Chapter 3
Convective Dynamics
(Part III, Squall Lines)

3.4. Squall Lines
Observations, Theories and Numerical Modeling

Text book materials to read:
Houze sections 8.11, 9.2
Bluestein Part II section 3.4.9

Squall Lines

- We are going to look at
  - General Characteristics of Squall Lines – organization, structure, weather
  - Conceptual Models
  - Theories of Long-lived Squall Lines

Squall Lines – Definition

- **Squall Line is a type of multicell storm - consist of a line of storms with a continuous, well developed gust front at the leading edge of the line.**
- **These storms can produce small to moderate size hail, occasional flash floods and weak tornadoes.**

Squall Lines – Definition

- Squall lines are bands of precipitation that are at least partly convective.
- Frontal rainbands containing only forced precipitation are not considered squall lines
- Squall lines can stretch hundreds or even thousands of kilometers in length and last for many hours. They therefore fall into the category of mesoscale convective system.

Radar View of Squall Lines

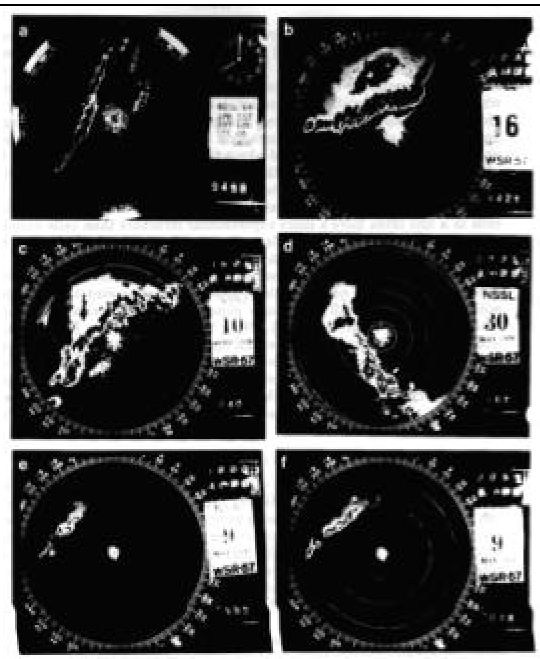
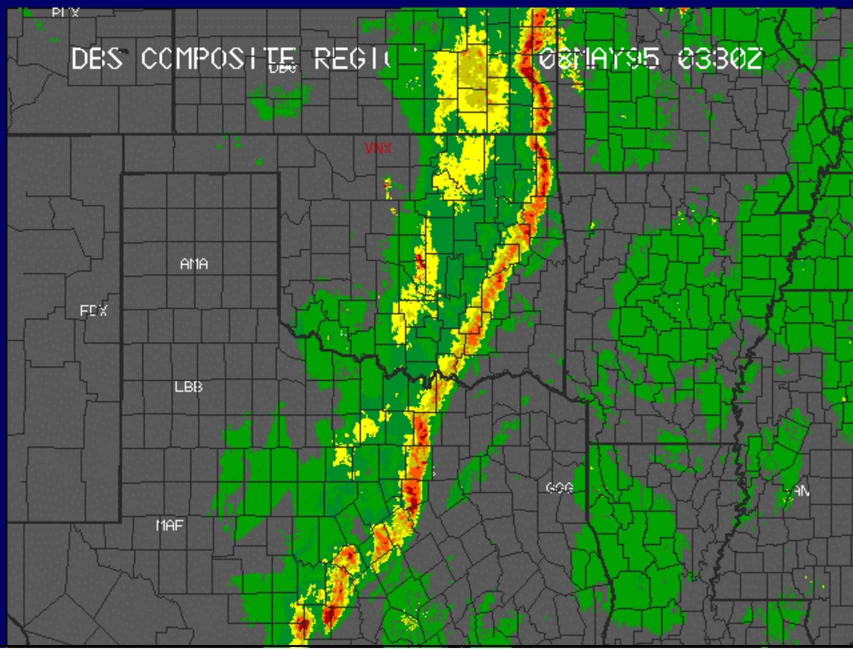
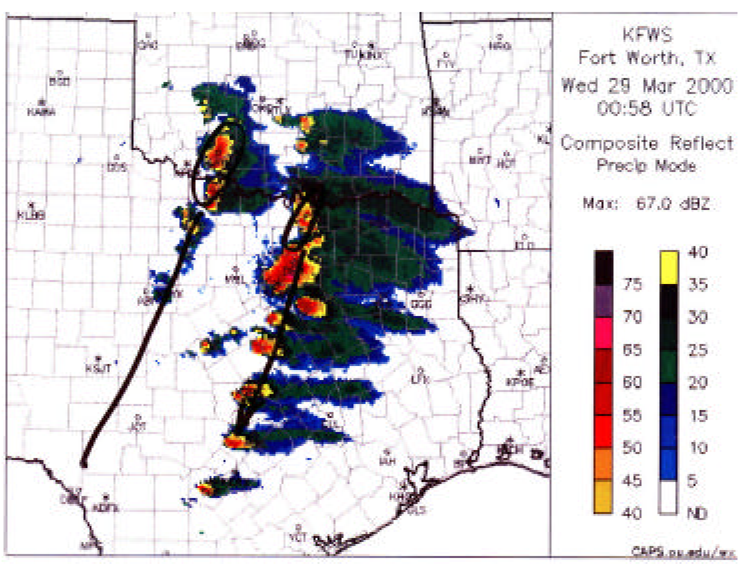


