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AN EVALUATION OF THE ASOS TEMPERATURE SENSORS AND HEATED TIPPING BUCKET RAIN GAUGE AT SYRACUSE, NEW YORK

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Editor's Note: Most of this work was done while Mr. Bartholf was stationed at WSO Syracuse, NY.

1. INTRODUCTION

In September 1992, the Automated Surface Observing System (ASOS) was installed at the Hancock International Airport in north Syracuse, NY. Upon installation, the temperature sensing portion of the instrument array contained the standard HO83, with modifications (HO83R). On September 15, 1993, the HO83R was replaced with a 1088 temperature sensor.

As described by Gall et al. (1992), the temperature sensor in the HO83 is located in the top of a cylindrical housing mounted 6 feet above the ground. The dewpoint temperature sensor (chilled mirror) is located near the base of the cylinder with an aspirating fan located at the bottom. The aspiration rate is on the order of 0.1 to 0.2 m/sec. The fan draws air from the top of the unit down through the sensor group.

The 1088 sensor is modified to reverse the flow of air (i.e., from the bottom of the unit up through the sensor group). The fan is located at the top of the cylindrical housing. The aspiration rate is approximately 0.2 to 0.4 m/sec. The early ASOS temperature sensor (HO83R) was similar to the standard HO83, except the fan was located at the top of the housing. Air flow through the sensor group was increased. Preliminary results indicated that the resulting ambient readings were about 1 to 2° (F) cooler than the HO83.

Several studies (Gall 1992; Kessler 1993) have noted a warm bias in the HO83 system, due to the slower rate of aspiration and the dewpoint sensor being located below the temperature sensor. The dewpoint sensor utilizes a heating element that could be producing a warm bias in the temperature sensor. The 1088 attempts to overcome these biases.

Heated tipping buckets (HTB) have been used by the NWS to measure rain amounts since the 1970's. Early models had problems accurately measuring the liquid equivalency of frozen precipitation, due to the excessive heating of the unit, which resulted in too much evaporation. To overcome this problem, the ASOS HTB applies less heat over a longer heating cycle. An algorithm has also been used to correct for the sensor's underestimation of precipitation during heavy rainfall events, which is caused by missed precipitation during the tipping process.

The ASOS User's Guide (National Weather Service 1992) describes the HTB as consisting of six main components. These are:

1) an alter shield;
2) an 8 inch collector funnel;
3) a pivoting dual chamber tipping bucket;
4) an electronic switch which counts the number of tips per minute;
5) a drain pan and drain tube; and,
6) a heating element to prevent freezing during cold weather.

The ASOS User's Guide also describes the two heating elements utilized in the system. One element is wrapped around the underside of the collector funnel and the other around the drain tube. Each heater is separately controlled and maintains a constant temperature of 40°F.

The ASOS precipitation algorithm uses the following equation to adjust the measured rainfall each minute.

$$C = A (1 + 0.54A), \qquad (1)$$

where C = the calculated rainfall amount, and A = the measured amount from the tipping bucket.

2. ANALYSIS PROCEDURES

2.1 Temperature

The standard HO83 sensor located at the Weather Service Office (WSO) in Syracuse (SYR) is within 400 feet of the ASOS platform. It is located over the same type of grassy surface and at approximately the same height above the ground as ASOS. As a result, a reasonable comparison can be made between the WSO SYR HO83 and the ASOS HO83R, and also the HO83 and the ASOS 1088. This study will examine the differences between the maximum and minimum temperatures reported by the standard HO83, and the ASOS sensors.

The comparison of the HO83 and HO83R extended from March 17 to September 14, 1993. A comparison between the HO83 and the 1088 was made from September 15 to December 31, 1993.

2.2 Precipitation

A direct comparison in total precipitation was made between the standard Belfort weighing rain gauge and the ASOS HTB. The ASOS HTB is located approximately 1 mile southeast of the Belfort gauge near the center of Hancock International Airport.

Events were broken into three categories, those where precipitation occurred with temperatures at or above 40°F for the entire event, those that were below 40°F for the entire event, and those that occurred both above and below 40°F. The demarcation of 40°F was chosen because that is the default setting of the thermostat. If the temperature falls below this, the heaters are turned on. This is also the point at which the magnitude of the precipitation measurement errors increases.

