# A DECEMBER STORM ACCOMPANIED BY TORNADOES

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## INTRODUCTION

On December 2, 1950, a storm over the central United States was accompanied by three tornadoes in Illinois and one in Arkansas. In Illinois tornadoes are relatively rare during December, a total of only 3 days with tornadoes, one each in 1876, 1949, and 1950, and a total of six tornadoes, having been reported since 1835. Table 1 shows the approximate time of the tornadoes on December 2, 1950, their path, and extent of damage. These storms occurred in an elongated low pressure system which extended from northern Texas and Arkansas thence north-northeastward over Lake Michigan, and they were associated with polar maritime air aloft from the Pacific which had moved rapidly across the Plateau on November 30 and December 1.

It is difficult if not impossible in synoptic studies to point out the conditions that are unique to tornado formation because of the relatively small size of these storms as compared to the density of observational data. For this reason the following discussion will attempt only to point out some of the synoptic features frequently observed with tornadoes and which are evident in the situation of December 2.

## PRECEDING SYNOPTIC CONDITIONS

The synoptic situation on the early morning of the preceding day is shown in figure 1, the surface map for 0630 GMT December 1. Significant features include the quasi-stationary front extending east-west across the Southern States and the maritime Pacific cold front moving eastward through Idaho, Nevada, and California. At the same time, gradient level winds over Louisiana and eastern Texas were southerly at about 40 knots; they

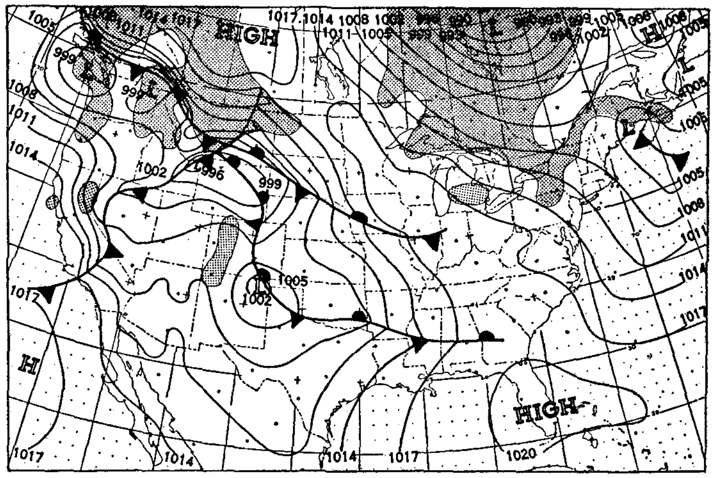


FIGURE 1.—Surface weather chart for 0630 GMT, December 1, 1950. Shading indicates areas of active precipitation.

had increased in speed and were bringing warm moist air over the central United States. Along with this northward flow of warm air, the front across the Southern States began thereafter to move rapidly northward as a warm front. Twenty-four hours later (fig. 2) this front had moved into Illinois and Indiana, while the Pacific cold front extended through Texas, Oklahoma, and aloft over Kansas. Northward flow of warm moist air had further increased, so that maritime tropical air with its unseasonably high surface temperature and moisture content extended into southern Illinois.

Progress of the leading edge of polar maritime air from the Pacific can be seen in figure 3, where positions of the Pacific front are shown at 3-hour intervals. Beginning near or shortly after 0630 GMT of the 2d, this front was no longer evident at the surface. This means that the

TABLE 1.—*Tornadoes on Dec. 2, 1950*

| Location of origin | Approximate time of origin | Path | Location of termination | Approximate time of termination | Effects |
|---|---|---|---|---|---|
| ILLINOIS | *GMT* | | | *GMT* | |
| Near Fosterburg (Madison County) | 2100 | 25 mi. ENE | Near Mount Olive (Macoupin County) | 2140 | Slight damage, 1 death, 3 injuries. |
| Near Highland (Madison County) | 2200 | 22 mi. ENE | Greenville (Bond County) | 2210 | $500,000 damage, 2 deaths, 24 injuries. |
| 4 mi. NW of Sparta (Randolph County) | 2330 | 11 mi. ENE | | | $45,000 damage, no deaths or injuries. |
| ARKANSAS | | | | | |
| Near La Cross (Izard County) | 2225 | 8 mi. NE | Near Myron (Izard County) | | Slight damage, no deaths or injuries. |

NOTE: Since time of occurrence and location are approximate, the data given will not accurately represent the speed of the tornadoes.

leading portion of the polar maritime air was overriding the surface layer of maritime tropical air, a condition that is frequently observed with tornado situations in the central United States. In such cases the polar maritime air, while relatively cold when passing over the Plateau, becomes progressively warmer in its movement over the mountain region and the higher portion of the east slope so that its leading edge acquires a potential temperature higher than that of the low level maritime tropical air over the central Plains. This is in agreement with the mechanism for tornado formation proposed by Lloyd [1] and is similar to a situation described by Fulks [2].