Figure 16.1. PPI displays of squall lines from the WSR-57 radar at the National Severe Storms Laboratory, Norman, Okla. Squall lines occurred on (a) 26 April 1969; (b) 16 May 1977; (c) 10 April 1979; (d) 30 May 1979; (e,f) 9 May 1979.

7 May 1995 Squall Line with Trailing Stratiform Precipitation



A squall line made up of discrete thunderstorms



Idealized Formation of Squall Lines

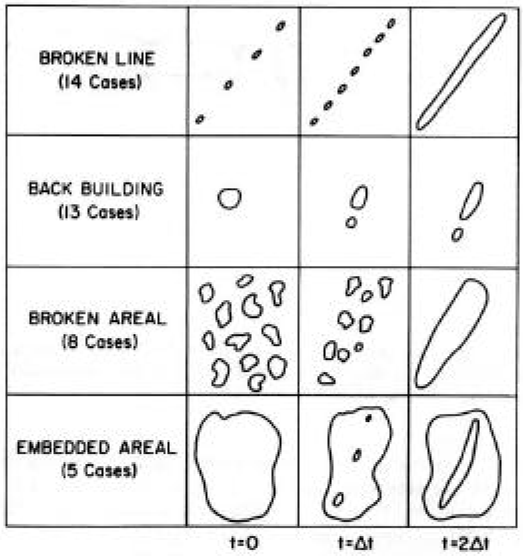


Figure 3.72 Idealized depiction of squall-line formation in the Southern Plains of the United States during the spring (from Bluestein and Jain, 1985). (Courtesy of the American Meteorological Society)

Composite Sound and Hodograph of Squall Line Cases Studied by Bluestein and Jain (1985)

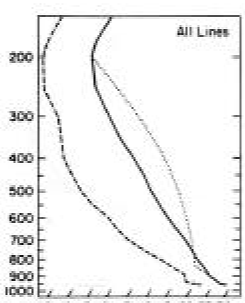


Figure 3.74 Composite sounding for severe squall lines in the Southern Plains of the United States during the spring. Skewed abscissa and logarithmic ordinate are the temperature (°C) and pressure (mb), respectively. Temperature and dew-point profiles plotted as solid lines and dashed lines, respectively. Path taken in temperature–pressure space by surface air parcel as it ascends (dotted line) (from Bluestein and Jain, 1985). (Courtesy of the American Meteorological Society)

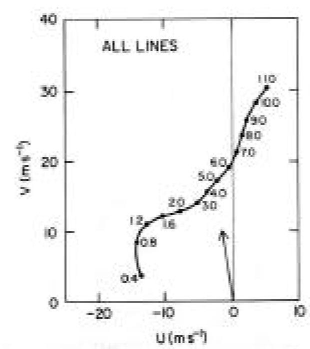


Figure 3.75 Composite hodograph, in a coordinate system moving along with the line, for severe squall lines in the Southern Plains of the United States during the spring. The cell motion is indicated by the vector (from Bluestein and Jain, 1985). (Courtesy of the American Meteorological Society)

Cross-section through a squall line of 21 May 1961 that passed OKC (after Newton 1966)

