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A LIGHT SNOW EVENT GENERATED BELOW THE 850 MB LEVEL

Steven J. Capriola
National Weather Service Forecast Office
Portland, Maine

1. INTRODUCTION

On 18 January 1995 a light snow event occurred across southwest Maine and southeast New Hampshire. Snow accumulations were rather light, having no impact on snow removal efforts. However, for aviation purposes the event was more critical due to low ceilings and visibilities along with low-level icing. This event was of particular interest because the vertical temperature profile during this event is not commonly associated with a snow event and would be difficult to forecast using standard snow forecasting techniques.

Several snow forecasting techniques have been developed over the years. For example, snow will fall on the cold side of the 0 ºC isotherm at the 850 mb level (George, 1960). These techniques have been applied to case studies (e.g., Marine and Capriola 1994) to aid forecasters in predicting snow events, in particular, heavy snow events. These studies do not account for the rare events, such as this one, that produce snow despite the vertical temperature profile showing significant above-freezing levels. However, as stated by Bluestein (1992, 1993), snow can be produced in a sub-freezing layer below an above-freezing layer. This case is a good example of this.

This paper will: 1) explain why employing standard forecasting techniques would fail in this case, 2) examine the intricate features that produced the precipitation, and 3) explain why the vertical temperature profile supported snow.

2. IMPACT

Light snow was reported across southwest Maine and southeast New Hampshire during the afternoon and evening hours of 18 January 1995 (Fig. 1). Precipitation amounts were very light, on the order of only a few hundredths of an inch (0.01 inch at Portland, ME (PWM)). Of more significance were the low ceilings and reduced visibility in the saturated low-level environment. Ceilings lowered below one thousand feet and visibility was reduced below 3 miles in light snow resulting in instrument flight rules (IFR) conditions. Eventually the precipitation changed to light freezing drizzle as it tapered off. In addition, low-level icing was also a concern for aviation safety as reported by several aircraft (Fig. 2).

3. SYNOPTIC OVERVIEW

There was no upper air support, such as positive isothermal vorticity advection (PIVA) (Fig. 3), to generate precipitation. Rather, low-level convergence (surface to 850 mb) was the generating feature. An analysis of 850 mb flow showed convergence over the region (Fig. 4) which is supported by the convergent wind field on the 850 mb data plot (Fig. 5). Note the east wind at Yarmouth, Nova Scotia (YQI), the south southwest wind at Gray, ME (GYX) and the west wind at Albany, NY (ALB).

High pressure (1036 mb) centered over the Canadian Maritimes extended south and west into New England at 0000 UTC 19 June 1995 (Fig. 6). This resulted in low-level cold air damming on the lee side of the Appalachian Mountains with an associated developing coastal front (Bosart et al 1972; Bosart 1975).

The coastal front was first detected on the 0000 UTC surface plot (Fig. 7) as an inverted trough extending north to south from Mount Desert Rock, ME (MDRM1) into the eastern Gulf of Maine. East of this surface boundary winds were from the east-northeast. West of the boundary surface winds, on average, were from the north-northeast. Surface temperatures were at or just below freezing across Maine and New Hampshire and were falling during the event in response to cold air advection at ground level. This resulted in low-level convergence from the surface to the 850 mb level.

At 0000 UTC the 850 mb thermal field displayed mild temperatures across New England with the 0 ^{o}C isotherm extending west to east, across far northern Maine (Fig. 5). The 5 ^{o}C isotherm cut across central Vermont, southern New Hampshire then eastward just south of Gray, ME (GYX). Normally the 0 ^{o}C isotherm is the critical value for determining rain versus snow during a precipitation event. The 850 mb analyses also revealed ample low-level moisture just south and east of Maine with dewpoint depressions of 5^{o}C or less (Fig. 5).

At the 700 mb level temperatures were still unseasonably mild, with GYX reporting 2 ^{o}C and Caribou, Maine (CAR) 0 ^{o}C (Fig. 8). The large 700 mb dewpoint depressions showed the very dry air at midlevels.

The 1200 UTC 18 Jan. and 0000 UTC 19 Jan. upper air soundings for GYX and CAR (Figs. 9, 10, 11 and 12) illustrate the cold air damming across northern New England. Temperatures were below freezing from the surface to about 900 mb (except to only about 925 mb at GYX at 1200 UTC). Ample moisture was found through this layer. Above the 900 mb level the sounding both warmed (above 0 ^{o}C) and dried out, in part, due to a subsidence inversion associated with the high pressure center to the northeast. Observations from Mount Washington, NH (MWN, elevation 6228 feet) through this period revealed the lower clouds below station elevation, while the mountain peak was free of clouds along with above freezing temperatures. Also at MWN large temperature-dewpoint spreads of about 22 ^{o}C were observed prior to the event, only lowering to around 6 ^{o}C through most of the event.

4. DISCUSSION

Analyses of thickness values for specified layers can be used in addition to vertical temperature profiles to determine precipitation type (Younkin, 1967). For example, despite the above freezing temperatures at 850 mb, the 1000 to 850 mb thickness analysis (Fig. 13) at this time showed values (1295 GPM at GYX and 1284 GPM at CAR, specific values not depicted) below the critical threshold of 1300 GPM for snow versus rain over Maine while values exceeded the 1300 GPM threshold over southern New Hampshire. Above this layer, 700 to 850 mb thicknesses were warmer than the critical threshold of 1540 GPM for snow (1588 GPM at GYX and 1572 GPM at CAR). As will be discussed in more detail later, the warm layer aloft was not as critical in determining precipitation type for this event as it would be for more widespread, heavy precipitation events.

