EASTERN REGION TECHNICAL ATTACHMENT
NO. 94-12A
DECEMBER, 1994

A COMPARISON BETWEEN AUTOMATED SURFACE OBSERVING SYSTEM OBSERVATIONS AND STANDARD MANUAL OBSERVATIONS DURING AN ARCTIC OUTBREAK OVER THE SOUTHEASTERN UNITED STATES

Michael B. Sporer
National Weather Service Office
Binghamton, New York

Editor's Note: Most of this work was done while Mr. Sporer was stationed as NWSFO Columbia, SC.

1. INTRODUCTION

One of the goals of the National Weather Service (NWS) Modernization and Associated Restructuring (MAR) program, is to replace antiquated computing technology currently in use with state-of-the-art equipment. This equipment is needed to streamline NWS operations and to improve weather forecast and warning accuracy. An important part of the modernization is the Automated Surface Observing System (ASOS; Aircraft Armaments Inc. 1992). ASOS units are being installed across the country to increase the temporal and spatial resolution of surface aviation observations that are currently taken manually by human observers. Much of the information reported in manual observations is obtained directly from sensible weather instruments. However, some of the most important information is obtained using the observers subjective judgement and experience. Thus, an important question with regard to ASOS, is how well will it report rapidly changing weather conditions without human augmentation?

The weather events of January 17, 1994 in Columbia, SC, presented an ideal situation to compare the manual and ASOS observing techniques. Manual surface aviation observations taken by the staff of NWSFO Columbia (CAE) were compared with test observations from a newly installed ASOS unit, to see how well each observation method performed during this weather situation. NWSFO CAE and the ASOS unit are both located at the Columbia Metropolitan Airport, separated by approximately 3/8 of a mile. Temperature, dew point, and wind sensors for both ASOS and NWSFO CAE are located on the relatively flat runway complex surrounded by small grassy areas. The ASOS ceilometer is also positioned on the airfield while NWSFO CAE uses a ceilometer adjacent to the office.

2. METEOROLOGICAL CONDITIONS

On January 17, 1994, a cold arctic airmass was moving southward out of Canada across the eastern United States. The 1800 UTC surface analysis showed that the leading edge of the airmass (i.e., an arctic front) extended from West Virginia to northern Georgia, then continued across southern Alabama and into the Gulf of Mexico (Fig. 1). A weak low pressure wave was developing along the arctic front over southern Alabama, with an associated warm front extending through the coastal plain of South Carolina. Cold air damming was evident east of the Appalachian Mountains in areas north and west of the warm front due to a previous arctic airmass that moved over the region 4 days earlier. By 2000 UTC, the warm front had moved westward into the wedge of arctic air (not shown), allowing warm air to spread over the eastern two thirds of South Carolina. The resulting moderate southerly flow raised the temperature at NWSFO CAE from 51°F at 1951 UTC, to 63°F at 2052 UTC (Table 1).

By 2105 UTC, the eastern edge of the cold air (i.e., the warm front) had shifted eastward (not shown). At NWSFO CAE, this shift was accompanied by heavy rainfall (Fig. 2), an abrupt wind shift with associated wind squalls to 43 kt (Fig. 3), a temperature drop of 23°F between 2118 and 2125 UTC (Table 2), and a distinct pressure trough (A in Fig. 4). The combination of these weather occurrences suggest that a pressure rise-type gravity wave, formed by air moving over the southern Appalachians, propagated along the top of the cold air dome and caused the shift of the cold air wedge. The large temperature change, not usually associated with the passage of gravity waves (Schneider 1990), was caused by the eastward shift of the wedge boundary allowing cold air to spread over the region again under the influence of the gravity wave. A case linking gravity waves to similar weather events over the middle Atlantic states was studied by Young (1995). This situation also fits the conceptual model described by Bosart and Sanders (1986) regarding pressure and wind direction (Fig. 5). Note, this paper is not intended to be a rigorous investigation of gravity waves and their implications to cold air damming episodes along the eastern seaboard. The focus here is to examine the actual observed weather changes rather than what caused them.

As the arctic front and the associated low pressure wave passed over NWSFO CAE at 0135 UTC, a sharp Barogram-V (Appendix A) marked the discontinuity between airmasses (B in Fig 4). Surface wind speeds decreased significantly, indicating close proximity to the low pressure wave center of circulation (Fig. 6). The precipitation ended as stable arctic air moved into the area with brisk northwest winds (Figs. 2 and 6). The arctic front continued to advance toward the coast (Fig. 7) with the surface analysis from 0400 UTC January 18 indicating the front across the coastal plain of South Carolina.

3. DISCUSSION

In order to make a meaningful comparison between ASOS and manual observations taken during the preceding events, each element in the observations will be analyzed separately. Though all observations generated by both ASOS and NWSFO CAE were examined, only selected observations are listed in Tables 1 and 2 for brevity. The following discussion will focus on the individual elements which showed the greatest disparity.

