Overview

- Introduction to MCSs
- Squall Lines
- Bow Echoes
- Mesoscale Convective Complexes

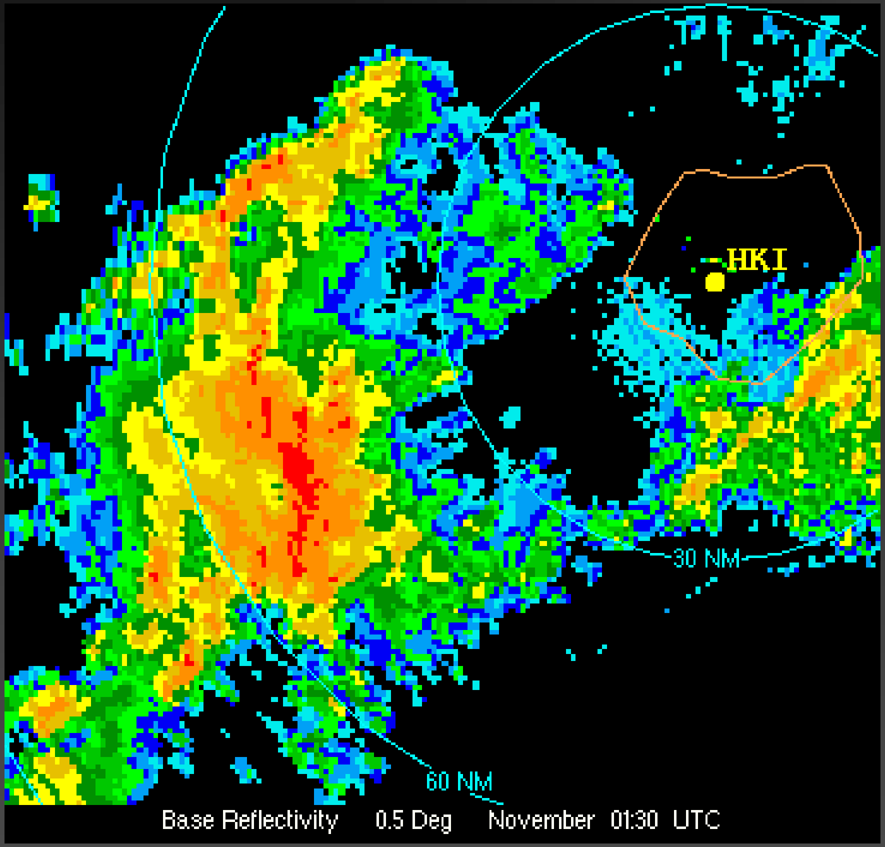
Definition

- Mesoscale convective systems (MCSs) refer to all organized convective systems larger than supercells
- Some classic convective system types include:
  - squall lines, bow echoes, and

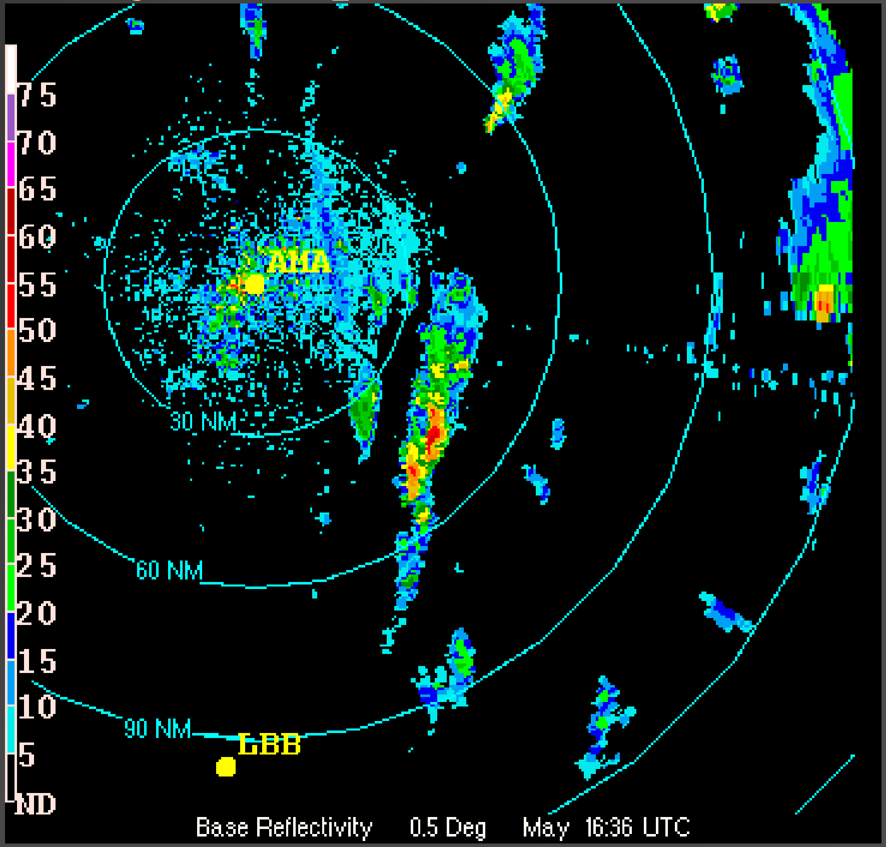
  mesoscale convective complexes (MCCs)
- MCSs occur worldwide and year-round
- In addition to the severe weather produced by any given cell within the MCS, the systems can generate large areas of heavy rain and/or damaging winds

Examples

Hawaiian Bow Echo



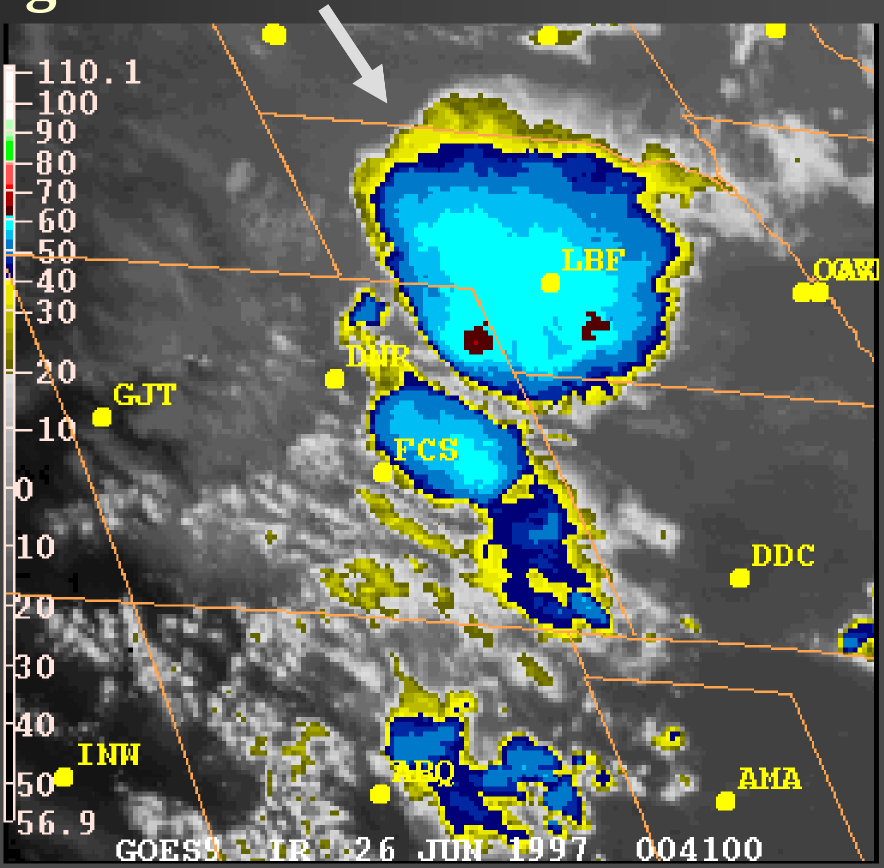
Dryline Squall line in Texas



Note the scale difference!

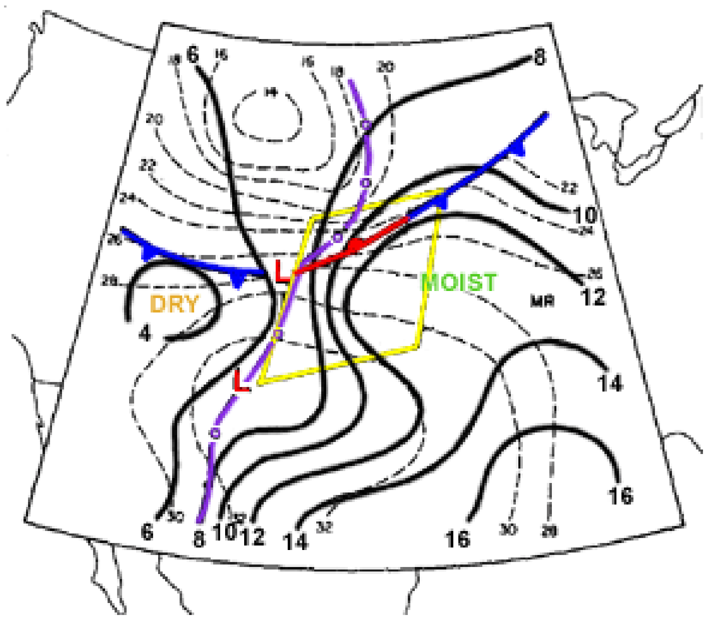
Examples cont.

MCC initiating over Nebraska



Synoptic Patterns

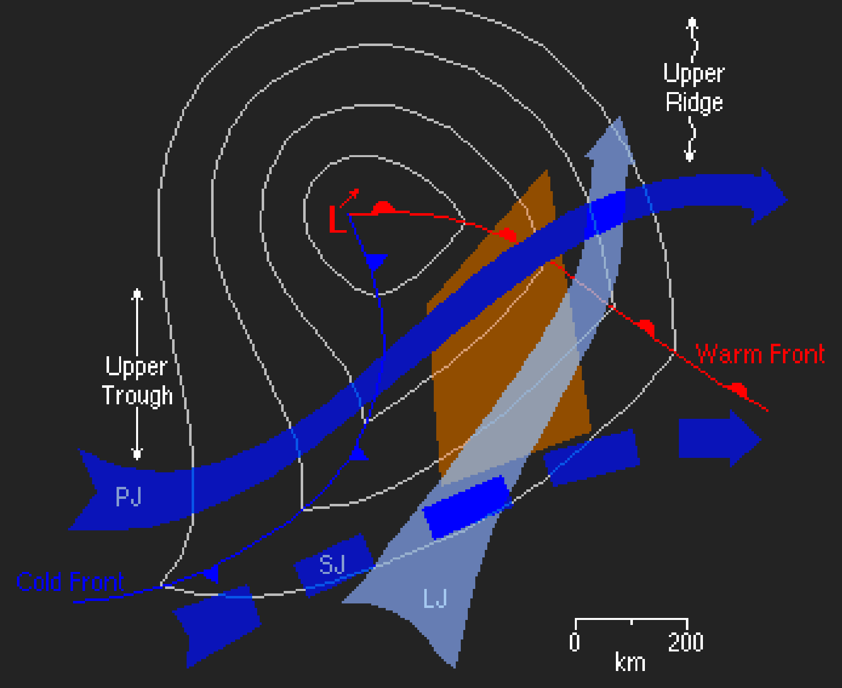
- Favorable conditions conducive to severe MCSs and MCCs often occur with identifiable synoptic patterns



Composite surface chart prior to MCC development.

