P4.6 PRELIMINARY ANALYSIS OF THE DIFFERENCE BETWEEN TEMPERATURE OBSERVATIONS RECORDED BY COOP AND USCRN SYSTEMS

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1. INTRODUCTION

Instrumentation systems in the U.S. surface observing networks have changed with time and varied by network. The U.S. Climate Reference Network (USCRN) is a new network which started deploying stations in 2001, and as of July 2004 60 stations have been commissioned. When fully deployed, the USCRN will consist of approximately one hundred stations nationwide at locations selected to capture both the national and regional climate trends and variations for temperature and precipitation (Vose and Menne 2004). The first and foremost objective of the USCRN instrument suite is to provide benchmark quality air temperature and precipitation measurements free of time-dependent biases. In this study, a comparison will be made between maximum and minimum temperature (T_{max} and T_{min}) measurements recorded at Cooperative Observer Network (COOP) stations and co-located CRN sites. The USCRN configuration uses three separate aspirated shields each of which contains one Platinum-wire Resistance Thermometer (PRT) sensor to measure ambient air temperature. The primary COOP instrument systems are the Liquid-in-Glass (LIG) thermometers that are housed in the Cotton Region Shelter (CRS) and the thermistor Maximum-Minimum Temperature System (MMTS) housed in cylindrical louvered instrument shelter. Both of these instrument systems are non-aspirated. Using USCRN data as the reference, an analysis of COOP measurement characteristics will be helpful in constructing long-term homogeneous time series and surface observing network integration.

2. DATA

The COOP daily data used in this study are from the TD3200 file, which has undergone a set of quality assurance checks. As of July 2004 the latest TD3200 data archived at NCDC are through February 2004. In this analysis we selected those COOP stations which are within 10 km of USCRN stations and have at least one month of data overlapping the USCRN data. The COOP stations selected for comparison should not have experienced changes in location, instrumentation, or time of observation during the period of comparison. Once the COOP stations' metadata were reviewed, there were 21 COOP stations available for analysis.

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Figure 1 shows the USCRN sites, which have at least one COOP station co-located within 10 km. The red dots represent paired USCRN stations. This study also uses the USCRN station at Fairbanks, AK with a COOP station nearby to illustrate the role of siting effect on co-located station temperature differences.

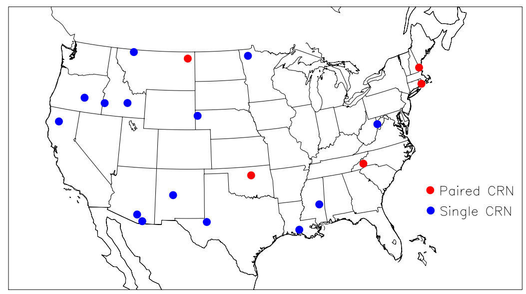

Figure 1. USCRN stations which have at least one COOP station co-located within 10 km and have at least one-month data overlapping the COOP data. As of July 2004 the latest available COOP data were through February 2004, and there are 14 single USCRN sites and 5 paired USCRN sites in the contiguous U.S., and 1 single site at Fairbanks, Alaska (not shown).

USCRN stations do not directly record daily T_{max} and T_{min}. Instead, hourly T_{max} and T_{min}, represented by values of 5-min averages, are recorded for each hour of the day. To avoid time of observation biases (Karl et al. 1986), the USCRN T_{max} and T_{min} are calculated to match the "observation day" of the nearby COOP stations. For example, COOP temperature measurements at Durham, NH, are made at 1700 LST. The T_{max} and T_{min} at nearby USCRN station are thus calculated from the period of 1700 LST of previous day to 1700 LST of current day.

3. RESULTS

3.1 *Differences at co-located sites*

Figure 2 shows values of COOP-minus-USCRN T_{max} and T_{min}. For each season, the mean value and the 95% confidence limit of the mean bias are calculated from all co-located sites. As illustrated in Figure 2, a warm T_{max} is shown in all seasons with the maximum of 1.11^{o}C in summer and a minimum of 0.67 ^{o}C in winter. The 95% error bars are one order smaller than the magnitude of the mean differences, suggesting that the

COOP T_{max} is significantly warmer than the USCRN T_{max}. A cooling of 0.21 ^oC ~ 0.44 ^oC is observed in the COOP T_{min}. Note the error bars are approximately the same magnitude as the mean differences for all seasons. This implies the mean COOP T_{min} cooling is statistically less significant.

