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USING PROFILER DATA TO DIAGNOSE THE ATMOSPHERE — A CASE STUDY

Eric R. Thaler
National Weather Service Forecast Office
Denver, Colorado

Having upper air observations on an hourly basis should be far superior to the usual 00Z and 12Z radiosonde observations currently available. At the National Weather Service Forecast Office in Denver we have had the privilege of access to data from four wind profilers located in northeast Colorado (see Figure 1). All four provide winds aloft on an hourly basis with Stapleton reporting temperature and dew point as well as winds (winds only up to about 500 mb). This technical note will show how the profilers were used to observe the passage of a deformation zone across northeast Colorado.

Figure 2 shows the 400 mb streamline analysis on October 6, 1988 at 12Z. Note the well defined closed cyclone over southern Nevada with an associated deformation zone extending to the northeast over the central Rockies. The axis of dilatation in this deformation field is very near the Wyoming-Colorado border at this time with westerly winds south of the axis and northerly winds to the north.

Satellite imagery (not shown) delineated this axis quite well with IR imagery showing a thin band of cirrus along it. The VAS 6.7 micron water vapor loop showed the axis even better with an area of mid-level moisture indicating upward vertical motion along and south of the axis and an area of little mid-level moisture (i.e., downward vertical motion) to its north. This loop also showed the axis moving slowly southward and the ongoing stretching along the axis very nicely.

RAOB's from 12Z, October 6, 1988, for Lander, Wyoming (LND) and Denver, Colorado (DEN) (Figure 3) show a very definite difference in the air mass on either side of the axis. The precipitable water differs by nearly .40 inch and stability indices are also markedly different.

As the day progressed, the deformation zone continued moving southward, with a band of altocumulus and some cumulus developing along it. This can be seen in the observations at Denver between 17Z and 20Z (Figure 4).

Figure 5 contains vertical time sections of the four profilers. Time increases to the left along the bottom, pressure in millibars is shown on the right, and height above sea level in kilometers is shown on the left. The dilatation axis passed by the profiler at Fleming between 13Z and 15Z as evidenced by a decrease in wind speed and a veering of the wind from northwest to north in the layer around 300 mb.

Platteville's profiler noted the passage of the axis between 14Z and 16Z shown in the winds near 400 mb. Winds at all levels made a marked shift from westerly to northerly after the axis passed. Stapleton showed the passage between 15Z and 17Z while the axis never reached Flagler (note constant wind direction).

By 19Z, skies north of the axis had virtually cleared of all clouds except for some stratus in extreme northeast Colorado and a few showers over the foothills in the northern part of the Front Range. South of the axis, several cloud decks were observed along with some stronger convection.

Figure 6 is another profiler graphic giving a simultaneous display of data from all four profilers. (To get a perspective of what this graphic is, consider yourself sitting in the Texas Panhandle and looking to the northwest.) This graphic clearly shows the location of the dilatation axis with northerly winds at all the profiler sites with the exception of Flagler, which is some 100 miles to the southeast of Denver. This graphic has the added feature that it can be animated with up to eight frames of data in the loop. The animation of this graphic gives the user a very nice picture of the movement of this axis.

Animation of the NCAR Doppler radar (CP2) (not shown) confirmed the location of the axis in both the reflectivity and velocity data. Precipitation echoes to the north of the axis were moving nearly due south and dissipating while at the same time those to the south of the axis were moving almost straight east and remaining strong, with some even developing into thunderstorms. Doppler velocities showed moderate shifting along the axis.

Figures 7 and 8 contain several more profiler derived graphics which also aid in the diagnosis of the atmosphere. These types of graphics are often discussed in the literature where they are based on twice-a-day radiosonde observations. Until the advent of the profilers, this data was not available to the operational forecaster on a real-time basis.

Figure 7 is based on the Stapleton profiler only, with time increasing to the left. The right hand side of the figure shows vertical time sections of temperature change, the top one from 17Z to 21Z and the bottom one from 16Z to 20Z. Notice the cooling aloft prior to 1730Z which is right ahead of and at the time of the axis passage. After this, warming aloft occurred most likely due to subsidence behind the axis.

The left hand side of Figure 7 shows vertical time sections of potential temperature for the same time periods as the temperature changes described above. Although subtle, note the tightening of the vertical potential temperature gradient during these time periods, especially in the layer from 350 mb to 500 mb. This, of course, implies an increase in stability.

Even without the use of satellite and radar data, information gathered by the profilers allowed for a complete diagnosis of the vertical motion field.

The vertical time sections of the winds aloft showed the exact location and movement of the dilatation axis. The temperature change and potential temperature graphics showed how the air mass was changing both ahead of and behind the axis. Ahead of the axis upward vertical motion existed as shown by cooling aloft, the production of several cloud decks, and moderate convection. Behind the axis, downward vertical motion was observed along with warming aloft, an increase in stability, and cloud and shower dissipation. Satellite and Doppler radar data served only to confirm what was determined from the profiler data and surface observations.

