**3.10 EXAMINATION OF POTENTIAL BIASES IN AIR TEMPERATURE CAUSED BY POOR STATION LOCATIONS**

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## 1. INTRODUCTION

During the last couple decades, a great deal of effort has gone into developing methods to adjust station temperature time series to account for inhomogeneities caused by changes in instrumentation, observing practices, and the many other factors that can cause non-climatic biases in the time series. Reviews of homogeneity testing and adjustment techniques indicate that many approaches successfully remove discontinuities from the time series no matter what the cause (Aguilar, 2005; Peterson et al.,1998). But can these approaches compensate for problems caused by poor siting and particularly changes to siting? Davey and Pielke, Sr. (2005; hereafter Davey and Pielke) did an in-depth analysis of weather observing stations in eastern Colorado and concluded that sites with good temperature exposure characteristics were in the minority. They expressed concern that the poor siting could be causing a bias in the temperature record but, as noted by Vose et al. (2005), did not show that the problem actually resulted in spurious trends.

These two competing hypotheses yield very different predictions. If the homogeneity adjustments are appropriately accounting for changes at the stations, then a temperature time series from the poorly sited stations should be very similar to the time series from the stations with good siting. The trends from the poorly sited stations may be a little higher or a little lower, but they should still be about the same. On the other hand, the presence of biases caused by poor siting would predict that the stations with poor siting would have distinctly increased temperature trends compared to the stations with good siting. While Davey and Pielke suggested the poor siting induced bias could be positive or negative, the underlying concern about the effects of potential siting biases is whether a significant portion of the recent warming indicated by the U.S. and global temperature record could be due to this bias rather than climate change.

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## 2. METHODOLOGY

To test these two hypotheses, U.S. Historical Climatology Network (USHCN; Easterling et al., 1996) mean temperature data were analyzed for the stations listed in Davey and Pielke with good exposure and those with poor exposure. Mean temperature time series from these stations were converted to anomalies by subtracting the average 1971-2000 temperature at each station from its time series. The good exposure station anomaly time series were averaged together as were the poor exposure time series. While Davey and Pielke report that ten USHCN stations were inspected, only 8 USHCN stations were described in detail. Two stations were listed as having good exposure, Trinidad and Cheyenne Wells. Two stations were described as having questionable site exposure or a mixture of conditions such as being well ventilated but near a gravel road and were not used in this analysis. Four stations were listed as having poor exposure: Eads, Lamar, Las Animas and Holly. These sites had multiple problems with the most dominant one being sited too close to obstructions such as houses.

The current USHCN adjustment methodology is based on metadata. If a station history file indicates a change, for example, in instrumentation or station location, took place, the historical record is adjusted up or down to make it equivalent to what would have been observed by the current instrumentation at the current observing location. Table 1 shows the dates of the homogeneity adjustments made at these six stations (two good, four poor) during the last 40 years for changes in station location, instrumentation and time of observation. Note that one the two stations with good siting had no homogeneity adjustments during this period and the other only had minor changes in time of observation. No adjustment of any kind was applied to any of the stations after 1993.

Unfortunately though, some station changes are not documented in the station history file. A new adjustment methodology for the USHCN that also uses statistical techniques to find undocumented changes is in the evaluation phase (Williams and Menne, 2005). The preliminary results of this technique indicated that one of these six stations had an undocumented change. That was Holly in 1996. Therefore, Holly, one of the poorly sited stations, was not included in the analysis.

**Table 1. Dates of homogeneity adjustments since 1965.**

| Station | Changes in location | Change in instrumentation | Major changes in time of observation[1] | Minor changes in time of observation[2] |
|---|---|---|---|---|
| Trinidad | None | None | None | None |
| Cheyenne Wells | None | None | None | 1981, 1987 |
| Eads | 1981 | 1986 | 1982, 1987 | 1993 |
| Lamar | 1978, 1986, 1991 | 1988 | 1989 | 1979, 1992 |
| Las Animas | None | 1986 | 1989 | None |
| Holly | None | 1988 | 1988 | 1990 |

[1] Major changes are when, for example, a morning reader becomes an afternoon reader.

[2] Minor changes when for example, a morning observer stays a morning observer but the time of observation changes from 8:00 AM to 7:00 AM.

## 3. RESULTS

The average anomaly time series for the last 40 years from the two stations with good exposure and the three stations with poor exposure are shown in Figure 1 for raw data and Figure 2 for homogeneity adjusted data. Examination of the linear trends from 1965 to 2004, which are also shown, reveals that the stations with good siting show significantly more temperature increase than the stations with poor siting in the raw data but the trends are not significantly different in the adjusted data. However, if one analyzes different periods one can find times when the difference in trends in the adjusted data is significant and when the sign of the trend in the difference series is positive or negative. If the analysis had included the incompletely homogenized data from Holly, the results would have indicated that with homogeneity adjusted data the stations with good siting were warming significantly more than the stations with poor siting.

The key feature of Figure 2 is not that the trends are similar but that the entire time series are very similar. As indicated in Table 1, neither of the stations with good siting had significant homogeneity adjustments so that the raw and adjusted time series are essentially identical[†]. The stations with poor siting, however, underwent significant homogeneity adjustments for changes in instrumentation, time of observation, and station location. These adjustments brought the quite different time series from the poorly sited stations into close agreement with the homogeneous stations with good siting.

[†] Due to two small changes in the time of observation at Cheyenne Wells, the homogeneity adjusted anomaly time series for the stations with good siting is 0.000 to 0.008 °C cooler than the raw values for the period 1965-1980, 0.069 to 0.121 °C warmer during 1981-1987, and 0.046 to 0.049 °C cooler for the period 1988-2004.

