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USING THE WIND PROFILER'S RANGE NORMALIZED RETURNED POWER TO MONITOR MOISTURE CHANGES

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1. INTRODUCTION

The National Weather Service (NWS) is currently deploying in the central United States a network of 30 Doppler wind profilers collectively called the Wind Profiler Demonstration Network (WPDN). These profilers provide a vertical wind profile throughout the troposphere beginning approximately 500 meters above ground level. The wind profiles have a 250-m resolution in the lower troposphere and 1000-m resolution in the upper troposphere. The profiler data are collected centrally at a profiler Hub in Boulder, Colorado and are then transmitted hourly to the Automation of Field Operations and Services (AFOS) through the NWS Telecommunications Gateway. The General Sciences Corporation, under contract with the Techniques Development Laboratory, has developed profiler applications software for use on AFOS. As a result of these efforts, profiler time sections, cross sections, and plan views are now available hourly at Weather Service Forecast Offices (WSFOs).

Wind profilers are vertically pointing Doppler radars that receive their signal from backscattering due to inhomogeneities in the radio refractive index. These inhomogeneities are due to turbulence scale discontinuities in temperature and specific humidity (Gage and Balsley, 1978). A measure of the profiler's signal is the returned power. In the absence of hydrometeors and large stability fluctuations, hourly changes in the normalized returned power should correlate with changes in both the magnitude and vertical gradients of humidity in the lower and middle troposphere (Ottersten, 1969). This paper highlights the profiler's potential for monitoring hourly changes in the atmosphere's vertical moisture distribution with the profiler's normalized returned power. A case study from the WPDN's Sudbury, Massachusetts (SBYM3) profiler (Fig. 1) illustrates this concept.

2. SYNOPTIC SITUATION APRIL 15, 1991

On April 15, 1991, the northeast portion of the United States was under the influence of a strong, slow-moving ridge. The westward tilt with height of this ridge is evident in both the Nested Grid Model's (NGM's) analyses (Fig. 2) and the horizontal wind time-height section from the SBY profiler (Fig. 3). The south-southwesterly winds observed below 800 mb indicated that the low level ridge was to the east of SBY throughout the time period. Above 650 mb, winds slowly backed with time from northwesterly to more westerly as the ridge to the west slowly approached the area. The combination of the dry northwesterly airflow and synoptic scale subsidence produced an unusually dry airmass over the region. The 1000-500-mb mean relative humidity (Fig. 4) had decreased to about 10 percent by 0000 UTC April 15 and was forecast by the NGM to increase rapidly to near 60 percent by 1200 UTC April 15 as the ridge began to move east of the area.

3. DISCUSSION

A series of NGM soundings from the 0000 UTC April 15 model run (Fig. 5) reveals the vertical structure of the forecast moistening with time. Above

500 mb, the soundings indicate that relative humidities would increase during the 0000-0600 UTC period and then slightly decrease from 0600-1200 UTC. In the 700-500-mb layer, the model forecast relative humidities to remain very low during the first 6 hours and increase dramatically during the second 6-h period. At levels below 700 mb, the model actually forecast further drying before moistening the 850-700-mb portion of the layer late in the period.

Figure 6 shows the observed SBYM3 normalized returned power time-height section corresponding to the forecast period. In general, substantial power increases occurred aloft first, and subsequently, at lower and lower levels with time. The returned power at most levels rose from 60 to 80 dB in approximately a 2-h interval before leveling off between 70 and 80 dB. Because dB is a logarithmic scale, a 20-dB increase corresponds to a 100-fold increase in the profiler signal. Since the profiler signal is sensitive to both the magnitude and the gradient of specific humidity, the largest returned powers (>80-dB) likely indicate that the vertical gradients of specific humidity were largest at those altitudes and times. The short duration of the greater than 80-dB signals at most levels implies that the moistening was quite rapid. All of the above observations are quite consistent with the model forecast. In fact, the returned power fluctuations with time from below 700 mb and above 500 mb correspond extremely well with the forecast moisture fluctuations. The 80-dB return observed at 0200 UTC at 2.8 km results from missing data and is a product of the contouring routine.

