AN INSTABILITY LINE DEVELOPMENT AS OBSERVED BY THE TORNADO RESEARCH AIRPLANE

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ABSTRACT

A case study of the formation of an instability line traversed by the tornado research airplane before, during and after development is presented. Five traverses at the 800-mb level and two traverses at the 700-mb level were flown normal to the line. Gradients of moisture and temperature and their changes in time and space as shown from the aircraft data are presented. The dew-point front at the 800-mb level was traversed in a distance of one mile and was observed on all 800-mb traverses. The instability line developed immediately ahead of this front.

1. Introduction

During the spring and summer of 1956, the tornado research airplane, a P-51 piloted by Mr. James M. Cook, was flown into a number of tornado forecast areas. The objective of this flying was to obtain some much-needed facts about the causes and characteristics of tornadoes and their environmental conditions. It is well known that many tornadoes are associated with thunderstorms which occur in the vicinity of instability lines. The case study presented here shows the development of a line of moderate intensity in western Nebraska during the afternoon of 11 June 1956. Although no severe local storms were predicted or observed in this situation, it is an excellent example of a series of horizontal traverses normal to the line both before and after development. The horizontal traverses over the area in which the line developed show considerable detail regarding temperature and humidity gradients that were heretofore unknown. Three flights were flown in this situation, beginning at 1022 CST and ending at 1845 CST. The flight paths were generally between Cheyenne, Wyo., and Grand Island, Nebr.

The synoptic situation on the day of the three flights to be described here was one favorable for the afternoon development of a mountain lee trough in-

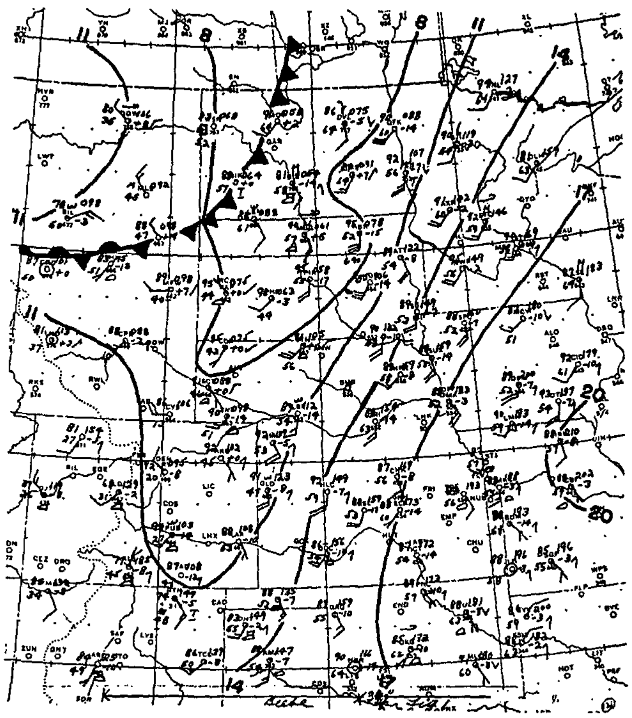

FIG. 1. Sectional surface map at 1230 CST, 11 June 1956.

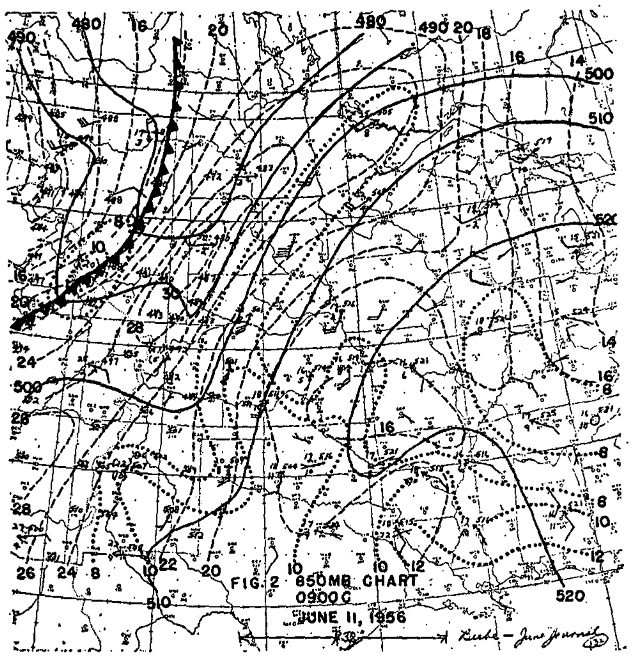

FIG. 2. Sectional 850-mb chart at 0900 CST, 11 June 1956. The solid lines are height contours in tens of feet, the dashed lines are isotherms in C, and the dotted lines are dew-point lines in C.