3.1 Sky Conditions

Sky condition reports from both the manual and ASOS observations were in general agreement throughout the event except for two notable exceptions. First at 2123, and again at 2134 UTC, manual observations reported a sky condition of two to four tenths partially obscured by heavy rain (Table 1). Comparable ASOS observations from 2125 and 2132 UTC (Table 2), contained no mention of a partial obscuration. This is because the unit is not programmed to report this condition (Aircraft Armaments Inc. 1992). ASOS can infer a total obscuration by assessing atmospheric variables, but apparently the situation in question did not satisfy ASOS criteria for such a report.

Second, the 2356 UTC ASOS observation reported a broken ceiling of 300 ft (Table 2). At 0004 UTC on January 18, ASOS reported the 300 ft cloud layer as scattered and lifted the ceiling to 2800 ft. The ceiling remained above 1000 ft until 0056 UTC when a broken ceiling of 100 ft was reported. During this same time period, manual observations (Table 1) consistently reported a broken ceiling of 300 ft.

One possible explanation for this discrepancy may be that ASOS bases its reports on data from a ceilometer mounted perpendicular to the ground. This will analyze the sky directly above the unit, but cannot account for cloud cover variations elsewhere across the celestial dome. It is possible that when breaks in the 300 ft ceiling moved overhead, ceilometer data as processed by ASOS algorithms (Aircraft Armaments Inc. 1992) indicated only scattered clouds.

In contrast, manual observations examine the entire celestial dome as well as utilizing ceilometer data to determine the sky condition. This method can incorporate both cloud cover directly overhead and clouds at a distance from the station which fall outside of the range of the ceilometer. It is appears the human observer concluded that sufficient cloud cover remained in the vicinity of the station to retain the 300 ft cloud layer as a broken ceiling.

3.2 Weather Phenomena

Comparing weather phenomena reported in manual and ASOS observations is difficult. Both sets of observations report beginning and ending times of precipitation. However, only manual observations record times of precipitation intensity changes, as well as beginning and ending times of obstructions to vision for daily climatological purposes. In order to make a meaningful comparison between the two types of observations, a weather matrix was created comparing manual observations and ASOS observations (Table 3). Weather phenomena are assumed to begin at the time of the first observation in which they appear, and continue until the time of the last observation in which they are reported.

3.2.1 Precipitation

Inspection of the weather matrix shows that both ASOS and manual observations were very similar in their precipitation intensity estimates. The minor variations that are present are due to the original assumptions used to construct the matrix. Since the precipitation intensity change was estimated using only observations transmitted by ASOS, any intensity fluctuations occurring at non-observation times were lost.

Evidence of the good agreement between manual and ASOS intensity estimates is illustrated by examining the weighing rain gauge trace shown in Figure 2, and the intensity criteria from Federal Meteorological Handbook No. 1 (FMH-1; National Weather Service 1988) listed in Appendix A. The rainfall rates indicated by the trace around 2125 UTC, correspond to heavy rain which both observations reported. The trace then indicated the rainfall intensity to be light from roughly 2145 to 2215, but increased to an intensity of moderate to heavy from around 2215 to 0000 UTC on January 18. During these periods, the corresponding ASOS and manual observations both reported the rainfall intensities accurately.

Toward the end of the event when precipitation was diminishing, the slope of the precipitation trace gradually went to zero and both the ASOS and manual observations reported light rain. With reported and actual intensities in such good agreement, the ASOS tipping bucket, the observers tipping bucket, and the weighing rain gauge all recorded 0.62 inches of rainfall for the event.

3.2.2 Obstructions to Vision

Fog was generally reported by ASOS almost 1 1/2 hours before it was reported manually, and it was dissipated by ASOS long before it was brought to a gradual end by manual observations. When attempting to compare reported obstructions to vision, it must be remembered that automated observing units are not directly equipped with obstruction sensors. They infer the presence of obstructions through analysis of other data such as visibility and temperature/dew point spread (Aircraft Armaments Inc. 1992). This is one possible explanation for the difference in fog reports between the two sets of observations.

Another possible explanation involves the methodology used for manual observations when the visibility is below 4 miles. At these times, the airport tower at the Columbia Metropolitan Airport (approximately 100 ft AGL) is consulted when determining the visibility. It is possible that fog had formed in a layer near the ground that was deep enough to be detected by ASOS but was too shallow to reduce the tower visibility. On the other hand, if the fog developed above the ground, ASOS would not report any obstructions while the tower would now report fog.