While increasing relative humidity due to moisture advection in a layer does not always result in cloud cover, any layer that does become cloudy has moistened. Surface observations from BOS, Boston, Massachusetts (Table 1), located east of SBYM3, do indicate rapid changes in cloud layer heights and coverages. The lowest reported cloud layer at each hour is indicated by an X on Fig. 6. All nighttime reported heights (those prior to 1000 UTC) were subjectively estimated, while subsequent heights were measured. An excellent correlation exists between the slope with time of the lowering cloud deck and the 80-dB contour, especially during the period when measured observations were reported. In this case, the 80-dB returns almost always precede the cloud deck observations by about 1 hour. This displacement in time is reasonable given the location of SBYM3 relative to BOS and the mean wind flow at cloud levels. The slope of the peak returned power with time during the 0000-0600 UTC period also indicates a more linear decrease in ceiling level than reported in the estimated cloud layer observations. It is quite possible that a more linear decrease did occur, given the difficulty in detecting slight changes in cloud heights at those altitudes during the nighttime.

4. CONCLUSION

More frequent, accurate, and densely spaced wind profiler measurements should lead to a better understanding of evolving weather situations, and consequently, better forecasts. However, there is a need for ways to interpret and translate this new information into improvements in NWS operational forecasts. A case study has been presented to demonstrate a relationship between changes in the wind profiler's range normalized returned power and moisture. These changes correlated extremely well with both observed and forecast moisture changes near the SBYM3 profiler. This case demonstrates that at least under some conditions hourly moisture changes and cloud deck altitudes can potentially be monitored using time-height sections of the profiler's returned power.

ACKNOWLEDGMENTS

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REFERENCES

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Ottersten, H., 1969: Atmospheric structure and radar backscattering in clear air. Radio Sci., 4, 1179-1193.

