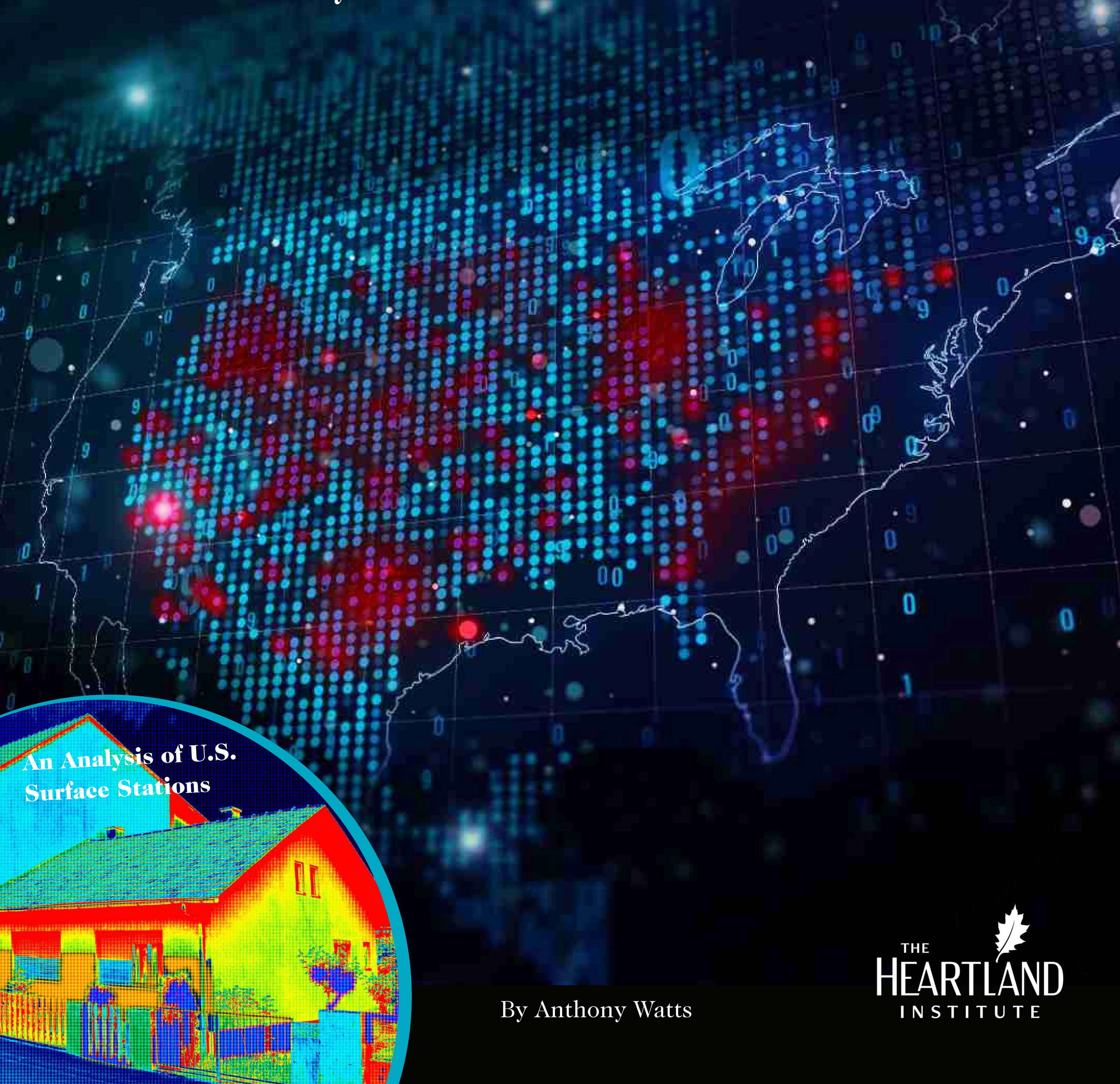
2022 EDITION

CORRUPTED CLIMATE STATIONS

The Official U.S. Temperature Record Remains Fatally Flawed



By Anthony Watts

THE HEARTLAND INSTITUTE

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FOREWORD

This report examines the accuracy and reliability of U.S. temperature stations from which official temperature records are reported, following up from a March 2009 study, titled "Is the U.S. Surface Temperature Record Reliable?"[1] The original report found the ground-based system for measuring surface temperatures in the United States was biased by asphalt, machinery, and other heat-producing, heat-trapping, or heat-accentuating objects located near many official temperature stations and their sensory equipment. The new study reexamines these temperature stations and equipment to determine whether there remains flaws in the official U.S. surface temperature record. This report finds approximately 96 percent of U.S. temperature stations fail to meet what the National Oceanic and Atmospheric Administration (NOAA) considers to be "acceptable," uncorrupted placement. These findings strongly undermine the legitimacy and the magnitude of the official consensus on long-term climate warming trends.

The U.S. surface temperature record is determined from data gathered by the Cooperative Observer Network (COOP), administered by NOAA's National Weather Service (NWS) division.[2] Data are then compiled and presented to the public for climate change tracking by the National Centers for Environment Information (NCEI), formerly known as the National Climatic Data Center (NCDC).[3] NOAA defines the NWS COOP Network as:

> The National Weather Service (NWS) Cooperative Observer Program (COOP) is a network of daily weather observations taken by more than 8,500 volunteers. These data, which include observations from the late 1800's, are vital to understanding the U.S. climate, and also provide near real-time information that supports forecasts, warnings and alerts, and other public service programs. Observations are taken from around the U.S. and its territories at National Parks, seashores, mountaintops, farms, and many urban and suburban areas. COOP data usually consist of daily maximum and minimum temperatures, snowfall, snow depth, and 24-hour precipitation totals. Observations may include additional hydrological or meteorological data such as evaporation or soil temperatures.

The quality of temperature data gathered via the COOP network of stations is what is examined in this report.[i]

[i] For a glossary of acronyms and terms used in this report, please reference Appendix C.

REVIEW OF THE 2009 REPORT[ii]

In the 2009 report, station inspection concentrated on a subset of the COOP network called the United States Historical Climatology Network (USHCN). At the time, USHCN was comprised of 1,225 stations out of the 8,700 stations making up the greater COOP network.[4] The USHCN subset provided a representative sample of the entire system.

