D3-47
13 P

1.2.1 EXAMPLES OF MESOSCALE STRUCTURES AND SHORT-TERM WIND VARIATIONS DETECTED BY VHF DOPPLER RADAR

N87-10422

G. S. Forbes

Department of Meteorology
The Pennsylvania State University
University Park, PA 16802

INTRODUCTION

The first of three wind profilers planned for operation in central and western Pennsylvania began full-time, high-quality operation during July 1985. It is located about 20 km south-southeast of University Park and operates at 50 MHz. Another 50-MHz radar and a 400-MHz radar are to be installed over the next few months, to complete a mesoscale triangle with sides of 120-160 km.

During the period since early July, a number of weather systems have passed over the wind profiler. Those accompanied by thunderstorms caused data losses either because the Department computer system lost power or because power went out at the profiler site. A backup power supply and an automatic re-start program will be added to the profiler system to minimize such future losses. Data have normally been averaged over a one-hour period, although there have been some investigations of shorter-period averaging. In each case, preliminary examinations reveal that the profiler winds are indicative of meteorological phenomena. The only occasions of bad or missing data are obtained when airplane noise is occasionally experienced and when the returned power is nearly at the noise level, at the upper few gates, where a consensus wind cannot be determined. Winds are being examined in high-resolution (close range) mode and low-resolution (far range) mode. Range gates are separated by about 290 m in the former and about 870 m in the latter. For the types of examples presented in this paper, with emphasis on mesoscale variations, illustrations below are normally taken from the high-resolution data.

SUMMARY OF ANALYSIS SCHEME DEVELOPMENT

Before the first Penn State profiler began operation, much effort was put into the development of analysis and display schemes. These were first tested on data obtained on tape from the Fleming radar of the Wave Propagation Laboratory. Some of these techniques are illustrated with Penn State data in the sections that follow. Among the schemes developed are:

- Power spectra displays
- Tabulations of wind components, returned power, consensus statistics
- Displays of u and v component vertical profiles
- Time-height section displays of u, v, velocity vectors, wind speed, wind direction, returned power
- Time series displays of u, v, wind speed, wind direction at a selected level
- Tabulations of vertical wind shear and component normal to the shear vector
- Tabulations and profile displays of temperature gradient, temperature advection, stability gradient, and stability advection
- Hodograph displays

In the temperature gradient, temperature advection, stability gradient, and stability advection calculations, it has been assumed, as a first approximation, that the vertical shear of the wind is in geostrophic (i.e., thermal wind) balance, even though the individual winds themselves may have an ageostrophic component. The idea of computing the shear vector at various levels and the wind components normal to these shear vectors is that (1) many atmospheric banded features are oriented along the shear vector and (2) these features are steered by the normal component of the mean wind in the layer.

CONFLUENCE ZONE ALONG WEST SIDE OF WARM CONVEYOR BELT

On 27 August 1985, at about 1400 GMT, a sharp wind shift occurred at the 8-9 km levels (Figure 1). The wind shift was accompanied by the passage of a narrow band of cirrus clouds that marked the western edge of a warm conveyor belt which was only partially filled with clouds. There was also a marked decrease in wind speed at this time. While satellite imagery showed a near discontinuity at this time, conventional upper-air analyses (Figure 2) did not indicate that a wind shift would be expected over Pennsylvania. In fact, a much more marked wind shift was evident across central Ohio. Knowledge of the profiler wind would have allowed for a better interpretation of the hints of a trough axis near Buffalo, New York, by allowing for a diagnosis that the main part of the trough was negatively tilted (from near Buffalo to central Pennsylvania) and was "lifting out" rapidly toward the northeast, leaving behind the southern, positively tilted portion of the trough from central Ohio to Tennessee and Louisiana. This shearing of the trough became apparent on the next upper-air charts 12 hours later.

TAIL OF COMMA CLOUD

The extreme southern end of the tail of a comma cloud pattern passed over the profiler at about 1000 GMT on 19 August 1985. Its approach was accompanied by a weak trough (backing) in the wind field, and a sudden clockwise shift (veering) of the wind at its rear edge (Figure 3). The comma was accompanied by a wind speed maximum. The data suggest that the trough line was nearly vertical from surface to upper troposphere.