The passage of this dilatation axis set the stage for overnight events. The subsidence and attendant drying behind the axis produced a stable air mass with clear skies which provided for excellent radiational cooling. Furthermore, a weak pressure surge followed the axis passage and light upslope winds developed through a fairly deep layer based at the surface. Figure 8 shows the Denver RAOB taken at 00Z on October 7, 1988. Note the significant changes in precipitable water and stability from the previous sounding. As one might expect with strong radiational and upslope surface winds, fog and low stratus formed in Denver and, in fact, was quite widespread over northeast Colorado by sunrise.

Profiler data was used in this case study to determine the air mass structure over northeast Colorado as a rather strong axis of dilatation passed over the area. This is only one of numerous examples of how the profiler can be utilized to help diagnose the atmosphere. Axes of this type can be crucial in the cool season as they can influence both rate of fall and total snowfall in winter events. With the profiler data available, the forecaster can obtain a better picture of what is happening in the forecast area which obviously will lead to a better forecast product, in turn improving service to the public.

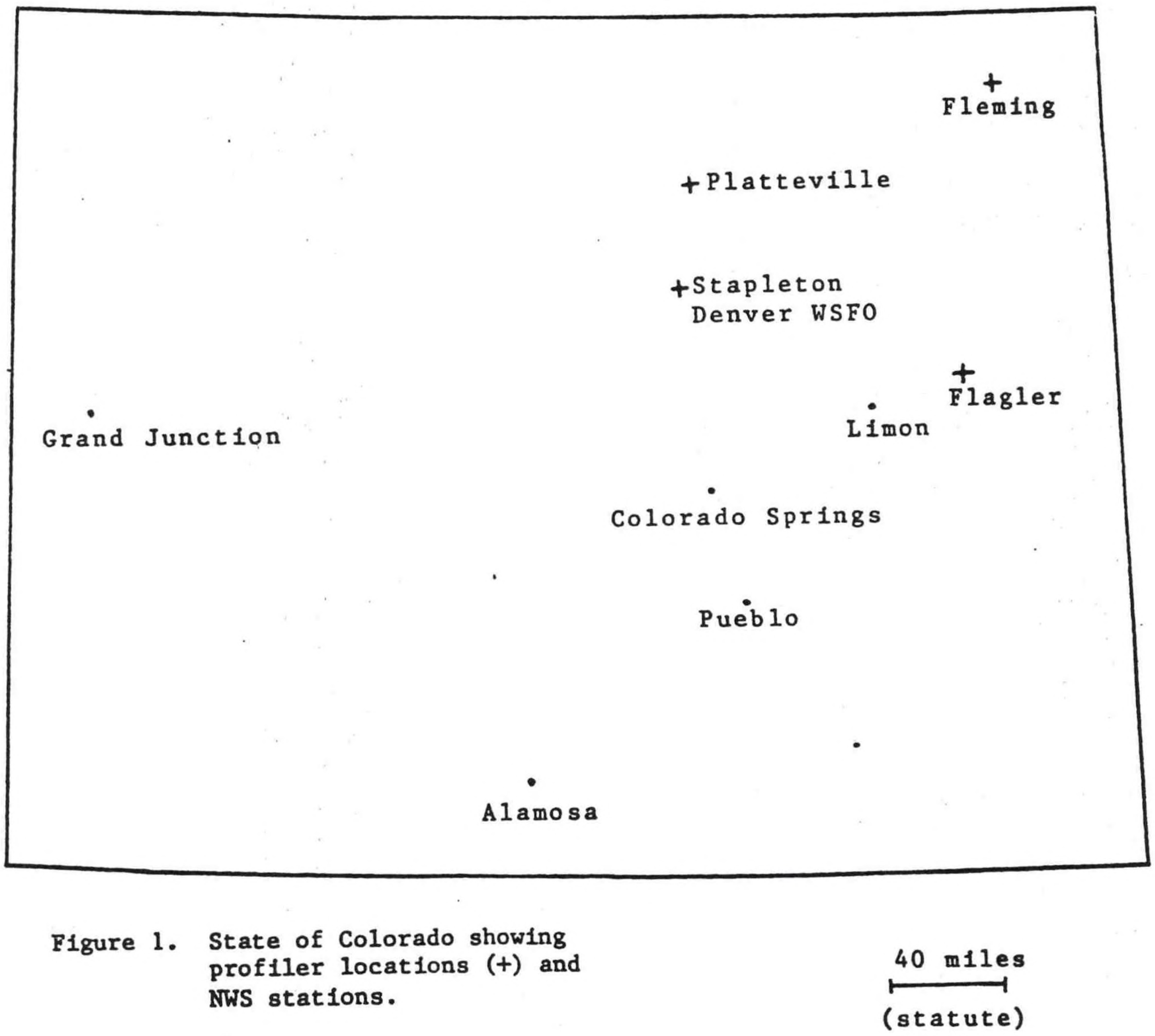

Figure 1. State of Colorado showing profiler locations (+) and NWS stations.

