Linear array fixed site configuration for sampling of the convective portion of the bow echo or MCS. Red x's represent M-GLASS sounding locations in advance of the bow echo. During passage of the convective line, the MP will be located several kilometers up-track of the MIPS. Soundings will be launched in strategic locations in front of the bow echo at 1 – 1½ h time intervals.

b) Sampling of the Bow Echo or Mature MCS Stratiform Region

After the convective region passes over the MP (i.e., the threat of hail and severe winds diminishes at the MP location), it will resume sampling the stratiform region along north-south legs about 40 km long, passing close to, but not necessarily centered on the MIPS. Since the MP crew will be driving through rain (and potentially heavy rainfall accumulations delivered by the convective region), they will drive at relatively slow speeds along short legs. Round trips along legs that are about 40 km long should be completed in about 1 h.

MIPS and GLASS locations will not change after the convective region passes over. The MIPS will continue sampling in the precipitation mode, and GLASS soundings will be released at variable time intervals so that key locations in the MCS can be sampled. These key locations include:

- a) the rear inflow jet from just behind the convective region, to the upper part of the RIJ as defined by WSR-88D or NOAA P-3 Doppler radar measurements;
- b) locations within the comma head along the northern periphery of the bow echo system (around the region of the M-GLASS 2 location in Fig. 3.4), in a region where a developing or maturing MCV is often located.

Fig. 6.4 shows ideal sounding locations for the generic bow echo shown in the figure. Again, the BOC will be notified of planned sounding release times, or will coordinate the sounding releases,

in order to insure aircraft safety. This is especially important for GLASS soundings launched from the MIPS site in the case of a P-3 spiral-sampling pattern within the stratiform region.

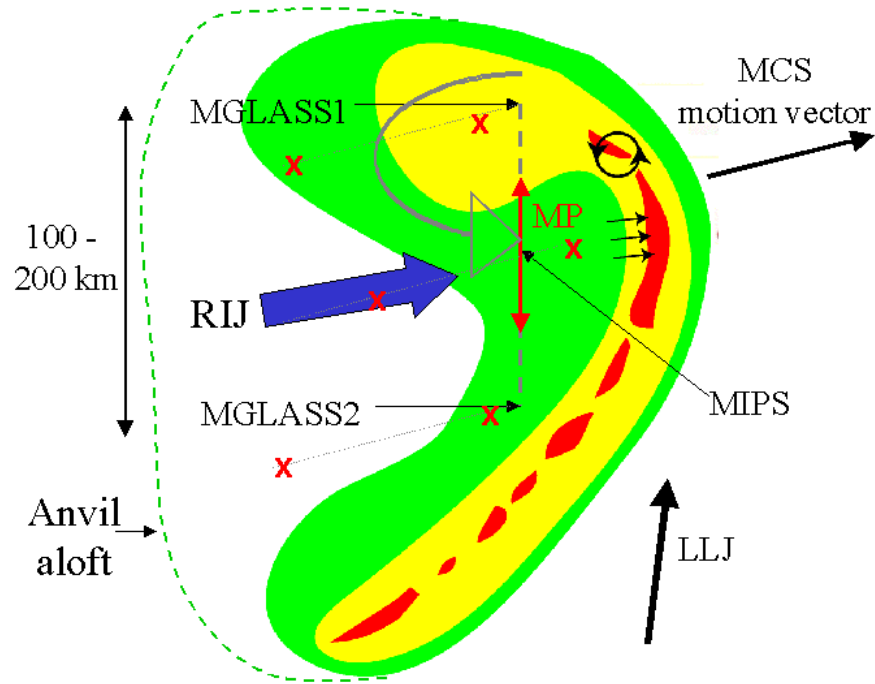


Fig. 3.4. GBOS configuration for sampling of the stratiform region of a bow echo or MCS. The MP sampling line is represented by the red line passing near the MIPS site. Potential GLASS sounding locations are indicated by the red “x” symbols. The descending rear inflow jet is designated as RIJ. For this scenario, soundings will be launched in strategic locations of the bow echo, as shown.

3.4.4 MCV network design

a) MCV, Part I (Ahead)

Since estimates of mesoscale vertical motion around MCV’s are desired, the GBOS will assume a triangular configuration shown in Fig. 3.5. The MIPS will typically be located on the south side of the inverted triangle in order to sample boundaries and low level wind profiles in the MCV down shear sector. If precipitation is not anticipated for >1 h, the MIPS will operate in the ABL mode. Full tropospheric soundings will be launched simultaneously at 1½ h intervals. The top priority of the MP is to monitor surface conditions (near the MIPS or within the triangle) around developing deep convection, or in an area where deep convection is anticipated. For the latter case, the MP may sample existing boundaries, or regions where horizontal variations in diabatic heating may exist, such as cloudy and/or rainy to clear zones.

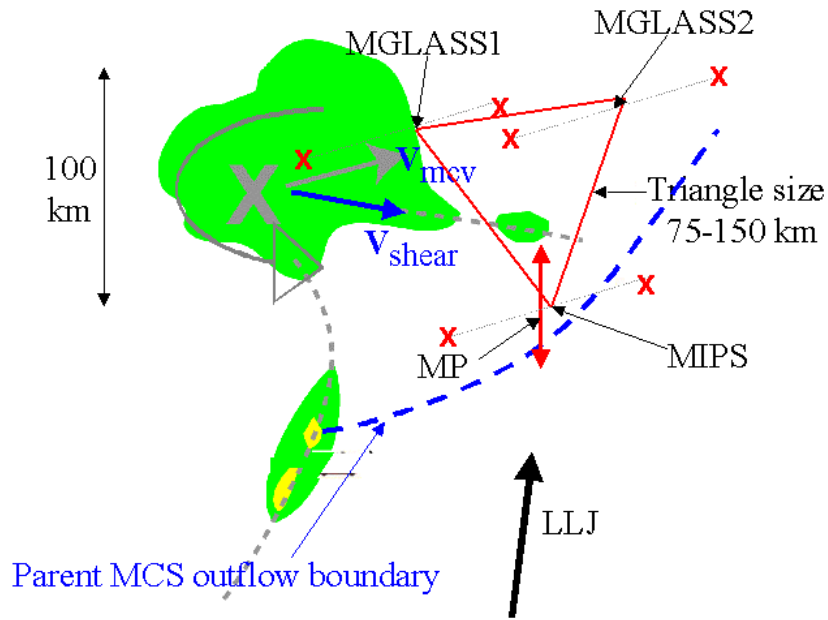


Figure 3.5. Deployment configuration ahead of an MCV. The gray “X” indicates the location of the mid-level vorticity maximum, which is moving in the direction of the gray arrow, labeled V_{mcv} . The shear vector over the 900-600 hPa layer is designated as V_{shear} . The blue dashed line represents the outflow boundary of the parent MCS (from which the MCV originated), and the dashed gray lines indicate other possible locations of surface boundaries. Red x’s show sounding locations. In this case, soundings are launched simultaneously for computation of vertical motion within the triangle.

b) MCV, Part II (Beneath)

The GBOS sounding configuration will remain unchanged as the MCV center passes over or near the triangular array (Fig. 3.6). If precipitation is present, the MIPS will change its sampling mode to a deep precipitation mode. The MP will continue to sample the region in which deep convection is expected to form, which is typically in the down shear (as defined by $V_{900mb} - V_{600mb}$) flank. The MP will sample legs about 50 km long, and will take 1-1.5 h to complete. Quite often, this region includes the old outflow boundary from the parent MCS and a low-level baroclinic region produced by horizontal variations in diabatic heating between cloudy/rainy and clear regions.

If the MCV motion is less than 10 m s^{-1} , it may be possible to redeploy the GBOS array within a 2-3 h time frame.

3.4.5 Large MCS’s and MCC’s

Since large nocturnal MCS’s and MCC’s are common to the BAMEX region, there will be opportunities for GBOS measurements of their structure. Meso- α components that exhibit bow echo structures, as illustrated in Fig. 3.6, may be common in MCC’s. The GBOS configuration will be similar to that for bow echoes, as discussed in Section 3.4.3.

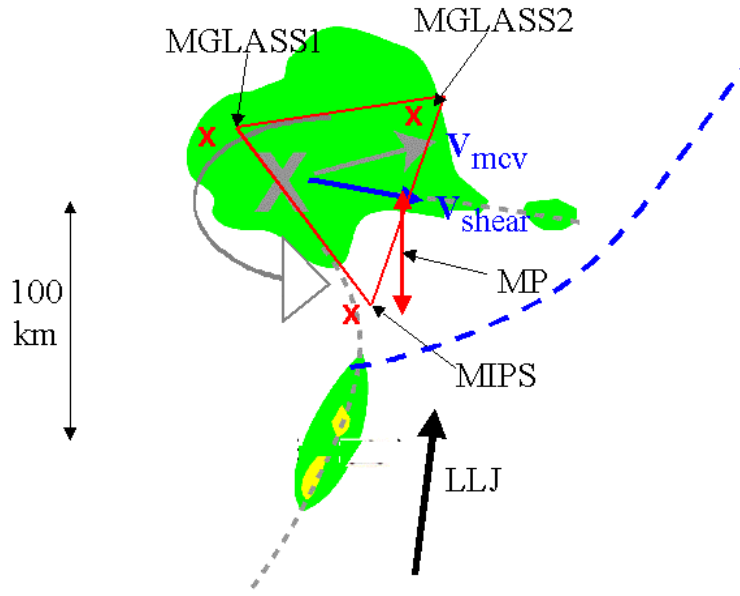


Figure 3.6. As in Fig. 3.5, except for GBOS deployment configuration within the MCV. The MP sampling line will be flexible in location and orientation, depending on boundary locations, potential variations in clouds and surface winds, and virtual temperature.