One final explanation may be in the way ASOS measures the visibility compared to manual observations. ASOS uses a transmissometer to determine the visibility through a small segment of air over the instrument pad (Aircraft Armaments Inc. 1992). Manual observations utilize the concept of prevailing visibility, reporting the greatest visibility over half or more of the horizon circle. This may cause ASOS and manual observations to report different visibility values due to small scale phenomena affecting only a portion of the airfield. While this scenario is possible, it cannot be confirmed because there were no sector visibility remarks reported in the manual observations.

3.3 Wind

Figure 3 shows the wind trace associated with the passage of the gravity wave over NWSFO CAE between 2117 and 2126 UTC. This provided a good opportunity to compare the wind character reported in both the manual and ASOS observations. Average 1-minute wind speeds began to increase after the warm front passed and were sustained at around 14 kt just prior to the gravity wave passage. As the gravity wave passed, average 1 minute wind speeds suddenly increased to 33 kt and remained at this level for approximately 8 minutes. These conditions met wind squall criteria as established by FMH-1, and were reported as such in the 2118 and 2125 UTC ASOS observations (Table 2). The manual observation from 2123 UTC mistakenly reported the wind character of a gust, which was not representative of actual conditions accompanying the gravity wave (Table 1). Both observations correctly reported the wind shift as the gravity wave passed with only slight differences in timing.

3.4 Remarks

The remarks section of the observations offers a final comparison between the manual and ASOS observations. At 2052 UTC, manual observations reported rain of unknown intensity along the southwest to west horizon. No mention of this impending precipitation can be found in the ASOS observations since the phenomena occurred beyond the range of its instrumentation. Both observations did well in reporting the changing pressure tendencies associated with the two pressure troughs recorded by the NWSFO CAE barograph (Fig. 4). The ASOS unit, with a pressure data sampling rate of 10 seconds (Aircraft Armaments Inc. 1992), was able to report the pressure jumps which occurred with the passage of the gravity wave and arctic front. However, ASOS software does not contain procedures for reporting a Barogram-V so only manual observations reported the lowest pressure attained at the bottom of the second trough.

The numerical data reported in both the manual and ASOS observations, such as temperature and altimeter setting, will not be compared. It is assumed any variances in these parameters are caused by spatial differences or differences in instrumentation as opposed to contrasting observing methods. However, some brief comments are warranted to address the anomalous dew point temperatures reported by ASOS between 1956 UTC on January 17, and 0556 UTC on January 18. During this time, ASOS reported a nearly steady dew point of 31°F which is markedly different from the comparable manual observations. It is possible that a coating of ice had formed on the dew point sensor and caused the readings to be held around the freezing mark until the ice was melted off. This problem is not unique to automated observing systems, since it is occasionally noted with a similar hygro-thermometer used for manual observations. While this small problem did not affect other aspects of the ASOS unit operation, it is conceivable that it could impact reports of fog and haze in different weather scenarios.

4. CONCLUSION

From an analysis of the available data from January 17, 1994, it can be seen that all of the weather events from the initial warm frontal passage to the passage of the arctic front and associated low pressure wave, occurred approximately between 1950 and 0235 UTC. During this period, 14 surface aviation observations were taken manually at NWSFO CAE, which gives a manual observation frequency of approximately 2.1 observations per hour. By comparison, the ASOS unit generated 19 observations, which yields an automatic observation frequency of approximately 2.8 observations per hour, an increase of 33% over manual observations. It should be noted that the two corrected manual observations at 2251 and 0154 UTC were not included during the calculation of the manual observation density, since they served only to correct previous observations which contained erroneous data.

The purpose of this study was to compare ASOS and standard manual observations to see how well each method performed during a complex weather situation. The data presented in this paper show that ASOS is a capable weather observing system within the range of its instrumentation. However, there are instances where an analysis of the entire celestial dome is necessary to get an accurate representation of critical weather conditions. This is especially true when the weather phenomena are not directly overhead. Therefore, it will ultimately be up to the user of the system to access and integrate other sources of information such as Doppler weather radar, lightning detection systems, satellite data, and pilot reports to more fully discern what types of weather conditions are actually occurring.

REFERENCES

Aircraft Armaments Inc., 1992: *Automated Surface Observing System Ready Reference Guide*. Report No. RSMI005-00038, Rev. F, 100 pp.

Bosart, L. F. and F. Sanders, 1986: Mesoscale structure in the megalopolitan snowstorm of 11-12 February 1983. Part III: A large-amplitude gravity wave. *J. Atmos. Sci.*, **43**, 924-939.

National Weather Service 1988: Federal Meteorological Handbook No. 1 Surface observations, FCM-H1-1988, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 276 pp.

Schneider, R. S., 1990: Large-amplitude mesoscale wave disturbances within the intense midwest extratropical cyclone of 15 December 1987. *Wea. Fcstg.*, **5**, 533-558.