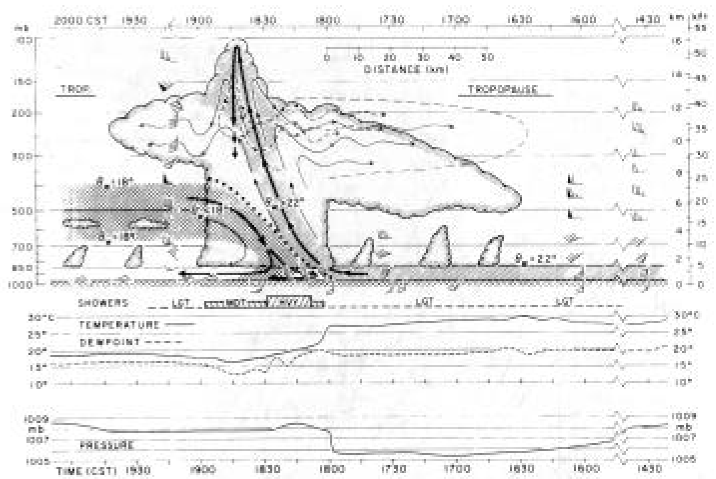


Figure 16.5b. Cross section through squall line of 21 May 1961 as it passed Oklahoma City. Hatching indicates probable extent of high θ_w air of low-level origin; cross-hatching indicates location of low θ_w air of probably middle-level origin. Heavy arrows are axes of main drafts; thin arrows are streamlines, dashed where air emanates from core of stratospheric tower. Long dashes suggest outline of air plume originating in storm; at lower altitude cloud plume consists of small precipitation particles. (After Newton, 1966.)

Conceptual Model Squall Lines with Trailing Stratiform Precipitation (Houze 1989)

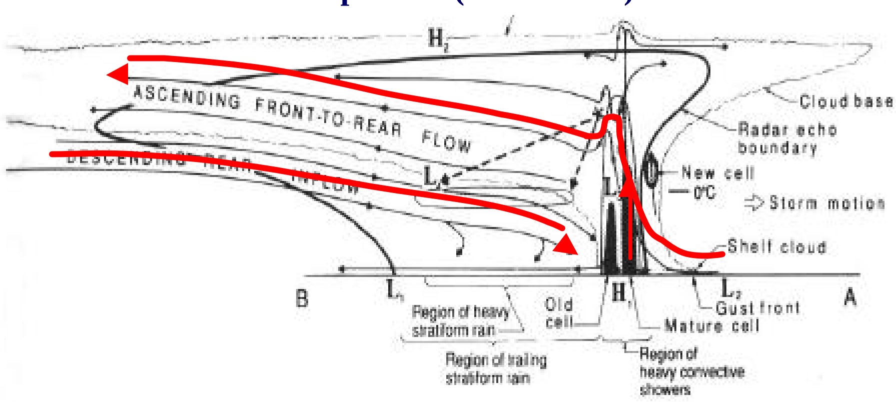


Figure 9.13 Conceptual model of the kinematic, microphysical, and radar-echo structure of a convective line with trailing stratiform precipitation viewed in a vertical cross section oriented perpendicular to the convective line (and generally parallel to its motion). Intermediate and strong radar reflectivity is indicated by medium and dark shading. The location of line AB is shown in Fig. 9.14. (From Houze *et al.*, 1989. Reproduced with permission from the American Meteorological

Vertical cross section and surface pressure, wind and precipitation distributions during the matur stage of a squall line

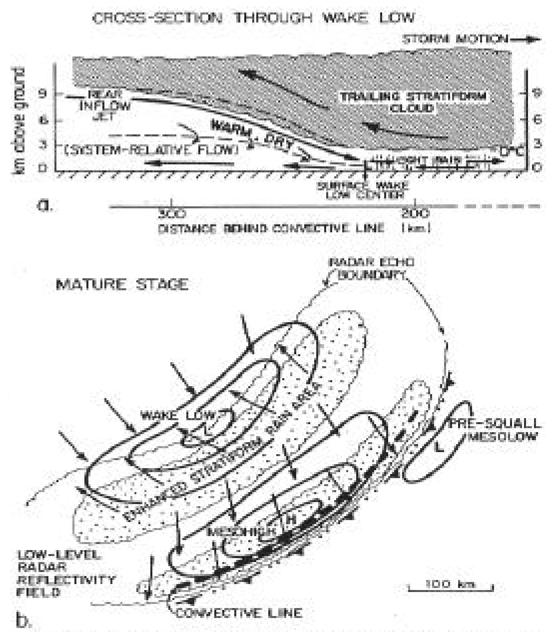
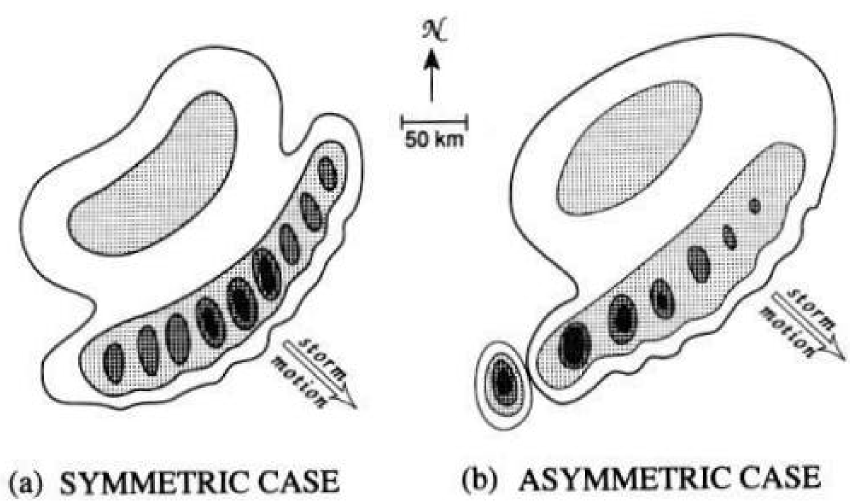


