# The Life Cycle of the Dryline

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## ABSTRACT

The dryline, a narrow non-frontal zone of sharp moisture discontinuity, has long been known as a preferential location of thunderstorm development. Through an examination of several years of data, a conceptual model of the dryline life cycle is developed.

The dryline originates along the trailing edge of a continental air mass and is coincident with an old frontal surface. As it moves, it is located on the surface projection of the western edge of the low-level inversion. The dryline is destroyed either by a new cold air outbreak or by becoming too diffuse to be easily recognizable.

## 1. Introduction

Severe thunderstorms over the Great Plains Region of the United States often occur in conjunction with a dryline (Rhea, 1966). This synoptic phenomenon is a narrow zone, other than a classical front, across which a sharp surface moisture gradient exists. It is frequently present in west Texas and Oklahoma during the spring (U. S. Navy, 1952), and is occasionally found as far north as the Dakotas (Fujita, 1958). While dewpoint temperature gradients larger than 10F $\mathrm{km}^{-1}$ normal to the dryline are not uncommon, afternoon virtual temperatures (and thus densities) are effectively constant across it (McGuire, 1962). This paper is a synoptic study of the life cycle of the dryline. Previous papers (Schaefer, 1973a, 1974) describe and theoretically explain dryline motion.

Gently sloping terrain is a feature of the region affected by the dryline. West of 104W, the Rocky Mountains, with elevations greater than 5000 ft MSL, present an almost continuous barrier to atmospheric flow. From this meridian eastward, the terrain approaches sea level with a decreasing slope (Fig. 1). Climatologically, the months of April, May and June display the greatest contrasts of dewpoint temperature over the south-central plains (Dodd, 1965). During this time there is a mean moist southeasterly flow from the Gulf of Mexico. The rising terrain retards this flow and forces the moist air into longitudinal motion. Over the mountainous region, relatively dry westerlies prevail. On the eastern mountain slopes, where these two flow regimes are juxtapositioned, a climatological dewpoint gradient of $\sim$15F (400 km)$^{-1}$ exists with the dewpoint isopleths approximately paralleling terrain contours (Fig. 2.) The purpose of this study was to determine how a dryline with a much sharper moisture gradient than the climatological average is established.

## 2. Dryline identification

To determine the synoptic mechanism which causes dryline development, surface charts for the years 1966 through 1968 were examined. Several criteria were developed and applied. The dryline's signature is, of course, a sharp moisture discontinuity. For this study, an east-west dewpoint temperature difference of at least 10F between reporting stations was required. To exclude local variations within an air mass, the discontinuity had to exist between several pairs of stations and remain identifiable for at least 6 hr. To further insure a distinct discontinuity, dewpoints in the moist air were required to be fairly uniform and have a mean value of at least 50F so that the mixing ratio difference corresponding to a 10F dewpoint change exceeded 3 gm $\mathrm{kg}^{-1}$.

Classical fronts were excluded by selecting only those cases in which small virtual temperature gradients existed across the moisture discontinuity during the afternoon. Also, a diurnal change in the direction of the temperature gradient was required to insure that there was no systematic density change across the line.

Critical evaluation of surface weather maps, subjected to the above selection criteria, showed that during the three-year period 22 distinct dryline cases occurred during the months of April, May and June. A dryline was present over the south-central United States on all or part of 114 days. Thus, more than 41% of the springtime days exhibited this synoptic feature.