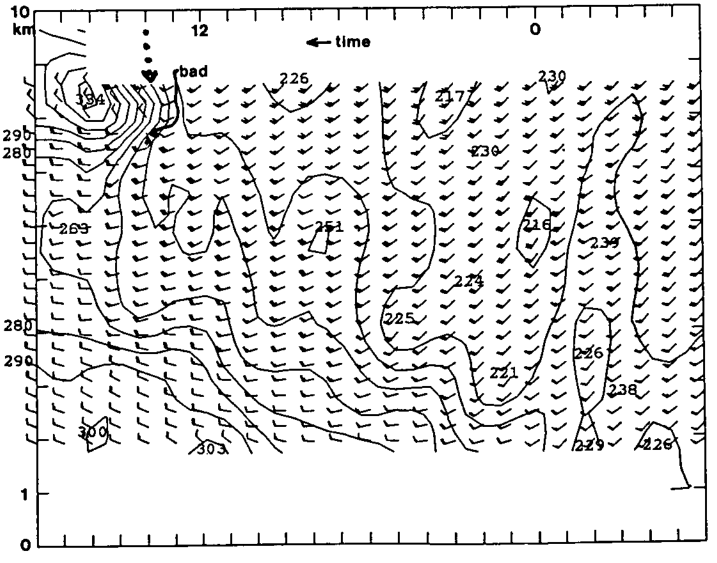

Figure 1. Time-height section of hourly wind vectors (one barb equals 5 m/s) and isopleths of wind direction from 1800 GMT on 26 August 1985 (right) to 1800 GMT on 27 August 1985 (left). Dots indicate cloud band.

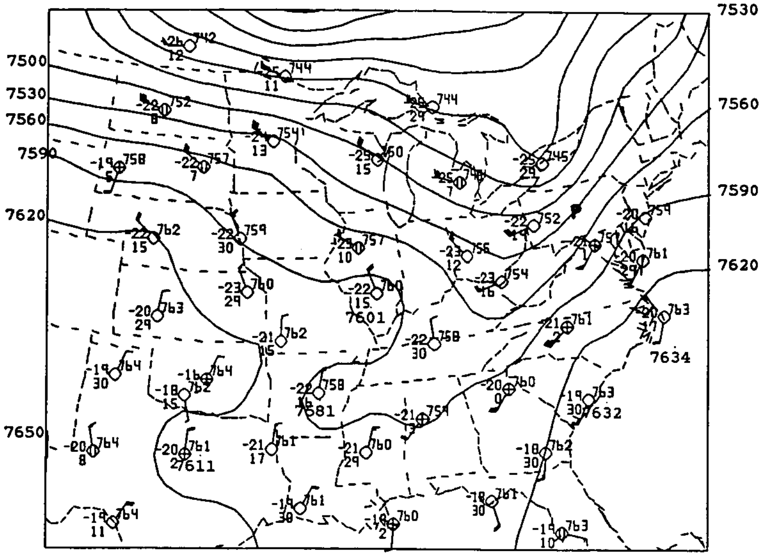

Figure 2. Upper-air chart of the 400 m surface at 1200 GMT on 27 August 1985. Winds are in knots, and a flag is approximately 5 m/s.

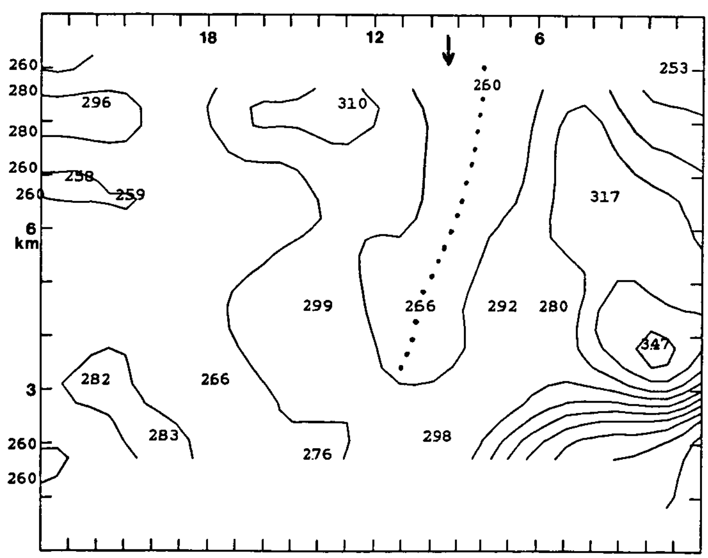

Figure 3. Isopleths of wind direction from 0000 GMT on 19 August 1985 (right) and hourly to 0000 GMT on 20 August 1985. Trough line is shown by dots, and center of comma cloud tail by arrow.

MINOR TROUGH AND CLOUD BAND

During the morning hours of 19 September 1985 an unexpected thin patch of clouds drifted across central Pennsylvania. These accompanied a rather dramatic pattern of wind shifts shown in Figure 4. The clouds occurred near the axis of a minor short wave trough at the 3-5 km levels from about 0500-1300 GMT, marked by a shift of the winds from N or NW to almost westerly before veering back to north. There was no reason to expect this trough, based upon the previous 0000 GMT upper-air charts (Figure 5).