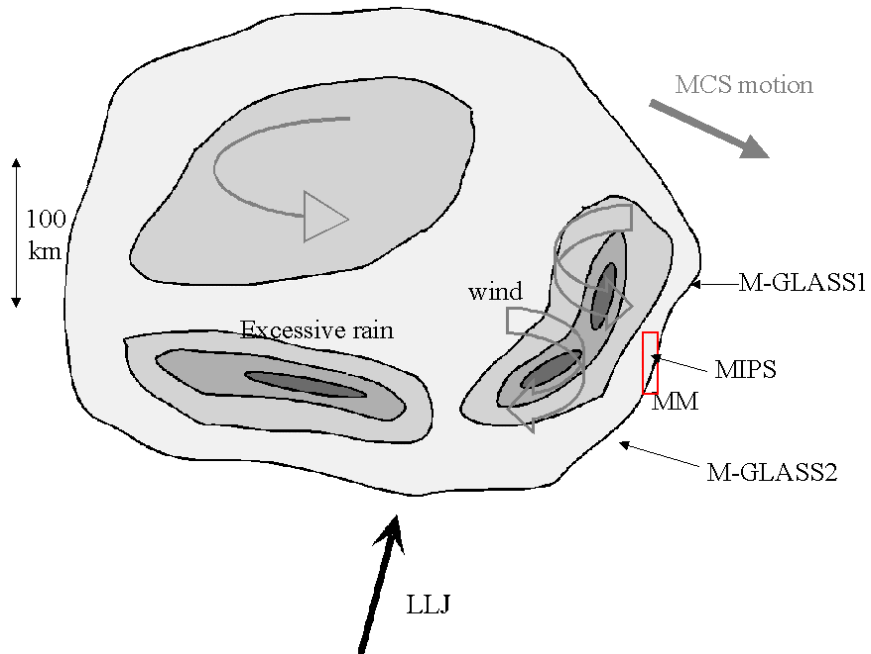


Figure 3.7. GBOS experimental design for an MCC containing a meso-scale bow echo.

3.5 Deployment Procedures

3.5.1 Selection of the Intensive Observing Domain (IOD)

The selection of and timely deployment by the GBOS inside a target Intensive Observing Domain (IOD) represents an important first step. We expect that the IOD will often straddle a stationary frontal boundary, a region is most likely for bow echo occurrence. The initial IOD may subsequently be modified during the afternoon and evening to account for changes in storm development/movement that may not be anticipated during the initial selection process.

A proactive decision process involving the GBOS and BOC will determine the appropriate IOD location. Locations and modes of operation of the mobile platforms will be coordinated following the predetermined, GBOS observing strategies described previously in Section 3.4.

The IOD determination will involve several factors:

- The forecast location of MCS's.
- Time required for GBOS travel to the IOD.
- Locations, such as military bases, large airports, and population centers, that are off limits to the BAMEX research aircraft.
- Locations of WSR-88D radars and NOAA 404 MHz profilers.
- Enhanced operational research networks, such as the Norman, OK region (Doppler and polarization radars, lightning mapping array, state surface mesonet), and the Huntsville, AL region (dual Doppler radar, lightning mapping array, local surface mesonet).

The following subsections describe details of the deployment modes and GBOS strategies.

3.5.2 Daily Schedule

Table 3.3 provides an overview of the daily schedule for the GBOS. This times listed provide a general guideline for typical operations.

Table 3.3. GBOS daily schedule.

<i>Time (CDT)</i>	<i>Activity</i>
0900	Update on Day 1 forecast and Day 1 (current day) activities. A tentative location for the Intensive Operational Domain (IOD) will be selected.
1000-1200	“GO” decision: Motel check-out and departure for the IOD. “NO-GO” decision: remain at motel, or drive to better location for anticipated Day 2 activities.
1400-2000	Set up at the IOD and begin the GBOS Intensive Operational Period (IOP). <ul style="list-style-type: none">- A typical operational period will be ~8 h in duration.- The IOP may begin earlier if an early MCS can be sampled.- The MIPS may remain in the field longer if secondary MCS's are expected to move into the IOD.
2000-0200	End of IOP. Travel to motel for check-in and required 10 h rest period.

3.5.3 Preparation for Departure

A pre-deployment briefing will occur at 0900 CDT. This briefing will be presented by the BAMEX forecast team, and will involve key BAMEX personnel, including the GBOS and aircraft PI's, the GBOS coordinator, and the BAMEX mission scientist(s). The outcome will be a GO or NO-GO decision for mobile ground-based operations for the current day (Day-1). This communication will be done interactively via phone between the BOC and GBOS coordinator and/or PI's. For purposes of documentation, an email message sent to BAMEX personnel will contain the GO/NO-GO status for the current day, and a forecast for the most likely IOD location for the next day. A later email message may be issued which explains the reasons for a NO-GO decision. The reasoning behind a GO decision will be explained at the 0900 CDT weather briefing.

A final GBOS decision for the day (GO or NO-GO) must be made by 1130 CDT in order to provide time for GBOS checkout. The decision will again be communicated by phone or text pager to the GBOS team leader, and posted immediately on the Internet using a short email message to all participants. If the status is GO, all participants should be prepared to depart by 1200 CDT. If the status is NO-GO, there will be no ground-based mobile operations and the GBOS will remain at the current motel, unless there is a compelling reason to move to a new location. If convection is forecast to develop relatively early, or an MCS is already developing by 0900 CDT, a GO decision (with a GBOS departure shortly thereafter) may be finalized as early as the 0930-1000 CDT time frame.

Ordinarily, a STANDBY decision will be used for BAMEX mobile ground-based operations in only for the possibility of Day-2 operations. STANDBY decisions will not be feasible for Day-1 operations, because the GBOS would need to deploy no later than 1200 LT to reach the target IOD by late afternoon, assuming a ferry time of five hours. Therefore, delaying a deployment decision may be tantamount to making a NO-GO decision.

The 0900 CDT operations decision will be made in the following manner. If 1200 UTC soundings, morning analyses and the previous evening's model data indicate a good chance MCS activity within about 6 hours of the current GBOS location, the operations decision will probably be GO and the GBOS will depart for the IOD. If it appears there is a reasonable chance of MCS activity beyond about 6-7 hrs of driving time, the decision could be either GO or NO-GO. In either event, it may ultimately be decided to abort if the forecasters determine later (between 0900-1130 CDT) that conditions clearly no longer look favorable.

Prior to deployment of the GBOS, the nowcaster should identify the location and nature of boundaries. Both prior to and after deployment, boundaries should be identified based on wind shifts, WSR-88D finelines and virtual temperature and humidity contrasts if these are starting to develop. The overall highest priority for BE nowcast support is to provide the GBOS coordinator with any needed refinements of the target IOD based on the latest weather information.

3.5.4 Travel to IOD

The GBOS will ordinarily depart the motel by 1200 CDT and travel together to the target region, allowing for refueling stops. During transit, VHF radio will be used to update the GBOS teams on weather and changes in the IOD. We will attempt to refuel prior to commencing field data collection operations. The MP will serve as a scout vehicle to select a site for the MIPS

operations. This vehicle will move ahead of the GBOS about 2-3 h prior to expected deployment time.

The BAMEX nowcasters will communicate with the GBOS via the GBOS field coordinator, passing on and receiving mesoscale weather information and facilities updates. The refined Day-1 target IODs (based on the Day-1 Forecast #2), the Day-2 outlook and the tentative Day-2 mission status will be relayed from the GBOS coordinator to the GBOS field leader.

In the early stages when the field teams are not yet in position collecting data, the target location might be somewhat uncertain. The nowcaster will need to monitor rapidly evolving MCS's so that the field teams can quickly re-deploy to a newly identified target IOD. Timely updates will be essential due to the limited maximum speed of ground teams.

The travel window duration depends on the required travel time from the morning departure site to the IOD area. During the travel window, the BAMEX forecasters will be successively refining the forecast of boundary locations, convective mode, evolution, and time of arrival at the IOD. As the forecasts are refined and communicated to the GBOS, the route plan may be revised accordingly.

TRAVEL activities will include Mobile Probe data collection. In addition, certain preparations for intercept experiments can be conducted in the vehicles as the GBOS travels to the IOD (e.g., camera, film, documentation preparation, summaries of previous days activities). Briefings from the GBOS field leader to the other GBOS units will be broadcast on the VHF radio as required (e.g., when new information is received from the BOC).

3.5.5 Deployment

During travel to the IOD, the GBOS experimental design will be finalized. At this point, all GBOS units will know setup coordinates (within several km) and the initial sampling strategy. The total setup time, detailed in Table 3.4, is 20-30 min for the MIPS and M-GLASS units.

Table 3.4 GBOS set up times*.

