4.1 A Study on the USCRN Air Temperature Performance

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1. INTRODUCTION

Air temperature is a critical variable in the US Climate Reference Networks (USCRN). The USCRN air temperature measurement system consists of an aspirated radiation shield and a platinum resistance thermometer (PRT). To detect the air temperature signal, the air temperature sensor and the air sensor's physical body must be coupled to the atmospheric air temperature. The air temperature measurement biases/errors have two components: microclimate-induced error caused by incomplete coupling between the atmosphere and the sensor's body (including radiative error and errors related to the ventilation rate) and electrical-induced error from the electrical components and circuitry in the measurement system (including sensor's error and data acquisition error). Minimizing both errors is equally important to obtain data of high quality and fidelity. In this study, we evaluated the field performance of the USCRN PRT sensors based on one year of field observations taken in Lincoln, NE. The electrical analysis is based on the measurement process implemented through the sensor and data logger. The field observations are analyzed by an inter comparison with two precision aspirated air temperature systems: R. M. Young air temperature system (RMY) and Precision Meteorological Thermometer system (PMT), in which the observations were taken during 2002 and 2003.

This paper explores both microclimate-induced bias and possible electrical-induced bias in observations from a one year intensive measurement period in Lincoln, Nebraska.

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2. EXPERIMENTAL MEASUREMENTS

The experimental measurements in the field were conducted from November 2002 to October 2003 at the University of Nebraska's Horticulture Experiment Site (40°83' N, 96°67' W , elevation 383m). The ground surface height was maintained at about 8 cm by mowing. Two USCRN PRT sensors (PRT1 and PRT2) combined with two USCRN air temperature radiation shields were used in this study. The experimental measurements also include measurements of solar radiation and ambient wind speed installed at a height of 1.5 m for monitoring the solar radiation and ambient wind speed (Fig. 1).

Two air temperature references used in this study are: 1) R. M. Young 43347 temperature probe (± 0.1 °C accuracy of manufacturer's statement) combined with an aspirated radiation shield (model 43408-L, R. M. Young Inc.); and 2) Precision Meteorological Thermometer (± 0.05 °C accuracy of manufacturer's statement) (Model PTM-2005, Yankee Environmental Systems, Inc). We refer to these two reference system as RMY and PMT in this paper. Both system were newly calibrated by the manufacturers immediately before the measurement period began.

Fig. 1. Instrumentation illustration: the array of air temperature monitoring systems used (USCRN PRT sensors and shields, two RMY systems, one PTM system, two ASOS 1088 as well as two MMTS systems) at the experimental field.

All sampling rates were 5 seconds with one minute average outputs. Data were available for 6749 hours during the one year period. An hour was eliminated when one or more of the sensors was malfunctioning or maintenance was being performed. In our study, the temperature bias is defined as the temperature difference relative to the RMY or PTM system

3. PRELIMINARY RESULTS AND DISCUSSION

The USCRN air temperature bias relative to the RMY and PTM is shown in Fig. 2. Obviously, the air temperature bias of the USCRN PRT during nighttime was smaller than that during daytime for both cases. It was clear that the USCRN PRT system had better performance when compared to the PMT system rather than the RMY system. Considering the monthly differences, Table 1 illustrates the monthly average and standard deviation of the USCRN PRT sensors. The monthly average bias range of the USCRN PRT at the 95% confidence level was less than ± 0.3 ^{o}C, which satisfied with the requirements that USCRN program proposed (± 0.2 to ± 0.3 ^{o}C). The larger bias occurred during daytime, especially for the temperature difference between the USCRN PRT versus the RMY, suggesting that any of these three air temperature systems could possibly be contaminated by the microclimate effects at the observation site.

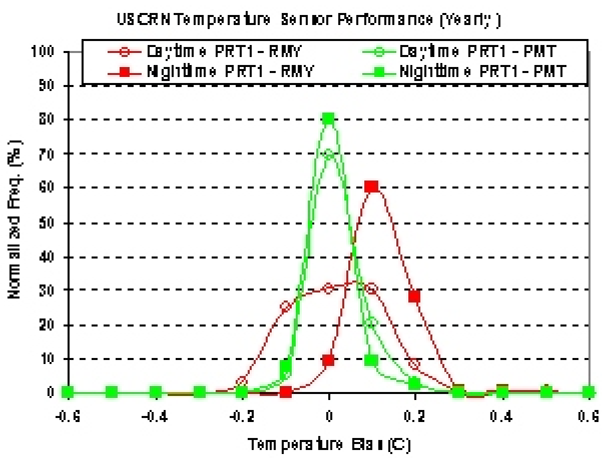

Fig. 2. Yearlong USCRN air temperature bias relative to the RMY and PMT systems.

