2.2. Development and Evolution of Drylines

The dryline is a mesoscale phenomena whose development and evaluation is strongly linked to the PBL.

Text books containing sections on dryline:

The Dry Line. Chapter 23, Ray, P. S. (Editor), 1986: Mesoscale Meteorology and Forecasting. American Meteorological Soc., 793 pp..

Pages 292 – 290. Bluestein, H. B., 1993: Synoptic-Dynamic Meteorology in Midlatitudes. Vol. 2: Observations and Theory of Weather Systems. Oxford University Press, 594pp.

The dryline

1. **Definition**: A narrow zone of strong horizontal moisture gradient at and near the surface.

2. **Most observed in** the Western Great Plains of the U.S. (also in India, China, Australia, Central Africa,....)

3. **Over the U.S., the dry line is** a boundary between warm, moist air from the Gulf of Mexico, and hot, dry continental air from the southwestern states or the Mexican plateau

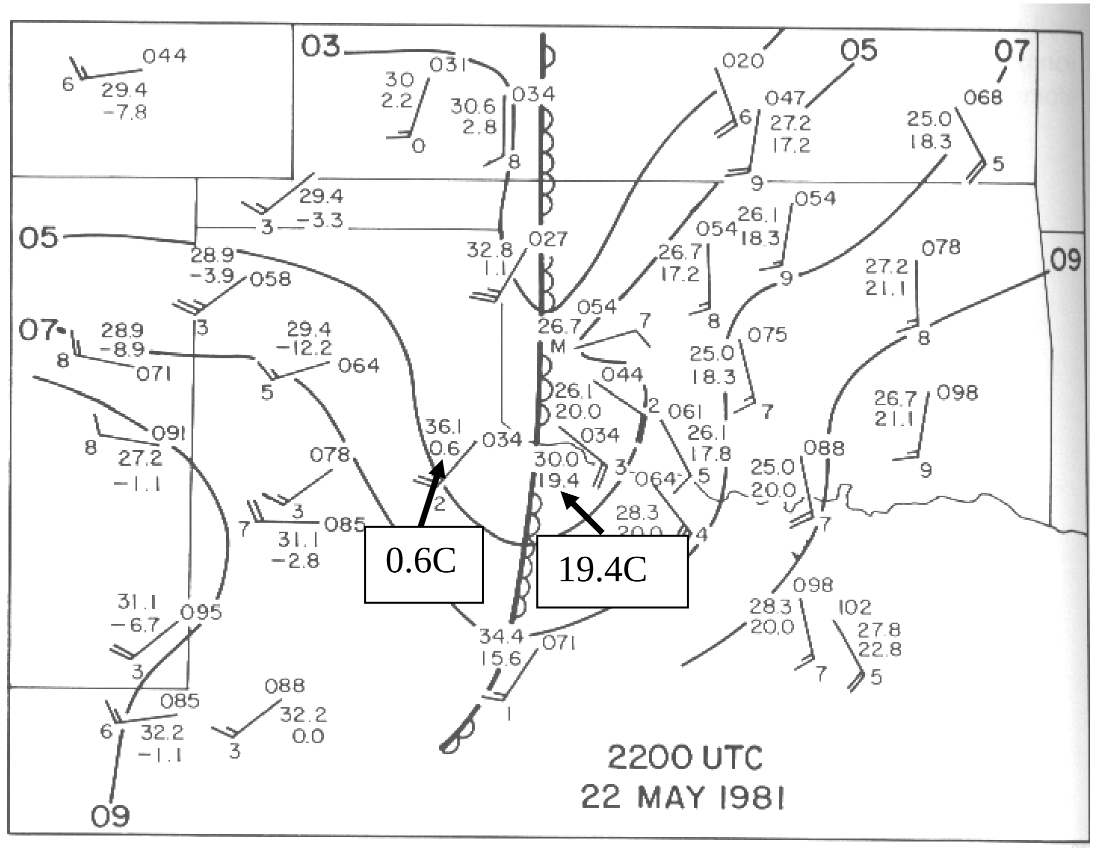
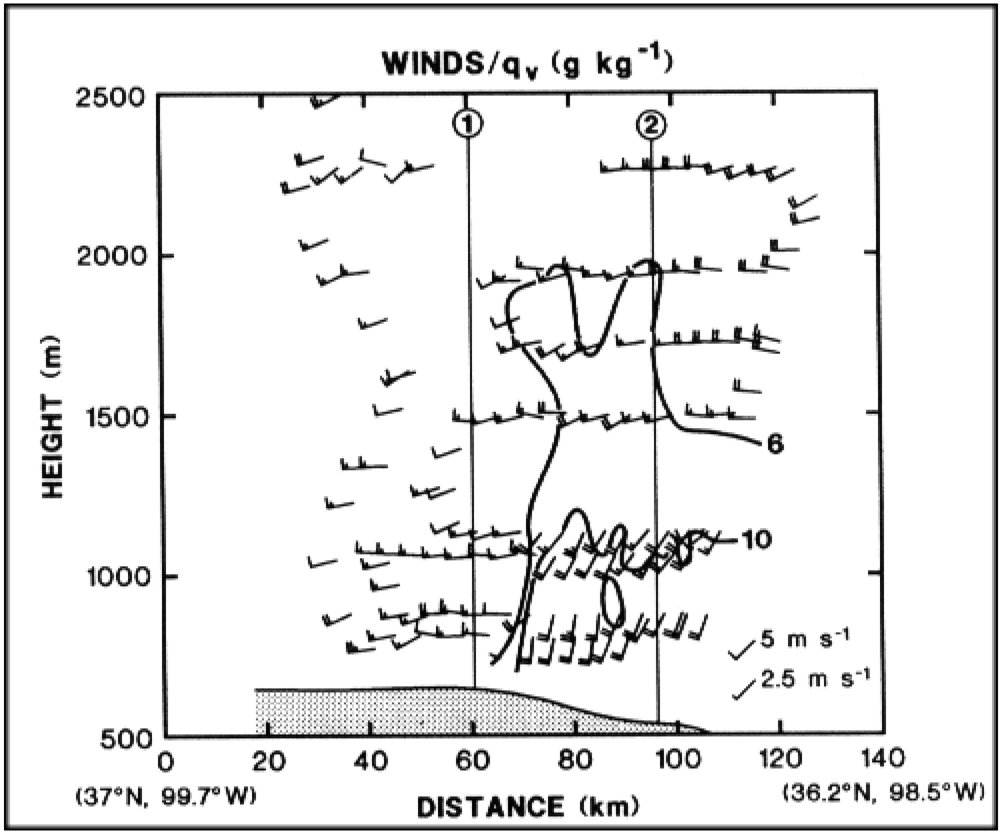


