The Bow Echo and Mesoscale Convective Vortex Experiment (BAMEX)

Chandra Pasillas  April 2021
Overview

• MCS, MCV and Bow Echo Basics
• 5WH and Experimental Design
• Key Science Questions and Findings
• Summary

https://www.eol.ucar.edu/system/files/opsplan_0.pdf
- BAMEX OPERATIONS PLAN
Mesoscale Convective System (MCS) and Mesoscale Convective Vortices (MCV) and Bow Echo Basics

- MCSs usually being as single larger or small group of strong convective cells and evolved into a bow shape with surface cold pool expansion and finally comma shape
- Midtropospheric vortices in stratiform region associated with mesoscale convective systems and their rotation
- Bow Echo – looks like a bow
  - Strong leading-line updrafts follows by intense downdraft and divergent cold outflow
  - Often has a “notch” with strong rear inflow
  - Booked ended voricities (cyclonic anti cyclonic pair)
  - Scale: 10s- 100s km in size, 10s on min to hours duration
  - Cause: strong straight line winds, 20% of tornadoes without radar
Who

- Funded mainly by NSF
- NRL
- NOAA
- JOSS - NCAR
- SPC-NCAR
- NWS
- Penn State
- Texas A&M
- Colorado State
What

• A study using highly mobile platforms to examine the life cycles of mesoscale convective systems, specifically rotationally dominated MCSs. It represents a combination of two related programs to investigate
  – bow echoes, principally those which produce damaging surface winds and last at least 4 hours
    • The main objectives regarding bow echoes are to understand and improve prediction of the mesoscale and cell-scale processes that produce severe winds
  – larger convective systems which produce long lived mesoscale convective vortices (MCVs).
    • 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.
• 1st study designed to sample multiscale aspects of Bow Echoes /MCVs throughout their life cycle
  – Examined structures on the meso–gamma, meso–beta, and meso-alpha scales
• Unprecedented dataset for the study of the lifecycle of MCSs
When:  
20 May – 6 July 2023

18 Intensive Observing Periods (IOPs)

1 IOP had all 3 aircraft

11 Bow Echos – 9 sampled

5 Mature MCVs

Estimated 35-40 mesoscale vortices formed in MCSs during campaign

<table>
<thead>
<tr>
<th>IOP</th>
<th>Location</th>
<th>Nonbowed MCS</th>
<th>Mature MCV</th>
<th>Forming MCV</th>
<th>Bow echo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: 24–25 May</td>
<td>OK, AR</td>
<td>X(2, 2, 4)</td>
<td>X(2, 3, 4)</td>
<td>X(2, 2, 4)</td>
<td>X(2, 3, 4)</td>
</tr>
<tr>
<td>2: 28–29 May</td>
<td>IL, IN</td>
<td>X(1, 2, 4, 5)</td>
<td>X(2, 3, 4)</td>
<td>X(2, 3, 4)</td>
<td>X(2, 3, 4)</td>
</tr>
<tr>
<td>3: 30–31 May</td>
<td>IL, IN</td>
<td>X(1, 2, 3, 4, 5)</td>
<td>X(2, 3, 4)</td>
<td>X(2, 3, 4)</td>
<td>X(2, 3, 4)</td>
</tr>
<tr>
<td>4: 2–3 Jun</td>
<td>KS, AR, MS</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>5: 5–6 Jun</td>
<td>TX, AR</td>
<td>X(3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>6: 8 Jun</td>
<td>IN, OH</td>
<td>X(2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>7: 9–10 Jun</td>
<td>NE, IA, MO, KY, TN</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>8: 11 Jun</td>
<td>AR</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>9: 20–21 Jun</td>
<td>NE</td>
<td>X(2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>10: 22 Jun</td>
<td>SD</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>11: 23 Jun</td>
<td>NE, KS</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>12: 24 Jun</td>
<td>NE, IA</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>13: 25–26 Jun</td>
<td>IL</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>14: 29 Jun</td>
<td>KS</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>15: 29–30 Jun</td>
<td>KS</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>16: 2–3 Jul</td>
<td>MN</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>17: 4–5 Jul</td>
<td>IA, IL, IN</td>
<td>X(1, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
<tr>
<td>18: 5–6 Jul</td>
<td>NE, IA</td>
<td>X(1, 2, 3, 4)</td>
<td>X(4)</td>
<td>X(4)</td>
<td>X(4)</td>
</tr>
</tbody>
</table>

