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CLIMATE NETWORK FLAWS

# MONTH OF MENACE

## EXPLAINING THE MAY 2003 OUTBREAKS

# MICROCLIMATE EXPOSURES OF SURFACE-BASED WEATHER STATIONS

## Implications For The Assessment of Long-Term Temperature Trends

BY CHRISTOPHER A. DAVEY AND ROGER A. PIELKE SR.

New photographic metadata of eastern Colorado stations are examined, raising questions about the usefulness of current surface datasets for climate applications.

The U.S. Historical Climate Network (USHCN; Karl et al. 1990) consists of a subset of stations from the National Weather Service (NWS) cooperative (COOP) station network. The USHCN stations are used in the construction of homogeneous climate data reference series and in the detection and monitoring of long-term climatic trends. Stations are selected for the USHCN dataset based on the length of period of record, the percentage of missing data in the station's record, the total number of station moves and other station changes that may affect the homogeneity of the site's data, and, finally, how the site contributes to the spatial coverage of the USHCN network.

By themselves, these criteria, however, are not adequate in addressing specific station characteristics such as how well the instrument siting adheres to internationally accepted standards of exposures (described fully in WMO 1996). In particular, it is important to know the site of stations relative to various structures and surfaces. Generally, near-surface air temperature observations should be representative of the free-air conditions over as much of the vicinity as possible, at a height approximately 1.5 m above the ground. The site should be level, without locally significant topographical variations or steep slopes or hollows, and should offer free exposure to both sunshine and wind (not to close to trees, buildings, or other obstructions; WMO 1996).

It thus becomes critical to conclusively determine how much of any potential regional change in observed air temperatures might be due to land-use changes at the site itself. These changes may include local-scale urban development around the site, changes in local vegetation characteristics, etc. Those who are monitoring long-term climate trends need

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**Fig. 1. MMTS installation near Lindon, CO.**

**Fig. 2. MMTS installation near John Martin Reservoir, CO.**

to know local-scale exposure characteristics to account for this potential problem. Unfortunately, access to such information is difficult. The primary source of metadata for the NWS COOP station network is the database of B-44 forms kept by the National Climatic Data Center in Asheville, North Carolina. Prior to the 1980s, most B-44 forms included a site sketch, illustrating the location of the weather station instrumentation, and the locations of nearby obstructions. Most of the current forms, however, have vague documentation regarding the station's site exposure characteristics. This is true especially for descriptions regarding a site's terrain and surface features. It is important that these types of site sketches be made available again for each COOP station, along with data such as updated site digital photographs, in order to better document site exposures.

In the late spring and early summer of 2002, we visited 57 of the temperature-measuring COOP sites of the plains of eastern Colorado, giving particular emphasis to the USHCN sites (10 total). As a group, these sites revealed a wide variety of site exposure characteristics. Many stations were located at the observer's residences; the temperature sensors, of which the vast majority are now electronic Maximum Minimum Temperature Sensor (MMTS) devices (see Fig. 1), are often unsatisfactorily close (within 2–3 m) to buildings (Fig. 2). This siting practice reflects an effort to minimize the costs of providing electrical power to the sensor, while at the same time providing a measure of open ventilation to the sensor.

In another common situation, the temperature sensor is in a relatively open location, but the surface under and around the sensor is a patchwork of different land-cover types. Frequently, lawn, asphalt, gravel, bare dirt, and concrete were all in relatively close proximity to each other. Sites that met all the WMO site exposure requirements (e.g., Fig. 3) were in the minority.