The different behavior of T_{max} and T_{min} is also exhibited in Table 1, which lists all individual locations with the availability of all four seasons' values in both COOP and USCRN stations. The COOP stations with CRS are grouped separately from the ones with MMTS. As seen in Table 1, USCRN stations generally are deployed at an elevation higher than the neighboring COOP stations. For COOP stations with either CRS or MMTS, T_{max} is warmer than the USCRN T_{max} at all of the sites considered, while COOP T_{min} can be warmer or cooler than the USCRN T_{min} depending on location. Also, T_{max} differences at most of the stations average around 0.9 ^oC, while a larger station-to-station variability is shown in values of T_{min} difference.

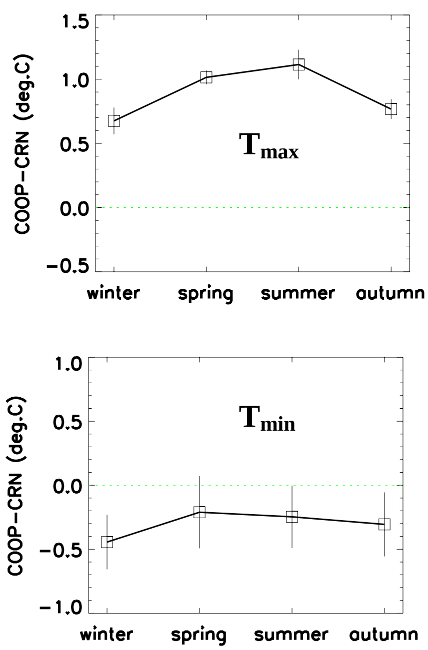

Figure 2. COOP-minus-USCRN T_{max} (upper plot) and T_{min} (bottom plot) calculated from stations co-located within 10km. Error bars represent 95% confidence limits of the mean bias. The annual mean differences are 0.92 ^oC with a 95% error bar of 0.07 ^oC) for T_{max} and -0.23 ^oC (with a 95% error bar of 0.27 ^oC) for T_{min}.

A difference in temperature measurement between two nearby stations (as shown in Figure 2 and Table 1) can be influenced by many factors, including the difference in instrumentation and surface characteristics. The difference in instrument systems includes primarily the difference in radiation shields and physical characteristics of the sensors. We are aware that the response time for sensors of LIG, MMTS and PRT differ from each other (Dr. X. Lin at University of Nebraska-Lincoln, personal communication) and this might result in differences in measured temperatures. However, the data we have only allow us to investigate the influence of solar radiation and wind speed. These two factors explain the majority of sensed temperature differences between aspirated and non-aspirated shields.

Two sets of co-located stations with the longest records available were selected for the analysis of shield effect: Kingston, RI with the CRS system and Durham, NH with the MMTS system. A solar-driven warming effect is shown at both sites (Figure 3): the COOP-minus-USCRN T_{max} increases significantly with the increase in solar radiation. This may explain why highest and lowest T_{max} differences occur in summer and winter, respectively (Figure 2). T_{max} differences tend to decrease with the increase in ambient wind speed, although the relationship is not statistically significant. The solar and wind effects in Figure 3 are quite similar to those obtained from experimental data (Lin et al. 2001), indicating the related warmer COOP T_{max} most probably due to the absorption of solar radiation into the non-aspirated shield. We did not notice any statistical relationship between wind speed and COOP-minus-USCRN T_{min}. As will be shown in the next section, the probable reason is the signal of the instrument bias is masked by the strong effect of siting exposure. Section 3.2 also will discuss why the COOP-minus-USCRN T_{max} and T_{min} behave so differently from station to station.