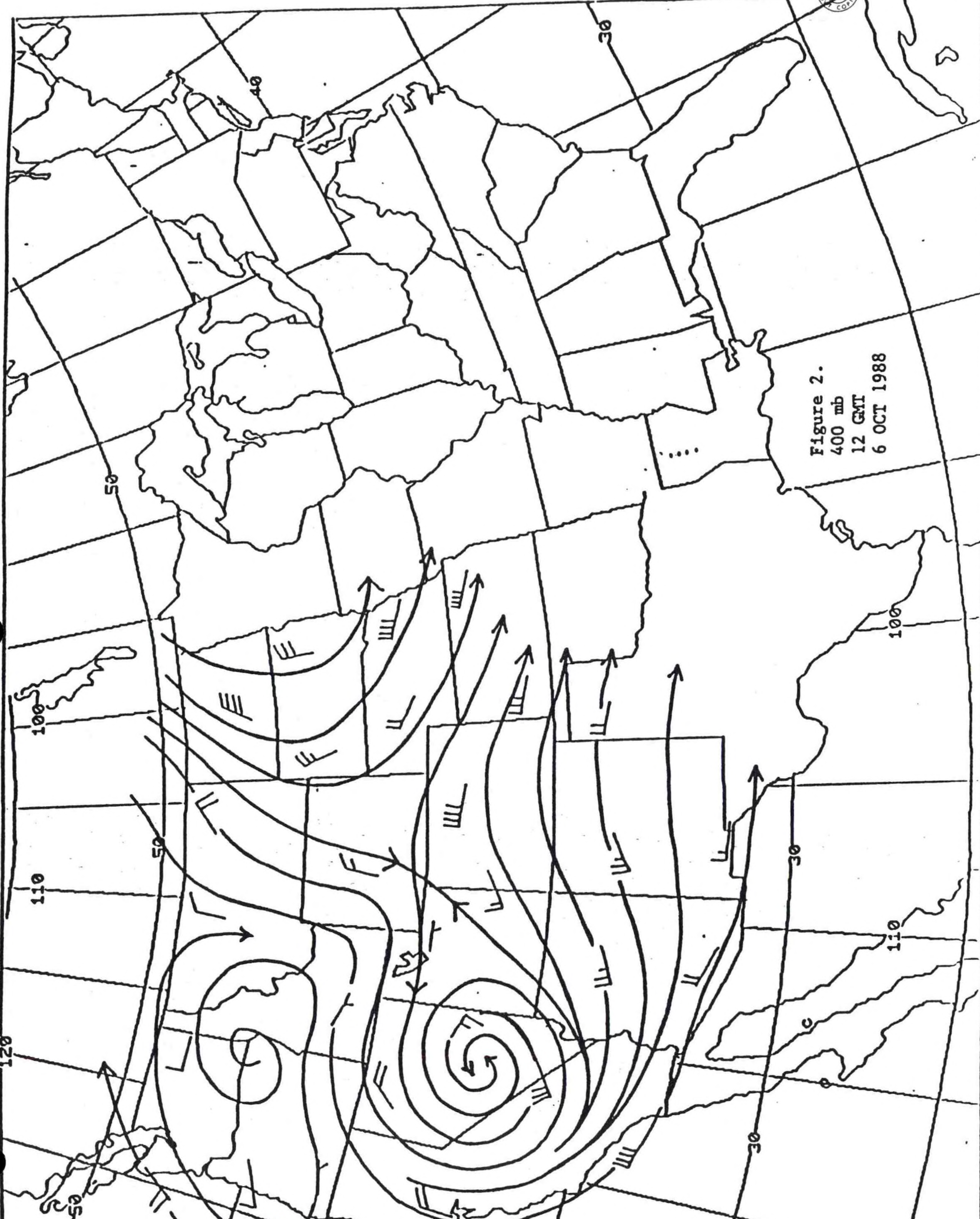

Figure 2.
400 mb
12 GMT
6 OCT 1988

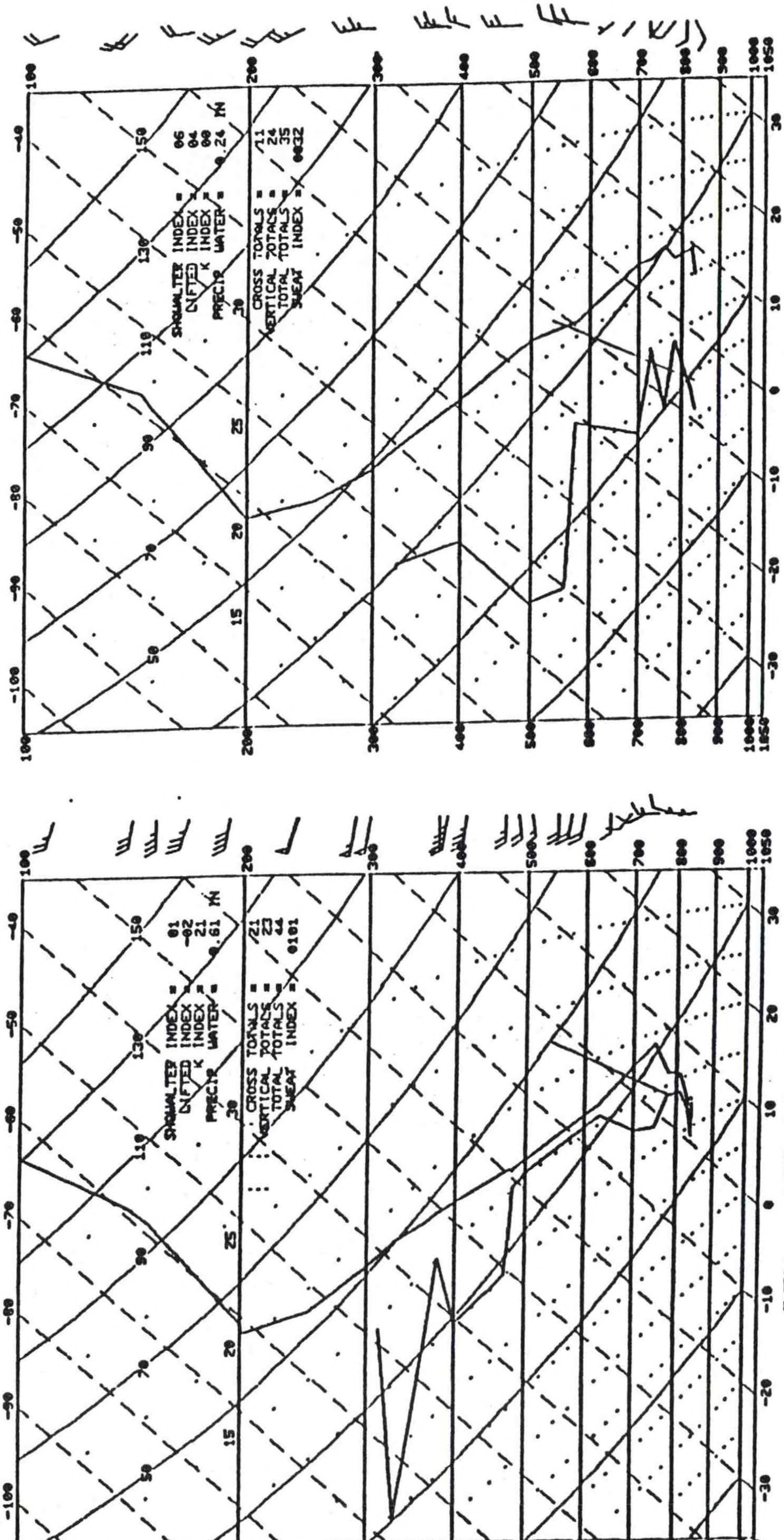

Figure 3. Radiosonde observations for Denver, CO (DEN) and Lander, WY (LND)

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DEN RS 1153 M2 OVC 1/2F 264/39/39/3304/040/R35RVR16V35 SFC VSBY 1/
    302 16// 36 RADAT 22079
DEN SP 1140 M1 OVC 1/2F 2504/040/R35RVR08V15 SFC VSBY 1
DEN SA 1053 W0 X 3/8F 264/38/38/0104/039/R35RVR14V20 TWR VSBY 1/2
DEN RS COR 0951 M1 OVC 3/8F 264/38/38/3605/039/R35RVR 06-V30 TWR
    VSBY 1/2                                                      ...
DEN RS 0951 M1 OVC 3/8F 264/38/38/039/R35RVR 06-V30 TWR VSBY 1/2
DEN RS 0951 M1 OVC 3/8F 264/38/38/039/R35RVR 06-V30 TWR VSBY 1/2
DEN SP COR 0923 M1 OVC 1/2F 3406/039/R35RVR 06-V55
DEN SP 0323 M1 OVC 1/2F 3406/039/R35RVR 06-V55
DEN RS 0852 W0 X 3/8F 263/38/38/3604/039/R35RVR 06- TWR VSBY 1/2/ 400
DEN SP 0834 M1 OVC 3/8F 3503/020/R35RVR 06-V14 TWR VSBY 1/2
DEN SP 0818 M2 OVC 1F 3604/040/R35RVR 24V60+
DEN SP 0809 M3 OVC 2F 3604/040/TWR VSBY MSG THN SPTS 1OVC
DEN SA 0750 3 SCT 7 268/37/37/3506/039/ 98541