<i>Platform</i>	<i>Sensor description, setup requirements, or specific action</i>	<i>Approx. setup time</i>
<i>MIPS</i>	Satellite communication system operational	15 min
	Start generator and connect power to MIPS van	5 min
	Level the MIPS instrument trailer	5 min
	915 MHz Doppler profiler	7 min
	2 kHz sodar	7 min
	Lidar ceilometer (mounted on trailer)	7 min
	Microwave Profiling radiometer: mount and wait for warm-up	15 min
	Surface sensors (mounted on van roof)	immediate
	Raingages and disdrometer (set up and connect cables)	15 min
	Electric field mill (mounted on trailer; start program)	10 min
	Activate GLASS	20 min

	Secure and ground all equipment	20 min
	Total setup time*	<i>20-30 min</i>
<i>M-GLASS</i>	Set up surface station	15 min
	Activate GLASS	10 min
	Secure and ground all equipment	<i>15 min</i>
	Total setup time*	<i>20-25 min</i>
<i>Mobile Probe</i>	Begin mobile measurements	immediate

* Setup of components is done in parallel. Therefore, the total setup time is not the sum of individual components.

3.5.6 Redeployment to new IOD

The REDEPLOY activity will relocate the GBOS to a new IOD. The REDEPLOY decision will occur via discussion among the BOC lead scientist, GBOS PI's, and BOC nowcasters. The REDEPLOY will be accomplished in the following sequence:

- a) Determine a new IOD location based on trends in convective evolution and organization. A new IOD candidate should be determined by 2200 CDT at the latest. For the case of slowly-moving MCV's, a REDEPLOY may be implemented as described in Section 3.4.3
- b) Relocate the GBOS to the new IOD and re-establish the same or modified experimental configuration, which would be determined during the transit to the new IOD.
- c) If already airborne, aircraft would modify their flight plan to the new IOD center point after the GBOS completes REDEPLOY.

Possible reasons for conducting REDEPLOY are listed below.

- d) The current target MCS dissipates or assumes a less favorable organization.
- e) A new MCS, or a different meso- α component of a squall line believed to have much greater bow echo potential (e.g., stronger surface moisture convergence, deeper BL moisture, higher vertical shear) develops/evolves and can be intercepted by the GBOS before ~2200 CDT.
- f) A slow-moving MCV passes over the GBOS, and the GBOS elects to redeploy in front of the MCV for a second sampling.

A REDEPLOY would be communicated by VHF radio if all GBOS units are in proximity, or otherwise by cell phone calls to the MGLASS and MP teams. When possible, all GBOS teams should meet at a predetermined intersection point, determined by the GBOS TL, and then travel together to the new IOD.

3.5.7 Debriefing

The DEBRIEF will occur (a) if GBOS operations are terminated because no MCS target develops, or (b) at the completion of a IOP. In the case of (a), a proactive decision to terminate field operations would be made through consultation among BAMEX PIs and leaders. After the cessation of activities, the DEBRIEF activity may commence.

Ideally, the teams would reform a caravan and would be polled by the GBOS TL via VHF radio. Teams may report technical or logistical problems, and could note significant meteorological observations they think will be of interest to all BAMEX participants. Notes on locations of wind damage will also be valuable to BAMEX and should be logged. The GBOS TL will log this information and transfer it to the BAMEX web site.

Within 24 h of the termination of an IOP, logs containing instrument operations and observations should be uploaded to the BAMEX web site. This information will include a summary of the GBOS operations, MIPS operations, and meteorological observations.

During the DEBRIEF, an overnight accommodations location, arranged by the GBOS logistics coordinator, will be identified.

3.5.8 Check-In

GBOS teams should complete timely data backups for each mission. The cognizant PIs for the individual platforms will have worked out specific data archival procedures for each platform. Data backups could be conducted either during travel, or after returning, to the motel. Team leaders should be responsible for data until it is turned in to the BAMEX Data Manager.

3.6 Communications

3.6.1 Communication types

3.6.1.1 VHF Communications

All BAMEX GBOS platforms will be equipped with VHF transceivers that will operate at the NCAR frequency of 163.1 MHz (Secondary special use simplex 163.275 MHz). VHF transceivers, with transmitted power adjustable from 5 W up to 55 W, normally provide voice communications over several miles in range in the case of a ground-level transmitter-receiver pair. VHF communication will be particularly valuable during ferry to an IOD and coordination of the initial deployment within the IOD.

Adhering to a communications protocol would greatly facilitate smooth and productive BAMEX operations. The success of the experiment hinges on the concept of efficient, timely field coordination and this in turn requires that radio traffic be kept at the minimum necessary level. Therefore, the TL will utilize broadcasts, at regularly scheduled intervals, of all relevant weather information (nowcasts).

3.6.1.2 Cellular Phones

All GBOS teams will carry cellular phones. These will be very useful when long distances preclude VHF communications. The MIPS GBOS TL will need to communicate with MGLASS and MP units frequently to define the experimental configuration, coordinate sounding releases, and obtain weather information from other GBOS sites. By agreement of individual PIs, phone number lists will be distributed at the start of the experiment to facilitate field communications.

3.6.1.3 Satellite Phones and Text Pagers

Satellite phones and iridium text pagers will be used to supplement or backup communication among the BOC and GBOS units. MIPS and MP personnel will carry iridium

text pagers, which can receive messages up to 120 characters long, sent via e-mail. NCAR GLASS personnel will carry Qualcomm satellite phones (Globalstar satellite) as a backup communication device. The NCAR cell phones will support text messages.

3.6.1.4 E-mail

Email will be an efficient means of communicating with the BOC. Once the MIPS satellite system is operational (about 15 min after stopping), e-mail will be used to send information and status reports from the MIPS to the BOC, or from the MIPS to MGLASS units via text pagers. Likewise, updates from the BOC can be e-mailed to the MIPS. Because the NOAA P-3 aircraft also has email access, information will be sent from the MIPS to the NOAA P-3 lead scientist via email.

3.6.2 GBOS to GBOS communication

When VHF communication is not possible between GBOS units, cell phones will be used to exchange information. We expect that VHF will be the primary mode of communication during DEPLOY, REDEPLOY and DEBRIEF, while cell phone will be used during GBOS operations due to long distances between GBOS components. For many of the generic GBOS configurations, the Mobile Probe and MIPS will be within VHF range as the MP passes close to the MIPS about every 30 min. Updates on experimental plans, boundary locations, etc., will be discussed during those time periods. A detailed, generic “play book” that contains details on GBOS setup and operations, and contingency plans in the event that cell phone communication is poor, will facilitate GBOS coordination.

3.6.3 GBOS to aircraft communication

Communication between the aircraft and GBOS will require an aircraft radio operating at 122.925 MHz, which is unlikely. It would be advantageous for the aircraft at use radios operating at the NCAR frequency of 16x.xxx MHz.

3.6.4 Communication between GBOS and BOC

Communication between the GBOS teams, and the GBOS coordinator at the BOC, is necessary for GBOS coordination (e.g., sounding release times), dissemination of forecast information to the GBOS teams, and update reports on the status of the GBOS components and weather conditions. This communication will typically be accomplished with cell phone. Satellite text pagers will also be used to send short messages from the GBOS coordinator to the MIPS team leader. Once the MIPS satellite communication system is deployed, information will be forwarded to the BOC via email and data transfer to a dedicated web site. This will represent the common mode of data transfer between the MIPS and the BOC.

3.6.5 Forecast updates and warning dissemination

The GBOS team leader will communicate frequently (via cell phone) with the GBOS coordinator in order to receive forecast updates and discuss forecasts, GBOS observations, or GBOS operations. It is imperative that the BOC forecasters closely monitor the GBOS domain for the threat of severe weather (tornadoes, strong winds, and hail), and promptly communicate this to the GBOS team leader and team members.

All GBOS units should be equipped with (a) a scanner to monitor the local storm spotter broadcasts, and (b) weather radio to monitor local NWS storm warnings.

3.6.6 Navigation software

All GBOS teams, and the GBOS coordinator located at the BOC, will use a common navigation software, *Topo USA*. This greatly facilitate coordination among the GBOS components and the GBOS coordinator.

3.7 Logistical Issues

3.7.1 Continuous road travel

Continuous road travel, with no fixed base, brings up several important issues regarding acquisition of expendables and supplies, equipment maintenance, crew exchanges, food and lodging. Because GBOS personnel will always carry personal items (e.g., luggage) with them, plans for luggage storage space will be required.

3.7.2 Supplies

The most significant expendable is Helium (He) for GLASS launches. NCAR/ATD personnel have finalized arrangements to use one distributor with multiple distribution locations within the BAMEX domain. The M-GLASS logistics vehicle (pickup) will provide this service for the two M-GLASS units, and a MIPS team member will do likewise for the MIPS GLASS system. If possible, NCAR and UAH will coordinate this activity.

3.7.3 Maintenance

Equipment maintenance will be a challenge, since the GBOS has no fixed base, and hence no garage to use for repairs. This issue will addressed when problems arise.

3.7.4 Crew exchanges

Each group will make their own plans for efficient crew exchange. Exchanges should be timely, since the demands of frequent road travel (and the weather) will produce relatively high stress. The UAH team will alternate on a 12-13 day cycle, and the NCAR teams will rotate on a variable (up to 3 weeks) period.