Maddox, 1983

Dynamic Pattern b

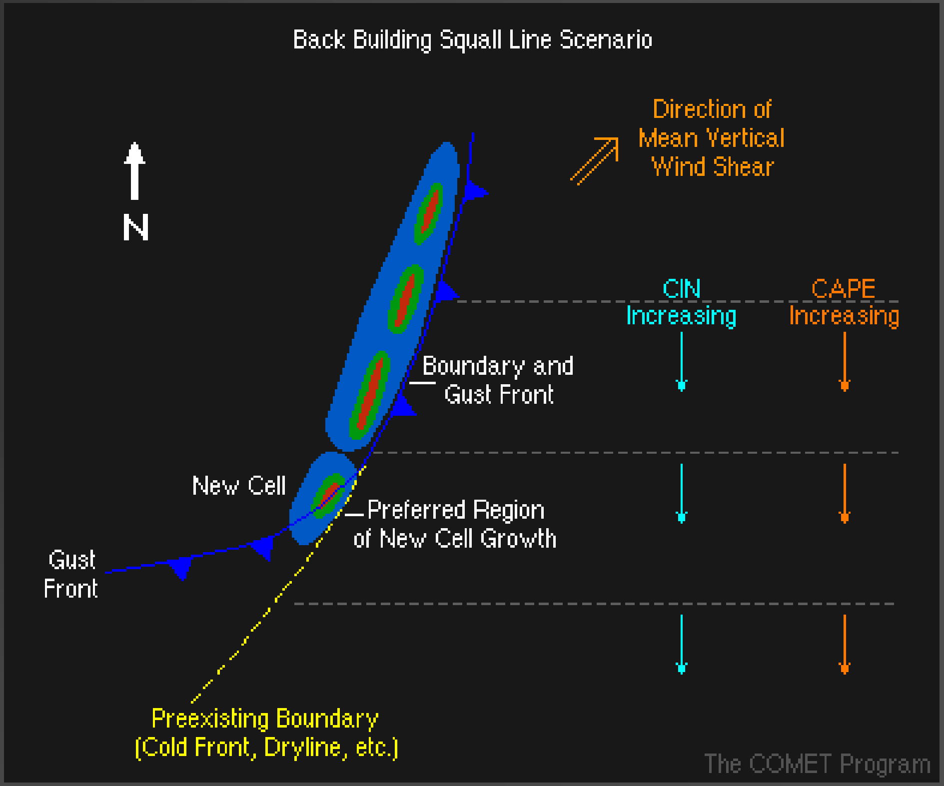


Idealized midlatitude synoptic-scale situation favorable for development of squall lines with extensive bow echo-induced damaging winds.

Johns, 1993

Environmental Factors

- Both synoptic and mesoscale features can significantly impact MCS structure and evolution

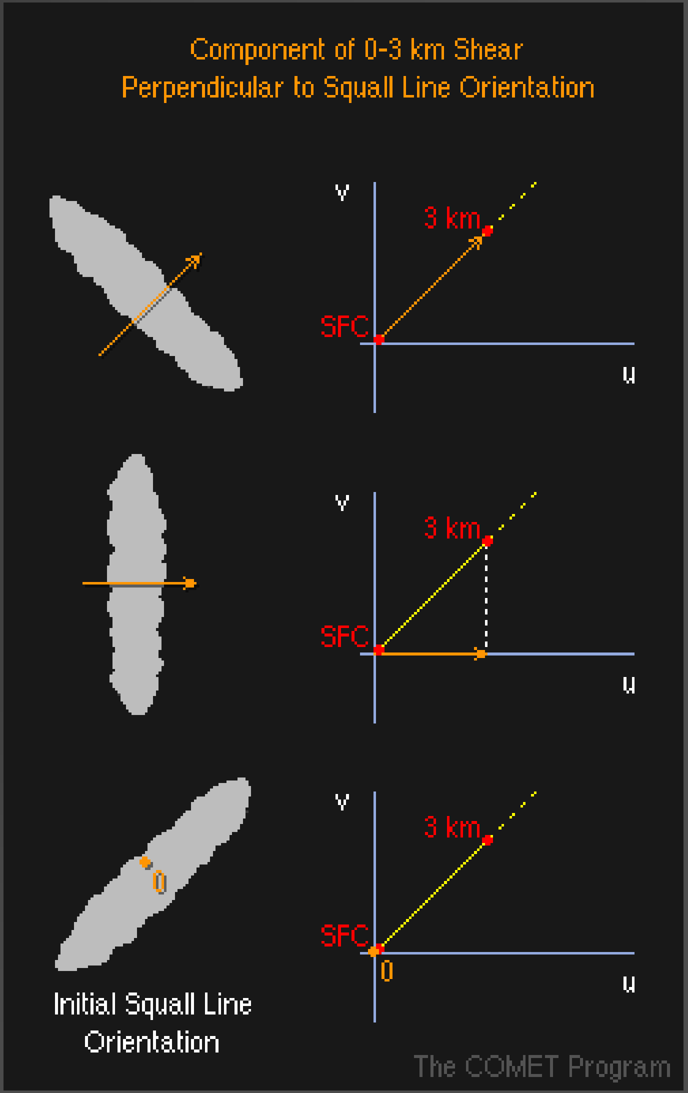


Importance of Shear

- For a given CAPE, the strength and longevity of an MCS increases with increasing depth and strength of the vertical wind shear
- For midlatitude environments we can classify Sfc. to 2-3 km AGL shear strengths as
  - weak <10 m/s, mod 10-18 m/s, & strong >18 m/s
- In general, the higher the LFC, the more low-level shear is required for a system’s cold pool to continue initiating convection

Which Shear Matters?

- It is the component of low-level vertical wind shear *perpendicular* to the line that is most critical for controlling squall line structure & evolution



Component of 0-3 km Shear
Perpendicular to Squall Line Orientation

Initial Squall Line Orientation

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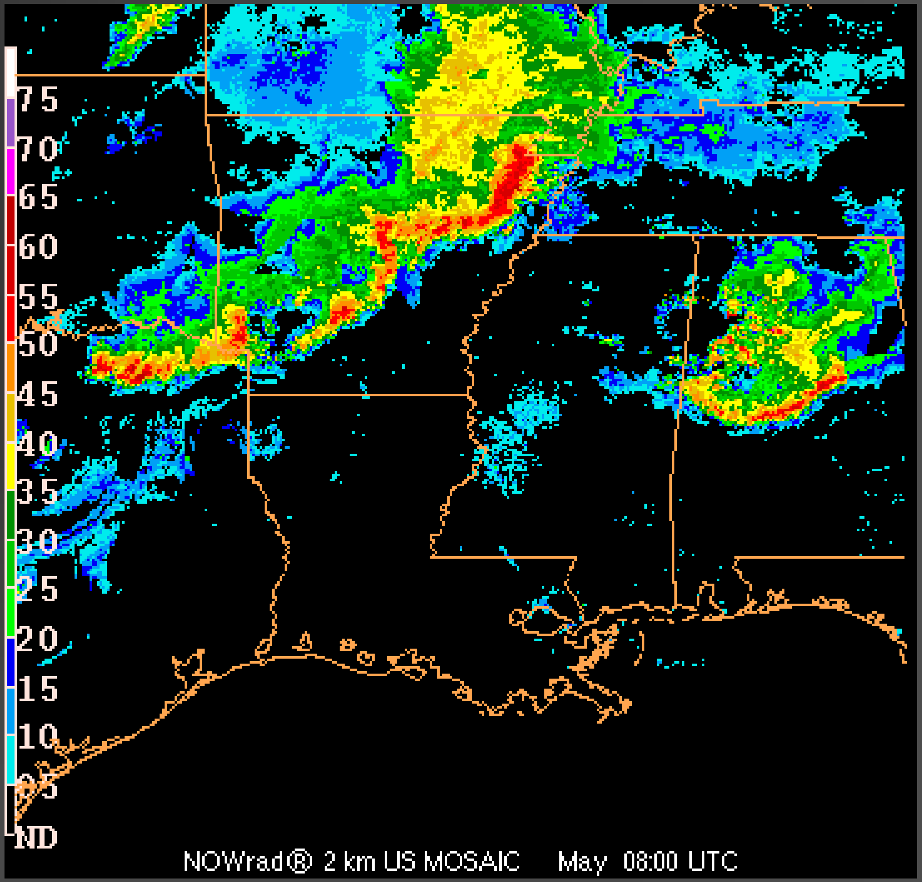
Squall Lines

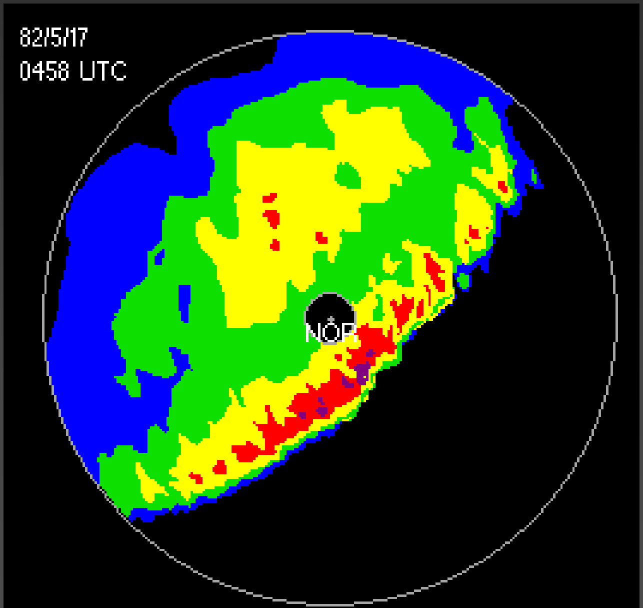
Squall Line Definition

- A squall line is any line of convective cells. It may be a few tens of km long or 1000 km long (>500 nm); there is no strict size definition

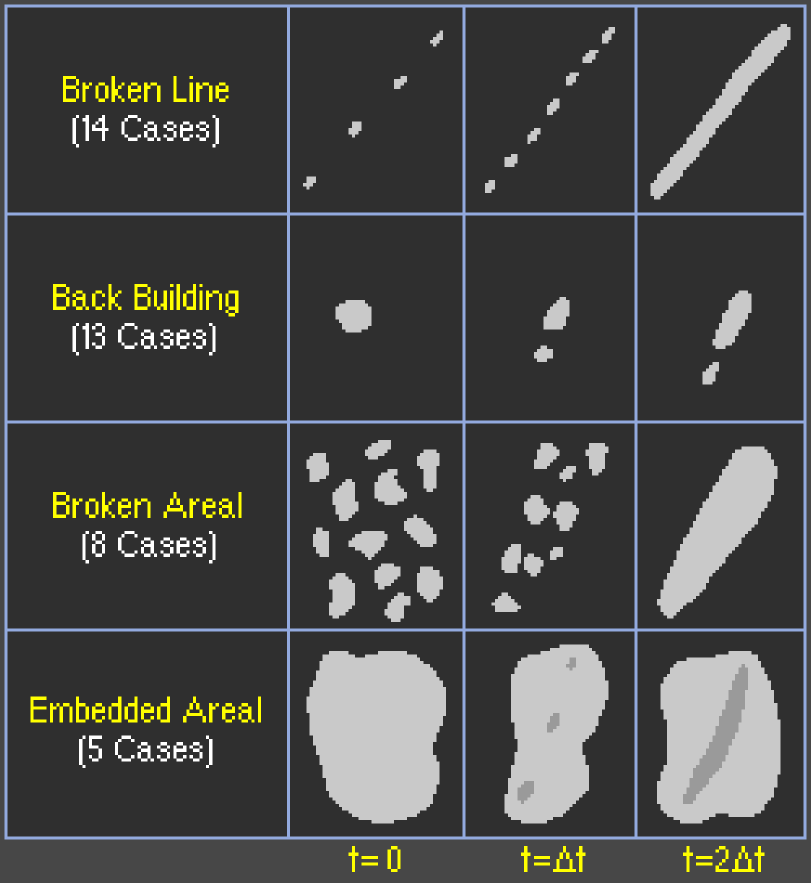


Initial Organization

- Squall lines may either be triggered as a line, or organize into a line from a cluster of cells



Modified from Houze, Smull, and Dodge, 1990

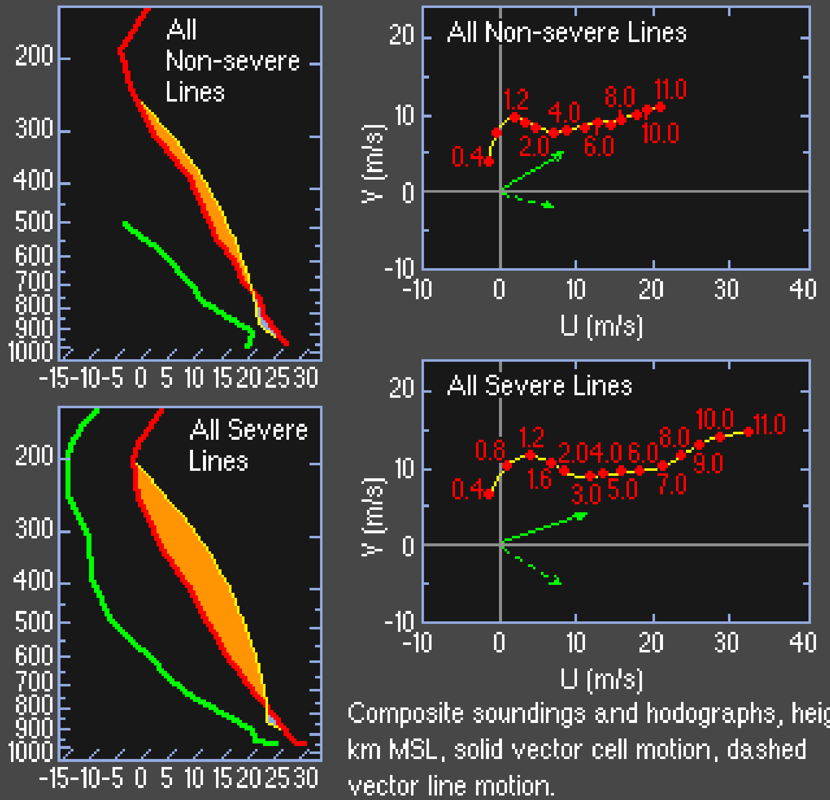


Idealized depiction of squall line formation.