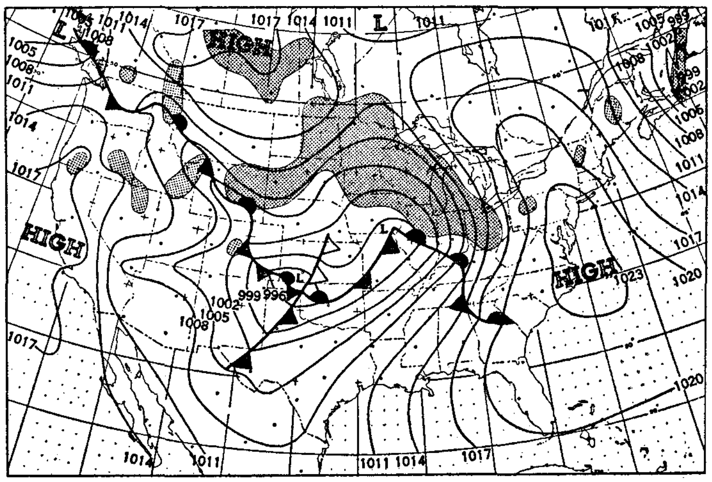


Figure 2.—Surface weather chart for 0630 GMT, December 2, 1950.

## SYNOPTIC FEATURES DURING TORNADO CONDITIONS

Progress of the frontal systems during the time of tornado occurrences may be seen in figure 3. Figures 4, 5, and 6 show details of the synoptic situation at 1830 and 2130 GMT on December 2 and 0030 GMT December 3. The first tornado began near Fosterburg, Ill. (northernmost of small solid squares in fig. 5) about the time of figure 5, and the last (southernmost of the three tornadoes in Illinois) began near Sparta within the hour preceding the time of figure 6. The position of the main surface front and minor wave in Missouri and central Illinois as shown in figures 4, 5, and 6, is located to a fairly high degree of accuracy on the basis of hourly reports from St. Louis, Mo., Belleville, Rantoul, and Springfield, Ill., and other suronnding stations; also a radar line-echo report from Belleville which was taken to be the cold front. The upper cold front is confirmed by upper air reports, particularly in six-hourly radiosonde ascents at Rantoul in eastern Illinois, but it cannot be located with the same precision as the surface front.

The evidence indicates with reasonable certainty that the tornadoes occurred between the surface cold front and the upper front, that is, in the area where tropical air was being overrun by polar maritime air. The distance ahead