	COOP station	Sept. (km)	Elev. (m)	T_{max} (^oC)	T_{min} (^oC)
CRS Vs. USCRN	Fletcher, NC	0.8	-30	1.49	-2.12
	Kingston, RI	0.9	-24	1.11	-0.14
	Newston, MS	1.0	-91	0.93	-0.82
	Kingston,RI	1.1	-40	1.12	-0.67
	St. Martinville,LA	1.3	-5	1.14	0.23
	Brady Aznoe, MT	8.0	42	0.73	-1.25
	Whiskeyton Res., CA	8.0	-117	0.63	0.70
	Fletcher, NC	9.3	-130	1.21	-1.07
	Candler,NC	9.5	157	0.54	1.11
MMTS Vs. USCRN	Stillwater,OK	0.4	-15	0.66	0.50
	Gilmore Creek, AK	0.8	-260	0.22	-3.74
	Stillwater,OK	2.3	-14	0.89	1.30
	Tucson, AZ	2.9	-207	0.95	-0.10
	Durham, NH	3.0	-83	0.90	-0.31
	Canelo,AZ	4.1	152	0.39	-2.26
	Durham, NH	4.6	-25	0.74	0.04

Table 1. Annual means of COOP-minus-USCRN T_{max} (Column 5) and T_{min} (Column 6) at co-located sites (within 10km). Column 2 denotes the station separation distances at the co-located sites and Column 3 represents the COOP-minus-USCRN elevation differences. Some COOP stations are listed twice as they are compared to each of the paired USCRN sites.

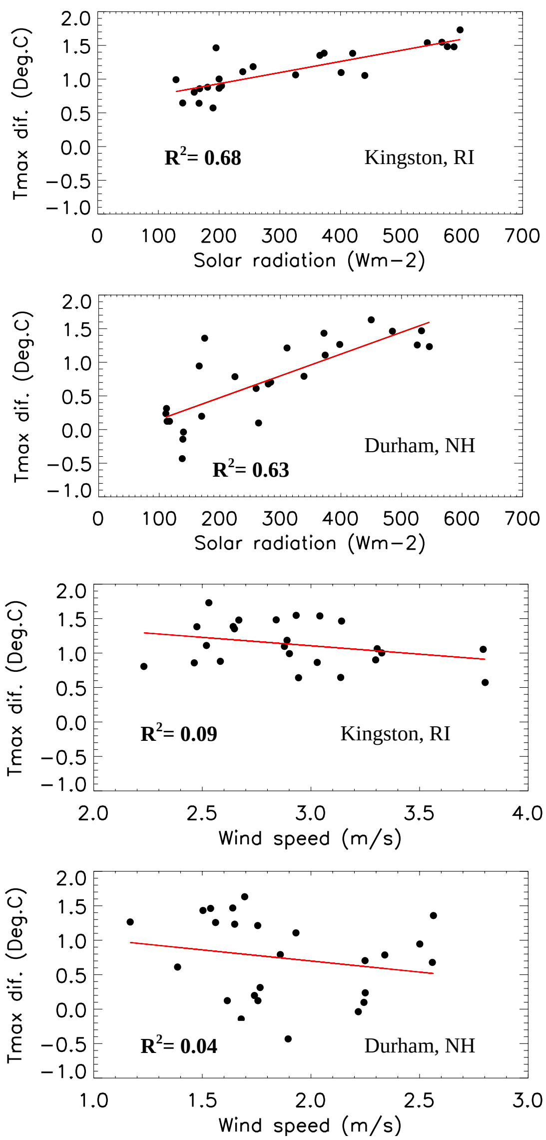

Figure 3. Influences of solar radiation and wind speed on COOP-minus-USCRN T_{max} differences. Monthly values from Kingston, RI and Durham, NH are shown.

3.2 *Siting Effect*

It is practically impossible to separate instrument biases from siting or exposure biases. USCRN sites are generally located in open and rural areas, however the microclimatic environments at paired USCRN sites still differ from site to site. As a result, the data from these paired stations provide an ideal resource to analyze the effect of the siting differences, since the paired stations employ identical temperature sensors, radiation shields, and common sampling periods of the raw data.

Table 2 shows temperature differences at seven sets of paired sites. At all individual paired sites, T_{min} differences are much larger than T_{max} differences. The mean absolute difference averaged from all seven sets is 1.00°C for T_{min}, about 2.5 times larger than for T_{max}. The mean absolute difference averaged from paired stations within 10 km is 0.71°C for T_{min}, about 4 times larger than for T_{max}. The weaker effect of siting on T_{max} is the consequence of daytime heating and the enhanced mixing of the lower atmospheric boundary layer. However, the effect of siting is stronger for T_{min} since it is highly sensitive to surrounding environment and local terrain. For example, the USCRN site at the Arboretum near Asheville, NC is located in a shallow topographic bowl and is surrounded by trees 25 to 50 meters away. These siting characteristics allow for low wind speeds, reduced mixing of the boundary layer, and the drainage of cooler air towards the site. Contrasted to this is the USCRN site at the Horticultural Center only 10 km to the South-Southeast. It is open to the wind and sits on a small hill that allows any locally cooled air to drain away from the site. Thus the mean difference of T_{min} is 1.11°C cooler at the Arboretum. Paired stations at Stillwater OK are both located at fairly open sites, however, one station is located on a slight hillside while the terrain surrounding the other station is quite flat. The cold air drainage effect at the first site thus brings a T_{min} difference of 0.85°C between these two sites. A dramatic effect of cold air drainage is better seen at Gilmore Creek, AK, where the COOP station is only 0.8 km away from the USCRN station but lower in elevation by 260 meters. This different exposure leads to a T_{min} difference of 3.74°C annually.

