14.2 Preliminary Results from a Field Comparison of Relative Humidity Sensors

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1. INTRODUCTION

Chilled-mirror hygrometers and capacitive relative humidity (RH) sensors are two of the most commonly used sensors for monitoring air vapor quantities in the atmosphere. Because of the increasing need for high fidelity climate data and the recent availability of new humidity sensors, there is a need for field comparison among various air humidity sensors to determine field performance. Three RH sensor types are evaluated: HMP45C temperature and relative humidity sensor, HMP233 "Smart" humidity/dewpoint transmitter (Vaisala Inc), and MP101A temperature and relative humidity sensor (Rotronic Instrument Co). Two of each type RH sensor were installed in the aspirated radiation shield (Met-One Instruments Inc), which has been selected for use in the U.S. Climate Reference Network (USCRN). Another two HMP45C sensors were installed in the non aspirated Gill shield. Two chilled-mirror hygrometers : DewTrack 200M Meteorological Humidity System (EdgeTech Inc) and ASOS HO-1088 (Technical Services Laboratory Inc) hygrometer were also employed at the testing site.

This paper explores both relative humidity bias and dew point temperature bias of each sensor in field observations over four month intensive measurements in Lincoln, Nebraska.

2. EXPERIMENTAL MEASUREMENTS

The experimental measurements in the field were conducted from March 2002 to September 2002 at the University of Nebraska's Horticulture Experiment Site (40°83' N, 96°67' W , elevation 383m). The ground surface was typical mowed grass during this study. The experimental measurements also include ambient air temperature, air pressure, solar radiation, and ambient wind speed (Fig. 1).

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The DewTrack 200M hygrometer with the NIST traceable calibration was used as a reference for both RH and dew point sensors in this study. The accuracy of the DewTrack 200M is ± 0.25°C dew point temperature and ±1.0 to 1.5% relative humidity. The HMP45C, MP101A, DewTrack 200M, and temperature sensor as well as solar radiation and wind speed were measured by a CR7 datalogger (Campbell Scientific. Inc.) at the height of 1.5 meters, which refers to air uptake height for aspirated sensors and the sensor height for non aspirated shields. The HMP233 and ASOS HO-1088 sensors were detected by directly connecting into a PC via RS232 cables.

Fig. 1. Instrumentation illustration: the array of RH and dew point temperature sensors used (two HMP45C inside the USCRN shields, two HMP45C inside the Gill shields, HMP233 sensors and MP101A sensors in the USCRN shields) at the experimental field.

All measurement sampling rates were 5 seconds with one minute average outputs. The term RH and dew point temperature bias for each air humidity system (HMP45C, HMP233, MP101A, and ASOS HO-1088) in this paper is defined as the difference relative to the DewTrack 200M system. The available data were taken from June 1st to September 31, 2002 including 166,742 observations for all RH sensors and chilled mirror hygrometers. Less than five days during this period were missing and not included in following data analysis.

3. PRELIMINARY RESULTS AND DISCUSSION

RH bias is shown in Fig. 2. Two of HMP45C inside the USCRN shields (HMP45-RH1 and HMP45-RH2) had a wet bias from 1.1% to 2.9% RH on monthly average. However, two non aspirated HMP45C sensors (HMP45-RH3 and HMP45-RH4) experienced a dry bias from -0.5% to -1.0% RH on monthly average. Considering the absolute bias, the difference between them might suggest that USCRN aspirated shield provided for the HMP45C sensor might not be better than non aspirated shields during summer time. Both case had almost the same standard deviation for all four months from 1.3% to 2.0% RH.

Two MP101A sensors (MP-RH1 and MP-RH2) shown in Fig. 2 presented a more biased performance on average compared to others. Around 95% observations of MP101A sensors had a positive bias. The monthly average bias ranged from 2.2% to 3.5% of RH. The HMP233 sensors provided the smallest biases. Both average bias and standard deviation were relatively smaller than others (Fig. 2). It suggests that the accuracy of HMP233 RH sensor in field are the most close to the accuracy in the laboratory during summer time. Noting that we re-calibrated all RH sensors (@ varied temperatures from 0 to 49 ^{o}C) right before installation at the site and the accuracy of each sensor were within the manufacturer's specifications.

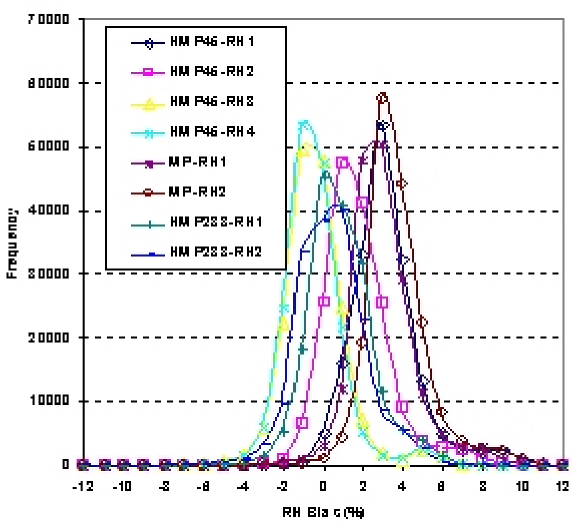

Fig. 2. RH bias for each type RH sensor.