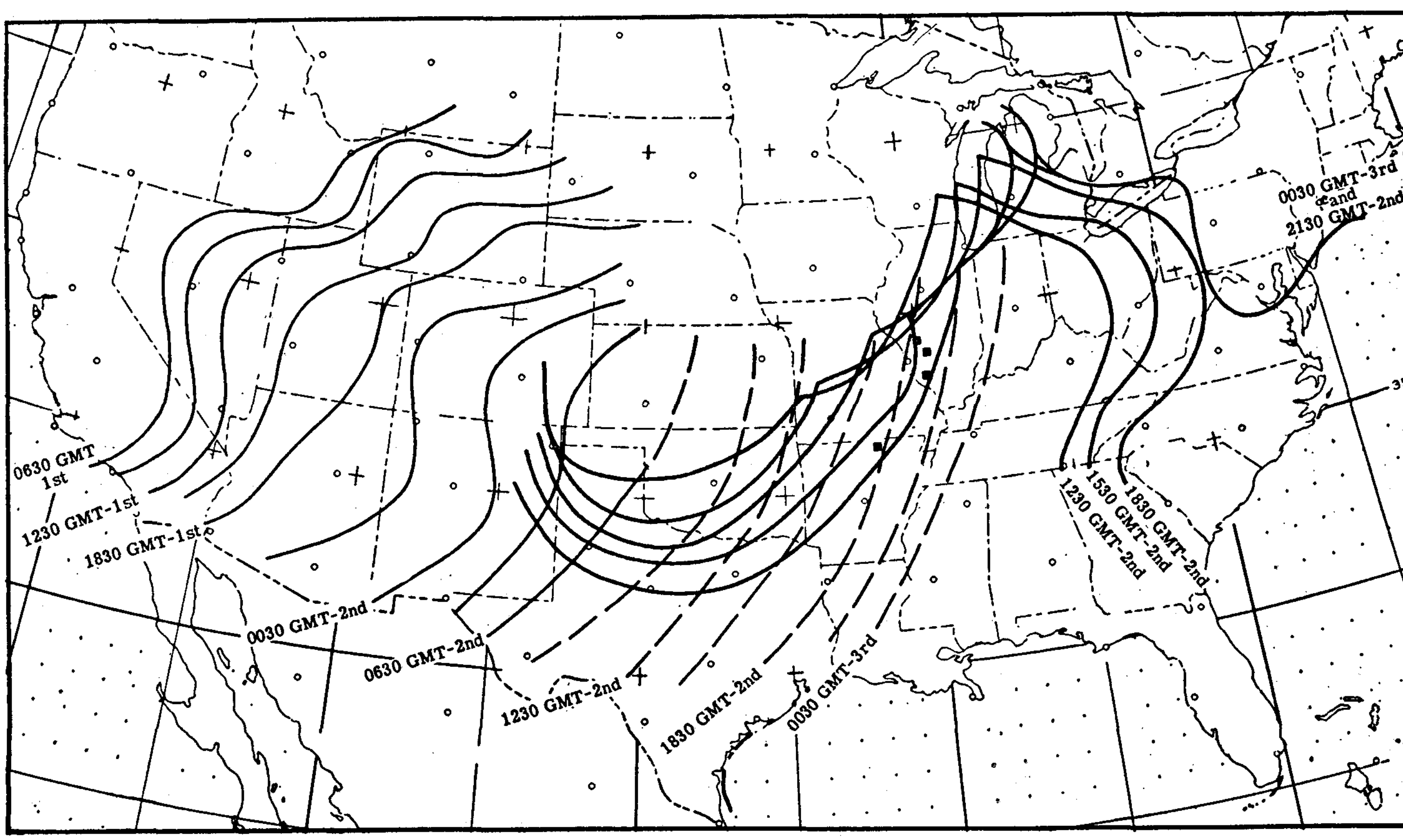


Figure 3.—Positions of the significant fronts at intervals of 3 hours. Tornadoes occurred between 2100 and 2400 GMT at locations indicated by black squares.

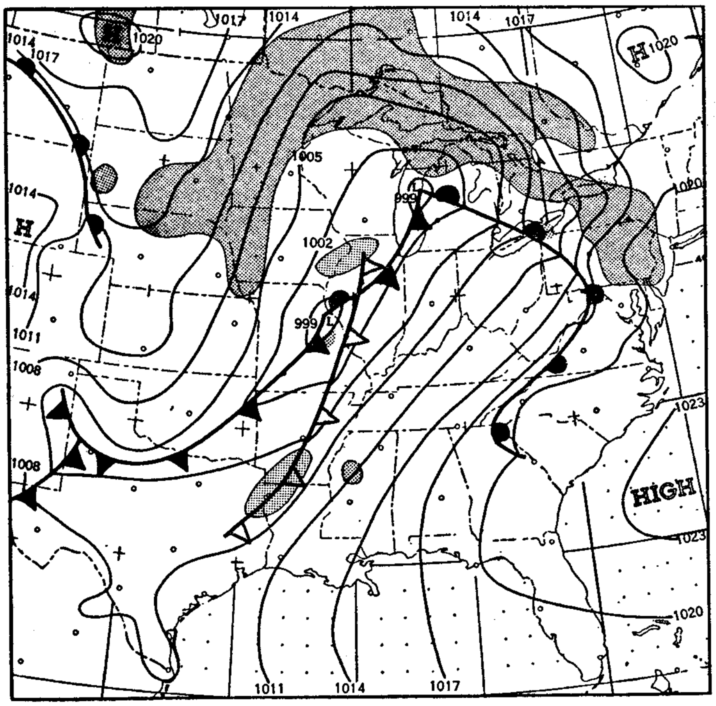


FIGURE 4.—Surface weather chart for 1830 GMT, December 2, 1950.