Rainfall totals estimated by ASOS (i.e., ASOS down for maintenance, warm reboot on the system, etc.) were not included. Also, it was noted on several occasions that the circuit breaker for the HTB heaters tripped, leaving the HTB unheated in cold precipitation events. These events (a total of four) were not included in the data set.

3. RESULTS

3.1 Temperature

Table 1 depicts the monthly average temperatures for the ASOS instrumentation versus the HO83. Figure 1 illustrates the algebraic difference in the monthly average temperature between the HO83 and the ASOS temperature sensors (HO83 - HO83R average and HO83 - 1088 average).

The cool bias of the HO83R is apparent, especially with regard to the average daily maximum temperature. The maximum temperature consistently averaged more than 2° F cooler than the WSO SYR HO83 sensor. The magnitude of the minimum temperature cool bias was less, but still exceeded 1° F. The installation of the ASOS 1088 on September 15 also produced cooler averages. However, the magnitude was considerably less than those associated with the HO83R.

3.2 Precipitation

Table 2 summarizes the results for the three precipitation event categories. There were 68 events with temperatures below 40°F, 53 events with temperatures greater than or equal to 40°F, and 32 events when the temperature straddled the 40° threshold.

Computation of the mean difference of the HTB from the standard Belfort weighing rain gauge showed that ASOS under reported precipitation during events below 40°F by approximately 0.06 of an inch per event. When the temperature equalled or was above 40°F, the difference was 0.02 of an inch. The events where the temperature straddled 40°F showed a difference of 0.03 of an inch.

Table 3 lists the total precipitation reported by the ASOS HTB versus the Belfort weighing rain gauge. The totals do not include the four events where the ASOS heaters were not functioning with precipitation occurring below 40°F, nor the events where ASOS estimated the precipitation (i.e., down part of the time for maintenance, upgrades, etc.). It is apparent from this table that there is considerable under reporting of precipitation during the winter months of December through March.

Table 4 illustrates the performance of the ASOS HTB in heavy rain events (>0.75 inch/24-h) to determine the accuracy of the algorithm in correcting for the underestimation of precipitation by the ASOS HTB. For six heavy rain events, the ASOS HTB measured 92.5% of the total as measured by the weighing rain gage. The algorithm (Eqn. 1) is designed to add a fraction of the one-minute measured rainfall to the total.

Table 5 further examines hourly precipitation data collected on August 24, 1993 to evaluate the performance of the algorithm. Hourly rainfall totals from the Belfort weighing rain gauge are compared to those from the ASOS HTB. Note that for the 1-h period (1800 - 1900 UTC), the algorithm apparently was working properly. In particular, nearly 1 inch of rain was measured in the Belfort gauge. There was only a 0.03 inch difference between the two measurements during the 1-h period.

Figure 2 presents a scatter plot of the three precipitation categories to further show the relationship between the Belfort weighing gauge and the ASOS HTB. As depicted in Figure 2, the relationship appears to be near linear. However, a closer examination indicates that most events below 40°F, are skewed to the right of the data set, indicating an under reporting of precipitation by the ASOS HTB.

4. CONCLUSION

Results of this study show that the temperature biases, which may have been introduced by the HO83 temperature sensor (Kessler et al., 1993), were reduced by the new ASOS temperature sensors (HO83R and 1088) installed at Syracuse, NY.

With the increased flow of air through the ASOS sensor group (induced by the new aspirator fan), any influences of the dewpoint temperature sensor heater on the measurement of the ambient air temperature have been negated. Results of this study also indicate that the early ASOS model (HO83R), apparently overcompensated for the heater and introduced a cool temperature bias.

The ASOS temperature sensor measured on average about 1.0°F cooler for maximum temperatures, and about 0.5°F cooler for minimum temperatures than the WSO SYR HO83 sensor.

The ASOS HTB consistently under reported precipitation. The main source of error is most likely due to evaporation losses caused by heating of the funnel area. A possible solution to this problem would be to reduce the amount of the heated area on the funnel. However, the amount of heat removed must not prevent the unit from functioning in cold (below freezing) temperatures.

