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# THE USE OF AIRCRAFT-REPORTED TEMPERATURES FOR DETERMINING PRECIPITATION TYPE

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## 1. INTRODUCTION

While increasingly sophisticated computer models, satellites, and radar systems have contributed to a noticeable improvement in weather forecasting, meteorologists remain hampered by the spatial and temporal limitations of the upper-air observational network. This limitation is especially important when attempting to determine the precipitation type associated with a winter storm. Since a slight temperature change of only one or two degrees can make the difference between an ice, rain, or snow storm, knowledge of the atmospheric temperature profile is crucial to the production of an accurate forecast. Unfortunately, upper-air soundings are routinely taken at 12-hour intervals, and at distances of 300 miles or more apart.

This study focuses on three instances where aircraft-reported temperatures were solicited between upper-air balloon flights in order to determine what, if any, change had occurred to the temperature profile of the low levels of the atmosphere. The aircraft reports were also used to verify the numerical guidance of the most recent LFM/NGM model run, and most importantly, to update the forecast to give a more accurate indication of the current or upcoming weather.

## 2. METHODOLOGY

When faced with a situation where precipitation type is in doubt, a call is made to the Buffalo air traffic control (ATC) facility to request temperature reports from the next arriving or departing aircraft. The temperatures are normally requested for altitudes of 2,000, 4,000 and 6,000 feet above ground level. Upon receipt of these data, the forecaster modifies the most recent sounding with the aircraft-reported observations. This can be accomplished on a standard SKEW-T chart, or by using the SHARP software (Hart and Korotky 1991). The forecaster then decides if the new information appears reasonable, and if so, whether it agrees with the current forecast, or if an update is needed.

## 3. DATA

The following three events during the 1991-92 winter season were examined:

November 10-11, 1991; November 27-28, 1991; and February 28, 1992.

*a. Source*

Temperature reports were obtained mainly from commercial aircraft (Boeing 727s, 737s and McDonnell Douglas MD80s) that were departing from, or arriving at, the Greater Buffalo International Airport. The reports were transmitted by voice from the aircraft flight crew to the Buffalo ATC tower, and then relayed to the forecaster at WSFO Buffalo (BUF) via a dedicated phone line.

*b. Quality*

With one exception, the aircraft data for these cases appeared reasonable, and were consistent with the temperature profile of the next scheduled sounding. Researchers have found temperature sensors on commercial aircraft to be accurate to within 0.7°C (Petersen 1992, personal communication). Benjamin et al. (1991) noted two studies (Brewster et al. 1989; and Sparkman and Giraytys 1981), which indicated significant errors were usually limited to instances where the data were acquired via voice transmission, as opposed to those that were disseminated automatically by commercial aircraft using ACARS (an air-to-ground communications system that processes and transmits aircraft performance and meteorological data). In general, the frequency of errors when voice transmission is used, can approach 30%.

## 4. RESULTS

A case study of the November 10-11, 1991 frozen precipitation event is presented to demonstrate the usefulness of the aircraft-reported temperatures.

In particular, the 1200 UTC surface map on November 10, (Fig. 1) showed high pressure centered over the Canadian Maritimes and low pressure near the North Carolina coast. As the high moved east, southerly flow west of the high caused temperatures to climb into the low to mid 40s (°F) across western and central New York under partly sunny skies. At 500 mb (Fig. 2), a cut-off low was off the coast of South Carolina, and was forecast by the dynamical model guidance provided by the National Meteorological Center (NMC) to drift north.