The more commonly used 1000 to 500 mb thicknesses showed this much deeper layer to be warmer than the 5400 GPM critical threshold for rain versus snow with values ranging from 5500 to 5520 GPM (Fig. 6). The depth of the layer in this particular thickness analysis is too deep to discern the shallower layers of warm and/or cold air. It is these shallow layers of cold and/or warm air, as can be better depicted by 1000-850 mb and 850-700 mb thickness analyses, that would help portray freezing rain/sleet scenarios or situations of low-level-driven snow events like this one.

At 0000 UTC the soundings also showed an east to southeast low-level flow, just above northerly surface winds, providing the influx of moisture from the ocean. This low-level onshore flow is also illustrated by the 0000 UTC boundary level wind chart (Fig. 14). For any precipitation to form in this environment it would have to be driven by low-level forcing, obtaining available moisture from low levels. The low-level dynamics acted on the low-level moisture which coincided with below freezing temperatures to produce the frozen precipitation. The lack of any one of these three features would have precluded the snowfall.

5. CONCLUSIONS

It is quite apparent that this event was driven by low-level convergence, below the 850 mb level, otherwise the precipitation type would have been freezing rain rather than light snow. The low-level convergence acted on the available moisture supplied by onshore flow below the 850 mb level. Snowfall amounts were not significant for highway crews while the aviation community was more adversely affected by IFR conditions and low-level icing. Although 850 mb temperatures and 1000-500 mb thicknesses can be good predictors for determining precipitation types, this is not always the case. Vertical temperature and moisture profiles, in addition to derived products (such as thickness analysis through critical layers and low-level convergence analysis) and detailed surface and upper air analysis, can aid forecasters in predicting both the occurrence of precipitation and the type of precipitation to be expected. In the absence of any synoptic scale forcing, quantitative precipitation estimates of light amounts can be made with good success.

ACKNOWLEDGMENT

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REFERENCES

Bluestein, H. B., 1992: *Synoptic-Dynamic Meteorology in Mid-latitudes Vol. I Principles of Kinematics and Dynamics*. Oxford University Press, 431 pp.

_____, 1993: *Synoptic-Dynamic Meteorology in Mid-latitudes Vol. I I Observations and Theory of Weather Systems.*. Oxford University Press, 594 pp.

Bosart, L. F., 1975: New England Coastal Frontogenesis. *Quart. J. Roy. Meteor. Soc.,* **101**, 957-978.

_____, C. J. Vaudo, and J. H. Helsdon, Jr., 1972: Coastal Frontogenesis. *J. of Appl. Meteor.,* **11**, 1236-1258.

George, J. J., 1960: *Weather Forecasting for Aeronautics.* Academic Press, 673 pp.

Marine, R. A. and S. J. Capriola, 1994: A Synoptic and Mesoscale Examination of the Northern New England Winter Storm of 29-30 January 1990. NOAA Tech. Memo. NWS ER-88, NOAA/NWS, Bohemia, NY, 39 pp.

Meier K., 1994: PC-GRIDDS User's Manual (ver. 12/93), National Weather Service, NOAA, Department of Commerce, 102 pp. [Available from NWS Western Region Headquarters, Scientific Services Division.]

Younkin, R. J., 1967: A Snow Index, ESSA Tech. Memo. WBTM NMC-40, NOAA/NMC, 7 pp [NTIS PB-175-641].

SA 1156 AO2A M14 OVC 10+ 289/33/28/0309/038/ 53018 10051 20033 TNO ZRNO
SA 1256 AO2A M14 OVC 10+ 299/32/28/0412/041/ TNO ZRNO
SA 1356 AO2A M14 OVC 10+ 303/32/28/0512/042/ TNO ZRNO
SA 1456 AO2A M12 OVC 10+ 309/32/28/0210/044/ 51020 TNO ZRNO
SA 1556 AO2A M14 OVC 7S- 305/32/28/0307/043/ TNO SB46 ZRNO
SA 1656 AO2A M12 OVC 7S- 299/32/28/0308/041/ TNO
SA 1756 AO2A 12 SCT M18 OVC 10+S- 295/33/29/0307/040/ 6000/ 58014 10036 20032 TNO
SA 1856 AO2A M18 OVC 10+S- 293/34/28/0207/039/ TNO PCPN M
SA 1956 AO2A M20 OVC 10+S- 295/34/28/0306/040/ TNO
SA 2056 AO2A 14 SCT M20 OVC 10+ 296/33/28/0307/040/ 6000/ 53001 TNO SE52 ZRNO
SA 2156 AO2A M20 OVC 10+ 298/33/29/3605/041/ TNO ZRNO
SA 2256 AO2A M22 OVC 10+ 298/33/29/3607/041/ TNO ZRNO
SA 2356 AO2A M15 BKN 22 OVC 10+S- 302/32/29/0107/042/ 6000/ 53006 10034 20032 TNO SB23
SP 0033 AO2A M19 BKN 24 OVC 21/2S-F 300/32/30/0306/041/ TNO PCPN M
SA 0056 AO2A M20 OVC 21/2S-F 298/31/31/0207/041/ TNO PCPN M
SP 0106 AO2A 7 SCT M20 OVC 21/2S-F 298/31/31/0105/041/ TNO PCPN M
SP 0141 AO2A M7V BKN 18 OVC 3S-F 295/31/31/3607/040/ CIG 5V10 TNO PCPN M
SA 0156 AO2A M5 BKN 16 OVC 3S-F 295/31/31/3407/040/ BKN V SCT TNO PCPN M
SP 0217 AO2A 5 SCT M16 OVC 5S-F 291/31/30/3507/039/ TNO PCPN M
SP 0238 AO2A 10 SCT M14 OVC 5S-F 288/31/30/0106/038/ TNO PCPN M
SP 0246 AO2A M8V BKN 14 OVC 5S-F 288/31/30/3605/038/ CIG 5V11 TNO PCPN M
SA 0256 AO2A M8V OVC 10+ 288/31/30/0106/038/ 6001/ 58014 CIG 5V11 TNO SE50 ZRNO
SA 0356 AO2A M6 OVC 10+ 282/31/30/3607/036/ TNO ZRNO

