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# AN INITIAL COMPARISON OF MANUAL AND AUTOMATED SURFACE OBSERVING SYSTEM OBSERVATIONS AT THE ATLANTIC CITY, NEW JERSEY INTERNATIONAL AIRPORT

JAMES C. HAYES

National Weather Service Forecast Office
New York City, New York

STEPHAN C. KUHL

National Weather Service Eastern Region Headquarters
Bohemia, New York

Scientific Services Division
Eastern Region Headquarters
Bohemia, New York
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United States
Department of Commerce
Ronald H. Brown
Secretary

National Oceanic and
Atmospheric Administration
D. James Baker
Under Secretary

National Weather Service
Elbert W. Friday, Jr.
Assistant Administrator

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# 1. INTRODUCTION

The National Weather Service (NWS), in conjunction with the Federal Aviation Administration (FAA) and the Department of Defense, will deploy a new Automated Surface Observing System (ASOS) network during the 1990s. This system when implemented, will be installed in 900 to 1700 airports throughout the United States. ASOS is a stand alone observing system designed to support aviation operations and weather forecasting activities (National Weather Service 1991).

ASOS was installed at the Atlantic City International Airport (ACY) in Egg Harbor Township, NJ, in late September 1991. The presence of ASOS provided an excellent opportunity to evaluate the effectiveness of an automated surface observing system. The purpose of this study is to objectively compare ASOS to manual surface weather observations (SAO).

# 2. METHODOLOGY

The study period extended from January 1 to April 30, 1992. All observations, record and special, as well as selected climatic data, were collected for analysis. During the study period, ASOS occasionally missed observations due to hardware and/or software modifications. To ensure a matched data set, the corresponding manual observations taken while ASOS was inoperable were deleted from the manual observations database. Table 1a shows the list of dates with missing data. Table 1b depicts the major software and hardware changes made during the study period.

Figure 1 illustrates the locations of the ASOS and manual observation sensor locations, as well as the location of the Weather Service Office (WSO) at ACY. It is important to note that ASOS and human observers did not evaluate prevailing conditions in the same physical location.

The ASOS sensor site is located about 750 ft northeast of the centerline of runway 13-31, or about 1 1/2 mi northwest from the WSO located in Building 301. The sensors located at the site are: the hygrometer; anemometer; ceilometer; present weather indicator and tipping bucket rain gauge. The visibility sensor is also located at the ASOS site. With the exception of the wind equipment, all of the sensors are less than 20 ft above ground level (AGL).

Data from the sensors are collected by the Data Collection Package and transmitted to the Acquisition Control Unit (ACU) located in the WSO using radio frequency modems. The pressure sensors are also located at the ACU. It is not the purpose of this study to give an in depth review of ASOS sensors and specifications. The ASOS User's Guide provides a comprehensive review of the technical attributes of ASOS (National Weather Service 1991).

The manual observation main sensor site is located near the airport's center field location, about 1/2 mi northwest from the WSO. The hygrometer, anemometer and ceilometer are located at center field, about 1 mi northeast of the ASOS unit. The altimeter and weighing rain gauge are located at the WSO.

Manual visibility observations are determined from the roof of Building 301, which is about 80 ft AGL. Since ACY is a FAA towered airport, the official visibility is the lower visibility reported by either the FAA tower (which is approximately 160 ft AGL) or the manual observer located at Building 301. The data were divided into two major subsets: (1) data concerning aviation: and, (2) climatic data.

Table 2a lists the category divisions for ceiling and visibility analysis. The categories chosen represent the National Weather Service criteria for special surface weather observations at ACY. The highest ceiling category coincides with Marginal Visual Flight Rules (MVFR) criteria, while the highest visibility category coincides with Instrument Flight Rules (IFR) criteria.

Table 2b lists selected remarks and other climatic data. Temperature, precipitation, and wind data were analyzed and compiled into some of the more common climatic parameters. Percentage of sky cover was also tabulated for each data set.

## 3. RESULTS

### 3.1 Ceiling Data

Table 3a lists the frequency distribution for each category of restricted ceiling for each data set. Note that for the highest ceiling category (3000 ft or less), ASOS and manual observations were separated by only 4 occurrences. This result was somewhat surprising, considering ASOS uses only a single ceilometer to evaluate total sky cover, compared to the "celestial dome" observation taken by manual observers. The trend of nearly identical ceiling height frequencies continued for subsequent categories, with the largest frequency difference occurring for ceilings of 200 ft or less. This difference may be due to ASOS processing radiation fog events as low ceilings and will be discussed later.

The most revealing result of the ceiling analysis is the difference in the number of special observations. The 535 specials generated by ASOS represents about 2 1/2 times as many specials generated by manual observers. This result may be attributed to a true "continuous weather watch" afforded by a dedicated observing system.

Figure 2a depicts the lag time between ASOS and manual observations for the beginning of restricted ceilings. The lag time was defined as the difference in time (in min) between manual observers and ASOS reporting the development of the same restricted ceiling event. In order to ensure the same ceiling event was evaluated for both data sets, the starting times had to be within 90 min of each other. The manual observations were designated as the standard. ASOS events starting before manual events were considered positive, while ASOS ceiling events beginning after manual ceiling events were considered negative.

About half of the ASOS ceiling events started within 10 min of manual ceiling events. Approximately 80% of ASOS ceiling event started within 30 min of the manual observations. Since ASOS uses a time averaging scheme to determine ceilings, some differences should be expected (as evidenced by the symmetrical nature of the curve shown in Figure 2a). There was no clear bias for ASOS ceiling events to start before or after manual observations.