A depiction of station coverage in the contiguous United States can be seen in Figure 1.

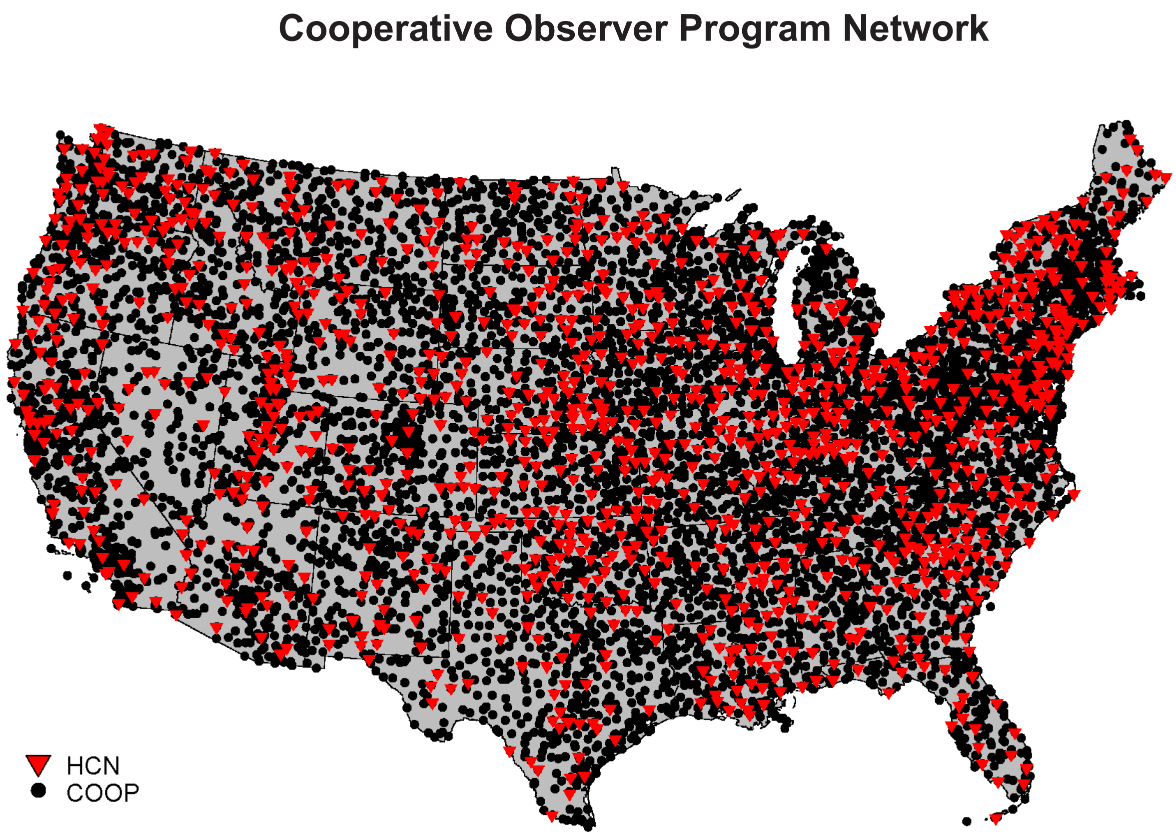


Figure 1: Map of station placement in the U.S. Cooperative Observer Network in black combined with station placement in the U.S. Historical Climatology Network (HCN) in red. Source: NOAA / NCEI.[5]

As seen in Figure 1, the United States is broadly covered with weather stations used for both weather and climate monitoring. All of the stations are placed, maintained, and administered by the NWS utilizing personnel at local and regional NWS Forecast offices.[6]

[ii] The following pages review the 2009 report findings, and reactions from the government and scientific community. For a review of the 2022 report's new findings, skip to page 20.

The COOP and USHCN stations consist of two types of temperature measurement equipment given to the volunteer observers by the NWS. When the network was originally established in 1890, Stevenson Screen or Cotton Region Shelter (CRS) enclosures were used to house mercury-based glass thermometers. This system was gradually phased out by newer Maximum Minimum Temperature Systems (MMTS) housing Nimbus digital thermometers starting in the 1980s. Figure 2 illustrates the comparison between CRS and MMTS enclosures.

