Chapter 3
Convective Dynamics
(Part III, Squall Lines)

3.5. Squall Lines
Observations, Theories and Numerical Modeling

Text book materials to read:
Bluestein Part II section 3.4.9
Houze sections 8.11, 9.2
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 10-1: PPI displays of squall lines from the WSR-57 radar at the National Severe Storms Laboratory, Norman, Okla. Squall lines occurred on (a) 20 April 1989; (b) 18 May 1977; (c) 16 April 1979; (d) 30 May 1979; (e) 9 May 1979.
A squall line made up of discrete thunderstorms

Idealized Formation of Squall Lines

<table>
<thead>
<tr>
<th>BROKEN LINE</th>
<th>BACK BUILDING</th>
<th>BROKEN AREAL</th>
<th>EMBEDDED AREAL</th>
</tr>
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<tbody>
<tr>
<td>(14 Cases)</td>
<td>(5 Cases)</td>
<td>(8 Cases)</td>
<td>(5 Cases)</td>
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Figure 3.72: Idealized depiction of squall-line formation in the Southern Plains of the United States during the spring (from Bluestein and Jain, 1989). (Courtesy of the American Meteorological Society)
Composite Sound and Hodograph of Squall Line Cases Studied by Bluestein and Jain (1985)

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

Figure 3.74 Composite sounding for severe squall lines in the Southern Plains of the United States during the spring. Shown are altitude and isobars at altitudes A. Temperature (°C) and pressure (mb), respectively. Temperature and dew-point profiles are shown as solid and dashed lines, respectively. Each line is a temperature-pressure profile 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 (see Bluestein and Jain, 1985). (Courtesy of the American Meteorological Society)

Figure 10.5b. Cross section through squall line of 21 May 1961 as it passed Oklahoma City. Hatching indicates probable extent of high $\theta_v$ air of low-level origin; cross-hatching indicates location of low $\theta_v$ air of probably middle-level origin. Heavy arrows are axes of main drafts; thin arrows are streamline, dashed where air masses from core of stratiform tower. Long dashes suggest outlines of air masses originating in storm; lower altitude cloud plane consists of small precipitation particles. (After Newton, 1966.)
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 mature stage of a squall line

Fig. 25. Schematic cross section through wave low (a) and surface pressure and wind fields and precipitation distributions during squall line mature stage (b). Winds in (a) are system-relative with the dashed line denoting zero relative wind. Arrows without streamlining, and without crossbars, indicate wind vectors. Wind speed is indicated by crossbars (represented in b) representing actual winds. Note that horizontal scales differ in the two schematics.
Theories for Intense, Long-Lived Squall Lines

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