Paired site	Sept. (km)	Elev. (m)	T_{max} (°C)	T_{min} (°C)
Kingston, RI	1.5	4.8	0.07±0.02	-0.48±0.01
Stillwater, OK	2.5	0.3	-0.28±0.01	-0.85±0.03
Durham, NH	7.2	17.4	0.16±0.01	-0.37±0.02
Asheville, NC	10.0	30.0	-0.18±0.02	1.12±0.03
Newton, GA	13.7	1.2	0.15±0.02	0.72±0.03
Wolf Point, MT	21.7	169.8	1.63±0.04	-2.78±0.11
Lincoln, NE	29.9	63.0	0.47±0.03	-0.64±0.04

Table 2. T_{max} and T_{min} differences between stations at paired USCRN sites. The differences are calculated by subtracting values of stations with higher elevations from of stations with lower elevations. Column 2 denotes the station separation distances at paired sites. Column 3 is the station elevation differences. The 95% confidence limits are also listed in Table.

It is concluded from Table 2 that differences in siting exposure can lead to a significant T_{min} difference between two nearby stations. In other words, T_{min} is highly site-sensitive. The difference in T_{min} introduced by a difference in siting exposure in fact is much larger in magnitude than the instrument bias found in experimental data (Lin et al. 2001). This may explain why the station-to-station variability in COOP-minus-USCRN T_{min} (Figure 2 and Table 1) is so large. Although its physical forcing may vary with time and space, siting effect can be well described by certain meteorological parameters. Table 3 shows an example of influences of cloud and wind on siting exposure effect calculated from paired USCRN sites at Asheville, NC: siting effect decreases in magnitude with increases in cloud cover and decrease in cloud height and wind speed.

Cloud Cover Effect

Sky condition	Clear, few, scatter	broken	overcast
Hours	5438	1092	1500
Temp. dif. (^oC)	1.40	0.56	0.32

Cloud Height Effect (overcast case)

Cloud height (m)	500~2000	0~500
Hours	564	753
Temp. dif. (^oC)	0.39	0.15

Wind Effect

Wind speed (ms^{-1})	0~1.5	1.5~3	>3
Hours	4328	931	179
Temp. dif. (^oC)	1.22	0.91	0.53

Table 3. Influence of cloudiness and wind speed on siting effect. Nighttime hourly data from the paired USCRN stations at Asheville, NC (see Table 2) are used. Cloud information was obtained from the ASOS station at the Asheville Regional Airport. Temperature differences between these two paired CRN stations are used to characterize the siting effect.

4. SUMMARY

Temperature comparisons of COOP stations with USCRN stations co-located within 10 km revealed that (a) a warming of 0.92^{o}C (with a 95% error bar of 0.07 ^{o}C) occurs in COOP T_{max} and this apparent warming most probably is dominated by the effect of non-aspirated radiation shields used in COOP stations; and in contrast (b) an average annual cooling of 0.23^{o}C is shown in COOP T_{min} but with a large station-to-station variability. Analysis of data from paired USCRN stations (within 10 km) indicates siting effect associated with T_{min} is 0.71^{o}C, about 4 times greater than T_{max}. The T_{min}-related siting effect can be thus overwhelmingly larger in magnitude than the instrument bias. Cautions are therefore needed in the homogeneous adjustment of historical datasets by using the USCRN measurements.

Due to limited data samples, results drawn from this study are preliminary. At the time when datasets with longer records and from more stations are available, we will analyze the temperature differences separately for CRS and MMTS systems, which may be different as suggested by Quayle et al. (1991).

5. REFERENCES

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