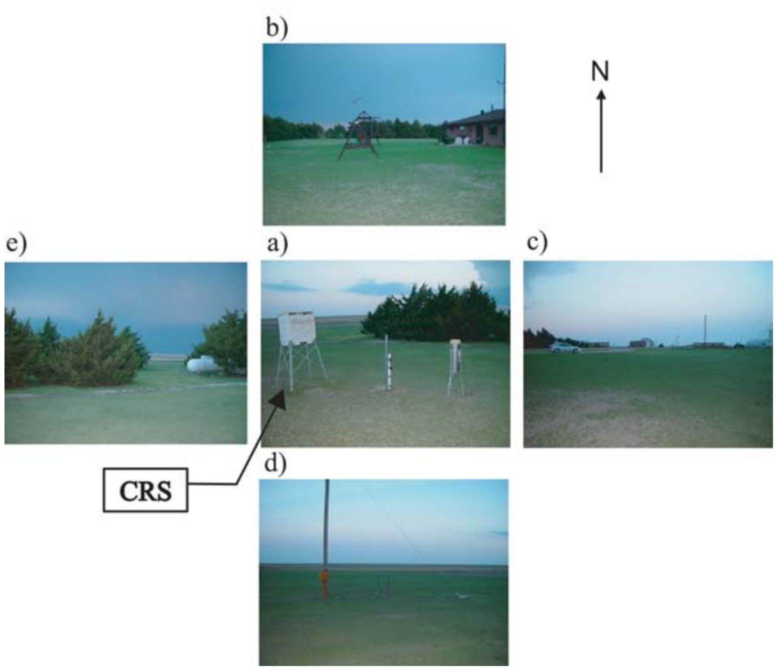


**Fig. 3. Photographs of the temperature sensor exposure characteristics of the COOP station Arapahoe 14N, near Arapahoe, CO. (a) The temperature sensor is a Cotton Region Shelter (CRS). (b)–(e) The exposures viewed from the temperature sensor looking north, east, south, and west, respectively.**

The poorest exposures usually had excessive vegetation around the temperature sensor (Fig. 4) or were locally urbanized and thus not representative of the immediately surrounding region (Fig. 5).

The majority of the USHCN stations we visited had at least one of these common siting problems. Because the criteria used to select USHCN sites, in large part, do not address site exposure features, these sites may indeed reflect a level of variability of site exposures similar to that of the larger COOP network. This poses a potential problem in constructing long-term climate records.

## FIELD SURVEYS OF STATION EXPOSURES.

Temperature data from USHCN locations that we visited (see Figs. 6–14) were used in Pielke et al. (2000, 2002) to investigate the spatial homogeneity of climate trends in eastern Colorado. Those studies concluded that no one site adequately described multiyear trends. Our current study offers one explanation as to why.

The majority of stations were surveyed (with permission of the observers) in June 2002. The stations along the northern Front Range corridor from Denver to Fort Collins, Colorado, were surveyed in July 2002.

At each site, we recorded the latitude and longitude coordinates using a Garmin® 12XL GPS unit and checked them against the metadata available for the station. Next, we photographed each station's temperature sensor and its surroundings. Finally, we sketched the temperature sensor and its site characteristics. These sketches were similar to those that were available on B-44 forms prior to the mid-1980s. We documented the location of the sensor itself along with the locations of all the nearby features and surfaces, within a radius of about 100 m, which may influence temperature readings. These features include, but are not limited to, buildings, trees, and streets.

In addition, at each site, we took at least five photographs. One was a picture of the temperature sensor itself. The other four illustrated the views from the temperature sensor in each of the four cardinal directions (north, east, south, and west). Additional photographs were taken as necessary in order to document important site characteristics.