Some other types of displays are illustrated in Figures 6-9. Figure 6 is a vertical profile of geostrophic temperature advection at 0600 GMT on 19 September. Note that veering and backing of the winds indicate warm/cold advection by the geostrophic wind. Figure 7 is a hodograph of the low-resolution (far range) winds at this time. Figure 8 shows an overlay of three vertical profiles of the v component of the wind at 0000, 0600, and 1200 GMT on 19 September 1985. Figure 9 is a time series of the u component of the winds at 5.12 km MSL from 0000 to 1800 GMT on 19 September 1985. Each of these displays reveals that the temporal and spatial variations of the wind are rather systematic and contain little apparent noise.

JET STREAM AND WARM CONVEYOR BELT

The rear edge of a warm conveyor belt cloud pattern passed over the profiler at about 1200 GMT on 20 August 1985. Wind speeds were high within the conveyor belt (Figure 10), in excess of 25 m/s at the 8-km level, and decreased rapidly as the west edge of the cloud pattern passed. Wind directions also began to veer abruptly aloft (Figure 11) as the edge of the clouds passed.

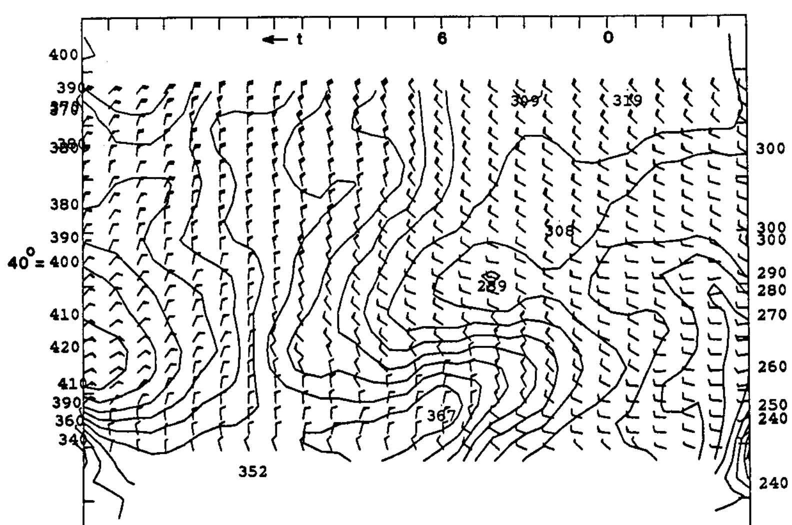

Figure 4. Time-height section of hourly wind vectors and isopleths of wind direction from 1900 GMT on 18 September 1985 (right) to 2900 GMT on 19 September 1985. Vertical scale is 0-10 km at 1-km intervals.

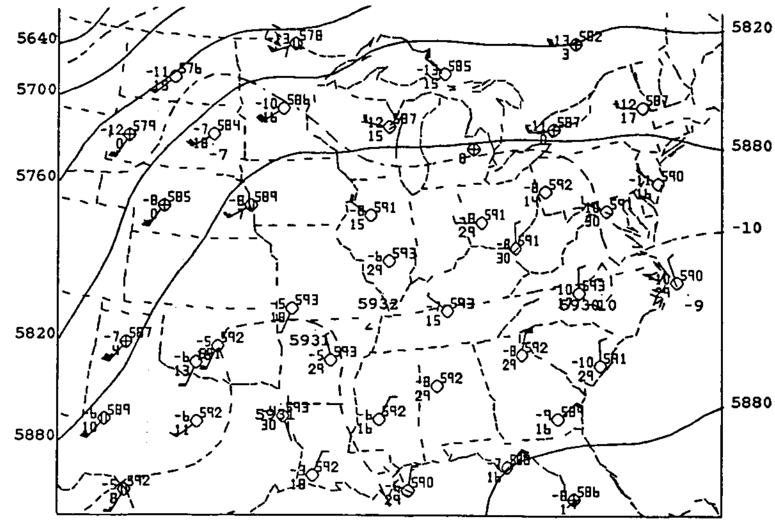

Figure 5. Upper-air chart of the 500-mb surface at 0000 GMT on 19 September 1985.