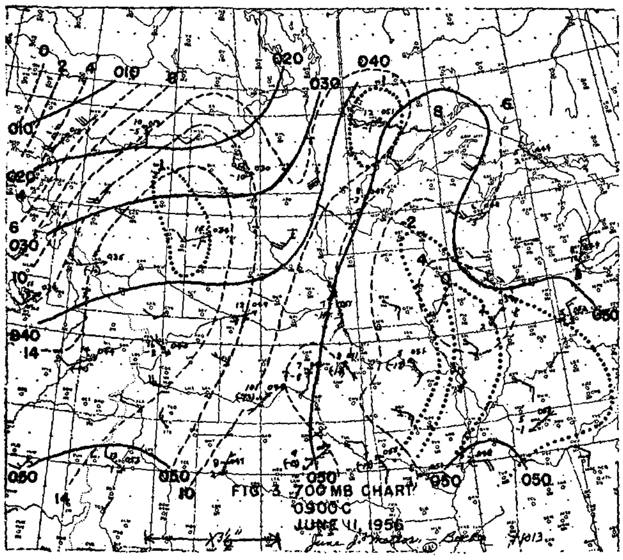

FIG. 3. Sectional 700-mb chart at 0900 CST, 11 June 1956. The lines and analyses are similar to those in fig. 2.

stability line. Low-level moisture values were not high and no marked surface low development was expected, so it was predicted that this line formation would not produce tornadoes or severe thunderstorms. Fig. 1 is a sectional surface map at 1230 CST. Note the high-surface dew points (54F at North Platte) just ahead of the lee trough line and the very low dew points (13F at Cheyenne) behind it. At the 850-mb level, fig. 2, some moisture advection may be noted near North Platte, the area of expected line development. The temperature advection is near zero so no important temperature change would be anticipated from this cause. At the 700-mb level, fig. 3, it may be observed that dew points over the area and upstream are below −6C. Also, there is no temperature advection of consequence over or near the area. Fig. 4 illustrates the North Platte sounding at 0900 GCT.

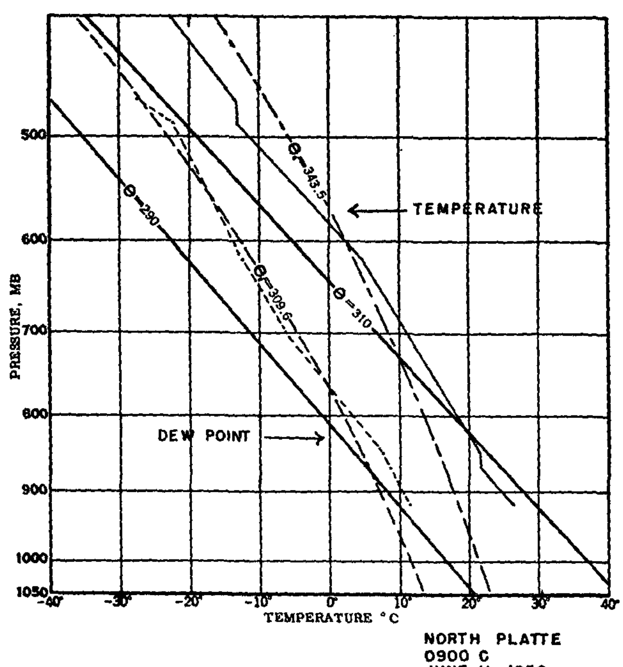

FIG. 4. North Platte sounding at 0900 CST, 11 June 1956. The solid line is the temperature curve and the dashed line is the dew-point curve.

The first of three flights was dispatched from Scottsbluff, Nebr., at 1022 CST. The flight paths, times and levels are shown in fig. 5. The instability line was penetrated three times, twice at the 800-mb level and once at the 700-mb level. The dew-point "front" was crossed, at the 800-mb level, on four traverses. After obtaining a sounding to 16,000 ft, behind the instability line on the last flight, the pilot flew on to Scottsbluff and landed at 1845 CST.