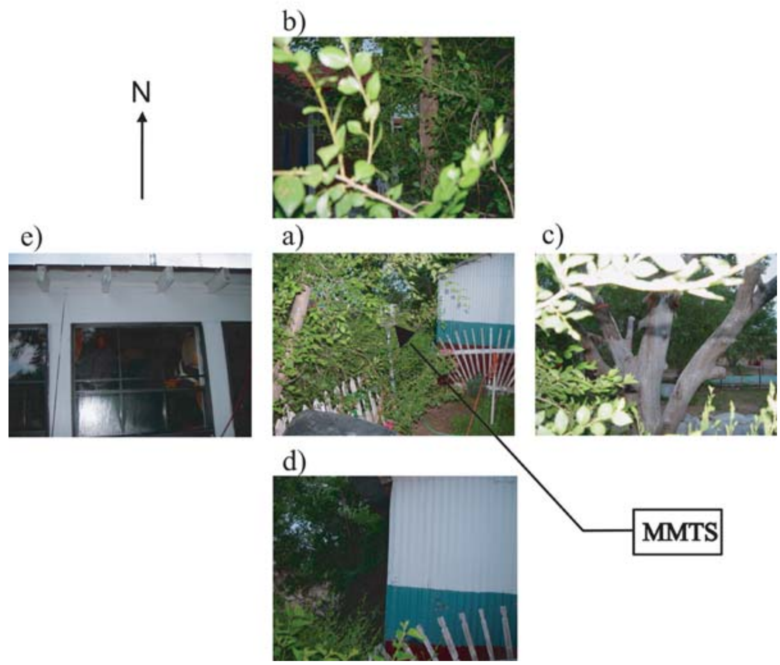


**Fig. 4. Same as Fig. 3, except for the Maximum Minimum Temperature Sensor (MMTS) at Campo 7S, near Campo, CO.**

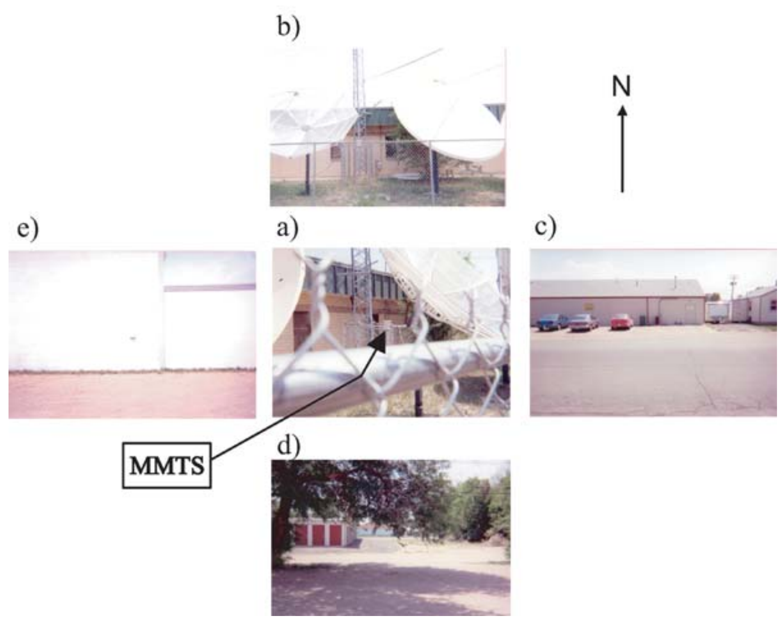


**Fig. 5. Same as Fig. 3, except for Sterling, CO.**

## EXPOSURES AT USHCN SITES.

*Proximity to ventilation obstructions.* The USHCN sites at Eads and

Holly are both examples of exposures where the air temperature sensor is too close to obstructions. The Eads site (Fig. 7) is located in a mobile-home neighborhood on the south side of the town. The MMTS temperature sensor is over a grass lawn on the north side of the observer's mobile home. Small trees and bushes are about 10–15 m east of the sensor and help to shield the sensor from any influences from the street to the east of the observer's property. The site is relatively open to the north and west, with the one exception of a 1.5-m wood fence, about 5 m feet away from the sensor, running along the north side of the observer's property. The one primary flaw for this site is that the temperature sensor is only about 3 m north of the observer's mobile home. Thus, the mobile home may obstruct the sensor's ventilation when there is a southerly wind component.

The Holly USHCN temperature sensor (Fig. 8) is also too close to the observer's home—in this case, 5 m off of the northeast corner. Although this spacing is better than at the Eads site, the two-story home at the Holly site is likely to significantly influence the ventilation of the temperature sensor. Several trees 15 m in height around the north and west sides of the property may further restrict ventilation. Fortunately, the sensor is positioned over a surface consisting of a mixture of grass and weeds.