## 3. Origin of the dryline

During the spring, the principal track of migrating anticyclones passes across the northern Great Plains

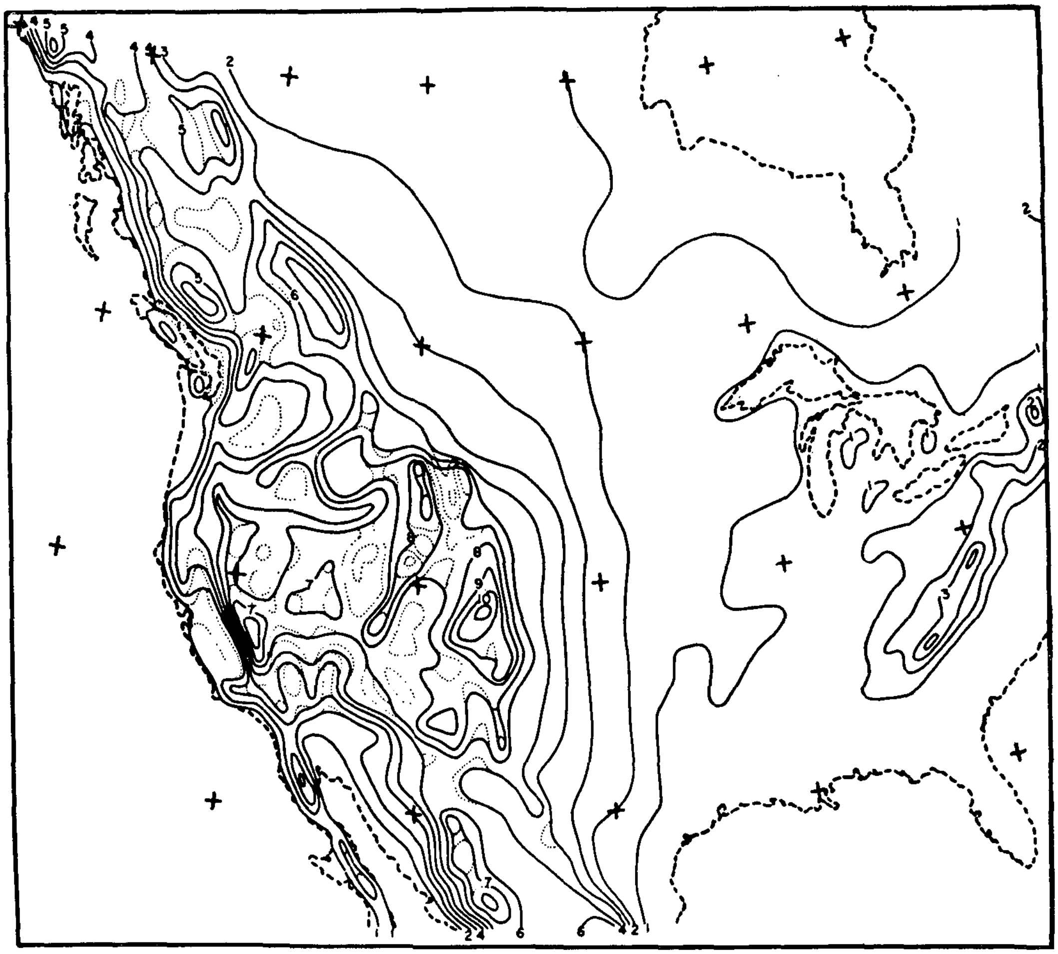


FIG. 1. Mean topography of the United States in thousands of feet (from McClain, 1960).