Light rain and sleet began over western New York during the mid evening hours as temperatures fell back into the upper 30s. The afternoon forecast called for light rain, and possibly a few areas of freezing rain for the overnight hours. However, forecasters on the evening shift noticed that the 1200 UTC sounding (Fig. 3) might support frozen precipitation. A call was placed to the Buffalo ATC tower at 2200 UTC and pilot reports were solicited. The results were as follows:

| LEVEL (FT, AGL) | TEMPERATURE (°C) |
|---|---|
| 2,000 | 0 |
| 4,000 | +6 |
| 6,000 | +5 |

The aircraft-reported temperatures were plotted on the 1200 UTC BUF sounding (dashed line on Fig. 3), and it appeared that frozen precipitation was likely, provided that the low levels were still dry. When the 0000 UTC November 11 BUF sounding (Fig. 4) arrived, the forecasters saw that the low levels were indeed dry, and that the aircraft-reported temperatures closely resembled those on the new sounding. The SHARP program was utilized to plot the wet-bulb temperature. This plot indicated that the wet-bulb temperatures were sub-freezing at all levels, except within a few hundred feet of the ground (Fig. 4). Hence, barring substantial warm air advection in the low levels, frozen precipitation was more likely than rain.

In contrast, guidance from the 1200 UTC dynamical models depicted a rain event. The 1000-500 mb thickness values forecast from both the NGM and LFM FOUS products (Table 1) were 550 dm at 0000 UTC on November 11 and 547 dm by 1200 UTC. The LFM mean boundary layer temperatures were forecast to fall from 277 to 275°K. The key to this forecast was the very dry air in the low levels, which would cool below freezing by evaporation and/or sublimation when the precipitation began. In addition, upward vertical motion (+3.5 microbars/s) was forecast by the NGM.

A Winter Weather Advisory was issued at 0100 UTC by the WSFO Buffalo staff for all of western and central New York, except for the counties immediately south of Lake Ontario (where low level northeast winds blowing over the relatively warm waters would keep the boundary layer too warm for frozen precipitation).

At 0400 UTC, another request for aircraft-reported temperatures yielded the following:

| LEVEL (FT, AGL) | TEMPERATURE (°C) |
|---|---|
| 2,000 | -1 |
| 4,000 | -1 |
| 6,000 | 0 |

These values showed that the low levels had already cooled to within a few degrees of the wet-bulb temperatures depicted in Fig. 4, confirming the forecaster's earlier suspicion that this might be a frozen precipitation event.

Rain gradually changed to sleet and snow during the overnight hours as temperatures dropped to near freezing. An inch of snow and sleet was on the ground at Buffalo at 1200 UTC on November 11, with another 3 inches of snow accumulation by 1800 UTC. The same was true over most of western and central New York, except for the counties bordering Lake Ontario, where rain was most prevalent. By 1200 UTC on November 11, surface low pressure had moved from the North Carolina coast to the Delmarva peninsula, bringing precipitation (mostly rain) to much of the northeastern United States.

The early evening aircraft-reported temperatures motivated the forecasters to think about frozen precipitation instead of rain, while the late evening readings provided reassurance that they had made appropriate updates to the forecast.

## 5. OTHER EVENTS

An event that occurred on November 27-28, 1991 was not as dramatic as the November 10-11 example. At 1200 UTC on November 27, high pressure was over the Eastern Seaboard, while an occluded front trailing south from low pressure over Lake Huron (not shown) was forecast by the NMC models to move northeast into Ontario. This scenario was expected to produce some light precipitation across western and central New York. The morning and afternoon local forecasts from

WSFO BUF called for periods of wet snow or rain on the evening of November 27, changing to light rain on November 28.

While a forecast of rain or wet snow in the winter season usually doesn't attract very much attention in western New York, November 27 was the night before Thanksgiving. In an effort to refine the forecast for the holiday travelers, aircraft-reported temperatures were requested during the evening hours. These values showed that temperatures had warmed above freezing from the surface to 700 mb, ending the threat of freezing or frozen precipitation. With this in mind, the forecast was updated to indicate "periods of rain or drizzle," which perhaps alleviated some winter weather driving concerns that travelers might have had.

The instance when obviously erroneous temperatures were received, occurred on February 28, 1992. Surface low pressure was forecast to move across southern Ontario and bring rain or snow showers to western New York. The 1200 UTC sounding (not shown) was entirely sub-freezing, but exhibited strong veering with height, suggesting warm air advection. As the low approached during the afternoon, strong southwest winds brought milder air into the region, raising surface temperatures into the low 40s. Aircraft reported temperatures were requested at 1900 UTC, shortly after light rain showers had begun in Buffalo. The aircraft reports from 2, 4 and 6 thousand feet were all several degrees below freezing, which contradicted the current weather (rain showers) and the expected changes to the atmosphere (warming). Therefore, the aircraft data were ignored, and adjustments to the forecast were made in accordance with the standard operating procedure. Perhaps, the erroneous information was due to the hazards of voice transmission as noted in Section 3b.