Young, D. C., 1995: WSR-88D Images of a Small-Scale Ducted Gravity Wave Event on 24 February 1994. *Preprints, 14th Conference on Weather Analysis and Forecasting*, Amer. Meteor. Soc., Dallas, 6 pp.

Table 1. Select January 17-18, 1994 NWSFO CAE manual surface aviation observations. All times UTC.

SA 1951 30 SCT M95 OVC 15 121/51/37/1006/988/PRESFR

SA 2052 35 SCT E95 BKN 150 OVC 15 105/63/50/1715G21/984/ RU SW-W

SP 2123 -X M23 BKN 75 OVC 1/2R+ 3224G43/994/R4 WSHFT 15 PRESRR

SP 2134 -X 10 SCT M28 BKN 70 OVC 1R+ 3224G32/995/R2 PRESRR

RS 2251 10 SCT E30 BKN 45 OVC 5R 142/36/34/0503G20/994/ BKN V SCT

SP 2325 3 SCT E30 BKN 50 OVC 4RF 1804/994

SA 2350 M3 BKN 25 OVC 2RF 139/36/35/1804/993/ 03254 172/ 63

SA 0052 E3 BKN 25 BKN 60 OVC 2R-F 120/37/36/1307/988/ PRESFR

SA COR 0154 M2 BKN 25 OVC 2F 114/40/39/3308/986/PRESRR LOWEST PRES 090 2035 RE38

Table 2. Select January 17, 1994 NWSFO CAE ASOS surface aviation observations. All times UTC.

```
TP 2118 AO2 32 SCT M70 BKN 100 OVC 7R- 126/61/31/3130Q37/
990/ TEST OVC V BKN RB15 PCPN 0000 WSHFT 2103 WND 27V35 PK
WND 3237/2118 PRESRR

TP 2125 AO2 29 SCT M41 BKN 95 OVC 11/2R+ 135/38/31/
3329Q39/993/ TEST RB15 PCPN 005 WSHFT 2103 PK WND
3239/2119 PRESRR $

TP 2132 AO2 28 SCT M34 BKN 70 OVC 1R+F 142/35/31/3223G39/
995/ TEST RB15 PCPN 0010 WSHFT 2103 PK WND 3239/2119
PRESRR $

TA 2156 AO2 M28 BKN 34 OVC 5R-F 144/35/31/3310/995/ TEST
RB15 PCPN 0015 WSHFT 2103 PK WND 3239/2119 PRJMP 9/2110/
2123 $

TP 2226 AO2 M30 OVC 4R+F 144/35/31/3304/995/ TEST
PCPN 0006 $

TA 2256 AO2 M41 OVC 5R+F 137/35/31/0000/993/ TEST
PCPN 0016 $

TP 2326 AO2 3 SCT 20 SCT M55 OVC 4RF 135/35/32/0000/993/
TEST PCPN 0008 $

TS 2356 AO2 M3 BKN 19 BKN 70 OVC 4RF 134/35/31/1903/992/
TEST 50034 6045/ 10062 20025 BKN V SCT PCPN 0014 $

TP 0004 AO2 3 SCT M28 BKN 75 OVC 5RF 133/35/32/1903/992/
TEST PCPN 0001 $

TP 0012 AO2 3 SCT M39 BKN 70 OVC 5R- 131/36/31/0000/992/
TEST PCPN 0002 $

TS 0056 AO2 M1 BKN 60 BKN 85 OVC 5R-F 112/36/32/1408/986/
TEST BKN V SCT PCPN 0004 PRESFR $

TA 0156 AO2 M3 OVC 10+ 110/39/31/3208/985/ TEST RE37
PCPN 0003 PRJMP 5/0136/0144 $
```

Table 3. January 17, 1994 NWSFO CAE and ASOS weather matrices. All times UTC.

NWSFO CAE

Type	Began	End
R-	2103	2120
R	2120	2121
R+	2121	2135
R	2135	2156
R-	2156	2208
R	2208	0003
F	2300	CONT
R-	0003	0138

ASOS

Type	Began	End
R-	2115	2125
R+	2125	2143
F	2132	0056
R	2143	2156
R-	2156	2226
R+	2226	2326
R	2326	0012
R-	0012	0137