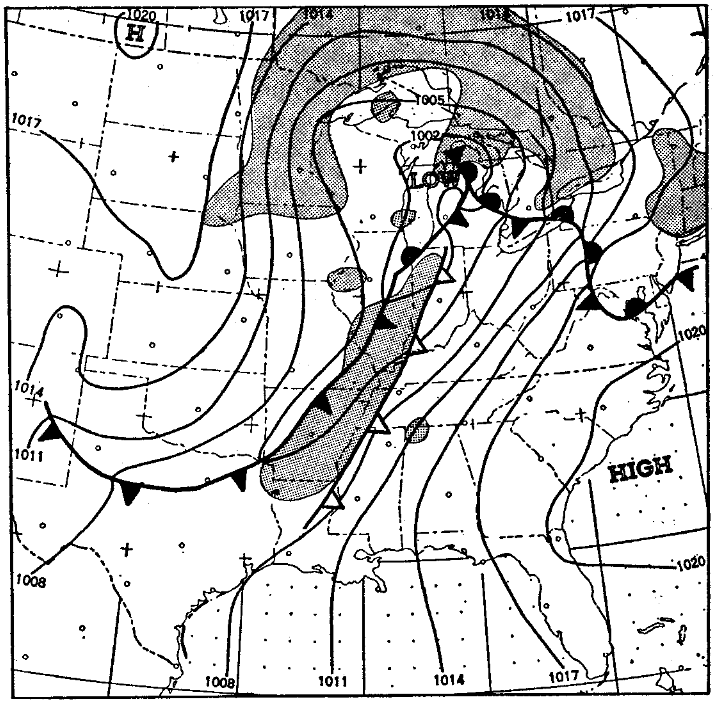


FIGURE 6.—Surface weather chart for 0030 GMT, December 3, 1950.

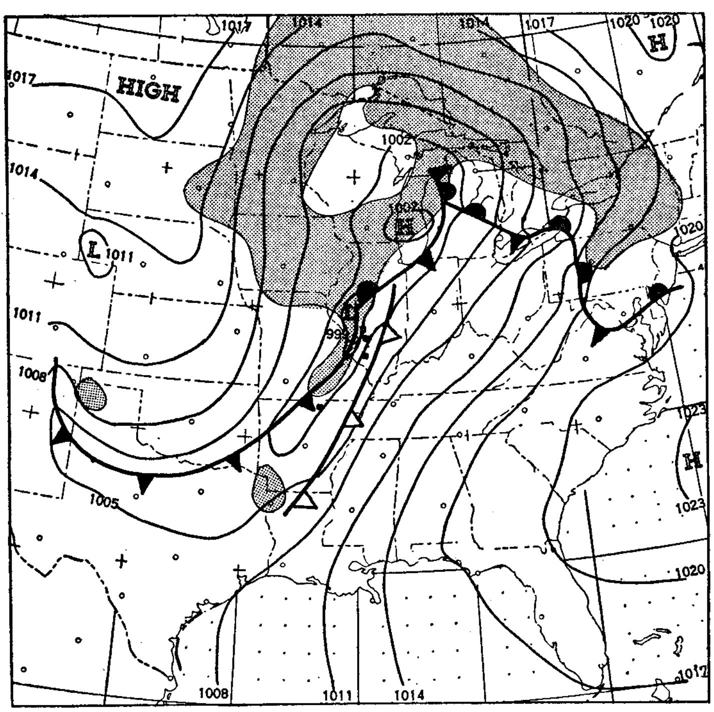


FIGURE 5.—Surface weather chart for 2130 GMT, December 2, 1950.

of the cold front is estimated in each case to be of the order of 15 or 20 miles, based on interpolated positions of the cold front; the cold front appears to have arrived about thirty minutes after beginning of the tornado. The tornadoes in Illinois were south of the center or apex of a small wave along the cold front, the first tornado estimated to be about 40 miles south-southeast of the moving center, the second about 90 miles directly south, and the third about 180 miles south-southwest. Taken in the order of time of occurrence, each of the Illinois tornadoes was progressively farther southward and farther from the apex of the wave. It is possible that the Arkansas tornado also occurred in connection with a very minor wave along the front, as is suggested in figure 6 by the shape of the cold front in that area, but evidence for the wave is uncertain.

Occurrence of the tornadoes behind rather than along the upper cold front suggests that the necessary degree of vertical instability did not develop upon arrival of the leading edge of the colder air aloft, but that instability became sufficient as the polar maritime air aloft became deeper and colder.

Significant features of the upper air structure may be seen in figures 7–10, inclusive. Figures 7 and 8, containing radiosonde data from Little Rock, Ark., and Rantoul, Ill., respectively, illustrate the temperature and moisture distribution in the warm air. In figure 7, for Little Rock, the sounding for 1500 GMT on the 2d (before arrival of the polar maritime air aloft) shows moist convectively unstable air up to 750 mb. (about 8,000 ft. msl), capped by an inversion above which the relative humidity was noticeably lower. The zero (°C) wet-bulb temperature was at 700 mb., immediately above the inversion, and the air from the top of the inversion up to 560 mb. was also convectively unstable. The second sounding in figure 7, for 0300 GMT on the 3d, was taken about the time of arrival of the surface cold front, yet cooling had occurred between 750 and 600 mb., wiping out the inversion and indicating arrival of the polar maritime air aloft; this is further indicated by higher relative humidity above 750 mb.