## 6. CONCLUSION

This limited study shows that temperature reports from commercial aircraft can be used by meteorologists to refine and enhance the precipitation type forecasts associated with winter storms. However, care must be taken to identify and disregard erroneous data.

Forecasters must also realize that flight crews and ATC personnel may sometimes be too busy to supply the desired information. However, the staff at WSFO BUF have found flight crews and the ATC to be willing participants when aircraft-reported data were requested, since all three groups benefitted from the issuance of an improved forecast.

## 7. REMARKS ON THE FUTURE OF AIRCRAFT-REPORTED DATA

The use of aircraft temperature data is certainly not limited to wintertime precipitation events. This information can be used during the convective season (i.e., to see if a capping inversion has strengthened or diminished). The data might also be useful at stations that are distant from a routine upper air site.

Aircraft with inertial navigation systems can also supply very accurate reports of wind speed and direction. The author has experimented with aircraft-reported winds to forecast the movement of Lake Effect snow squalls from lakes Erie and Ontario during the 1992-93 winter season with very favorable results.

Aircraft-reported data will likely become an increasingly important data source in the years to come. These observations are utilized in the initialization of the NMC models (Fig. 5). These data also are used in the Mesoscale Analysis and Prediction System (MAPS Benjamin et al. 1991), which is a mesoscale model that produces short-term 3-hour forecasts. MAPS has been evaluated by WSFO Denver for the past several years (Holmes 1993).

Forecasters eventually will be provided with flight-level aircraft observations from throughout the country, although ascent-descent data will probably not be available for several years.

## ACKNOWLEDGEMENTS

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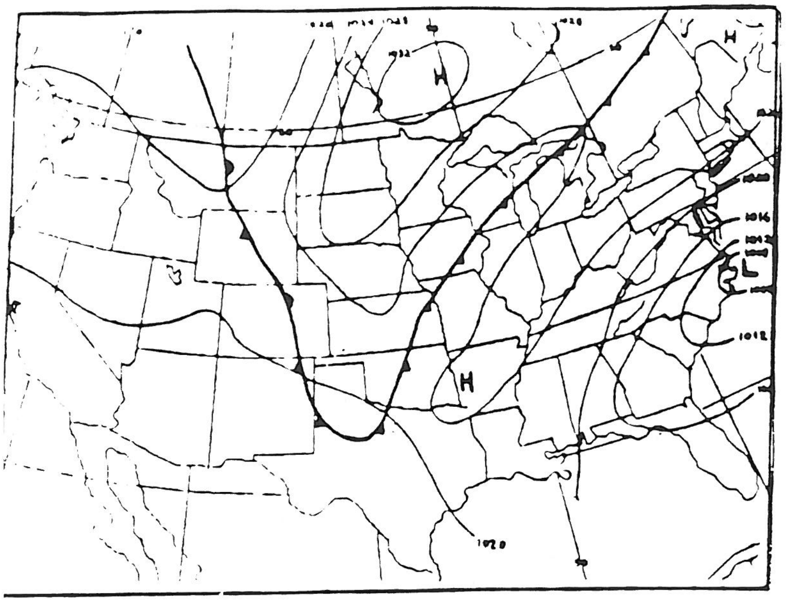