Figure 2.38 Surface analysis in Oklahoma, Texas, and Kansas of a dryline (scalloped line) under "quiescent" conditions at 2200 UTC, May 22, 1981. Altimeter setting (solid lines) in mb without the leading 10; temperature and dew point plotted in °C; altimeter setting plotted in tens of mb, without the leading 10; whole barb = 5 m s⁻¹; half barb = 2.5 m s⁻¹. At the time of this analysis tornadic storms were occurring just east of the dryline in western Oklahoma. Winds east of the dryline are generally from the south and southeast, while winds west of the dryline are from the southwest and west. Dew points east of the dryline are around 20°C; dew points west of the dryline are near and below 0°C.

In this example, some 20^0C dew-point temperature gradient is observed across the dryline in the above example.

4. **The dry line is not a front**; i.e., there is very little density contrast between warm, moist air and hot, dry air (because dry air is more dense than moist air – the two effects offset each other – virtual temperature – a measure of relative-density of moist air, is $T_v = T(1+0.61q)$)

5. **A veering wind shift** usually occurs with dryline passage during the day because the dry adiabatic lapse rate behind the dry line facilitates **vertical mixing of upper-level westerly momentum down to the surface**.

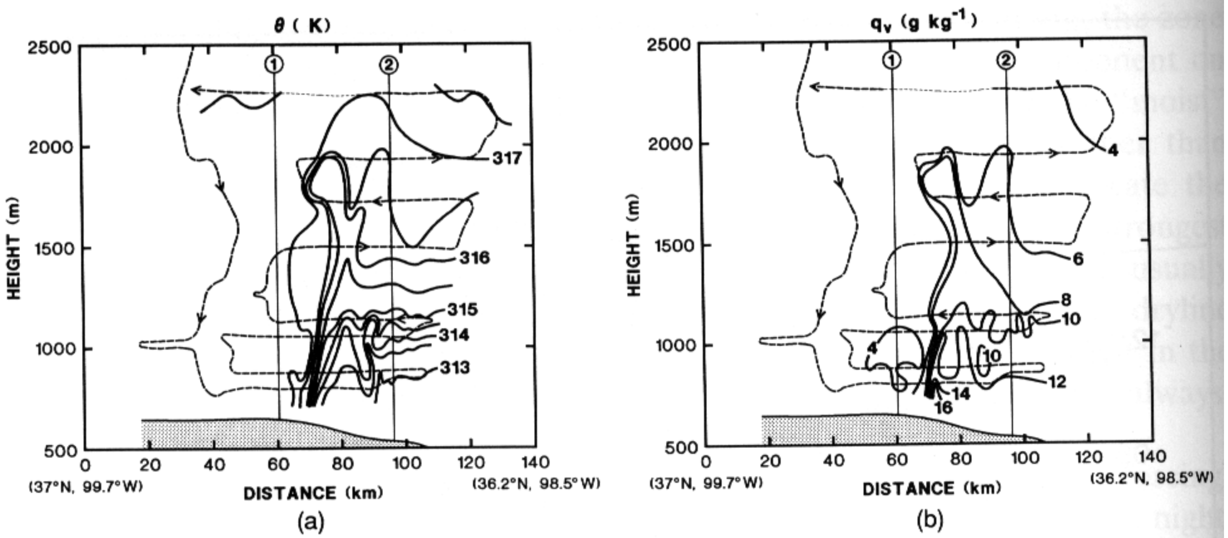


6. The dryline is often located **near a surface pressure trough** (often a lee trough or "heat trough"), but does not have to be coincident with the trough. (see the first example).

7. **Typical moisture** (in terms of dew-point temperature) **gradient** is 15^0C per 100 km, but 9^0C in 1 km has been observed.

8. **Vertical structure**: Is nearly vertical for < 1 km and then "tilts" to the east over the moist air (see Figures)