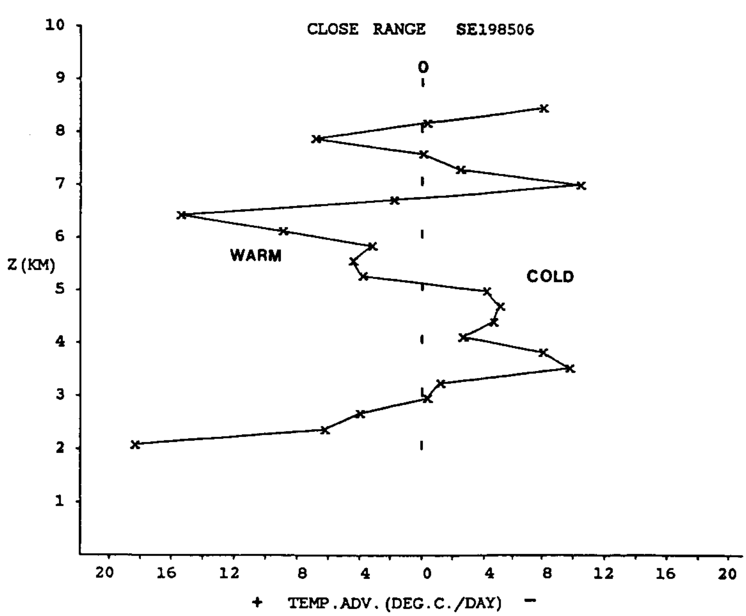

Figure 6. Vertical profile of geostrophic temperature advection at 0600 GMT on 19 September 1985.

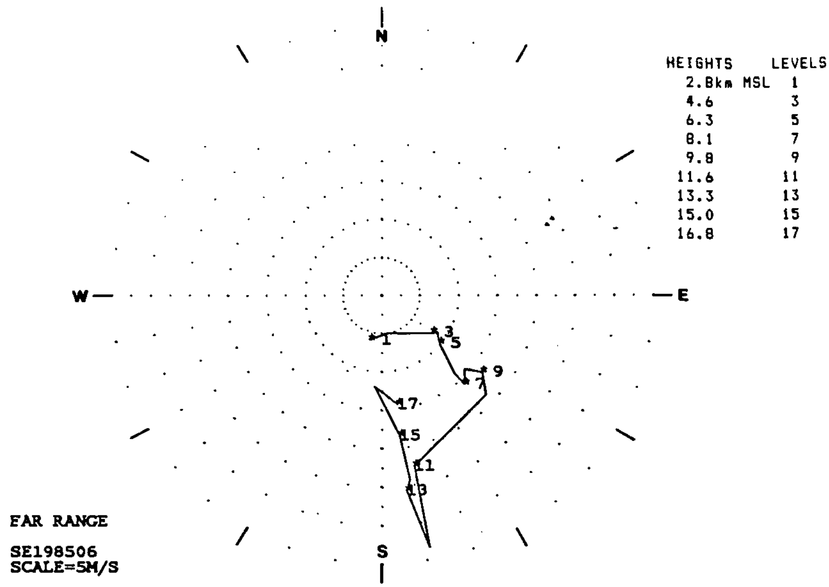

Figure 7. Hodograph of the low-resolution (far range) winds at 0600 GMT on 19 September 1985.

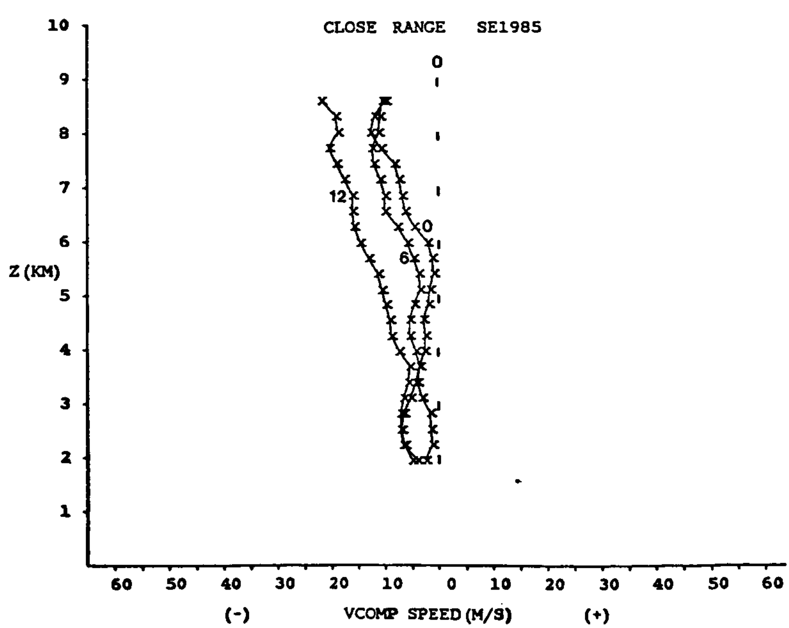

Figure 8. Sequence of vertical profiles of the v (north-south) component of the wind at 0000, 0600, and 1200 GMT on 19 September 1985.

