Summary

Convective storms occur in many sizes and can produce a variety of hazardous weather events lasting from a few hours to a couple of days. While many storms are isolated, they often become organized into larger clusters of storms known as mesoscale convective systems (MCSs).

MCSs

- May start from one cell or from a group of convective cells
- May initiate as a line along a cold front, dryline, or other mesoscale boundary
- Occur worldwide and year round
- Are generally stronger and more organized in a sheared and highly unstable environment
- Are strongest and live longest when strengths of the cold pool and low-level vertical wind shear remain in balance

MCS Types

- Squall line
- Bow echo
- Mesoscale convective complex (MCC)

MCS Weather Threats

- Damaging winds
- Severe turbulence and wind shear
- Intense lightning
- Large hail
- Heavy rain and flooding
- Tornadoes

Squall Lines

- Most common form of MCS. Vary greatly in strength, length, and width
- Usually composed of ordinary cells, but may contain supercells, especially near breaks or southern end
- Severity increases with increasing atmospheric instability
- Usually strongest when oriented perpendicular to the mean vertical wind shear vector
- Often evolve from merger of convective clusters, which results in a larger, longer-lived system that tends to produce more severe weather
- Line Echo Wave Pattern (LEWP) may occur if several portions of the line bow outward

Types of Squall Line Formation

- Broken line
- Back building
- Broken areal
- Embedded areal

Squall Lines in Weak–to-Moderate Vertical Wind Shear

- Weak-to-moderate range for midlatitude lines is < 15 m/s (30 kt) perpendicular to the line over the lowest 3 km AGL (9,000 ft)
- Cold pool strength dominates the vertical wind shear balance
- New cells become sheared and do not stay with the leading edge of gust front cold pool
- Have a wide area of precipitation, well behind advancing gust front in their later stages of evolution
- Tend to be relatively short-lived, unless they move into more favorable environments

Squall Lines in Moderate–to-Strong Vertical Wind Shear

- Moderate-to-strong range for midlatitude lines is > 15 m/s (30 kt) perpendicular to the line over the lowest 3 km AGL (9,000 ft)
- Cold pool strength and vertical wind shear tend to be balanced
- New cells remain along or just behind the advancing cold pool gust front
- Rear-inflow jet possible, depending on temperature of cold pool versus air above

Squall Line Movement and Cell Motion

- Cells form down-shear of the low-level wind shear vector along leading edge of the cold pool
- Each cell generally moves with the low-level mean wind vector (non-supercells)
- For longer lines:
    - Individual cells may move at an angle to the line
    - Net motion of the line usually stays perpendicular to its initial orientation
- For shorter lines:
    - Systems reorient themselves perpendicular to the mean low-level shear
    - Lines then propagate in the direction of the low-level shear vector
    - New cells are more easily triggered along the down-shear gust front

Squall Line Evolution (Northern Hemisphere)

- Can develop rotation at each end (most significant for short lines)
- Northern (cyclonic) vortex usually becomes dominant (after 3-4 hours) due to Coriolis effect
- Takes on "pork chop" appearance on radar
- System's surface high-low pressure couplet shifts to north, becoming asymmetric

Tropical Characteristics

Tropical squall lines are structurally similar to their midlatitude counterparts, but show some different characteristics:

- Generally, move east to west
- Higher storm tops (due to higher tropopause)
- Develop in lower shear, lower LFC environments
- More easily triggered
- Weaker system cold pools
- Slower movement
- Less tendency toward asymmetric evolution (less Coriolis effect).

Bow Echoes

- Range in size from ~ 20 to 120 km (10 to 65 km) in length
- Especially known for producing swaths of damaging winds
- Have bookend vortices in close proximity, which can focus and intensify the RIJ
- Tend to occur in high CAPE, high vertical wind shear environments that also contribute to their severity
- When they occur within a squall line are often called LEWPs
- Can lead to extensive and nearly continuous straight-line wind damage events called derechos
- Are associated with tornadoes, especially in the region north of the bow apex

Operational Bow Echo/Wind Potential Indicators

- Buoyancy values LIs of -8 or lower, CAPEs >= 2500 J/kg
- Moderate-to-strong vertical wind shear
- Storm cell mergers
- HP supercells that begin to evolve into bow shapes
- Rear-Inflow Notches (RIN) in reflectivity data
- Mid-Altitude Radial Convergence (MARC) in velocity data

MCCs

Mesoscale convective complexes (MCCs) are yet a larger form of convective organization. Many MCSs never meet the minimum size, cloud temperature, or duration criteria to be labeled an MCC. Characteristics include:

- Large, general cloud shield with continuously low temperatures
- Very cold interior cloud region of a minimum size
- Occur worldwide, in similar environments
- Produce all types of severe weather, very heavy rain, and possible flooding

MCCs and other types of MCSs occasionally spawn an upper-level circulation called a Mesoscale Convective Vortex (MCV). Although its parent system has died, an MCV can continue moving downstream as a swirl in the atmosphere and trigger subsequent convection and MCSs.

MCSs and NWP

Due to problems with initial conditions and convective parameterization schemes, most operational models are unreliable for predicting MCSs.

Most NWP Models have difficulty predicting:

- Timing and location of convection initiation
- Convective system evolution
- Total precipitation amount
- Accompanying weather hazards
- Impacts on downstream weather

How can a forecaster use NWP intelligently to predict MCSs?

- Use models with higher resolution
- Look for favorable synoptic and mesoscale patterns in NWP products
- Look for predicted buoyancy and shear profiles conducive to MCS formation
- Be alert for synoptic positioning/timing errors and any known model biases
- Watch for predictions of unrealistic looking precipitation “bull's-eyes” due to convective parameterization limitations