Finally, the ASOS heavy precipitation algorithm was found to work well during several heavy rain events. However, there was a slight under reporting error on the order of 2 to 5% below the Belfort weighing gauge.

REFERENCES

Kessler, R.W., L.F. Bozart, and R.S. Gaza, 1993: Recent maximum temperature anomalies at Albany, N.Y: Fact or fiction? *Bull. Amer. Meteor. Soc.*, **74**, No. 2, 215-226.

National Weather Service, 1992: ASOS User's Guide. National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 187 pp.

Gall, R.K., R. Schotland, and J. Schmitz, 1992: The recent maximum temperature anomalies in Tucson: Are they real or an instrumental problem? *J. Climate*, **5**, 657-665.

Table 1. Monthly average temperatures (°F) observed by ASOS and the WSO SYR HO83. ASOS used and HO83R sensor from March 17 to September 14, 1993. The ASOS 1088 sensor was installed on September 15, 1993.

MONTH	ASOS MAX	HO83 MAX	ASOS MIN	HO83 MIN
MARCH (17-31)	40.7	42.9	21.4	22.2
APRIL	55.2	56.9	35.6	36.8
MAY (1-12)	73.7	75.9	47.1	49.0
JULY (4-15, 17-28, 31)	81.2	83.1	62.0	63.2
AUGUST (1-30)	79.0	81.0	58.6	59.8
SEPTEMBER (2-14)	74.7	76.4	54.2	55.2
SEPTEMBER (15-30)	62.6	63.4	45.6	46.1
OCTOBER	57.2	57.6	38.5	38.8
NOVEMBER	46.9	47.4	30.3	30.2
DECEMBER	34.5	35.6	19.3	20.1

Table 2. Measured precipitation difference between the ASOS HTB and the WSO SYR Belfort weighing rain gauge. All units are negative (under reporting measurement by ASOS) unless indicated by **BOLD** type.

EVENTS WITH AMBIENT TEMPERATURE BELOW 40° F.

0.02	0.04	0.02	0.04	0.13	0.03	0.13	0.02	0.02	0.01	0.04	0.03	January
0.02	0.03	0.01	0.04	0.06	0.22							
0.01	0.13	0.08	0.01	0.18	0.07	0.08	0.36	0.37	0.02	0.13		February
0.04	0.06	0.02	0.08	0.01	1.31	0.63	0.00	0.08	0.06	0.08		March
0.05	0.01	0.02	0.07	0.18								April
0.13												October
0.00	0.13	0.02	0.01	0.09	0.01	0.00						November
0.09	0.01	0.00	0.02	0.01	0.22	0.05	0.00	0.03	0.03	0.28	0.02	December
0.02	0.12											

68 Events, Mean Difference -0.06"
(64 events used in calculations, 4 events occurred when heaters were not operating)

EVENTS WITH AMBIENT TEMPERATURE AT OR ABOVE 40° F.

0.02												January
0.00	0.09	0.02	0.04									April
0.06	0.01	0.01	0.01									May
0.05	**0.04**	0.07	**0.01**	**0.03**	0.01	0.18	0.00	0.01	**0.01**	**0.03**		July
0.01	0.04	0.00	**0.04**	0.00	0.00	0.01	0.11					August
0.03	0.16	**0.01**	0.01	**0.06**	0.00	0.01	**0.01**	0.01	0.05	0.03	0.02	September
0.00	0.00											
0.02	0.02	0.01	0.06	0.03	**0.01**	0.01	0.00					October
0.00	0.00	0.02	**0.01**									November

53 Events, Mean Difference -0.02"

EVENTS WITH AMBIENT TEMPERATURE ABOVE AND BELOW 40° F.

0.05	0.03							January
0.13	0.06	0.01	0.05					March
0.04	0.05	**0.01**	**0.03**	0.03	**0.01**	0.01		April
0.01								September
0.00	0.01	**0.01**	**0.02**	0.03				October
0.01	0.06	0.03	0.06	0.06	0.00	0.00	0.00	November
0.00	0.00	0.00	0.04	0.05				December

32 Events, Mean Difference - 0.03"

Table 3. ASOS HTB measurements (inches) versus the WSO SYR Belfort weighing gauge. "*" indicates missing data. Note the consistent low bias of ASOS.