FIG. 25. Schematic cross section through wake low (a) and surface pressure and wind fields and precipitation distribution during squall line mature stage (b). Winds in (a) are system-relative with the dashed line denoting zero relative wind. Arrows indicate streamlines, not trajectories, with those in (b) representing actual winds. Note that horizontal scales differ in the two schematics.

Common patterns of mature mesoscale convective systems – a leading line of convective showers trailed by a region of stratiform rain



Common patterns of mature mesoscale convective systems

The leading *convective line* has

1. Arc shape (convex toward the leading edge).

2. Generally northeast-southwest orientation.

3. Rapid movement with an eastward and/or southward component (<10 m s * in a direction normal to the line orientation).

4. Solid appearance (a series of intense reflectivity cells solidly connected by an echo of more moderate intensity).

5. Very strong reflectivity gradient at leading edge (i.e., gradient much stronger at the leading edge than the back edge of the convective region).

6. Serrated leading edge (leading edge of echo is jagged, with forward- extending protrusions at an apparent wavelength ~ 5-10 km).

7. Elongated cells oriented 45-90° with respect to line

Common patterns of mature mesoscale convective systems

The *trailing stratiform region* has:

8. *Large size ($>10^{4}$* km^2 in horizontal area).

9. *Notch-like concavity at rear edge* (believed to be associated with meso-scale inflow of dry air that erodes a portion of the stratiform echo).

10. *A secondary maximum of reflectivity* (separated from the convective line by a narrow channel of lower reflectivity).

Life cycle of a precipitation area associated with a typical squall line

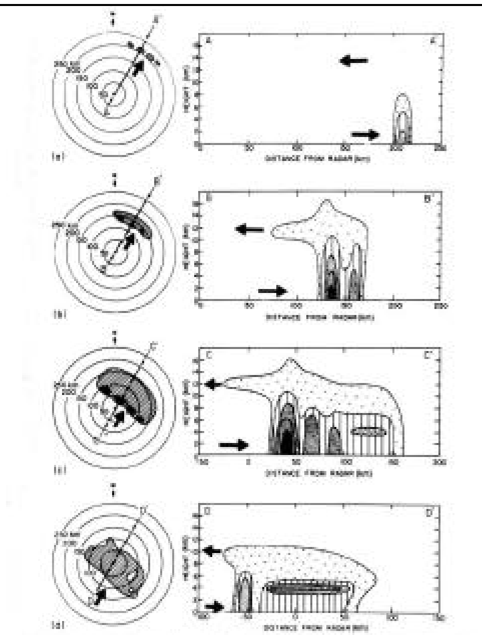


Figure 9.11 Schematic of the life cycle of the precipitation area of a mesoscale convective system as it would appear on radar in horizontal and vertical cross sections during (a) formative, (b) intensifying, (c) mature, and (d) dissipating stages. The outside contour of radar reflectivity represents the weakest detectable echo. The inner contours are for successively higher reflectivity values. Heavy arrows indicate the direction of the wind relative to the system. (From Leary and Houze, 1979. Reproduced with permission from the American Meteorological Society.)

Theories for Intense, Long-Lived Squall Lines

- Three theories for long-lived squall lines – all deal with the optimal environmental conditions for them.
  - Thorpe, Miller and Moncrieff (1978, TMM theory, UK)
  - Rotunno, Klemp and Weisman (1988, RKW theory, NCAR)
  - Xue, Xu and Droegemier (OU)