Figure 2b illustrates the lag time between ASOS and manual observations for the dissipation of restricted ceilings events. The convention is the same as that used for ceiling development. ASOS ceiling events that ended before manual ceiling events were considered to be positive and ASOS ceiling events ending after manual ceiling events were negative.. The category with the greatest frequency of occurrence was within 10 min of manual observations. The slight negative skew of the curve indicates a tendency for ASOS to dissipate restricted ceilings after manual observations. Again, this result may be due to the time average scheme used by ASOS for sky cover determination.

## 3.2 Visibility Data

Table 3b lists the frequency distribution of hourly observations meeting IFR visibility criteria. The most striking result is the difference in the frequency of IFR visibilities between ASOS and manual observations. The difference is greatest for visibility frequencies between 1 and 3 miles. Although a definitive explanation for the large frequency difference is not clear, the results appear to emphasize that visibility is site dependent. Recall that the visibility observations evaluated in this study came from two different physical locations, as well as two considerably different heights above ground level (AGL).

ASOS generated more than five times as many special observations than manual observations for visibility. Part of the reason for the large discrepancy is that ASOS used two intermediate special criteria values (1 3/4 and 1 1/4 mi), which manual observers did not. Also, the continuous "weather watch" afforded by an automated system may have contributed to the difference.

Graphical representations of visibility lag times are illustrated in Figures 3a and 3b. An IFR visibility event started with a record or special observation with a visibility of 3 miles or less, and ended with a record or special observation with a visibility greater than 3 mi. However, due to the variable nature of visibility, gaps of up to one record observation were permitted during the event, as long as the visibility did not exceed 4 mi. As was the case with the ceiling analysis, the start times for the ASOS and manual events had to be within 90 minutes of each other. If they were longer than 90 min apart, they were considered separate events. ASOS visibility events beginning before manual events were considered positive, and ASOS events beginning after manual events were considered negative. The dissipation convention is essentially the same as that used for ceilings.

Figure 3a illustrates the lag time for the development of IFR visibilities. There is a distinct peak at -5 to -15 min, indicating that ASOS tended to report the development of an IFR visibility event 5 to 15 min after manual observers. A secondary peak (although considerably less in magnitude) occurred for +80 to +90 min, suggesting a start time of approximately 1 1/2 hr earlier than manual observers.

Figure 3b illustrates the lag time for the dissipation of IFR visibilities. The largest peak is +80 to +90 min. The results appear to indicate that ASOS tended to end an IFR visibility event about 1 1/2 hr earlier than manual observers. Another broad peak, extending from -30 to +40 min; indicates the large amount of variability seen throughout the visibility analysis.

Because the visibility analysis did allow for temporal gaps in the visibility events, it is possible that the amount of time each data set retained IFR visibilities may have been overestimated. To account for this, for each day that had at least one observation (record or special) with a visibility of 3 mi or less, the total number of minutes with IFR visibilities was tabulated.

Differences in the total numbers of minutes between manual observations and ASOS observations were calculated when both observations reported IFR visibilities for a given day. Differences for which manual observations had more time (in minutes) with IFR visibilities per day than ASOS were considered positive. Differences were considered negative when ASOS observations had more time with IFR visibilities. Means and standard deviations were calculated. Extreme values, the largest difference between manual and ASOS observations for any single day, were also tabulated.

The results presented in Table 4 indicate that manual observations averaged over 2 hours per day of IFR visibilities than ASOS observations. The standard deviations, reveal the large variability in the IFR conditions. (Note, shortly after the installation of ASOS at the Atlantic City International Airport, it was determined that the site was located in an area subject to ground fog. Hence, for visibility, at least, the impact of the ASOS siting on the results of this study are inconclusive.)

Figure 4 depicts the difference, in minutes per day, between manual and ASOS observations for IFR conditions. The primary peak occurred for differences within 60 min of each other. However, the negative skew of the curve suggests manual observations had, in some cases, considerably more time with IFR visibilities. This point is also emphasized by the extreme values observed. The largest difference in manual observations was just over 9 hr (547 min), while the largest difference with ASOS was just under 5 hr (296 min). Figure 4 also illustrates that the mean difference between the ASOS and manual observations for visibilities of 1 mi or less and 1/2 mi or less, were about the same as those for 3 mi or less, as were the standard deviations.

Manual observations had more time with IFR visibilities for 32 of the 41 days in the study period. In contrast, the number of days during which only ASOS reported IFR visibility (Table

4) is three times that of manual observations (data exclusive of the 41 days). This is likely due to ASOS reporting low visibilities associated with radiation fog.

Analysis of the visibility data appears to converge on one major point. For a given IFR visibility event, manual observers on average, tended to report IFR visibilities longer than ASOS. Manual observers and ASOS (for the most part) reported the beginning of IFR visibilities within 15 min of each other, with ASOS showing a 5 to 15 min lag.

Dissipation results, on the other hand, showed ASOS ending IFR visibilities up to 90 minutes earlier than manual observers. For days when manual and ASOS observations both reported IFR visibilities, manual observations averaged over 2 hr per day more than ASOS. The extreme time difference values tended to be greater as visibilities decreased, reaching over 10 hours for visibilities of 1/2 mi or less.

It is possible that the height differential for visibility observations makes ASOS susceptible to "radiation" fog events. For this study, a radiation fog event was defined as an event in which only ASOS reported an IFR visibility with clear skies and light winds (3 kt or less). Clear skies (for ASOS) was defined as the absence of clouds below 12,000 ft. The event had to span at least two observations (record or special, to begin and end the event). Concurrent manual observations had to be clear below 12,000 ft and have an unobstructed visibility. Table 5 illustrates the result of this analysis. This criteria yielded 5 radiation fog events, ranging in length from 13 to 109 min.