Figure 1. Surface aviation (SA) and special (SP) observations for Portland, ME (PWM) for 18 Jan. to 19 Jan. 1994. Times are UTC.

PWM UA /OV PWM/TM 0019/FLDRGD/TP PA31/SK OVC 032/IC LGT-MDT MXD

BGR UA /OV BGR/TM 0020/FLDRGC/TP C208/SK 005 OVC 035 CA/TA +09 @ 080/TB NEG/IC LGT RIME IC

BGR UA /OV BGR/TM 0141/FL035/TP C208/SK OVC 035/IC MDT RIME IC/RM LOST ICE ABV 035

PWM UA /OV PWM/TM 0235/FL060/TP PA31/SK 012 OVC 033 CA/TA 05/IC LGT MXD 020-033

Figure 2. Pilot reports (PIREPS) for Maine for 19 January 1994 Times are UTC. Standard FAA and NWS contractions are used. Note the overcast conditions and icing reported at or below 3500 feet.

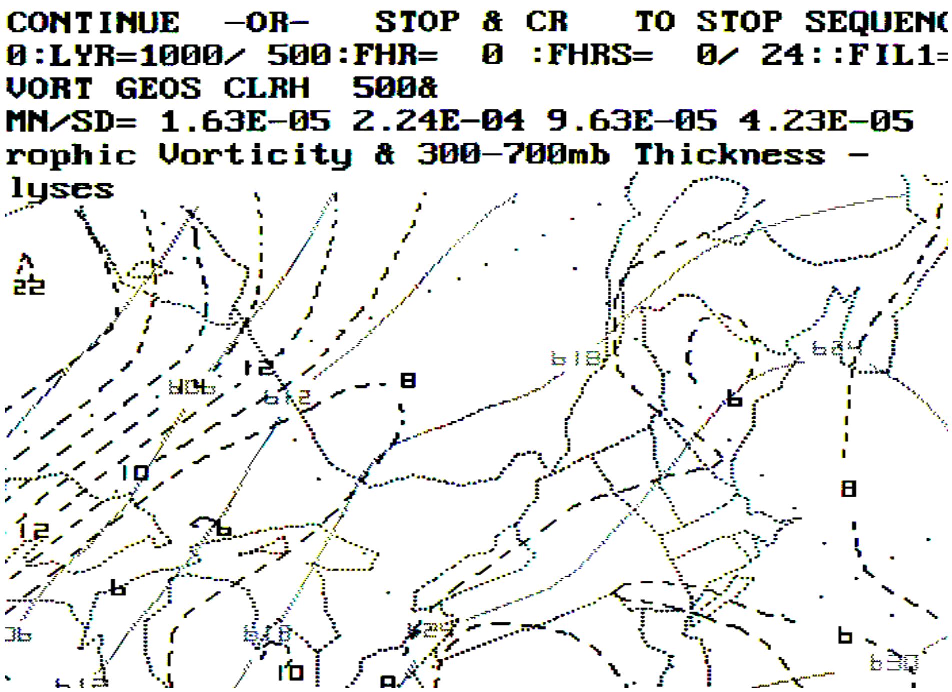

Figure 3. ETA model analysis of 500 mb geostrophic vorticity (solid lines, units are $10^{-5}sec^{-1}$) and 300-700 mb thickness (dashed lines in dm) using PC-GRIDDS (Meier 1994) to determine positive isothermal vorticity advection at 0000 UTC 19 Jan. 1995.