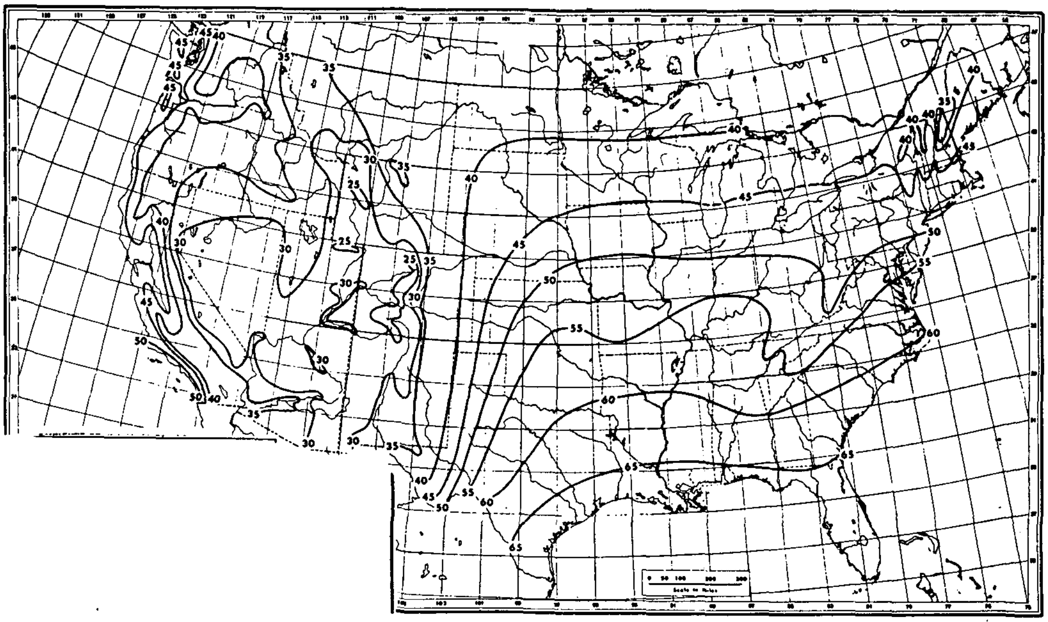


FIG. 2. Mean dewpoint temperature field (°F) in May (from Dodd, 1965).

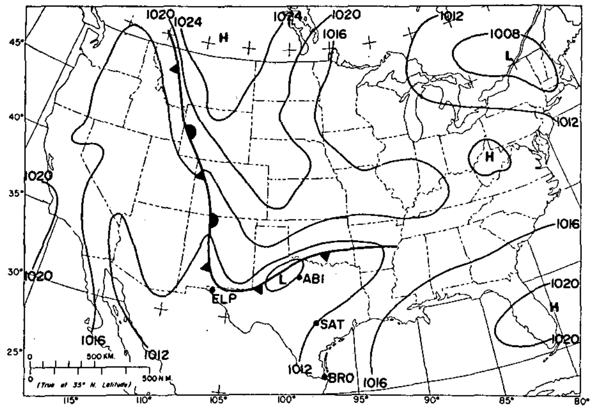


FIG. 3. Surface analysis for 1200 GMT 8 April 1966.

(Klein, 1957). As the center of an anticyclone follows this track, the air diverges and spreads horizontally except to the west where it is blocked by the mountains. A cold front initially delineates the edge of the advancing continental air mass, but as heating from the underlying surface modifies the low-level air, the surface front starts to lose its thermal identity. Over the high plains, this identification is further complicated by orographic features which mask the organization of the surface wind field. Analysis of either the surface potential temperature field or the vertical thermal stratification are the only sure ways of locating the continental air-mass boundary.

Three major ways in which moisture is brought into the initially dry air mass are evaporation from falling precipitation, evaporation from a sea surface, and evapotranspiration from a land surface. The evaporation rate of precipitation behind a front is proportional to the difference between the water temperature and the wet-bulb temperature of the air. When an air mass crosses the Gulf of Mexico, evaporation proceeds quite rapidly. Evaporation rate determination is extremely difficult since it depends on wind speed, water temperature, air mixing ratio, and other factors. The evapotranspiration process is also not amenable to general statements since both local vegetation and subsurface geology play a significant role. However, a continental air mass over the south-central plains typically requires less than four days to acquire moisture content commensurate with maritime air.

The dryline forms along the trailing edge of a returning continental air mass after its temperature contrast with the adjacent air has decreased and its moisture content has risen to a level similar to maritime air. The dryline appears coincident with the old front and lies parallel to the mountains. An inversion marks the upper boundary of the moist air and the overlying air displays the same general characteristics as the air west of the dryline.