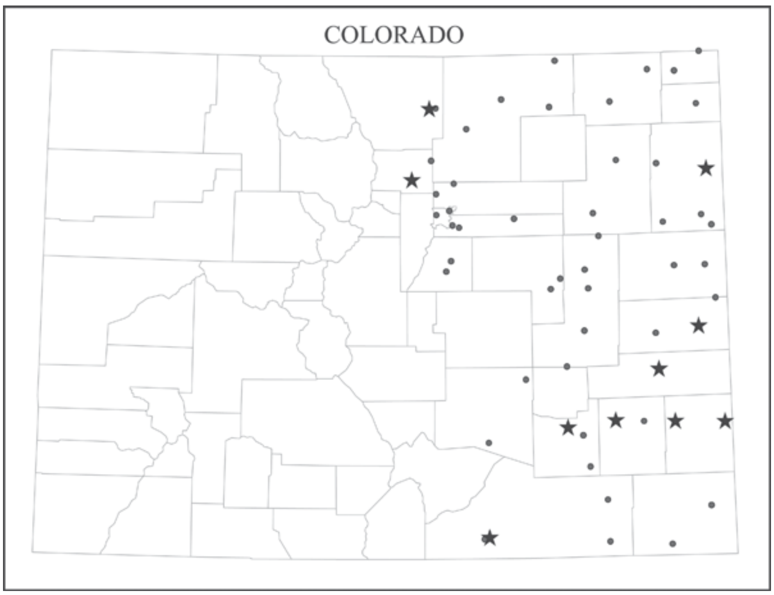


**Fig. 6. Map of study region, showing all surveyed COOP sites. The USHCN sites are indicated by stars.**

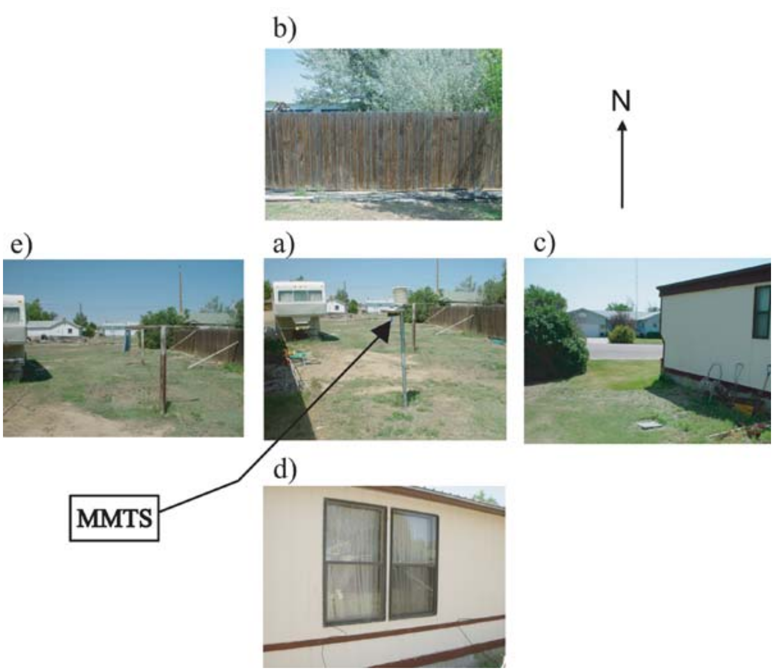


**Fig. 7. Same as Fig. 3, except for Eads, CO.**

*Patchy land surfaces*. At the USHCN sites we also observed sensors that were situated over a satisfactory surface, such as grass lawn or other natural groundcovers, but had multiple types of land covers and surface materials nearby. In these cases, the temperature sensor was usually situated in an open, well-ventilated location. At Rocky Ford 2SE (Fig. 9) in the Arkansas River valley, the temperature sensor shelter is located on the east edge of a gravel driveway. To the north, east, and south, there are scattered one-story buildings, interspersed with larger expanses of grass lawn and/or bare dirt. Fields containing various crops are everywhere to the west of the sensor site. This is definitely an open and well-ventilated site, but the gravel surface beneath the sensor does not represent the region as a whole. There are also many different land covers and surfaces represented at the site. Although the various crops at this site are all commonly found in the region, the complex interaction of the various field plots could still have a marked influence on temperature readings at the site.

*Multiple exposure problems*. There are sites within the USHCN group that, due to multiple site problems, clearly do not meet the WMO exposure criteria for temperature sensors. The USHCN site at Lamar is one example. It is in a mobile-home neighborhood where there is little open space between residences and accompanying buildings (Fig. 10). The temperature sensor is on a grass lawn and is about 1–2 m off the northeast corner of the observer's home. There are only a few meters of open space between the sensor and the neighbor's mobile home. An air conditioning unit on the wall of the observer's home is about 7 m south of the temperature sensor. Just to the east of the residence is a large, deciduous tree about 15 m tall. An asphalt street is about 4 m east of the sensor. In summary, several site exposure factors likely work against obtaining representative temperature observations at this USHCN site.