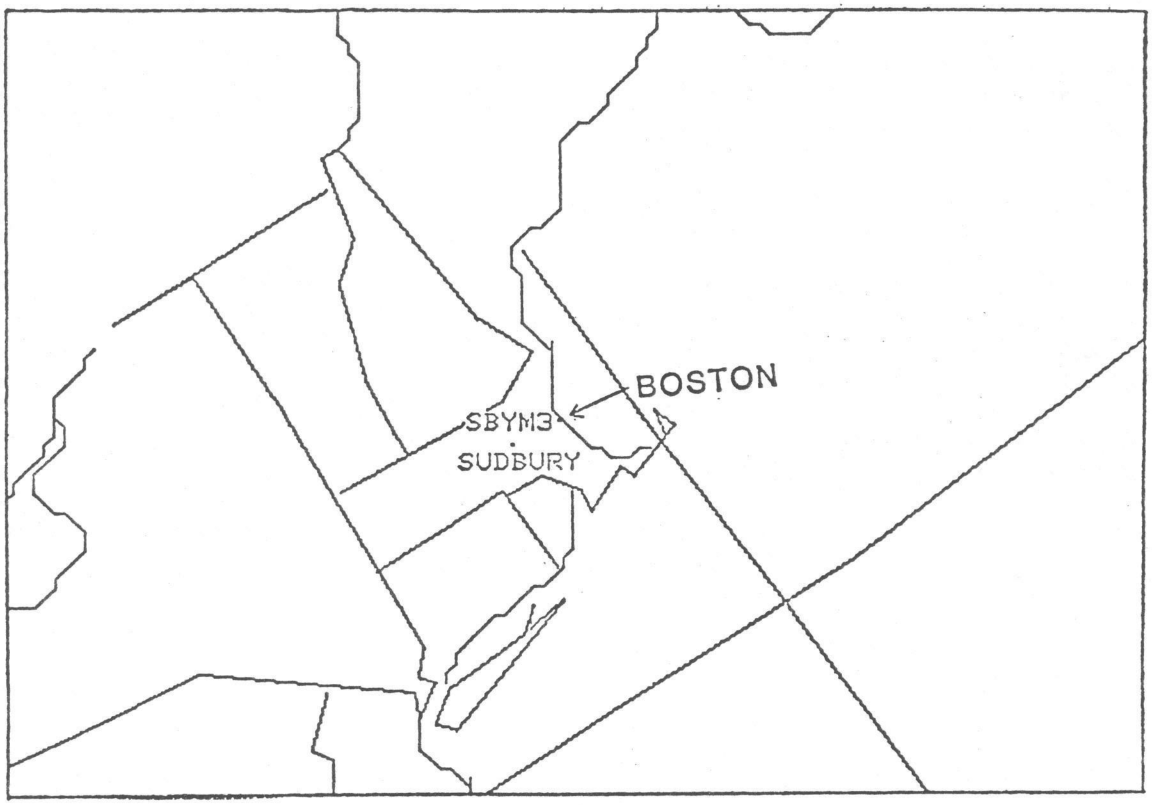

Figure 1. Locations of the Boston, Massachusetts WSFO and the Sudbury, Massachusetts wind profiler.