## 4. Illustrative case study: 8–16 April 1966

To demonstrate dryline evolution, a case study of the first 1966 event is presented. At 1200 GMT 8 April, the surface map (Fig. 3) indicated a cold air outbreak over the central Great Plains. Along the mountains of Colorado and New Mexico, where westward motion of the cold air was blocked, a stationary front existed. On the continental anticyclone's southern boundary, where there is no orographic block, a well-defined cold front was present. This front extended east-northeastward from extreme southwest Texas into the southeastern corner of Oklahoma. On 10 April, after two synoptically quiescent days, a dryline appeared in west Texas in a position corresponding to the old stationary front.

Radiosonde data 12 hr either side of the 1200 GMT map on the 8th show the effect of the front. As shown in Fig. 4, Abilene, Tex. (ABI), which was south of the front at 1200, experienced approximately a 180° wind shift below 800 mb and the development of a low-level inversion between 0000 on the 8th and 0000 on the 9th. A somewhat similar effect is also evident in Fig. 4 at San Antonio, Tex. (SAT). This station, which was well south of the front at 1200 on the 8th, experienced the frontal influence near 0000 on the 9th. A comparison of the 0000 GMT soundings before and after the disturbance (8 April vs 10 April) reveals the change in air mass below 790 mb. The low-level winds shifted from southerly to easterly, and the low-level inversion base lifted more than 50 mb. On 10 April, the Abilene and San Antonio soundings are strikingly similar, with inversion bases at the same pressure level and virtually equivalent stratification.

The Brownsville, Tex. (BRO), soundings also illustrated the frontal passage (Fig. 5). Passage occurred there at about 0000 GMT 10 April with low-level winds veering from southerly to easterly. The thermal change is not as well defined as at Abilene and San Antonio due to close proximity of the Gulf but, after the disturbance passed, a definite stable layer separated low-level air from that aloft.

The stratification west of the region affected by the front is shown by the El Paso, Tex. (ELP), soundings, also given in Fig. 5. Here the lapse rate remained nearly adiabatic throughout the entire lower half of the atmosphere, indicating no frontal passage. This condition persisted until another front passed El Paso on the 14th. It is notable that vertical stratification at this location is similar to that above the inversion at the other stations. This implies that the air above the inversion has the same general source as that west of the dryline and results from subsidence east of the Rocky Mountains.

In this environment, a dryline formed and propagated. By 0000 on the 11th, the dryline was positioned through Abilene, the low-level inversion had completely disappeared, and the sounding was very