3.7.5 Food and Lodging

Since GBOS operations will ramp up as the day proceeds, opportunities for meal breaks will become tenuous as the evening approaches. An 1800 CDT sit-down dinner should not be expected on operational days. Each GBOS team should maintain a food supply sufficient for dinner and even lunch.

Reservations for lodging (required on a daily basis) will require the assistance of a GBOS logistics coordinator. Searches for motels will be simplified if 2-3 motel chains are selected (e.g., Best Western, Super 8, Days Inn). Since motel check-in times will often be late when the GBOS is operational, the GBOS logistics coordinator will need to advise motel clerks of this when reservations are made. Easy access to clothes washers/dryers and grocery stores will be necessary.

4 Forecasting and Nowcasting

Forecasting and nowcasting duties for BAMEX will be completed by a group of National Weather Service (NWS) forecasters in conjunction with BAMEX researchers. Forecasters will be primarily responsible for issuing Day 2 and beyond outlooks, as well as updating the Day 1 outlook, as defined below. Nowcasters will be primarily responsible for issuing Day 1 updates and monitoring existing weather as it applies to ongoing BAMEX observational activities. Both the forecasters and nowcasters will contribute to the formal daily briefing, and will communicate with the Mission Scientist and Operations Director as needed. Decisions for deployment as regards weather will be made by the Mission Scientist in consultation with the forecasters, nowcasters, Operations Director, and BAMEX PIs.

4.1 Forecasting

4.1.1 Personnel

Will be staffed by 2 personnel at the Operations Center on a daily basis from **7:00 am - 3:00 pm cdt.**

4.1.2 Primary Responsibilities:

- Generate a DAY 2 forecast and beyond.
- Also responsible for a morning update of DAY 1 scenario.

4.1.3 DAY 1 Update:

- will be needed daily at **9:00 am cdt.**
- This update will be given to the Operations Director, Mission Scientists, and GBOS Coordinator. They will decide on initial **GBOS** deployment strategy.

4.1.4 Daily Weather Briefing:

- will be given between 12 noon and 1:00 PM cdt
- 5 to 10 minute update of the current Day 1 weather scenario.
- 10 to 15 minute discussion of Day 2 and beyond scenario.
- updating current day prospects for GBOS deployment strategies and projected aircraft departure times.
- overview of Day 2 and beyond outlook.
 - will be used to set initial projected aircraft take-off times for **Day 2**
 - plan for possible multi-day operations, strategic down days etc

4.1.4.1 Products required:

- Map of anticipated MCS locations and time (beginning-midpoint-end point). Also include any significant fronts, boundaries in the vicinity of the MCS.
- Map of anticipated CAPE along the path of the MCS.
- Map of the anticipated vertical wind shear along the path of the MCS
- (0-3 / 0-6 km Bulk Shear).
- best guess of the anticipated mode of the MCS (e.g. severe, long-lived bow echo or MCV).

4.1.5 Written Brief Summary and Graphic:

- Forecasters will be required to submit a brief written summary of **Day 1, Day 2** and beyond forecasts for inclusion on the BAMEX WEBSITE.
- A graphical map will be constructed daily showing the genesis...mid point and ending point of a QLCS or MCS.

4.1.6 Range of Questions

Day 1 Update:

- a) Is there an MCV evident from the previous night's convection?
- b) Will there be a significant convective system later in the day?
- c) What will be the most prevalent mode of convective system organization? (e.g. convection retriggered from previous MCV, new MCV-producing system, bow echo-derecho-type system).
- d) Where and when will the convection initiate?
- e) Where and when will any subsequent convective system mature?
- f) Will there be any significant surface boundaries / baroclinic regions interacting with the mature convective system?
- g) How severe will the convective system be?
- h) How long will the convective system last?

Day 2 Update:

- a) Will there be a significant convective system tomorrow?
- b) What will be the most prevalent mode of convective system organization (e.g. MCV from previous night's convection, new MCV-producing system, bow echo-derecho-type system).
- c) Where and when will the convective system mature?
- d) What are the prospects for significant convective systems on subsequent days?

4.2 Nowcasting

4.2.1 Personnel

Will be staffed by 2 personnel at the Operations Center on a daily basis and will consist of two shifts:

- Nowcast Shift 1: 12 noon - 8:00 pm cdt
- Nowcast Shift 2: 7:00 pm - 3:00 am cdt

For NWS personnel - these nominal shift times may be altered no more than one hour depending on the weather scenarios.

4.2.2 Primary Responsibilities

- Shift 1 nowcasters are *required* to attend the mid-day briefing.
- Generate short-term (**0-3 hr forecast updates**) to Mission Scientist and Operations Director.
- Addressing near-time MCS development, characterizing expected or existing MCS mode, and projecting future MCS locations and propagation characteristics.

- **Updates from NOWCASTERS will be used to:**
 - 1) modify GBOS deployment strategies
 - 2) projected aircraft departure times as needed
 - 3) monitor and modify data collection strategies once an MCS is targeted.
- **Keep Operations Director and Mission Scientist informed of any potential weather hazards that could impact the safe return of the aircraft to St. Louis.**

4.2.3 Range of Questions:

Before Convective Initiation

- a) Where and when will the convection initiate?
- b) Where and when will any subsequent convective system mature?
- c) What is the anticipated mode of convective organization?
- d) Are there any significant surface boundaries, baroclinic regions that could interact with the mature convective system?
- e) How severe will the convective system be?
- f) How long will the convective system last?

After Convective Initiation

- a) Where is the convection? (Latitude-Longitude)
- b) What is the current mode of convective organization?
- c) Are there any significant surface boundaries / baroclinic regions that are interacting with the convection?
- d) How severe is the convection?
- e) Will GBOS be impacted by the severe weather?
- f) When will the convection organize into a system?
- g) What are the propagation characteristics of the convection / convective system?
- h) How long will the convective system last?
- g) Is an MCV present?
- h) Will aircraft returning to St. Louis be impacted by any significant weather hazard?

4.3 Forecast Tools:

4.3.1 Hardware:

- Operations center will be equipped with laptops hooked to large monitors
- Printer (black and white images)

4.3.2 Software / Web links:

- FX-NET (AWIPS-style output)
- Standard Websites:
 - RAP
 - SPC (BAMEX Meso-analysis page)
- WRF Model output (WRF Web page)
- MGLASS Soundings - made available through RAP webpage.

4.4 Forecast/Nowcast Personnel:

4.4.1 Chief forecast / nowcast coordinators:

Morris Weisman
 Ron Przybylinski
 Lance Bosart
 Bob Johns
 Stan Trier

The following table lists the forecast/nowcast personnel as of April 28, along with a tentative schedule:

Table 4.1 BAMEX Schedule (NWS Forecasters) (All times Local Standard Time)

May 19-31, 2003				
		Forecast (07-15L)	Nowcast-1 (12-20L)	Nowcast-2 (19-03L)
19	Mon	<u>J</u> <u>T</u>	<u>P</u>	
20	Tue	<u>J</u> <u>T</u>	<u>P</u> <u>MR</u>	<u>C</u> <u>JR</u>
21	Wed	<u>J</u> <u>T</u>	<u>P</u> <u>MR</u>	<u>C</u> <u>JR</u>
22	Thu	<u>J</u> <u>T</u> <u>B</u> <u>G</u>	<u>P</u> <u>MR</u>	<u>C</u> <u>A</u> <u>JR</u>
23	Fri	<u>J</u> <u>B</u> <u>G</u>	<u>P</u> <u>MR</u>	<u>C</u> <u>A</u> <u>JR</u>
24	Sat	<u>J</u> <u>B</u> <u>G</u>	<u>P</u> <u>MR</u>	<u>C</u> <u>A</u> <u>JR</u>
25	Sun	<u>J</u> <u>B</u> <u>G</u>	<u>P</u> <u>MR</u>	<u>A</u> <u>JR</u>
26	Mon	<u>J</u> <u>B</u> <u>G</u>	<u>P</u> <u>MR</u>	<u>A</u> <u>JR</u>
27	Tue	<u>J</u> <u>B</u> <u>G</u>	<u>P</u> <u>MR</u>	<u>A</u> <u>JR</u>
28	Wed	<u>J</u> <u>T</u>	<u>P</u> <u>MR/DB</u> <u>G</u>	<u>A</u> <u>JR</u>
29	Thu	<u>J</u> <u>T</u>	<u>G</u> <u>DB</u>	<u>A</u> <u>JR</u>
30	Fri	<u>J</u> <u>T</u>	<u>G</u> <u>DB</u>	<u>A</u> <u>JR</u>
31	Sat	<u>J</u> <u>T</u>	<u>G</u> <u>DB</u>	<u>A</u> <u>JR</u>