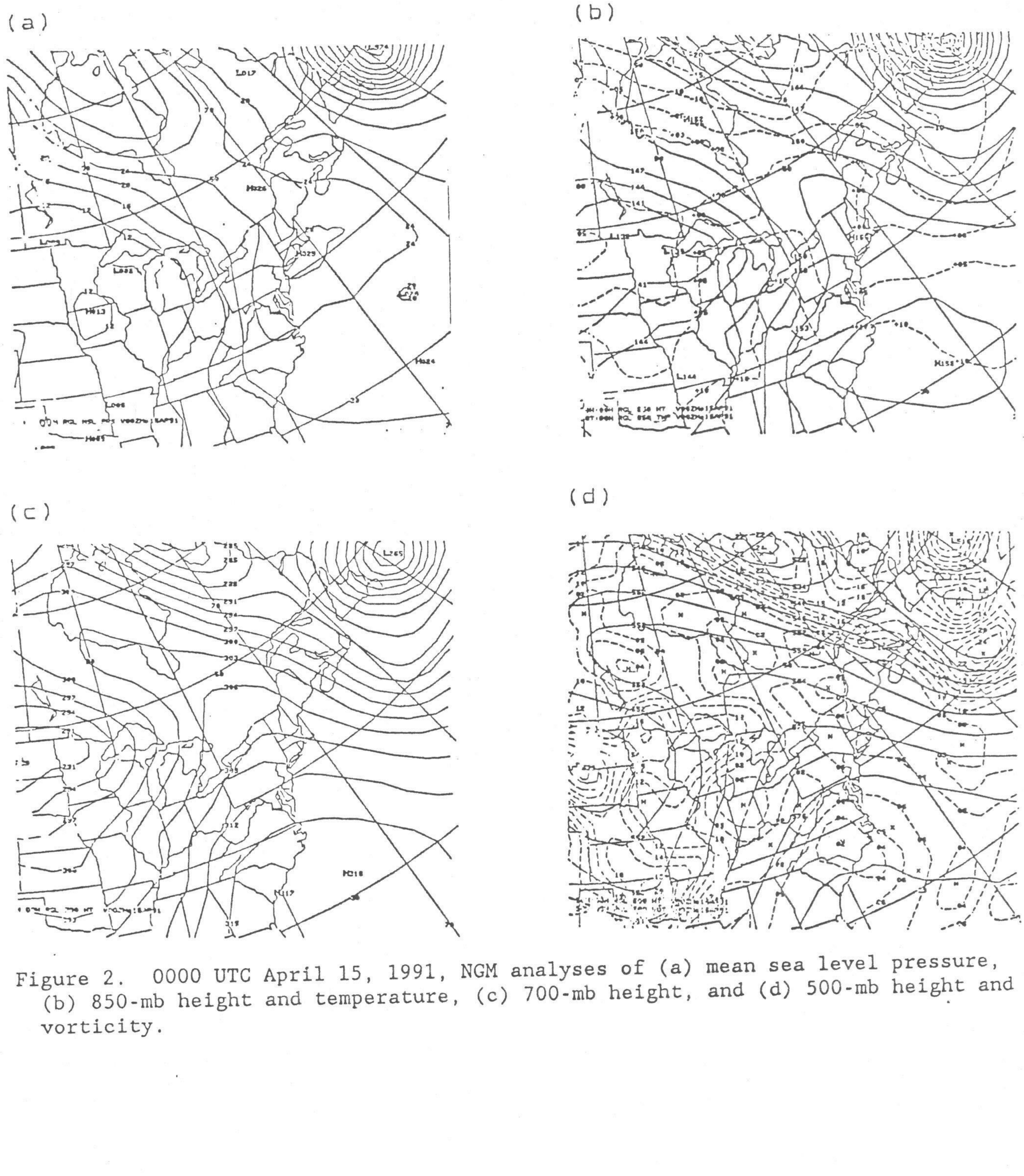

Figure 2. 0000 UTC April 15, 1991, NGM analyses of (a) mean sea level pressure, (b) 850-mb height and temperature, (c) 700-mb height, and (d) 500-mb height and vorticity.