Wray is another USHCN site with questionable site exposure (Fig. 11). The site is in a river valley that becomes quite narrow as it passes through the east side of Wray, creating significant local topographical variations. The weather station is about midway down the south bank of the valley, so the site is not level. Locally, the valley is also quite sinuous, thus restricting ventilation under certain conditions. The temperature sensor itself is over a grass surface, about 4 m away from the west side of a building and 3 m north of a large satellite dish. These features would both likely restrict ventilation. They could also be sources of artificial heating.

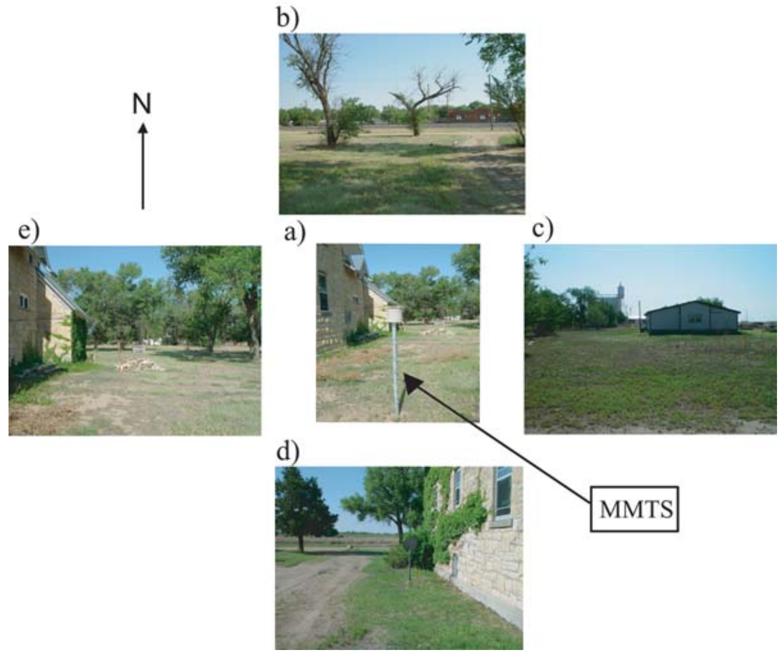


**Fig. 8. Same as Fig. 3, except for Holly, CO.**

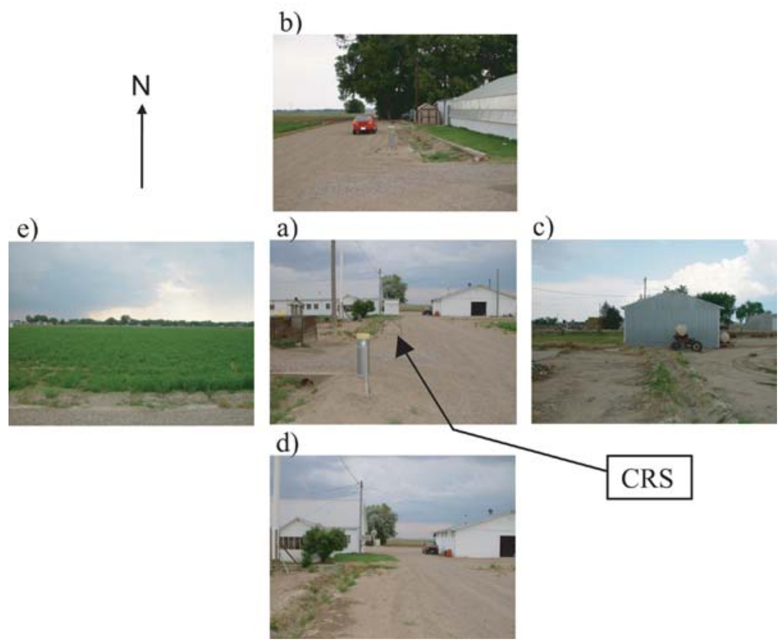


**Fig. 9. Same as Fig. 3, except for Rocky Ford 2SE, near Rocky Ford, CO.**

The Las Animas site had, by far, the poorest exposure for the USHCN sites we visited (Fig. 12). The temperature sensor is set up over a gravel surface at the southeast corner of the main building of the Las Animas Power Plant. The sensor was moved in the 1980s from an open field about 50 m northwest of the power plant building to its current location on the southeast side. The 10-m building is only about 2 m west of the sensor. It blocks ventilation for the sensor in all directions north and west. Additionally, an exhaust vent is only 2 m north of the sensor; any air discharges from this vent would very likely affect temperature readings. There are also three short stacks between 3 and 10 m north of the sensor. To the north and east, about 10–20 m away, are several sheds with metal siding, along with several other metal storage features. In summary, this is a very poor site for measuring air temperatures. Sites