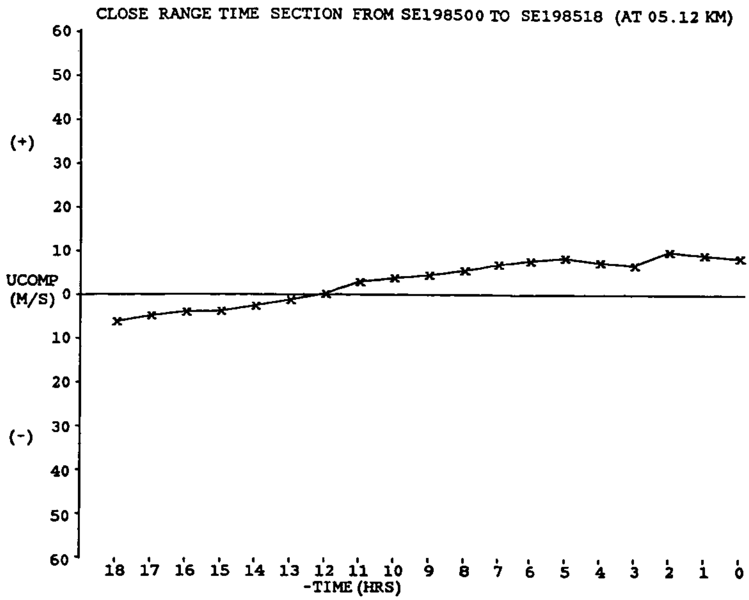

Figure 9. Time series of the u (east-west) component of the wind at 5.12 km MSL from 0000 GMT (right) to 1800 GMT (left) on 19 September 1985.

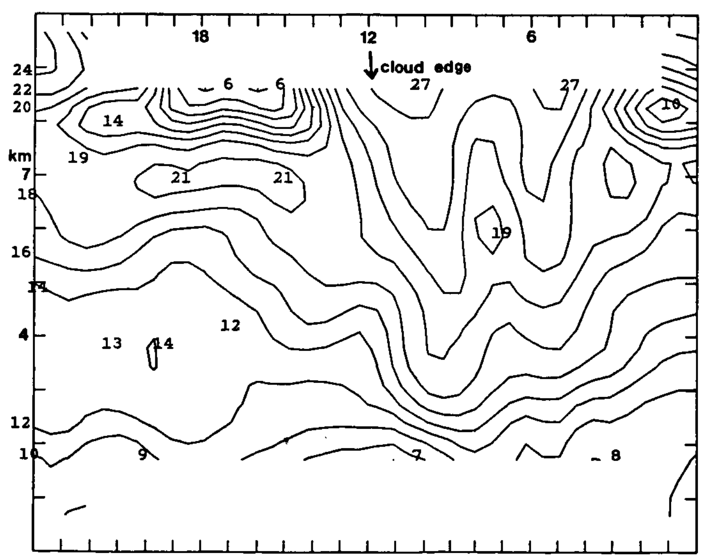

Figure 10. Time-height section of the wind speed (m/s) from 0000 GMT 20 August 1985 (right) to 0000 GMT 21 August 1985 (left).

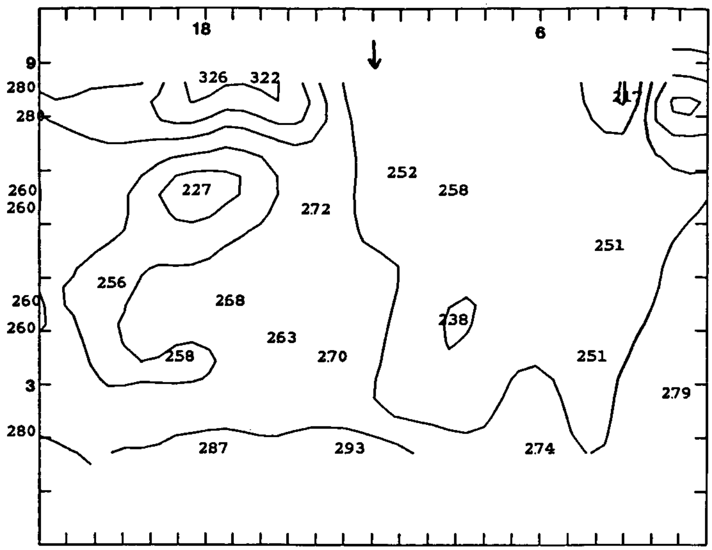

Figure 11. Time-height section of the wind direction from 0000 GMT 20 August to 0000 GMT 21 August 1985.