The Rantoul sounding for 1500 GMT, December 2 (fig. 8) is similar to the Little Rock sounding for the same time. The 2100 GMT sounding shows slight cooling between 780 and 580 mb. and a noticeable increase of moisture above 700 mb. The sounding for 0300 GMT of the 3d shows both the arrival of the surface cold front and further cooling at higher levels associated with the cold front aloft.

Figures 9 and 10 are vertical cross sections for 1500 GMT of the 2d and 0300 GMT of the 3d, respectively, taken approximately through the tornado area. The inversion or stable layer, which is shown between 6000 and 8000 feet at Rantoul in figure 9, was capping the lower warm moist air and was accompanied by much drier air above. This is typical of conditions preceding tornadoes. Winds of around 50 knots within the lower layer of warm moist air, as may be seen at St. Louis and Springfield in figure 9, are also typical of wind conditions frequently observed immediately ahead of tornadoes. Whether or not there was marked cyclonic shear along the line of tornado formation cannot be determined from available data, but strong southerly flow ahead of the surface front suggests this possibility; such a line of shear (or local zone of cyclonic rotation) is necessary at least in the immediate vicinity of a tornado if we accept as a requirement for tornado formation that there must be low-level convergence within a zone of marked cyclonic vorticity.

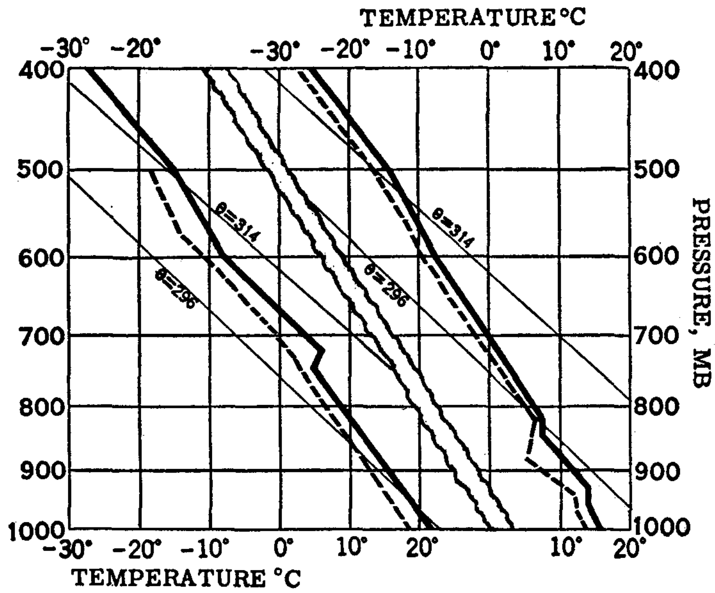


FIGURE 7.—Radiosonde observations at Little Rock, Ark., plotted on a pseudo-adiabatic diagram: Left—1500 GMT, December 2, 1950; Right—0300 GMT, December 3, 1950. Dashed curves are wet-bulb temperature.

Figure 10 shows the eastward extension of the cold front aloft with respect to the surface cold front and the consequent steepening of the lapse rate immediately above the lower moist air. It is not intended, however, to suggest that all steepening of the lapse rate aloft ahead of the surface cold front was the result of intrusion aloft of a colder air mass. While the intrusion of colder air seems clearly indicated in this case, as well as with tornado situations in general, there is reason to believe that vertical motion aloft over a surface warm sector may also be a factor tending to increase the lapse rate.