Modified from Bluestein and Jain, 1985

Lots of Shear/Impact of CAPE

- Both severe and non-severe squall lines usually have lots of low-level shear, but severe lines usually develop in much more unstable environments.



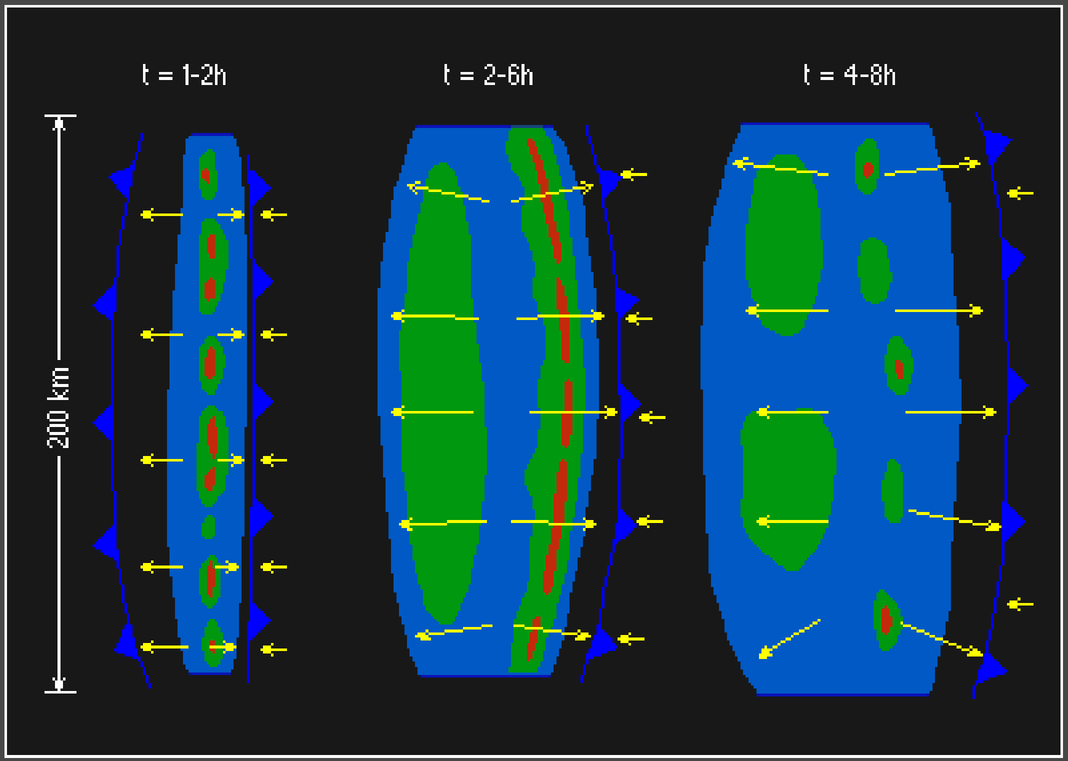
Composite soundings and hodographs, heights km MSL, solid vector cell motion, dashed vector line motion.

Modified from Bluestein & Jain, 1985; Bluestein, Marx, & Jain, 1987

Classic Evolution (with weak shear)

- The characteristic squall line life cycle is to evolve from a narrow band of intense convective cells to a broader, weaker system over time

Weak-Moderate Shear Squall Line Evolution with Low-Level Flow



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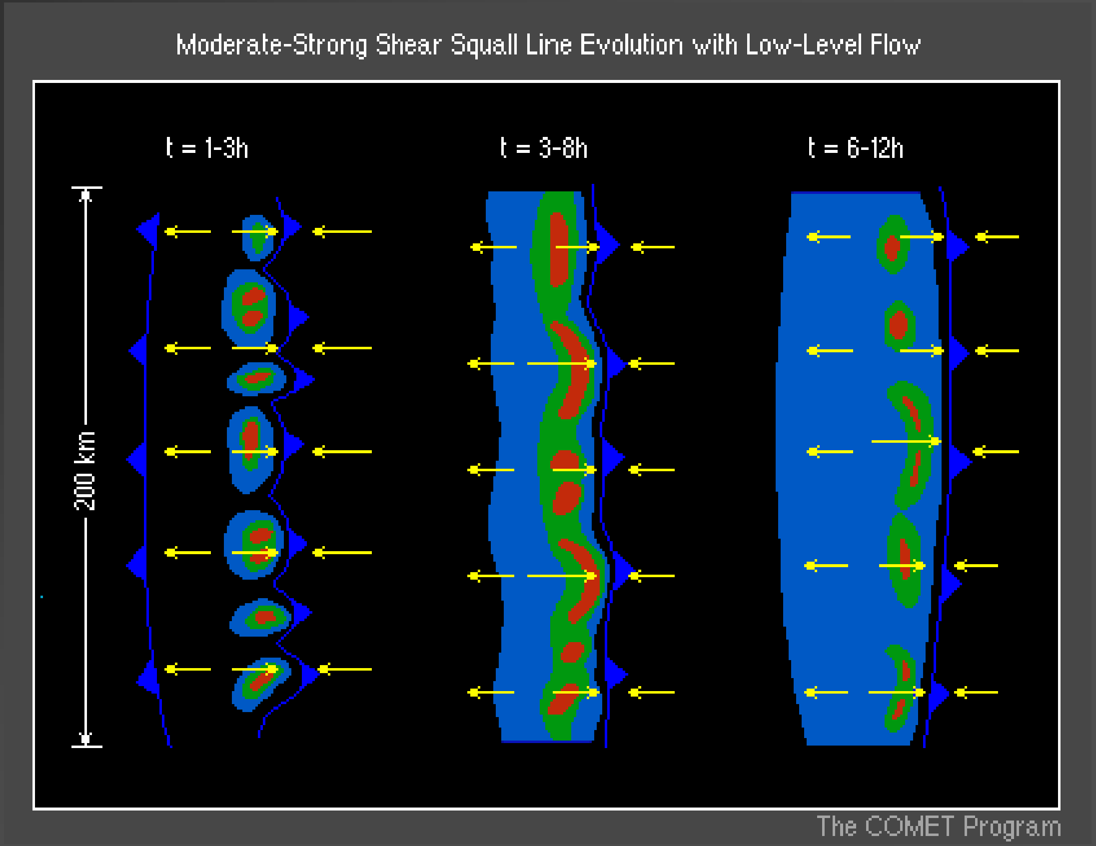
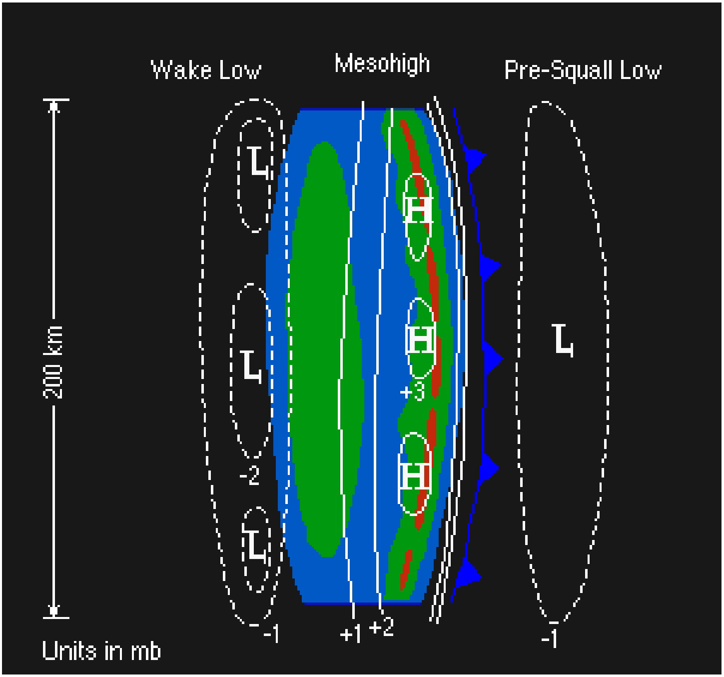
Classic Evolution with More Shear

- Stronger shear environments produce stronger long-lived lines composed of strong leading line convective cells and even bow echoes



Surface Pressure Fields

Weak-Moderate Shear Squall Line Evolution with Pressure Field



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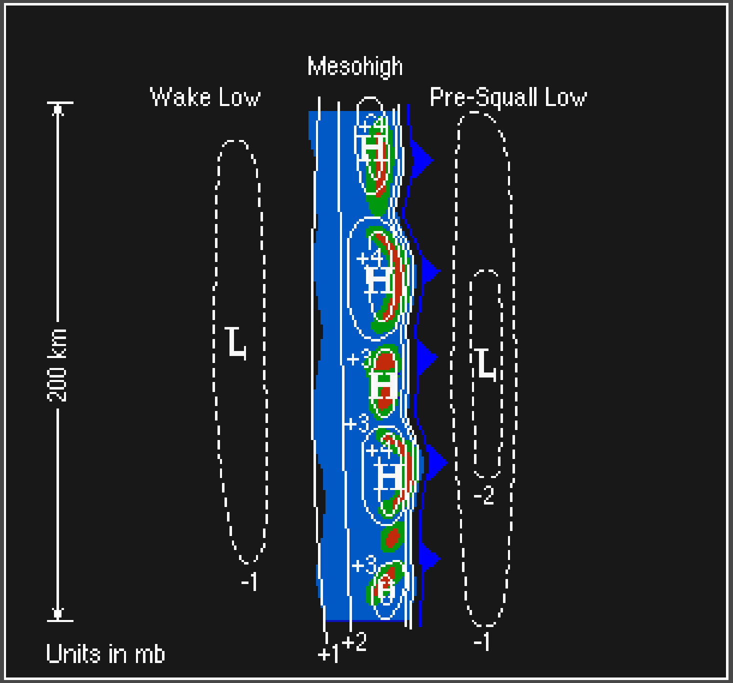
Moderate-Strong Shear Squall Line Evolution with Pressure Field