COUPLED UPPER AND LOWER JET STREAK CIRCULATIONS

The exit region of an upper-tropospheric jet streak began to affect the profiler about 1100 GMT on 1 September and apparently had maximum impact at low elevations at about 1600 GMT. While there was little speed increase at the 2.5-km level, there was a marked backing of the flow to a direction from the southwest (Figure 12), becoming almost normal to the prevailing flow in this region to the west side of the trough axis. There had also been a previous jet streak, which passed over the profiler at about 0600 GMT on 1 September (Figure 13). The flank of the secondary streak passed the profiler at about 1900 GMT.

The response of low-level winds to upper-tropospheric jet streaks has been discussed by UCCELLINI and JOHNSON (1979). Briefly, at low levels beneath the exit region of an upper-tropospheric jet streak there is an indirect vertical circulation and a transverse flow toward the cold side of the jet. In this case, the transverse flow was from the southwest since the jet stream was from the northwest.

UNEXPECTEDLY SHARP RIDGE AXIS

Figure 14 shows a rather rapidly evolving pattern of wind directions, even if the noise in the upper left is ignored. The winds progressively evolved from easterly to southeasterly at elevations below about 5 km MSL. At about 6 km, it can be deduced that the high-pressure center passed just to the north of the profiler, allowing winds to retain an easterly component throughout the period and to shift from ENE to ESE (compare to Figure 15, the 500 mb chart).

DIURNAL OSCILLATIONS/TRAVELLING MESOSCALE RIDGES

Pronounced wind variations have been observed during a quiescent period dominated by a quasi-stationary ridge axis located several hundred kilometers southwest of the profiler. Without cloud patterns to supply some independent mesoscale data, interpretation of the variations has been difficult. A good

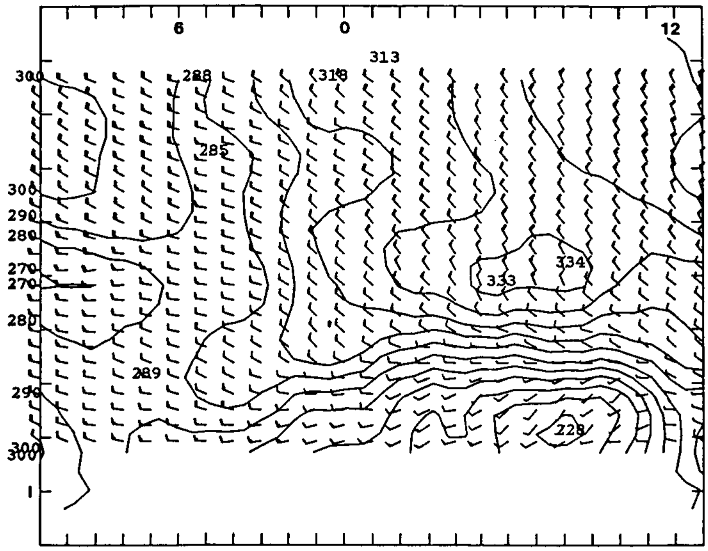

Figure 12. Time-height section of wind vector and wind directions from 0000 GMT on 1 September to 1100 GMT on 2 September 1985.

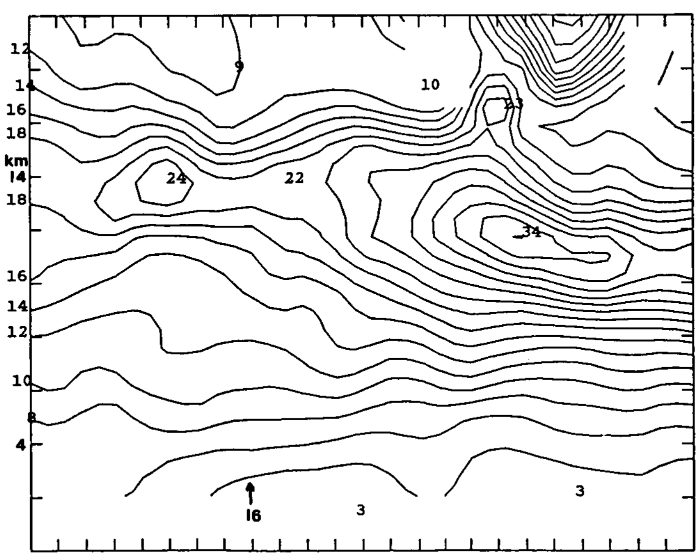

Figure 13. Far-range (low resolution) time-height section of wind speed from 0000 GMT on 1 September 1985 (right) to 0000 GMT on 2 September (left).