DEN SA 0651 CLR 10 268/38/37/3404/039/SIFRA 5 MND W
DEN SP 0635 CLR 10 3006/039/SIFRA 5 MND W
DEN SA 0552 CLR 10 262/41/39/0306/039/ 112 65
DEN SA 0452 CLR 15 263/41/38/3607/039
DEN SA 0353 CLR 15 261/44/39/3603/038
DEN SA 0253 CLR 15 252/47/40/0908/035/ 317
DEN SA 0152 250 -SCT 12 248/53/41/1012G18/033
DEN SA 0050 CLR 12 233/57/41/1106/030
DEN SA 2351 250 -BKN 12 225/62/41/0205/029/TCU SW-W OMTNS/ 307 1270
    65 RADAT 68115
DEN SA 2250 250 -BKN 12 214/64/41/3608/027
DEN SA 2152 130 SCT 250 -BKN 15 211/63/39/0106/026/ CB DSNT NW
DEN SA 2053 130 SCT E250 BKN 10 211/64/41/3507/027/ CB DSNT NW 803 1372
DEN SA 1952 80 SCT 120 SCT E220 BKN 7 213/61/42/0108/027
DEN SA 1851 70 SCT E120 BKN 220 BKN 7 220/60/43/0109/029
DEN SA 1750 70 SCT 85 SCT E120 BKN 7 215/61/45/0111/028/ TCU SW/
40000 1270 42
DEN SA 1650 70 SCT 120 SCT 7 219/60/45/0106/028
DEN SA 1550 120 SCT 6F 219/56/47/2107/028/CU SC W-NE
DEN SA 1450 120 SCT 6F 226/50/46/1807/028/CU SC W-N/ 30300 1070
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Figure 4. Surface observations from WSFO Denver, CO.