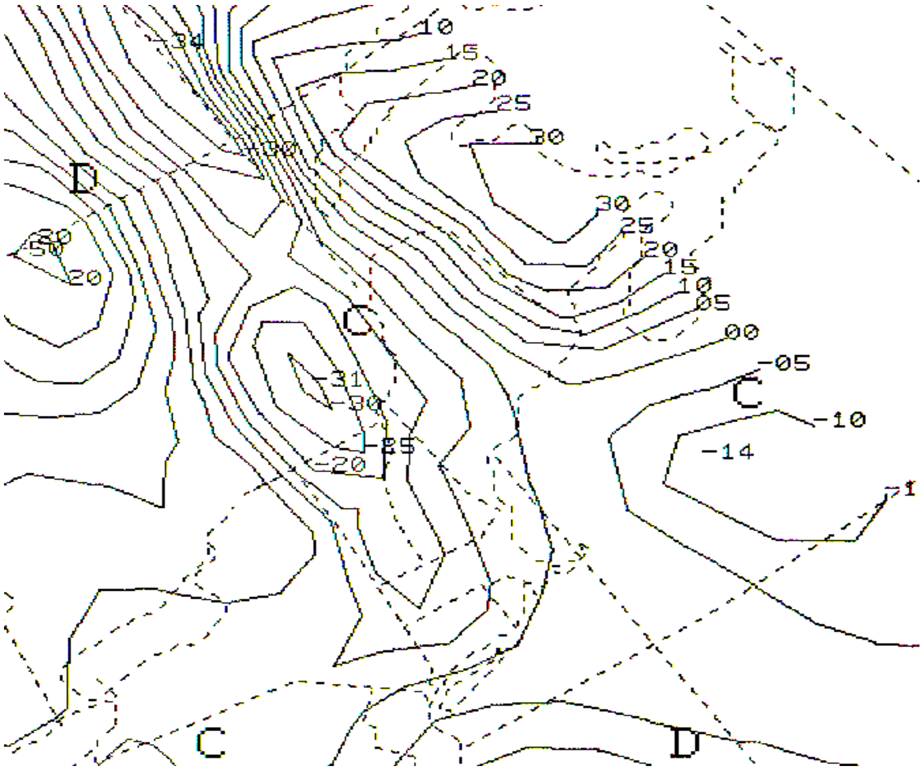

Figure 4. 850 mb convergence chart at 0000 UTC 19 Jan. 1995. Negative values represent convergence with minimum values denoted by a "C". Positive values represent divergence with maximum values denoted by a "D". Units are $10^{-6}sec^{-1}$.

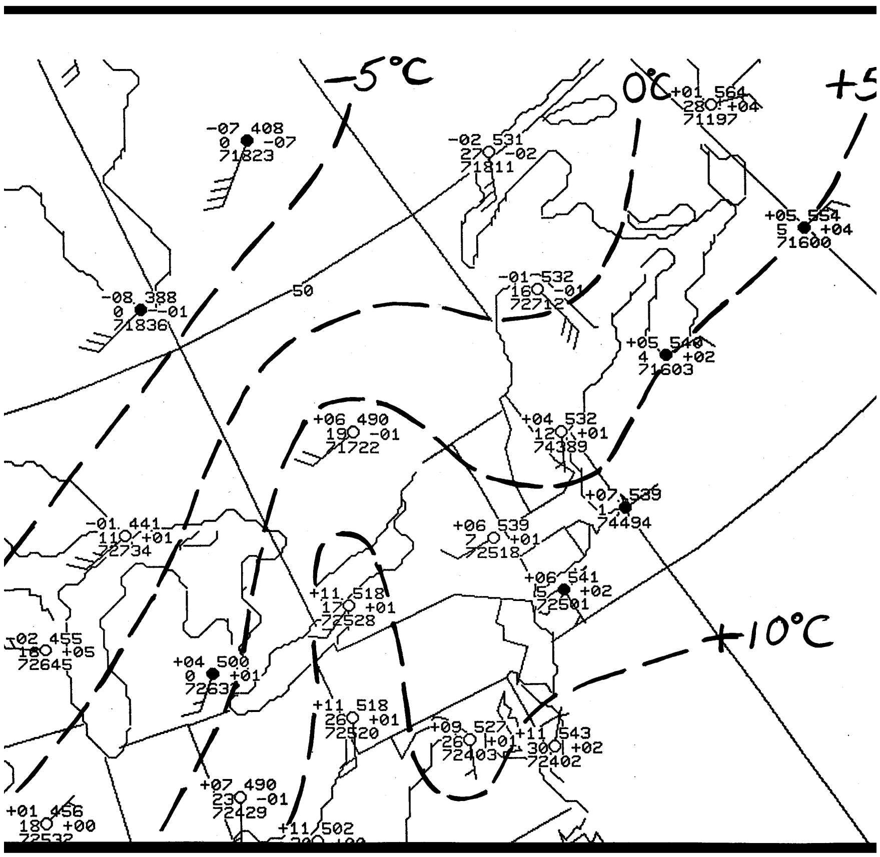

Figure 5. 850 mb data plot at 0000 UTC 19 Jan. 1995. Standard notation used to represent upper air parameters. Dashed lines represent isotherms. Note shaded circles represent moisture with temperature - dewpoint depressions of 5 °C or less.