θ q_v



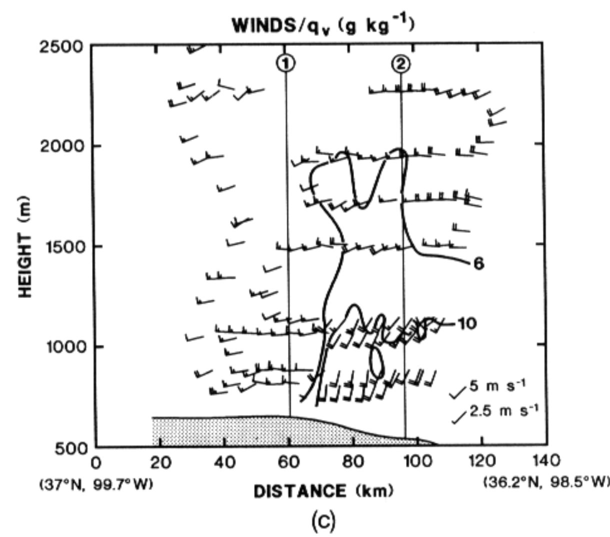
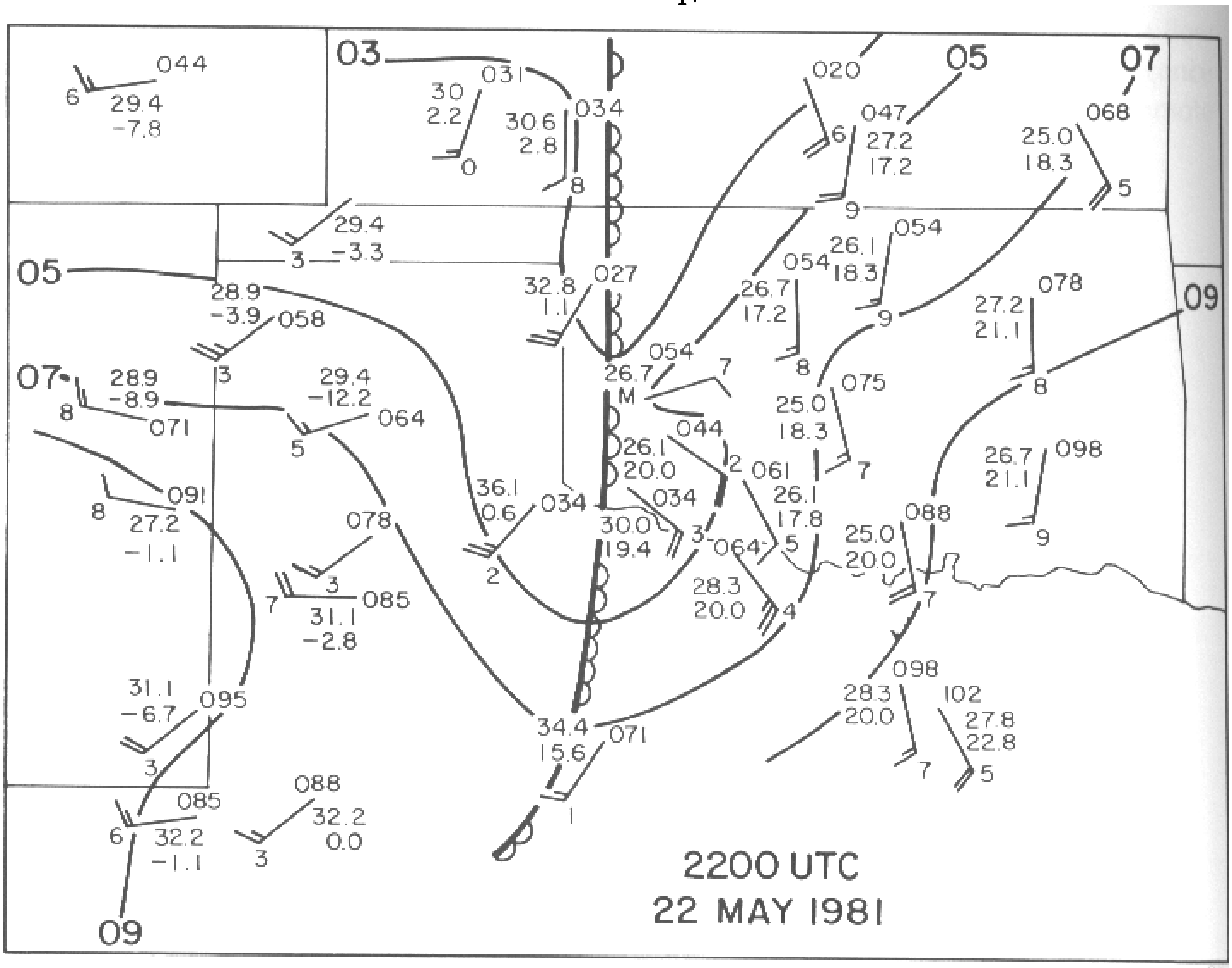


Figure 2.41 Example of the vertical structure across a quiescent dryline as determined from an aircraft 2019-2228 UTC, May 24, 1989. (a) Vertical cross section of potential temperature (K); (b) as in (a), but for water-vapor mixing ratio ($g\ kg^{-1}$); (c) winds and water-vapor mixing ratio. Flight track indicated in (a) and (b) by dashed line. (Courtesy C. Ziegler, National Severe Storms Laboratory)

Wind + q_v



03
05
07
05
07
09
09
044
29.4
-7.8
031
30
2.2
034
30.6
2.8
020
047
27.2
17.2
068
25.0
18.3
29.4
-3.3
054
26.1
18.3
027
32.8
1.1
28.9
-3.9
058
054
26.7
17.2
078
27.2
21.1
28.9
-8.9
071
29.4
-12.2
064
26.7
M
075
25.0
18.3
044
26.1
20.0
061
26.1
17.8
26.7
21.1
098
091
27.2
-1.1
36.1
0.6
034
034
30.0
19.4
064
25.0
20.0
088
078
085
31.1
-2.8
28.3
20.0
098
28.3
20.0
102
27.8
22.8
31.1
-6.7
095
34.4
15.6
071
088
32.2
0.0
085
32.2
-1.1
2200 UTC
22 MAY 1981

Amarillo TX and OKC soundings at 12 UTC (6am CST) May 22, 1981 and 00 UTC (6pm CST) May 23, 1981, corresponding to last example case