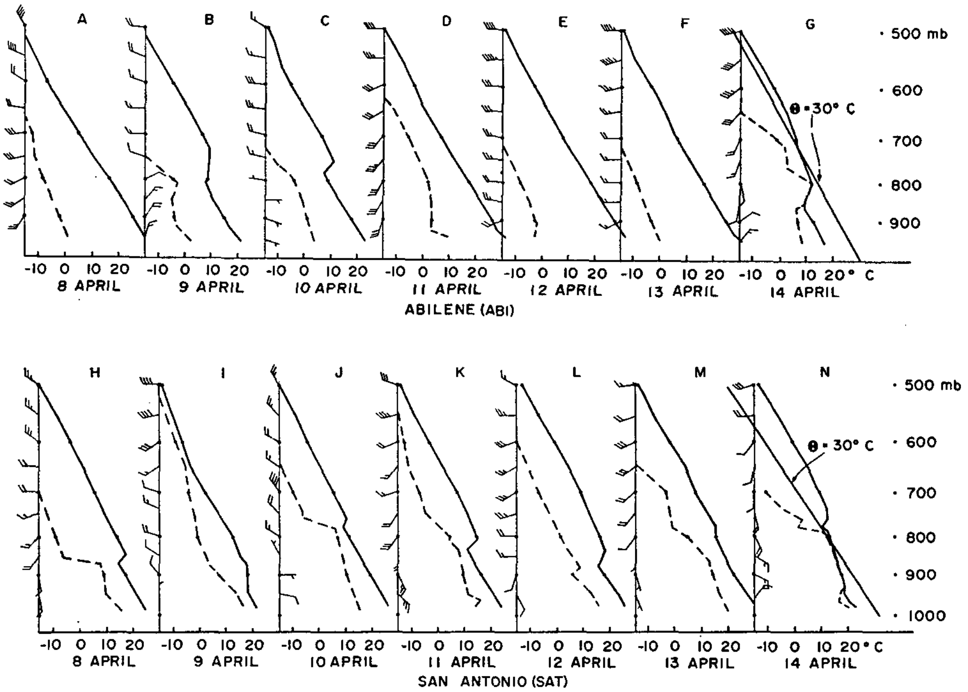


FIG. 4. Dryline soundings at 0000 GMT from 8–13 April 1966 for Abilene and San Antonio: solid line, temperature; dashed line, dewpoint; whole wind barb, 10 kt.

dry except for the lowest 18 mb (Fig. 4d). There is a marked similarity between this sounding and the simultaneous one at El Paso (Fig. 5j). At stations east of the dryline, San Antonio and Brownsville (Figs. 4k and 5c), the inversion persisted and the conditions were similar to those of the previous day. This pattern showed no appreciable change during the next two days.

The frontal passage on the 14th (which destroyed the dryline) is apparent in the sounding changes at Abilene and San Antonio. By the following day, this front had not only passed Brownsville but also El Paso,

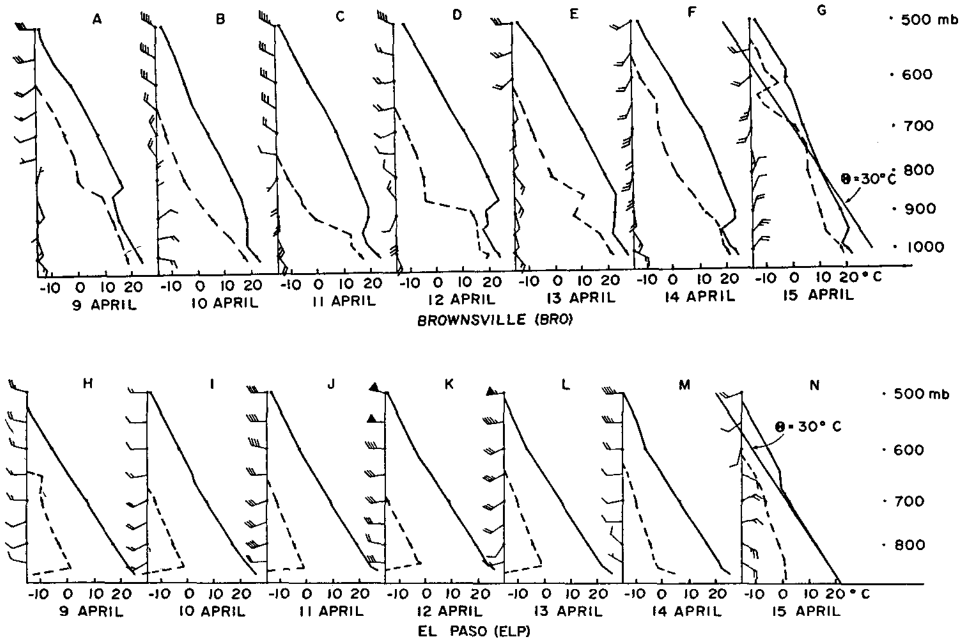
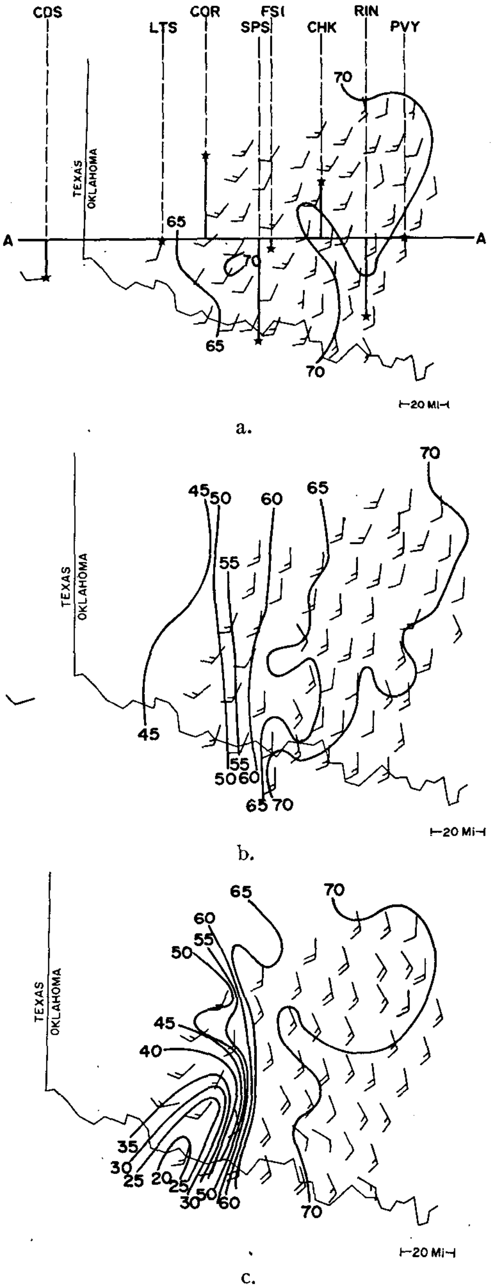