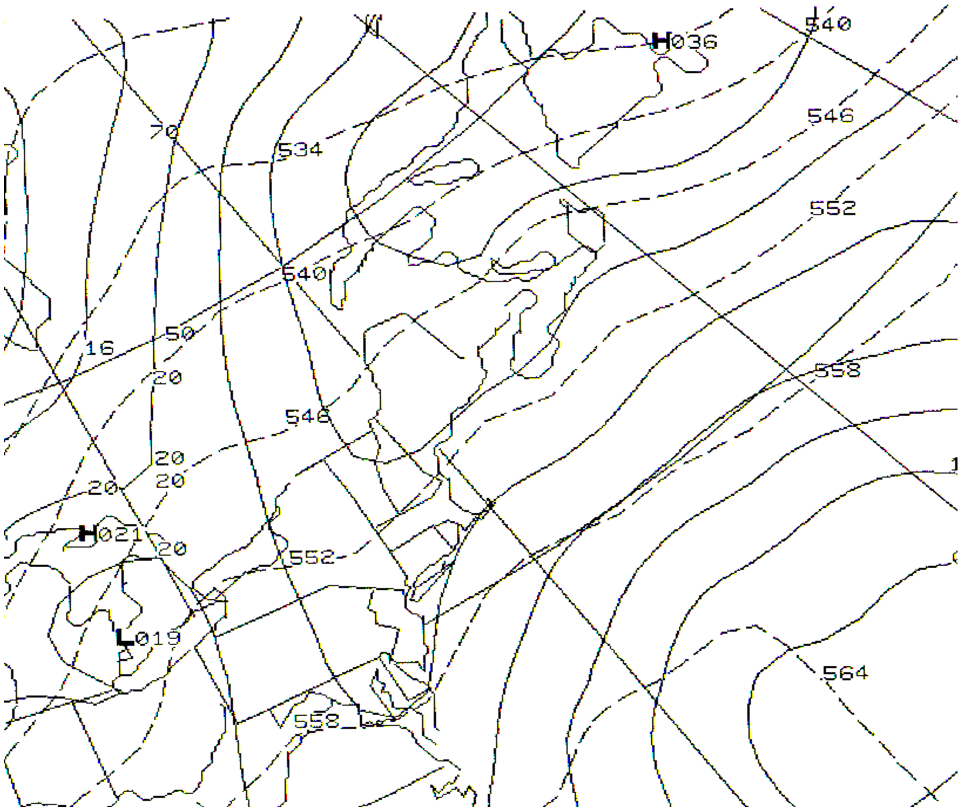

Figure 6. Surface analysis at 0000 UTC 19 Jan. 1995. MSL pressure (in mb) with isobars analyzed every 4 mb and 1000-500 thickness dashed lines (in dm).

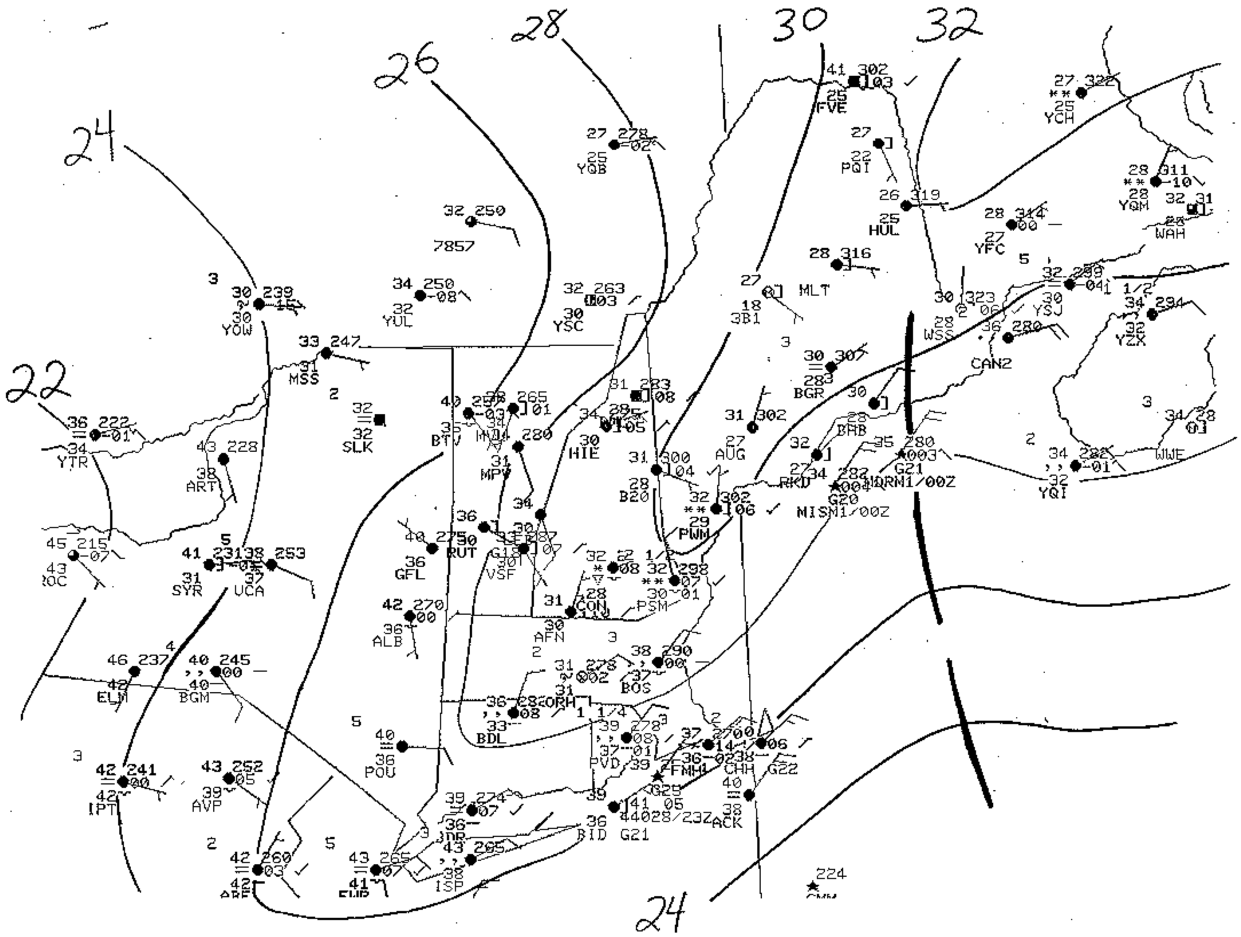

Figure 7. Surface plot at 0000 UTC 19 Jan. 1995. Standard notation used to represent surface parameters. Isobars (solid lines) analyzed every 2 mb. Surface trough indicated by heavy broken line.