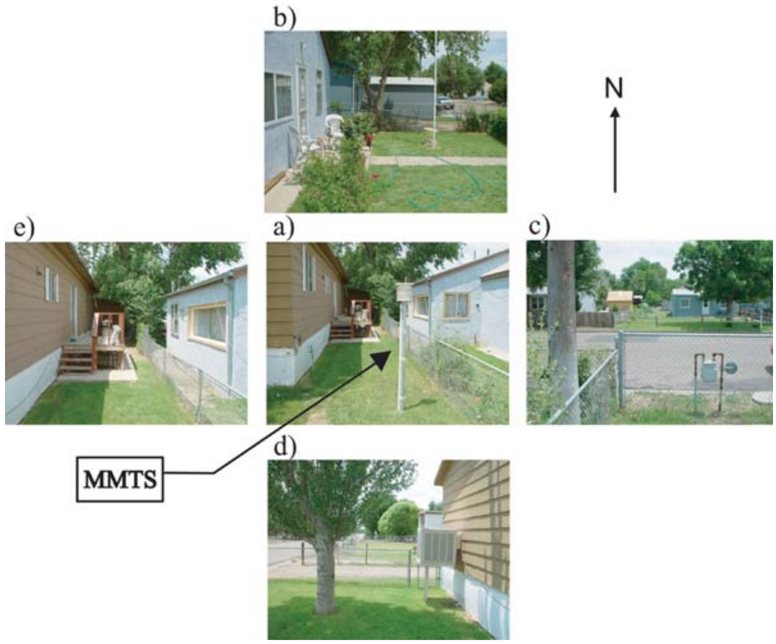


**Fig. 10. Same as Fig. 3, except for Lamar, CO.**

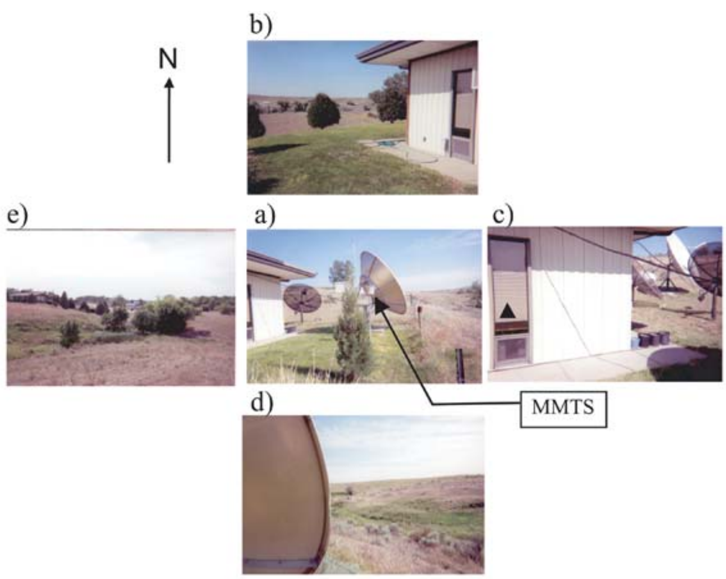


**Fig. 11. Same as Fig. 3, except for Wray, CO.**

such as these, which are blatantly unrepresentative of the surrounding area's climate characteristics, should not be used for developing long-term climate reference datasets and for monitoring long-term climate change.

*Sensor heights*. There were numerous examples of other minor incompatibilities with the WMO temperature sensor exposure standards. The most common incompatibility we found relates to the actual sensor height above ground level at some locations. We never observed sensor heights less than 1.5 m above ground level; rather, all nonstandard sensors we observed had height over 15 m. In fact, some sensor heights were just over 2 m above ground level. This highlights the need for greater care in installing the temperature sensors. Occasionally, there was localized overgrowth of vegetation around the temperature sensors. However, regular maintenance of the land surface (e.g., mowing) can quickly remedy such problems.