Because the criteria for visibility used in this study was based on NWS special observation criteria (National Weather Service 1988), the majority of the analysis was focused on IFR visibilities. There was no attempt made to scrutinize visibilities greater than 3 mi. However, all record observation visibilities for each data set were collected into a visibility matrix (Table 6), modeled after the matrix used by Bradley and Nadolski (1985). Note that some visibilities were summed to accommodate the visibility values reported by ASOS. The majority of the time, ASOS and manual observers agreed on visibilities (or category of visibility), especially during VFR conditions. The matrix does indicate a divergence of agreement on visibility for Marginal Visual Flight Rules (MVFR; ceilings between 1,000 - 3,000 ft and surface visibilities between 3 - 5 mi) and lower cases.

### 3.3 Wind

Seventy percent of ASOS record observations had a wind direction within 10° of the corresponding manual observation. Furthermore, 90% of ASOS record observations had a wind direction within 20° of the corresponding manual observation. The mean ASOS observed wind speed was 1.2 kt lower than manual observations.

Table 7 summarizes some of wind and pressure data collected during the period of study. ASOS reported more than twice as many wind shifts (45 vs. 18) as manual observers. Manual observers coded wind shifts according to Federal Meteorological Handbook (FMH) Number 1 (National Weather Service 1988) criteria, characterized by a 45° or more change in wind direction that occurs in less than 15 min. ASOS reported wind shifts using criteria outlined in an updated version of FMH #1 (National Weather Service 1992). This uses the same criteria outlined in the 1988 version, except that a wind speed of 10 kt or greater is required.

To further analyze the wind shift discrepancy, wind direction changes and corresponding wind speeds were collected for each wind shift. The wind direction change was defined as the directional difference between wind directions reported in the observations prior to and subsequent to the wind shift. Manual observations showed a mean wind direction change of about 90° for each wind shift, while ASOS had a mean wind shift of 25°. Note that the ASOS mean wind direction change does not meet the directional change requirement for a wind shift as defined in the updated FMH #1.[1]

The large difference in the number of peak winds reported during the study is mainly due to different reporting criteria. Manual observers use wind gusts in excess of 35 kt to record a peak wind, while ASOS generates a peak wind remark for wind gusts of 25 kt or greater (criteria changed in the updated version of FMH #1, National Weather Service 1992).

### 3.4 Pressure

Eighty seven percent of ASOS record observations had an altimeter reading within 0.01 inches of the corresponding manual altimeter setting. It is interesting to note that 63.4% of ASOS observations had an altimeter reading exactly 0.01 greater than the manual reading. Since the pressure sensors for ASOS and the altimeter used for manual observations are at approximately the same height, the reason for this consistent discrepancy is unclear.

Furthermore, 98 % of the ASOS observations had altimeter readings within 0.02 inches of the corresponding manual observations. The tolerance of the ASOS altimeter is 0.02 inches (National Weather Service 1991).

ASOS reported 3 times as many pressure falling rapidly (PRESFR) remarks as manual observers did, and about 2 1/2 as many pressure rising rapidly (PRESRR) remarks (Table 7). This is likely due to the "continuous weather watch" capability of ASOS and the difference in the way the algorithm computes pressure remarks (National Weather Service 1994).

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[1]According to the National Weather Service (1994), once each minute, ASOS examines all 2-minute average wind speeds during the past 15 minutes. If all the wind speeds are greater than 9 kt, the algorithm will compare the current 2-minute average wind direction to the direction of the 2-minute average wind of 15 minutes earlier. If the 2-minute average wind direction has changed by 45° or more, a special alert is issued and a wind shift remark (WSHFT hhmm) is generated. Changes to the (WSHFT) remark algorithm are being planned for a future software build according to Nadolski and Murray (1995 personal communication).

### 3.5 Temperature

The mean monthly temperatures (°F) derived from ASOS for each of the 4 months (January through April) were lower than the corresponding manual observation mean temperatures (Table 8). The greatest departure occurred in March, while the smallest occurred in April. The ASOS mean maximum and mean minimum temperatures were also lower than the manual observation means, with the greatest departures occurring in the mean minimum temperatures. It appears that some of this temperature discrepancy may be associated with the location of ASOS, which is slightly below runway level, allowing for cold air drainage. In addition, the hygrometer used for ASOS (HO83R) is not identical to the HO83 hygrometer used for manual observations (National Weather Service 1991). Recently, design modifications made to the HO83 have reversed the flow of air through the system. This modification corrects for the warm bias inherent in the HO83 hygrometer that is used by manual observers.

### 3.6 Precipitation

Table 8 also illustrates the ASOS and manual observations monthly precipitation amounts. The largest discrepancy in monthly precipitation measurements occurred in January. The majority of this difference occurred on January 4, when ASOS reported over 2 inches of rain while manual observers reported only 3/10 of an inch. High winds during the event may have caused precipitation amounts reported by manual observers to be unrepresentative. The weighing gauge located at WSO ACY is not equipped with wind baffles, which often causes an underestimation of precipitation amounts during periods of high wind.

ASOS had 6 events during which it reported greater than 15% more precipitation than manual observers. In each of these events, the mean wind speed for the day was greater than 10 kt. Furthermore on January 16, 1992, ASOS incorrectly reported measurable precipitation with only scattered clouds. It was determined that strong surface winds were causing the ASOS tipping bucket to tip, resulting in the incorrectly reported accumulated precipitation. This problem appears to have been alleviated by subsequent software and hardware modifications.

The months of February, March, and April had monthly ASOS precipitation totals within 15% of the manual observed monthly totals. During the period of study, ASOS logged 58 precipitation events, of which 18 were a trace. Manual observers logged 59 events, 19 of which were a trace.