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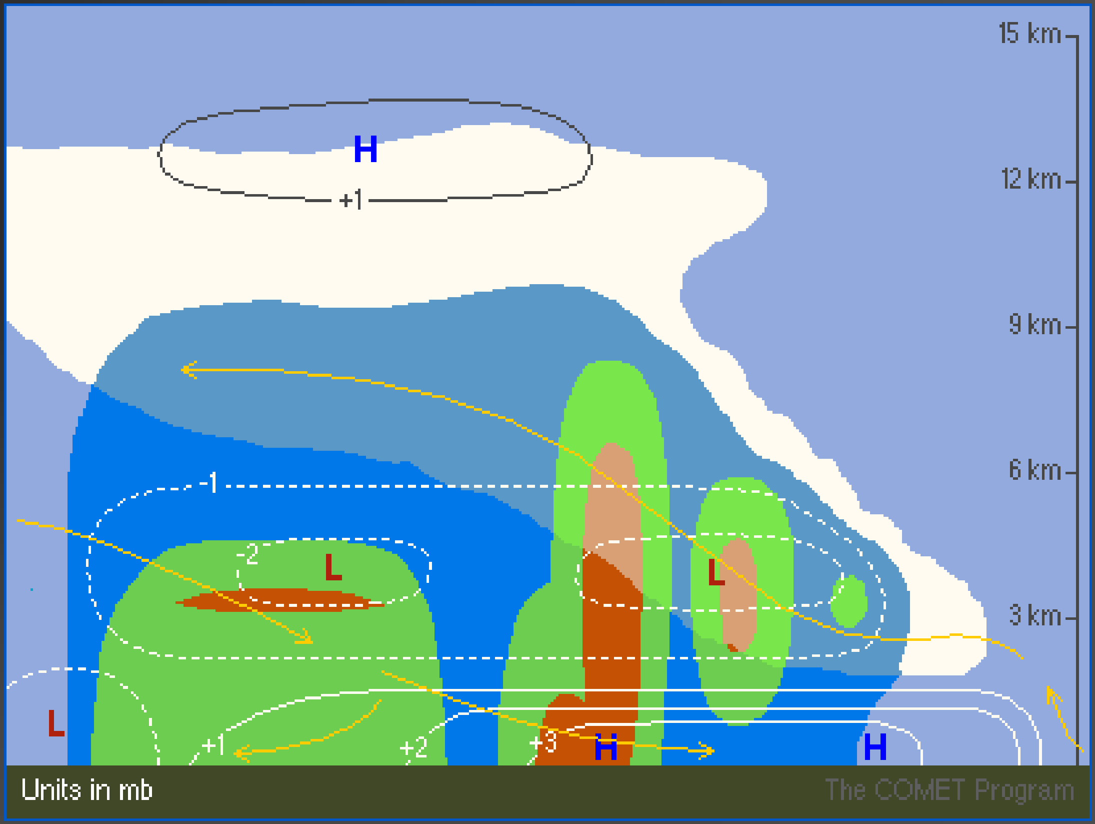
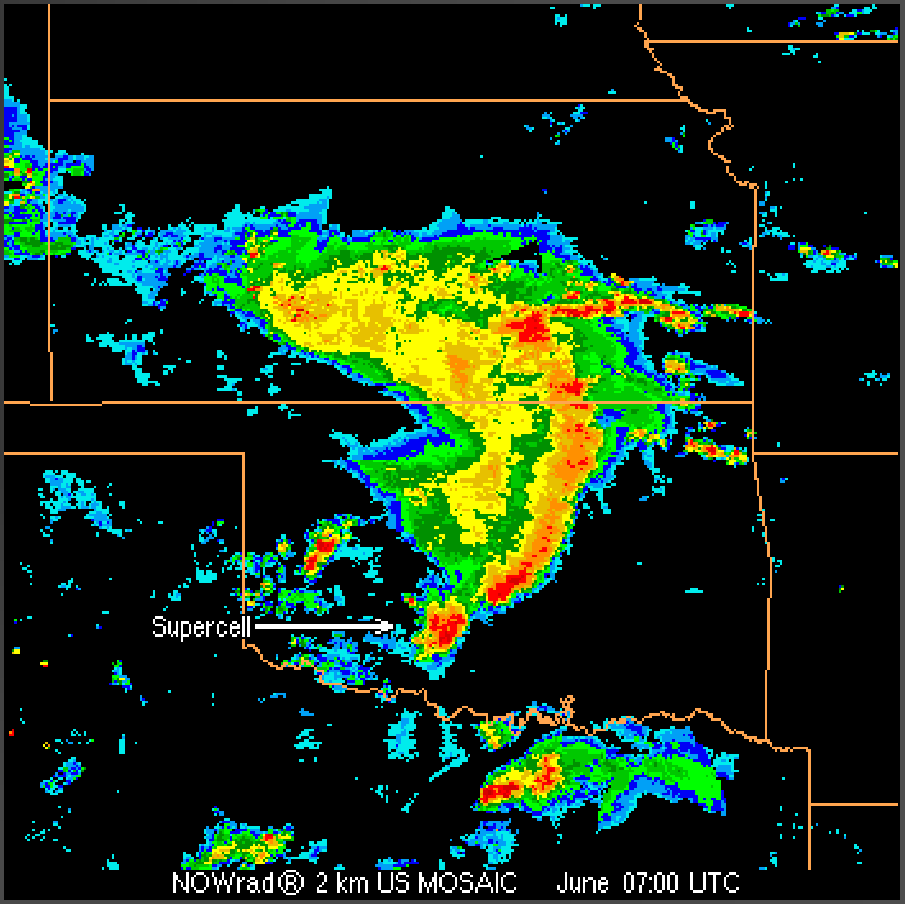
Vertical Cross Section View

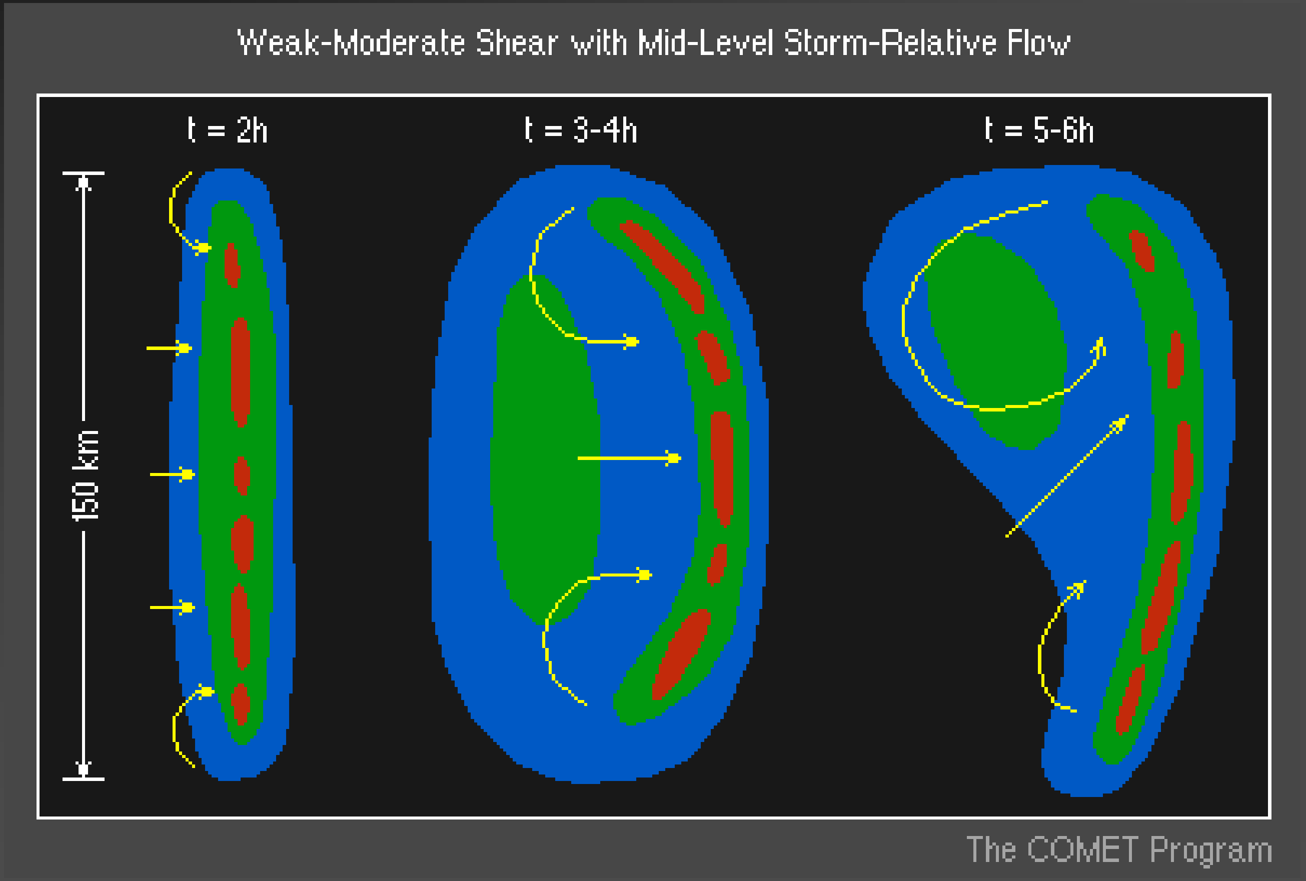


Likely Supercell Locations

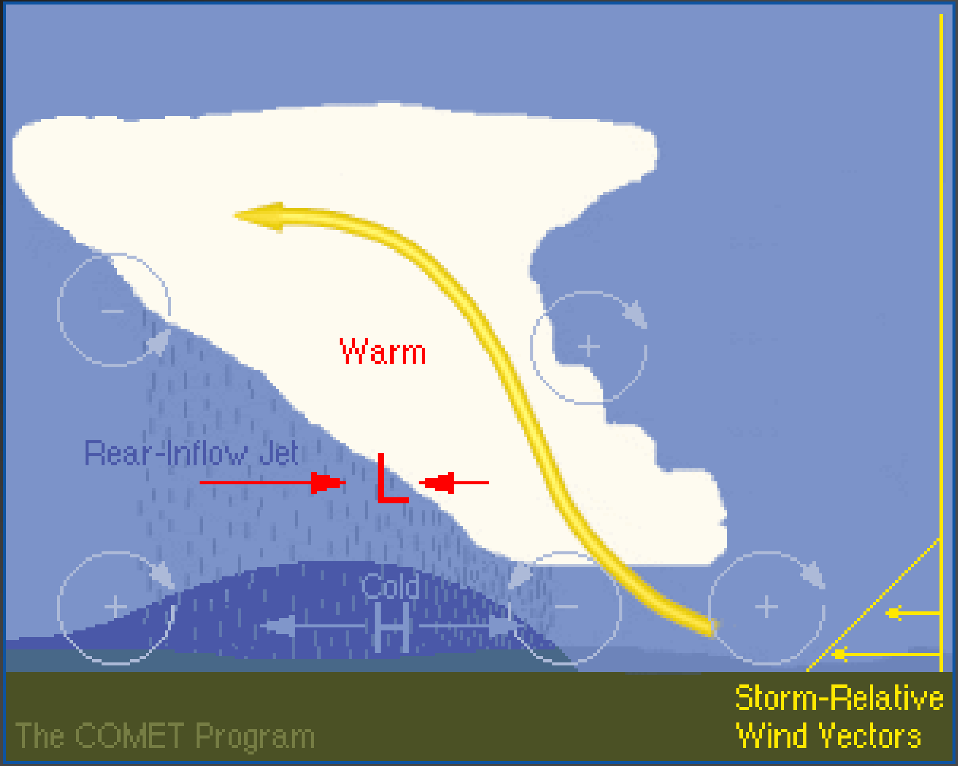
- Supercells within lines tend to become bow echoes, but cells at the ends of squall lines can remain supercellular for long periods of time