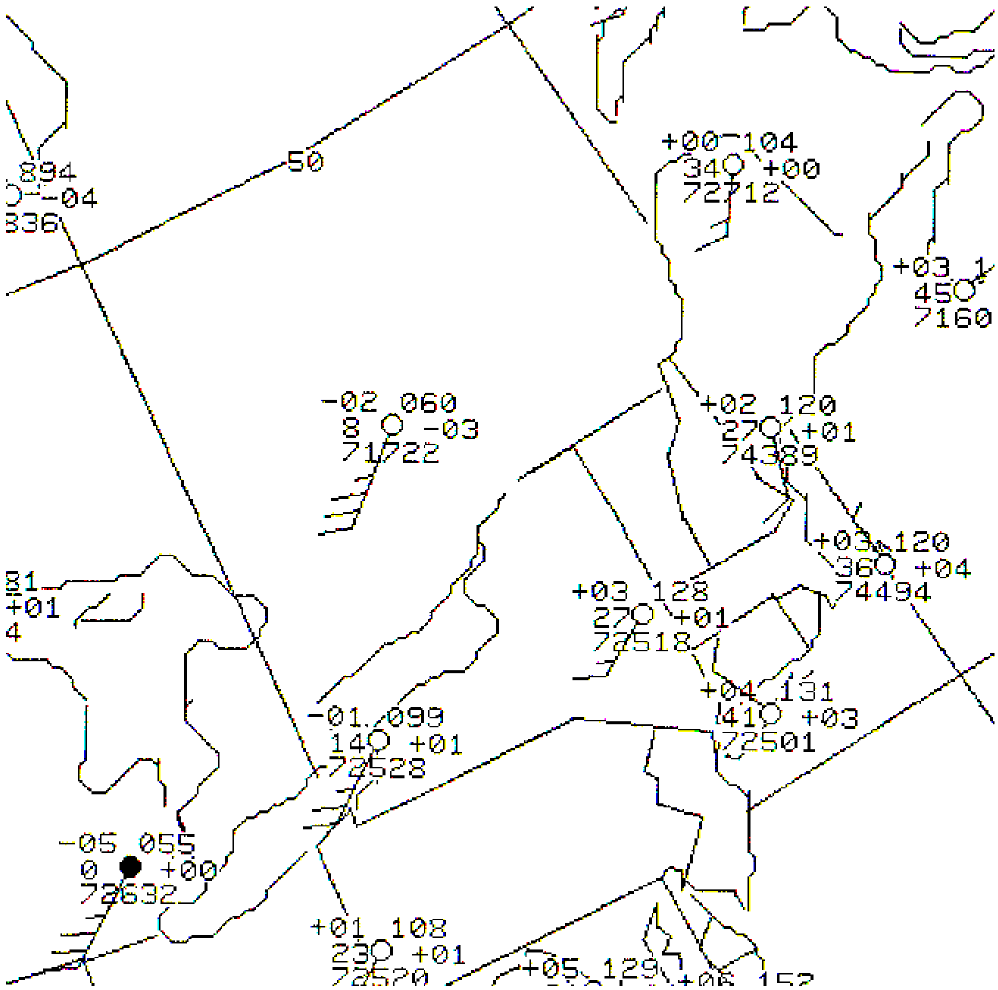

Figure 8. 700 mb data plot at 0000 UTC 19 Jan. 1995. Standard notation used to represent upper air parameters.

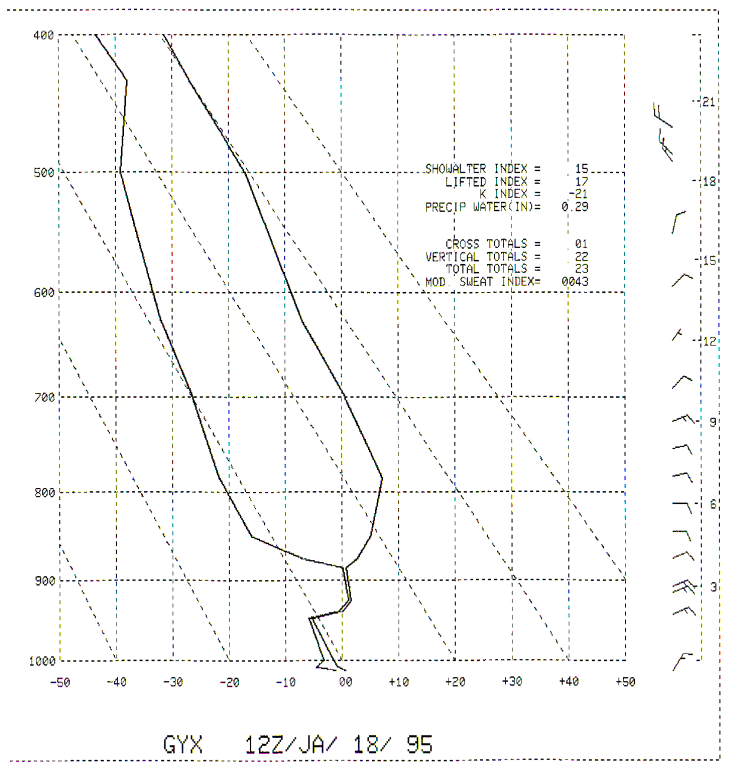

Figure 9. Pseudo-adiabatic chart depicting upper air sounding for Gray, ME (GYX) at 1200 UTC 18 Jan. 1995.