Other missions

7–8 Jun | TX | X(1) |
10 Jun | MO, IL | X(3) |
Where:
MidAmerica St Louis Airport, Mascoutah Illinois

Area of Interest chosen due to climatological frequency of bow echos and MCVs which were also located in a network of concentrated wind profilers, mesonet and WSR-88D radar.

Figure 2.1 Approximate BAMEX flight domain defined by the 1.5 hr ferry range of the turboprop aircraft (~425 nm mi). The National Weather Service (NWS) identifiers show locations of NEXRAD radar sites.
Why

- Process on how they form was not well observed before BAMEX
- No known comprehensive studies capturing the life cycle of bow eas at that time
- MCVs can provide a focus for the development of new convection and thus play a key role in multi-day convective events that can affect areas larger than 1000 km in length with heavy and even flooding rains.
How

- System following strategy
- 3 Aircraft
- Ground-Based Observing System (GBOS) consisting of the University of Alabama-Huntsville Mobile Integrated Profiling System (MIPS), two NCAR MGLASS radiosonde systems and one UAH mobile probe vehicle
- Leverage existing WSD 88 coverage, soundings, wind profilers and observations
- "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."

Fig. 1. BAMEX facilities.
Flight Ops

BAMEX used three aircraft, two equipped with dual Doppler radar capability, one equipped with dropsondes, to map the mesoscale evolution of long-lived MCSs including the development of mesoscale vortices and rear-inflow jets.

Dropsondes were 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.

First ever “quad doppler”
Ground Ops

- Augment airborne radar coverage
- Document the thermodynamic structure of the PBL, including any existing convergence boundaries
- Probe the surface cold pool
- Measure surface horizontal pressure and wind variations behind the leading convective line.
Communications

• “BAMEX represented the first extensive use of satellite internet capability to coordinate multiple aircraft flight patterns in rapidly evolving weather systems”

• “One innovative aspect of the communications strategy was the use of an internet “chat room” to keep all principal BAMEX components informed of the rapidly changing weather and observing strategies”
Forecasting

- 16 forecasters and 7 scientists
- 3 forecast models w fully explicit convection at 4km or less
  - RAMS – Regional Atmospheric Modeling System
  - MM5 – 5th gen Penn States-NCAR Mesoscale Model
  - WRF – Weather Research and Forecasting (newly developed)*
- Data collected enabled the verification of mesoscale and cloud system resolving for these models
- Power loss at Ops Center during one IOP

*Follow on study showed WRF at 12-36 hrs explicitly represented mode of convection.
Key Science Objectives

Improve predictability of bow echo disturbances, especially those producing severe weather (damaging winds / non-supercell tornadoes).

Improve predictability of secondary convection generated by mesoscale vortices.

Document and understand factors contributing to the development of horizontal circulations with long-lived convective systems.

Understand the coupling between boundary-layer and free-tropospheric circulations within MCSs, in particular how the rear-inflow penetrates to the surface in nocturnal severe wind cases.

Map the mesoscale evolution of long-lived MCSs including the development of mesoscale vortices and rear-inflow jets. Understand how new convection is initiated and organized IVO long lived MCVs.

Improve 6-24 hour Quantative Precipitation Forecasts (QPF).
Cloud micro physics measurements

- 16 spiral descents
- First observations of the microphysical structure of the stratiform region behind bow echos acquired in conjunction with Doppler observations
Case: Straight line winds 5 July 2003
Evolution of Event
Vertical Cross Sections of July 5th Storm
Questions?