Amarillo TX | OKC

12 UTC, 22 May (6am LST)

00 UTC, 23 May (6 pm LST)

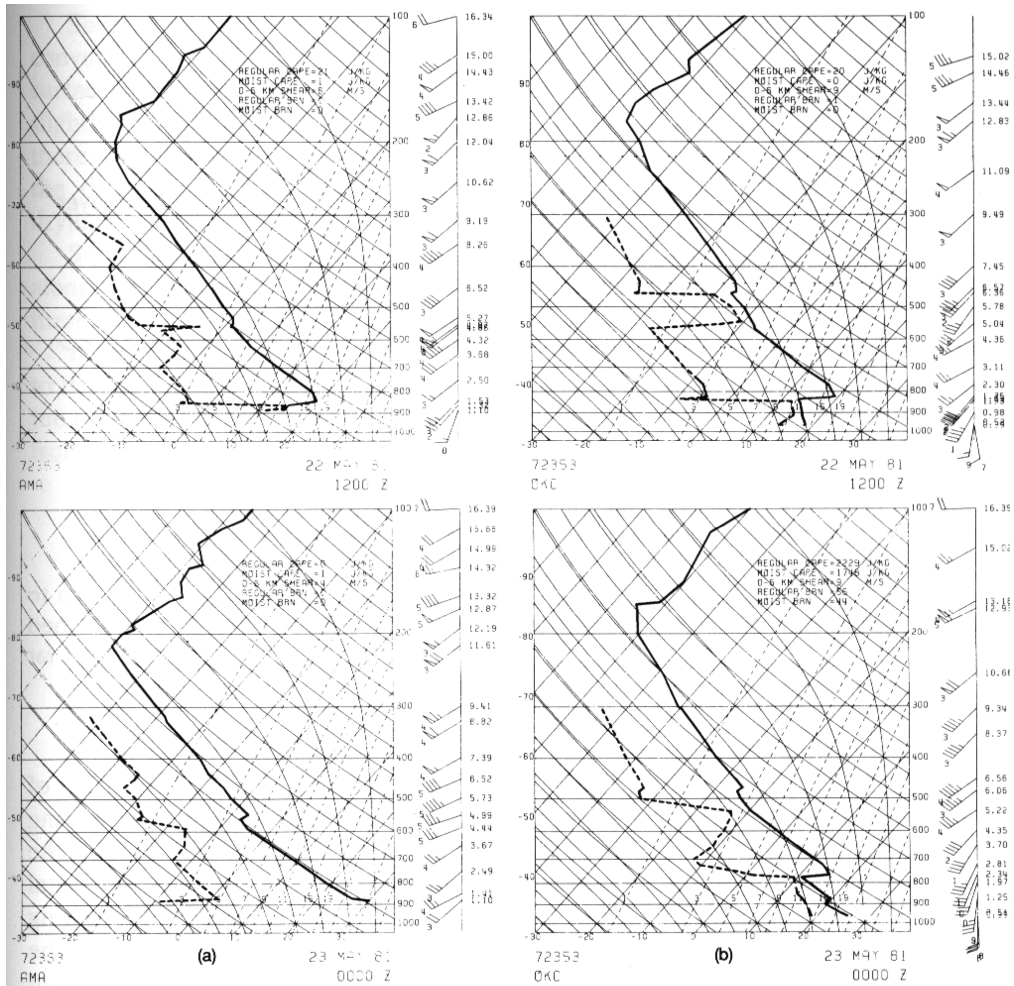


Figure 2.42 Soundings characteristic of the air masses (a) west and (b) east of the dryline on May 22, 1981. Soundings (skew T–log p diagrams) for (a) Amarillo, Texas

Figure 2.42 Soundings characteristic of the air masses (a) west and (b) east of the dryline on May 22, 1981. Soundings (skew T–log p diagrams) for (a) Amarillo, Texas at 1200 UTC (top) and at 0000 UTC, May 23 (bottom); (b) Oklahoma City, Oklahoma at 1200 UTC (top) and at 0000 UTC, May 23 (bottom). Skewed abscissa is temperature (°C); logarithmic ordinate is pressure (mb). Temperature and dew point plotted as solid line and dashed line, respectively. Winds plotted at the right at the plotted heights (km MSL); pennant = 25 m s^{-1}; whole barb = 5 m s^{-1}; half barb = 2.5 m s^{-1}. The morning Amarillo sounding has a very shallow moist layer near the ground, which mixes out completely with the dry air above when the surface temperature warms up to 24°C; at early evening, there is a deep dryadiabatic layer from the surface up to 560 mb; a shallow stable layer is found at the top of the dryadiabatic layer; a very shallow superadiabatic layer is found near the ground. The morning Oklahoma City sounding has a 130-mb deep moist layer near the ground, which is nearly well mixed, capped by a sharp inversion, and surmounted by a deep nearly dryadiabatic layer extending up to 560 mb; by early evening the moist layer has thickened somewhat, while the capping inversion remains. The dryadiabatic layer above the capping inversion has approximately the same potential temperature (313 K) as the deep dryadiabatic layer to the west at Amarillo.

The May 11, 1970 Case

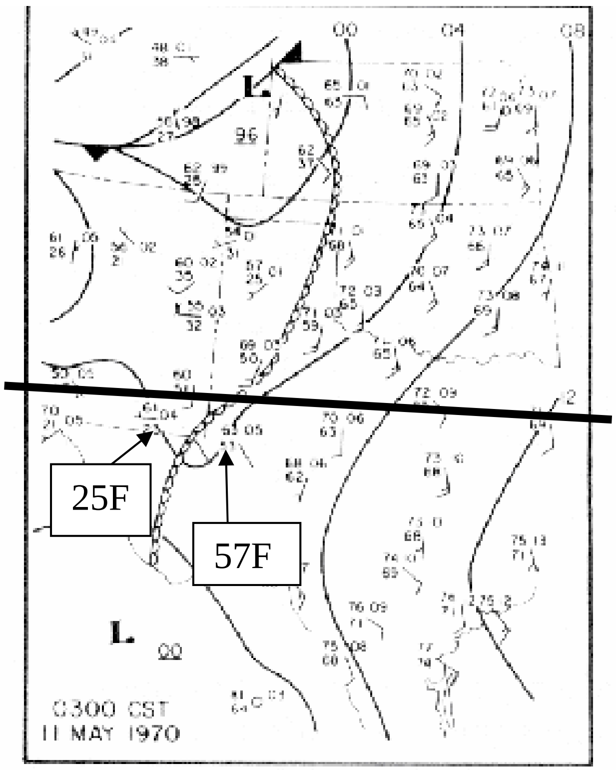


Figure 23.1. Surface analysis, 0300 CST, 11 May 1970.