ASOS HTB	BELFORT	HTB/BELFORT %	
1.94	3.16	61.4	January*
0.69	1.40	49.3	February*
1.06	1.67	63.5	March*
5.48	6.55	83.7	April
0.44	0.53	83.0	May*
3.11	3.26	95.4	July*
4.36	4.49	97.1	August*
3.34	3.77	88.6	September*
2.63	2.91	90.4	October
2.48	2.76	89.9	November
2.25	3.24	69.4	December
27.78	33.74	82.3	Overall

Table 4. ASOS HTB precipitation measurements (inches) versus the WSO SYR Belfort weighing gauge during heavy rain events (>0.75 inch/24-h). Note that ASOS precipitation algorithm has corrected ASOS precipitation amounts.

ASOS HTB	BELFORT	HTB/BELFORT %	
1.34	1.52	88.2	July 19
0.82	0.83	98.8	August 2
2.81	2.91	96.6	August 24
0.77	0.80	96.3	September 26
0.85	0.91	93.4	October 17
0.80	1.02	78.4	December 21
7.39	7.99	92.5	Overall

Table 5. Hourly precipitation (inches) comparison of the ASOS HTB and the WSO SYR Belfort weighing rain gauge on August 24, 1993.

TIME	ASOS HT	BELFORT
13-14 EST	T	T
14-15 EST	0.99	0.96
15-16 EST	0.53	0.45
16-17 EST	T	T
17-18 EST	0.06	0.13
18-19 EST	0.33	0.35
19-20 EST	0.90	1.02
20-21 EST	T	T
TOTAL	2.81	2.91

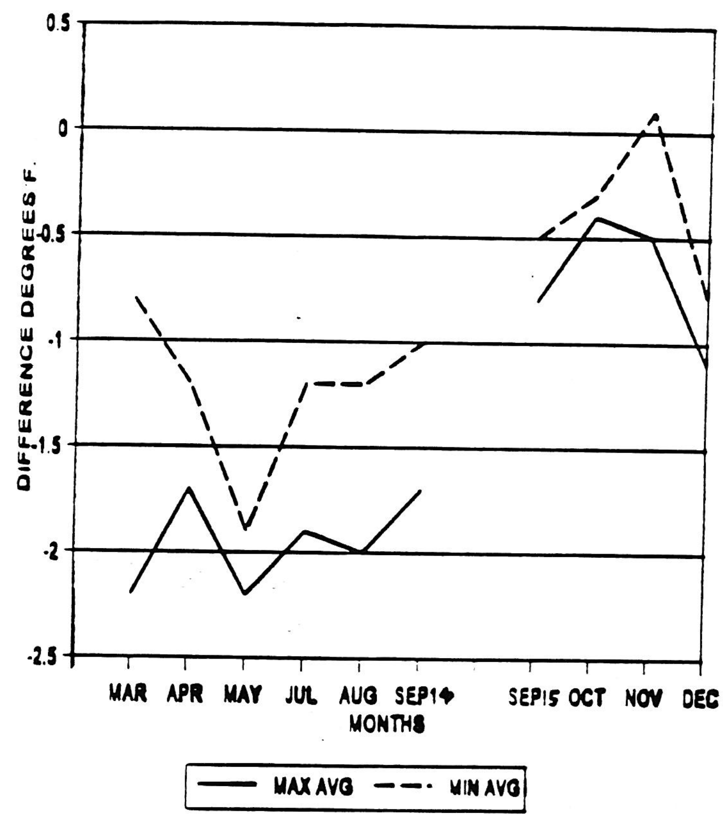

Figure 1. Monthly algebraic difference in air temperature between the WSO SYR HO83 and the ASOS (HO83R) temperature sensor (March 17, - September 14), and the (1088) sensor (September 15 - December 31). Note the cool bias of the ASOS sensor.