FIG. 5. Dryline soundings at 0000 GMT from 9–15 April 1966 for Brownsville and El Paso: legend as in Fig. 4.



a.

b.

c.

FIG. 6. Surface wind (whole barb 10 kt) and dewpoint temperature (°F) fields for 22 May 1966 at 1100, a., 1400, b., and 1700 CST, c.

since the cold air behind this front was deeper than for the previous case. This early season dryline clearly illustrated dryline genesis.

## 5. Relationship of the dryline to the inversion

Once a dryline forms, it is very intimately related to the low-level inversion or stable layer. Late afternoon (0000 GMT) soundings characteristically indicate a slightly unstable or neutral temperature profile on the dry (west) side while the inversion is very evident on the moist (east) side. The dryline is positioned along the projection of the western edge of this inversion onto the surface. As the dryline propagates, its positioning with respect to the edge of the inversion remains constant.

During the afternoon of 22 May 1966, a dryline entered the National Severe Storms Laboratory (NSSL) mesonetwork from the west. Surface data and serial soundings taken between 1100 and 1700 CST demonstrate the interrelationship between dryline position and vertical thermal structure. While it is tempting to use these data to analyze the kinematic features of the dryline environment, surface wind directions were measured on a 16 point compass and this coarseness of data combined with the inherent problems of computing surface divergence (Schaefer, 1973b) eliminate the possibility of drawing definitive conclusions from the surface data.

At 1100 CST the dryline was located between Childress, Tex. (CDS), and Altus, Okla. (LTS). All the NSSL surface sites were reporting high dewpoints (Fig. 6a). Fig. 7, a vertical cross section approximately normal to the dryline (all data points are projected onto line AA on Fig. 6a), from Childress to Pauls Valley, Okla. (PVY), indicates that a low-level inversion or stable layer (shaded area in the figure) capped the moist surface air east of the dryline while no inversion was present on the west side. While the high-frequency "wiggles" present on the inversion surface are possibly caused by the horizontal displacement of the stations, aircraft investigations of the dryline have shown a definite wavy character of the isentropes and isohumes (Beebe, 1958; Fujita, 1958; Staff NSSP, 1963).

