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Perspectives on Temperature Trends and Variability from the First US Climate Reference Network Stations

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1. INTRODUCTION

The United States Climate Reference Network (USCRN) is a National Oceanic and Atmospheric Administration (NOAA) initiative that when fully commissioned in 2009 will be comprised of 114 climate stations across the U.S. The ultimate goal of USCRN is to provide long time series of homogenous climate observations, for temperature and precipitation in particular. These high-quality observations can be utilized in concert with data from denser networks to increase the fidelity of numerous monitoring applications, such as placing real-time observations into a historical perspective, as well as the detection and attribution of present and future climate change.

In June 2000, the first two USCRN stations were installed near Asheville, NC, which is located in western North Carolina. After months of testing and evaluation, these stations became operational in mid-2001, supplying the first stream of data from the USCRN. The seven years of data collected since that time support an early analysis into trends and variability in temperature and precipitation. In the present investigation, monthly temperature data from these pioneering stations are analyzed and compared with homogeneity adjusted data from nearby COOP stations to examine the potential usefulness of USCRN data.

2. ASHEVILLE USCRN STATIONS

The two Asheville USCRN stations are located in the valley south of downtown Asheville. The first station is located at the North Carolina Arboretum, and is also called the Bierbaum site (we denote this as station A). The other USCRN station is located at the North Carolina Mountain Horticultural Crops Research Center (station B), which is also referred to as the Backlund site. The former station is located near the Blue Ridge Parkway, whereas the latter is located within a few miles of the Asheville Regional Airport (AVL). See Figure 1 for more details.

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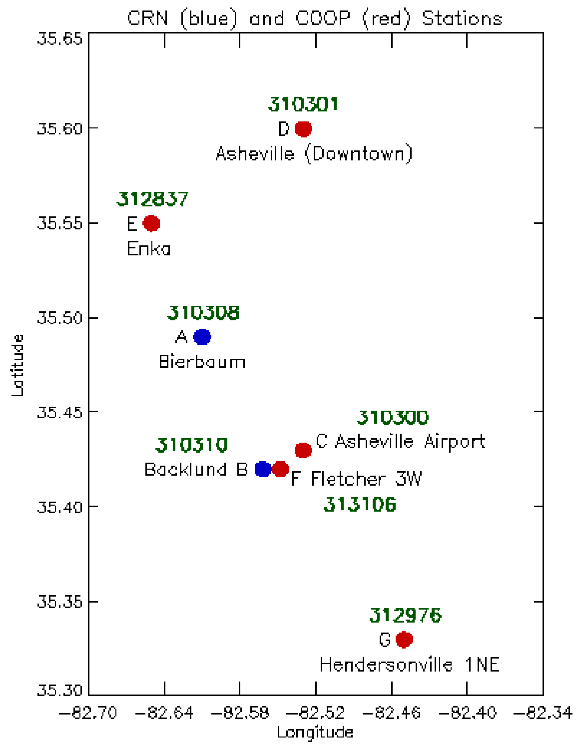

Figure 1. Location of the USCRN and COOP stations, including COOP ID's.

3. NEARBY COOP STATIONS

Five nearby COOP stations were utilized for comparisons with the USCRN data (see Figure 1). Collectively, all seven stations are located at elevations ranging from 625m to 683m, with the two USCRN stations falling near the middle of this range (see Table 1). Only COOP stations with few missing/flagged values were included, eliminating several stations in the vicinity. The five COOP stations are located at AVL (C), Asheville (D) in the city's downtown, Enka (E), Fletcher 3W (F), and Hendersonville 1NE (G). This COOP data set underwent rigorous quality control (QC), including various bias adjustments (including time of observation bias) and homogenization. More information on the QC can be found in Menne and Williams (2008) and Menne et al. (2008).

Table 1. COOP ID, elevation, and the specific months for which there are missing/flagged data values.

COOP ID	Elevation (m)	Months Missing/Flagged
310308 (A)	656	7/02,8/03,10/03
310310 (B)	641	6/02,7/02,10/03
310300 (C)	652	-
310301 (D)	683	7/08
312837 (E)	625	8/01,9/01,1/02
313106 (F)	631	-
313976 (G)	659	5/04

4. METHODOLOGY

First, missing values were filled based on neighboring data values. Collectively, less than 2% of data values were missing/flagged, and only one month (July 2002) was missing/flagged for more than one station. Normal deviates were computed for each month at each station. Missing values were filled by taking the average normal deviates of neighboring non-missing values, multiplying by the local standard deviation of non-missing values, and adding the local mean of non-missing values.