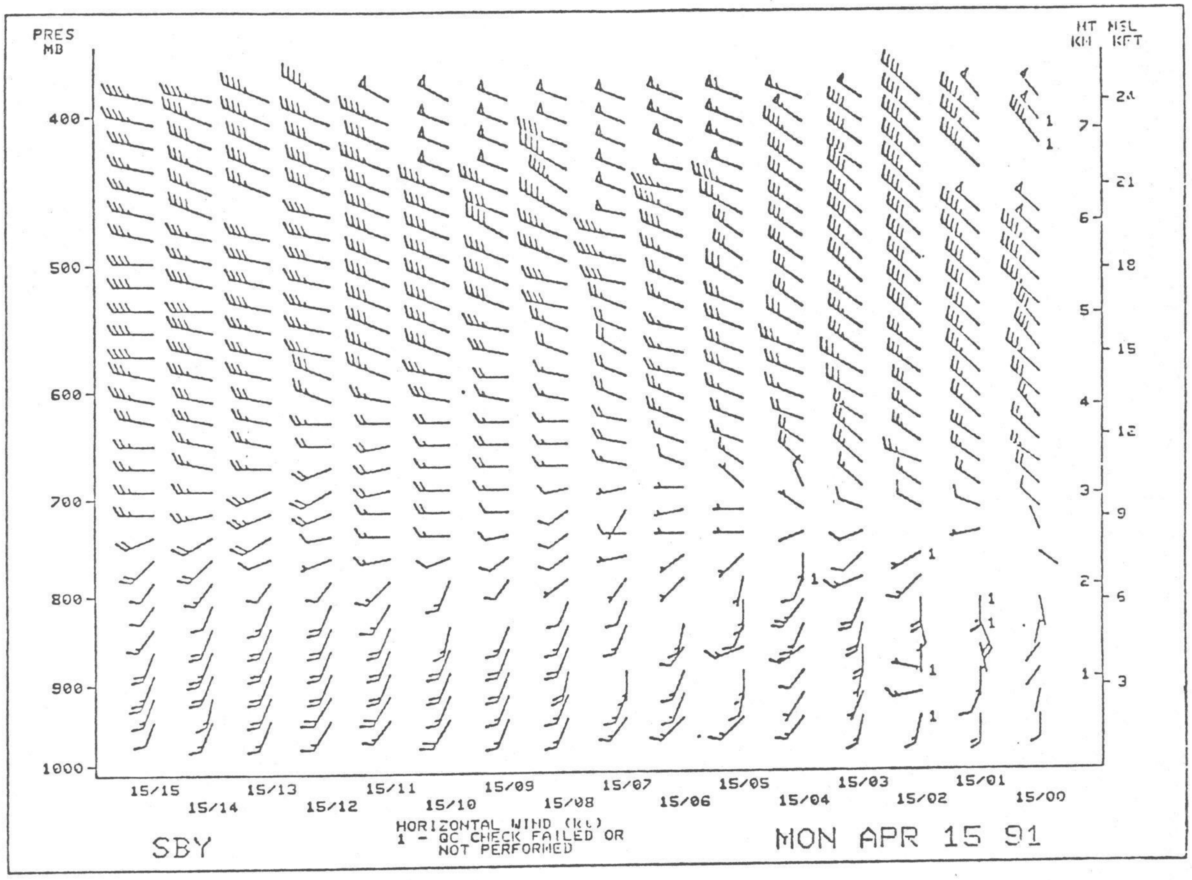

Figure 3. Time-height section of the horizontal wind from the SBYM3 wind profiler for the period 0000-1500 UTC on April 15, 1991.

(a)

(b)