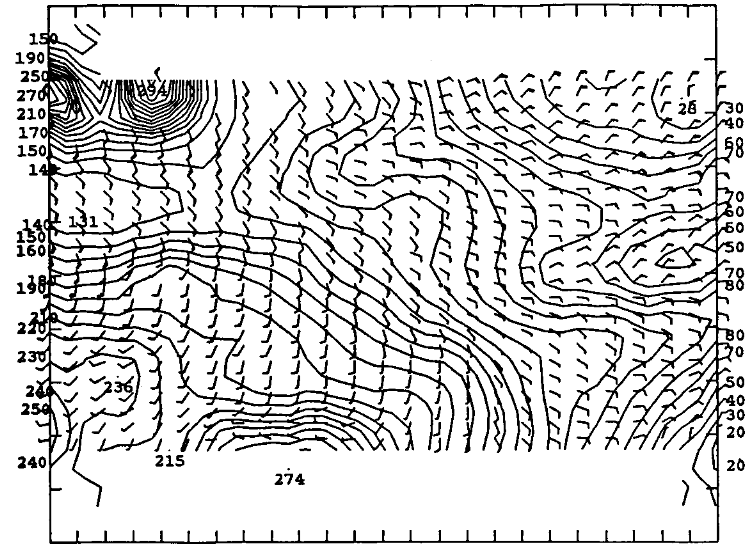

Figure 14. Time-height section of wind vectors and wind direction from 0000 GMT on 20 September 1985 to 0000 GMT on 21 September 1985.

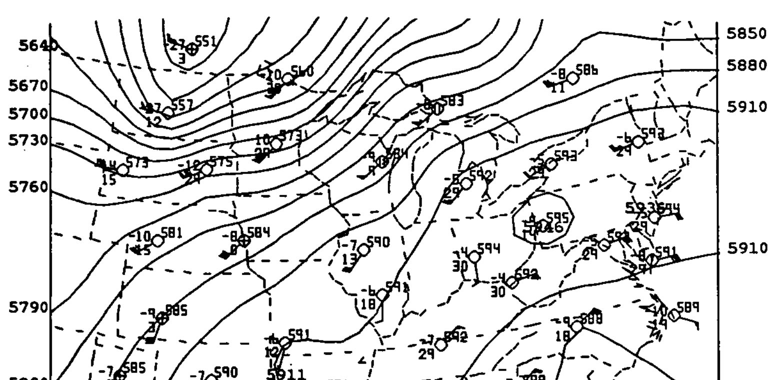

Figure 15. Upper-air chart of the 500-mb surface at 1200 GMT on 20 September 1985. Notice the high pressure system centered near Pittsburgh, PA.

example is the north/west/north pattern at about 3 km on Figure 16, with apparent period of about 18-19 hours. This is approximately the period of an inertial oscillation at the latitude of the profiler (about 41.5°N). It is, of course, well known that there is an oscillation of the wind induced by the diurnal mixing cycle (BLACKADAR, 1957), wherein winds that are subgeostrophic at the top of the boundary layer in late afternoon undergo an inertial oscillation during the nighttime and become supergeostrophic at some time before sunrise. In the case of Figure 16, the geostrophic winds were from the northwest, such that the wind oscillation shown appears to have the proper phase. However, there may also have been some substructure within the ridge, with short-wavelength ridges or lobes travelling around its periphery. As these approached, winds would become more northerly, and then become more westerly as the mesoscale disturbance passed to the south of the profiler. Upper-air observations were inadequate to definitively resolve these features, if they did exist.

HIGH-TEMPORAL-RESOLUTION DATA

Figures 17 and 18 show about one hour of profiler winds comprised of about 2-minute averages. There is obvious noise in the 3 upper gates and the contamination from aircraft near 6 km in the sixth profile. Some eddy-like variations can be seen in the lowest three gates during the early minutes. Otherwise, the 2-minute-sampled winds are quite steady. These winds were measured during a meteorologically quiescent period, which suggests that (1) random fluctuations may not pose a problem for short-term measurements, and (2) the potential exists for accurate measurement of short-term variations when mesoscale features are present. Research on this topic and on the application of VHF Doppler radar for nowcasting and very-short-term forecasting will continue.

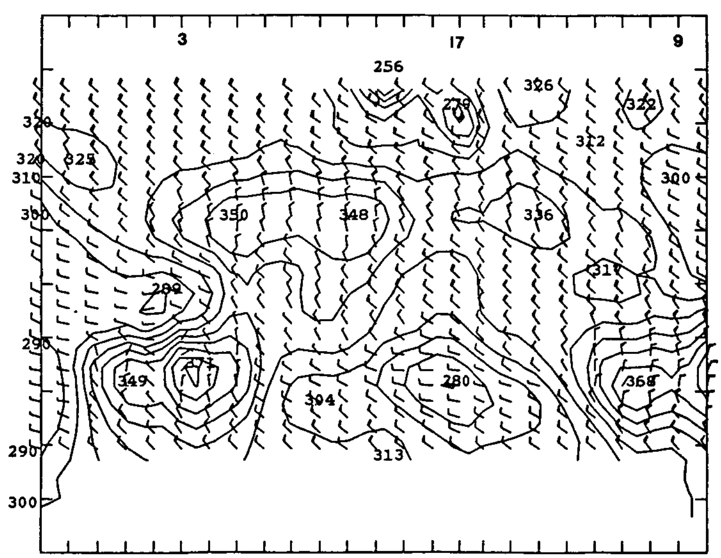

Figure 16. Time-height section showing oscillations in the wind direction during the period from 0800 GMT on 7 September to 0800 GMT on 8 September 1985.