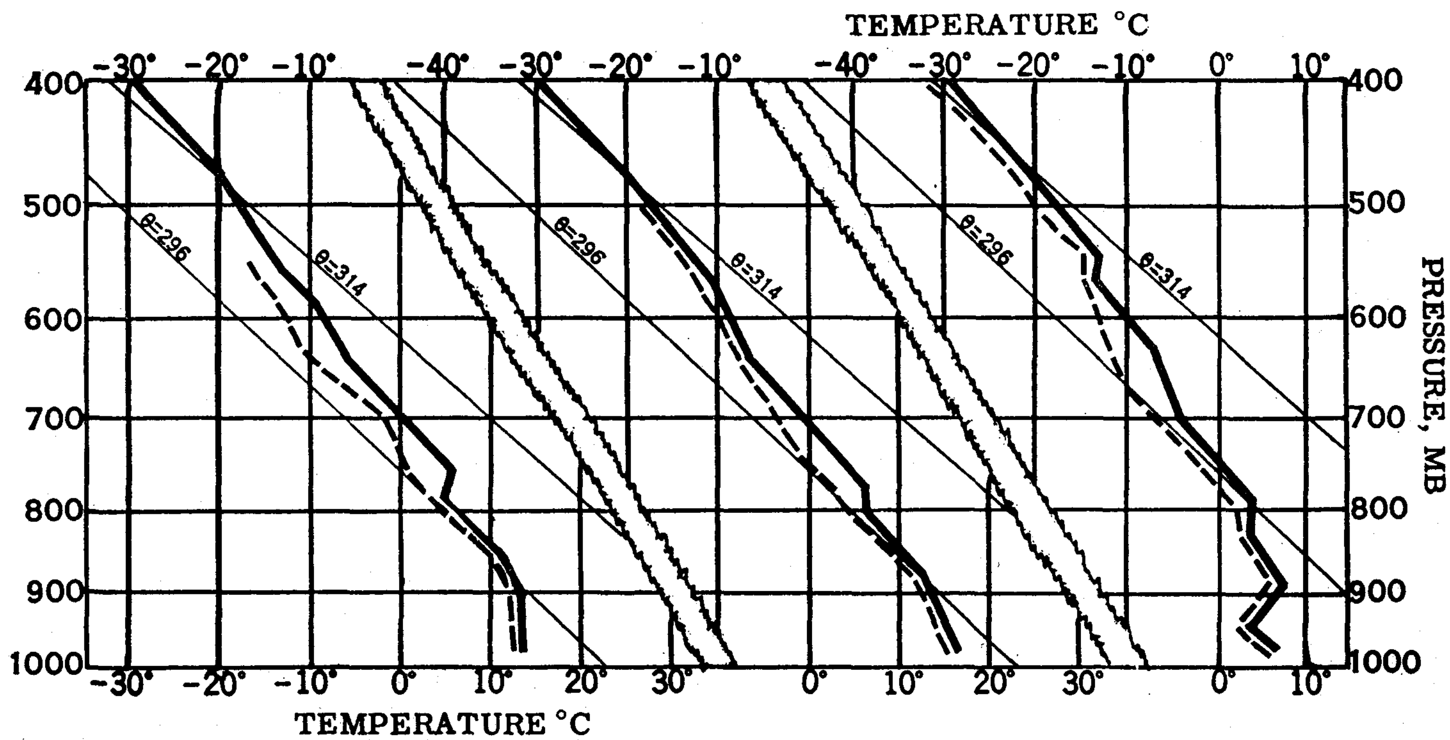


FIGURE 8.—Radiosonde observations at Rantoul, Ill., plotted on a pseudo-adiabatic diagram: Left—1500 GMT, December 2, 1950; Center—2100 GMT, December 2, 1950; Right—0300 GMT, December 3, 1950. Dashed curves are wet-bulb temperature.