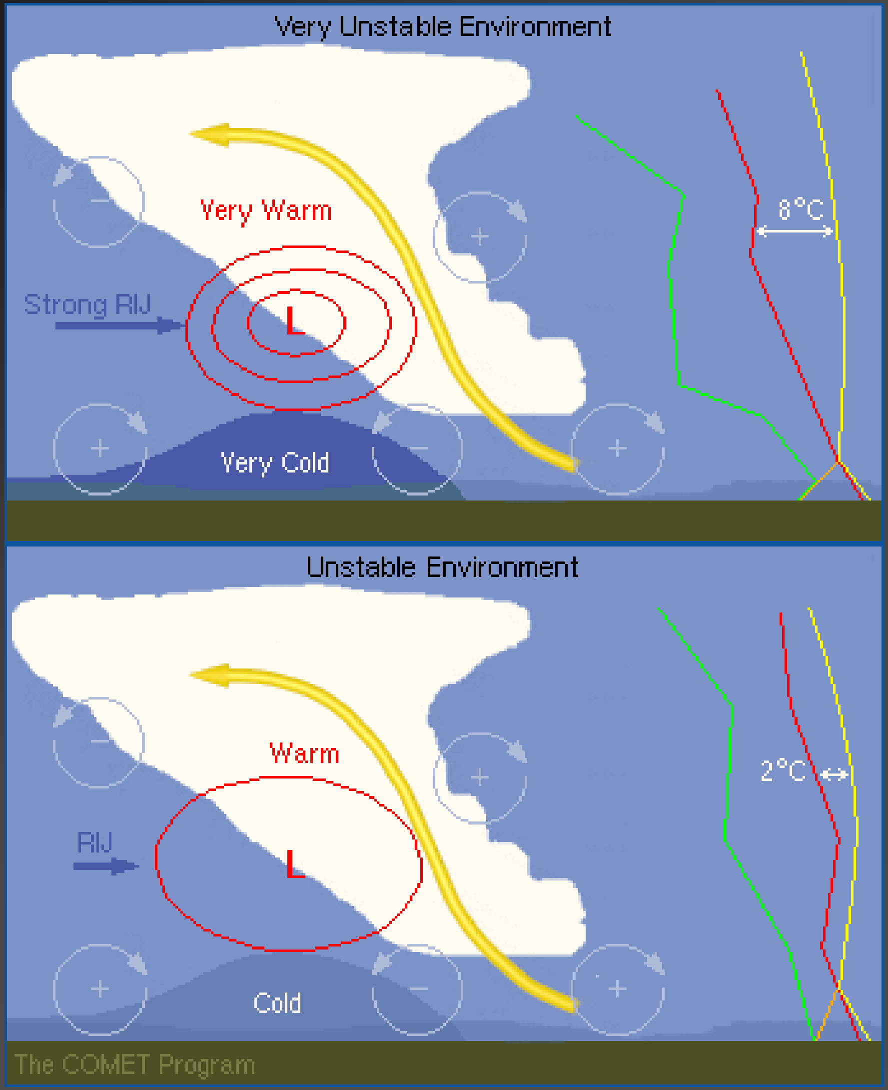
Later Evolution and the Coriolis Force (in weak-to-moderate shear)



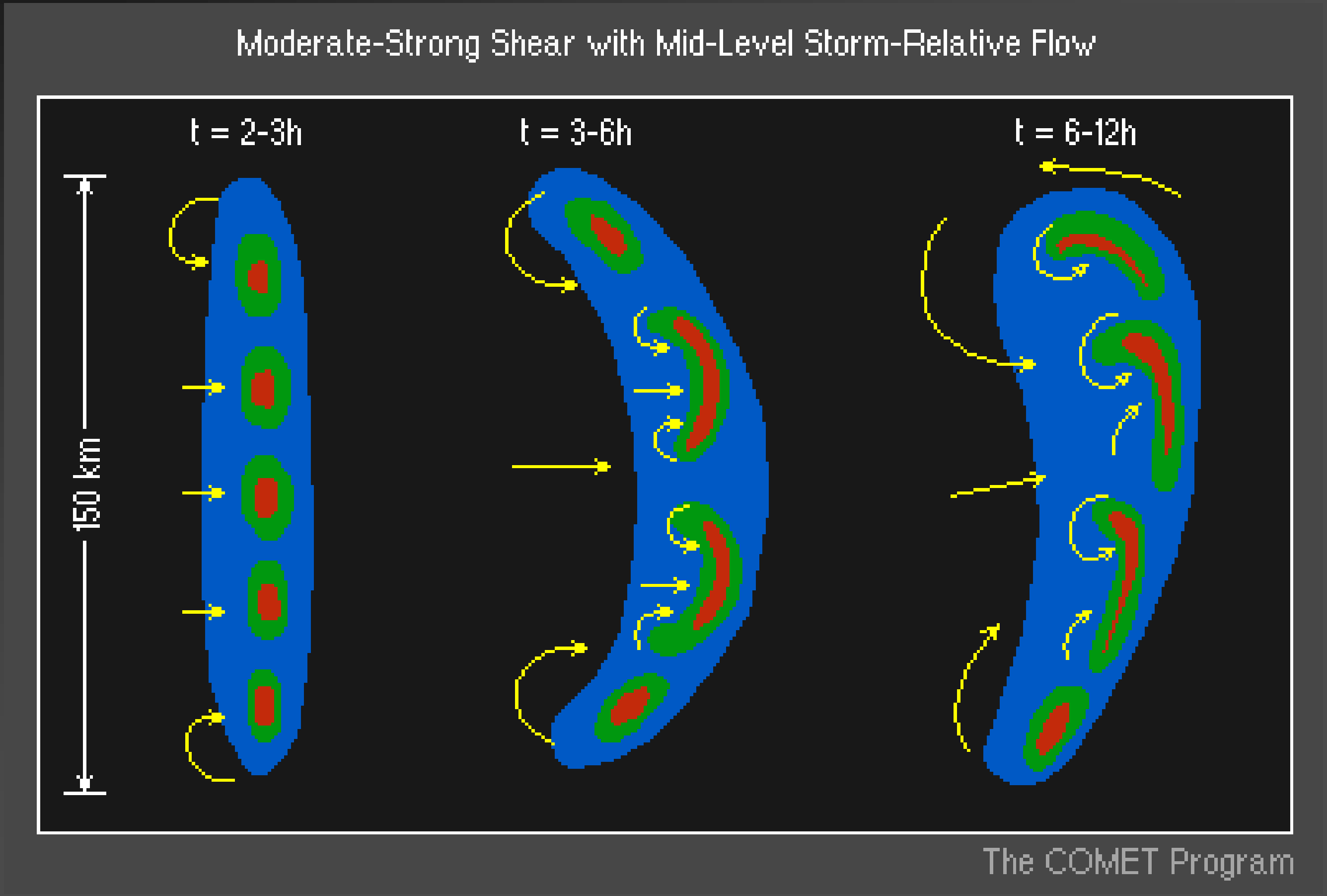
The Rear-Inflow Jet (RIJ)



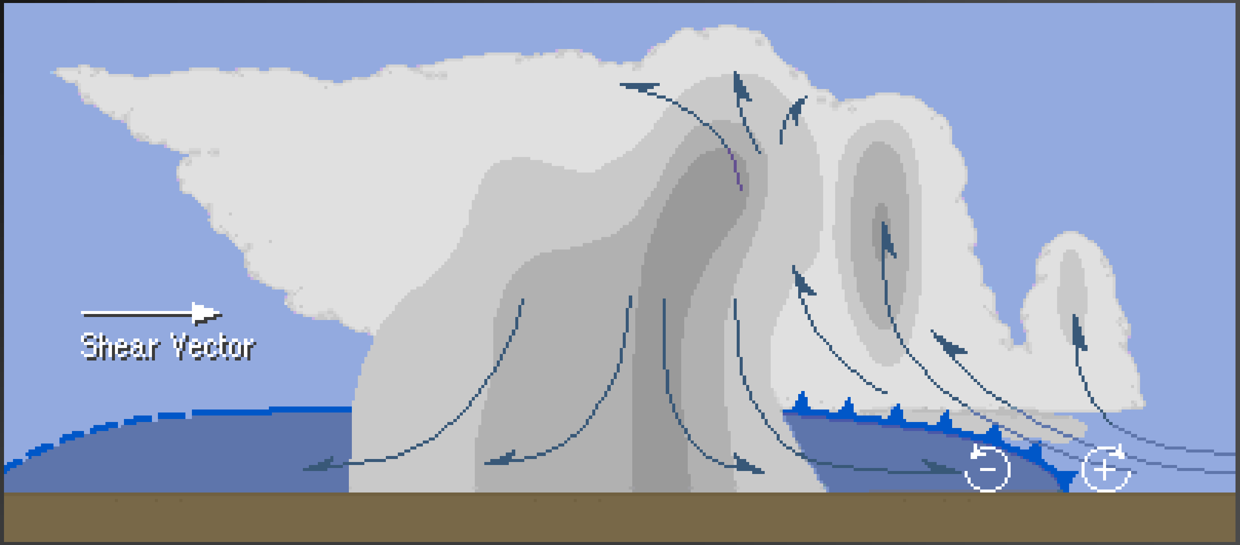
The RIJ cont.


Very Unstable Environment
Very Warm
Strong RIJ
L
Very Cold
8°C
+
−
Unstable Environment
Warm
RIJ
L
Cold
2°C
The COMET Program

Later Evolution and the Coriolis Force (in moderate-to-strong shear)



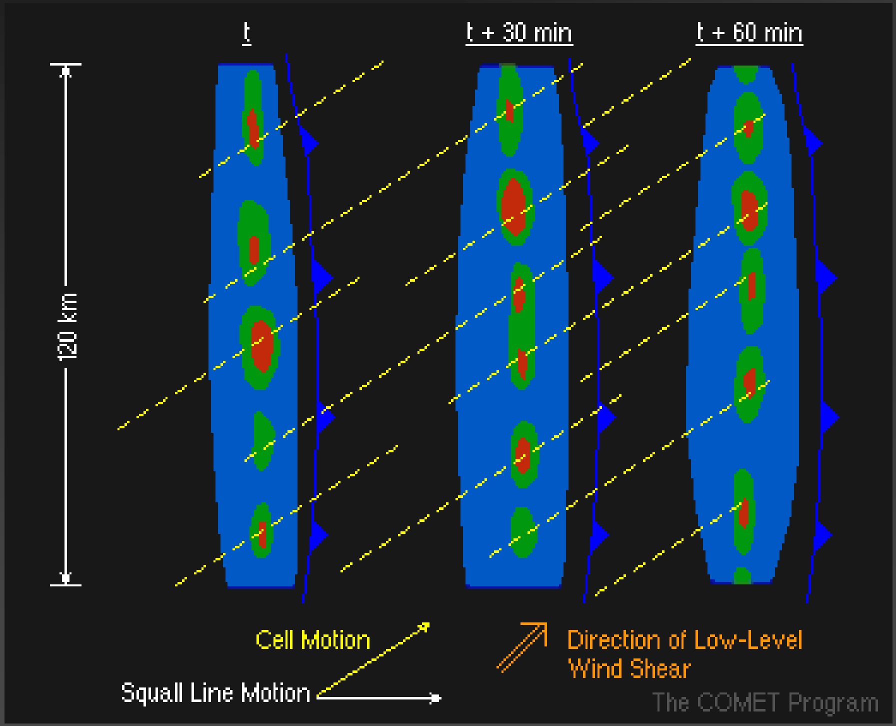
System Cold Pool Motion



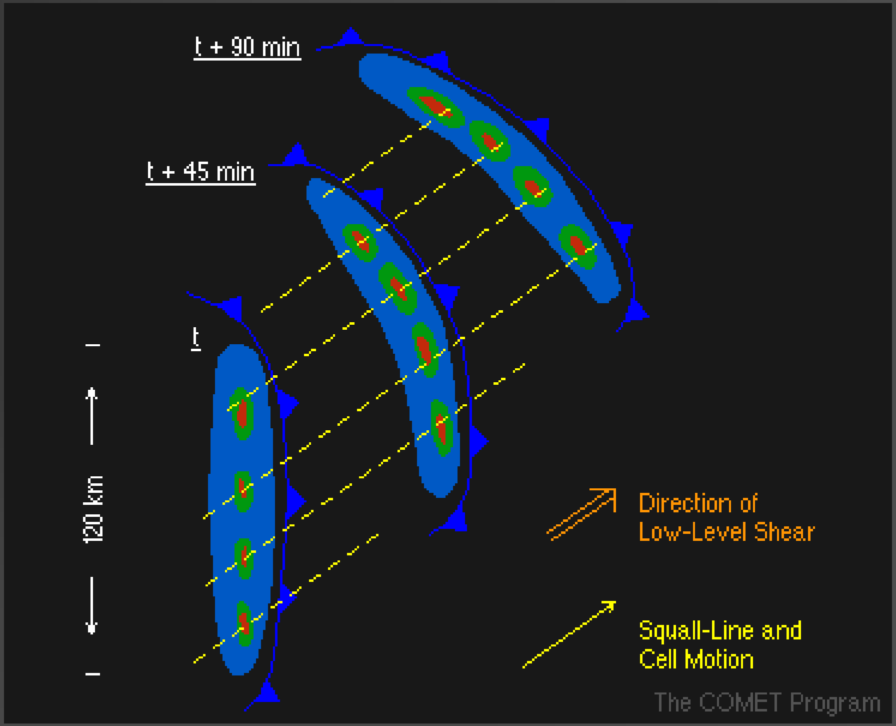
- The overall propagation speed of a squall line tends to be controlled by the speed of the system cold pool
  - new cells are constantly triggered along its leading edge
- At midlatitudes an "average" cold pool speed is on the order of ~20 m/s (40 kts).