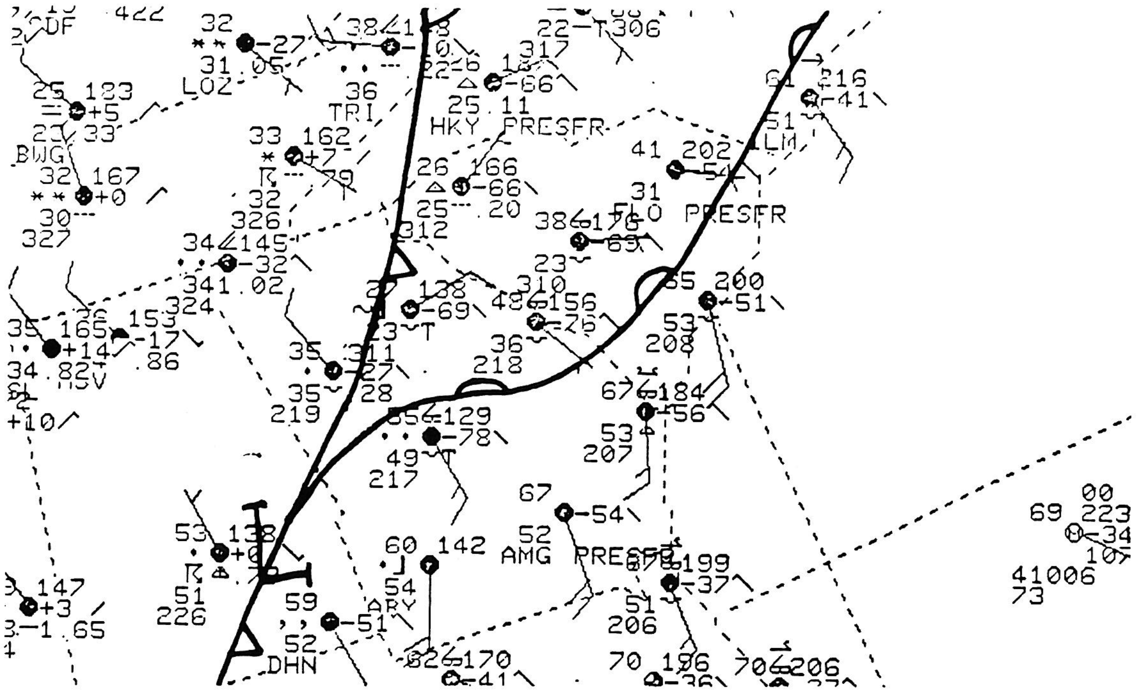

Figure 1. 1800 UTC January 17, 1994 surface analysis.

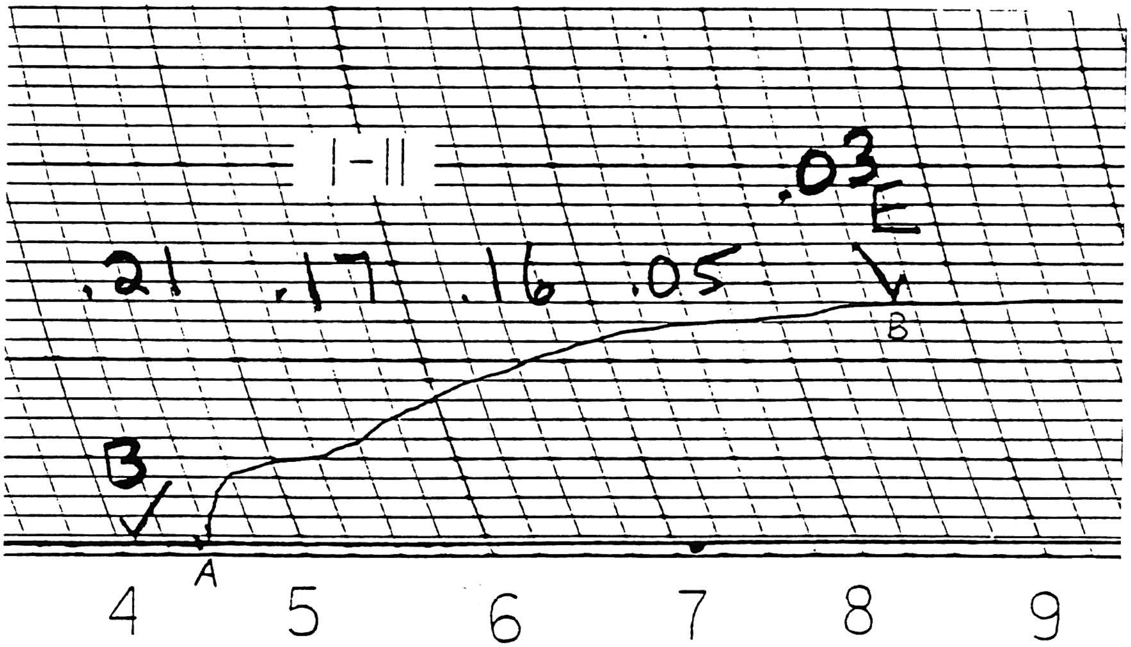

Figure 2. January 17, 1994 NWSFO CAE precipitation trace. "A" shows heavy rainfall during passage of the gravity wave. "B" shows rain ending behind the arctic front. Times are EST.