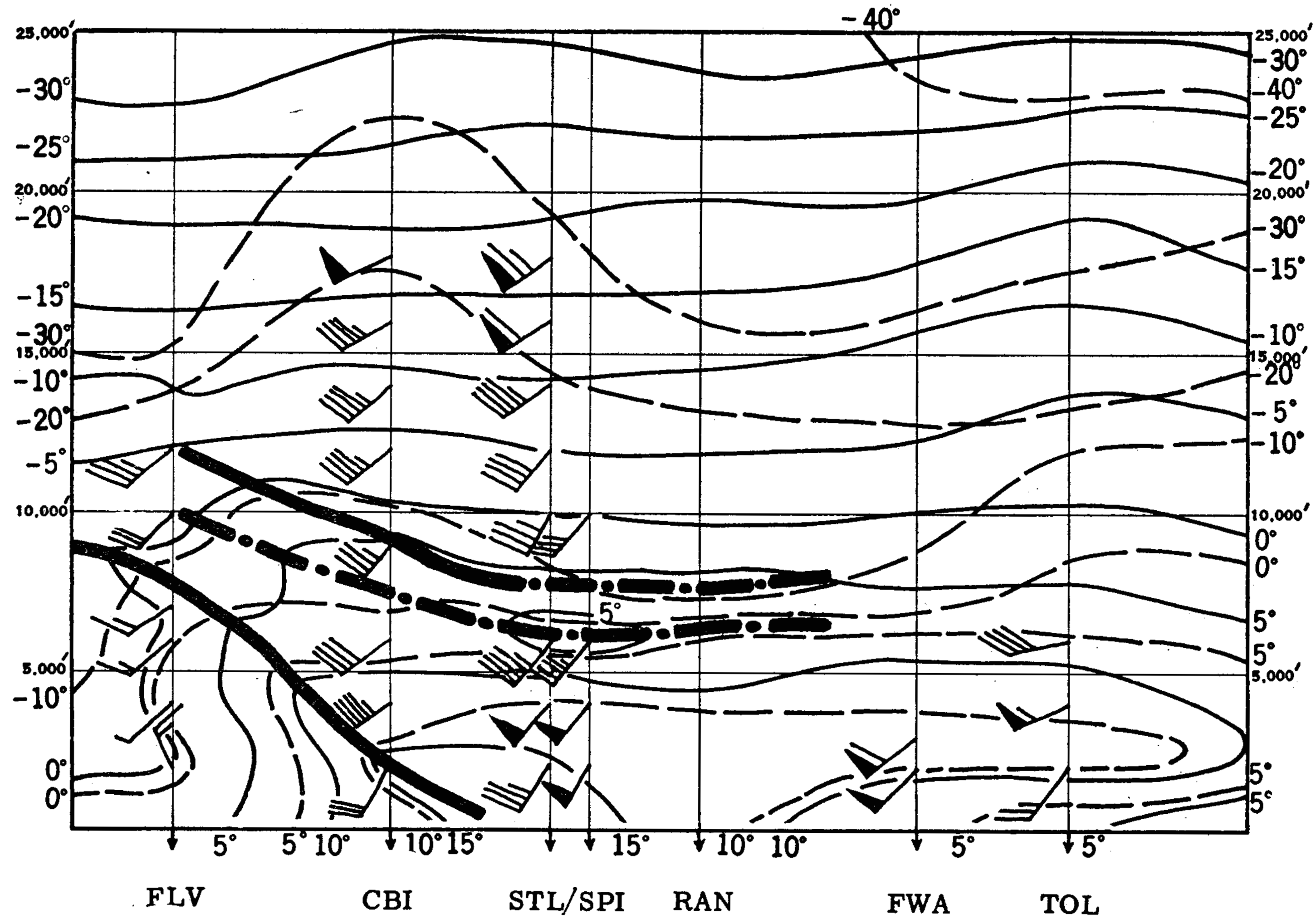


FIGURE 9.—Atmospheric cross section, 1500 GMT, December 2, 1950. Barbs on wind shafts are for speeds in knots; half barb=5 knots, full barb=10 knots, and pennant=50 knots. Arrows point upward for south winds, horizontally and to the right for west winds, etc. Thick solid lines are cold fronts. Thin solid lines are isotherms of temperature °C; Dashed lines are isotherms of dew point °C. Dot-dash lines bound temperature inversion or stable layer. Stations are from left to right, Fort Leavenworth Kans., Columbia, Mo., St. Louis, Mo., Springfield, Ill., Rantoul, Ill., Fort Wayne, Ind., and Toledo, Ohio.

## REMARKS

The main features of this tornado situation are very similar to those frequently observed with tornado conditions, in spite of the fact that in this case tornadoes occurred in an area where they are rare in December. For example, tornadoes are commonly associated with active thunderstorms, some of which produce hail. In this case many thunderstorms were reported. St. Louis, Mo., experienced an intense hail storm at 2130 GMT, about a half hour before development of the tornado which began near Highland, Ill., some 30 miles to the east-northeast of St. Louis. Since the Highland tornado was along the approximate path of the thunderstorm (assuming it to have moved in the same direction as the tornado), it is probable that the Highland tornado was associated with the St. Louis thunderstorm. The first of the three Illinois tornadoes began at Fosterburg, about 25 miles north-northeast of St. Louis, at about the same time that the thunderstorm was occurring at St Louis.

Showalter [3] has listed a number of features commonly associated with tornadoes. Of those he lists or discusses, the following seem especially evident in the December 2 situation:

1. Horizontal surface cyclonic wind shear in the general area of the tornadoes, together with strong low-level winds in the warm air.
2. Convergence associated with frontal activity.
3. Potentially unstable air.
4. Local wave development along the associated cold front.
5. An inversion or stable layer capping the lower warm moist air ahead of the tornado zone.
6. Active thunderstorms in the general vicinity, usually with hail.