## 4. CONCLUSIONS

Classically, science progresses by developing hypotheses that lead to predictions which can be evaluated by comparison with physical reality. Each successful prediction adds to the weight of evidence supporting the theory, and any unsuccessful prediction demonstrates that the theory is imperfect and requires improvement or abandonment. As the number of stations evaluated in this study is quite limited, the results can not be definitive but they can supply some evidence in support or rejection of a hypothesis. The results clearly support the theory that homogeneity adjustments can account for changes in siting of stations, even changes to poor siting conditions, and serve as counter-example to the hypothesis that poor current siting causes a warm bias or even any bias in the homogeneity adjusted U.S. temperature record.

Because the data from the stations with good siting were essentially homogeneous to begin with, having the adjustments change the time series from the stations with poor siting from being very different to agreeing very well with the time series from the stations with good siting indicates that homogeneity adjustments do an excellent job of compensating for bias producing changes at the stations no matter what the cause. Indeed, the similarity between the two homogeneity adjusted time series supports the view that even stations which do not, upon inspection, appear to be spatially representative can, with proper homogeneity adjustments, produce time series that are indeed representative of the climate variability and change in the region.

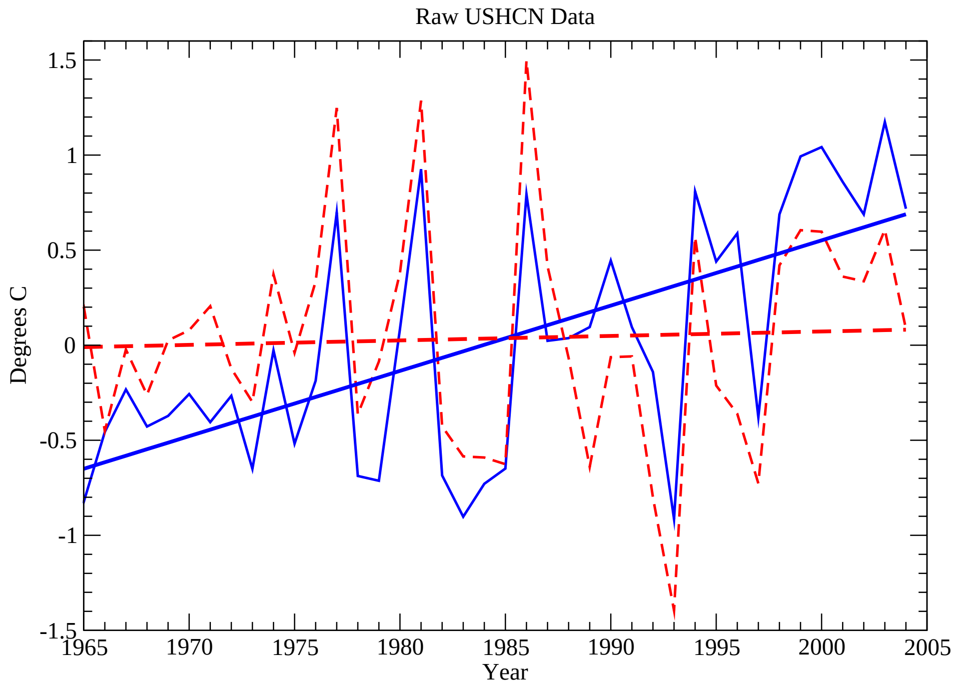


**Figure 1. Anomaly time series of raw USHCN mean temperature of the average of two stations in eastern Colorado with good siting (blue) and the average of three stations with poor siting (dashed red). Linear regr**

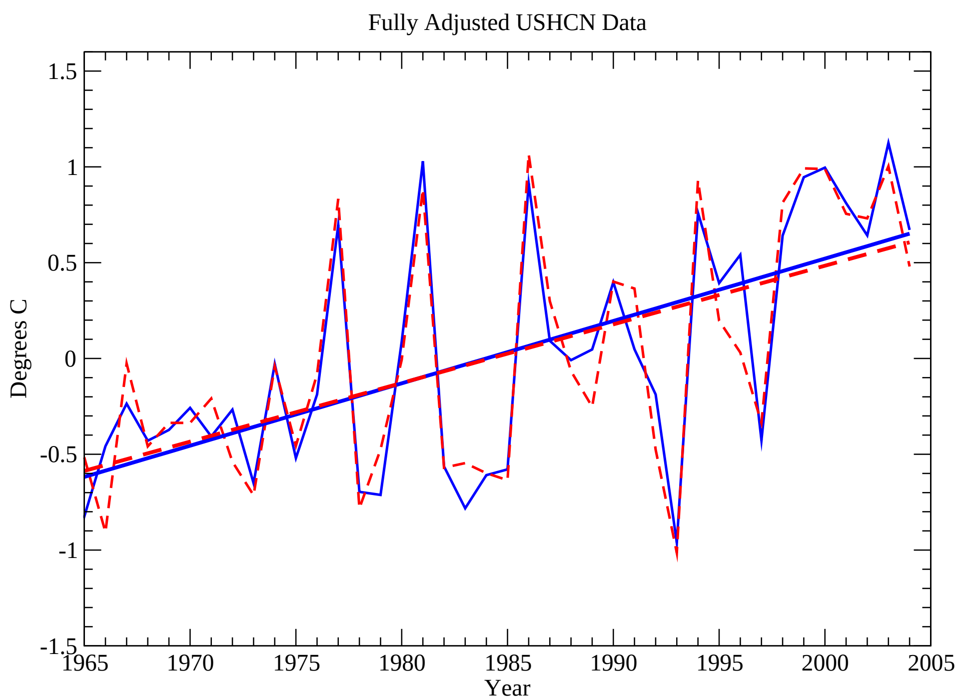


**Figure 2. The same as Figure 1 but using fully adjusted USHCN data.**

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