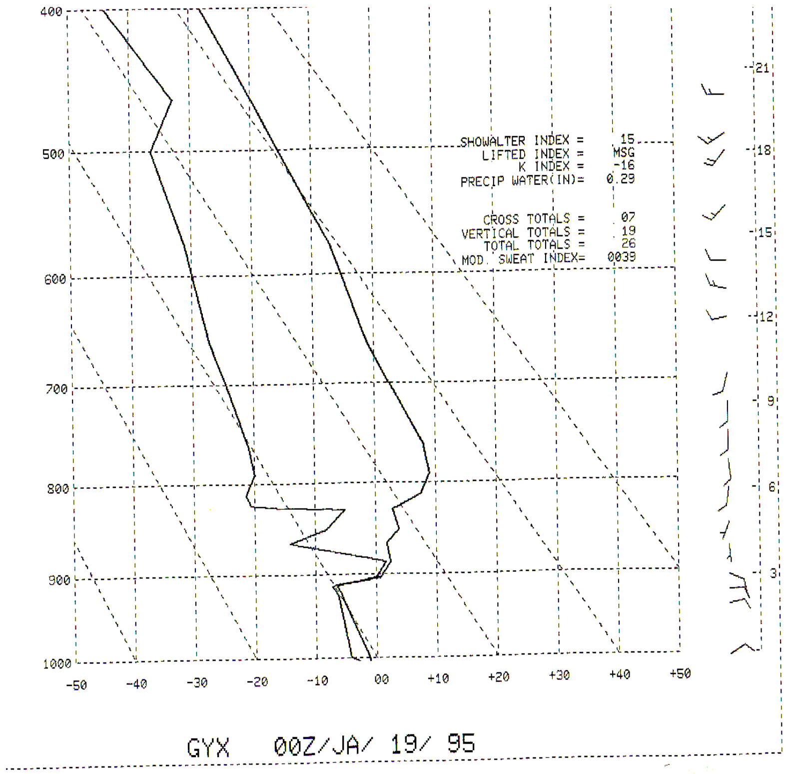

Figure 10. Pseudo-adiabatic chart depicting upper air sounding for Gray, ME (GYX) at 0000 UTC 19 Jan. 1995.

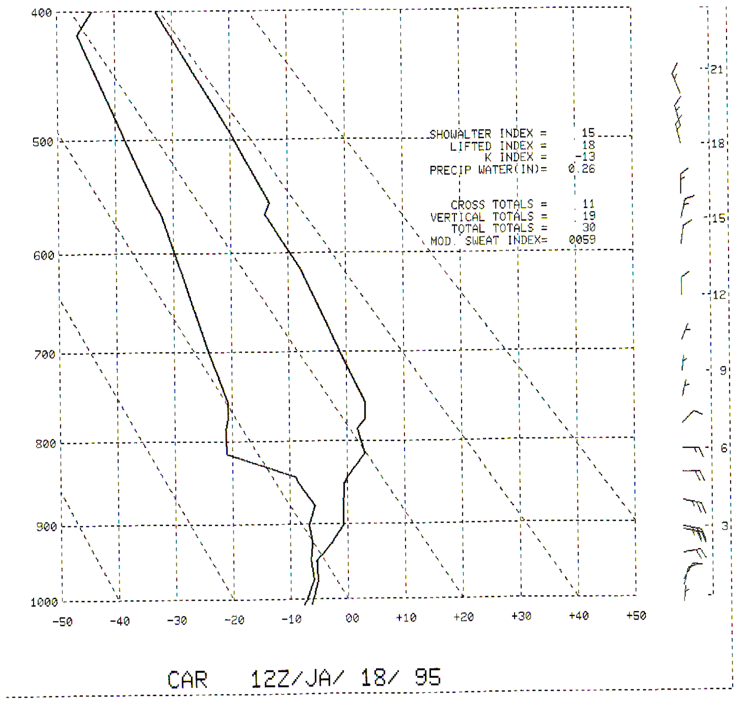

Figure 11. Pseudo-adiabatic chart depicting upper air sounding for Caribou, ME (CAR) at 1200 UTC 18 Jan. 1995.

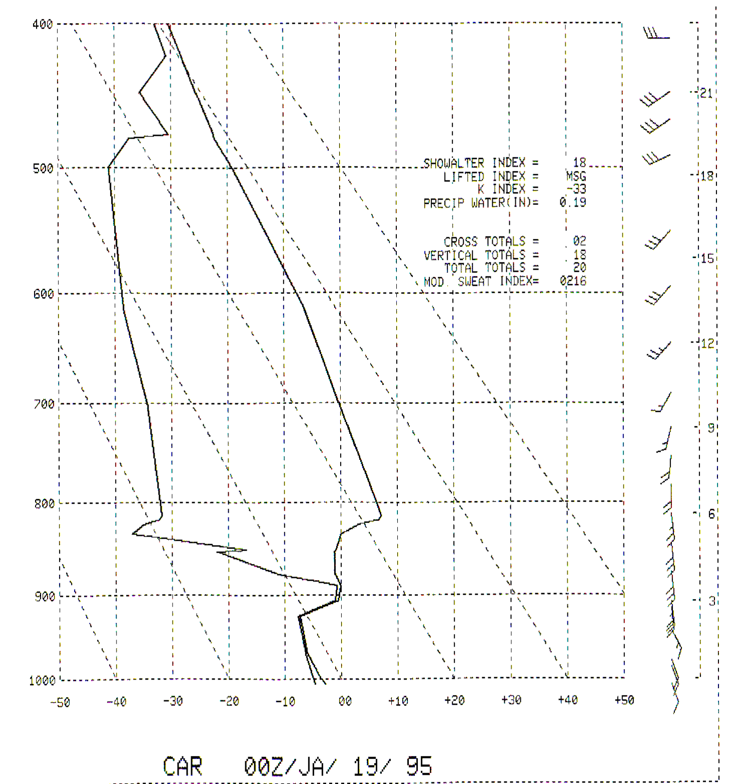

Figure 12. Pseudo-adiabatic chart depicting upper air sounding for Caribou, ME (CAR) at 0000 UTC 19 Jan. 1995.

