EASTERN REGION TECHNICAL ATTACHMENT
NO. 95-9B
SEPTEMBER, 1995

A SHORT-TERM EVALUATION OF THE AUTOMATED SURFACE OBSERVING SYSTEM AT CLEVELAND, OHIO

Victor S. Passetti
National Weather Service Forecast Office
Cleveland, Ohio

Editor's Note: The author's current affiliation is NWSO Flagstaff, Arizona

1. INTRODUCTION

The National Weather Service Forecast Office (NWSFO) in Cleveland (CLE), Ohio has been performing a study of the NWSFO CLE Automated Surface Observing System (ASOS). This study was performed in conjunction with precommissioning activities for the NWSFO CLE ASOS. After the performance of the NWSFO CLE ASOS is judged consistent with the standards set by the ASOS Transition and Implementation Branch (ATIB) of the National Weather Service (NWS), as found in the ASOS Site Component Commissioning Plan (National Weather Service 1993), it will be commissioned and become the primary reporter of surface weather observations at NWSFO CLE.

Using human observations as a guide, a plan that employs the standards for which ASOS was designed was developed to study the quality of ASOS data collected at NWSFO CLE. The findings of this study are the result of data collected from both the human observer and ASOS from 23 April to 7 August 1994. Specifically, ASOS was evaluated in three ways. First, the ASOS weather observations at NWSFO CLE were examined to determine if the system was performing within guidelines specified by the ATIB. Second, ASOS and manual special observations were compared to determine how ASOS reported critical changes in ceilings and visibility as compared to the human observer. Third, to ensure that consistency of reported climatological information continues after the unit is commissioned, ASOS values of 24-h precipitation, and maximum and minimum temperature were compared to corresponding variables observed manually at NWSFO CLE.

2. METHODOLOGY

For the procedures that are involved in producing ASOS observations, refer to the ASOS User's Guide (National Weather Service 1992a) and Algorithms for the Automated Surface Observing System (Chu 1994). Federal Meteorological Handbook No. 7 (National Weather Service 1994) provides additional information regarding manual observing procedures.

2.1 Objective Analysis of ASOS Observations

Direct comparisons of ASOS and manual record Surface Aviation Observations (SAOs) were used to determine the representativeness of ASOS weather observations at NWSFO CLE. The standards for these comparisons were obtained from the NWS ATIB (National Weather Service 1993) and are presented as Tables 1a thru 1i. The ATIB recommends that any direct comparison between ASOS and manual SAOs be performed in real-time. This is recommended so that explanations for noted differences in the two observations can be thoroughly explored through the examination of the current weather. This method is preferred to collecting a "paper-trail" of observations, and then trying to explain discovered differences without the benefit of observing the current weather at both the ASOS and the manual observation point.

ASOS and manual special SAOs were not included in this objective analysis because the random nature of special SAOs would have made evaluating ASOS using special SAOs difficult. In addition, it was assumed that if ASOS was reliably reporting the elements of a record SAO, it would do the same for a special SAO. Based on this assumption, ASOS special observations are evaluated separately in this paper.

Two factors at NWSFO CLE facilitated the real-time comparisons of ASOS and manual record SAOs. First, the ASOS Primary Sensor Group is visible from the manual observation site. At the Cleveland Hopkins International Airport, the ASOS Primary Sensor Group is located on the airport field approximately 3/4 of a mile east of the manual observation site. The environment for both sites consists of runways, taxiways, and short grass. However, there is a gradual increase in elevation (about 20 ft) from the manual observing site to the ASOS Primary Sensor Group (National Weather Service 1992b).

Second, ASOS and the manual observer both report record SAOs near the top of the hour (the observer by H+54 and ASOS at H+58). With the close proximity of the two observation sites and the similar observing periods of ASOS and the observer, it appeared that under most circumstances, ASOS would report the same weather conditions in its record SAO as the manual observer.

However, under certain weather conditions to be noted later, the separation of the ASOS Primary Sensor Group and the manual observation site and/or the temporal difference between when the observer examined the weather and the last data was collected by ASOS, made use of direct comparisons of the two record SAOs unreliable. To account for these potential problems, and to streamline the real-time evaluation, a computer program that compared ASOS and manual record SAOs, hereafter referred to as QC-ASOS, was employed for this study (Beasely 1994).

At the time of this study, the QC-ASOS program was under development at the Techniques Development Laboratory, but still was applicable for the purpose of this study. On 22 April 1994, the QC-ASOS program was installed on the NWSFO CLE Automation of Field Operations and Services (AFOS) computer system. Throughout the evaluation period, the program compared the elements of ASOS and manual record SAOs, immediately after both observations were transmitted, and printed any discovered differences at 2 minutes past each hour.

An example of the information produced by the QC-ASOS program is given in Figure 1. In column one, under the header "WORD" is a list of numbers that correspond to data found in the ASOS record SAO and differed from the manual record SAO. For example, the first number in column one is "9," which corresponds to the amount of the highest cloud. The definitions of all numbers assigned by the QC-ASOS program is presented in Table 2.

Under the header "ELEMENT," column two, are codes used to further explain the information found in column one. The code "Nh" corresponds to the reportable categories for the highest cloud amounts which are either "U" for unlimited or clear, "S" for scattered, "B" for broken, or "O" for overcast. Information for decoding the data found in column two is also presented in Table 2.