June 1-14, 2003				
		Forecast (07-15L)	Nowcast-1 (12-20L)	Nowcast-2 (19-03L)
1	Sun	<u>J</u> <u>T</u>	<u>S</u> <u>FG</u> <u>A</u>	<u>G</u> <u>DB</u>
2	Mon	<u>A</u> <u>T</u>	<u>S</u> <u>FG</u> <u>A</u>	<u>G</u> <u>DB</u>
3	Tue	<u>A</u> <u>T</u>	<u>S</u> <u>FG/GS</u>	<u>G</u> <u>DB</u>
4	Wed	<u>A</u> <u>T</u>	<u>S</u> <u>FG/GS/JP</u>	<u>G</u> <u>DB</u>
5	Thu	<u>A</u> <u>T</u>	<u>S</u> <u>FG/JP</u>	<u>G</u> <u>GS</u>
6	Fri	<u>A</u> <u>B</u>	<u>G</u> <u>JP</u>	<u>S</u> <u>GS</u>
7	Sat	<u>A</u> <u>B</u>	<u>G</u> <u>JP</u>	<u>S</u> <u>GS</u>

8	Sun	<u>A</u> <u>B</u>	<u>G</u> <u>MB</u>	<u>S</u> <u>JP</u>
9	Mon	<u>A</u> <u>B</u>	<u>G</u> <u>MB</u>	<u>S</u> <u>JP</u>
10	Tue	<u>A</u> <u>B</u>	<u>G</u> <u>MB</u>	<u>S</u> <u>JP</u>
11	Wed	<u>T</u> <u>LB</u>	<u>G</u> <u>MB/EB</u>	<u>S</u> <u>JP</u>
12	Thu	<u>T</u> <u>LB</u>	<u>G</u> <u>MB/EB</u>	<u>S</u>
13	Fri	<u>T</u> <u>LB</u>	<u>EB</u>	<u>S</u>
14	Sat	<u>T</u> <u>LB</u>	<u>EB</u>	<u>S</u>

June 15-30, 2003				
		Forecast (07-15L)	Nowcast-1 (12-20L)	Nowcast-2 (19-03L)
15	Sun	<u>T</u> <u>LB</u>	<u>S</u>	<u>EB</u>
16	Mon	<u>S</u> <u>LB</u>	<u>T</u>	<u>EB</u>
17	Tue	<u>S</u> <u>LB</u>	<u>T</u> <u>GK</u>	<u>EB</u>
18	Wed	<u>S</u> <u>LB/DS</u>	<u>GK/BN</u>	<u>EB</u>
19	Thu	<u>S</u> <u>DS</u>	<u>GK/BN</u>	
20	Fri	<u>S</u> <u>DS</u>	<u>GK/BN</u>	
21	Sat	<u>S</u> <u>DS</u>	<u>GK/BN</u>	
22	Sun	<u>DS</u>	<u>JR</u> <u>GK</u>	<u>BN</u>
23	Mon	<u>A</u> <u>DS</u>	<u>JR</u> <u>GK</u>	<u>C</u> <u>BN</u>
24	Tue	<u>A</u> <u>DS</u>	<u>JR</u> <u>GK</u>	<u>C</u> <u>BN</u>
25	Wed	<u>A</u> <u>DS/DS2</u>	<u>JR</u> <u>CB</u>	<u>C</u> <u>BN</u>
26	Thu	<u>A</u> <u>DS2</u>	<u>T</u> <u>CB</u>	<u>C</u> <u>JR</u>
27	Fri	<u>A</u> <u>DS2</u>	<u>T</u> <u>CB</u>	<u>C</u> <u>JR</u>
28	Sat	<u>A</u> <u>DS2</u>	<u>P</u> <u>CB</u>	<u>C</u> <u>JR</u>
29	Sun	<u>T</u> <u>DS2</u>	<u>P</u> <u>JR</u>	<u>C</u> <u>CB</u>
30	Mon	<u>T</u> <u>DS2</u>	<u>P</u> <u>WB</u>	<u>C</u> <u>CB</u>

July 1-6, 2003				
		Forecast (07-15L)	Nowcast-1 (12-20L)	Nowcast-2 (19-03L)
1	Tues	<u>T</u> <u>DS2</u>	<u>P</u> <u>WB</u>	<u>JR</u> <u>CB</u>
2	Wed	<u>T</u> <u>DS2</u>	<u>P</u> <u>WB</u>	<u>JR</u> <u>CB</u>
3	Thu	<u>T</u>	<u>P</u> <u>WB</u>	<u>JR</u>
4	Fri	<u>T</u>	<u>P</u> <u>WB</u>	<u>JR</u>
5	Sat	<u>T</u>	<u>P</u> <u>WB</u>	<u>JR</u>
6	Sun	<u>T</u>	<u>P</u> <u>WB</u>	<u>JR</u>

Forecaster by Code		Forecaster by Last Name	
A	Eyad Atallah	Eyad Atallah	- A
B	Lance Bosart	Llyle Barker (WFO ILX)	- LB
BN	Bill Nichols (WFO DVN)	Dan Baumgardt (WFO ARX)	- DB
C	Mike Coniglio	Evan Bookbinder (WFO SGF)	- EB
CB	Christopher Buonanno (WFO LIT)	Lance Bosart	- B
DB	Dan Baumgardt (WFO ARX)	Mark Britt (WFO LSX)	- MB
DS	Dan Spaeth (WFO PAH)	Wes Browning (WFO SGF)	- WB
DS2	Dan Smith (WFO ILX)	Christopher Buonanno (WFO LIT)	- CB
EB	Evan Bookbinder (WFO SGF)	Mike Coniglio	- C
FG	Fred Glass (WFO LSX)	Tom Galarneau	- G
G	Tom Galarneau	Fred Glass (WFO LSX)	- FG
GK	Greg Koch (WFO EAX)	Bob Johns	- J
GS	Gary Schmocker (WFO LSX)	Greg Koch (WFO EAX)	- GK
J	Bob Johns	Bill Nichols (WFO DVN)	- BN
JP	Jason Puma (WFO IND)	Ron Przybylinski	- P
JR	Brian Jewett/ Bob Raber	Jason Puma (WFO IND)	- JP
LB	Llyle Barker (WFO ILX)	Mark Ratzert (WFO LOT)	- MR
MB	Mark Britt (WFO LSX)	Gary Schmocker (WFO LSX)	- GS
MR	Mark Ratzert (WFO LOT)	Dan Smith (WFO ILX)	- DS2
P	Ron Przybylinski	Brandon Smith	- S
S	Brandon Smith	Dan Spaeth (WFO PAH)	- DS
T	Stan Trier	Stan Trier	- T
WB	Wes Browning (WFO SGF)	Brian Jewett/ Bob Raber	- JR

4.5 Forecasting Convective Mode:

While all significant MCS will be of interest to BAMEX, we are especially interested in documenting two particular somewhat distinct scenarios: systems that produce multiday MCVs and systems that produce especially strong, long-lived bow echoes / derechos. Being able to anticipate which of these two modes of organization will have important implications for timing and planning for aircraft and GBOS, both for the ‘current day’ as well as ‘subsequent days.’ When considering the “best” scenarios for each mode, recent numerical and observational studies suggest that the environments for the strongest, most long-lived bow echoes are quite distinct from environments that produce multi-day MCVs. In particular, the strongest, most organized bow echoes prefer environments with moderate-to-strong 0-5 km vertical wind shear magnitudes (e.g. at least 15 - 20 m s⁻¹ of shear), and large CAPE (greater than 2000 J/Kg). Such systems also tend to be associated with pre-existing boundaries and upper-level waves. Multiday MCV’s also prefer large CAPE, but are usually associated with weak-to-moderate 0 - 3 km shear and weak upper-level shear. In addition, there is also weak synoptic-scale forcing, although low-level jets are often quite prevalent. Obviously, many cases will reside somewhere in-between

these regimes. Since we do not have sufficient resources to observe all systems, we must consider how to set priorities for operations.

One criteria which is common to both MCV and bow echo scenarios is large CAPE. Thus first and foremost, priority should be given to those days for which the CAPE is anticipated to be large over a wide region, to support long-lived systems. Based on recent studies, anticipated widespread CAPES of 1500 J/Kg or greater would be sufficient to eliminate weaker systems.

Given large CAPE, a distinction between the bow echo and MCV priorities can best be made based on the anticipated vertical wind shear. In particular, the highest priority for a bow echo / derecho study should be made only for stronger-shears of 20 m s⁻¹ or greater over the lowest 0 - 5 km AGL. MCVs will be the priority for all other cases.

5 Coordination of Operations

5.1 Overview of Operations Center and Airport

5.1.1 MidAmerica Airport (MAA) Facility

The MidAmerica St. Louis Airport (MAA) will house the BAMEX Operations Center and be the base of aircraft operations. MAA is located approximately 25 minutes from St. Louis, MO on Interstate I-64 near Belleville, IL and is adjacent to Scott Air Force Base. The airport has dual ILS Category II runways (14L/32R, 14R/32L) and the tower has 24 hour 7day per week operations. Official FAA airport designation is BLV.

5.1.2 Operations Center Space

The BAMEX Operations Center will occupy approximately 4000 sq.ft. behind the ticketing lobby and in the arrival/baggage claims area all on the ground floor of the airport terminal (see Figure 5.1). Additional storage space and adjacent ramp access is provided. Temporary space and related support (e.g. janitorial, power, lights, phones) will be handled by temporary lease between the airport and UCAR.

5.1.2.1 Security

All BAMEX participants will be required to fill out an application for airport access ID. This will include background check, photograph and fingerprinting pursuant to TSA regulations. All long term BAMEX participants are required to obtain a badge and wear it in a visible location at all times while on airport property. All vehicles will () also require ID registration. U.S. Government employees may be able to use their current picture ID during the project.