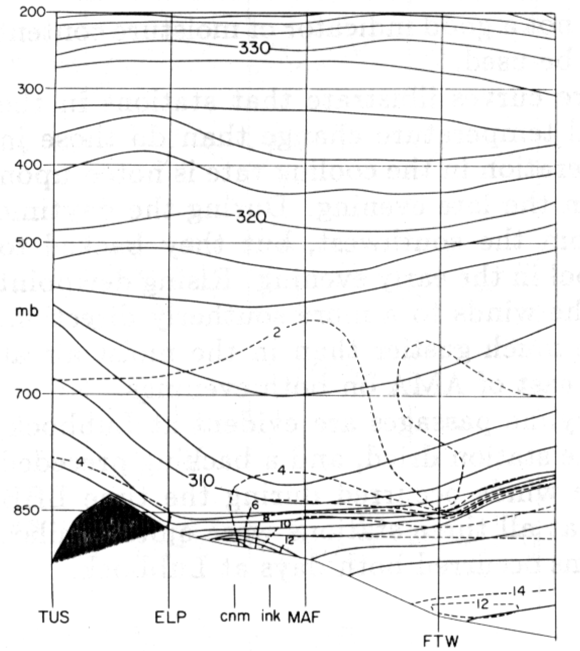


Figure 23.7. Cross section from Tucson, Ariz., to Shreveport, La., for 0600 CST, 11 May 1970. Solid lines are isentropes; dashed lines are isohumes (mixing ratio in g kg^{-1}).

03 CST, 11 May 1970

06 CST, 11 May 1970

- Strong moisture gradient is found across the dryline
- Nocturnal inversion is found at the surface.
- An inversion is found to the east of the dryline at ~850mb level, capping moist air below
- No clear horizontal θ gradient separating the dry and moist air

Dryline was between Carlsbad, New Mexico (T_d = 25 F) and Wink, Texas (T_d = 57 F).

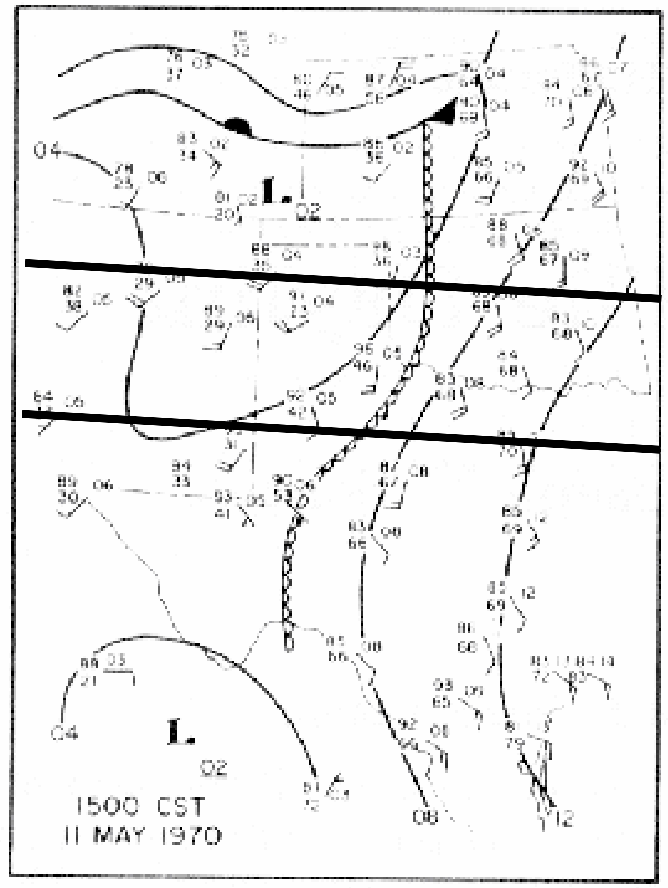


Figure 23.2. Surface analysis, 1500 CST, 11 May 1970.

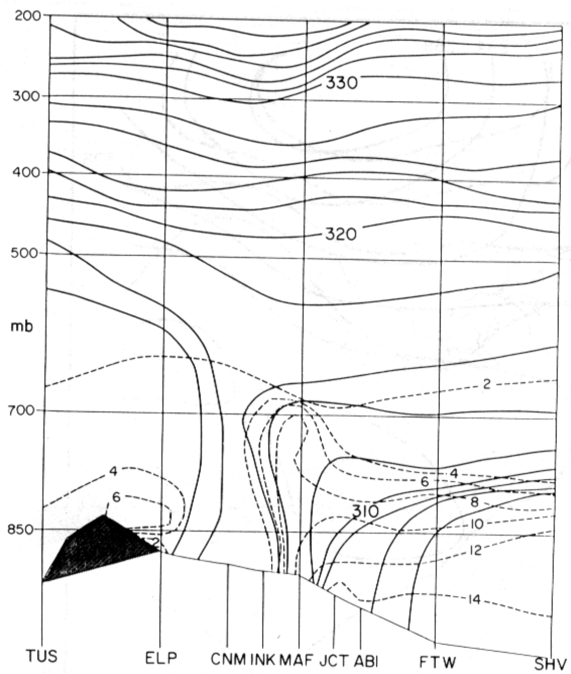


Figure 23.10. Cross section from Tucson, Ariz., to Shreveport, La., for 1800 CST, 11 May 1970.