Columns three and four of Figure 1 present what the manual observer and ASOS reported in their record observations, respectively. Column five, labeled "DIFFERENCE," reveals the difference between what the observer and ASOS reported. For example, in Figure 1, the observer reported the highest cloud layer to be scattered (S), while ASOS reported the highest cloud layer to be broken (B) producing a difference of -1 category.

With the comparison of ASOS and manual record SAOs computed by the QC-ASOS program, the observer could quickly determine if the differences noted by the program agreed with ATIB standards (National Weather Service 1993). If the ASOS observation did not agree with ATIB standards, the observer would seek and document explanations. If the ASOS record SAO differed from the manual record SAO because of spatial differences between the two observation sites, or temporal differences in observing periods, the ASOS observations would not be judged unfairly.

2.2 Evaluating ASOS Special Observations

For each weather event during the evaluation period that required special observations, ASOS and manual specials were compared after the event, to determine the differences in the frequency of reported specials for critical ceiling and visibility changes.

As suggested in the ASOS Site Component Commissioning Plan (National Weather Service 1993), ASOS should only be evaluated against the standards for which it was designed. At times, these standards differ from those required of the manual observer. With this principle in mind, manual special observations that report tornadoes, funnel clouds, waterspouts, thunder, or hail were not considered in the study. In addition, the NWSFO CLE ASOS was not equipped with wind instruments during the evaluation period, due to the reconfiguration in the design of the ASOS wind bottles. As a result, manual specials observations, which reported wind shifts, were not considered.

2.3 Evaluating ASOS Climatological Reports

Once the NWSFO CLE ASOS is commissioned, it will officially report 24-h precipitation amounts and daily maximum/minimum temperature. To evaluate climatological consistency, ASOS reports of these values were compared to those currently collected by the manual observer.

ASOS reports of 24-h precipitation and maximum/minimum temperature were collected from daily summaries produced by ASOS at midnight LST. These values were directly compared to those gathered by the observer. The close proximity of the ASOS Primary Sensor Group to the manual observing point allowed for a fairly reliable comparison of maximum and minimum temperatures, while the 24-h precipitation amounts were scrutinized for differences that might have been the result of convective precipitation events.

3. ASOS EVALUATION

3.1 The Representativeness of ASOS Weather Observations

ASOS and manual record SAOs were compared to determine how well the NWSFO CLE ASOS reported cloud heights, cloud amounts, visibility, present weather, obstructions to visibility, precipitation intensity, temperature, dew point temperature, and altimeter readings. Since the NWSFO CLE ASOS did not yet employ wind sensors, evaluation of wind reports was not possible.

3.1.1 Cloud Height and Amounts

Evaluating the representativeness of ASOS reports of cloud heights and amounts was the most difficult aspect of the study. The QC-ASOS program detected several ASOS record observations, which contained reports of cloud heights and amounts that did not meet the ATIB standards (Tables 1a-b) when compared to the manual record SAOs. However, after the observer examined the information produced by the QC-ASOS program and searched for explanations of the discrepancies, it became apparent that the NWSFO CLE ASOS was reliably reporting cloud height and amount within the standards for which it was designed. This point reinforces the principle of evaluating ASOS observations in real-time. Possible reasons for the discrepancies in the cloud height and amount are explained in the following paragraph.

Cloud heights reported by ASOS were representative throughout the evaluation period. Naturally, for ASOS to be representative in reporting cloud heights when compared to the human observer, it must detect the same clouds as the observer which leads into the evaluation of ASOS reports of cloud amount. After examining weather events when the ASOS reports of cloud amount did not meet ATIB standards (Table 1b) when compared to the human observer, a few trends were noticed. First, during thunderstorms, when cumulonimbus, stratocumulus, and cumulus fractus clouds were passing through the area, reported cloud heights from the human observer and ASOS tended to vary. Second, when fair-weather cumulus clouds were present, ASOS would occasionally report an overcast sky while the observer reported the sky as being scattered. In addition, when a cloud layer was advancing (retreating) toward (from) the NWSFO CLE vicinity, ASOS would often be delayed in reporting the increasing (decreasing) sky cover. These trends can be attributed to the different procedures employed by ASOS and the observer to report cloud amount. Put simply, ASOS deduces cloud amount from information from a small portion of the sky directly above the site. This information is received solely from its ceilometer, which is then processed by the ASOS Sky Condition Algorithm (National Weather Service 1992a). In contrast, the human observer uses a ceilometer, but also visually examines the entire celestial dome to determine the percentages of cloud cover (National Weather Service 1994).

3.1.2 Visibility

With few exceptions, ASOS visibility values were consistently representative throughout the evaluation period. Table 3 illustrates the events where the ASOS visibility, when compared to the observer's, differed from ATIB standards (Table 1c). For the 12 events where the NWSFO CLE ASOS reported a visibility greater than the human observer, the human observer reported a visibility less than or equal to 3 miles.

At NWSFO CLE, when the visibility is reduced to 3 miles or less, the manual observer remains in contact with the air-traffic controllers in the tower. When the air traffic controller reports the tower visibility to be less than the observer's surface visibility, the tower visibility replaces the observer's surface visibility in the observation (National Weather Service 1994). In the future, tower visibility will be added to ASOS observations when needed.

Another potential explanation for the discrepancies in visibility may be the fundamental differences between how ASOS and the observer judge visibility. While the manual observer examines the entire horizon to determine the prevailing visibility, ASOS produces a local visibility from data obtained from its visibility sensor and associated algorithms. FMH-7 (National Weather Service 1994), the ASOS User's Guide (National Weather Service 1992a), and Algorithms for the Automated Surface Observing System (Chu 1994) are available for additional information regarding the visibility observing procedures.