### 3.7 Sky Cover

Record observations of both ASOS and manual data bases were examined for sky cover. Table 9 illustrates an overview of the results. Sky cover was placed into 1 of 4 categories: 1) clear (CLR); 2) scattered (SCT); 3) broken (BKN); and, 4) overcast (OVC). Initially, clear was defined as no clouds reported below 12,000 ft. The results showed that ASOS, with respect to manual observers, tended to overestimate the frequency of clear and overcast sky covers. In fact, ASOS reported about 75 more ceiling events (BKN, OVC) than manual observers. Recall that ASOS uses a single ceilometer and a time average scheme to determine cloud amounts. Another possible cause for the ASOS overestimation of overcast sky conditions is the close proximity of the site to the Atlantic Ocean.

Manual observations were also evaluated for total sky cover above 12,000 ft (undetected by ASOS). The results showed that 513 ceilings were detected, yielding an average of 4.3 ceilings per day.

## 4. SUMMARY AND CONCLUSION

It is the goal of any automated observing system to accurately portray the prevailing conditions of its surroundings. The main purpose of this study was to compare how ASOS reported prevailing conditions at the Atlantic City International Airport, in comparison to manual observations. In addition to the inherent differences in manual and automated observational techniques, the measuring equipment ASOS uses to determine the prevailing conditions are not in the same physical location as the equipment used by human observers. For these reasons, the conditions reported by ASOS were not expected to be exactly the same as those reported by manual observers. However, the results of the comparison of ASOS and manual observations did reveal some interesting tendencies.

In general, for IFR and lower ceilings, ASOS and manual observers agreed fairly well. However, there were a few differences. The largest discrepancy of any ceiling category was for those ceilings occurring at a height of 200 ft or less. This may have been caused by ASOS processing radiation fog "events" as low ceilings. A lag time analysis showed, in general, that ASOS detected and dissipated restricted ceilings within 10 min of manual observations. This tendency, due to the time averaging scheme employed by ASOS to determine total sky cover, was expected.[2]

The largest discrepancy occurring between ASOS and manual observers was with regard to surface visibility. In general, ASOS tended to report IFR and lower visibilities for a shorter duration than manual observers. Although there is a considerable difference in the physical location and height for visibility determination, ASOS and manual observers both attempted to ascertain prevailing visibility. It should be mentioned that ASOS samples a relatively small volume of air over the sensor site, then processes that data into a prevailing visibility.

[2] It has been noted that the ASOS ceilometer has difficulty determining ceilings below 300 ft due to the split beam geometry ceilometer. Since the projector and receiver are physically located several inches apart, beam overlap doesn't occur until the projector beam is several hundred feet AGL. Below this height, cloud detection may occur when energy is scattered back to the receiver. This scattering may cause ASOS to report anomalous ceilings according to Bradley and Murray (1995 personal communication). Also, low-level fog may cause ASOS to report a restricted ceiling according to Nadolski and Murray (1995 personal communication).

Preliminary results suggest that the ASOS prevailing visibility assumption might be suspect for ACY, due in part to the siting problems discussed in Section 3.2.

For overall sky cover (all sky conditions), ASOS tended to overestimate the frequency of clear (CLR BLO 120) and overcast (OVC) skies and underestimate the frequency of scattered (SCT) and broken (BKN) ceilings. This may be a function of ASOS using a single ceilometer and a time averaging scheme to determine sky cover. Additionally, manual observers reported more than 500 ceilings above 12,000 ft, which is currently above the operational range of ASOS.

Wind direction, wind speed, and surface pressure also agreed fairly well, although the ASOS altimeter setting did show a consistent higher reading of 0.01 inches.

After software and hardware modifications alleviated a precipitation overestimation tendency, precipitation totals for manual observations and ASOS were generally within 15% of each other. It should be noted that ASOS and manual observers used different rain gauge types for measured accumulated precipitation (ASOS uses a tipping bucket gauge, while manual observers use a weighing rain gauge).

The difference in monthly, mean, maximum, and minimum temperatures between ASOS and manual observers, may be a function of instrument location. The temperature sensors are approximately 1 mi apart on a large, grassy field which, during clear skies and relatively light winds, is subject to radiative processes. The ASOS temperature sensor is slightly below runway level, which may result in cold air drainage, influencing temperature readings, especially under radiative conditions. Finally, the HO83R hygrometer used by ASOS is different from the HO83 hygrometer used by the manual observers (National Weather Service 1991). However, design modifications made to the HO83 have corrected for the warm bias inherent to the hygrometer.

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**Table 1a**. Dates of missing ASOS data and the number of record observations missed due to hardware and software modifications at WSO ACY from January 1 to April 30, 1992.

| Date | No. of missing observations |
|---|---|
| March 16 | 24 |
| March 17 | 24 |
| March 18 | 24 |
| March 24 | 24 |
| March 25 | 24 |
| March 30 | 24 |
| April 26 | 24 |
| April 27 | 24 |
| Total | 192 |

**Table 1b.** WSO ACY ASOS hardware and software modifications from January 1 to April 30, 1992.

| Date | Modification |
|---|---|
| March 16 | New software and firmware load |
| March 17 | Installation of a new present weather sensor. Data missing due to data acquisition problems. |
| March 24<br>March 25<br>March 26 | Replacement of a bad memory board and installation of a freezing rain sensor. |
| April 26<br>April 27 | Reset of software and firmware load and calibration of LEDWI. |