**Fig. 1** Surface analysis for 1200 UTC November 10, 1991.

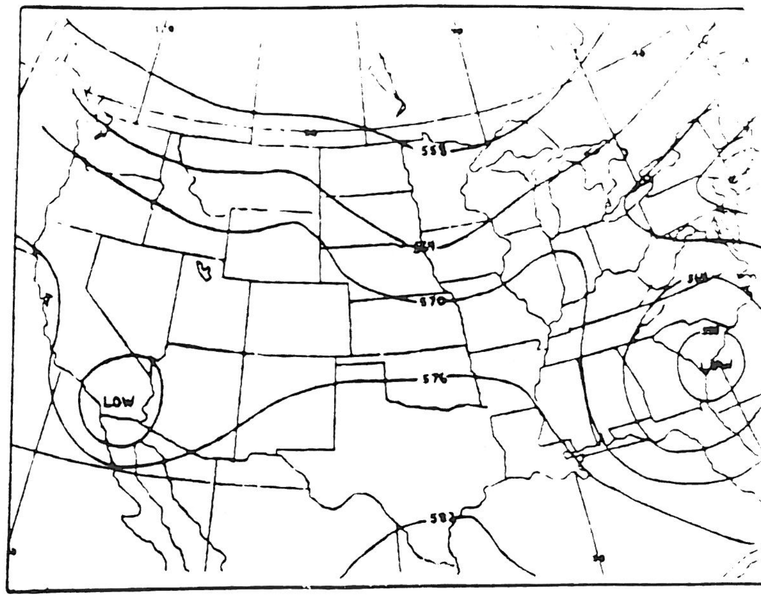

**Fig. 2** 500mb height analysis for 1200 UTC November 10, 1991.

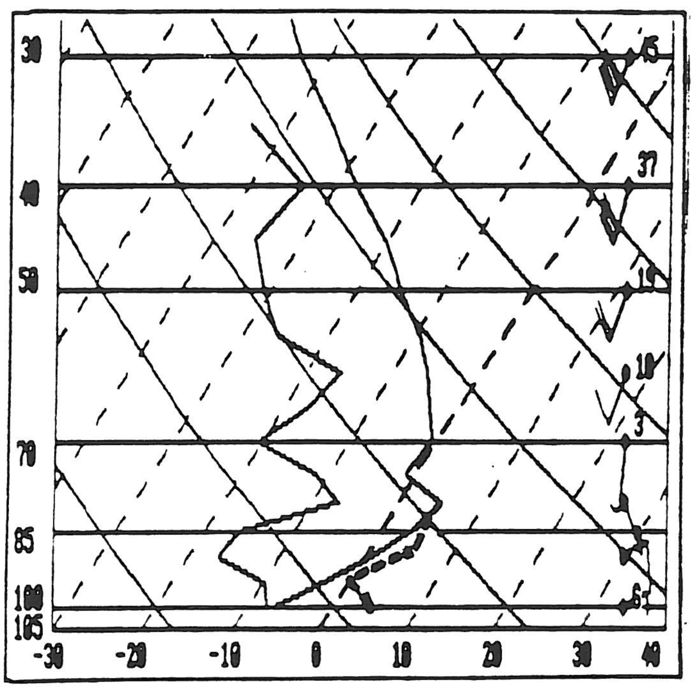

**Fig. 3** Buffalo, NY RAOB for 1200 UTC November 10, 1991.
Solid lines = temp/dewpoint
Dashed line = aircraft temp

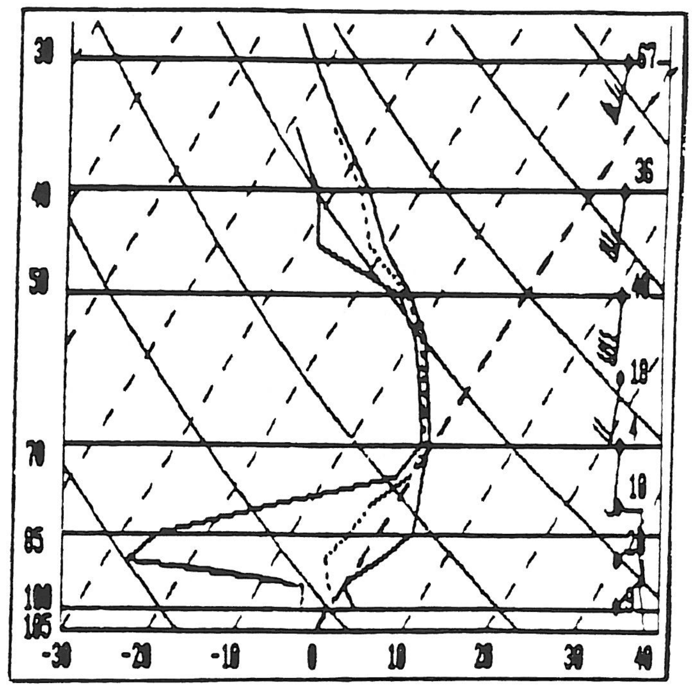

**Fig. 4** Buffalo, NY RAOB 0000 UTC November 11, 1991.
Soild lines = temp/dewpoint
Dashed line = wet bulb temp

LFM FOUS FCST FOR BUF 1200 UTC NOV 10 1991

| | | | * TONIGHT | * | TOMORROW | | * TMRW NGT | | * |
|---|---|---|---|---|---|---|---|---|---|
| | 12 | 18 | 00 | 06 | 12 | 18 | 00 | 06 | 12 |
| LI | 29 | 27 | 26 | 25 | 26 | 27 | 27 | 26 | 26 |
| VV | /// | 006 | 003 | 018 | 015 | 011 | -09 | -09 | -06 |
| RH | 39 | 41 | 55 | 74 | 82 | 87 | 69 | 45 | 34 |
| R3 | 37 | 48 | 75 | 94 | 94 | 93 | 66 | 22 | 05 |
| R2 | 33 | 36 | 46 | 65 | 76 | 85 | 70 | 57 | 51 |
| R1 | 64 | 52 | 48 | 63 | 75 | 75 | 69 | 65 | 61 |
| PTT | /// | 000 | 000 | 010 | 025 | 012 | 005 | 000 | 000 |