3.1.3 Present Weather

In addition to data obtained from the QC-ASOS program, which compared reported present weather in the ASOS and manual record SAOs, present weather remarks produced by ASOS and the manual observer for the start and end times of precipitation events were examined.

During the 3 1/2 month evaluation period rain occurred on 66 days. The NWSFO CLE ASOS performed fairly well in reporting present weather within ATIB standards (Table 1d). However, 19 events were identified where the manual observer reported light rain or drizzle and ASOS did not report any change in the present weather. The real-time evaluation performed during the study indicated that for these 19 events, precipitation was falling at both the ASOS Primary Sensor Group and the manual observing site. However, the precipitation was light and the average length for the 19 events was 21 min. ASOS reports present weather by detecting scintillation frequencies produced by precipitation falling through its Precipitation Identification Sensor (National Weather Service 1992a). It is likely that for the 19 events mentioned above, the rain intensity was not hard enough for the ASOS Precipitation Identification Sensor to report light rain.

Conversely, 10 events were identified where only ASOS reported a period of light rain. This may be attributed to the 24-h continuous weather watch that ASOS employs. The human observer may have not noticed the light rain, as the average length for these events reported solely by ASOS was only 13 min.

Twenty events were identified where the NWSFO CLE ASOS did not meet ATIB standards for reporting the start or end times of present weather (Table 1d) when compared to the manual observer. Several reasons are presented to explain these events. First, as previously mentioned, the rain intensity may have been too light for the ASOS Precipitation Identification Sensor to report light rain. This may have resulted in ASOS starting light rain later, or ending light rain sooner, than the human observer. Second, convective rains during the evaluation period did not always fall uniformly over both the NWSFO CLE ASOS and the manual observing site. As a result, different start or end times for light rain events can be expected. Third, because of its continuous weather watch capability, the NWSFO CLE ASOS may detect light rain before the observer (National Weather Service 1992a).

3.1.4 Obstructions to Visibility

ASOS reports of fog or haze are derived from ASOS values of visibility, temperature, dew point and present weather (National Weather Service 1992a). ATIB standards for evaluating ASOS reports of fog or haze are presented in Table 1f. These standards outline how ASOS determines whether to report either fog or haze.

Again, the standards for which ASOS was designed to operate must be incorporated into any ASOS evaluation. Whether or not ASOS reported fog or haze in its record SAOs, as compared to the manual observer's record SAOs is not fair criteria for evaluation. Since ASOS reports of fog or haze are derived from ASOS values of visibility, temperature, dew point, and present weather, these values must be representative for ASOS to report the same obstruction to visibility as the observer. ASOS visibility and present weather values were previously evaluated in sections 3.1.2 and 3.1.3, respectively. ASOS temperature and dew point values will be evaluated later in this paper.

3.1.5 Precipitation Intensity

Throughout the evaluation period, the NWSFO CLE ASOS consistently met ATIB standards for reporting precipitation intensity (Table 1e). Only two ASOS record SAOs contained an unrepresentative precipitation intensity. The QC-ASOS program did detect several differences in reported precipitation intensity between ASOS and the observer. However, after performing the real-time evaluation, the observer noted that on all but the two occasions, the discrepancies were the result of spatial differences in location and temporal differences in observing periods of ASOS and the human observer.

3.1.6 Temperature

The ATIB standard for evaluating ASOS temperatures is presented in Table 1g. During the evaluation period, ASOS reported the temperature as missing for six record SAOs due to a detected temperature sensor failure. These ASOS missing temperatures were not included in the comparison of ASOS and manual observer temperatures. Figure 2 illustrates the frequency when ASOS reported a temperature at least 3° F warmer than the observer. For the 87 ASOS temperatures that were at least 3° F warmer than the manual observer temperature, ASOS reported a temperature of 3° F warmer than the manual observer 33% of the time. The frequency that ASOS reported temperatures that were 4°F or warmer than the manual observer temperature dropped to 18%. Figure 3 illustrates the frequency when ASOS reported a temperature at least 3°F cooler than the observer. As with the warmer temperatures, ASOS reported a temperature of 3°F cooler than the manual observer 36% of the time. Sudden temperature rises or falls at sunrise or sunset accounted for six of the 87 temperature discrepancies represented in Figures 1 and 2.

For the remainder of the discrepancies, a couple of explanations are possible. First, the upward air flow through the ASOS hygrothermometer (1088) is opposite that of the hygrothermometer (HO-83) used by the manual observer, and the aspiration of the 1088 is greater than the HO-83 (McKee et al. 1994). These designs were employed in ASOS to avoid a warm bias that was occasionally noticed with temperatures measured by the HO-83. The HO-83 warm bias has been attributed to occasions when the surface winds are light and solar radiation warms the air surrounding the air intake at the top of the unit. Information regarding the occasional warm bias of the HO-83 was unavailable during the evaluation period and, as a result, events where a warm bias occurred were not verified in real-time. However, with the evaluation period taking place during the warm season, it is likely that on occasion, favorable conditions could have been present to cause a warm bias in temperatures obtained from the HO-83.