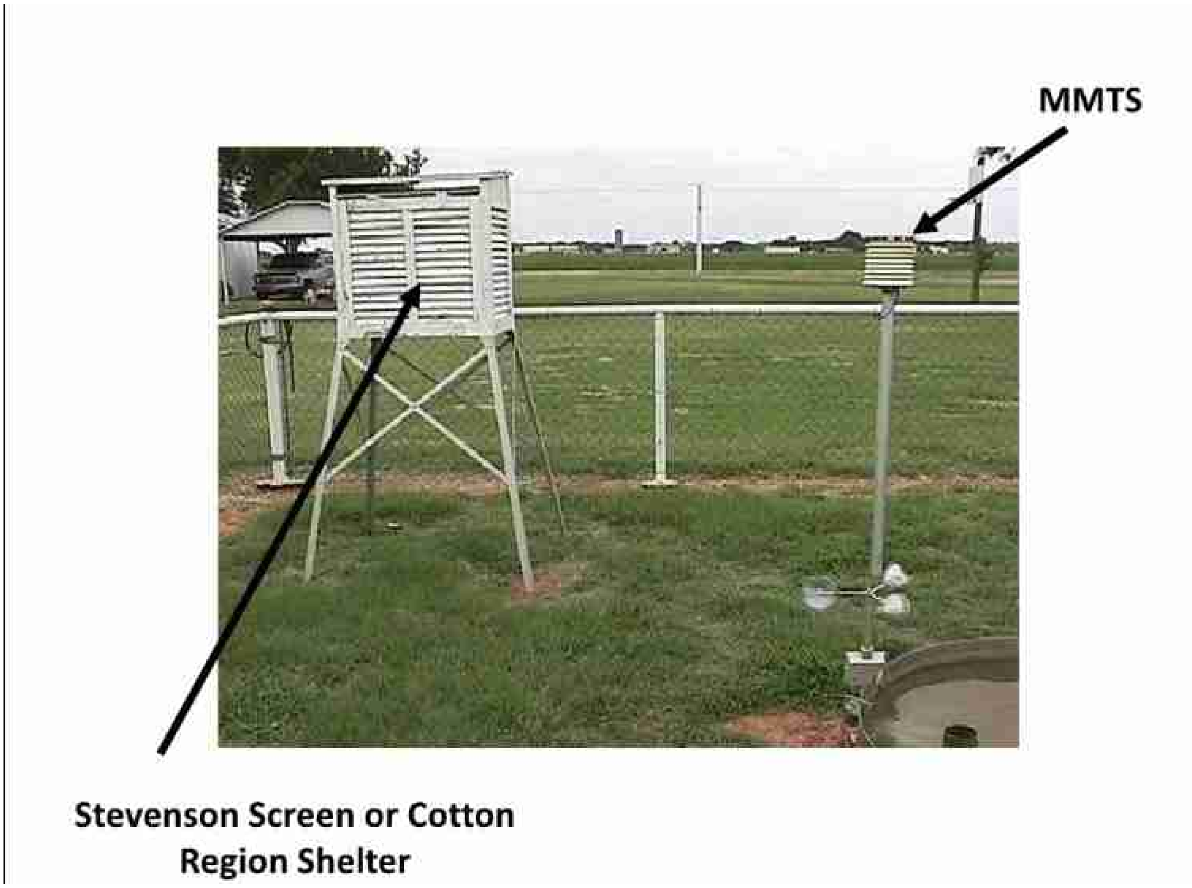


Figure 2: Examples of Stevenson Screen aka Cotton Region Shelter enclosures (left) and the newer MMTS electronic sensor enclosure (right). Source: Pat Guinan.[7]

These electronic thermometers utilize cables from the outdoor sensor that connect to Nimbus electronic readouts located in homes and offices, thereby limiting where the sensors could be placed. The inability of NWS personnel to bury cable under sidewalks, driveways, and roads often resulted in MMTS thermometers being placed closer to buildings, heat sinks, and heat sources compared to their original locations.

The 2009 report surveyed and photographed more than 850 USHCN stations, providing an analysis of their temperature data. The peer-reviewed paper was published and distributed to thousands of lawmakers, scholars, and scientists. Some of the most important findings in the original report are listed below:

- Many climate monitoring stations were located next to exhaust fans of air conditioning units, surrounded by asphalt parking lots and roads, located on blistering-hot rooftops, or placed near sidewalks and buildings that absorb and radiate heat.

- Sixty-eight stations were located at waste-water treatment plants (WWTP), where the process of waste digestion creates higher temperatures than in surrounding areas. In addition, the infrastructure of WWTPs is almost entirely asphalt and concrete, making them unrepresentative of the surrounding area and unsuitable for thermometer placement to measure long-term changes in temperature.

- Approximately 90 percent of the USHCN stations failed to meet the NWS's own siting requirements, which stipulate that stations must be 30 meters (100 feet) or more away from an artificial or radiating / reflecting heat source.[8] A rating system based on official NOAA documents was employed to assess each station.[9] See Figure 3.

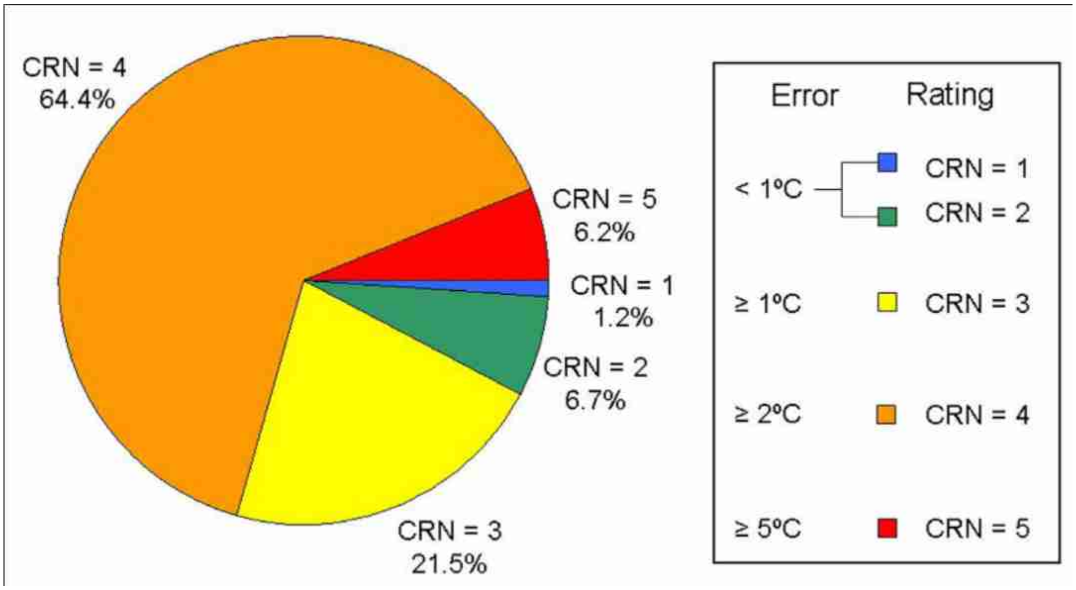


Figure 3: Station quality ratings of the USHCN surveyed in the 2009 report. Stations with CRN ratings of 3, 4, and 5 are deemed unacceptable. In this figure, representing 1,007 USHCN stations out of 1,221, 92.1 percent of all stations surveyed in the USHCN were unacceptably sited by NOAA's own standards. Source: Anthony Watts graphic at surfacestations.org, using data from NOAA / NCDC / NCEI.[10]

Class 1 (CRN1) - Flat and horizontal ground surrounded by a clear surface with a slope below 1/3 (< 19 degrees). Grass / low vegetation ground cover < 10 centimeters high. No artificial heating or reflecting surfaces (buildings, concrete, parking lots) within 100 meters. Far from large bodies of water unless representative of the area, and then located at least 100 meters away. No shading when the sun elevation > 3 degrees.

Class 2 (CRN2) - Same as Class 1 with the following differences: surrounding vegetation < 25 centimeters high, no artificial heating sources within 30 meters, no shading when sun elevation > 5 degrees.

Class 3 (CRN3) - (temperature error >= 1°C) - Same as Class 2, except no artificial heating sources within 10 meters.

Class 4 (CRN4) - (temperature error >= 2°C) - Artificial heating sources < 10 meters.