Temperature and humidity data were routinely taken from the original strip charts at one-minute intervals, which correspond to about four miles at average flight speed. In general, these were the data entered in figs. 6–10, although data at more frequent intervals from the original records were sometimes added at times of rapid changes. Since the flight level seldom deviated more than one or two mb from one minute to the next, no correction for change in elevation was applied to these data. The Navy Research Laboratories' axial-flow vortex thermometer was used to measure temperature on this project. Humidity was measured by the Weather Bureau's infra-red hygrometer. Pressure altitude was measured by a Kollsman pressure altimeter that was equipped with an electrical transducer and the output was fed into a Brown strip recorder through a servo system.

2. 800-mb flight data

Fig. 6 shows the first traverse at the 800-mb level. One of the very interesting aspects of this flight is the rapid change in moisture at the dew-point front just west of Pine Bluff. This change, from a dew point of −12C to near zero, occurred in about 20 sec of flight time or just over one mile. There is a marked tendency for the temperature and humidity curves to be out of

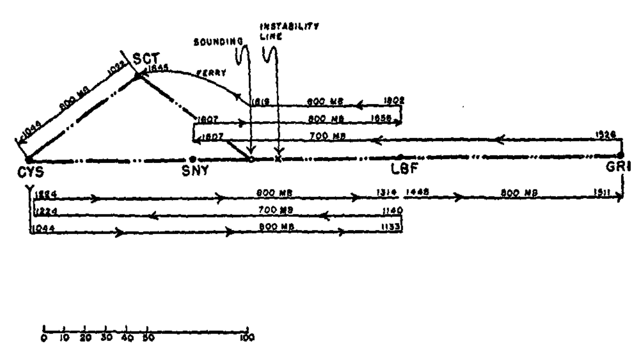

FIG. 5. Map showing flight tracks, times and levels of the three flights flown on 11 June 1956.

phase. Four "bands" of moisture were observed and a line of small cumulus clouds was observed by the pilot above the third band. Except for small temperature drops near the moisture bands, the temperature decreased rather gradually from 26C over Cheyenne to 18C over North Platte.

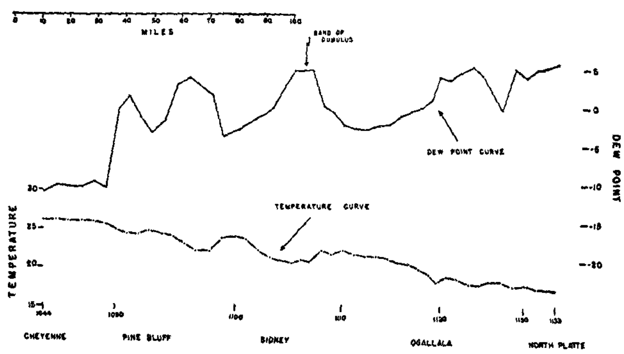

FIG. 6. Diagram illustrating the first 800-mb traverse, from Cheyenne to North Platte. Stations and times (CST) are shown along the bottom of the chart; temperature values in C on the left; dew-point values in C on the right; scale of miles is shown at the top. For convenience in drafting, the temperature and dew-point scales do not correspond with each other.

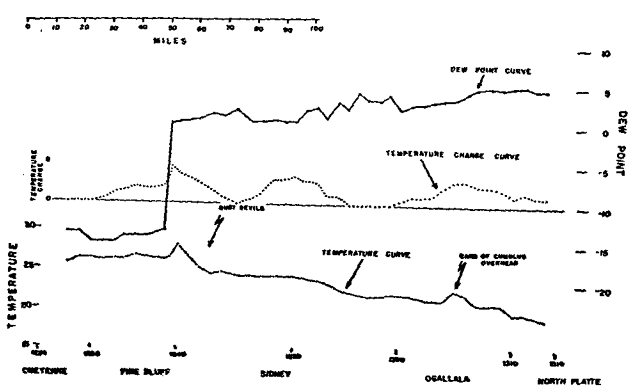

FIG. 7. Diagram illustrating the second 800-mb traverse, from Cheyenne to North Platte. Data shown are similar to those in fig. 6 except that a dotted temperature-change curve has been added. The magnitude of this change, during the 1:40 hr interval between flights, is shown on the left with values varying from 0 to +5C.