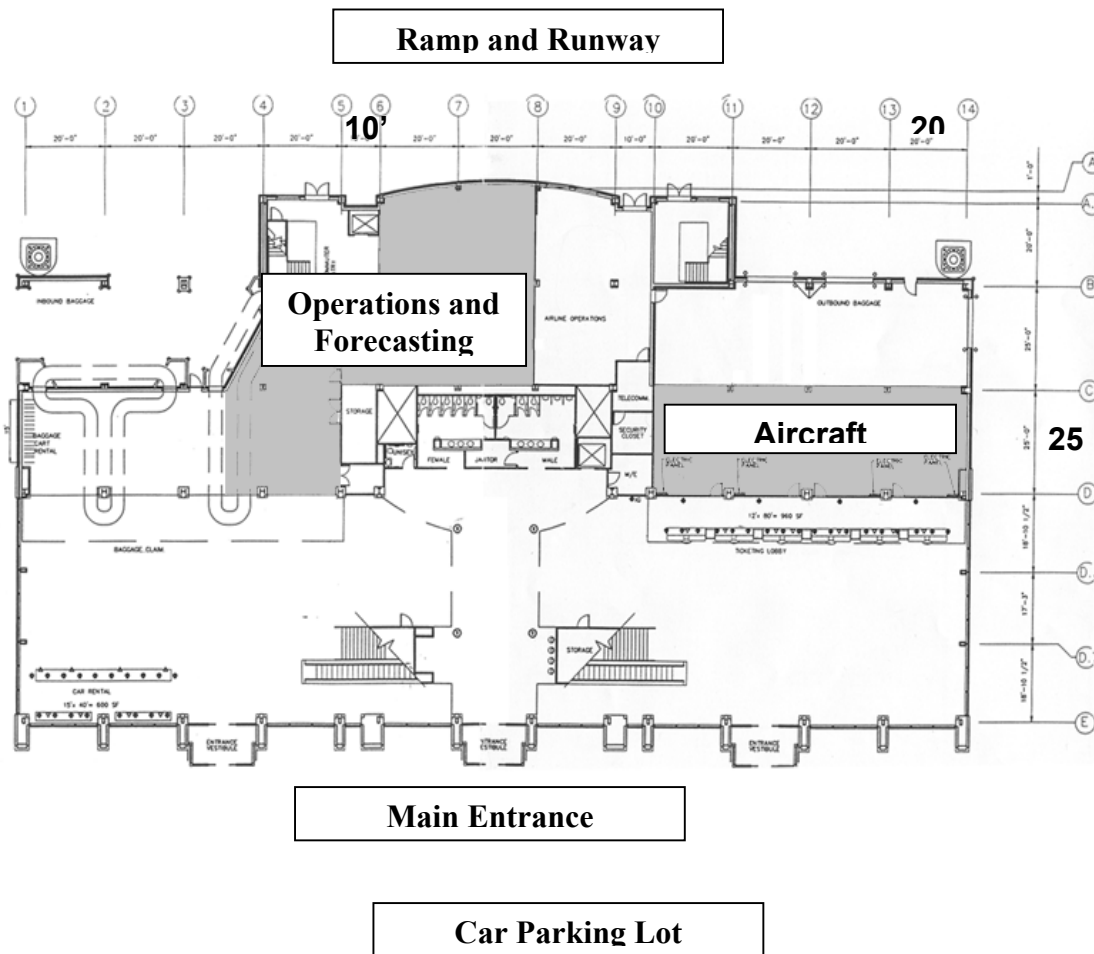


Figure 5.1 Plan view of MidAmerica Airport

5.1.2.2 Network Connectivity

MAA will have full T-1 network connectivity. NCAR/ATD has made arrangements for this connections and will also provide support for Local Area Network (LAN) connections and support in coordination with MAA personnel. It will be possible for Linux/Unix, PC and Macs all to be connected to the network using a standard Ethernet connection (RJ-45) or wireless transceiver provided by the user.

5.1.2.3 Power and Aircraft Support

Power is standard 60Hz/120v throughout the building. There is no 220v service that is easily accessible to the building. Complete fueling services are available as required for aircraft operations support. Other aircraft services are available as required to meet facility needs.

5.2 Operations Center Staffing

Science Director

- Co-chairs BAMEX Daily Planning Meeting
- Leads daily Mission Planning discussion
- Decides (with consultation) the final deployment of all facilities
- Works with OD and Nowcaster to produce flight track endpoints and GBOS locations
- Prepares Daily Mission Summary Report
- Provides Science Progress Reports to Daily Planning Meeting

Operations Director (2)

- Convenes and co-chairs the BAMEX Daily Planning Meeting
- Implements the daily BAMEX Operations Plan
- Provides Status Report summary to Daily Planning Meeting
- Coordinates required support activities
- Assigns duties to OCT personnel
- Responsible for form and content of Daily Operations Summary
- Updates BAMEX recorded status message
- Conducts aircraft flight and GBOS daily debriefings
- Monitors progress and integration of all mobile facility operations

Aircraft Coordinator

- Single Point of Contact for all BAMEX Aircraft Facility Managers
- Coordinates ATC requirements—alerts, advanced notifications, etc.
- Coordinates all communications between Operations Center and radar aircraft—flight track changes, data products transmitted to/from aircraft
- Works with SD, OD and DAC to affirm flight track endpoints

Dropsonde Aircraft Mission Coordinator (Deputy Aircraft Coordinator)

- Coordinates all communications between Operations Center and dropsonde aircraft – flight track changes, data products transmitted to/from aircraft
- Works with SD and OD to produce dropsonde aircraft flight track endpoints
- Monitors dropsonde expendables
- Assists Aircraft Coordinator

Ground Based Observing Systems Coordinator

- Point of Contact for Ground Based Observing Systems
- Works with SD and OD to affirm GBOS deployment locations and sounding launch strategies
- Coordinates all communications between Operations Center and GBOS—deployment locations and data products transmitted to/from GBOS
- Assures communication of safety information
- Assists GBOS with logistical arrangements

Field Documentation Coordinator

Forecasting Coordinator

- Establishes staffing and schedules for forecaster shifts
- Keeps OD informed as to availability and support during IOPs

Nowcasting Coordinator

- Establishes staffing and schedules for nowcaster shifts
- Keeps OD informed as to availability and support during IOPs

Airport Site Coordinator

Primary BAMEX contact and liaison with MAA

Logistics/Administrative Coordinator

Table 5.1 Staffing Matrix

Function	Participant
Science Director(SD)	C. Davis, Weisman, Trier, Trapp, Atkins, Rauber, Jewett, McFarquhar (see table below)
Operations Director(OD)	Dirks, Moore, Stossmeister
Aircraft Coordinator(AC)	Meitin, Williams
Dropsonde Mission AC	Knieval, Bartels, Ahijevych, Bryan, James, Hawblitzel
GBOS Coordinator	Dowell
Field Doc. Coordinator	Roberts, Stott, Loehrer (Goldstein)
Forecast Coordinator	Weisman, Przybylinski
Nowcaster Coordinator	Weisman, Przybylinski
Airport Site Coordinator	Dirks, Moore
Logistics/Admin Coord.	Tignor, Sandoval, ___

Table 5.1 Operations Center Positions

	Day 1A 0800-2000	Day 2 0900-1400 1700-2100	Day 1B 1900 – end of IOP	Day 1B (backup)
May 18		Weisman (test)		
19		Davis		
20	Davis	Weisman	Trapp	Rauber
21	Weisman	Davis	Atkins	Jewett
22	Davis	Weisman	Trapp	
23	Weisman	Davis	Atkins	
24	Davis	Weisman	Trier	

25	Weisman	Davis	Trier	
26	Davis	Weisman	Trier	
27	Weisman	Davis	Trier	
28	Davis	Weisman	Trier	
29	Weisman	Davis	Trapp	
30	Davis	Weisman	Atkins	
31	Weisman	Davis	Trapp	
June 1	Davis	Weisman	Atkins	McFarquhar
2	Weisman	Davis	Trapp	McFarquhar
3	Davis	Weisman	Atkins	McFarquhar
4	Weisman	Davis	Trapp	McFarquhar
5	Davis	Weisman	Atkins	Trier
6	Weisman	Davis	Trapp	Trier
7	Davis	Weisman	Atkins	Trier
8	Davis	Trier	Trapp	Jewett
9	Davis	Trier	Atkins	Jewett
10	Davis	Trier	Trapp	Jewett
11	Davis	Trier	Atkins	Jewett
12	Weisman	Trapp	Jewett	Bosart
13	Weisman	Trapp	Jewett	Bosart
14	Weisman	Trapp	Jewett	Bosart
15	Weisman	Atkins	Rauber	
16	Weisman	Atkins	Rauber	
17	Davis	Weisman	Rauber	
18	Weisman	Davis	Rauber	
19	Davis	Weisman	Rauber	
20	Weisman	Davis	Rauber	
21	Davis	Weisman	Rauber	
22	Weisman	Davis	Atkins	
23	Davis	Weisman	Bosart	Trier
24	Weisman	Davis	Bosart	Trier
25	Davis	Weisman	Bosart	Trier
26	Weisman	Davis	Bosart	
27	Davis	Weisman	Bosart	
28	Weisman	Davis	Bosart	Trier
29	Davis	Weisman	Atkins	
30	Weisman	Davis	Atkins	
July 1	Davis	Weisman	Atkins	
2	Weisman	Davis	Atkins	
3	Davis	Weisman	Atkins	
4	Weisman	Davis	Atkins	
5	Davis	Weisman	Atkins	
6	Weisman		Atkins	

Table 5.2 BAMEX Science Director Schedule

6 Conduct of Operations

6.1 General Overview

The BAMEX Operations Center (BOC) will be the central focus for forecasting, mission planning, coordination of all BAMEX facilities, FAA coordination, and any other activities crucial to the conduct of field operations.