*Ideal site exposure*. Certainly, some USHCN sites in our survey did meet the WMO air temperature exposure standards. These sites were very open, allowing for ample ventilation of the temperature sensor. Also, the land cover under the sensor and in the immediately surrounding area was relatively homogeneous.

The USHCN station in Trinidad is an excellent example (Fig. 13). The temperature sensor shelter is in the center of a grass lawn on the east side of the Trinidad Power Plant, between the plant building and U.S. Highway 160. There is at least 10–15 m of grass surface in all directions from the temperature sensor. This buffer is narrowest to the south and west, where an asphalt drive runs in front of the main power plant building. The sensor's exposure is most open to the north and east, toward U.S. Highway 160. Although the power plant is about 10–15 m tall, it is well over 25 m to the southwest of the temperature sensor.

Another USHCN site with good exposure is at Cheyenne Well (Fig. 14). The site is quite open, especially to the south. The site is situated on the south edge of a small bare-dirt lot holding various livestock pens. Farm equipment is scattered just to the north and east. There are open grass fields and pasturelands to the east, south, and west.

**CONCLUSIONS.** In eastern Colorado, variations in site exposures found with the USHCN sites roughly parallel the site exposure variations observed in the wider COOP network. The USHCN sites with good temperature exposure characteristics (i.e., meet all or almost all of the WMO standards) are in the minority in the set discussed in this paper. If the majority of observing sites elsewhere have similar problems to those in eastern Colorado, a significant number will have nonrepresentative exposure features.

Unfortunately, there are sites within the USHCN with poor exposure for air temperature measurements. These sites are not at all representative of their surrounding region. There may be many factors at such sites that could create artificial climate trends, trends that in reality are not being observed over the region as a whole. As such, it is not advisable to use these sites in the detection of climate trends and development of long-term climate datasets. Serious consideration ought to be given to whether or not these sites should be removed from the USHCN dataset. To compensate for the loss of such stations, there are candidate COOP sites that should be reconsidered for inclusion in the USHCN network.

Unless site exposure factors are accounted for, it becomes very difficult to develop spatially representative long-term climate records and conduct long-term climate studies for locations with idiosyncratic station sites. Moreover, it is imperative to determine whether there is a systematic warm or cold bias from site exposure in the set of data that are used to develop regional averages. Photographic documentation of the type gathered in this study can effectively determine whether or not such site exposure issues exist for other locations and should, therefore, be extended to the entire USHCN network as well as to all surface stations worldwide that are used in long-term temperature trend analyses. Similar variability in the climate observing sites in the worldwide dataset of land-surface temperature trends would raise questions concerning the use of the historical record to assess regional and even global temperature changes.

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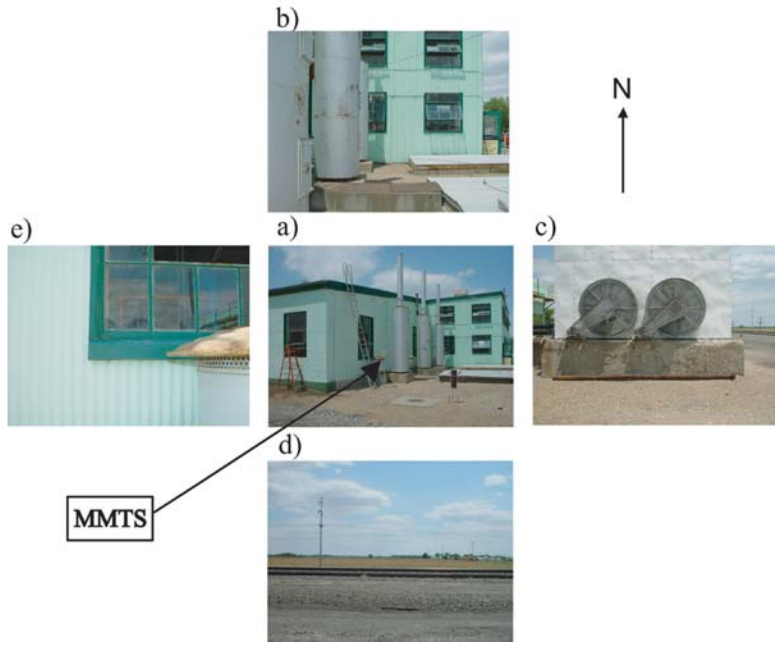


