Chapter 3
Convective Dynamics
Part V ñ Bright Bands, Bow Echoes and MCCs

Bright band associated with stratiform precipitation in a squall line system

Figure 9.34  Schematic of the two-dimensional hydrometeor trajectories through the stratiform region of a squall line with trailing stratiform precipitation. Trajectories were based on fall speeds and air motions measured by Doppler radar. Other aspects of this storm are illustrated in Figs. 9.15, 9.18, 9.21, 9.40, 9.41, 9.43, 9.44, 9.45, 9.48, 9.53, and 9.54. (From Biggerstaff and Houze, 1991a. Reproduced with permission from the American Meteorological Society.)
Bright band associated with stratiform precipitation

- In stratiform precipitation regions, such as that in a mature squall line, a horizontal band of enhanced radar echo is often observed that is referred to as a 'bright band'.
- The bright band is located at the level of zero degree C i.e., the melting level.
- As the ice particles, snow flakes etc are half way through melting, their reflectivity is increased as they become enclosed by liquid water (water reflects radar beams more effectively than ice particles) while still keeping their size, resulting in a steep jump in radar echo.
- As they completely melt into rain drops, their sizes are reduced resulting reduced echo level, therefore we observed a layer of significantly enhanced reflectivity.
- Such observations of reflectivity can be used to study the microphysical properties of the clouds.
- Sections 6.1.1-6.1.3 of Houze have detailed explanations of the microphysical processed involved.

Example of bright band associated with stratiform precipitation
Bow Echoes

- Bow echoes are relatively small (20-120 km [10-65 nm] long), bow-shaped systems of convective cells that are noted for producing long swaths of damaging surface winds.

- They are observed both as relatively isolated convective systems and as sub-structures within much larger convective systems.

- Bow echoes that develop within a squall line have been referred to as line echo wave patterns (LEWPs).
Bow Echo Conceptual Models

A bow echo has a well-recognized evolution starting as a strong isolated cell or a small line of cells that evolves into a symmetric bow-shaped segment of cells over a period of a couple hours, and eventually into a comma-shaped echo over several hours.

Cyclonic and anticyclonic line-end (or bookend) vortices are evident behind the northern and southern ends of the bow, respectively, in the early phases. This symmetric structure becomes more asymmetric during the comma echo phase when the cyclonic vortex begins to be dominant.

A weak echo notch behind the core of the bow, referred to as a "rear-inflow notch" (RIN), often signifies the location of a strong rear-inflow jet. When the rear-inflow jet descends to the ground at the leading edge of the bow, it can create a swath of damaging surface winds. Weak tornadoes are also often observed just north of this surface jet core.

Bow echoes tend to propagate in the direction of the low-level (0-3 km AGL) mean vertical wind shear vector, at a speed controlled by the propagation speed of the cold pool. Since the cold pools in bow echoes are often exceptionally strong, their propagation speed is often much faster than nearby convective cells or systems.

Fujitaís Conceptual Model

A typical morphology of radar echoes associated with strong and extensive downbursts.

Modified from Fujita, 1978
Bow Echo Vertical Cross Section

- A vertical cross section through the core of the bow depicts a strong, vertically erect updraft at the leading edge of the system, with a strong, elevated rear-inflow jet impinging to just behind the updraft region at mid-levels before descending rapidly to spread along the surface.

- Above the rear-inflow jet, the updraft current turns rapidly rearward, feeding into the stratiform precipitation region. The pressure field (not shown) is characterized by a strong mesohigh at the surface, associated with the cold pool, and a strong mesolow at mid-levels, just above the mesohigh.

Line-end Vortices in Bow Echoes

- Bow echoes' extreme intensity is due in large part to their relatively small size. In particular, the smaller distance between the bookend vortices enhances the focusing effect on the mid-level flow between the vortices, which can significantly strengthen the rear-inflow jet.

- The descent of this enhanced rear-inflow jet to the surface tends to produce extreme surface winds.
Rear Inflow Notch (RIN) Examples

A RIN apparent behind the bowing segment

A sharply defined RIN

Mid-Altitude Radial Convergence (MARC)

MARC is a Doppler velocity signature that can serve as a precursor to the initial onset of damaging downburst winds in a squall line.
Severe Bow Echo Environments

- Severe bow echoes are most often observed in environments with moderate-to-strong low-level shear and very high CAPE.

- From a climatological study by Johns and Hirt (1987), the lifted index (LI) averages about -8 K (this usually indicates a CAPE value >2500), with an average 700-mb wind magnitude of 17 m/s.

Severe Bow Echo Environments

- Bow echo and supercell environments have much overlap, with bow echoes often characterizing the later stages of a supercell event.

- However, bow echoes primarily occur in wind profiles with the strong vertical shear confined to low levels (lowest 2-3 km AGL), while supercells primarily occur with deeper vertical wind shear profiles (strong shear extending to at least 4-6 km AGL).
Progressive and Serial Derechos

- A severe convective system may be composed of several bow echoes at the same time or a sequence of such features over time.