Another possible explanation for the temperature discrepancies noted in Figures 2 and 3, may be attributed to overlapping standards for accuracy of the observer's HO-83 and the ASOS 1088. At NWSFO CLE, the H0-83 is evaluated weekly for accuracy. The temperature reported by the HO-83 must be within 1.8°F of the temperature which is measured from a thermometer in an instrument shelter (National Weather Service 1992c). It is possible that the overlapping standards employed for the HO-83 (± 1.8°F of shelter temperature) and for the ASOS 1088 (± 2°F from the HO-83) may have caused some of the ASOS 3° and 4°F temperature differences illustrated in Figures 2 and 3. For example, suppose the HO-83 reads a temperature of 78°, the standard mercurial thermometer reads 76°, and the ASOS 1088 reads 74°. These temperatures give the appearance that the ASOS temperature sensor reading is 4° cooler than the HO-83. However in reality, the ASOS temperature is within the required 2° tolerance of the standard mercurial thermometer.

It was also noted that for both the warm and cool temperature departures, there was a 3 to 1 ratio between discrepancies noted at night compared to during the day. It is possible that the nighttime warm temperature departures may be attributed to the difference in elevation between the ASOS Primary Sensor Group and the observer's HO-83. The elevation of the ASOS Primary Sensor Group is 19 ft higher than the observer's H0-83. This change in elevation occurs gradually over the 3/4 mi distance between ASOS and the H0-83, as the terrain slopes gradually downward from the airport field toward the Rocky River. During the evening, this difference in elevation could cause cold air drainage, resulting in the HO-83 reporting cooler temperatures than the ASOS 1088.

3.1.7 Dew Point Temperature

ATIB standards for comparing ASOS and manual dew points are presented in Table 1h. Throughout the evaluation period, the ASOS dew point temperature periodically ranged outside of ATIB standards.

After the dew point discrepancies became excessive, the ASOS dew point sensor, which is a chilled mirror (National Weather Service 1992a), was examined and jet exhaust from passing aircraft was discovered on the mirror. After cleaning the mirror, ASOS dew point temperatures were consistently representative. It was discovered that during periods of stagnant weather, the mirror would have to be cleaned more often to remove the jet exhaust.

Throughout the evaluation period the mirror was cleaned four times. This number of mirror cleanings was much greater than the current policy of performing maintenance on the mirror every 90 days (National Weather Service 1992c). Also, early in the evaluation period, the mirror would occasionally freeze, resulting in unrepresentative data. The NWSFO CLE ASOS self-corrected this problem by performing a 15 minute recalibration heat cycle on the mirror (National Weather Service 1992a).

3.1.8 Altimeter

The NWSFO CLE ASOS consistently reported the appropriate altimeter reading throughout the evaluation period. The standard for evaluating ASOS altimeter values is presented in Table 1i. During the evaluation period, only one ASOS record observation had an altimeter reading that was considered unrepresentative when compared to the manual observer's value.

3.2 Special Observations

Throughout the evaluation period, the NWSFO CLE ASOS produced 660 special observations. These special observations did not include special observations for waterspouts, thunder, or wind shifts. For the same period, the human observer recorded 309 special observations.

When clouds existed at varying heights below 3000 ft, ASOS often produced a special observation for every deduced change in ceiling caused by a low cloud of different height than the previous cloud passing over its ceilometer. On these occasions, the human observer would either deem the ceiling ragged (CIG RGD) or delay a special observation while determining if the ceiling height indicated by the ceilometer actually represented 6/10 of the sky (National Weather Service 1994).

The different procedures employed by ASOS and the observer to report visibility, also contributed to the greater number of ASOS specials. As mentioned previously, ASOS produces a sensor visibility from data received at its visibility sensor, while the human observer scans the entire horizon and reports a prevailing visibility. When precipitation, fog, or haze caused variable visibilities below 3 miles, ASOS frequently produced a special observation due to changes deduced at its visibility sensor. The human observer would often delay a special observation to evaluate if the prevailing visibility had indeed changed. In addition, manual special SAOs often used tower visibilities, which tended to be more consistent than the surface visibility.

3.3 Climatological Data

3.3.1 Max and Min Temperature

ASOS daily maximum and minimum temperatures were compared to the same values collected by the human observer. The mean daily maximum and minimum temperatures reported by both ASOS and the observer during the evaluation period are presented in Table 4. The ASOS mean daily maximum temperature was slightly cooler than that reported by the human observer while the ASOS mean daily minimum temperature was slightly warmer than that reported by the observer.

As previously mentioned, the temperature discrepancies between the manual observer and ASOS may be the result of system design and elevation differences between the observer's HO-83 and the ASOS 1088. The cooler ASOS mean daily maximum temperatures may be the result of the ASOS 1088 design that avoids the warm bias documented with the observer's HO-83 (Mckee et al. 1994). The possibility of cold air drainage due to the lower elevation of the manual observer's HO-83 may be the cause of the slight ASOS warm bias of the mean daily minimum temperatures found during the evaluation period.

Hayes and Kuhl (1995) also noted discrepancies between ASOS and human observer reports of daily maximum and minimum temperatures at the National Weather Service Office in Atlantic City, New Jersey, and ascribed the discrepancies to design and elevation differences between the ASOS and the observer's hygro-thermometers employed at that site.

3.3.2 Reported 24-h Precipitation

As with the daily maximum and minimum temperatures, the ASOS 24-h precipitation measurements were compared to 24-h precipitation measurements reported by the manual observer. The ASOS and the manual observer 24-h precipitation totals from the evaluation period are presented in Table 4. The NWSFO CLE ASOS reported 0.49 in more precipitation during the period of study than the human observer.