To investigate the microclimate effects, Figure 3 shows the solar radiation effects on the temperature difference between the USCRN PRT and RMY or PMT system. The result in Figure 3 reveals that radiative error exists in the RMY system and its magnitude was nearly a 0.2 ^{o}C warming bias when solar radiation was larger than 500 W m^{-2} (top graph in Fig. 3). However, there was no obvious solar radiation effects from the difference between the USCRN PRT and the PMT system. Thus, results in Fig. 2 for the larger bias during daytime were caused by the solar radiation effects. For the ambient wind speed effects, variations with changes of ambient wind speed were not found during either daytime observation or nighttime observation.

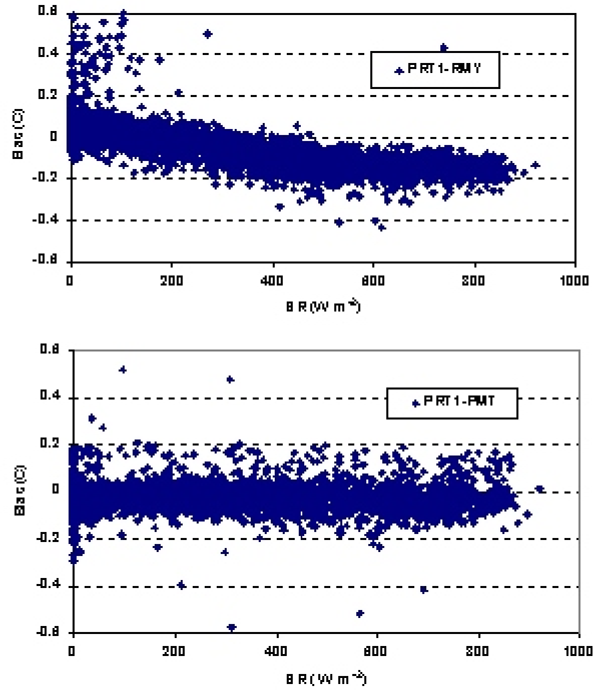

Fig. 3. Variations of the USCRN bias with changes of solar radiation [top graph: PRT1-RMY vs solar radiation (SR); bottom graph: PRT1 - PMT vs solar radiation (SR)].

As a result, we do not know whether the USCRN system (or USCRN radiation shield) is free of solar radiation bias. However, from our study, the USCRN system was better than the RMY system on shielding solar radiation and it nearly had an equal radiation efficiency with the PMT system. It should be noted that the solar radiation effects could make a temperature warming bias as much as +1.0 ^{o}C (Hubbard and Lin, 2002). Figure 4 illustrates the solar radiation effects when the radiation shield of air temperature system is a non aspirated shield (in this cas an MMTS system which is widely used in the NWS climate networks). There were two combinations of temperature sensor and radiation shields in Fig. 4: USCRN PRT sensor in the MMTS shield [PRT(MMTS)]; and the MMTS thermistor sensor in the USCRN radiation shield [MMTS(CRN)]. The MMTS and CRNP in Figure 4 refer to the normal MMTS measurement and normal USCRN temperature system. The results indicated that any temperature sensor placed in the non aspirated shield did have a warming bias (Fig. 4).

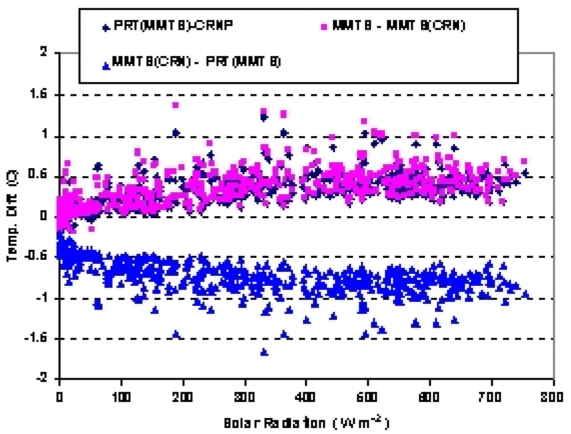

Fig. 4. Solar radiation effects on the USCRN PRT sensor combined with the MMTS radiation shield. Only two month observation data shown (September and October, 2003 at the site).