Squall Line Motion

Segment of a long squall line



A short squall line, < 55 nm long

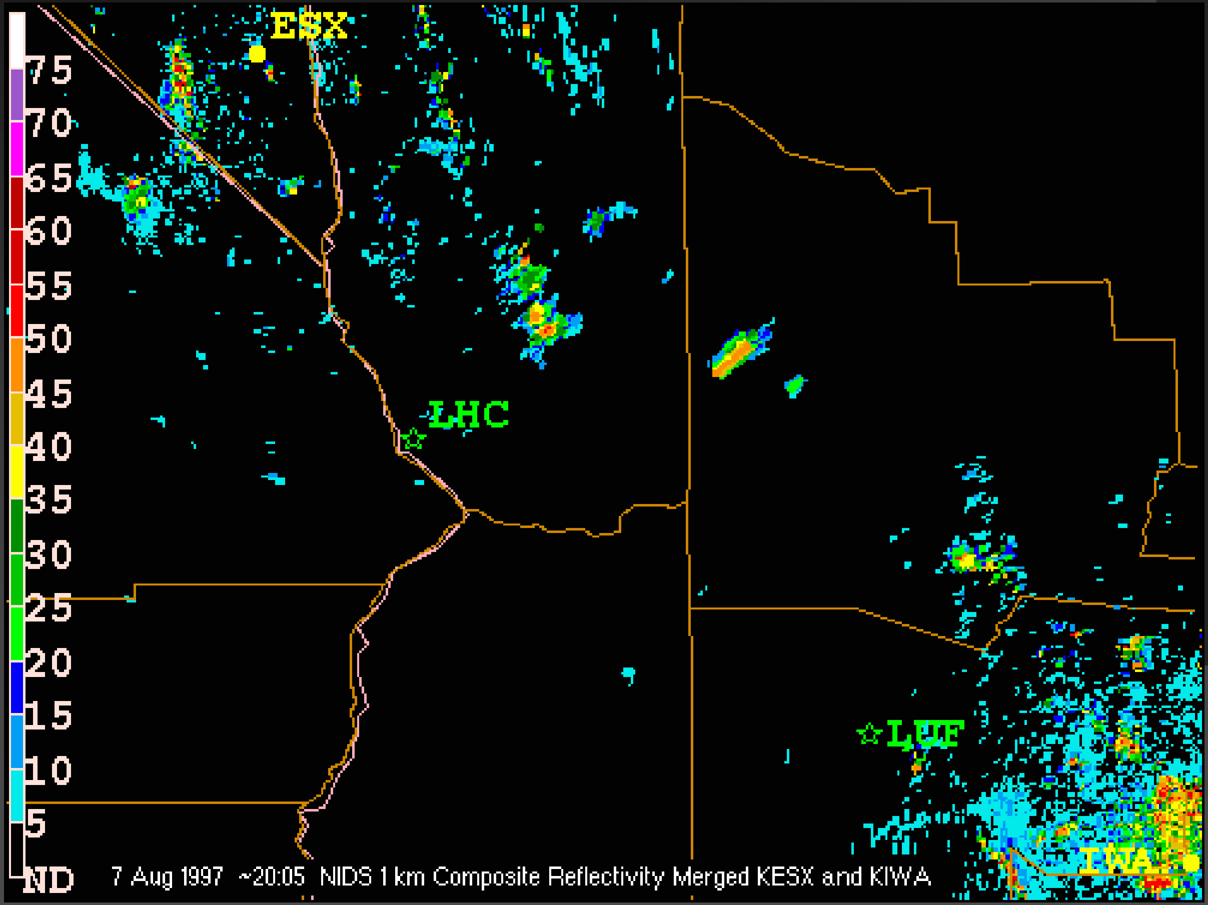


Tropical Squall Lines

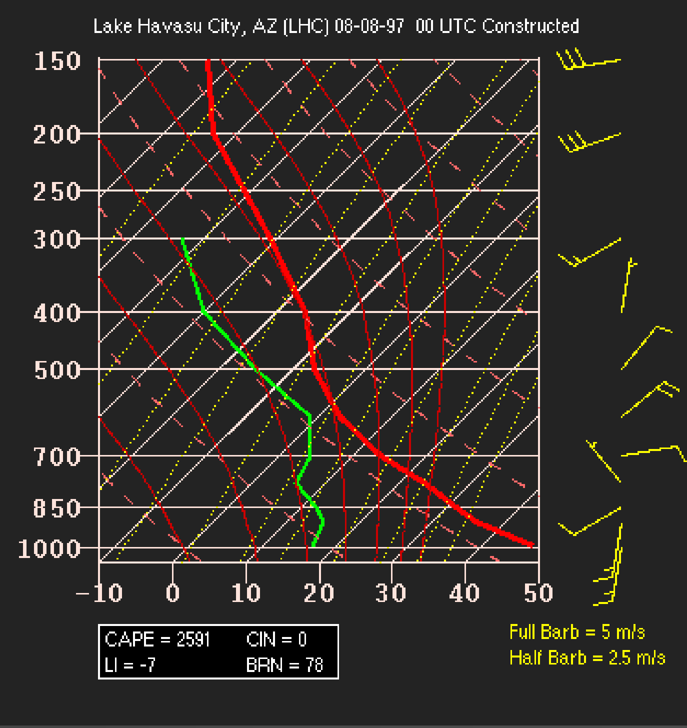
- Overall, squall lines in the tropics are structurally **very similar** to midlatitude squall lines. Notable differences include:
  - Develop in lower shear, lower LFC environments
  - Taller convective cells
  - system cold pools are generally weaker
  - less of a tendency toward asymmetric evolution AND
  - **Most tropical squall lines move from east to west rather than the west to east**

Sub-Tropical Squall Lines

Arizona Example



7 Aug 1997 ~20:05 NIDS 1 km Composite Reflectivity Merged KESX and KIWA



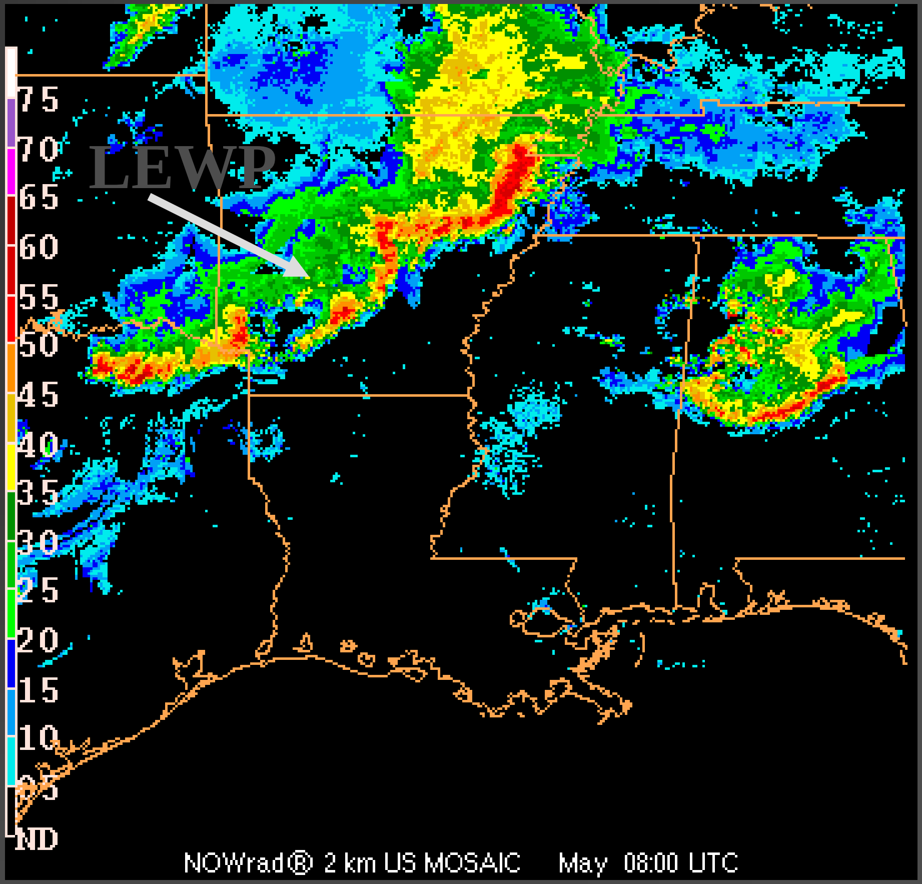
Lake Havasu City, AZ (LHC) 08-08-97 00 UTC Constructed