Table 5 outlines all events where ASOS and the manual observer reported different 24-h precipitation amounts, and defines each event as being either convective, stratiform, or unknown in nature. The NWSFO CLE ASOS reported an average of 0.02 in more precipitation per event than the manual observer. However when the three greatest precipitation amount discrepancies are removed from the data sample, the average difference between the 24-h precipitation reported by the NWSFO CLE ASOS and the manual observer is reduced to 0.0003 in.

As depicted in Table 5, the majority (85%) of the precipitation events listed were convective. As a result, varying reports of precipitation from two observation points separated by 3/4 of a mile are to be expected. In addition, ASOS employs a tipping bucket style rain gauge, while the manual observations are taken using a weighing rain gauge. The difference in measuring devices may also have contributed to the detected discrepancies.

One event was noted where ASOS reported 0.01 in of precipitation without reporting any rain in the previous 6-h. An examination of the observations from the human observer (not shown) confirmed that no precipitation fell in the previous 6-h period, and the sky condition during the previous 6-h was either clear or scattered. However, the manual observer did report sustained winds of 14 kt during the previous 6-h. These winds may have caused the ASOS tipping bucket gauge to trip, thus recording 0.01 in of precipitation.

4. CONCLUSION

Before becoming the primary recorder of surface weather observations, the NWSFO CLE ASOS observations must be deemed representative of the actual weather. This study examined the representativeness of ASOS weather observations from 23 April to 7 August 1994. The differences in how ASOS and human observers report special SAOs, and the representativeness of ASOS reported 24-h values of precipitation and daily maximum and minimum temperatures were also examined. Manual observations were assumed to represent "ground truth." All comparisons between ASOS and manual weather observations were carried out in real-time, to screen for reported discrepancies that may be caused by spatial differences between ASOS and the observer's location or temporal differences in observing periods. In addition, the ASOS unit was not penalized for reporting the weather within the standards for which it was designed, even though the report may have differed from the manual observations.

Throughout the evaluation period, ASOS reported values of cloud height, cloud amount, visibility, present weather, obstructions to vision, precipitation intensity, temperature, dew point, and altimeter readings were compared to the same values reported by the manual observer. Despite the inherent differences in creating an automated and human observation, the NWSFO CLE ASOS was found to be a reliable reporter of these phenomena according to the standards set forth by the ATIB (National Weather Service 1993).

Differences detected between ASOS and manual observer reports of cloud height and amount were noted during thunderstorms (when several cloud layers were present), with advancing or retreating cloud layers, and with fair weather cumulus clouds. These differences are attributed to ASOS examining the sky through a single ceilometer over time to determine cloud heights and amounts, while the human observer scans the entire celestial dome at one time.

For reported visibility, the NWSFO CLE

ASOS uses information collected from one visibility sensor to produce a visibility report (National Weather Service 1992a), while the human observer scans the entire horizon. During periods of variable visibilities, it was expected to note some discrepancies between the automated and human visibility report. In addition, tower visibilities were not included in ASOS observations, while they were included in the manual observations. After the commissioning of the NWSFO CLE ASOS, tower visibility will be added to the ASOS observations as needed.

The NWSFO CLE ASOS performed well in reporting present weather conditions when compared to the human observer. Several events were identified during the evaluation period where ASOS start or end times of light rain events differed by more than 10 minutes from the human observer. Light rain and the lack of rain droplets falling through the ASOS Precipitation Identification Sensor, the probability of inconsistent reported start or end times of convective events at two separated observation sites, and the 24-h continuous weather monitoring ability of ASOS, are likely to be the cause of these discrepancies.

ASOS temperature values were generally deemed representative during the evaluation period. However, the mean daily maximum temperature was slightly cooler than the temperature reported by the human observer, while the ASOS mean daily minimum temperature was slightly warmer than that reported by the observer. Explanations for events where ASOS and the human observer differed in reported temperature were attributed to differences in temperature sensor design, differences in site elevation, and overlapping standards for accuracy for the ASOS hygrothermometer (1088) and the observer's hygrothermometer (HO-83). In addition, for both warm and cool discrepancies, there was a 3 to 1 ratio between discrepancies occurring at night to those occurring during the day.

Several ASOS dew point temperature reports were found to be unrepresentative during the evaluation period. It was discovered that jet exhaust from passing airplanes was condensing on the ASOS dew point sensor. After removal of the exhaust, ASOS dew point temperature values were consistently representative.

Throughout the evaluation period the NWSFO CLE ASOS reported more than two times as many special observations than the observer. Of course, ASOS reports cloud heights and visibilities by processing information collected over one ceilometer and one visibility sensor over time, while the manual observer examines the entire celestial dome to deduce cloud and visibility values.

The mean daily maximum temperature reported by ASOS was found to be 0.7°F cooler than that reported by the human observer, while the ASOS mean daily minimum temperature was found to be only 0.1°F warmer than that reported by the observer. Again the differences in design and elevation of the 1088 and HO-83, are thought to be the cause of this discrepancy.

The NWSFO CLE ASOS reports of 24-h precipitation were representative throughout the evaluation period. Most of the differences detected were produced during convective rain events. With the ASOS and the manual observation site separated by 3/4 of a mile, differences in reported precipitation amounts can be expected with convective events. In addition, the different types of rain gauges used by the observer (weighing gauge) and ASOS (tipping bucket), may have contributed to some of the discrepancies of reported precipitation.

REFERENCES

Beasley, R., 1994: ASOS Quality Control Computer Programs. National Weather Service, NOAA, U. S. Department of Commerce, (under development).