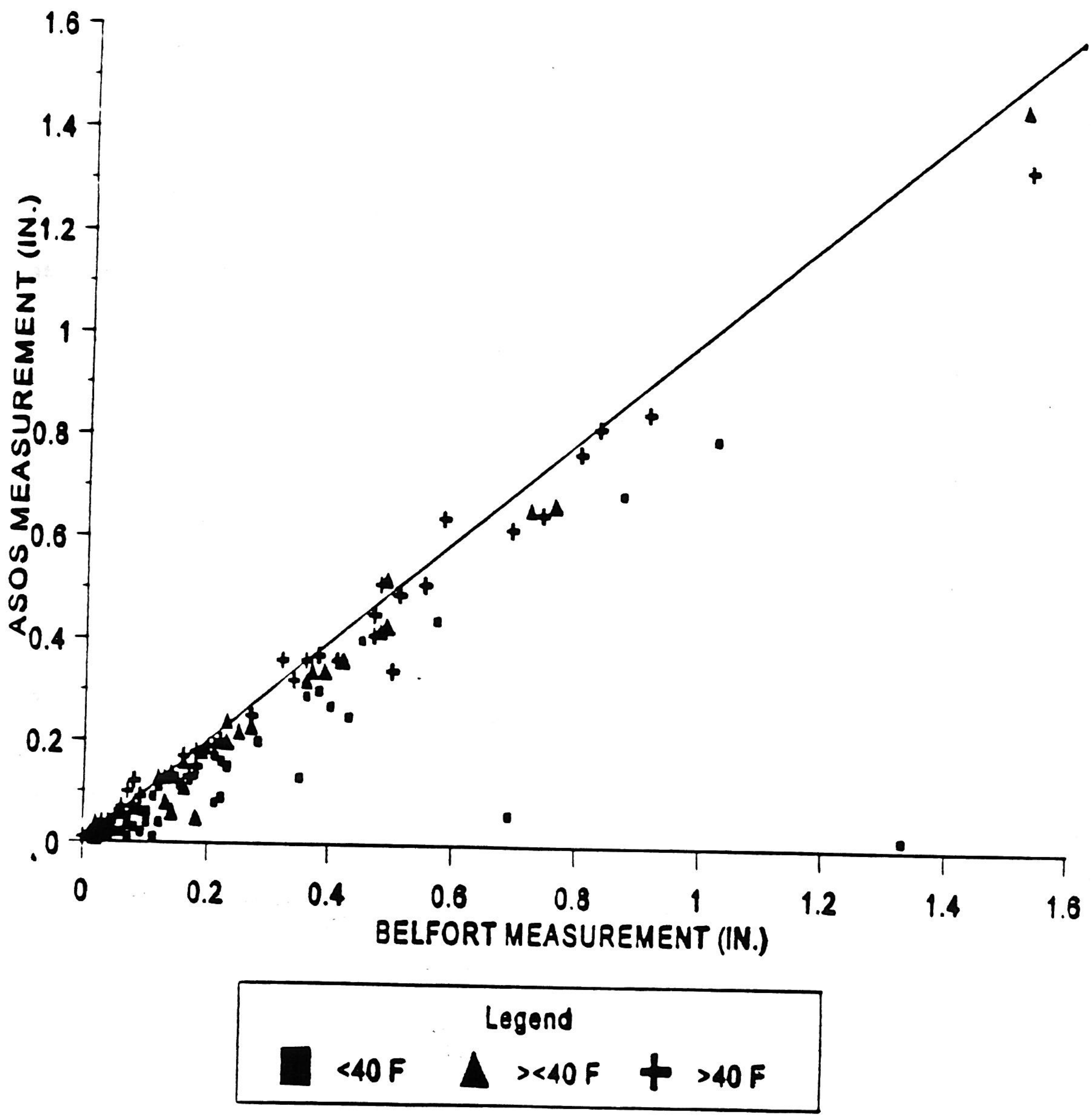

Figure 2. ASOS vs the Belfort Weighing Gauge scatter diagram comparing the three categories of precipitation events (temperatures < 40°F, temperature ≥ 40°F, and temperatures straddling 40°F).