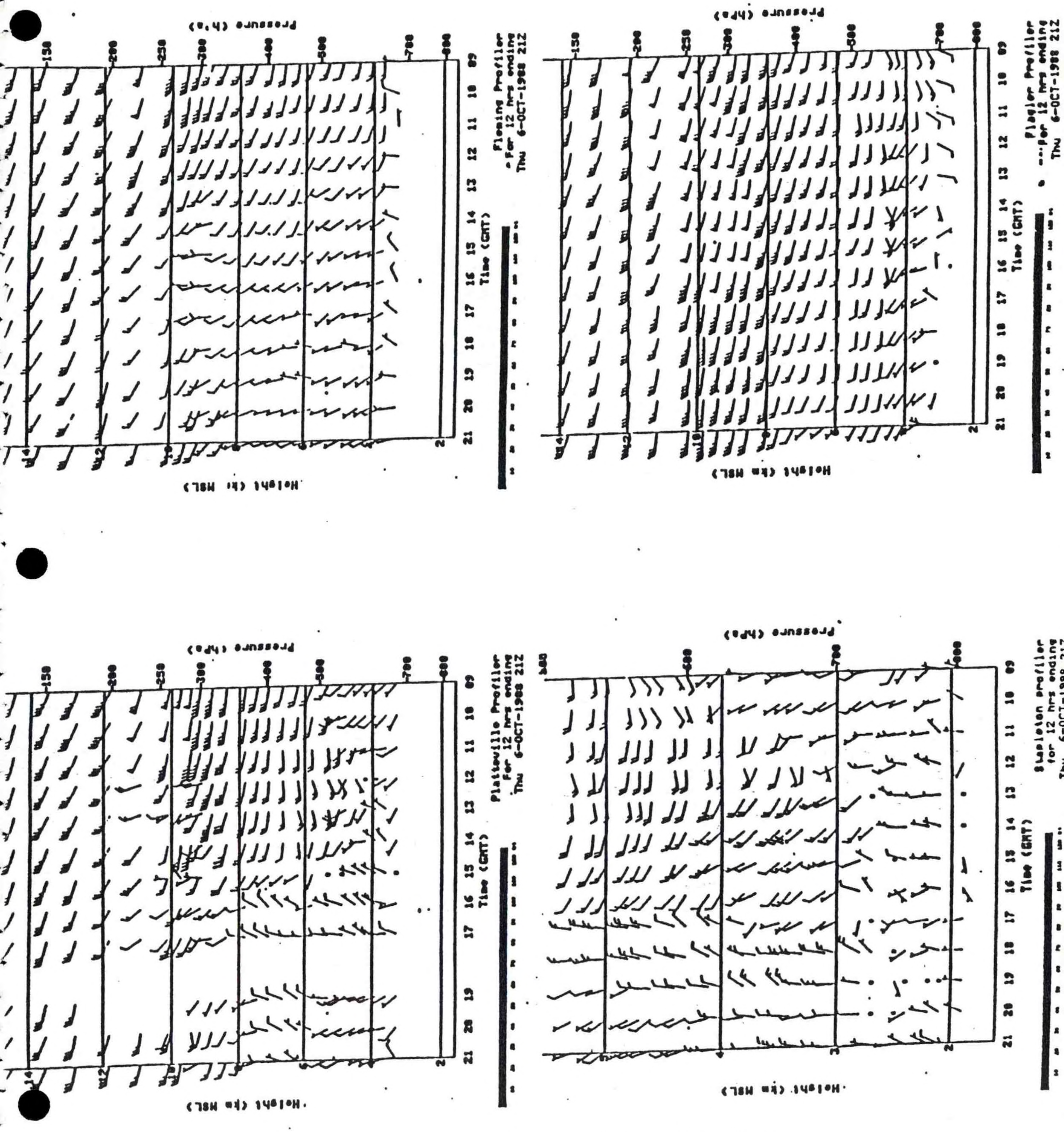

Figure 5. Vertical time-sections of winds aloft at Platteville, Fleming, Flagler, Stapleton profilers.