**Table 2a.** Ceiling and visibility categories used for data analysis at WSO ACY.

| Ceiling categories (for record observations (SA, RS) only) |
|---|
| 1) Ceilings above 3000 ft. No further analysis undertaken |
| 2) Ceilings 3000 ft or lower |
| a) 3000 ft or less |
| b) 1500 ft or less |
| c) 1000 ft or less |
| d) 800 ft or less |
| e) 700 ft or less |
| f) 600 ft or less |
| g) 500 ft or less |
| h) 400 ft or less |
| i) 300 ft or less |
| j) 200 ft or less |

| Visibility categories (for record observations only) |
|---|
| 1) Visibility greater than 3 mi collected in visibility matrix |
| 2) Visibility 3 miles or less |
| a) 3 mi or less |
| b) 2 mi or less |
| c) 1 1/2 mi or less |
| d) 1 mi or less |
| e) 3/4 mi or less |
| f) 1/2 mi or less |
| g) 1/4 mi or less |

**Table 2b.** Pressure and wind data collected at WSO ACY.

| Pressure | Wind |
|---|---|
| Altimeter setting | Wind direction |
| PRESFR remark | Wind speed |
| PRESRR remark | Peak wind remark |
| PJUMP remark | WSHFT remark |
| PRES UNSTDY remark | Calm winds |

Listed items collected from all record observations, where applicable.

**Table 3a**. Ceiling observations frequency distribution at WSO ACY from January 1 to April 30, 1992.

| Category | ASOS number | ASOS percent | MANUAL number | MANUAL percent |
|---|---|---|---|---|
| Total (RS,SA) | 2712 | 100.0 | 2712. | 100.0 |
| 3000 ft or less | 645 | 23.8 | 641 | 23.6 |
| 1500 ft or less | 524 | 19.3 | 532 | 19.6 |
| 1000 ft or less | 435 | 15.7 | 440 | 16.2 |
| 800 ft or less | 393 | 14.5 | 404 | 14.9 |
| 700 ft or less | 370 | 13.6 | 383 | 14.1 |
| 600 ft or less | 353 | 13.0 | 354 | 13.1 |
| 500 ft or less | 326 | 12.0 | 329 | 12.1 |
| 400 ft or less | 295 | 10.9 | 283 | 10.4 |
| 300 ft or less | 225 | 8.3 | 231 | 8.5 |
| 200 ft or less | 184 | 6.8 | 172 | 6.3 |
| special observations generated for ceilings | 535 | | 214 | |

**Table 3b**. Visibility observations frequency distribution of SAO's meeting NWS IFR criteria at WSO ACY from January 1 to April 30, 1992.

| Category | ASOS number | ASOS percent | MANUAL number | MANUAL percent |
|---|---|---|---|---|
| Total (RS,SA) | 2712 | 100.0 | 2712 | 100.0 |
| 3 mi or less | 248 | 9.1 | 343 | 12.7 |
| 2 mi or less | 153 | 5.6 | 255 | 9.4 |
| 1/2 mi or less | 108 | 4.0 | 223 | 8.2 |
| 1 mi or less | 82 | 3.0 | 174 | 6.4 |
| 3/4 mi or less | 70 | 2.6 | 122 | 4.5 |
| 1/2 mi or less | 62 | 2.3 | 107 | 3.9 |
| 1/4 mi or less | 37 | 1.4 | 75 | 2.9 |
| special observations generated for visibility | 688 | | 132 | |

**Table 4**. Difference in minutes per day from January 1 to April 30, 1992 between manual and ASOS observations for IFR visibilities at WSO ACY. Visibility categories: 3 miles or less; 1 mile or less; and, 1/2 mile or less.

| Data categories | < =3 mi | < =1 mi | < =1/2 mi |
|---|---|---|---|
| Number of days | 41 | 20 | 14 |
| Mean difference (min) | 131.6 | 124.5 | 127.6 |
| Standard deviation (min) | 192.6 | 170.5 | 193.0 |
| Extremes (min) | +547 | +622 | +643 |
| | -296 | -75 | -93 |
| Days with more minutes : | | | |
| manual: more minutes | 32 | 17 | 12 |
| ASOS: more minutes | 9 | 3 | 2 |
| manual observations only | 2 | 10 | 6 |
| ASOS observations only | 6 | 4 | 3 |

**Table 5**. ASOS radiation ground fog events at WSO ACY from January 1 to April 30, 1992. The length of time is in minutes. Visibility is in miles.

| Date | length | (UTC) start/stop | lowest vsby | # spl |
|---|---|---|---|---|
| 1/2 | 109 | 0514/0703 | 1 1/4 | 15 |
| 3/5 | 48 | 0545/0633 | 1 | 7 |
| 3/6 | 20 | 0248/0308 | 1 | 3 |
| 4/10 | 54 | 0520/0614 | 1/4 | 9 |
| 4/28 | 13 | 0808/0821 | 1 1/4 | 5 |

**Table 6.** Visibility matrix (in miles) of ASOS and manual observations at WSO ACY from January 1 to April 30, 1992.

| | | ASOS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | TOT |
| | A | 1940 | 71 | 7 | 4 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2028 |
| | B | 81 | 50 | 16 | 9 | 4 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 165 |
| M | C | 51 | 29 | 26 | 6 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 116 |
| A | D | 8 | 12 | 14 | 16 | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 60 |
| N | E | 4 | 10 | 19 | 15 | 10 | 7 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 69 |
| U | F | 0 | 5 | 4 | 5 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 |
| A | G | 1 | 2 | 3 | 9 | 8 | 6 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| L | H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | I | 0 | 2 | 6 | 12 | 7 | 5 | 4 | 4 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 46 |
| | J | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | K | 1 | 0 | 7 | 12 | 7 | 9 | 8 | 4 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 52 |
| | L | 0 | 1 | 0 | 1 | 1 | 5 | 0 | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 1 | 15 |
| | M | 1 | 0 | 0 | 1 | 1 | 4 | 7 | 4 | 5 | 1 | 2 | 1 | 4 | 0 | 1 | 32 |
| | N | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 5 | 2 | 2 | 6 | 6 | 0 | 24 |
| | O | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 4 | 13 | 15 | 12 | 51 |
| | | 2087 | 182 | 103 | 92 | 46 | 49 | 29 | 16 | 10 | 16 | 12 | 8 | 25 | 22 | 15 | 2712 |