An additional feature evident in this case and commonly observed in tornado situations is that of warm advection in the low levels (especially the lower 2,000 or 3,000 feet

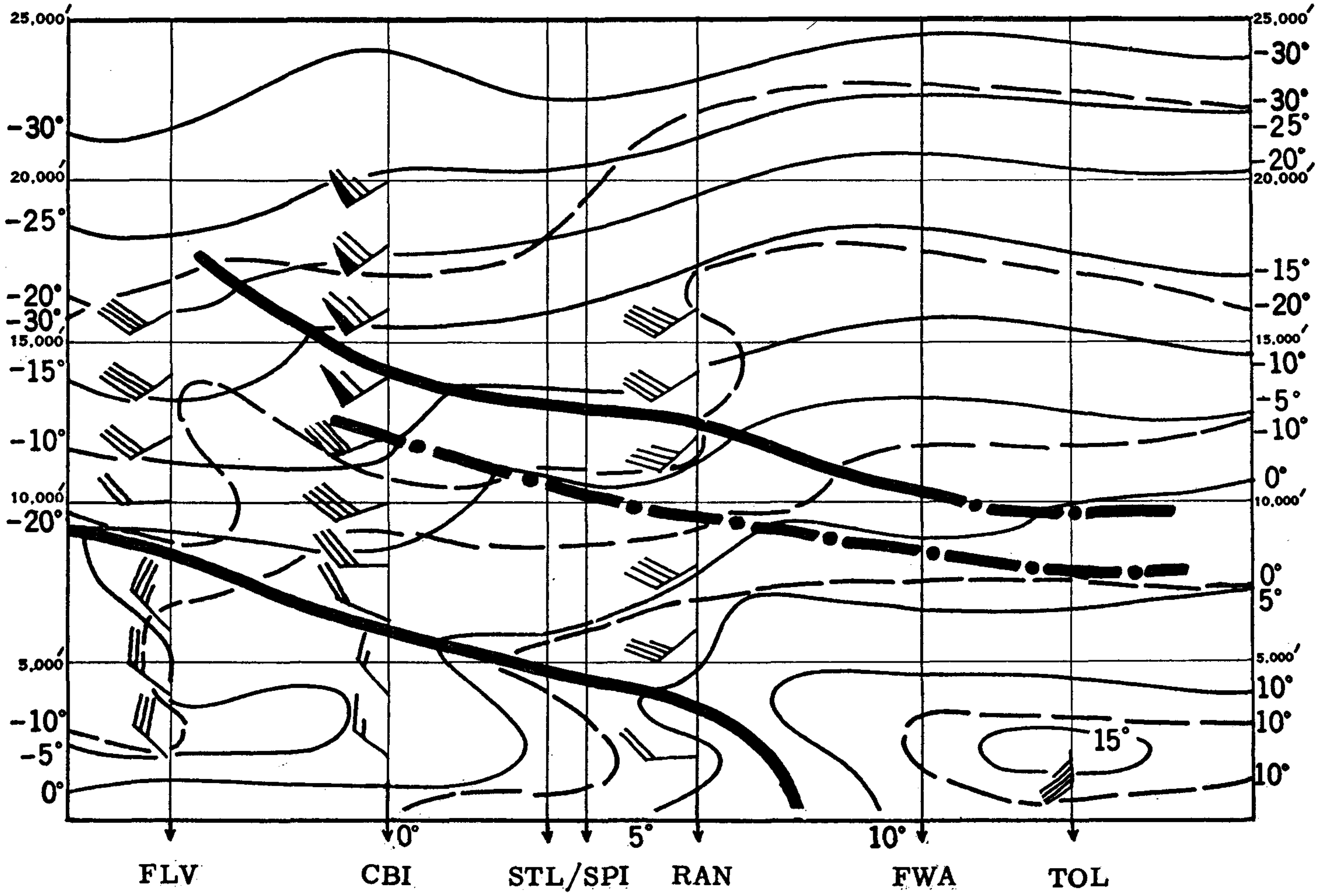


FIGURE 10.—Atmospheric cross section, 0300 GMT, December 3, 1950.

above the ground) immediately ahead of the tornado zone, and cooling aloft above the inversion or stable layer associated at least in part with cold advection aloft. These are important factors in the steepening of the vertical lapse rate. The importance of low-level warm advection in steepening of the lapse rate in connection with thunderstorms was pointed out by Means [4]. A related factor in this and with tornado situations generally is advection of moisture at low levels so as to increase the conditional and convective instability.

A feature which is frequently observed, but not evident in this case, is the association of tornadoes with a pre-cold frontal squall line (instability line) in the warm sector. The instability line, when it is associated with tornadoes, is at least in most cases the main squall line of the system. In the December 2 situation, the tornadoes were associated with (ahead of) the main squall line, but this was along the surface cold front so far as can be determined. There were, however, in this case, pre-frontal thunderstorms occurring ahead of both the surface cold front and the tornadoes but to the rear of the upper cold front.

## REFERENCES

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