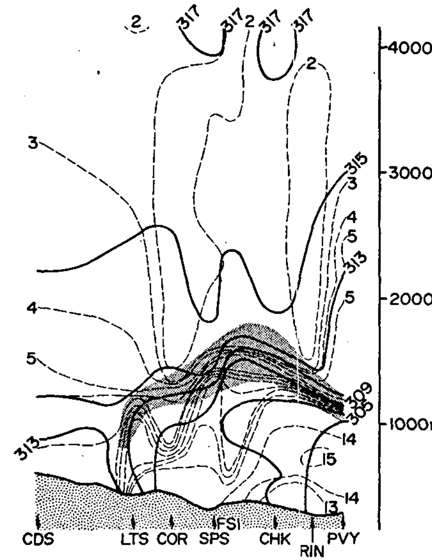


FIG. 7. Cross section at 1100 CST 22 May 1966 from Childress, Tex., to Pauls Valley, Oklahoma: dark lines, potential temperature (°K); dashed lines, mixing ratio (gm kg$^{-1}$). Shading denotes low-level inversion or markedly stable layer.

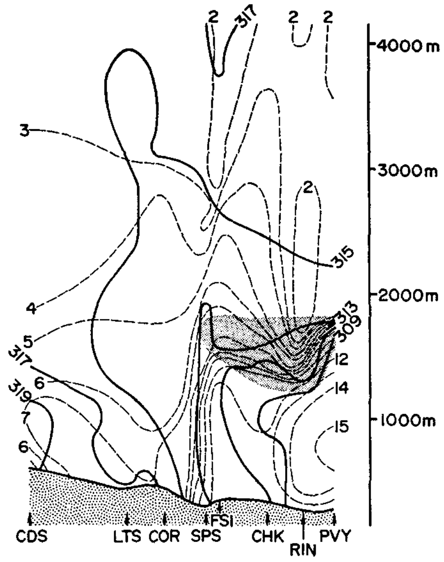


Fig. 8. As in Fig. 7 except for 1400 CST 22 May 1966.

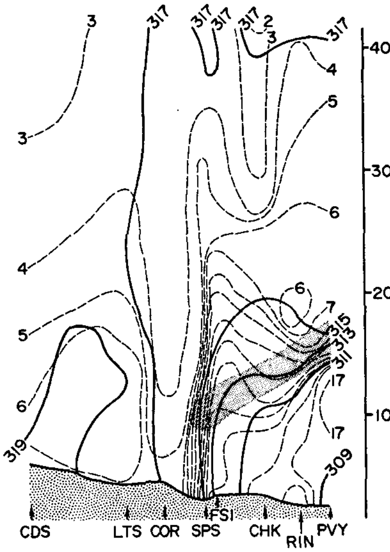


Fig. 9. As in Fig. 7 except for 1700 CST 22 May 1966.

During the next 3 hr, the dryline progressed eastward to between Altus and Fort Sill, Okla. (FSI), with dewpoints in western Oklahoma dropping over 15F (Fig. 6b). Once again, the normal cross section (Fig. 8) shows that the dryline coincides with the position of the inversion edge. By 1700 CST, the time of the last upper air data, the dryline travelled 20 n mi further eastward (Fig. 6c) and the inversion edge moved with it (Fig. 9). As surface temperatures fell during the evening, and a radiational inversion formed in the dry air, surface data indicated that the dryline weakened and moved westward out of the network.

This example is typical of all "fair weather" drylines. The horizontal termination of the low-level inversion and dryline position coincide. During the daytime the dryline moves eastward while at night it retrogrades westward. Once a dryline forms, it exists until it becomes too diffuse to be recognizable or until the inversion is destroyed by subsequent frontal passage. The latter condition normally prevents the dryline from being followed east of 96W (U. S. Navy, 1952).

## 6. Summary

The dryline forms along the backside of a continental air mass coincident with an old frontal surface. It lies along the surface projection of the western edge of the low-level inversion and both move simultaneously. If the dryline moves east of about 96W, it becomes too diffuse to be recognizable. If the dryline remains west of that longitude, it is ultimately destroyed by a subsequent cold frontal passage.

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