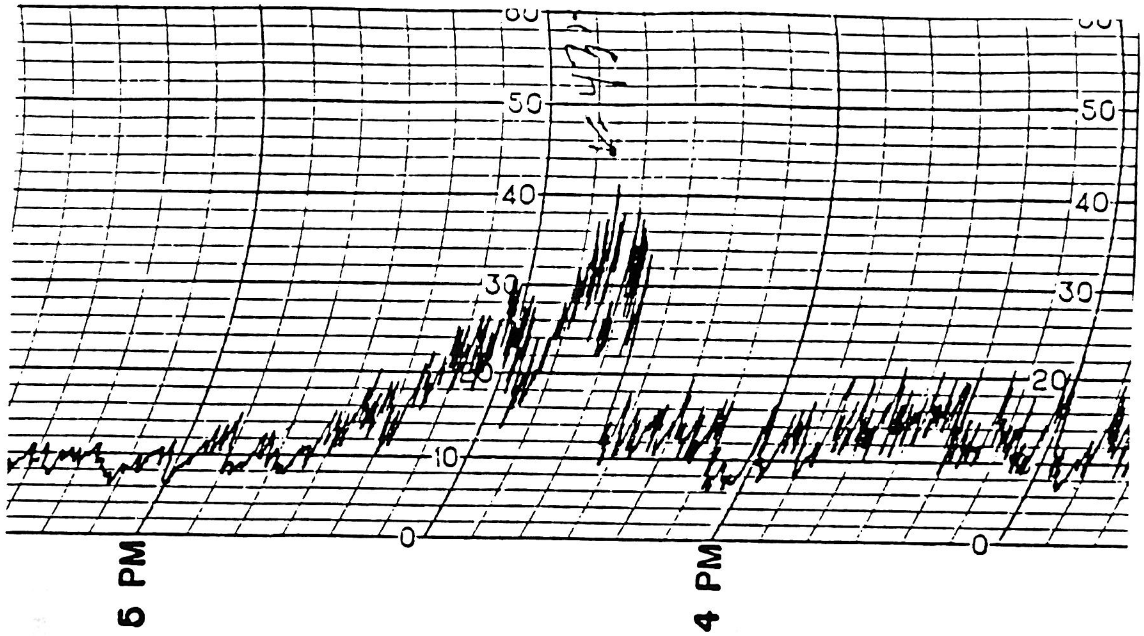

Figure 3. January 17, 1994 NWSFO CAE gust recorder chart showing wind squalls during passage of the gravity wave. Times are in EST.

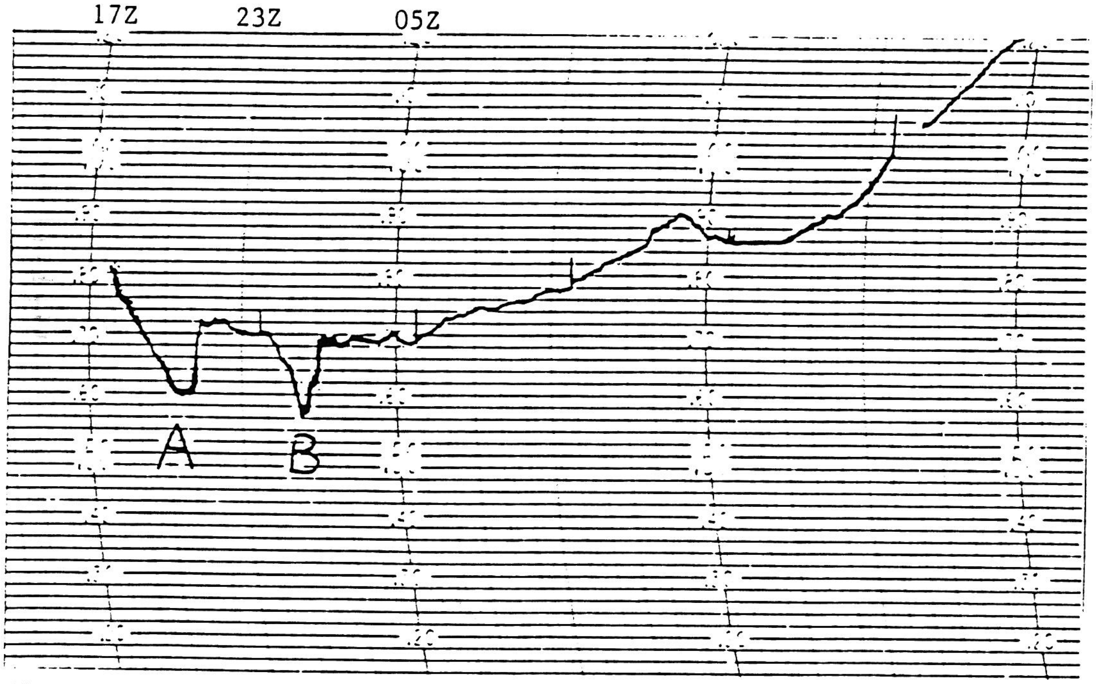

Figure 4. January 17-18, 1994 NWSFO CAE barogram. "A" shows the passage of the warm front and gravity wave. "B" shows the passage of the arctic front and low pressure wave.