CAPE = 2591 CIN = 0
LI = -7 BRN = 78

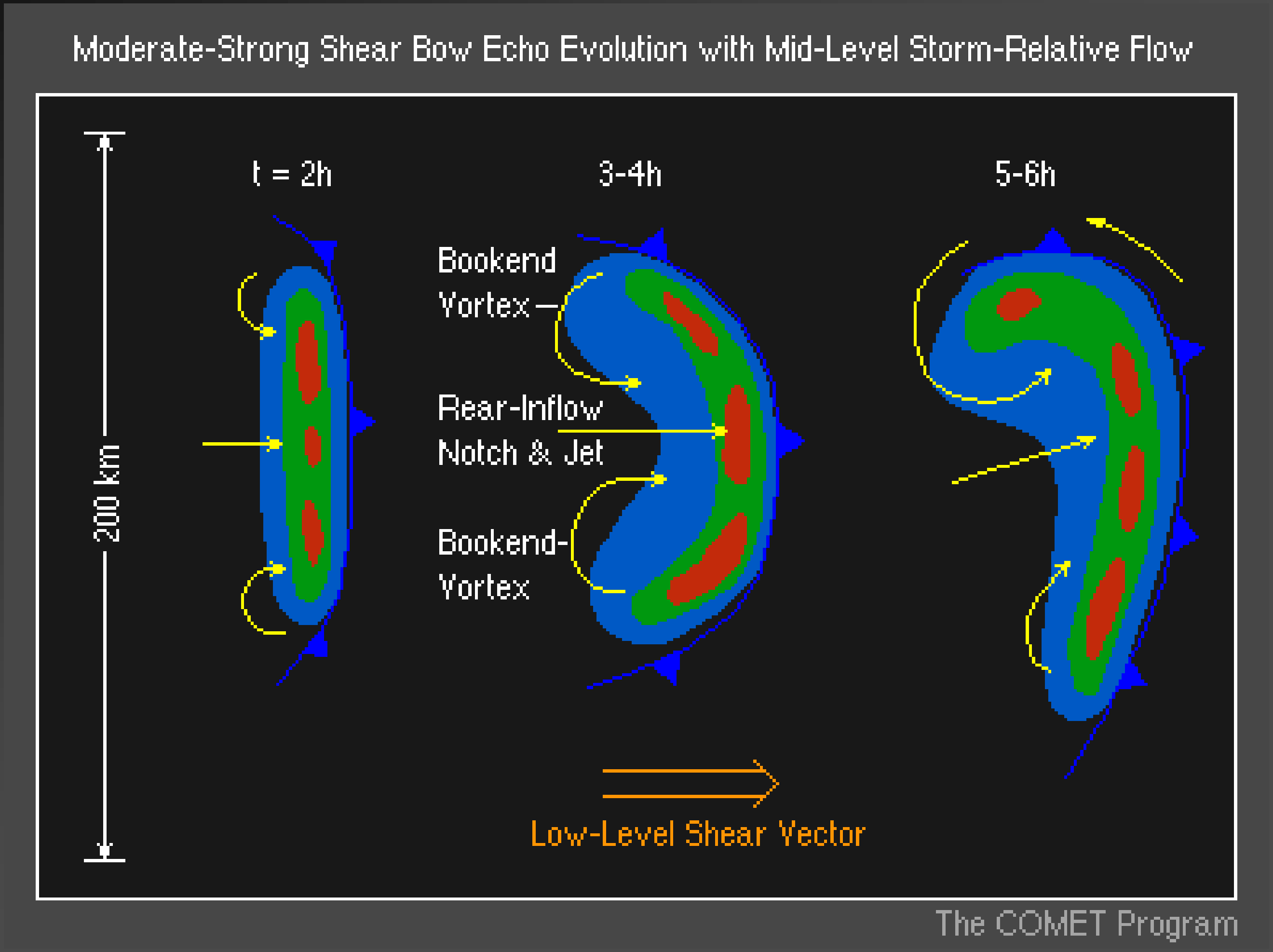
Bow Echoes

Bow Echo Definition

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



Bow Echo Evolution



Moderate-Strong Shear Bow Echo Evolution with Mid-Level Storm-Relative Flow

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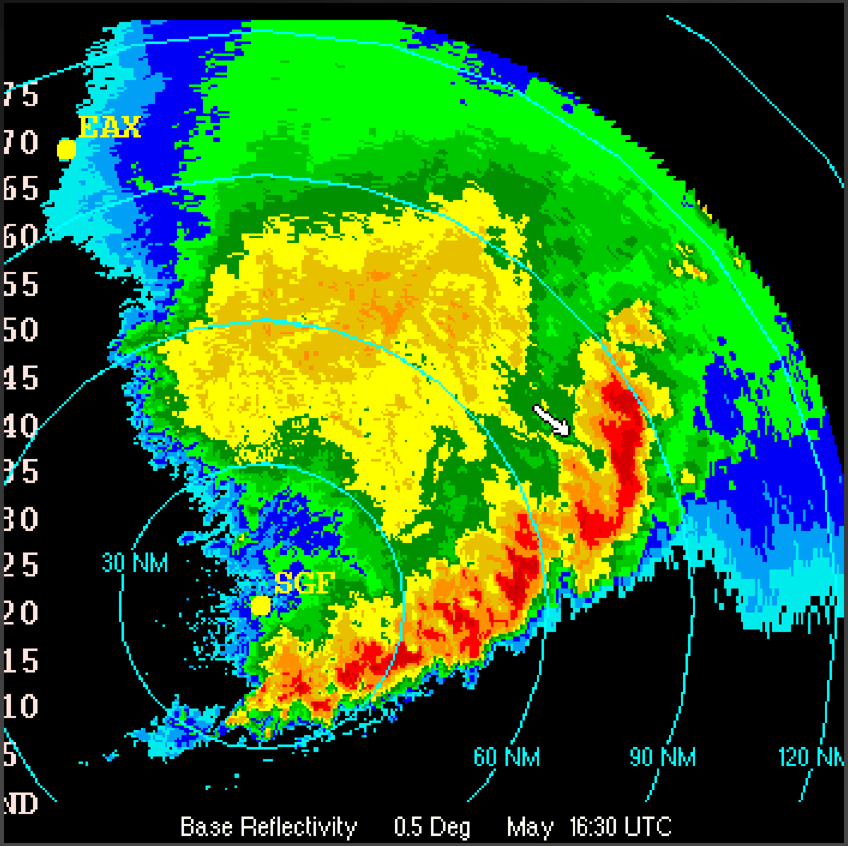
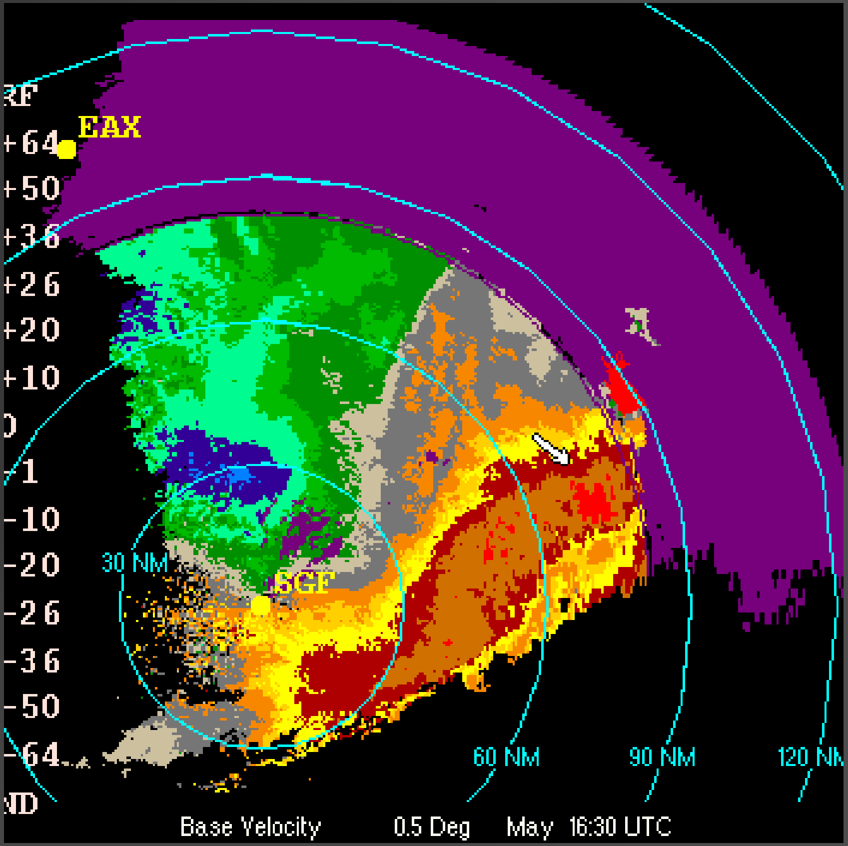
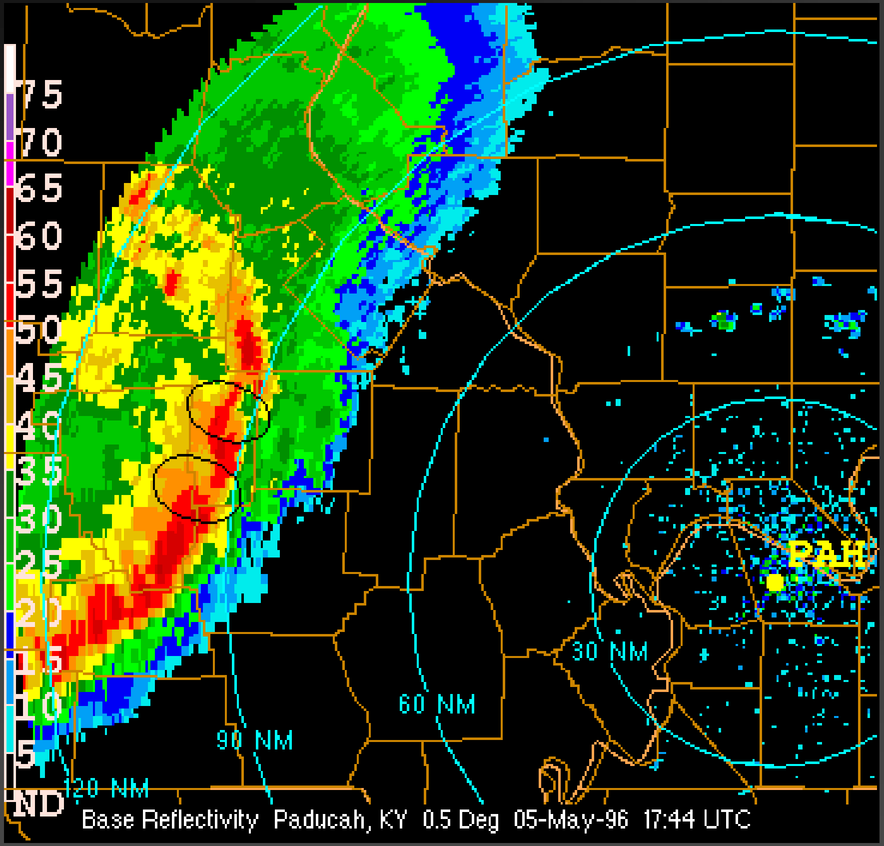
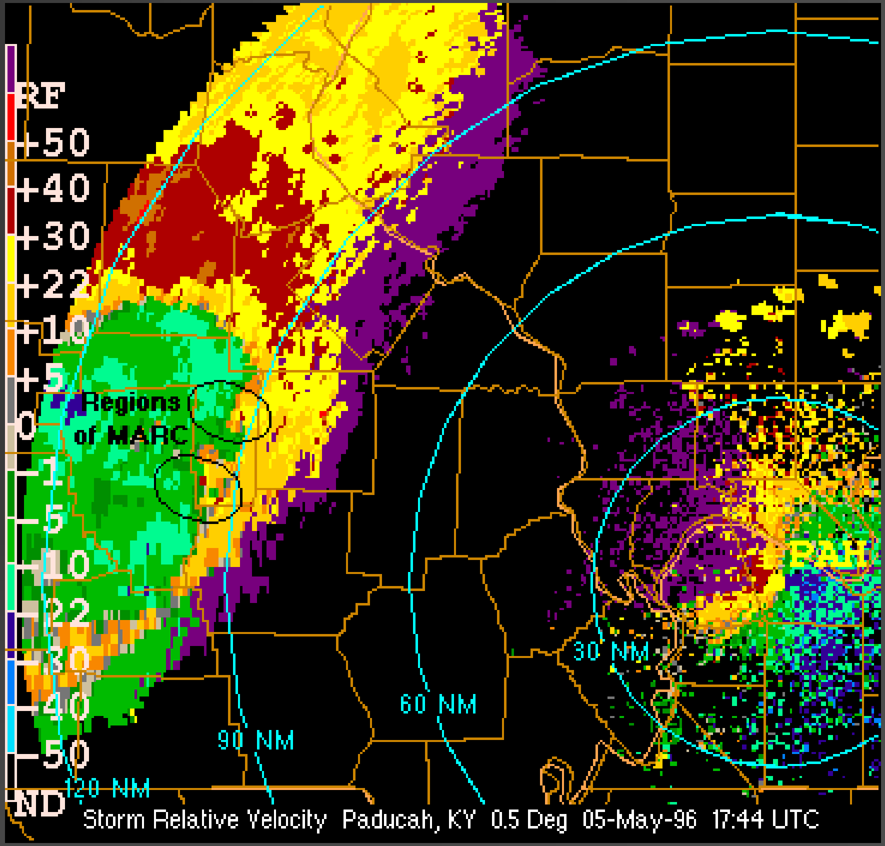
Rear-Inflow Notch Example





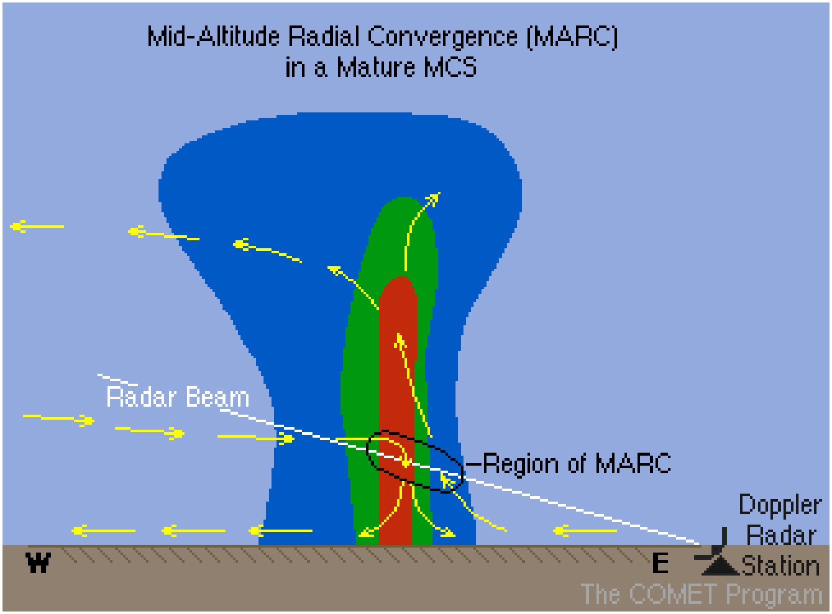
The MARC Signature


Base Reflectivity Paducah, KY 0.5 Deg 05-May-96 17:44 UTC

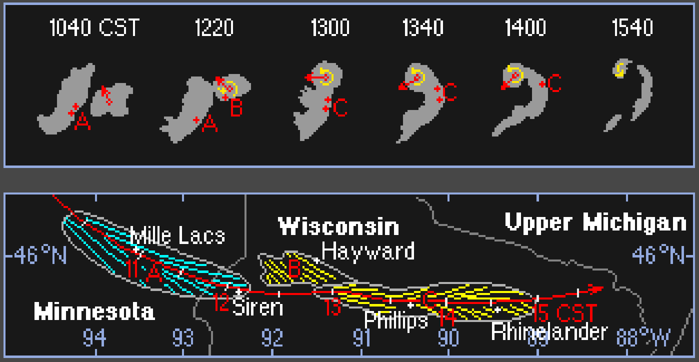

Storm Relative Velocity Paducah, KY 0.5 Deg 05-May-96 17:44 UTC

Summary of MARC Characteristics:

- Horizontal Extent
  - One to three locally enhanced convergent areas (velocity differentials) are found embedded within a larger region of convergence extending from 60 to 120 km (32 to 65 nm) in length
- Width
  - 2 to 6 km (1 to 3 nm)
- Depth
  - Average of 6.2 km (from 3 - 9 km or 9,800 - 29,500 ft) in height, with the maximum convergence found in the mid-levels of the storm (between 5 and 5.5 km or 16,400 and 18,000 ft in height)
- Magnitude
  - Typical velocity differences of 25 to 50 m/s (50 to 100 kts)

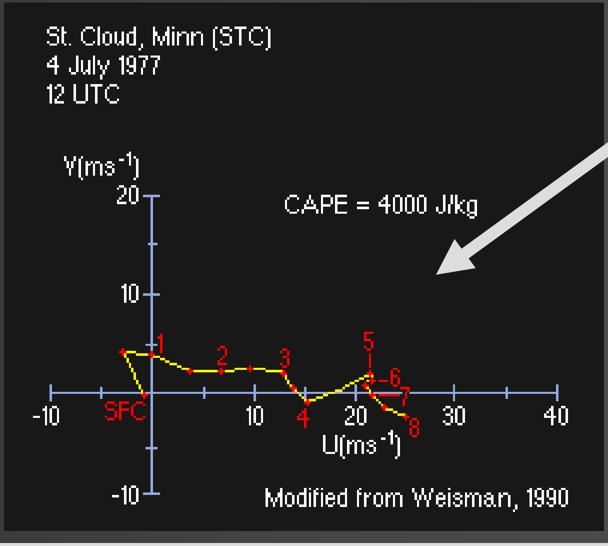


Bow Echo Environments



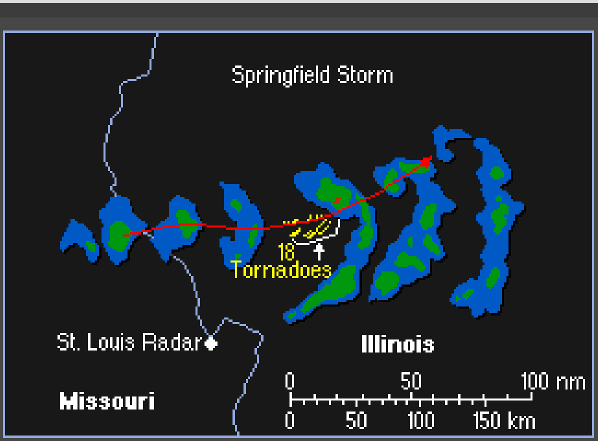
Evolution of a bow echo into a comma echo during the 4th of July, 1977 downbursts. Downbursts "A" and "C" were associated with a bow echo while "B" was associated with a hook echo.

Modified from Fujita, 1978


St. Cloud, Minn (STC)
4 July 1977
12 UTC

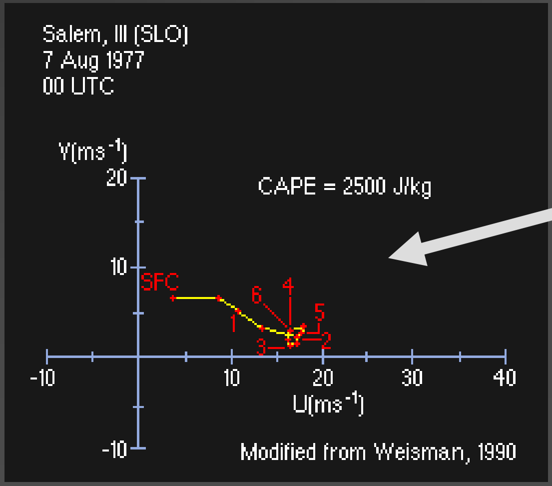
CAPE = 4000 J/kg

Modified from Weisman, 1990



Evolution of radar echoes associated with downbursts and tornadoes of August 6, 1977.

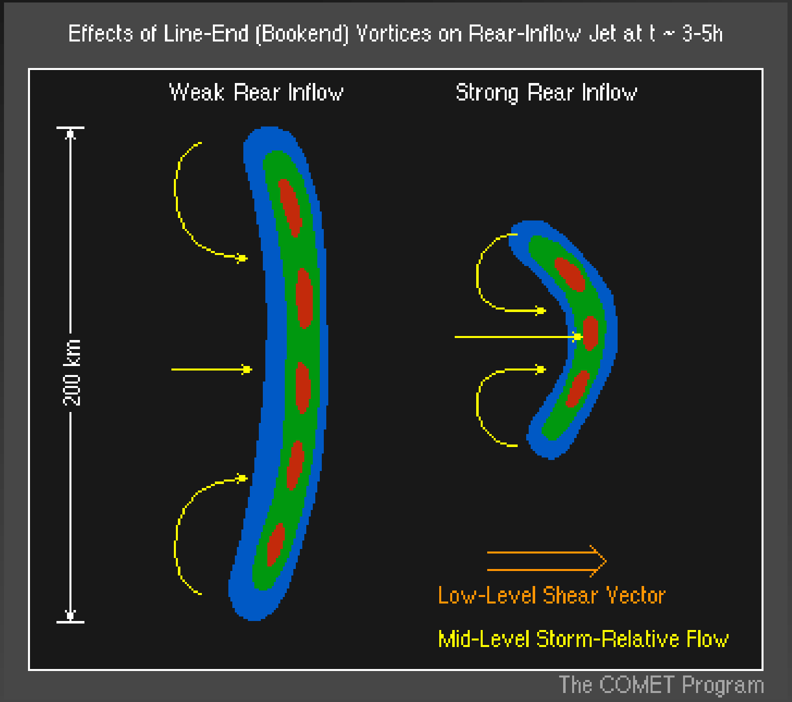
Modified from Fujita, 1978

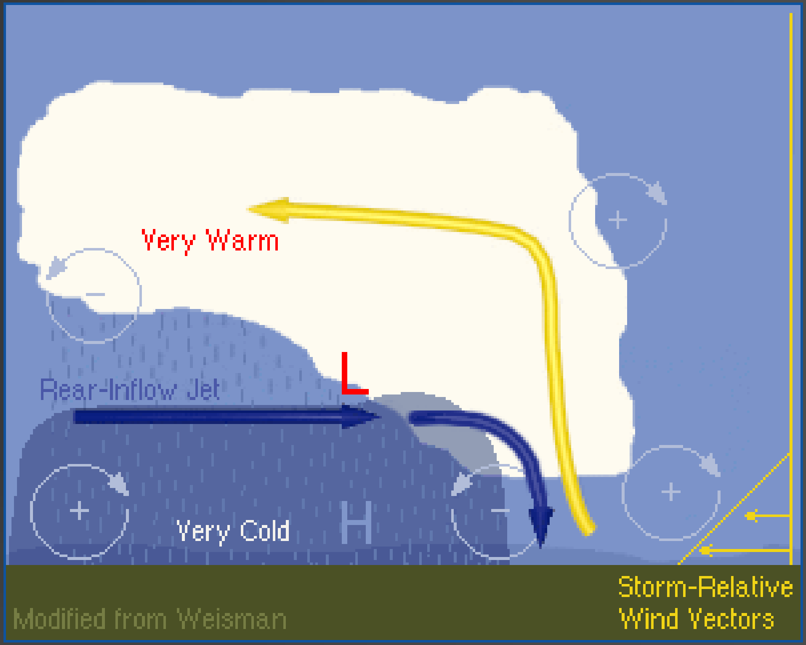

Salem, Ill (SLO)
7 Aug 1977
00 UTC

CAPE = 2500 J/kg

Modified from Weisman, 1990

Reasons for Bow Echoes Intensity



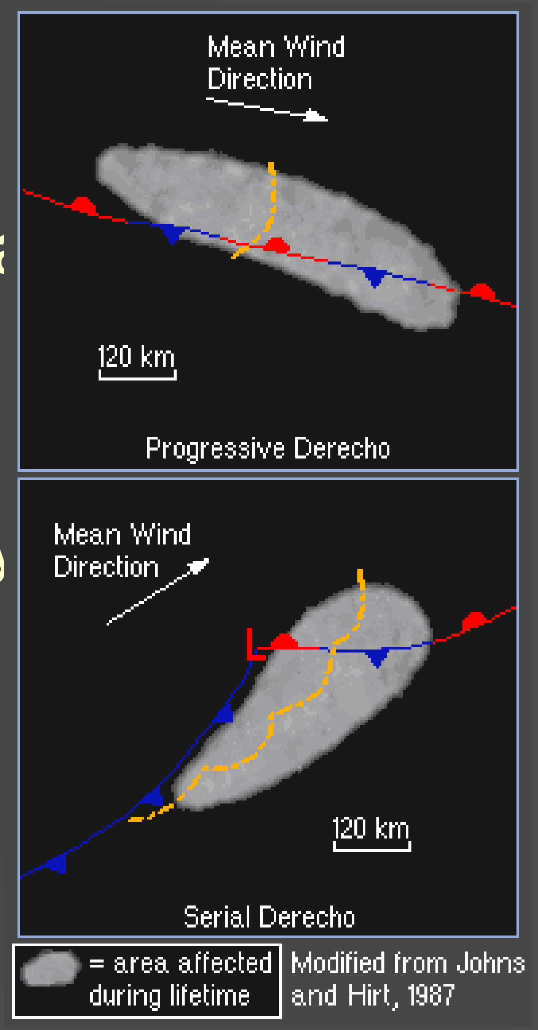


Derechoes Definition

- 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.
    - To be classified as a derecho, a **single convective system** must produce wind damage or gusts greater than **26 m/s (50 kts**) within a **concentrated area** with a major axis length of at least **400 km (250 nm).** The severe wind reports must exhibit a **chronological progression** and there must be at least **3 reports of F1 damage** and/or **convective wind gusts of 33 m/s (65 kts)** or greater **separated by at least 64 km** (40 nm). Additionally, **no more than 3 hours** can elapse between successive wind damage or gust events.

Derechoes cont.

- Progressive derechos are typically a single bow-shaped system that propagates north of and parallel to a weak east-west oriented stationary boundary
- Serial derechos are most commonly a series of bow-echoes along a squall line (usually located within the warm sector of a cyclone)



Modified from Johns and Hirt, 1987

Summary

- MCS structure and evolution depend on the characteristics of the environmental buoyancy and shear, as well as the details of the initial forcing mechanism.
- The strength and the degree of organization of most MCSs increases with increasing environmental vertical wind shear values.
- The most significant unifying agent for boundary-layer-based MCSs is the surface cold pool.
  - MCS evolution is heavily controlled by the interaction between the cold pool and the low-level vertical wind shear.
- Since MCSs usually last for > 3 hrs, the Coriolis effect significantly impacts system evolution.

References

- http://meted.ucar.edu/convectn/mcs/index.htm
- Hilgendorf, E.R. and R.H. Johnson, 1998: A study of the evolution of mesoscale convective systems using WSR-88D data. Wea. Forecasting, 13, 437-452.
- Houze, R.A., 1977: Structure and Dynamics of a Tropical Squall-Line System. Mon. Wea. Rev., 105, 1540-1567.
- Johns, R.H., 1993: Meteorological conditions associated with bow echo development in convective storms. Wea. Forecasting, 8, 294-299.
- Johnson, R.H., and P.J. Hamilton, 1988: The relationship of surface pressure features to the precipitation and airflow structure of an intense midlatitude squall line. Mon. Wea. Rev., 116, 1444-1472.
- Maddox, R. A., 1983: Large-Scale Meteorological Conditions Associated with Midlatitude, Mesoscale Convective Complexes. Mon. Wea. Rev., 111, 1475-1493.
- Przybylinski, R.W., 1995: The bow echo: Observations, numerical simulations, and severe weather detection methods. Wea. Forecasting, 10, 203-218.