Legend:

| | | | | | |
|---|---|---|---|---|---|
| A=10+ | B=7,8,9 | C=5,6 | D=4,3 1/2 | E=3 | F=2 1/2 |
| G=2 | H=1 3/4 | I=1 1/2 | J=1 1/4 | K=1 | L=3/4 |
| M=1/2 | N=1/4 | O=< 1/4 | | | |

**Table 7.** Supplemental SAO aviation/wind shift remarks at WSO ACY from January 1 to April 30, 1992. Wind direction is in degrees, wind speed is in kt.

| Supplemental aviation | ASOS | Manual |
|---|---|---|
| PRESFR | 57 | 19 |
| PRESRR | 81 | 33 |
| PJUMP | 4 | 0 |
| PRES UNSTDY | 0 | 0 |
| Peak wind | 179 | 22 |
| Calm winds | 283 | 198 |
| WSHFT | 45 | 18 |
| **Wind shift** | **ASOS** | **Manual** |
| Total number | 45 | 18 |
| Mean direction change | 24.7 | 88.3 |
| Mean wind speed | 10.6 | 9.1 |
| Gust remarks | 10 | 4 |

**Table 8**. Comparison of selected ASOS and manual climatic data for WSO ACY for January 1 to April 30, 1992. Mean daily max, mean daily mean, and monthly mean temperatures are in °F. Precipitation is in inches. Wind speed is in kt.

| Climatic data | ASOS | Manual | Diff. |
|---|---|---|---|
| January | | | |
| Mean daily max | 44.0 | 45.0 | -1.0 |
| Mean daily min | 22.0 | 23.3 | -1.3 |
| Monthly mean | 33.0 | 34.2 | -1.2 |
| Total precipitation | 3.60 | 0.92 | 2.86 |
| Mean wind speed | 9.1 | 10.7 | -1.6 |
| February | | | |
| Mean daily max | 45.0 | 46.2 | -1.2 |
| Mean daily min | 23.4 | 25.2 | -1.8 |
| Monthly mean | 34.2 | 35.7 | -1.5 |
| Total precipitation | 2.17 | 2.12 | 0.05 |
| Mean wind speed | 9.3 | 10.9 | -1.6 |
| March | | | |
| Mean daily max | 47.6 | 49.4 | -1.8 |
| Mean daily min | 27.4 | 29.5 | -2.1 |
| Monthly mean | 37.5 | 39.5 | -2.0 |
| Total precipitation | 2.83 | 2.94 | -0.11 |
| Mean wind speed | 9.5 | 11.4 | -1.9 |
| April | | | |
| Mean daily max | 60.5 | 60.6 | -0.1 |
| Mean daily min | 36.8 | 38.0 | -1.2 |
| Monthly mean | 48.7 | 49.3 | -0.6 |
| Total precipitation | 1.34 | 1.58 | -0.24 |
| Mean wind speed | 8.3 | 9.5 | -1.2 |
| Departure in mean daily max | | | -1.03 |
| Departure in mean daily min | | | -1.60 |
| Departure in mean for the study period | | | -1.33 |

**Table 9**. ASOS vs. manual observation sky cover at WSO ACY from January 1 to April 30, 1992.

ASOS observation sky cover

| Month | CLR | SCT | BKN | OVC | Total |
|---|---|---|---|---|---|
| January | 404 | 57 | 53 | 230 | 744 |
| February | 321 | 47 | 46 | 282 | 696 |
| March | 222 | 54 | 40 | 284 | 600 |
| April | 330 | 63 | 55 | 224 | 672 |
| Total | 1277 | 221 | 194 | 1020 | 2712 |
| Pct of total | 47.1 | 8.1 | 7.2 | 37.6 | |

Manual observations sky cover

| Month | CLR * | SCT | BKN | OVC | Total |
|---|---|---|---|---|---|
| January | 281 | 175 | 98 | 190 | 744 |
| February | 333 | 116 | 81 | 166 | 696 |
| March | 157 | 121 | 100 | 222 | 600 |
| April | 209 | 183 | 76 | 204 | 672 |
| Total | 980 | 595 | 355 | 782 | 2712 |
| Pct of total | 36.1 | 21.9 | 13.1 | 28.8 | |

* denotes clr blo 120 to coincide with ASOS reporting of clouds.