A dew point temperature comparison was conducted between the ASOS HO-1088 / HMP233 and DewTrack 200M sensors. Noting that the dew point temperature in the HMP233 sensor was a calculated variable in terms of the ambient temperature, relative humidity directly detected by sensor, and real-time air pressure value whereas the RH readings in DewTrack 200M are derived from chilled mirror dew point temperature, air temperature, and assigned (fixed) air pressure value. Fig. 3. shows that dew point temperatures in the ASOS HO-1088 were monthly unbiased on average. Results showed that calculated dew point temperature from the HMP233 sensors were about half degree lower than the DewTrack 200M sensor. It should be mentioned that we observed the ASOS dew point temperatures were obviously contaminated by daily adjustment of chilled mirror optical balance, which we call an 'operational bias' and it usually lasted five minutes to ten minutes per day. Such 'operational bias' data in this study were not included in Fig. 3.

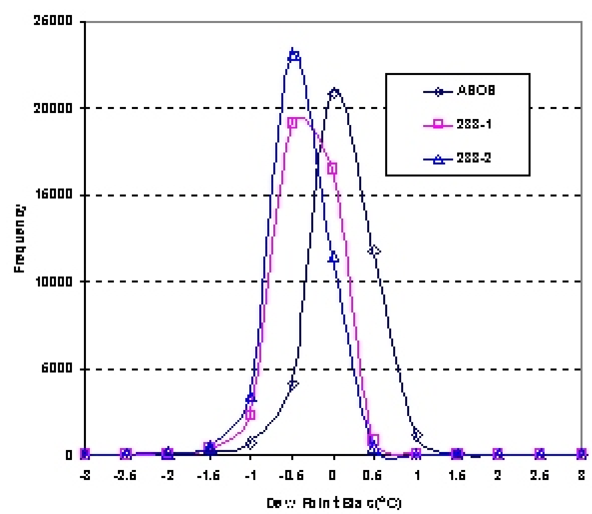

Fig. 3. The distribution of dew point biases in the ASOS and HMP233 sensors.

4. SUMMARY AND CONCLUSIONS

The field comparison of RH sensors and chilled mirror hygrometers revealed that the field performance of each type of sensor are different. The HMP233 performed the best during this study whereas the MP101A sensor had the largest bias. The HMP45C sensor in the aspirated shield was dry biased but the aspirated HMP45C was wet biased. The chilled mirror hygrometer ASOS HO-1088 system could reach ± 1.0 °C dew point temperature accuracy (95% confidence level) in field after removing the 'operational bias'. The calculated monthly dew point temperature in the HMP233 sensor was 0.3 to 0.6 °C lower on average. During the experimental period, monthly average, maximum and minimum bias, and standard deviation of bias are summarized in Tables 1 and 2.

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Table 1. Monthly RH bias for each RH sensor

		45-RH1	45-RH2	45-RH3	45-RH4	MP-RH1	MP-RH2	233-RH1	233-RH2
June	AVE	**2.6**	**1.7**	**-0.5**	**-0.7**	**2.8**	**3.5**	**1.2**	**0.9**
	STD	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2
	MAX	15.5	14.5	11.9	11.9	15.7	16.6	13.8	13.6
	MIN	-8.1	-8.8	-10.6	-10.7	-4.7	-4.3	-12.0	-11.9
July	AVE	**2.5**	**1.2**	**-0.9**	**-1.0**	**2.7**	**3.3**	**0.6**	**0.2**
	STD	1.5	1.4	1.3	1.3	1.4	1.4	1.5	1.5
	MAX	15.5	14.5	11.9	11.9	15.7	16.6	13.8	13.6
	MIN	-5.7	-7.9	-13.0	-11.3	-7.4	-5.4	-12.0	-11.9
Aug	AVE	**2.8**	**1.1**	**-0.9**	**-0.9**	**2.6**	**3.3**	**0.2**	**-0.4**
	STD	1.9	1.8	1.7	1.7	1.8	1.8	1.7	1.7
	MAX	11.1	9.7	7.7	8.2	10.9	11.1	8.9	8.6
	MIN	-4.9	-6.4	-9.5	-8.7	-8.3	-6.6	-11.0	-11.5
Sept	AVE	**2.9**	**1.1**	**-0.9**	**-1.0**	**2.2**	**2.9**	**-0.2**	**-0.8**
	STD	2.1	2.0	2.1	2.0	1.8	1.8	1.8	1.8
	MAX	12.1	10.3	7.0	6.7	13.0	12.2	9.8	8.4
	MIN	-6.7	-9.5	-15.1	-12.1	-7.6	-7.1	-12.0	-13.0
Overall	AVE	**2.7**	**1.3**	**-0.8**	**-0.9**	**2.6**	**3.3**	**0.4**	**0.0**
	STD	**1.7**	**1.7**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**

Table 2. Monthly dew point temperature bias.

		ASOS	233-DP1	233-DP2
June	AVE	**-0.1**	**-0.4**	**-0.5**
	MAX	9.5	1.3	1.3
	MIN	-5.3	-5.5	-5.5
	STD	0.5	0.3	0.3
July	AVE	**-0.1**	**-0.5**	**-0.6**
	MAX	11.9	1.1	1.0
	MIN	-12.4	-5.5	-5.7
	STD	0.4	0.3	0.3
Aug	AVE	**0.0**	**-0.5**	**-0.6**
	MAX	10.3	5.3	5.1
	MIN	-8.8	-14.0	-14.0
	STD	0.9	0.9	0.9
Sept	AVE	**0.2**	**-0.3**	**-0.4**
	MAX	13.3	5.2	5.1
	MIN	-3.3	-3.4	-3.9
	STD	1.4	1.3	1.3
Overall	AVE	**0.0**	**-0.4**	**-0.5**
	STD	**0.9**	**0.8**	**0.8**