Wind and Temperature Variations during Development of a Low-Level Jet

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ABSTRACT

The 1428-ft television transmitter tower, located at Cedar Hill, Texas, and instrumented to obtain continuous measurements of wind and temperature at 12 levels from 30 ft to 1420 ft above ground, is proving to be a useful research tool for investigating low-level meteorological phenomena, especially the low-level jet. During the night of 22-23 February 1961, a pronounced low-level jet was recorded. Systematic variations of wind speed and temperature with time and height will be discussed to illustrate the orderly development of the low-level jet, the upward growth of the nocturnal inversion, and the vertical extent of the mixing process within the deepening inversion.

1. Introduction

Detailed information on wind and temperature variations in low-level meteorological phenomena have become available from the meteorological research facility at the 1428-ft television transmitter tower at Cedar Hill, Tex., approximately 17 miles SSW of Dallas.

The meteorological system for the Cedar Hill tower was designed, assembled, and installed by the Electrical Engineering Research Laboratory, The University of Texas, under contract with the Air Force Cambridge Research Laboratories, with some financial assistance from the U. S. Army Signal Research and Development Laboratory. This system is designed to obtain continuous measurements of wind and temperature at 12 levels on the tower. The levels of observations are 30, 70, 150, 300, 450, 600, 750, 900, 1050, 1200, 1300, and 1420 ft above the ground. Wind measurements are made in the form of southerly and westerly wind components and temperature measurements in the form of ambient temperature at the lowest level and 11 temperature differences between the remaining levels. For routine operation the data are time-averaged for a period of 10 minutes. Averaging period can be changed as desired for any particular investigation. All measurements and recordings of the variables are performed automatically. A detailed description of the meteorological and data processing equipment is provided by Gerhardt, Mitchem, and Straiton (1962).

2. Discussion of data

Since the Cedar Hill meteorological system went into operation in late December of 1960, many low-level jets have been recorded. The most pronounced low-level jet developed on the night of 22-23 February 1961.

The synoptic situation during the night is best described by a series of surface weather maps (Figs. 1, 2, 3, and 4) analyzed for every millibar by the A and M College of Texas. The maps show a low center moving from eastern Colorado to the Texas Panhandle, with some increase of pressure gradient in the vicinity of the Cedar Hill tower. Throughout the period all stations surrounding the tower reported clear skies and light to moderate SSW to SW winds at the surface.

The winds aloft patterns over the same area are illustrated in Figs. 5, 6 and 7. The 4000-ft (above mean sea level) wind pattern at 1800 CST, 22 February (Fig. 5) shows the flow to be generally from SW and W. Strong winds of 31 kts are reported at Midland (MAF), Tex. and 32 kts at Little Rock (LIT), Ark., showing a tendency for a jet stream to be along the dashed-line oriented WSW to ENE. Six hours later, at 0000 CST, 23 February, the wind field (Fig. 6) shows the formation of an intense jet core with the 45-kt isotach enclosing a small area with Dallas and Fort Worth near the center.

The extent of the jet core in the vertical as well as in the horizontal is shown in Fig. 7 by vertical cross sections of wind speed at heights up to 12,000 ft above mean sea level along the two dashed lines in Fig. 5. One cross section extends from Midland to Memphis (MEM) through Amon Carter Field (ACF) almost parallel to the flow and the other from Oklahoma City (OKC) or Tulsa (TUL) to Shreveport (SHV) through Amon Carter Field almost normal to the flow. The analyses were made using the wind speeds as they were reported up to 12,000 ft without resolving the wind vectors into components. At 1800 CST all stations, in general, show wind speed increasing with height. By 0000 CST the wind pattern has changed completely. The winds at the higher level show a marked reduction

FIG. 1. Surface map for 1700 CST, 22 February 1961.
Isobars are shown at 1-mb intervals.

FIG. 2. Surface map for 2100 CST, 22 February 1961.

FIG. 3. Surface map for 0000 CST, 23 February 1961.

FIG. 4. Surface map for 0300 CST, 23 February 1961.

in speed and this is compensated by a marked increase of wind speed at the lower levels.

Fig. 8 shows the temperature and wind speed profiles obtained from the Cedar Hill tower for selected periods during the formation of the low-level jet. At 1700 CST, there is nothing unusual in the temperature or in the wind speed profile. The temperature gradually decreases with height and the wind speed from 30 to 1300 ft varies from 12 to 27 mph. At 1940 CST a strong,

shallow inversion exists from 30 to 450 ft and, with time, this nocturnal inversion propagates upwards. By 0300 CST the top of the inversion has reached the uppermost level of the tower. The wind speed profiles show the progressive rise of the level of maximum wind speed, with the levels of the wind speed maxima coinciding with the top of the rising inversion. The significance of the relationship between the wind speed maximum and the top of the nocturnal inversion is discussed by

Fig. 5. Wind field (in kts) at 4,000 ft for 1800 CST, 22 February 1961.

Fig. 6. Wind field at 4,000 ft for 0000 CST, 23 February 1961.

Fig. 7. Vertical cross sections of the wind field (in kts) along the dashed lines shown in Figs. 5 and 6.