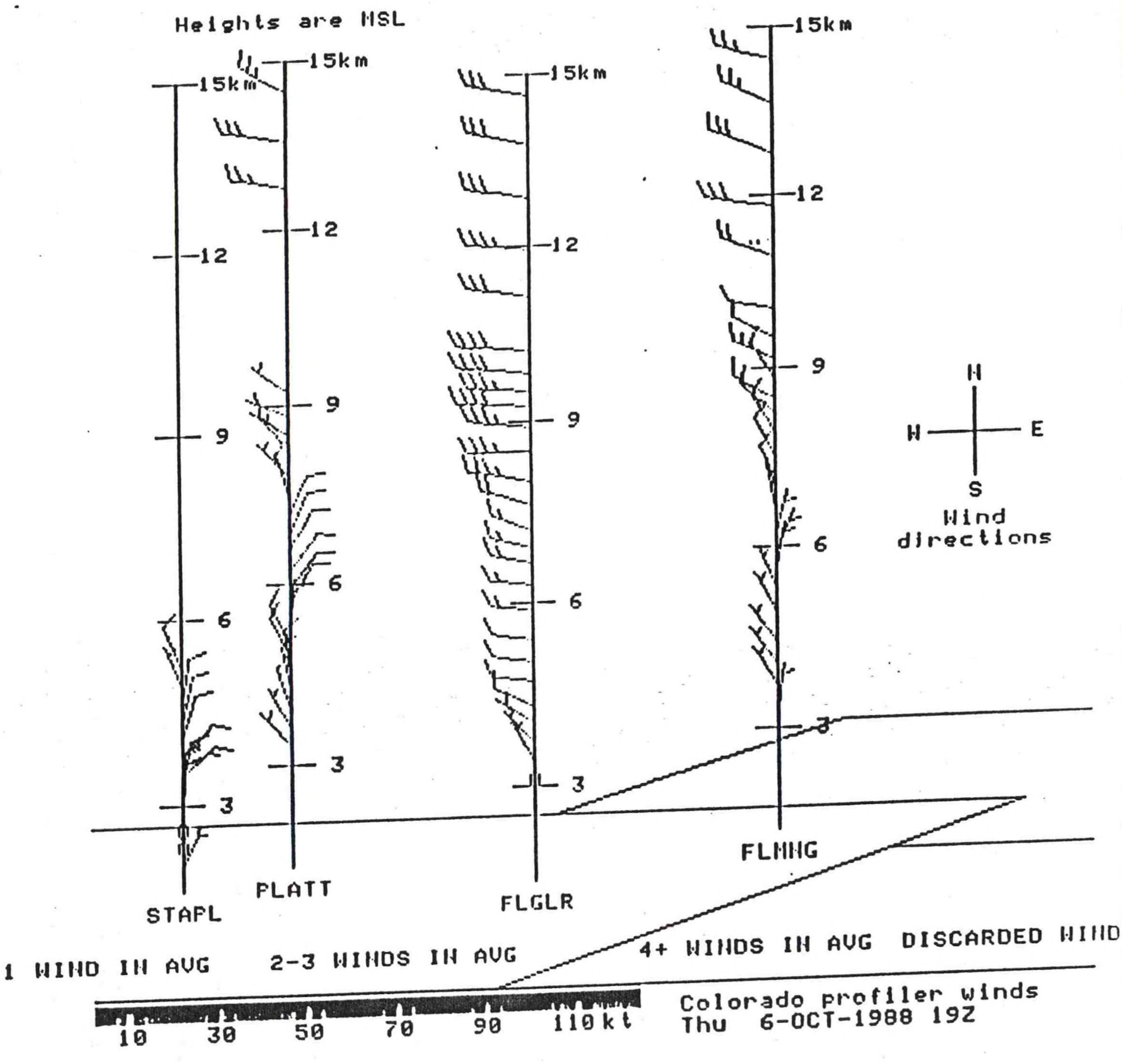

Figure 6. Simultaneous view of profiler data.