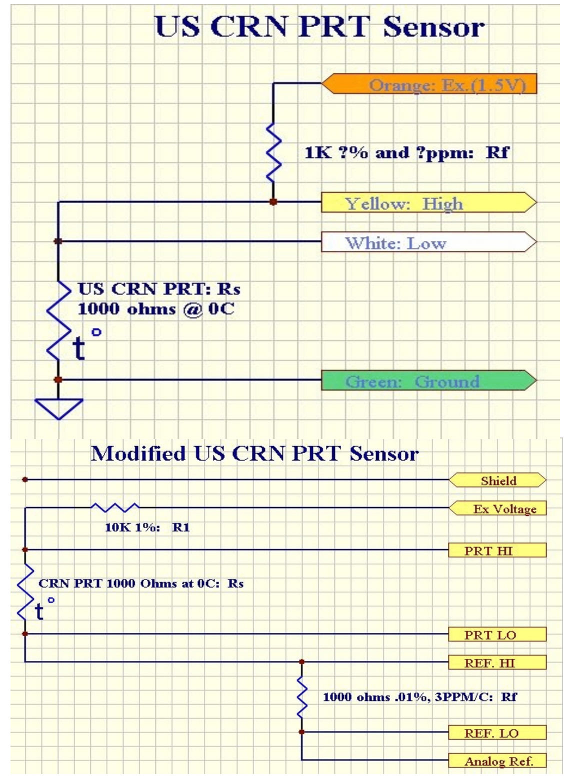

Fig. 5. Current USCRN PRT sensor during measurement (top graph) and a modified measurements of USCRN PRT sensor (bottom graph).

The electrically-induced bias in the USCRN PRT measurement, not only is associated with the PRT sensor itself, but also depends on the measurement circuitry. In the USCRN network, a CR23X (Campbell Scientific, Inc) was selected for measuring the USCRN PRT sensor (Fig. 5). There are several options for resistance measurement in the CR23X. Thus, the USCRN PRT sensor should be configured or wired under the most optimized condition. Theoretically in the Campbell data logger, measurements using configuration of the modified USCRN PRT sensors are better than the current USCRN PRT sensors (Fig. 5). This is because the modified circuitry not only improves the signal sensitivity but also further reduces the possible errors caused by the errors from the extension wires, ground point, and inaccuracies of excitation voltage (Lin and Hubbard, 2003). The disadvantage of the current circuitry used in the USCRN PRT is that only a small portion of full scale input range (FSR) is used by the CR23X and, thus, it has a relatively low signal sensitivity. The resistance measurements in the modified circuitry must be made differentially because the signal is measured twice to determine the resistance of the USCRN PRT although the CR23X also measures the resistance twice by polarity reversal of the excitation voltage. For the highest quality/fidelity air temperature measurements, we recommend the modified USCRN PRT circuitry is more applicable in the USCRN network.

4. SUMMARY AND CONCLUSIONS

The field comparison revealed that the field performance of the USCRN air temperature system was within ± 0.3 °C compared to the RMY and PMT systems at the 95% confidence level. The daytime measurements had more contaminated air temperature measurements compared to the nighttime measurements. We did not find any radiative errors in the USCRN PRT system when compared to the RMY and PMT system, rather we found that a warming bias might exist in the RMY system during daytime. The magnitude of this warming bias is a function of solar radiation and independent of the ambient wind speed. The result in this study indicates that non-aspirated radiation shields are likely to introduce a warming bias during daytime. During the experimental period, monthly average and monthly standard deviation of bias are summarized in Table 1.

REFERENCES

Hubbard, K. G. and X. Lin, 2002: Realtime data filtering models for air temperature measurements. *Geophysical Research Letters.* 29(10): 67-1:67-4.

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Table 1, Monthly USCRN PRT bias from Nov. 2002 to Oct. 2003. The unit is °C for all numbers except hours column.

Observations	Hours	PRT1-RMY		PRT2-RMY		PRT1-PMT		PRT2-PMT	
		AVE	STD	AVE	STD	AVE	STD	AVE	STD
Nov-02	665	0.05	0.07	0.06	0.06	-0.04	0.04	-0.03	0.04
Dec-02	611	0.06	0.07	0.08	0.06	-0.04	0.05	-0.02	0.05
Jan-03	744	0.07	0.09	0.08	0.08	-0.02	0.04	-0.01	0.03
Feb-03	547	0.05	0.11	0.06	0.10	-0.04	0.04	-0.02	0.03
Mar-03	715	0.05	0.14	0.07	0.13	-0.04	0.04	-0.02	0.04
May-03	564	0.03	0.15	-0.53	0.32	-0.04	0.04	-0.60	0.25
Jun-03	465	-0.01	0.16	-0.97	0.41	0.02	0.15	-0.94	0.36
Jul-03	590	-0.05	0.16	-0.03	0.16	-0.02	0.62	0.00	0.62
Aug-03	586	-0.05	0.13	-0.03	0.13	-0.04	0.08	-0.02	0.08
Sep-03	678	0.01	0.17	0.03	0.17	-0.04	0.12	-0.03	0.12
Oct-03	584	0.01	0.11	0.03	0.11	-0.04	0.10	-0.03	0.10
Monthly Average 95% Range		[0.27 to -0.23]		[0.25 to -0.18]		[0.21 to -0.27]		[0.25 to -0.28]	