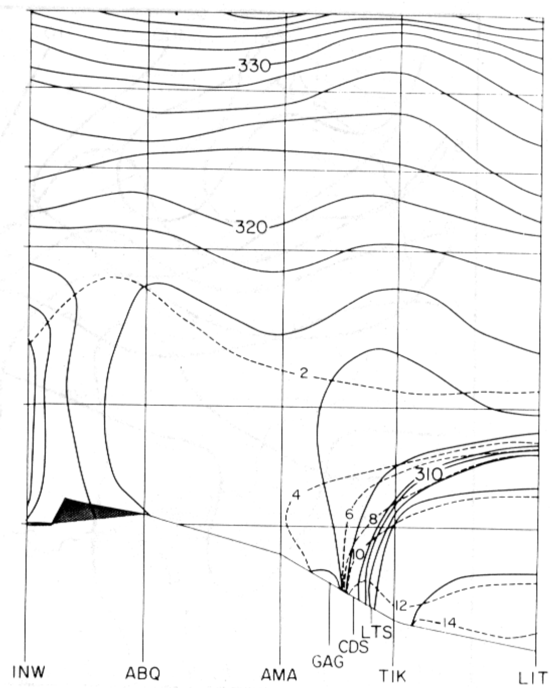


Figure 23.11. Cross section from Winslow, Ariz., to Little Rock, Ark., for 1800 CST, 11 May 1970.

In the afternoon, a typical dryline structure is found

- To the west of dryline, ML extended to ~600mb
- Upward bulge of moisture at the dryline is an indicator of moist convection
- A lid still exits to the east above the surface moist layer
- Second cross-section is about 200 miles to the north – it again shows a typical dryline structure

TYPICAL BACKGROUND CONDITIONS FOR DRY LINES

1. Surface anticyclone to the east, allowing moist Gulf air to flow into the Great Plains

2. Westerly flow aloft, causing a lee trough, and providing a confluence zone for the concentration of the moisture gradient

3. The presence of a stable layer or "capping inversion" or "lid" aloft. The southerly flow under this lid is often called "underrunning".

4. Because the terrain slopes upward to the west, the moist layer is shallow at the west edge of the moist air, and deeper to the east.

This sets the stage for understanding the movement of the dry line.

MOVEMENT OF THE DRY LINE

Under "quiescent" (i.e., in the absence of strong synoptic-scale forcing) conditions, the dryline usually moves eastward during the day and westward at night, as shown by the following example (we have just looked at the vertical structure of this case)

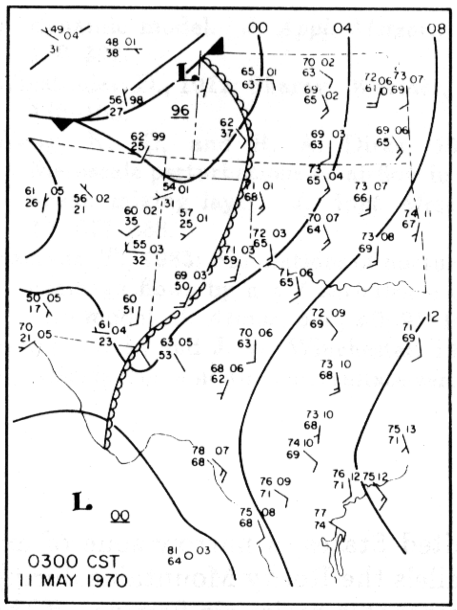


Figure 23.1. Surface analysis, 0300 CST, 11 May 1970.

0300 CST

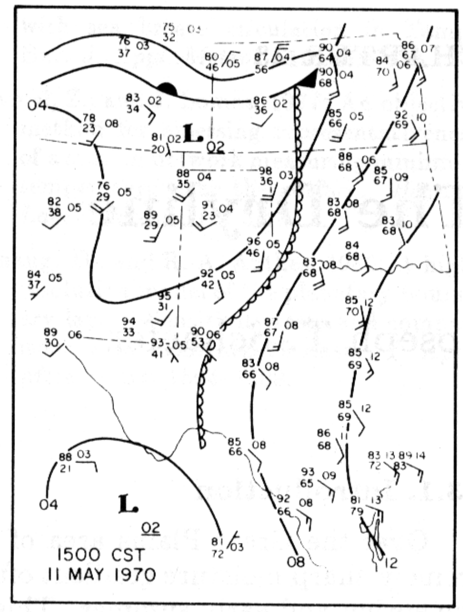


Figure 23.2. Surface analysis, 1500 CST, 11 May 1970.

1500 CST

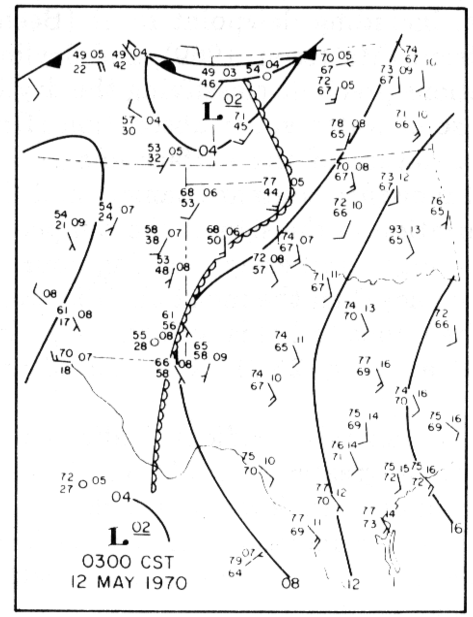


Figure 23.3. Surface analysis, 0300 CST, 12 May 1970.