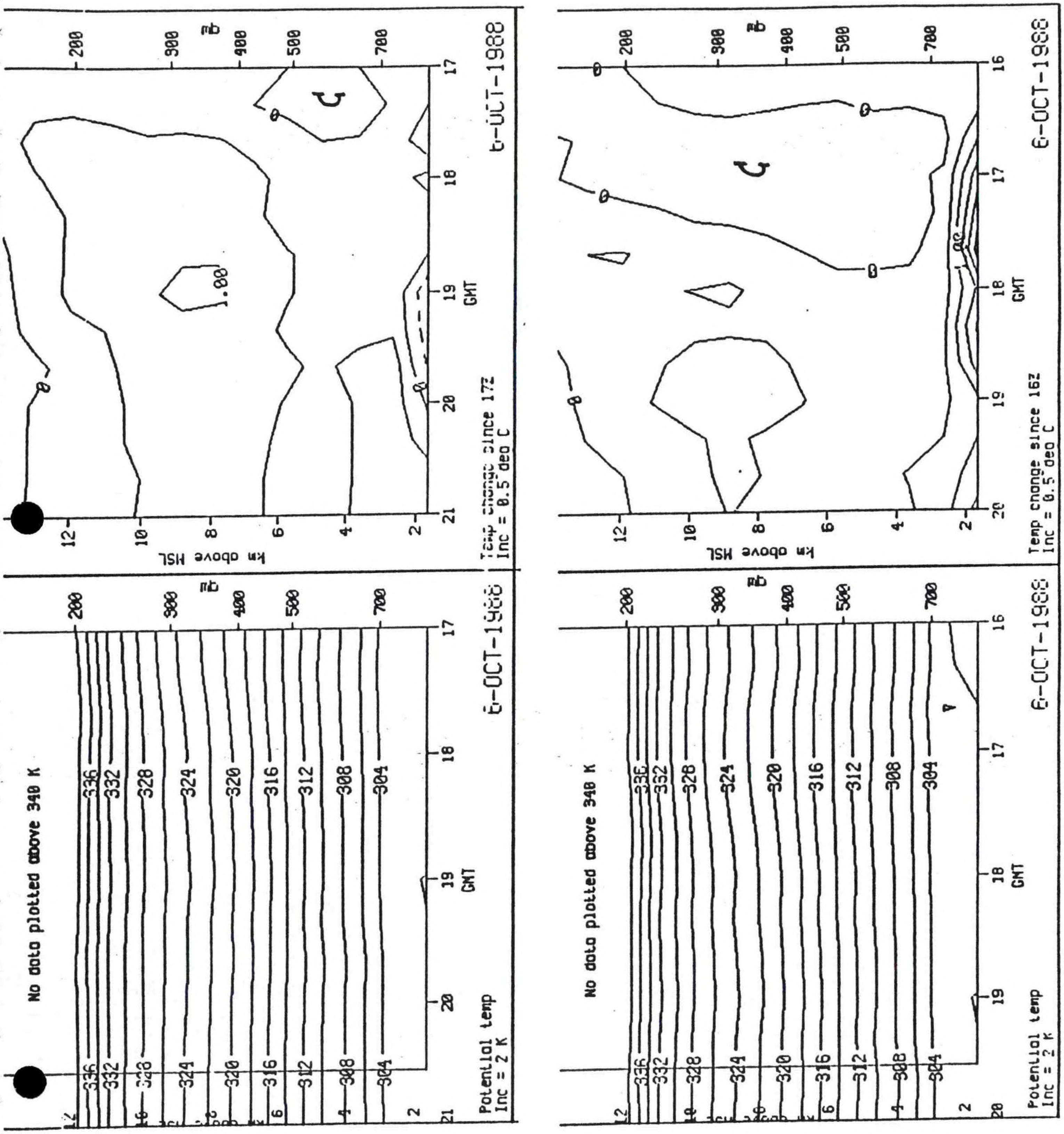

Figure 7. Vertical time-sections of potential temperature (left) and temperature change (right).