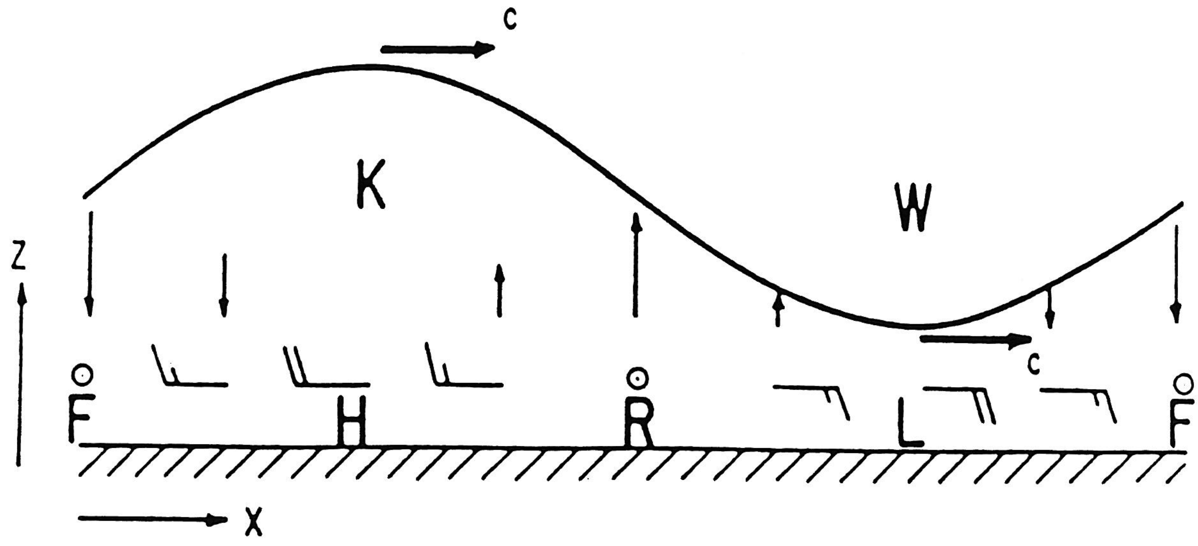

Figure 5. Idealized vertical cross section of a linear plane gravity wave, with no basic current, propagating toward the right at speed c. The heavy sinusoidal line is a representative isentropic surface or a temperature inversion. Surface pressure extrema are labeled H and L, while cold and warm temperature anomalies are denoted K and W, respectively (From Bosart and Sanders. 1986).

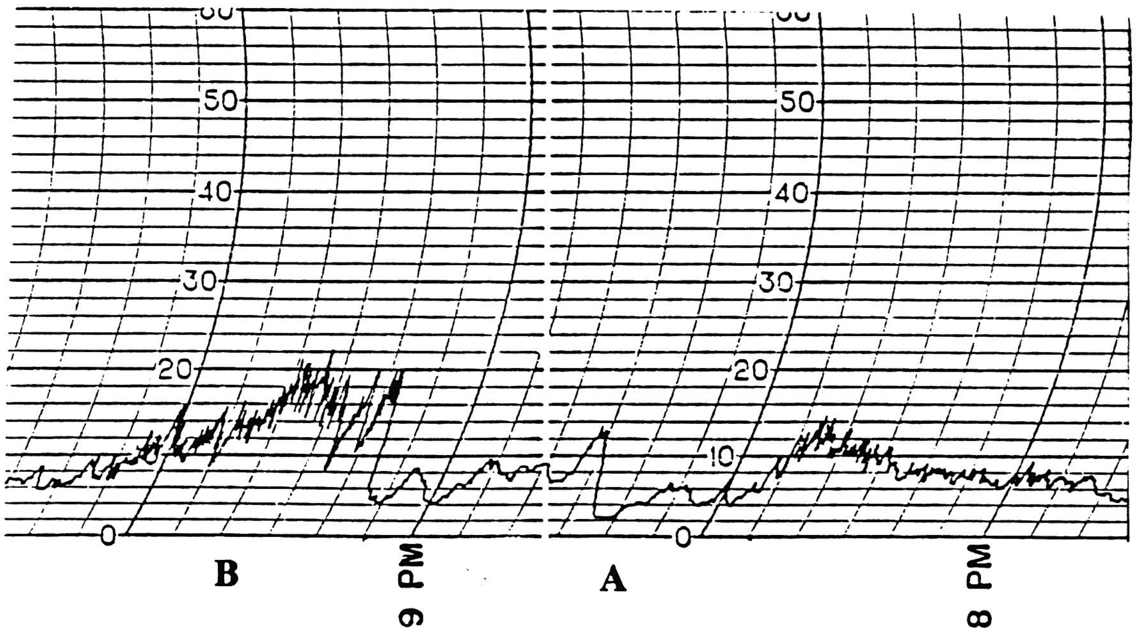

Figure 6. January 17, 1994 NWSFO CAE gust recorder chart. "A" shows the passage of the low pressure wave. "B" shows the northwest flow behind the arctic front. Times are in EST.