- If the cumulative impact of the severe wind from these events covers a wide enough and long enough path, the wind event is generically referred to as a "derecho."

- Johns and Hirt (1987) have classified derechos as either progressive or serial.

  - Progressive Derechos are usually characterized by a single bow-shaped system that propagates north of, but parallel to, a weak east-west oriented stationary boundary.

  - Serial Derechos are composed of a series of bow-echo features along a squall line, usually located within the warm sector of a synoptic-scale cyclone.

Bow Echoes Summary

- Bow echoes are typically 20-120 km (10-65 nm) long bow-shaped systems of convective cells that are noted for producing long swaths of damaging surface winds.

- Bow echoes may occur as either isolated convective systems or as part of much larger convective systems such as squall lines.

- The line-end vortices associated with bow echoes are often referred to as bookend vortices.

- A weak echo notch behind the core of the bow, referred to as a rear-inflow notch (RIN), often signifies the location of a strong rear-inflow jet.

- Bow echoes tend to propagate in the direction of the mean low-level vertical wind shear vector at a speed controlled by the cold pool propagation.

- A vertical cross section in the core of the bow echo reveals a strong, vertically erect updraft at the leading edge of the system; a strong, elevated rear-inflow jet impinging to just behind the updraft region before descending rapidly to the surface; and a system-scale updraft that turns rapidly rearward, feeding into the stratiform precipitation region.
Bow Echoes Summary

- Bow echoes often generate intense winds when the close proximity of the line-end vortices acts to strengthen the rear-inflow jet, leading to widespread, potentially damaging winds at the surface.
- If the cumulative impact of the severe wind from one or more bow echoes covers a wide enough and long enough path, the event is referred to as a derecho.
- Progressive derechos are characterized by a single bow-shaped system that propagates north of and parallel to a weak east-west oriented stationary boundary.
- Serial derechos are composed of a series of bow-echo features along a squall line, usually located within the warm sector of a synoptic-scale cyclone.
- Severe bow echoes are most often observed in environments with moderate-to-strong low-level shear and very high CAPE.
- Bow echo and supercell environments overlap, with bow echoes often characterizing the later stages of a supercell event.

Visual Siting of a Bow Echo
A numerical Simulation of a squall line with a serials of embedded bow echoes

Mesoscale Convective Complex (MCC)
Mesoscale Convective Complex (MCC)

Mesoscale convective complexes (MCCs) represent a larger form of mesoscale convective system (MCS) organization.

A system is identified as an MCC based on its characteristics as depicted on IR satellite imagery.

The physical characteristics include a general cloud shield with continuously low IR temperatures less than -32°C over an area ≥ 100,000 km², with an interior cold cloud region with temperatures less than -52°C having an area ≥ 50,000 km².

MCCs often last for 6-12 h, and are especially known for producing heavy amounts of rain, although severe winds, hail, and tornadoes can also occur during the early phases of MCC evolution.

**Table 17.1. Definition of mesoscale convective complex (MCC) based on analyses of enhanced IR satellite imagery**

<table>
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<th>Criterion</th>
<th>Physical characteristics</th>
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| Size¹ | A: Cloud shield with continuously low IR temperature ≤ -32°C must have an area ≥ 100,000 km².  
B: Interior cold cloud region with temperature ≤ -52°C must have an area ≥ 50,000 km². |
| Duration | Size definitions A and B must be met for a period ≥ 6 h. |
| Maximum extent | Contiguous cold-cloud shield (IR temperature ≤ -52°C) reaches maximum size. |
| Shape | Eccentricity (minor axis/major axis) ≥ 0.7 at time of maximum extent. |

*From Maddox (1980).

¹Initiation occurs when size definitions A and B are first satisfied.  
Termination occurs when size definitions A and B are no longer satisfied.
MCC Evolution

- During the early phases of evolution, the convective structures that make up an MCC may include multiple squall lines, bow echoes, or isolated convective cells, each evolving through its own lifecycle, with each system contributing to the expanding MCC anvil as depicted on a satellite image.

- During the later stages of evolution, however, a large stratiform precipitation region dominates the MCC, as it does in the later stages of squall line evolution.

The flow field in the later stages of an MCC is characterized by divergent, anticyclonic outflow near the surface and aloft within the anvil, with convergent cyclonic flow at mid-levels.

Like the northern line-end vortices of squall lines that sometimes grow quite large, this mid-level cyclonic flow is often referred to as a mesoscale convective vortex (MCV).

MCCs are most often observed at night, in areas in which the boundary layer is stable. The source of energy for such systems is often found in an elevated layer above the boundary layer, north of a weak surface warm front.

Observational studies suggest that MCC structure and evolution is more dependent on interactions with large-scale forcing features than the boundary-layer-based mesoscale convective systems (MCSs) such as squall lines and bow echoes.