Class 5 (CRN5) - (temperature error >= 5°C) - Temperature sensor located next to / above an artificial heating source, such as a building, roof top, parking lot, or concrete surface.

- Many stations often had missing, incomplete, or erroneous data, perhaps due to the volunteer-based network of observers who could not always record or report data based upon illness, week-day only reporting, and/or vacation days.

- The report found that major gaps in the data record were "infilled" with temperature data from nearby sites, compounding errors from other stations that were also non-compliant with station siting requirements.

- The report observed that changes in the technology of temperature stations over time resulted in many being placed closer to buildings, as well as other heat sinks such as asphalt, concrete, and brick infrastructure. In some cases, official NWS thermometers were moved to parking lots and next to external heat-generating air conditioner units from previously cooler locations that were no longer available for thermometer placement. See Figure 4.

Figure 4: Old Stevenson Screen / CRS and new MMTS / Nimbus electronic thermometer in Bainbridge, GA, circa 2008. The new MMTS station moved about 150 feet closer to the building to accommodate the new MMTS sensor cable length. The MMTS is recording heat from the air conditioning unit exhaust, house, cars, and asphalt parking lot, whereas the original placement had none of these issues. The station has since been closed by NOAA / NWS. Source: Joel McDade.

- Prior to the 2009 Surface Stations project, the weather stations that produced data for inclusion into the USHCN dataset had never undergone network-wide site quality assessment. The placement, maintenance, and calibration of each site is left up to the COOP manager at local National Weather Service Forecast Offices (NWSFOs).

- The gradual introduction of the MMTS / Nimbus electronic thermometers since their inception in the mid-1980s has likely introduced a slow warming bias. This is due to thermometers being moved closer to buildings, asphalt, concrete, and other man-made influences from older Stevenson Screen and Cotton Region Shelter enclosures. By February 2009, MMTS thermometers outnumbered CRS thermometers by a 2-to-1 margin. See Figure 5. The ratio in 2022 has likely increased significantly due to continuous upgrades over the past 13 years.

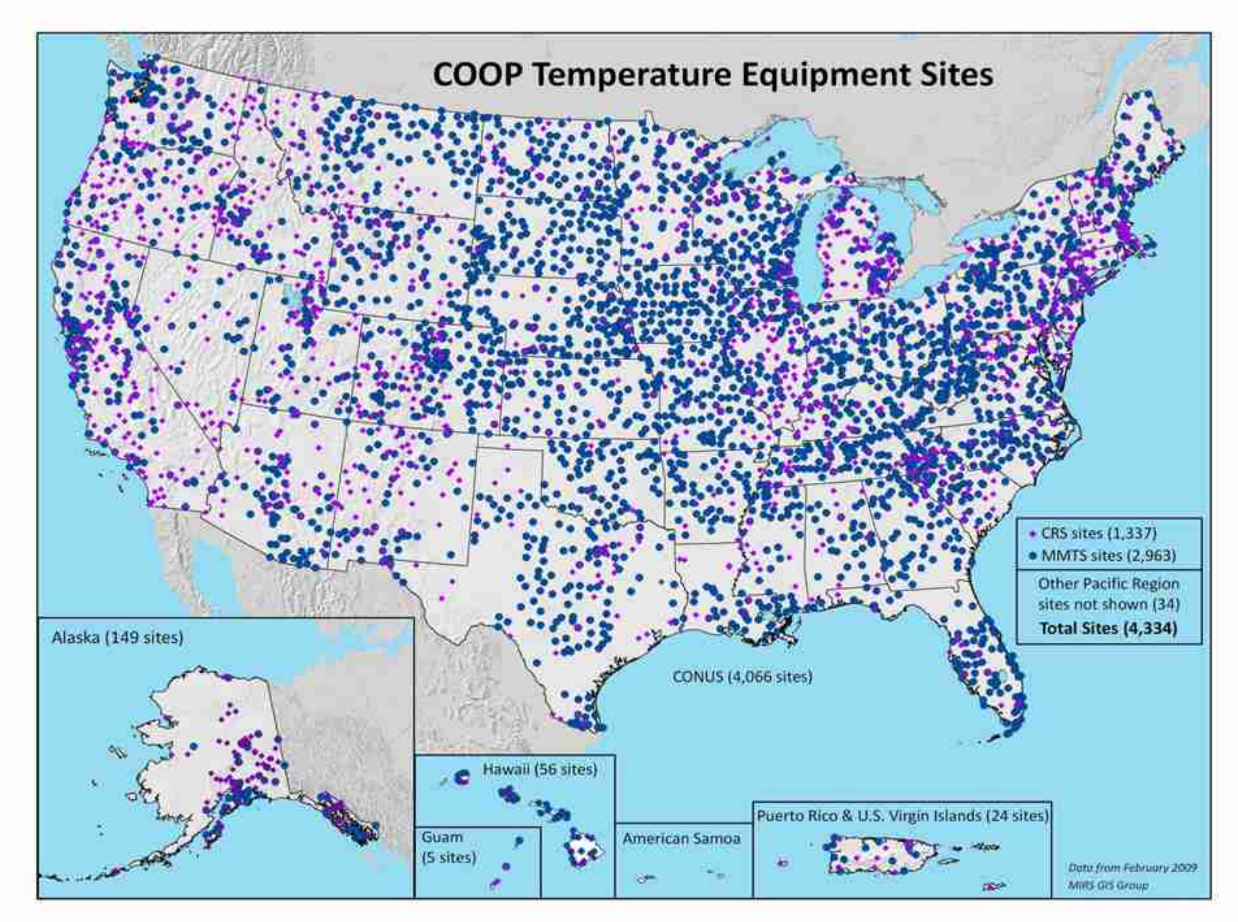


Figure 5: Map of contiguous United States, plus Alaska, Hawaii, and U.S. Territories showing CRS vs. MMTS temperature station placements, as of February 2009. Source: NOAA / NCEI.[11]

- The report concluded that nine of every 10 USHCN stations were likely reporting inaccurately high temperatures because they were poorly sited and in violation of NOAA / NWS published standards for thermometer placement.[12] An additional rating system was also used, pioneered by Michel Leroy of Météo-France, which allowed classification of stations by distance to buildings, asphalt, concrete, and other man-made influences.[13]

- The report suggested that adjustments to the temperature data by NOAA / NCEI also cause recent temperatures to appear higher, due to the infilling mechanism for missing data employed during creation of a national temperature average, as well as other adjustments.