Manual observations with clouds above 12000 feet

| Month | SCT | BKN | OVC | Total |
|---|---|---|---|---|
| January | 28 | 83 | 76 | 187 |
| February | 92 | 64 | 56 | 212 |
| March | 36 | 38 | 38 | 112 |
| April | 44 | 100 | 58 | 202 |
| Total | 200 | 285 | 228 | 713 |

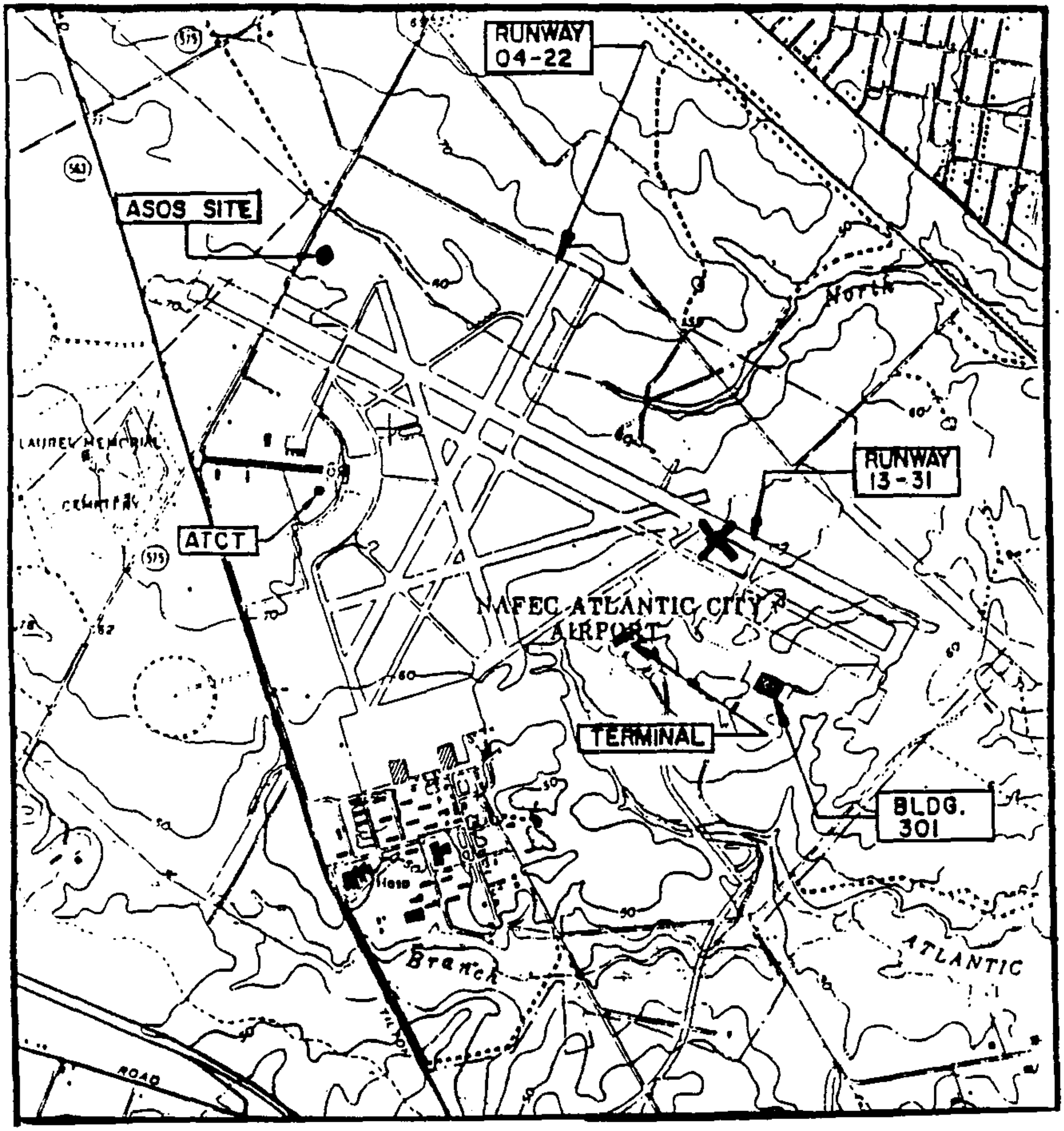


Figure 1. Location of the ASOS (●) and manual (X) observation sensor sites at the Atlantic City, NJ, International Airport.

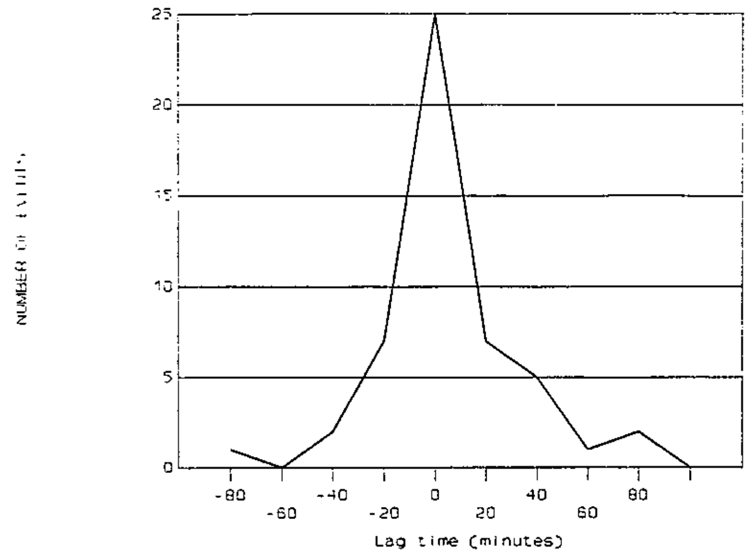


**Figure 2a.** Lag time for the formation of restricted ceilings between manual observations and ASOS at WSO ACY from January 1 to April 30, 1992.