0300 CST, day 2

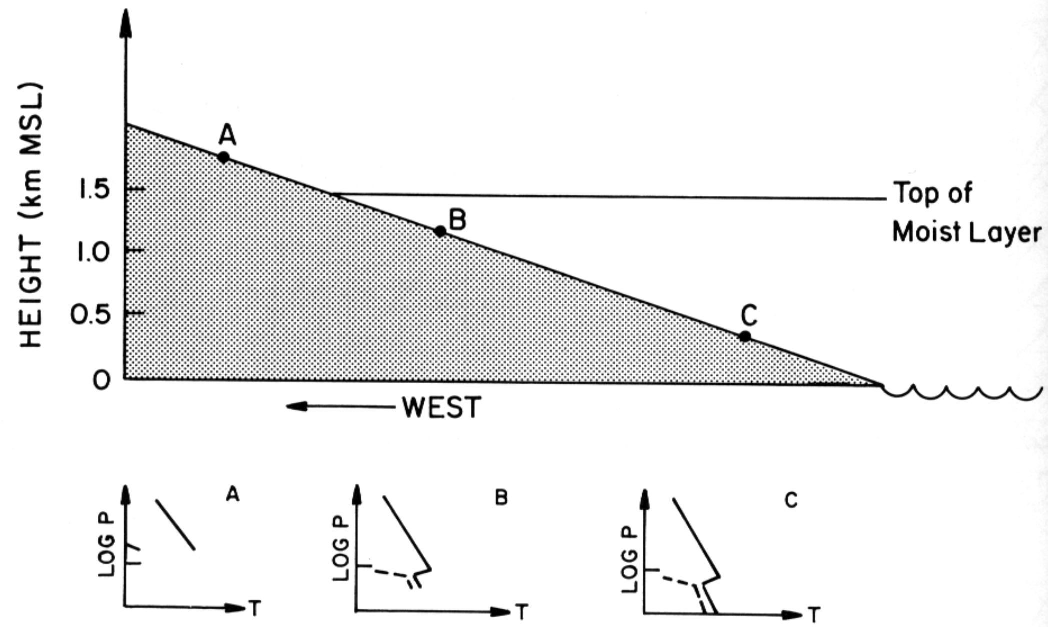


Figure 2.43 Schematic vertical cross section of the dryline and its relationship to topography. Idealized soundings (temperature, solid lines; dew point, dashed lines) at points A, B, C (bottom) represent the conditions west, just east, and far east of the dryline.

1. As the sun rises, the heating of the surface near the dry line is greater than that of the surface to the east in the deeper moist air (the difference in soil moisture content and low-level cloudiness often also contribute to such differential heating)

2. Thus it takes less insolation to mix out the shallow mixed layer just to the east of the initial dry line position (see Figure). This mixing out brings dry air (and westerly momentum) downward, and the position of the dry line 'moves' eastward.

3. As the heating continues, deeper and deeper moist layers are mixed out, causing the apparent eastward "propagation" of the dry line. This propagation is not necessarily continuous or at a rate equal to the wind component normal to the dry line.

4. Eventually, the heating is insufficient to mix out the moist layer and propagation stops.

5. If a well-defined jet streak exists aloft, we often see a "dry line bulge" underneath the jet, as this air has the most westerly momentum to mix downward. The strong westerly momentum mixed down from above provides extra push for the eastward propagation of dryline

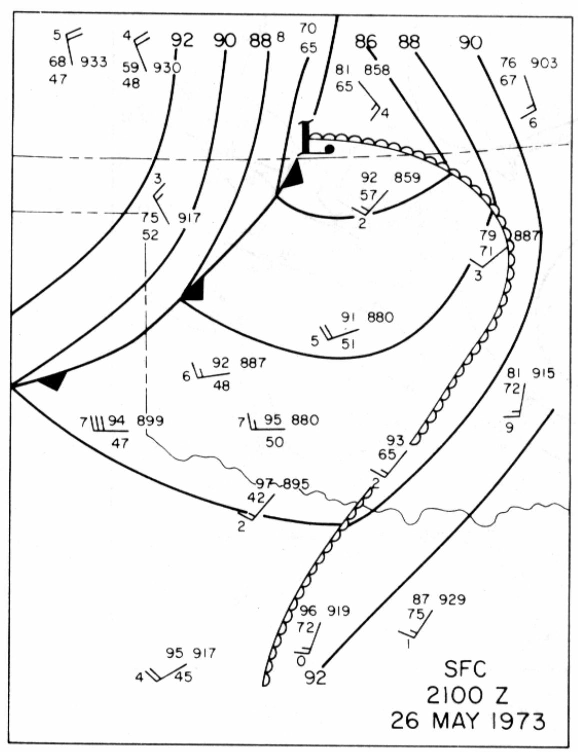


Figure 23.13. Dryline bulge from 1500 CST, 26 May 1973. (After Tegtmeier, 1974.)

6. After sunset, the vertical mixing dies out, the westerly momentum at the surface west of the dryline weakens, the surface winds will back to a southeasterly direction in response to the lower pressure to the west. The moist air east of the dry line will be advected back toward the west, and surface stations will experience an east to west dry line passage.

The above case assuming synoptic scale forcing is weak – the situation is quiescent. If synoptic forcing is strong, the dryline may continue to be advected eastward in association with a surface low pressure system.