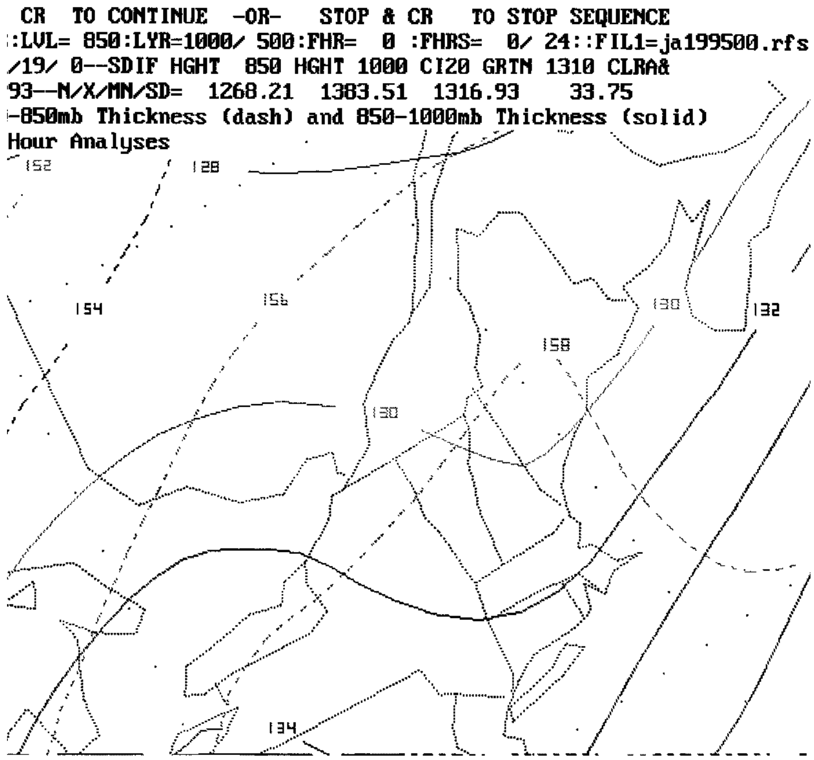

Figure 13. ETA model analysis of 1000 to 850 mb thickness (solid lines) and 850 to 700 mb thickness (dashed lines) using PC-GRIDDS at 0000 UTC 19 Jan. 1995. Units are in dm.

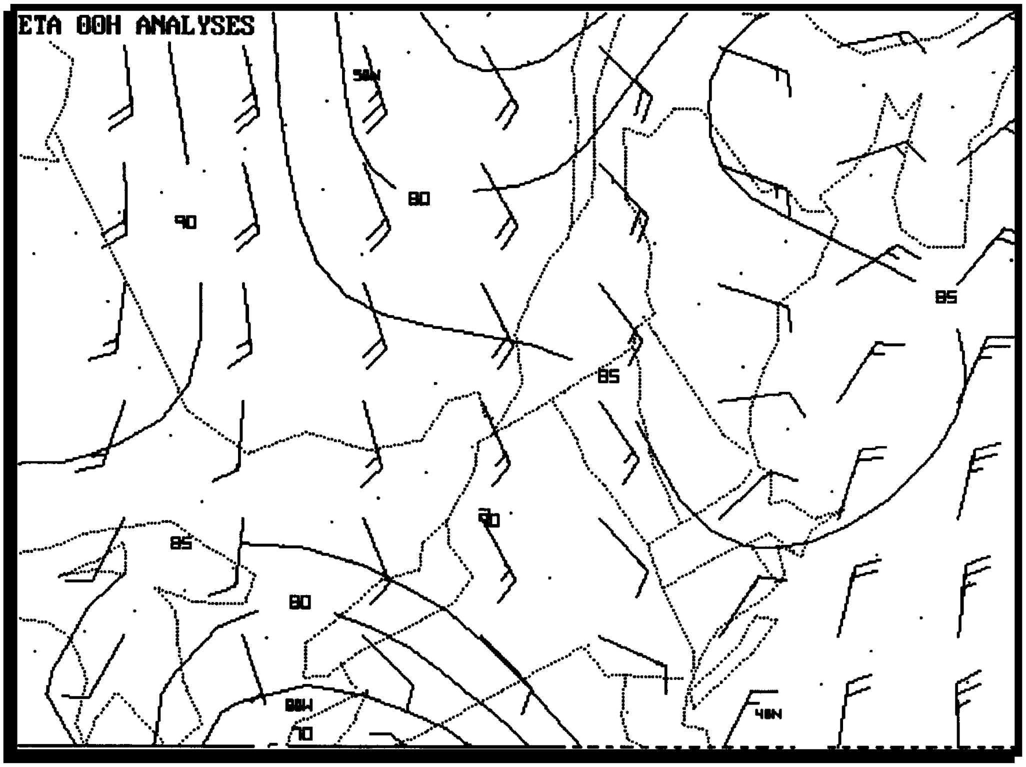

Figure 14. ETA model analysis of boundary layer mean relative humidity (solid lines in percent) and boundary level winds (wind barbs in knots where a long barb represents 10 knots and a short barb 5 knots) using PC-GRIDDS at 0000 UTC 19 Jan. 1995.