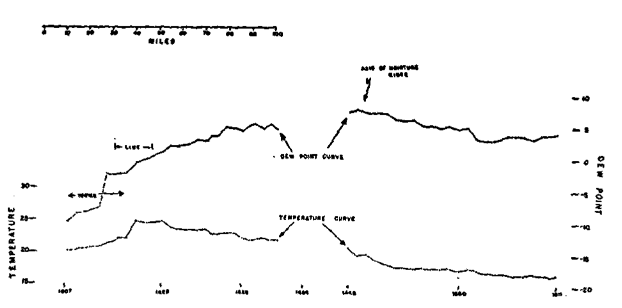

FIG. 8. Diagram illustrating the third and fourth flights at the 800-mb level. Data shown are similar to those in fig. 6. The third flight was from North Platte to Grand Island, and the fourth flight was from Sidney to North Platte. Note that on the fourth flight, shown on the left, temperature and dew-point values are for the 750-mb level from 1607 GCT to about 1620 CST.

The second 800-mb traverse along the same path (fig. 7) was made 1:40 hr later going east from Cheyenne to North Platte. The flight encountered the dew-point front 22 mi east of its previous position, a movement of 13 mph. The dew-point front was traversed in 15 sec, and the gradient is now even more pronounced, with values increasing from −14C in the dry air to +1C over a distance of one mile. Note that the moisture is much more uniformly distributed at this time. The dew point increased rather gradually to +5C near North Platte, whereas the previous flight showed values varying from −5C to +5C over the same area. Thus, there has been a general increase in moisture between these flights. The temperature curve is very similar to that of the previous 800-mb flight except for a sharp rise of some 2C just east of the dew-point front and another sharp rise (2C) below a band of small cumulus clouds. The temperature change in the 1:40 hr between flights is shown as a dotted curve in fig. 7. Of particular interest is the rise of 4.5C just ahead of the dew-point front. It was in this area that the pilot noticed numerous dust devils on this flight, and some three hours later the line developed here. The other two areas of marked temperature rise, near Sidney and Ogallala, corresponded to small bands of cumulus overhead (only one is indicated in fig. 7).

The third 800-mb flight, fig. 8, was made from North Platte eastward to Grand Island. The objective was to locate the axis of the moisture ridge and it was found to be just east of North Platte.

The fourth 800-mb traverse, fig. 8, was begun at 1607 CST near Sidney and was 4:05 hr after the second traverse. At this time, two individual cells observed on radar just east of Sidney were merging into a line so that this flight was made very close to the time of line formation, but about 1½ hr after the first

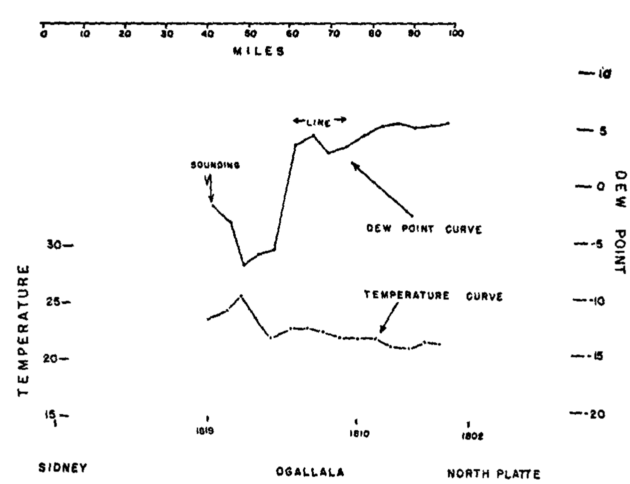

FIG. 9. Diagram illustrating the fifth, and last, 800-mb traverse from North Platte to just west of the line. Data shown are similar to those in fig. 6.

radar echo was observed. The positions and movement of the line as reported by the radars conformed reasonably well to those reported by the pilot. It must be remembered that visual observations are of clouds and that the line itself is usually preceded and followed by clouds of varying types and at different levels. In trying to penetrate this line of moderate echoes the pilot was unable to fly at the 800-mb level. Instead, he flew at 750 mb behind and to about the middle of the line, so data entered on fig. 8 (dashed) are shown for this level. In the middle of the line, the pilot was able to fly from near the 750-mb level to the 800-mb level in about one minute. The sharp temperature rise of 3C in one minute occurred at the 800-mb level. It may be noted that moisture increased very sharply at the dew-point front again, over a distance of about one mile. It had moved eastward at 13 mph since the flight 4:25 hr ago. The dew-point front also marked the western edge of the line as reported by the pilot in flight. It is interesting to note that moisture values increased 100 mi eastward from the center of the line. The pilot did not report rain on this penetration although he did report very light rain in the leading edge of the line 20 min earlier on the second 700-mb traverse. Temperature changes in 4:25 hr over the same area showed an increase of 3C near the leading edge and just ahead of the line, and 1–2C from this point to North Platte.