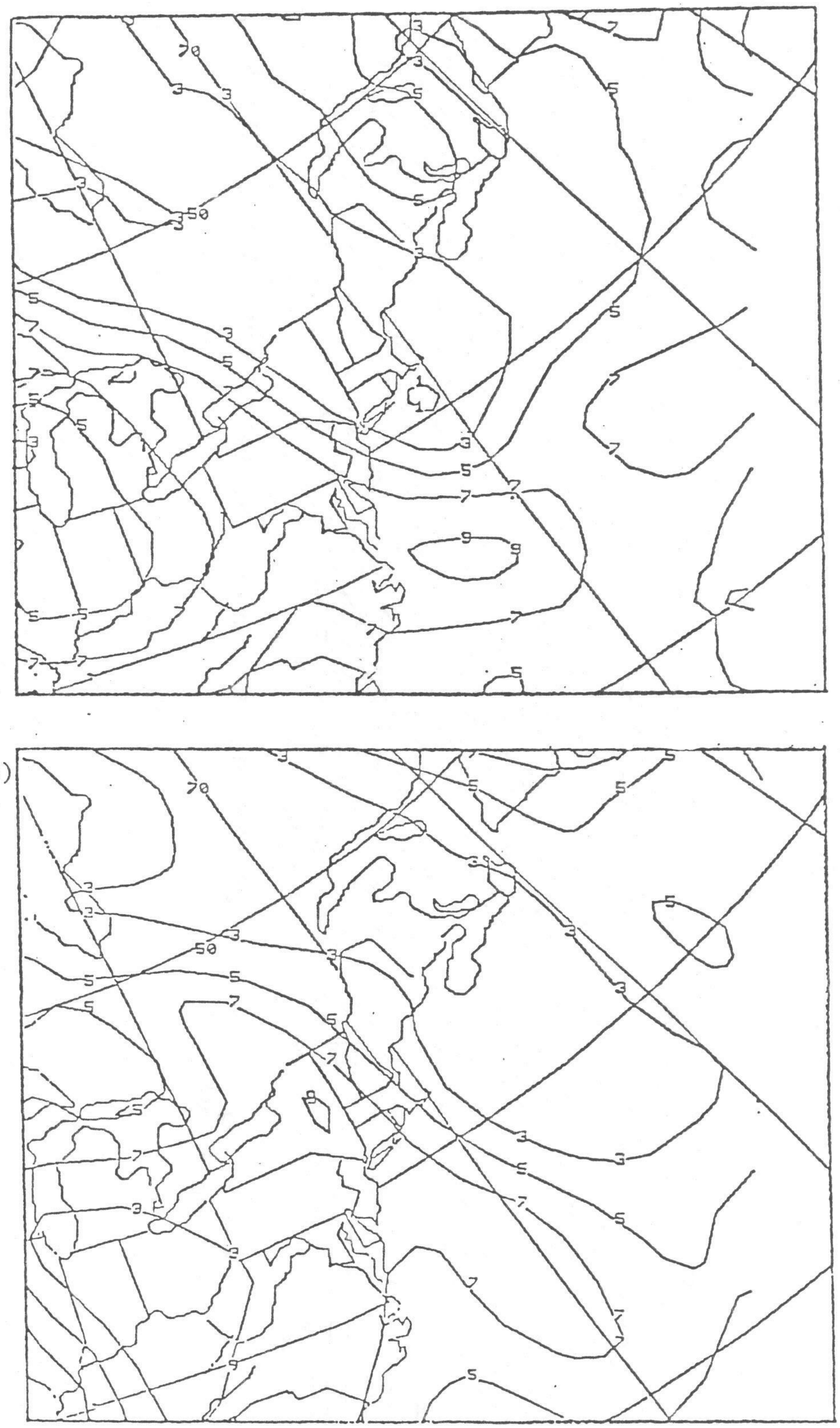

Figure 4. 0000 UTC April 15, 1991, NGM 1000-500 mb mean relative humidity (a) analysis and (b) 12-h forecast. Contours are labeled in tens of percent.

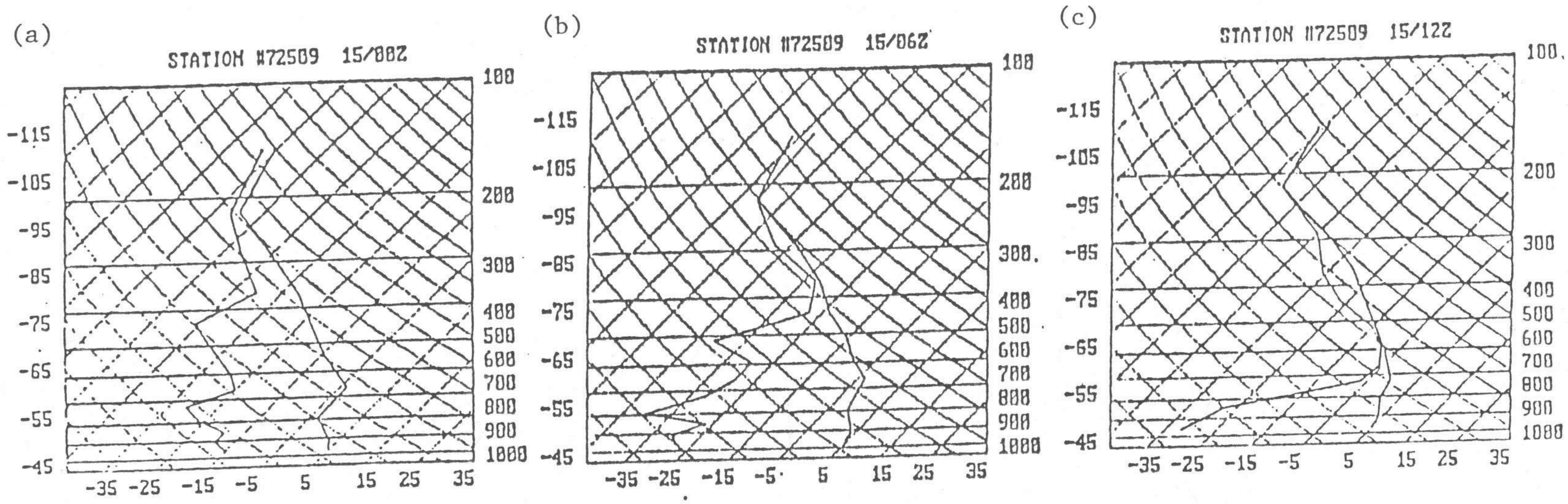

Figure 5. Skew t-log p diagrams of the 0000 UTC April 15, 1991, NGM (a) 0-h, (b) 6-h, and (c) 12-h projections.