**Fig. 12. Same as Fig. 3, except for Las Animas, CO.**

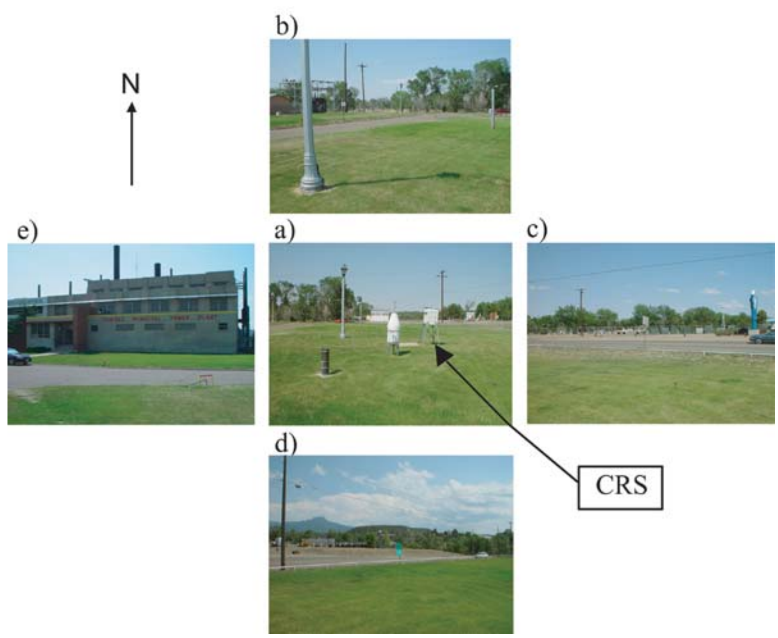


**Fig. 13. Same as Fig. 3, except for Trinidad, CO.**

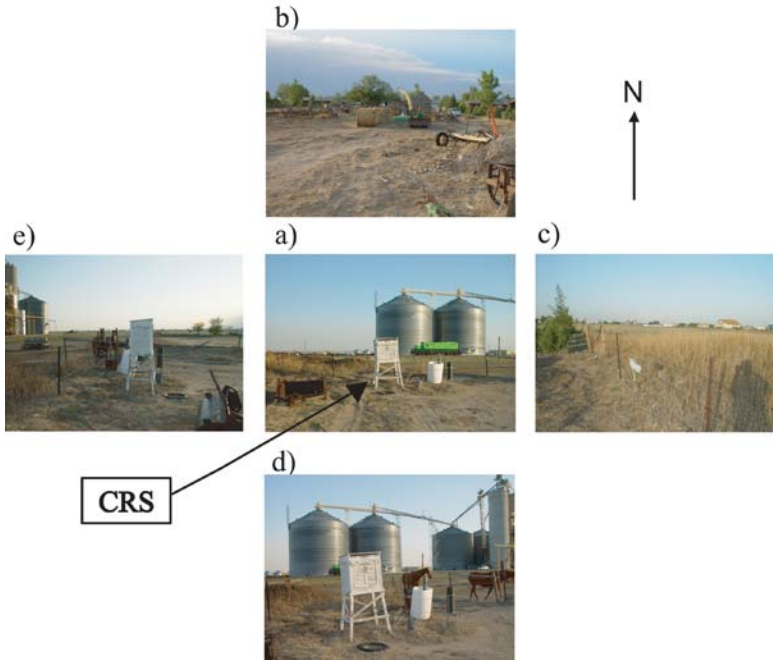


**Fig. 14. Same as Fig. 3, except for Cheyenne Wells, CO.**

also recognize and want to highlight the very important contributions that the Cooperative Observers provide to the monitoring of precipitation and temperatures for use by the National Weather Service and state and regional climate centers. Our paper illustrates only the problems in using temperature data from these sites for long-term climate trend assessment.

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