GOVERNMENT RESPONSES TO THE 2009 SURFACE STATIONS REPORT

When "Is the U.S. Temperature Record Reliable?" was published in March 2009, reactions were swift from social media, news outlets, government agencies, and the academic community. Outlets such as Fox News, *The New York Times*, the *Rush Limbaugh Show*, and many others covered the story, which elicited such broad interest because no comprehensive site quality assessment had ever been undertaken.

NOAA's National Climatic Data Center (NCDC) responded on June 12, 2009, with a memo containing "talking points," for which no author was attributed. The memo appeared designed for the media to rebut the findings of the March 2009 Surface Stations report. See Figure 6.

Figure 6: Screencap of the NCDC website from June 12, 2009. This memo has been removed from the internet, with this screencap seemingly the only record of its existence. Source: Anthony Watts.

A new version of these talking points was published on July 6, 2009, adding references to the U.S. Climate Reference Network and the USHCN modernization program (USHCN-M) that began in 2008.[14,15] Clearly, NOAA knew USHCN contained inherent problems and reacted by modernizing the network.

Climatologist Roger Pielke critiqued NOAA's press release.[16] He wrote of the problems:

> In their news release, they perpetuate the myth that they can correct "less-than-ideal" sites. The news release writes:
>
> > "Data gathered by those existing HCN stations that were located in less-than-ideal areas have been statistically corrected in the analysis of climate trends routinely reported by NOAA. Though some individual stations were placed in less-than-ideal areas, these data anomalies did not significantly alter overall climate measurements. The modernization will relocate these stations in areas that are closer to ideal."
>
> This ignores the evidence to the contrary that we have published in peer-reviewed papers.

On September 29, 2009, the U.S. Office of the Inspector General (OIG) sent a memorandum to NOAA Director Jane Lubchencko concluding that USHCN must undergo a review based upon "a congressional inquiry on the reliability of the network's data."[17]

OIG published its findings on July 29, 2010, essentially echoing Pielke's concerns. The report states:

> NOAA acknowledges that there are problems with the USHCN data due to biases introduced by such means as undocumented site relocation, poor siting, or instrument changes. The agency has taken steps to improve data quality by implementing enhanced quality control steps and algorithms (referred to as USHCN Version 2) and having them peer reviewed. According to the peer reviews we examined, the resulting dataset improves upon the algorithms in the prior Version I data.
>
> The respondents to our inquiries about the use of and adjustments to the USHCN data generally expressed confidence in the Version 2 dataset. Although experts from the three professional organizations we contacted had no official position on the efficacy of the adjustments, two of the experts stated that in their professional view the USHCN Version 2 dataset has value, with one expert saying it is the best dataset for detecting climate change and trends. All of the experts thought that an improved, modernized climate reporting system is necessary to eliminate the need for data adjustments. [18]

Another investigation into the USHCN was launched by the U.S. Government Accountability Office (GAO), which was published on August 31, 2011.[19] It noted a number of problems related to NOAA's quality-control system, concluding:

> GAO reviewed data and documents, interviewed key NOAA officials, surveyed the 116 NOAA weather forecast offices responsible for managing stations in the USHCN, and visited 8 forecast offices. According to GAO's survey of weather forecast offices, about 42 percent of the active stations in 2010 did not meet one or more of the siting standards… NOAA does not centrally track whether USHCN stations adhere to siting standards and the requirement to update station

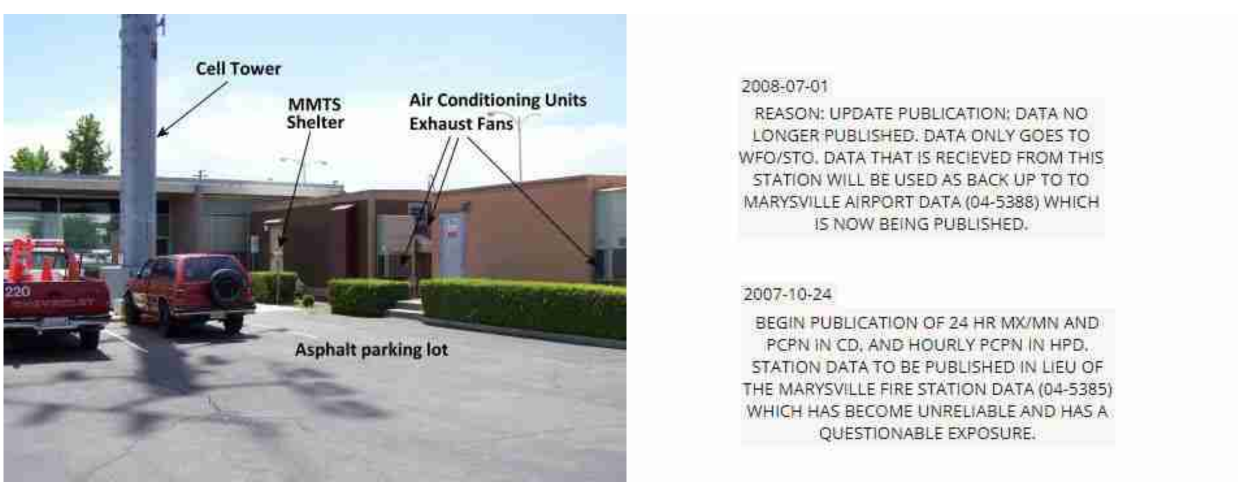
> records, and it does not have an agency-wide policy regarding stations that do not meet its siting standards…
>
> Without centrally available information, NOAA cannot easily measure the performance of the USHCN in meeting siting standards and management requirements. Furthermore, federal internal control standards call for agencies to document their policies and procedures to help managers achieve desired results. NOAA has not developed an agencywide policy, however, that clarifies for agency staff whether stations that do not adhere to siting standards should remain open because the continuity of the data is important, or should be moved or closed. As a result, weather forecast offices do not have a basis for making consistent decisions to address stations that do not meet the siting standards.[20]

GAO subsequently recommended NOAA enhance its information systems to centrally capture information useful in managing the USHCN and develop a policy on how to address stations that do not meet its siting standards. NOAA agreed with GAO's recommendations.