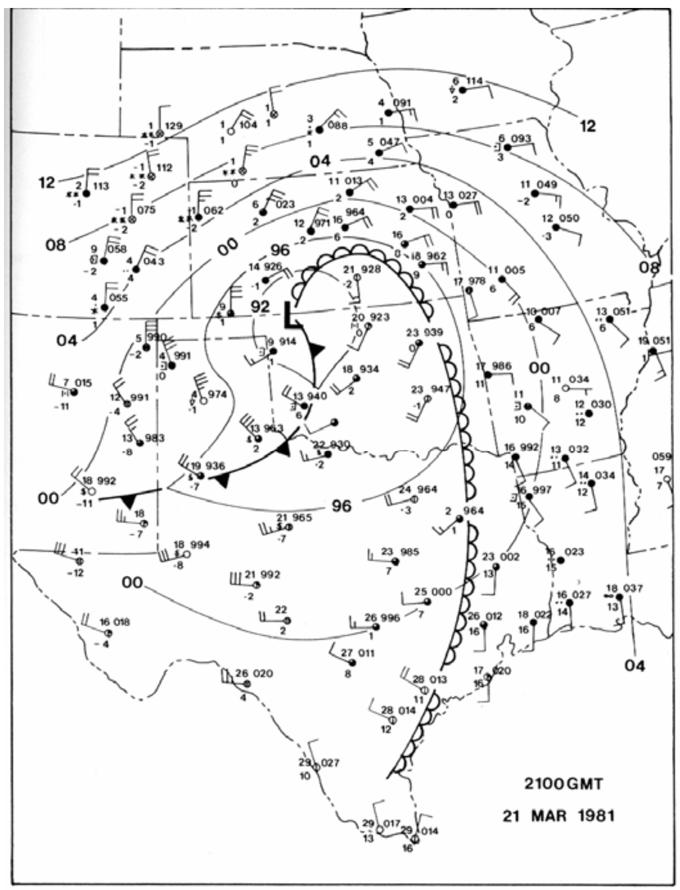


Figure 2.40 Example of a dryline (scalloped line) being advected far to the east by a strong synoptic-scale system 2100 UTC (GMT), March 21, 1981. Temperature and dewpoint in °C. Sea-level pressure in tens of mb, without the leading 9 or 10. Whole wind barb = 5 m s^{-1}; half wind barb = 2.5 m s^{-1}. Sea-level isobars in mb (solid lines), without the leading 9 or 10. Blowing dust is often observed when strong surface winds are found behind the dryline (from Carr and Millard, 1985). (Courtesy of the American Meteorological Society)

Sometimes, there exists a cold front behind the dryline that eventually catch up to the dry line.

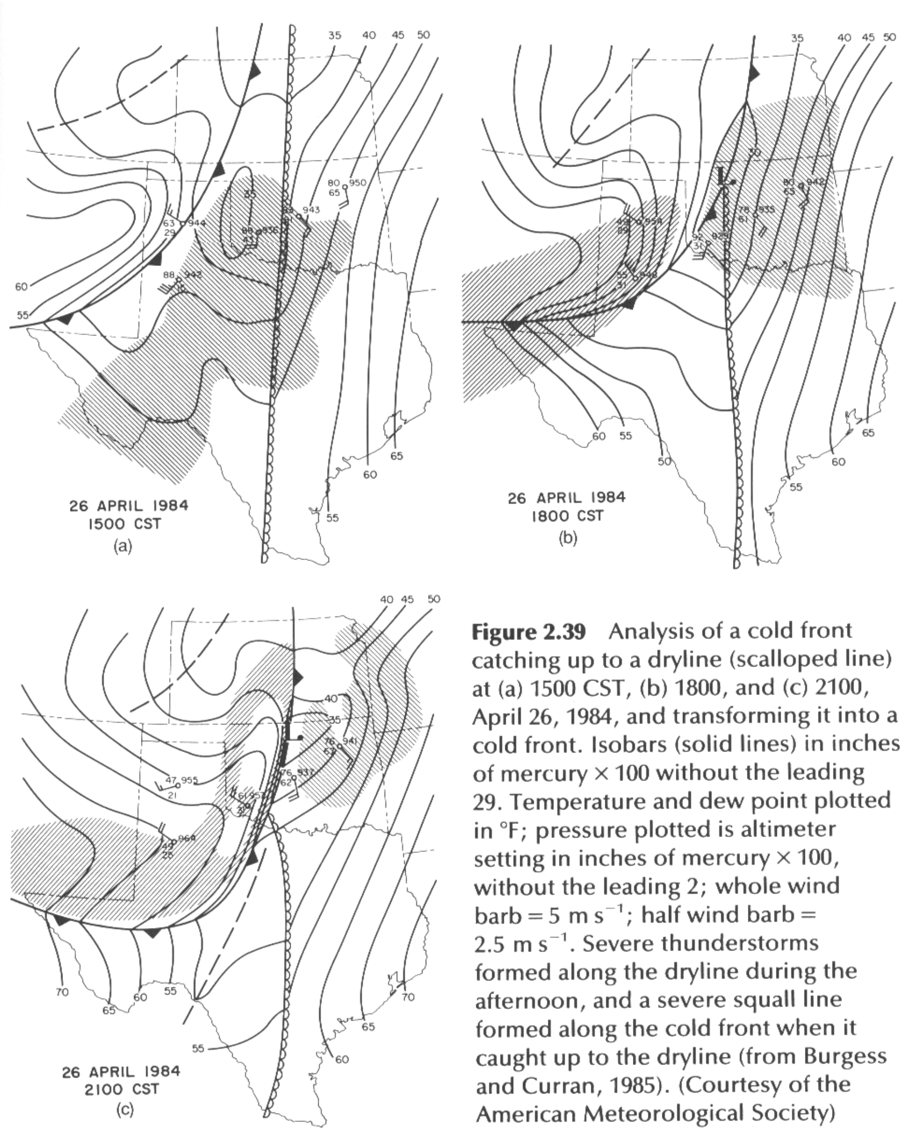


Figure 2.39 Analysis of a cold front catching up to a dryline (scalloped line) at (a) 1500 CST, (b) 1800, and (c) 2100, April 26, 1984, and transforming it into a cold front. Isobars (solid lines) in inches of mercury × 100 without the leading 29. Temperature and dew point plotted in °F; pressure plotted is altimeter setting in inches of mercury × 100, without the leading 2; whole wind barb = 5 m s^{-1}; half wind barb = 2.5 m s^{-1}. Severe thunderstorms formed along the dryline during the afternoon, and a severe squall line formed along the cold front when it caught up to the dryline (from Burgess and Curran, 1985). (Courtesy of the American Meteorological Society)

The dryline as a focus of convection

Possible reasons why convection initiates near dry lines:

1. Surface convergence between winds with easterly component east of the dry line and westerly component west of the dry line.

2. Dryline is the westernmost boundary of moist, convectively unstable air. The area along it and immediately east is the first region susceptible to convection encountered by the vertical motion associated with traveling disturbances from the west.

3. Gravity waves may form on or near the dry line, possibly triggering the first release of potential instability (Koch abd McCarthy 1982).

4. Dryline bulges provide an even greater focus for surface moisture convergence

5. "Underrunning" air moves northward until cap is weaker and/or large- or mesoscale forcing is strong enough to release the instability. Convective temperature may be reached just east of the dry line.

Some observations: The reason for most tornado chase "busts" is that the advection of warm, dry air over the moist layer is building the cap or lid strength faster than the surface heating can overcome, thus convection never occurs.