A Daily Planning Meeting (DPM) will be held every day of the project beginning on May 18, 2003. A Mission Selection Team (MST) comprised of available BAMEX PIs, the Scientific Coordinator, and the Operations Director, will make the decision to declare an Intensive Observation Period (IOP) and decide on the region of likely operations for the deployment of the ground-based facilities. Once an IOP is initiated, it will be executed under the guidance of an Operations Director, who will work with the Nowcaster and Science Director to provide guidance to the aircraft and ground-based facilities in the execution of their flight patterns and deployment locations, respectively. Once aircraft operations are underway an Aircraft Coordinator at the BOC will coordinate and communicate changes in flight operations by the SD and OD by working with the Nowcaster in monitoring the evolving precipitation pattern on the ground-radar network and other real-time data sets available at the BOC. The GBOS direction will be similarly coordinated and communicated by the Ground-based Facilities Coordinator. The leader of the GBOS is the GBOS Field Team Leader. A summary of the critical BAMEX staff jobs is shown in Table 5.1.

6.1.1 Aircraft Coordination

Determination of aircraft flight schedules will follow aircraft operational guidelines. Notification of planned take-off times will be given by the Operations Director (or Aircraft Coordinator) to the Aircraft Facility Manager and Flight Scientist at least 12 hours in advance and within crew work schedule constraints. The Aircraft Coordinator will provide advanced notification to appropriate ATC and Military Operations Centers as required. Aircraft pilots will submit flight plans following normal procedures. Individual pre-flight briefings will be given 2 hours prior to the scheduled take-off and will be prepared to meet individual aircraft facility requirements. Debriefing, following a mission, will be led by the Operations Director (or Aircraft Coordinator) and will be scheduled as soon as possible after landing so that all onboard scientists can participate.

Nominal Daily Schedule

7 days/week unless down day

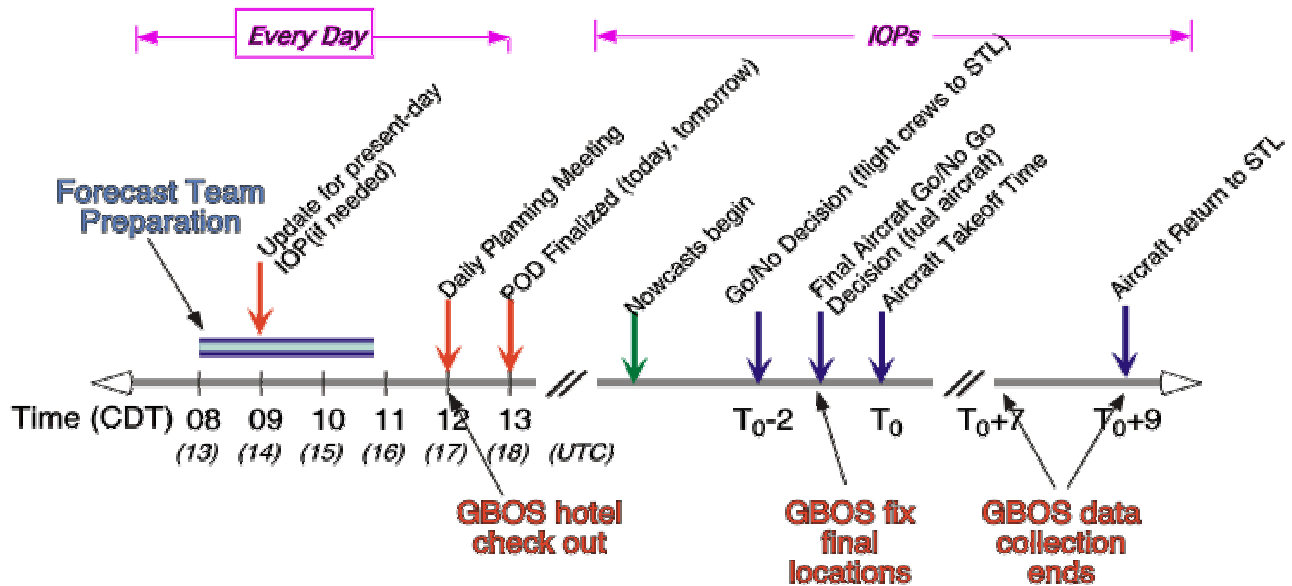


Figure 6.1 BAMEX daily operations schedule

6.1.2 GBOS Coordination

The BAMEX Ground Based Mobile observing systems (GBOS) consist of two mobile radiosonde systems (2 NCAR MGLASS) and the U. of Alabama Mobile Integrated Profiling System (MIPS). (One or more mobile Mesonet vehicles may also be available.)

Coordination of the GBOS facilities will come from the BOC. The GBOS systems will be continuously deployed throughout the intensive operational period. This is a key element to the design of the ground-based component of BAMEX. Since the platforms will not be required to return to a fixed base, they can be repositioned to take advantage of the prevalent weather patterns. This will maximize the opportunity to observe bow echo events without causing undue crew fatigue. This strategy permits adjustments within the overall operations area or to movement into a favorable regime associated with a large-scale weather pattern. The strategy is not meant to imply that the ground-based observing systems will be able to travel several hundreds of miles each day. Instead, the platforms will focus in an area of approximately 250-mile radius from the previous days' operations area.

Notification of the Daily Mission Plan will be made by the Ground System Coordinator (or Operations Director) to the individual mobile Facility Managers. Notification will consist of the scientific mission, description of the preliminary Intensive Observing Domain and a preliminary observing schedule. This notification will occur by 1600 LT the day prior to the mission operations and will also include a Pre-Deployment Briefing schedule for each system. A more complete BAMEX Daily Operations Summary will be prepared and distributed via the web. The

GBOS participants may be able to log on remotely to view this information. Access to the full BAMEX Field Catalog will also be possible via remote web access.

6.1.3 FAA Coordination

The BAMEX aircraft operations will cover several regions of the FAA national airspace system. The Air Route Traffic Control Centers (ARTCC)s that could be impacted by BAMEX flight operations include: Minneapolis, Chicago, Kansas City, Indianapolis and Memphis. Denver, Atlanta and Dallas/Fort Worth Centers may have BAMEX operations on a few occasions. The BAMEX domain contains several large cities and associated commercial airports—Kansas City, Chicago, Minneapolis and St. Louis. In addition there are several Military Operations Areas (MOA) that could restrict BAMEX operations.

It is likely that some sort of advanced notification scheme will be implemented after meetings with the affected ARTCCs occur in April. BAMEX will have a number of generic flight plans that will be used to properly sample the phenomena of interest. The BAMEX Aircraft Coordinator will make every effort to retain maximum flexibility in our sampling strategy within the practical constraints of the air traffic system.

7 BAMEX Data Management

The development and maintenance of a comprehensive and accurate data archive is a critical step in meeting the scientific objectives of BAMEX. The overall guiding philosophy for the BAMEX data management is to make the completed data set available to the scientific community as soon as possible following the field project in order to better accomplish the scientific objectives of BAMEX as well as incorporate these results into improved operational forecast and precipitation prediction models.

The BAMEX data management archive activities are being coordinated by the UCAR/Joint Office for Science Support (JOSS). These activities fall into three major areas:

- Determine the needs of the BAMEX scientific community and develop them into a comprehensive BAMEX Data Management Plan.
- Develop and implement a real-time web-based field data catalog to provide in-field support products for operations planning, project summaries and field phase documentation, facility and product status for the PIs, and
- Establish a BAMEX Data Archive Center (BDAC) which provides data distribution/support for the PIs and the general scientific community. This includes comprehensive seamless access to all operational and research data sets (i.e., distributed data archive) .

Full details of the BAMEX Data Management strategy and activities will be included in the BAMEX Data Management Plan document. The Data Management Plan outline is available at: http://www.joss.ucar.edu/bamex/dm/Data_Plan_Outline.html .

7.1 BAMEX Data Management Policy

The following is a summary of the proposed BAMEX Data Management Policy that all participants of BAMEX are requested to abide by.

1. All investigators participating in BAMEX must agree to promptly submit their data to the BDAC to facilitate intercomparison of results, quality control checks and inter-calibrations, as well as an integrated interpretation of the combined data set.
2. All data shall be promptly provided to other BAMEX investigators upon request. A list of BAMEX investigators will be maintained by the BAMEX Project Office and will include the Principle Investigators (PIs) directly participating in the field experiment as well as collaborating scientists who have provided guidance in the planning and analysis of BAMEX data.
3. During the initial data analysis period (one year following the end of the field phase; 6 July 2004), no data may be provided to a third party (journal articles, presentations, research proposals, other investigators) without the consent of the investigator who collected the data. This initial analysis period is designed to provide an opportunity to quality control the combined data set as well as to provide the investigators ample time to publish their results.
4. All data will be considered public domain after one year following the end of the BAMEX field experiment phase.
5. Any use of the data will include either acknowledgment (i.e., citation) or co-authorship at the discretion of the investigator who collected the data.