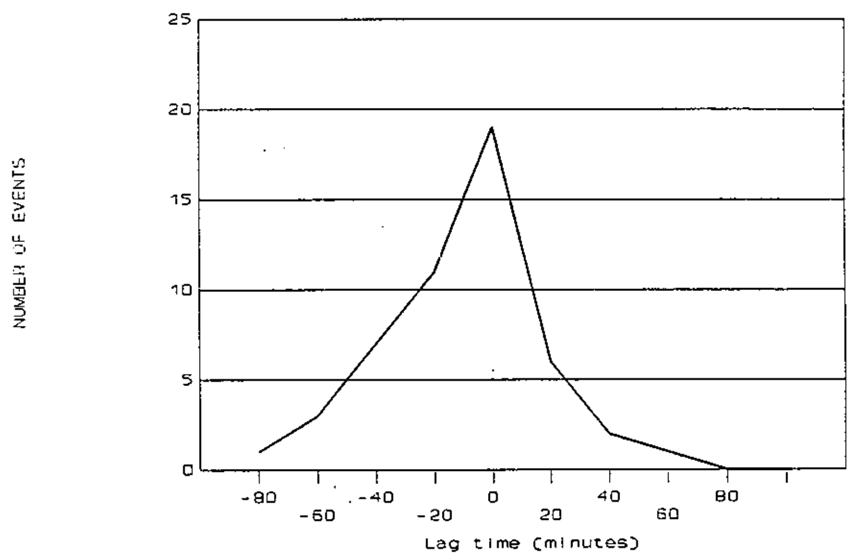


**Figure 2b.** Lag time for the dissipation of restricted ceilings between manual observations and ASOS at WSO ACY from January 1 to April 30, 1992.

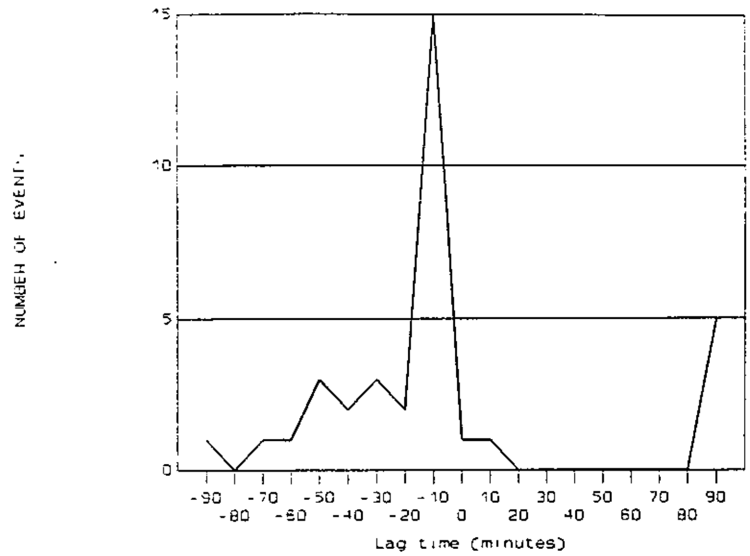


**Figure 3a.** Lag time for the formation of IFR visibility between manual observations and ASOS at WSO ACY from January 1 to April 30, 1992.

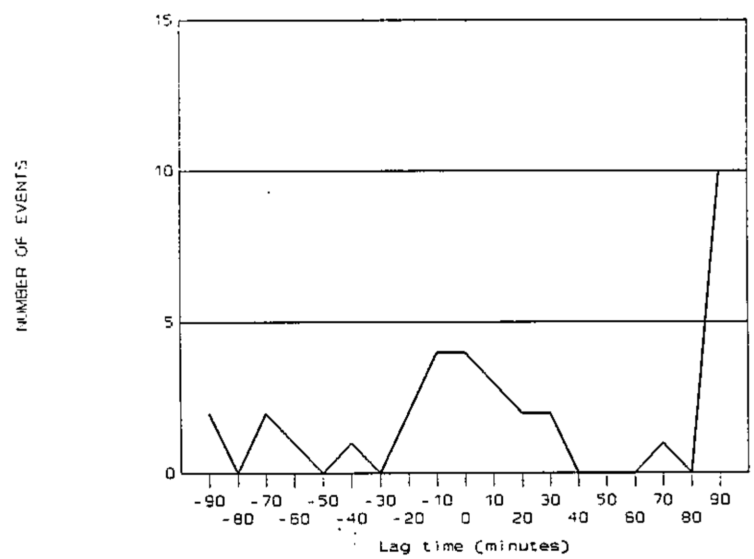


**Figure 3b.** Lag time for the dissipation of IFR visibility between manual observations and ASOS at WSO ACY from January 1 to April 30, 1992.

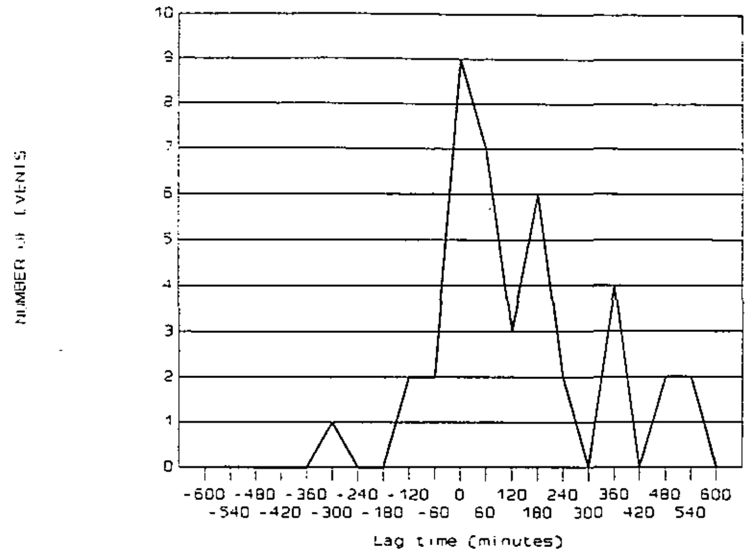


**Figure 4.** Difference per day, in minutes, between manual and ASOS observations, for IFR visibility at WSO ACY from January 1 to April 30, 1992.

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