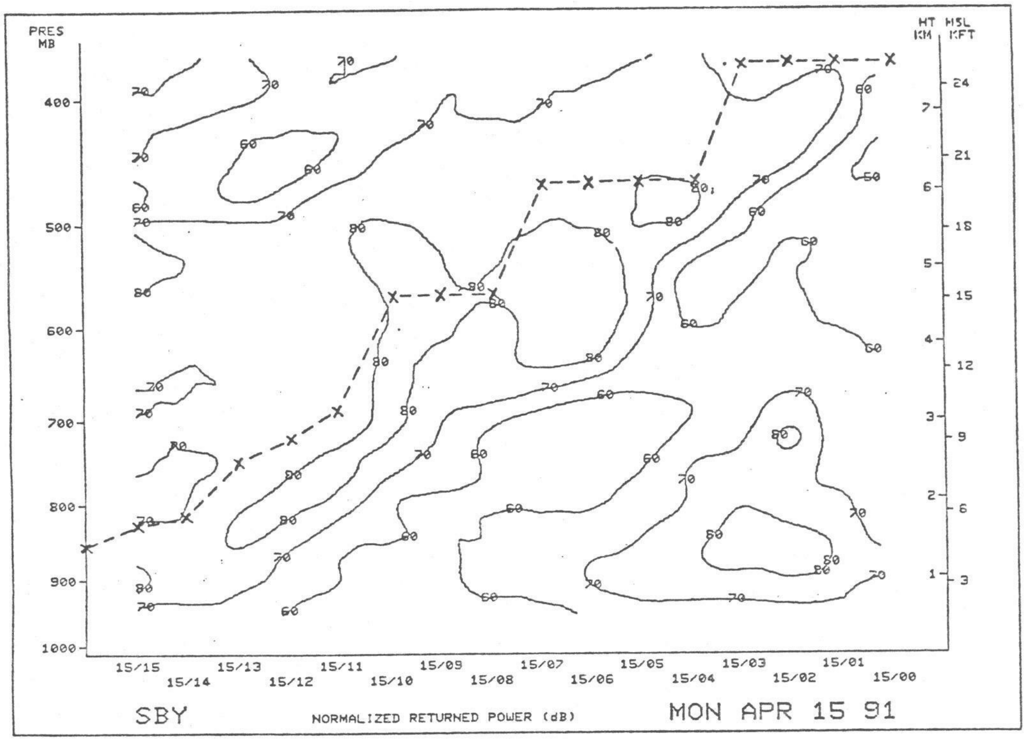

Figure 6. Time-height section of the normalized returned power from the SBYM3 wind profiler for the period 0000-1500 UTC on April 15, 1991. The dashed line indicates the height of the lowest observed cloud layer at BOS.

Table 1. Hourly surface observations from BOS for the period 2352 UTC April 14, 1991, to 1550 UTC April 15, 1991.

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BOS SA 1550 45 SCT M55 OVC 15 220/49/31/1809/018
BOS SA 1450 M55 OVC 15 234/48/29/1810/022/ 615 15//
BOS SA 1350 M60 BKN 80 OVC 15 234/47/27/1809/022
BOS SA 1250 M80 BKN 110 OVC 15 244/45/33/1808/025
BOS SA 1150 M90 BKN 110 OVC 15 249/44/32/1908/027/ 805 107/ 42 CHH
RADAT 20065
BOS SA 1050 100 SCT E150 BKN 250 OVC 15 256/43/30/2309/029/THN SPTS
IOVC FEW SML BINOVC
BOS SA 0950 E150 BKN 250 OVC 15 257/43/30/2407/029/OVC PTLY THN
BOS SA 0850 E150 BKN 250 OVC 15 254/43/30/2006/028/ 717 1071
BOS SA 0750 150 SCT 250 -OVC 15 257/43/29/2007/029/ 98734
BOS SA 0650 E200 OVC 15 266/44/28/2410/032
BOS SA 0550 E200 OVC 15 271/44/29/2312/033/ 720 1007 49
BOS SA 0450 E200 OVC 15 274/44/29/2311/034
BOS SA 0350 E200 OVC 15 286/44/30/2210/038
BOS SA 0251 E250 OVC 15 291/44/30/2110/039/THN SPTS IOVC/ 803 1007
BOS SA 0150 E250 OVC 15 295/43/32/1707/040/THN SPTS IOVC
BOS SA 0050 E250 OVC 15 298/44/31/1409/041/OVC PTLY THN
BOS SA 2352 E250 OVC 15 295/44/36/1209/040/THN SPTS IOVC/ 717 1007
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