The last 800-mb traverse, shown in fig. 9, was flown at about the time of maximum activity as shown by the radars at Goodland, Scottsbluff, and North Platte. At this time, all three radars were reporting moderate echoes in this line. These flight data show a temperature and moisture pattern very similar to that in fig. 8 in that the moisture increases gradually ahead of the line, temperature decreases gradually ahead of the line, and the dew-point front continues to be very sharply defined over a one-mile distance. However, behind the line both temperature and humidity undergo rapid and marked variations. Since a sounding was taken behind the line as soon as the pilot could make the climb to 16,000 ft, horizontal temperature and humidity data are available for only some 15 mi behind the line.

3. 700-mb flight data

The first 700-mb traverse, fig. 10, shows quite a uniform temperature distribution, decreasing from 16C over Cheyenne to 14C near North Platte. Moisture values were generally low and the gradient was fairly smooth. A region of moisture maxima was observed near Sidney where dew points were measured at −8C (this was the area in which the line developed some three hours later).

The second 700-mb traverse, fig. 11, was made near the time of line formation and the line was penetrated from east to west. The temperature distribution is rather smooth, but not as much so as on the first flight at this level. Temperature changes, over a four-hour period, show an increase of 1.5C immediately behind the line, uniform falls of 0.5C through the line, falls of 2C at 1550 CST at the time turbulence was encountered, and little change elsewhere. The humidity curve showed a marked decrease at the western edge of the line, but perhaps the most significant feature is that moisture values have increased from −8C to near zero in the area of line development and as much as 40 mi ahead of the line. This increase occurred outside the rain area. Since there was no apparent moisture advection indicated on the 700-mb chart at 0900 CST (fig. 3), it would seem most likely that this moisture increase came from some lower level.

4. Conclusions

From this study, the following conclusions have been drawn regarding this particular instability line development:

1. This instability line developed just ahead of a sharply defined low-level dew-point front. This is in agreement with the findings of Fawbush and Miller [1].

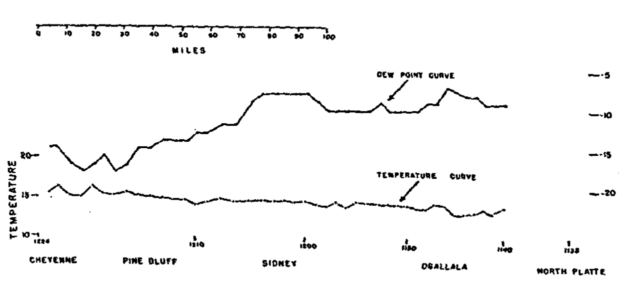

FIG. 10. Diagram illustrating the first 700-mb traverse from near North Platte to Cheyenne. Temperature in C is shown on the left and dew-point values in C are shown on the right.

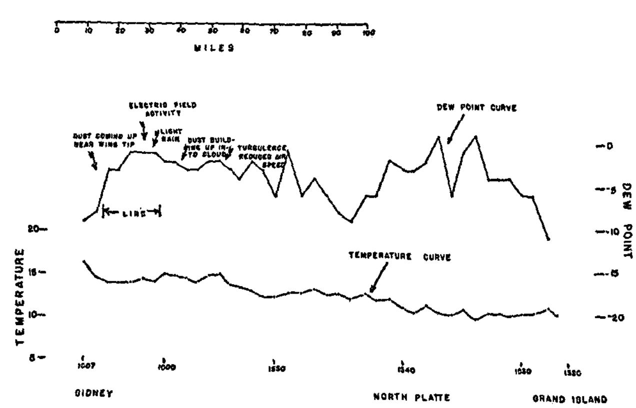

FIG. 11. Diagram illustrating the second 700-mb traverse from Grand Island to Sidney. Temperatures and dew points are similar to those shown in fig. 10.

2. The line developed in an area of relatively high moisture content but some 100 mi west of the axis of the moisture ridge.

3. The moisture at the 700-mb level in the vicinity of the line development was apparently increased from below, in agreement with findings of Beebe and Bates [2].

4. The line developed in an area where the local temperature increase at 800 mb was not due to advection as evidenced from 0900 CST charts. This warming was not noted at 700 mb.

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