| HH | 49 | 51 | 50 | 49 | 47 | 45 | 45 | 46 | 45 |
| DDFF | 1111 | 0710 | 0517 | 0317 | 0318 | 3517 | 3414 | 3114 | 3013 |
| TB | 73 | 77 | 77 | 77 | 75 | 74 | 74 | 74 | 75 |
| PS | 25 | 23 | 30 | 17 | 14 | 16 | 18 | 17 | 19 |

NGM FOUS FCST FOR BUF 1200 UTC NOV 10 1991

| | | | * TONIGHT | * | TOMORROW | | * TMRW NGT | | * |
|---|---|---|---|---|---|---|---|---|---|
| | 12 | 18 | 00 | 06 | 12 | 18 | 00 | 06 | 12 |
| LI | 18 | 16 | 12 | 11 | 10 | 10 | 12 | 12 | 13 |
| VV | -27 | -04 | 013 | 035 | -04 | 002 | -25 | -13 | -04 |
| PS | 27 | 22 | 20 | 18 | 16 | 16 | 16 | 18 | 17 |
| R3 | 22 | 44 | 53 | 76 | 83 | 82 | 68 | 44 | 50 |
| R2 | 24 | 40 | 67 | 83 | 90 | 86 | 68 | 45 | 34 |
| R1 | 59 | 40 | 43 | 61 | 84 | 73 | 66 | 76 | 88 |
| PTT | /// | 000 | 000 | 000 | 014 | 008 | 000 | 000 | 000 |
| DDFF | 0806 | 0709 | 0818 | 0517 | 0417 | 0115 | 0120 | 0115 | 0110 |
| HH | 48 | 52 | 50 | 50 | 47 | 46 | 45 | 44 | 43 |
| T5 | 03 | 04 | 03 | 02 | 00 | 00 | 99 | 99 | 99 |
| T3 | 01 | 04 | 04 | 03 | 02 | 00 | 99 | 99 | 98 |
| T1 | 99 | 04 | 04 | 02 | 00 | 02 | 02 | 00 | 99 |