Chu, R., 1994: Algorithms for the automated surface observing system (ASOS). *ISL Office Note* 94-4, National Weather Service, NOAA, U. S. Department of Commerce, 92 pp.

Hayes J. C. and S. C. Kuhl 1995: An initial comparison of manual and automated surface observing system observations at the Atlantic City, New Jersey international airport. *NOAA Technical Memorandum* NWS ER-89, NOAA, U.S. Department of Commerce, 21 pp.

McKee, T. B., N. J. Doesken, and J. Kleist, 1994: Climate data continuity with ASOS: 1994 annual report. *Preprints 11th International Conference on Interactive Information and Processing Systems (IIPS) Meteorology, Oceanography, and Hydrology,* Dallas, Amer. Meteor. Soc., 5 pp.

National Weather Service, 1992a: ASOS User's Guide. NOAA, U. S. Department of Commerce, 57 pp.

____, 1992b: ASOS Site Survey Report, Cleveland Hopkins International Airport, Cleveland, Ohio. NOAA, U. S. Department of Commerce, 24 pp.

____, 1992c: Automated Surface Observing System Site Technical Manual S100. Section 5. NOAA, U.S. Department of Commerce, S5-39 pp.

____, 1993: Automated Surface Observing System (ASOS) Site Component Commissioning Plan. NOAA, U.S. Department of Commerce, 32 pp.

____, 1994: Federal Meteorological Handbook No. 7: Surface Observations. NOAA, U.S. Department of Commerce, 186 pp.

Table 1a. ATIB standards for evaluating ASOS reports of cloud ceiling heights (National Weather Service 1993).

Condition	Allowable Difference
Up to 5,000 ft	± 500 ft
>5,000 to 10,000 ft	± 1,500 ft
>10,000 to 12,000 ft	± 3,000 ft

Table 1b. Same as Table 1a, except for cloud amounts.

Condition	Allowable Difference
Clear	Scattered
Scattered	Clear to Broken
Broken	Scattered to Overcast
Overcast	Broken

Table 1c. Same as Table 1a, except for visibility. ASOS reported visibilities: <1/4, 1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2, 1 3/4, 2, 2 1/2, 3, 3 1/2, 4, 5, 7, and 10 miles.

Condition	Allowable Difference
Up through 4 miles	± 1 mile
5 miles or greater	± 2 reportable values

Table 1d. Same as Table 1a, except for present weather.

Condition	Allowable Difference
Rain or Snow	Must be reported within 10 minutes of occurrence.

Table 1e. Same as Table 1a, except for precipitation intensity.

Condition	Allowable Difference
Light	Moderate
Moderate	Light, Heavy
Heavy	Moderate

Table 1f. Same as Table 1a, except for obstructions to vision.

Condition	Allowable Difference
Fog	Visibility < 7 miles and dew point depression ≤ 4° F Visibility < 7 miles and precipitation is occurring.
Haze	Visibility < 7 miles, dew point depression > 4° F and no precipitation is occurring.

Table 1g. Same as Table 1a, except for temperature.

Condition	Allowable Difference
-58° F through 122° F	± 2° F

Table 1h. Same as Table 1a, except for dew point.

Condition	Allowable Difference
-30° F through 86° F	± 4° F

Table 1i. Same as Table 1a, except for altimeter readings.

Condition	Allowable Difference
All readings	± .02 Hg with station ASI

Table 2. Definitions of data listed in columns one and two of the QC-ASOS program (Beasely 1994).

WORD	Definition	ELEMENT	Definition
9	Amount of highest cloud.	Nh	Reportable elements for Highest cloud amount U (clear), S (scattered), B (broken), O (overcast).
11	Highest cloud height.	Nm	Same as Nh except for second highest cloud amount.
13	Amount of second highest cloud.	Nl	Same as Nh except for lowest cloud amount.
15	Second highest cloud height.	HNh	Height of highest cloud in hundreds of feet, 999 reported for clear sky.
17	Amount of third highest cloud height.	HNm	Same as HNh except for second highest cloud.
19	Third highest cloud height.	HNl	Same as HNh except for lowest cloud height.
21	Visibility.	VSBY	Visibility.
23-27	Weather and obstructions to vision.	WX1-WX5	Present weather and obstructions to visibility.
28	Sea-level pressure.	SLP	Sea-Level Pressure.
29	Temperature.	TMPF	Temperature.
30	Dew point.	TDF	Dew point.
32	Wind direction.	DD	Wind direction.
33	Wind speed.	FF	Wind Speed.
34	Wind gusts.	GG	Wind Gusts.
35	Altimeter setting.	PRTND	Pressure Tendency.
41	Pressure tendency characteristic.		

Table 3. Detected differences between ASOS and manual visibilities (miles) from April 23 to August 7, 1994.

Date	Time (LST)	Observer	ASOS	Date	Time (LST)	Observer	ASOS
4/30/94	1400	2.5	5	6/19/94	0800	2	4
5/1/94	2100	1.5	3	6/19/94	0900	2.5	4
5/1/94	0100	3	7	6/27/94	1000	1.5	5
5/7/94	1700	2	3.5	6/27/94	1100	2	5
5/7/94	1800	2	4	6/27/94	1500	1.5	3
5/8/94	1900	1.5	3	7/6/94	0400	10	4
5/8/94	2200	2	5	7/7/94	0500	5	2.5
6/7/94	0500	4	2.5	7/7/94	0600	7	3.5
6/13/94	0400	7	3.5	7/14/94	2100	7	3.5
6/13/94	0600	4	2.5	7/29/94	0200	7	3
6/19/94	0600	4	2.5				

Table 4. ASOS and manual comparison of reported climatological data from April 23 to August 7, 1994.