Yet, one weakness of the report is GAO did not visit any faulty USHCN stations, instead relying upon interviews with NOAA / NWS personnel. This may account for the discrepancy in station siting non-compliance between GAO (42 percent) and the Surface Stations project (90 percent).

THE FEDERAL GOVERNMENT CLOSES SOME OF THE WORST USHCN STATIONS

After these problems were exposed, NOAA / NWS began to close some of the worst USHCN stations. The first of these was in Marysville, California, which was highlighted in the 2009 Surface Stations report as the worst offender and served as the impetus for further national investigation. Marysville was the **very first** of the "How Not to Measure Temperature" series published by WattsUpWithThat.com on May 26, 2007.[21] Just over a year after the 2009 Surface Stations report was released, NOAA reported it had closed Marysville. See Figure 7.[22]



2008-07-01
REASON: UPDATE PUBLICATION; DATA NO LONGER PUBLISHED. DATA ONLY GOES TO WFO/STO. DATA THAT IS RECIEVED FROM THIS STATION WILL BE USED AS BACK UP TO TO MARYSVILLE AIRPORT DATA (04-5388) WHICH IS NOW BEING PUBLISHED.

2007-10-24
BEGIN PUBLICATION OF 24 HR MX/MN AND PCPN IN CD, AND HOURLY PCPN IN HPD. STATION DATA TO BE PUBLISHED IN LIEU OF THE MARYSVILLE FIRE STATION DATA (04-5385) WHICH HAS BECOME UNRELIABLE AND HAS A QUESTIONABLE EXPOSURE.

Figure 7: Photograph of Marysville, CA, USHCN site taken in May 2007 (left). Report from NOAA Historical Observing Metadata Repository (HOMR) website on closure in July 2008 (right). Source: Anthony Watts (left), NOAA (right).

The NOAA HOMR database also reported that the duties of temperature and precipitation reporting at the Marysville station were assumed by the automated station at the Marysville airport.[23]

Soon after, NOAA closed the USHCN station at the University of Arizona Atmospheric Sciences Department in Tucson, Arizona. This station had been placed in the parking lot—by scientists who clearly should have known better—and quickly became a prime example of the inherent flaws within the COOP network. As seen in Figure 8, the station was closed just a few months after the 2009 report was published. The NOAA HOMR database confirms the station is closed and no longer produces data.[24]

Figure 8: Top: placement of CRS in parking lot at University of Arizona Atmospheric Sciences Department on July 21, 2007. Lower left: detail at ground level of CRS placement on July 21, 2007. Lower right: detail at ground level of CRS after removal on November 23, 2007. Source: Warren Meyer, Bob Thompson.

The 2009 report also describes two USHCN climate stations in which MMTS enclosures were mounted directly adjacent to city streets, compromising the integrity of site data. USHCN stations in Ardmore and Perry, Oklahoma, have since been closed for temperature reporting, as seen in Figures 9 and 10.

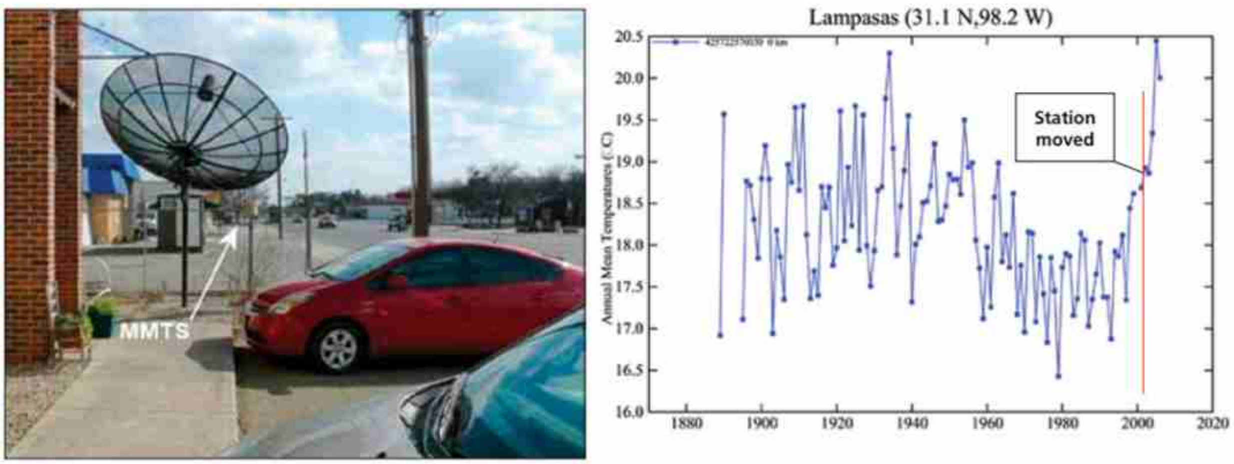
Figure 9: Before and after photographs of the Ardmore, OK, USHCN station. Source: Anthony Watts.

Figure 10: Before and after photographs of the Perry, OK, USHCN station. Top: natural and infrared photos indicating heat effects of building wall in January 2009. Bottom: Perry, OK, street view from August 2016. Source: Anthony Watts, Google Earth.

Ardmore, Oklahoma remains open as a precipitation reporting station at a new location, but the USHCN temperature sensor was removed in December 2009 according to the NOAA HOMR database.[25]

Perry, Oklahoma remains open as a precipitation reporting station only, and was moved 1.8 miles west to the city fire department building in December 2009. The USHCN thermometer was removed.[26]

Lampasas, Texas was home to one of the most poorly-sited stations in the USHCN network, being located in front of a radio station only a few feet away from a four-lane highway. The station received a large amount of media coverage, as its temperature record showed a clear warming spike after it was moved to that location. NOAA / NWS closed it in March 2013. Figure 11 illustrates the Lampasas station's exceptionally poor siting, along with the spike in temperature that occurred when it was moved. Figure 11 also shows the remarks entered into the NOAA HOMR database about its unsuitability in June 2011 and eventual closure in March 2013.[27] NOAA / NWS did not remove the temperature sensor, which still remains visible today.[28]



Remarks

DATES	TYPE	REMARK
2013-03-02 to Present	NWS COOP INGEST	CLOSING STATION
2013-03-02 to Present	NWS COOP INGEST	INACTIVATE STATION. DATA AT THIS LOCATION IS NO LONGER REPRESENTATIVE DUE TO CONSTRUCTION AND URBANIZATION. THIS IS AN HCN SITE. THIS STATION WILL BE REACTIVATED UPON RECRUITMENT OF SUITABLE OBSVR OR CLOSED IAW NWS INSTRUCTIONS.
2011-06-01 to Present	NWS COOP INGEST	REACTIVATE STATION AT SAME LOCATION WITH NEW PRIMARY OBSERVER. REACTIVATION AT THIS LOCATION WILL BE TEMPORARY UNTIL A MORE SUITABLE LOCATION CAN BE FOUND. DATA AT THIS LOCATION IS MARGINALLY SUITABLE DUE TO CONSTRUCTION AND URBANIZATION. THIS IS AN HCN SITE.