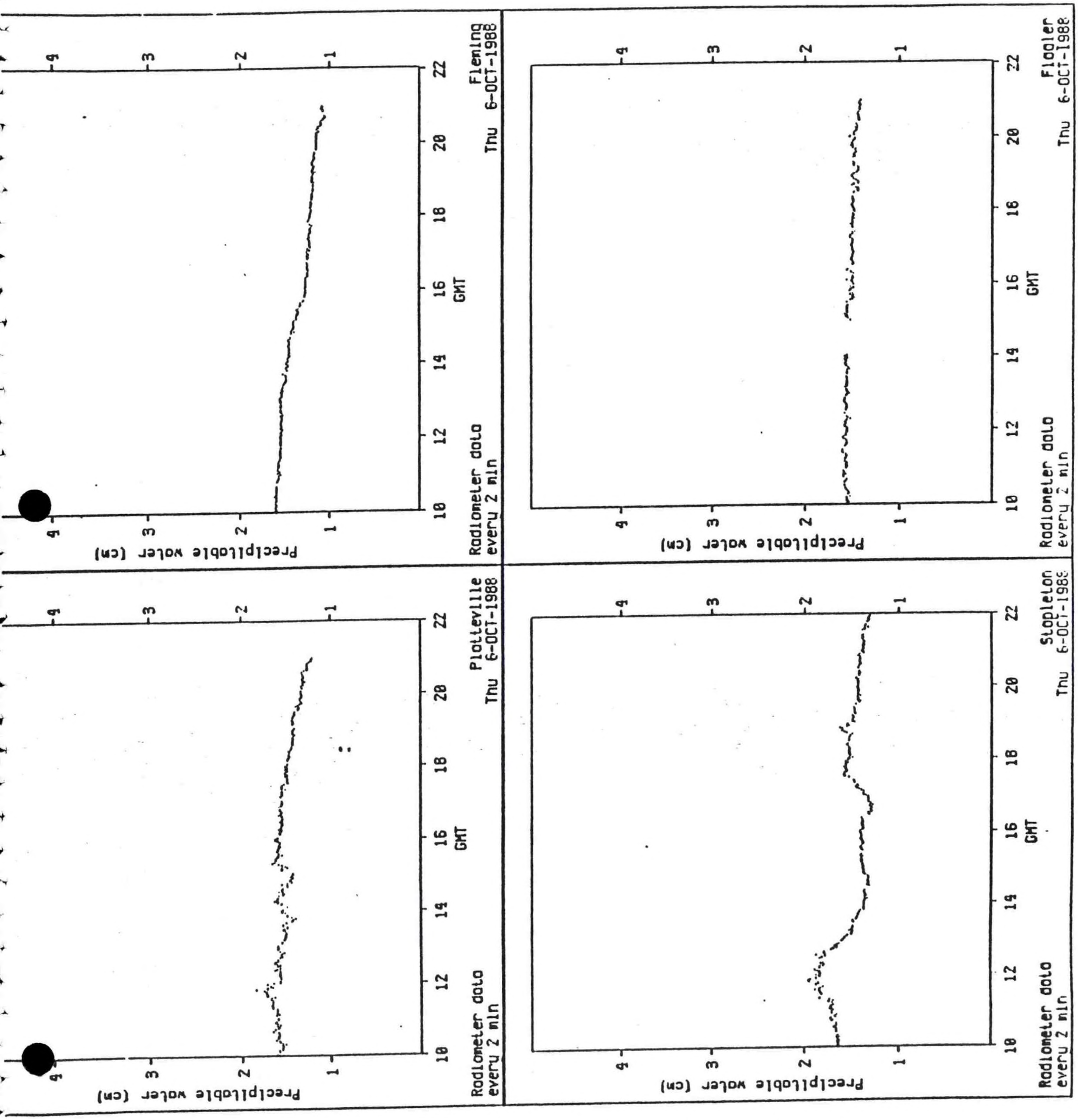

Figure 8. Vertical time-sections of precipitable water at Platteville, Fleming, Flagler and Stapleton profilers.

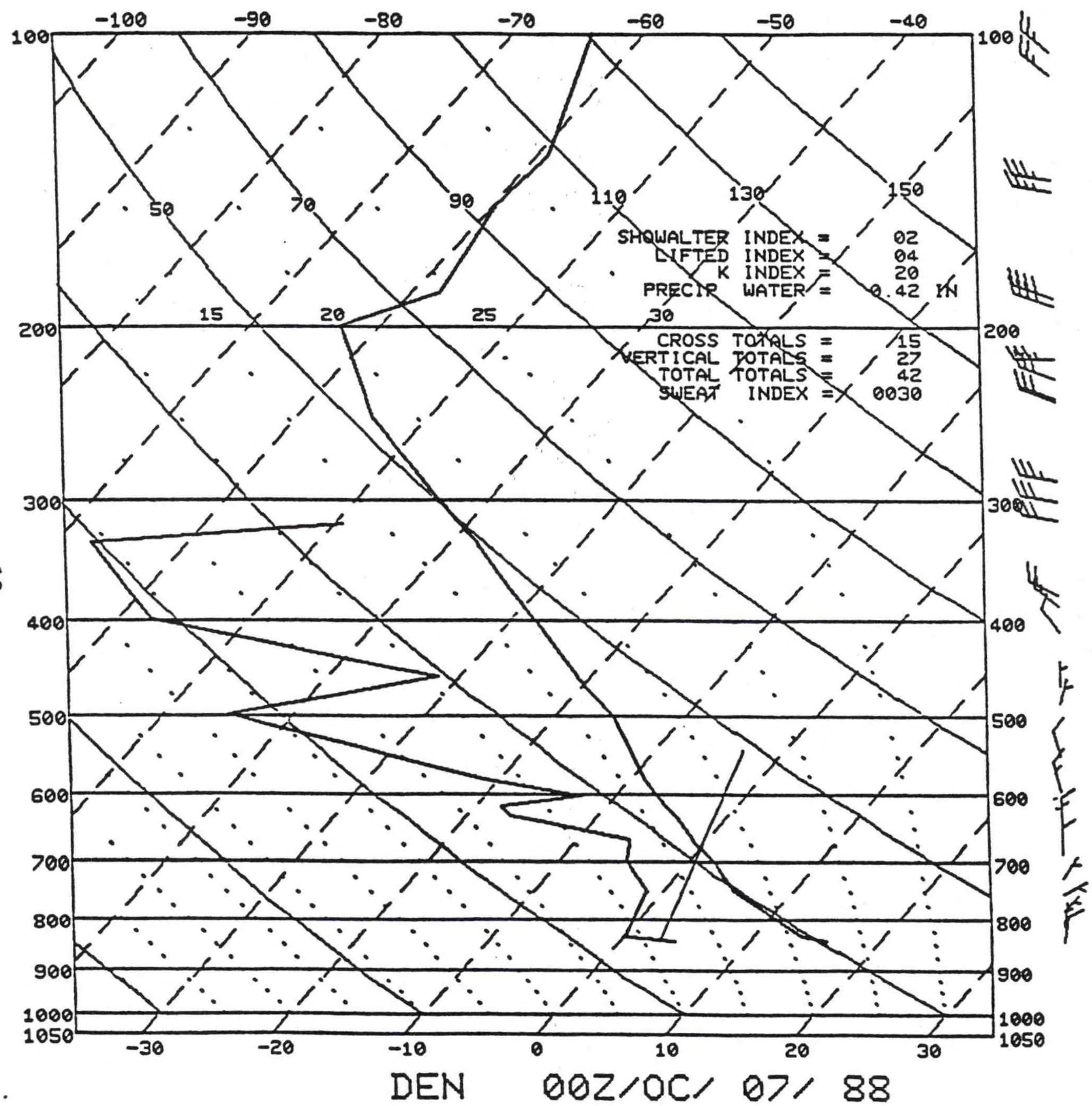

Figure 9. Radiosonde observation from Denver, CO (DEN)