**Table 1.** 1200 UTC November 10, 1991 LFM and NGM FOUS numerical guidance for Buffalo, NY.

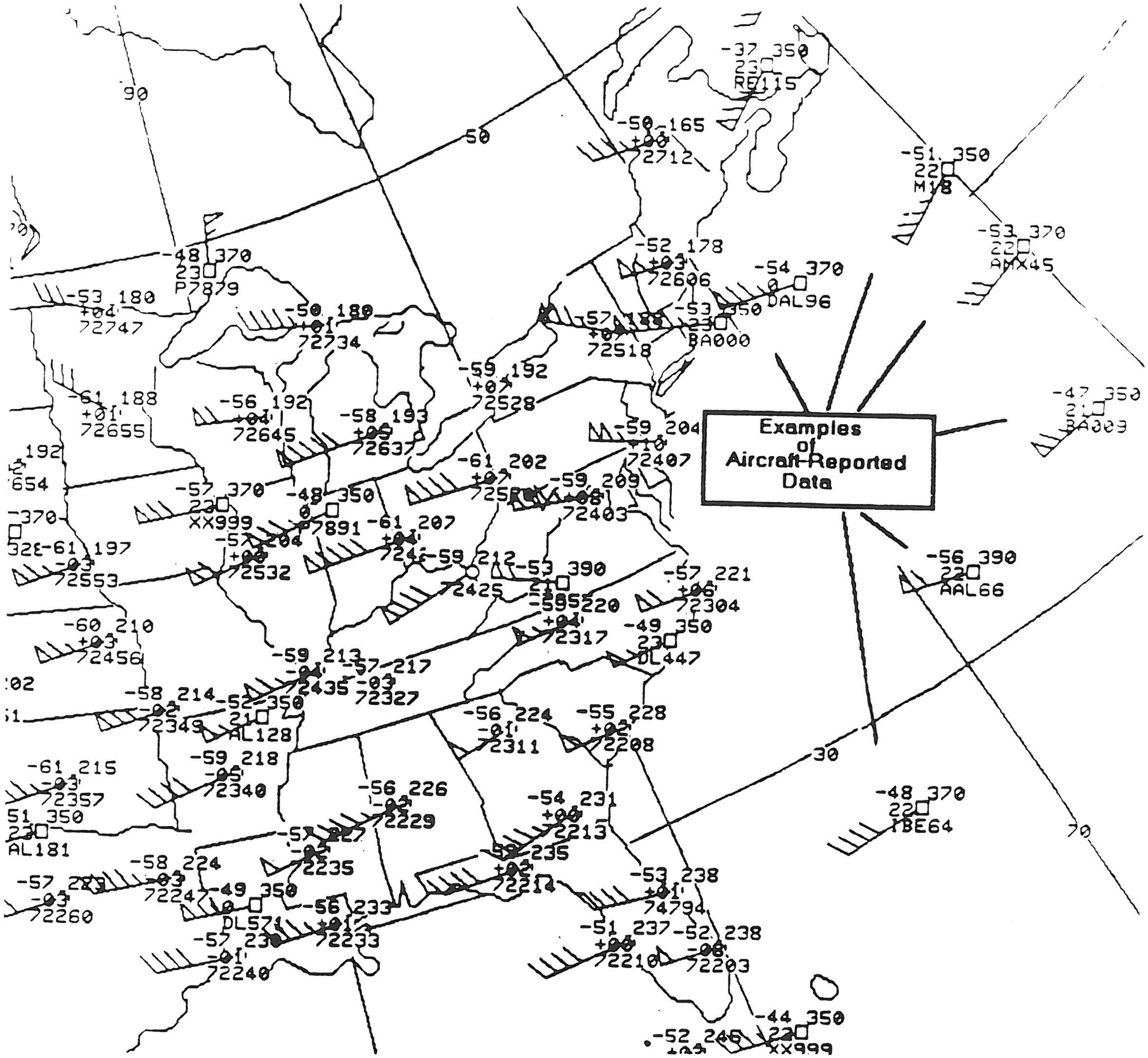


**Fig. 5** Example of aircraft-reported data used in the ETA 200 mb initial analysis for 0000 UTC June 4, 1993.

<u>Legend:</u>

TA - Air temperature (˚C)
HH - Hour of report (UTC)
ALT - Pressure altitude (ft)
PLANE - Airline/aircraft #
(usually not plotted)