Figure 11: Top left: USHCN temperature sensor (MMTS) in front of radio station on US 193 in Lampasas, TX. Top right: graph of temperature data at the Lampasas station showing the spike in temperature after the station was moved (NASA GISS). Bottom: screen capture of the remarks section of the NOAA HOMR database on the Lampasas station. Source: 2009 Surface Stations report.

It is clear the 2009 Surface Stations report had a substantial impact upon decisions to close the worst stations, based upon the aforementioned information.

SCIENTIFIC RESPONSES TO THE 2009 SURFACE STATIONS REPORT

The scientific community reacted swiftly to the 2009 report. *The Journal of Geophysical Research* published the first attempt to rebut the 2009 Surface Stations report in June 2010. The article by Menne *et al.* was written entirely by government employees at the National Climatic Data Center in Asheville, North Carolina.[29] The authors ultimately dismissed the 2009 report's findings, asserting statistical manipulation could account for and correct the siting problems observed at each station.

No evidence was cited to support the authors' claims. However, the paper left the door open for other possibilities, admitting in its concluding remarks: "Given the now extensive documentation by surfacestations.org that the exposure characteristics of many USHCN stations are far from ideal, it is reasonable to question the role that poor exposure may have played in biasing CONUS temperature trends… our analysis does provide evidence of bias in poor exposure sites relative to good exposure sites."[30]

Michel Leroy contributed a 2010 paper that examined the methodology used to quantify temperature biases in station siting, adding a critically important variable.[31] Previously, only distance to heat sinks, heat sources, and other biases was used to rate a station. This methodology was used in setting up the state-of-the-art Climate Reference Network utilizing Leroy's work from 1998, which spawned the 1 to 5 classification system. Leroy updated the methodology to include the surface area of biasing factors within a 100-meter radius of the thermometer.

After an extensive peer-reviewed process, the Surface Stations project authors published a 2011 report coming to a very different conclusion than the NCDC authors.[32] The paper incorporated comprehensive data analysis from both well-sited and poorly-sited stations, using a larger sample size of stations than NCDC's 2010 report, while remaining true to the NCDC's rating approach. The 2011 paper concluded, "According to the best-sited stations, the diurnal temperature range (DTR) in the lower 48 states has no century-scale trend."[33]

This report's finding of a zero-DTR trend is tremendously important, as DTR is an important climate trend indicator.[34] Since the daily high to low temperature (diurnal temperature) of the best-sited stations showed no global warming trend over 100 years of data, there is a strong possibility that NOAA's reports of rising temperatures were biased by the substantial number of stations classified as a CRN3, CRN4, and CRN5. Essentially, the overwhelming amount of "bad" data were swamping the "good" data.

Using Leroy's new methodology, the surfacestations.org team reanalyzed its earlier work to include surface areas and distances of heat sinks and sources within 100 meters of the thermometer. New tools, such as an enhanced version of Google Earth Pro, facilitated this process.[35,36] The authors presented the findings of their paper at the 2015 American Geophysical Union (AGU) convention.[37]

The Watts *et al.* paper introduced the concept of "unperturbed" stations. Through careful examination of each USHCN station, 410 stations were identified that experienced no changes in time of observation or geographical location from 1979 to 2008. Their stability made them excellent candidates for the study. The new heat sink evaluation process was applied to the entire sample.

The paper explains its methodological approach:

> Distance measurements of visible encroachments of heat sinks and sources were made, and a calculation was done to determine the percentage of area within the different radii (3m, 5m, 10m, 30m, and 100m) surrounding the thermometer per Leroy 2010, containing heat sinks and/or heat sources. The class rating assigned to the stations corresponds to the portion of the Leroy 2010 rating system dealing with artificial surfaces. The distance and area values were applied to the final rating for each station. Quality control checks were routinely done to ensure that the proper station was identified, that it matched descriptions in metadata provided by NCDC, that it was consistent with the latitude and longitude given for the station, and that the equipment seen in photography and described in survey reports matched the equipment description according to the NCDC HOMR database.

An example of a USHCN station analysis measuring surface area of heat sinks and heat sources is shown in Figure 12.

Figure 12: Analysis of artificial surface areas within 10- and 30-meter radii at Ashland, NE, USHCN station (COOP# 250375) using Google Earth tools. The NOAA temperature sensor is labeled as MMTS. The figure illustrates how the USHCN station, which was evaluated per Leroy (2010) procedures, showing the 10- and 30-meter radii, along with polygon surface (area outlines of visible heat sinks created with Google Earth Pro tools, providing a value of approximately 373 square meters of heat sink surface area within the 30-meter radius, and approximately 24 square meters within the 5-10-meter annulus). Source: Anthony Watts and Evan Jones.

The stations were classified based on proximity to artificial surfaces, buildings, and other such objects with unnatural thermal mass—the total measure of the heat sink effect, combining both surface area and distance—using guidelines established by Leroy’s 2010 report.

The United States temperature trends estimated from the relatively few stations in the classes with minimal artificial impact were found to be collectively about 2/3 as large as U.S. trends estimated in the classes with greater expected artificial impact. The trend differences are largest for night-time low temperatures and are statistically significant at the regional scale, across different types of instrumentation, and degrees of urbanization.