Next, correlation coefficients between the seven stations were computed on anomalies of the maximum and minimum temperature series. Anomalies were calculated by removing the monthly seven-year mean from each observation (including filled values). Finally, Empirical Orthogonal Function (EOF) analysis was applied to the space-time anomaly array of each variable.

5. RESULTS

Correlation coefficients are shown in Table 2. The red (blue) values denote maximum (minimum) temperature correlations. All values involving the USCRN stations are greater than +0.88, indicating very strong agreement between the USCRN sites and neighboring COOP stations.

Table 2. Correlation coefficients between the 7 stations for maximum (red) and minimum (blue) temperatures.

	A	B	C	D	E	F	G
A	1.00	0.99	0.97	0.92	0.92	0.89	0.93
B	0.97	1.00	0.98	0.91	0.91	0.90	0.94
C	0.92	0.98	1.00	0.95	0.90	0.92	0.95
D	0.89	0.95	0.98	1.00	0.88	0.90	0.94
E	0.90	0.94	0.93	0.91	1.00	0.83	0.88
F	0.88	0.94	0.95	0.94	0.92	1.00	0.90
G	0.91	0.96	0.97	0.94	0.94	0.92	1.00

The leading EOF modes for maximum, minimum, and mean temperature account for 94%, 93%, and 93% of the total variance, respectively (Table 3). Further demonstrating the viability of the USCRN readings, the station loadings for the leading EOF modes are relatively uniform. This, in conjunction with the large Eigenvalues, implies that the seven stations exhibit highly coordinated fluctuations with respect to their individual monthly normals. Residual EOF modes do not reveal any systematic biases over the entire seven-year period, and largely appear to be indistinguishable from noise (though some ephemeral spikes were detected).

Table 3. Station loadings for the leading modes of Tmax, Tmin, and Tavg.

	Tmax1	Tmin1	Tavg1
% Variance	94%	93%	93%
Loading A	0.380	0.397	0.377
Loading B	0.378	0.376	0.353
Loading C	0.374	0.370	0.369
Loading D	0.375	0.379	0.397
Loading E	0.376	0.388	0.389
Loading F	0.380	0.389	0.390
Loading G	0.383	0.344	0.369

The leading PC time series are plotted in Figure 2. These represent the common time evolutions of each of seven stations' time series. Month-to-month variations are clearly present, though the short seven-year record length precludes the use of spectral analysis to analyze inter-annual to longer scale variations. The effective trends (the product of the PC trend and the station loadings) are approximately +0.4°C dec^{-1}, -0.1°C dec^{-1}, and +0.2°C dec^{-1} for maximum, minimum, and mean temperature, respectively.

6. DISCUSSION

The analysis presented here provides an early look at the potential usefulness of the USCRN Network. The two pioneering Asheville, NC, sites are strongly correlated with neighboring COOP stations. In addition, the sites were utilized in conjunction with the COOP sites in EOF analysis, which showed the area has likely experienced a slight warming over the last seven years in maximum monthly temperature. As these USCRN stations, as well as the other 112 in the network, provide more mature climatological time series, their full potential will very likely be realized.

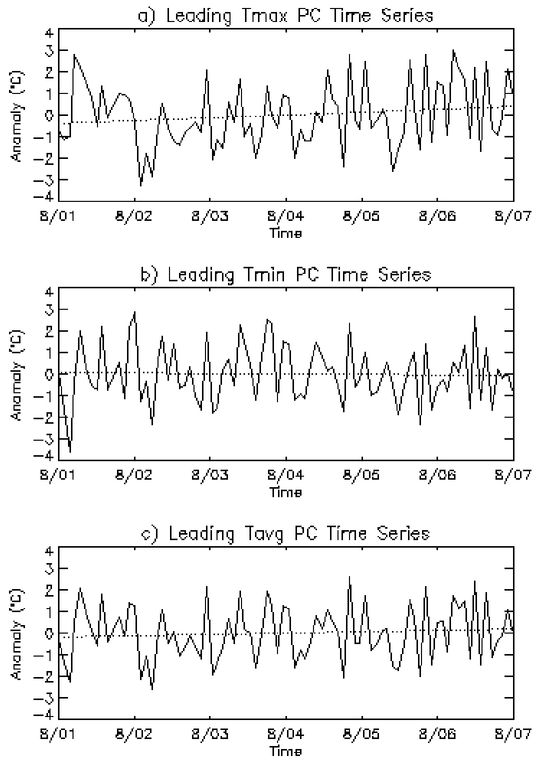

Figure 2. Leading PC Time Series for a) maximum, b) minimum temperature, and c) mean temperature. The best fit linear trend is shown as a dotted line.

7. REFERENCES

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