FIG. 8. Time variation of temperature and wind speed profiles measured on the Cedar Hill tower during the night of 22-23 February 1961.

FIG. 9. Hodographs for the same periods as in Fig. 8. The southerly wind component is indicated by v and the westerly component by u . End point of wind vector at 1300 ft is denoted by "x."

Blackadar (1957). At 0300 CST the wind speed maximum is shown to be below the top of the inversion and at this time the highest wind speed value of 63.7 mph is attained at 1200 ft, while at 30 ft the wind speed is 14.9 mph.

Fig. 9 shows the hodographs for the same periods as the previous figure. The ordinate is the southerly wind component and the abscissa the westerly wind component. The "x's" denote the end points of the wind vectors at 1300 feet. These hodographs show the customary veering of the wind with height. The kinks in the hodographs at points A, B, and C at 1940, 2240, and 0140 CST may appear questionable, but when the vertical temperature distributions are considered (Fig. 8), it is found that the kinks occur at the top of the inversion.

Figs. 8 and 9 show the systematic and orderly growth of the low-level jet and the close relationship between the level of maximum wind speed and the top of the nocturnal inversion.

The development of the low-level jet was marked by a very interesting sequence of wind speed and temperature changes. Fig. 10 shows the time variation of the wind speed for the lower levels of the tower. Wind

FIG. 10. Time variation of wind speed for the lower levels on the Cedar Hill tower during the night of 22-23 February 1961.

data for the period 1710 through 1910 CST are missing. The general trend in wind speed is upward between 1700 and 0300 CST at all levels above 150 ft, but the pattern at each level is made up of two time periods: the first marked by a significant increase of wind speed with time and the second by a leveling off, superimposed on which is a somewhat oscillatory pattern. Fig. 11 shows the time variation of the wind speed for the upper levels of the tower, using a different wind speed scale for each of the levels to avoid overlapping. Here we see the interesting sequence of changes in the wind speed and the distinct advantage of the height of the Cedar Hill tower over other meteorological towers and the advantage of the continuous observations at these heights over balloon observations. The wind speed trend at the 750-ft level is increasing until the first arrow. At this point the wind speed decreases abruptly, showing a sudden decrease of momentum, while 150 ft above at 900 ft the wind speed continues to increase. Similar behavior is noted for the other levels—the abrupt decrease in wind speed at one level is accompanied by a continued increase of wind speed at the level above. It is also noted from this figure and from Fig. 10 that the time of occurrence of the decrease in wind speed is later for each succeeding level between 300 ft and 1200 ft, and that the time between the decrease at one level and the decrease at the next level above (indicated by intervals between arrows in Fig. 11) decreases systematically until the time difference is approximately 20 minutes between the 1050-ft and 1200-ft levels. In spite of the fact that there is a positive systematic error in the 900-ft wind speed the data are used because they illustrate the trend shown by the other levels.

During this period of systematic wind speed change with time and height, the temperature at each level is also undergoing systematic changes. The time variation of the temperature for the various levels shown in Fig. 8 is presented in greater detail in Fig. 12. Between 2030 and 0300 CST the general trend in the temperature is downward in the lowest 450 ft, with the major variations approximately in phase. However, as in the wind speed history, at levels above 450 ft the major temperature decreases follow one another in time. Again, as with the wind speed, the difference in time between major temperature decreases for two adjacent levels at 150 ft apart decreases systematically: 140 minutes between 450 and 600 ft, 110 minutes between 600 and 750 ft, 40 minutes between 750 and 900 ft, 30 minutes between 900 and 1050 ft, until the time difference is approximately 20 minutes between 1050 and 1200 ft.

It should be added that the wind speed changes in Figs. 10 and 11 and the temperature changes in Fig. 12 occurred almost simultaneously. This relationship can be more easily seen in Table 1.

TABLE 1. Times of occurrence of major temperature decreases and of the associated wind speed changes. Time in CST.

Height (ft)	Time of temperature decrease	Time of wind speed change
450	2010	2020
600	2230	
750	0020	0040
900	0100	0110
1050	0130	0130
1200	0150	0150

FIG. 11. Time variation of wind speed for the upper levels on the Cedar Hill tower during the night of 22-23 February 1961.

FIG. 12. Time variation of temperature for the various levels on the Cedar Hill tower during the night of 22-23 February 1961.

3. Conclusions

This systematic behavior of temperature and wind speed suggest that colder air and lower momentum at lower levels are transported vertically in an organized fashion by mixing during the formation of a rather intense low-level jet. The time series of temperature and wind speed suggest that this vertical mixing process, as a significant process, starts at about the 300-ft level early in the evening and proceeds upward, slowly at first and more rapidly later, until it affects the temperature and wind profiles at 1200 ft above ground. The importance of wind shear as a destabilizing factor in the breakdown of steep wind gradients in inversions has been discussed by Durst (1933) and Wanta (1953); but an example of the associated sequence of temperature change, the vertical extent of the mixing process, and the rate at which it occurs is shown in detail by the data collected from the Cedar Hill tower during the night of 22-23 February 1961. In other low-level jets

which have occurred since February of 1961, similar patterns have been found.

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