	ASOS	Manual	Difference
Mean Daily Max. Temp. (°F)	75.4	76.1	-0.7
Mean Daily Min. Temp. (°F)	54.7	54.6	+0.1
Total 24-h Precipitation (inches)	9.39	8.90	+0.49

Table 5. Detected discrepancies of reported 24-hr precipitation (inches) from April 23 to August 7, 1994. The rain events were characterized as either convective (C), stratiform (S), or uncertain (U).

Date	Man.	ASOS	Diff.	Type	Date	Man.	ASOS	Diff.	Type
4/26	0.01	0.04	+0.03	C	6/24	1.09	1.10	+0.01	C
4/27	0.11	0.15	+0.04	C	6/25	0.19	0.15	-0.04	S
4/28	0.05	0.06	+0.01	C	6/26	0.11	0.12	+0.01	S
4/29	0.02	0.03	+0.01	C	6/27	0.39	0.42	+0.03	S
5/1	T	0.01	+0.01	S	6/29	0.74	0.68	-0.06	C
5/6	0.02	0.04	+0.02	C	7/5	0.23	0.30	+0.07	C
5/9	T	0.03	+0.03	C	7/7	0.43	0.42	-0.01	C
5/11	0.29	0.33	+0.04	C	7/8	0.05	0.07	+0.02	C
5/24	0.10	0.14	+0.04	C	7/9	0.02	0.05	+0.03	C
5/25	0.03	0.05	+0.02	C	7/14	0.54	0.50	-0.04	C
5/26	0.19	0.10	-0.09	C	7/21	0.82	1.01	+0.19	C
5/31	0.38	0.40	+0.02	C	7/22	0.01	0.02	+0.01	C
6/1	0.0	0.01	+0.01	U	7/24	0.07	0.19	+0.12	C
6/11	0.03	0.05	+0.02	C	7/25	0.04	0.01	-0.03	C
6/13	0.13	0.17	+0.04	C	7/28	0.14	0.07	-0.07	C
6/20	0.42	0.48	+0.06	C	7/30	0.07	0.11	+0.04	C
6/23	0.24	0.19	-0.05	C	8/4	0.90	0.87	-0.03	C

MANUAL-ASOS COMPARISON PROGRAM
DATA COMPARISON FOR: 6/15/94 0700Z
COMPARISON FOR STATION: CLE
DIFFERENCES:

WORD	ELEMENT	MANUAL VALUE	ASOS VALUE	DIFFERENCE
9	Nh	S	B	-1
11	HNh	250	999	
21	VSBY	10	7	-3
29	TMPF	74	77	3

Figure 1. Example of output from QC-ASOS program (from Beasely 1994).