Further details of the data management strategy are provided in the following sub-sections.

7.1.1 Data Processing/Quality Control

All data released in the field will be considered “preliminary” data to be used for planning and operational purposes *ONLY*. Preliminary data are defined as data that have not been thoroughly analyzed or quality assured (i.e., final instrument calibrations applied, etc.) by the PI to become “final” processed data. No distribution of preliminary data outside the BAMEX Operations Center will be permitted without the consent of the PI who collected that data. At the end of the BAMEX field phase, no preliminary data will be archived or distributed at the Data Archive Center unless agreed to by the PI. Individual PIs will be responsible for the final processing, quality control and submission of their own data sets to the Data Archive Center since they are best qualified to do so. The BAMEX Data Archive Center will perform any necessary processing for the operational data sets only (e.g., satellite, upper air soundings, surface observations, model output, etc.).

7.1.2 Data Availability

All PIs participating in BAMEX must agree to promptly (within 12 months following the conclusion of the field phase [i.e., 6 July 2003]) submit their processed, quality controlled “final” data to the BAMEX Data Archive Center. The requirement for PIs to submit their final data following 12 months after the field phase will facilitate intercomparison of results, quality control checks and inter-calibrations, as well as an integrated interpretation of the combined BAMEX data set. The PIs will greatly benefit by further collaborative analysis of her data sets within the BAMEX community. Complete metadata (including data set descriptions, documentation, calibrations, quality assurance results, etc.) must accompany the submitted data. Upon submission, unless otherwise specified by the PI, these data will be available to the general scientific community. The PI does reserve the right to request that the Data Archive Center

password protect these data or send notification when a request for his data is received during the initial one year data analysis period.

Most operational data sets collected in real time (e.g., satellite, upper air soundings, surface observations, model output) will initially be available through the BAMEX on-line Field Catalog for project operations purposes and archived and available through the BDAC no later than six months following the field phase. All field documentation (e.g., daily operations summaries, mission summaries, status reports, mission scientist reports, etc.) will also be available through the BAMEX Field Catalog and the BDAC in an electronic format.

7.1.3 Data Attribution

All data shall be promptly provided to other BAMEX PIs upon request with the approval of the PI that collected the data. BAMEX PIs are defined as those designated by the BAMEX Steering Committee/BAMEX Project Office and/or those directly participating in the field experiment. Distribution can be done either directly by the PI or through the BAMEX Data Archive Center with the permission of the PI.

During the initial data analysis period (up to one year after the data have been collected) no data may be provided to a third party (journal articles, presentations, research proposals, other investigators) without the consent of the PI that collected the data. This initial analysis period is designed to provide an opportunity to quality control and analyze the combined data set to release a better quality product.

7.1.4 Community Access to Data

It is the intent of the BAMEX Steering Committee that all data will be considered public domain no later than one year after the end of the field experiment (i.e., July 2004) and that any use of the data will include either acknowledgment or co-authorship of the PI who collected the data. General community access to the data will be available through the BAMEX Data Archive Center who will be responsible for making arrangements on data distribution (e.g., cost, if any, method of distribution, etc.) and coordinate data orders with the requestor.

7.2 On-Line Field Catalog

UCAR/JOSS will implement and maintain the web-based BAMEX Field Data Catalog that will be operational during the BAMEX field phase to support the field operational planning, product display, and documentation (e.g. facility status, daily operations summary, and mission reports). The catalog will be operational at the BOC with a "mirror" site in Boulder, CO. Data collection information about both operational and research products (including documentation) will be entered into the system in near real time beginning 1 May 2003. The catalog will permit data entry (data collection details, field summary notes, certain operational data etc.), data browsing (listings, plots) and limited catalog information distribution. A Daily Operations Summary will be prepared and contain information regarding operations (aircraft flight times, major instrument systems sampling times, weather forecasts and synopses, etc.). These summaries will be entered into the on-line Field Data Catalog either electronically (via WWW interface and/or e-mail) or manually. It is important and desirable for the PIs to contribute graphics (e.g., plots in gif, jpg, png, or postScript format) and/or data for retention on the catalog whenever possible. Updates of the status of data collection and instrumentation (on a daily basis

or more often depending on the platforms and other operational requirements) will be available. Public access to status information, mission summaries and selected data sets outside of the BOC will be available from the mirrored catalog system in Boulder.

7.3 Distributed Data Archive Center

The BDAC will be located at UCAR/JOSS in Boulder, CO, and data will be available through the existing JOSS Data Management System (CODIAC). CODIAC offers scientists access to research and operational data. It provides the means to identify data sets of interest, facilities to view data and associated metadata and the ability to automatically obtain data via Internet file transfer or magnetic media. The user may *browse data* to preview selected data sets prior to retrieval. Data displays include time series plots for surface parameters, skew-T/log-P diagrams for soundings and gif images for model analysis and satellite imagery. CODIAC users can *directly retrieve data*. Users can download data via the Internet directly to their workstation or personal computer or request delivery of data on magnetic media. Data may be selected by time or location and can be converted to one of several formats before delivery. CODIAC automatically includes associated documentation concerning the data itself, processing steps and quality control procedures.

Contact Information:

Contact:	CODIAC (codiac@joss.ucar.edu)
Mailing Address:	P.O. Box 3000, Boulder, CO, USA, 80307
Shipping Address:	3300 Mitchell Lane (Suite 175), Boulder, CO 80307, USA
Telephone:	(303) 497-8987, FAX (303) 497-8158
Internet Access:	http://www.joss.ucar.edu/codiac/

7.4 BAMEX Data Questionnaire

JOSS and the BAMEX Project Office developed and distributed an on-line data questionnaire to gather information from BAMEX Investigators regarding their needs for specific data sets. The information provided will help JOSS determine what data and products are necessary in real-time during the project (for inclusion into the field catalog) and what data need to be archived for analysis efforts by BAMEX PI's (both operational and research data sets). The questionnaire is available at: http://www.joss.ucar.edu/cgi-bin/bamex/q_data. Information will be compiled from all responses into a summary report and incorporated into the BAMEX Data Management Plan.

7.5 BAMEX Data Management WWW Pages

To organize BAMEX data management activities and access to data sets, JOSS has created and maintains BAMEX Data Management World Wide Web (WWW) pages located directly at: <http://www.joss.ucar.edu/bamex/dm/>. These pages (also linked from the BAMEX "Home" Page) will provide access to BAMEX data sources and information (in-situ, satellite, and model output), project documentation, on-line field catalog, data submission/guidelines, collaborating project data archives, and other relevant data related links. The future "Data Access" link from this page (or to be located directly at: <http://www.joss.ucar.edu/bamex/dm/archive/>) will consist

of a master table of all BAMEX data sets with links to distributed data sources (including documentation, data set status, and date of availability). As data sets become available, this table will be updated providing an easy “one-stop” access to all BAMEX data sets.

7.6 Hydrometeorological Networks in the BAMEX Region

A survey of all available hydrometeorological networks in the BAMEX Region has been completed and contains descriptions of possible in-situ operational data streams that are available to BAMEX. This survey includes surface meteorological (national, regional, and state/local), precipitation and radar, radiation/flux, soils, hydrology, and upper air networks. This information (network descriptions, measured parameters, maps, and relevant links, etc.) have been compiled, organized by State, and is available from the BAMEX Data Management WWW page or directly at: <http://www.joss.ucar.edu/bamex/dm/networks/>. Some of these data are available in real (or near real) time, while others would only become available after the completion of the field phase of BAMEX. Composite BAMEX Region maps of these networks is located at: <http://www.joss.ucar.edu/bamex/dm/maps.html>. JOSS has the responsibility to arrange for and collect network data relevant to BAMEX requirements.

8 Cell and Satellite Phone Numbers

Table 8.1 BAMEX Facility Contact Information	
MGLASS I Sat Phone	254 381 2906
MGLASS I Cell Phone	303 579 7238
MGLASS 2 Sat Phone	254 381 2907
MGLASS 2 Cell Phone	303 579 4623
MGLASS Support Cell Phone	303 579 7162
Lear Jet voice	011 8816 314 68482
Lear Jet data only	011 8816 314 68483
NRL P-3	1 866 508 5608
GBOS Operators:	
T. Lim	303 818 9906
N. Chamberlain	303 817 4034
L. Verstraete	303 597 4535
Radio Frequencies:	
	MHz
VHF for scientist to scientist	118-150
NOAA frequency	122.975
GBOS VHF Radio	163.1
GBOS Secondary special use simplex	163.275
ARC-182 VHF (aircraft to aircraft)	30-399.975
MIPS	400.25
dropsonde	400.5-401
NCAR 2	401.25
dropsonde	401.5-401.75

Glass sec freq	402
Mobile2 sounding	401.25
MIPS sounding	400.00
dropsonde	402.25-404.75
Mobile1 sounding	405.0
dropsonde	405.25-405.98