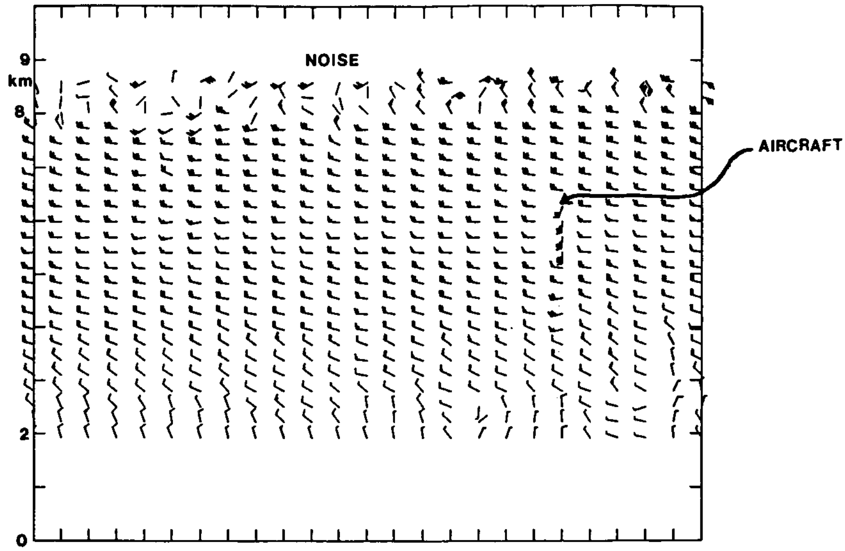

Figure 17. Time-height section of winds at about 2-minute intervals beginning about 0000 GMT on 12 September 1985.

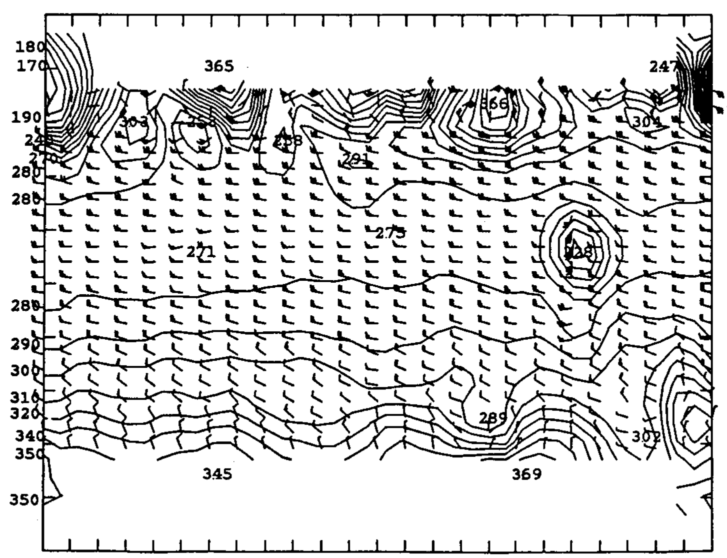

Figure 18. Time-height section of wind direction at 2-minute intervals beginning about 0000 GMT on 12 September 1985.

ACKNOWLEDGEMENTS

Art Person, Paul Neiman, Cathy Carlson, Scott Williams, John Cahir, Dennis Thomson, Chris Fairall, Bob Peters and others have contributed directly or indirectly to this research effort. The instrumentation acquisition and deployment has been supported by D.O.D. University Research Instrumentation Grant AFOSR-83-0275, and The Pennsylvania State University, which provided almost 30% of the funds. This research has been sponsored by the Air Force Geophysics Laboratory under contract F19628-85-K-0011.

REFERENCES

Blackadar, A. K. (1975), Boundary layer wind maxima and their significance for the growth of nocturnal inversions, Bull. Am. Meteorol. Soc., 38, 283-290.

Uccellini, L. W., and D. R. Johnson (1979), The coupling of upper- and lower-tropospheric jet streaks and implications for the development of severe convective storms, Mon. Wea. Rev., 107, 682-703.