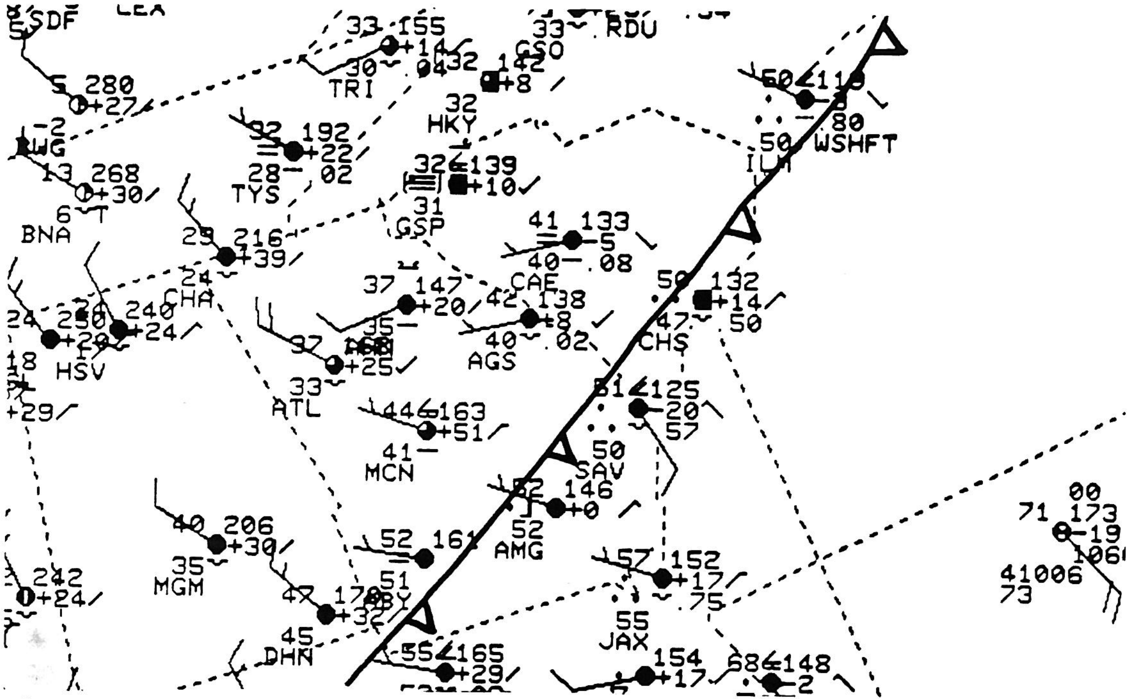

Figure 7. 0400 UTC January 18, 1994 surface analysis.

APPENDIX A

Select FMH-1 criteria and definitions. From the National Weather Service (1988).

Intensity estimates of rain or ice pellets by rate-of-fall:

light - scattered drops or pellets that do not completely wet or cover an exposed surface, regardless of duration to 0.10 inch per hour; maximum 0.01 inch in 6 minutes.

moderate - 0.11 inch to 0.30 inch per hour; more than 0.01 inch to 0.03 inch in 6 minutes.

heavy - more than 0.30 inch per hour; more than 0.03 inch in 6 minutes.

pressure falling/rising rapidly (PRESFR/PRESRR) - a fall or rise in station pressure at the rate of 0.06 inch or more per hour which totals 0.02 inch or more.

pressure jump (PRJMP) - generally, a rise in pressure exceeding 0.005 inch per minute which totals 0.02 inch or more, and the increase of at least 0.02 inches is maintained for 20 minutes.

Barogram-V - a fall in pressure at the rate of 0.06 inch or more per hour, followed by an abrupt rise in pressure at the rate of 0.06 inch or more per hour, and both the rise and fall each equalling 0.03 inch or more.

gust - rapid fluctuations in wind speed with a variation of 10 knots or more between peaks and lulls.

squall - a sudden increase of at least 15 knots or more in average wind speed and sustained at 20 knots or more for at least 1 minute.

wind shift - a term applied to a change in wind direction of 45° or more which takes place in less than 15 minutes and has sustained winds of 10 knots or more.