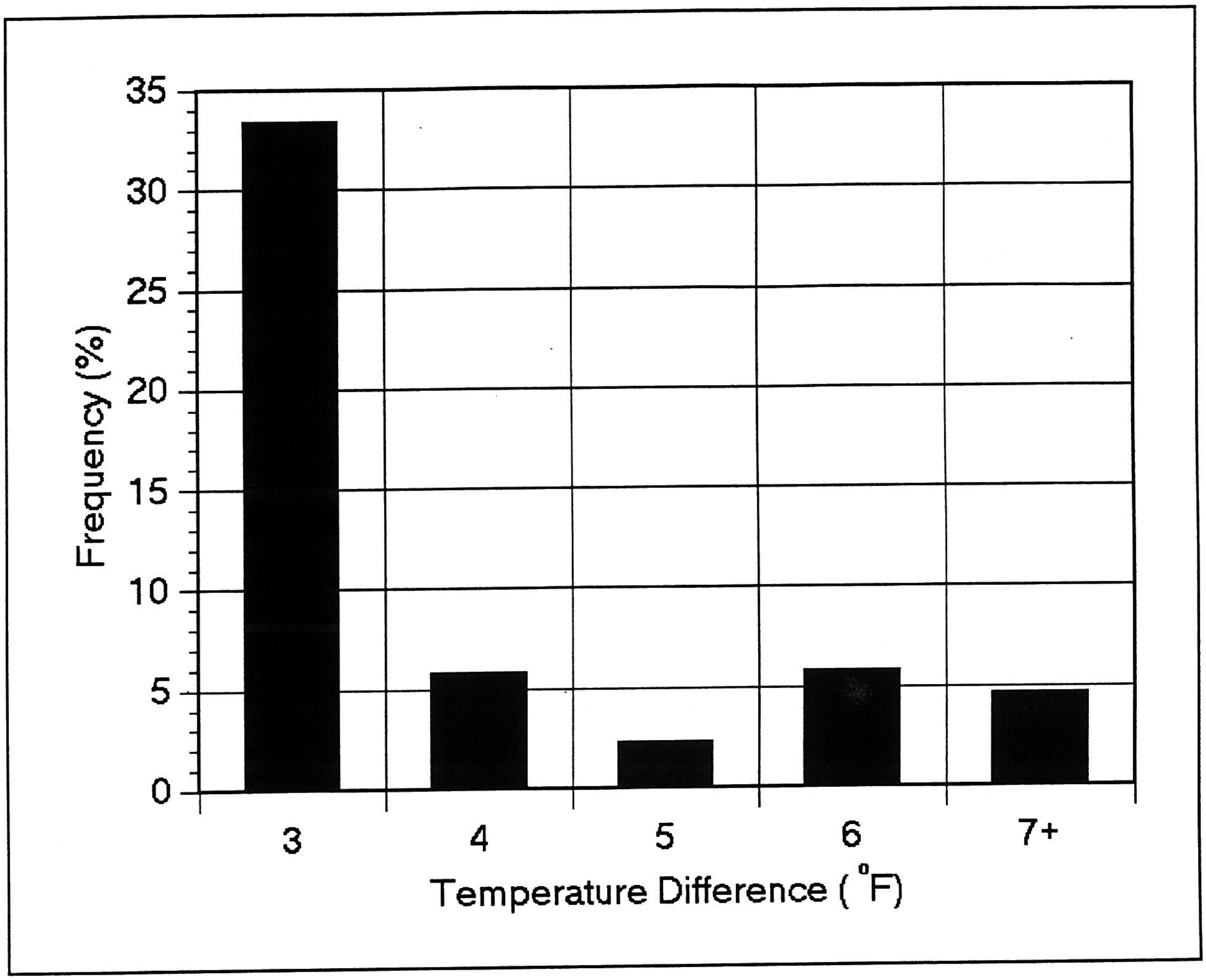

Figure 2. Frequency when the NWSFO CLE ASOS temperature was at least 3°F warmer than manual observer temperature from 23 April to 7 August 1994.

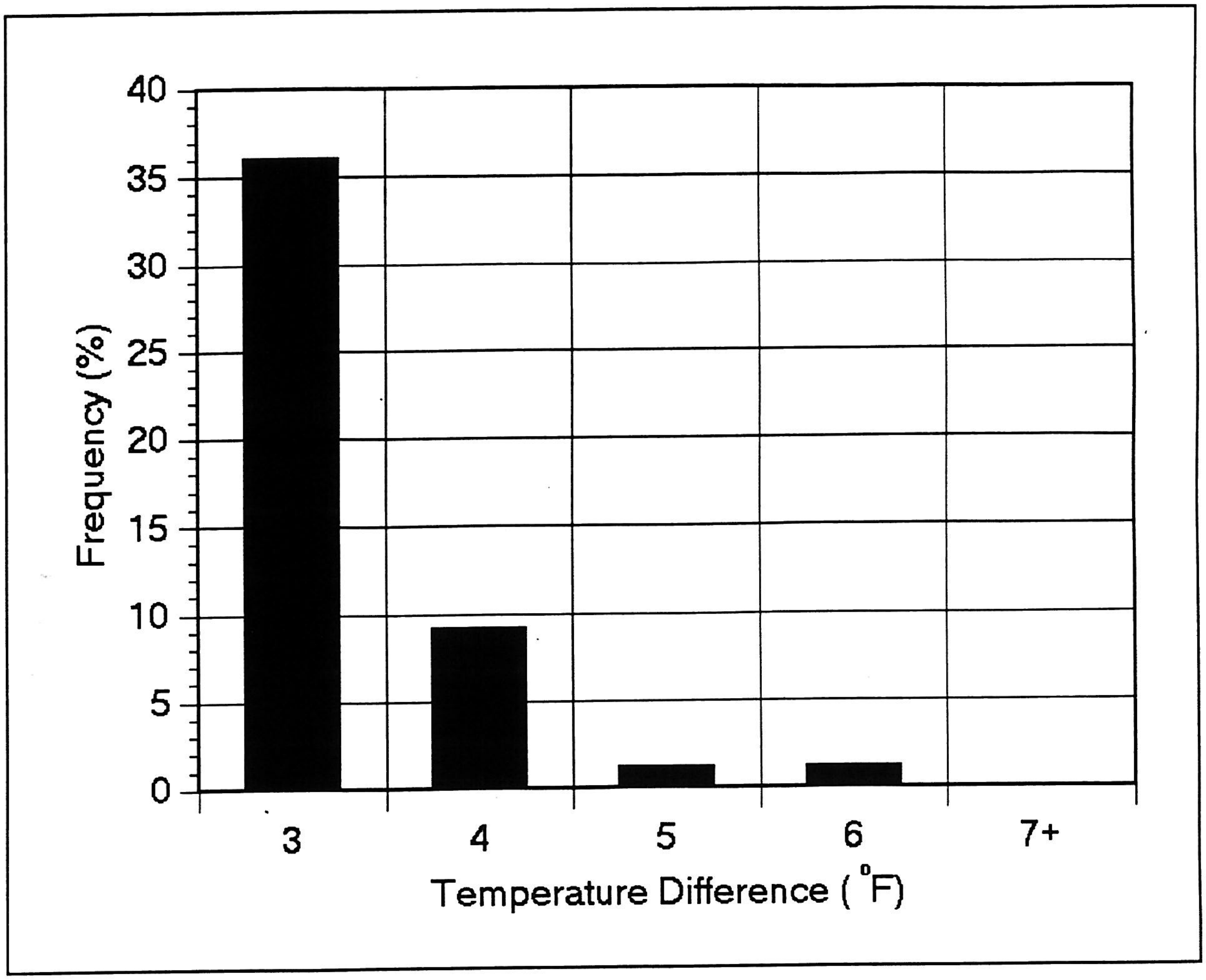

Figure 3. As in Figure 2, except for when the NWSFO CLE ASOS temperature was at least 3°F cooler than the manual observer temperature.