KEY FINDINGS OF WATTS *ET AL.*, 2015

It is well-established in peer-reviewed literature that heat sinks impact short-term temperature changes. Watts *et al.* demonstrated that the heat sink effect manifests itself in long-term temperature trends as well, contradicting the conclusions of the NCDC's rebuttal to the Surface Stations report. The overall warming effect of a heat sink on a nearby sensor is greater at the end of a warming phase than at its beginning. Therefore, the warming trend displayed over the 30-year study period is exaggerated, as it has been confounded by the heat sink effect.[iii]

The 30-year average temperature trend (Tmean) of unperturbed, well-sited stations is significantly lower than the Tmean of the official NOAA / NCDC record for all 1,218 USHCN stations. See Figure 13.

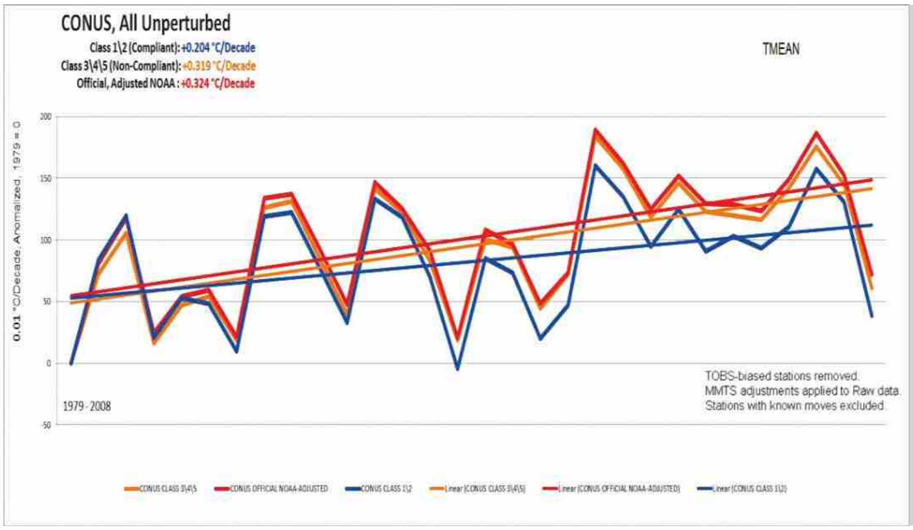


Figure 13: From Watts, *et al,* 2015. Comparisons of 30-year temperature trends for unperturbed and compliant Class 1 and 2 USHCN stations to unperturbed and non-compliant Class 3, 4, and 5 USHCN stations, compared to NOAA final adjusted V2.5 USHCN data in CONUS. Bias at the microsite level (the immediate environment of the sensor) in the unperturbed subset of USHCN stations has a significant effect on the mean temperature (Tmean) trend. Well-sited stations show significantly less warming from 1979 - 2008. Source: Evan Jones.

Two prominent peer-reviewed publications bolstered the findings of the 2015 report. A study by Kevin Gallo and George Xian found the problems related to Impervious Surface Areas (ISAs)—for example, asphalt, brick, concrete, and buildings—were only worsening.[38]

The authors discovered 32 percent of USHCN stations recorded at least a 20 percent temperature increase in the area of heat sinks within 100 meters of the thermometer. In the larger urban heat island areas, more than 52 percent of the USHCN stations saw a temperature increase of 20 percent or more from surfaces within 1,000 meters of the station producing a heat sink effect. Essentially, the presence of heat sinks is heavily correlated to high temperature readings.

The trend is clear: increased urbanization changes the environment near the thermometers to one that will hold more heat, thus supporting the conclusions of Watts *et al.*

The most significant response to the original 2009 Surface Stations report came from an experiment conducted by researchers at NOAA's Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge, Tennessee, and published in the *Bulletin of the American Meteorological Society.* The NOAA Oak Ridge Laboratory developed an experiment to measure the effects of heat sinks in proximity to thermometers.[39]

[iii] See Appendix B for the science behind heat sinks near these weather stations.

The abstract of the ATDD's 2019 report explains the experimental design:

> A field experiment was performed in Oak Ridge, TN, with four instrumented towers placed over grass at increasing distances (4, 30, 50, 124, and 300 m) from a built-up area. Stations were aligned in such a way to simulate the impact of small-scale encroachment on temperature observations. As expected, temperature observations were warmest for the site closest to the built-up environment with an average temperature difference of 0.31 and 0.24 °C for aspirated and unaspirated sensors respectively. Mean aspirated temperature differences were greater during the evening (0.47 °C) than day (0.16 °C) …
>
> These results suggest that small-scale urban encroachment within 50 meters of a station can have important impacts on daily temperature extrema (maximum and minimum) with the magnitude of these differences dependent upon prevailing environmental conditions and sensing technology.

The 2019 NOAA Oak Ridge Laboratory publication vindicated the findings of the original 2009 Surface Stations publication as well as Watts et al.'s 2015 follow-up.

ELIMINATION OF THE ENTIRE USHCN DATASET AND THE 'BAND-AID' REPLACEMENT

NOAA and its subordinate agencies clearly went to great lengths to defend the quality of the USHCN network. However, NOAA abruptly stopped using the USHCN dataset in 2014, switching to a new dataset called "*n*ClimDiv."[40]

USHCN's 1,218 stations were dwarfed by the nascent *n*ClimDiv initiative, which incorporates more than 10,000 installations in a network called "*n*ClimGrid." This new network combines the USHCN stations, in addition to thousands of stations from the Global Historical Climatology Network (GHCN).

The switch was likely a strategic maneuver by NOAA to draw attention away from the fact that its long-maintained USHCN had been riddled with poorly sited locations, compromising the temperature records it produced. Perhaps NOAA believed changing the name and the method would shield the system from further criticism.

NOAA / NCDC concurrently rolled out the new U.S. "Climate Reference Network" (USCRN), which it described as thusly:

> NCDC developed the U.S. Climate Reference Network (USCRN) to address the most basic of climate change questions that Americans will ask in the mid-21st century, "How has the climate of the Nation changed in the last 50 years?" The USCRN measures temperature with superior accuracy and continuity in places that land-use change will not likely impact during the next five decades. Built specifically for this purpose, it is unlike any other climate observation network in the United States. NCDC began the USCRN build-out in the lower 48 states in 2000 and completed the last of 114 station installations in 2008. Since 2005, the USCRN has operated a sufficient number of stations to generate accurate annual national temperature averages.
>
> The USCRN serves, as its name and original intent imply, as a reference network for operational

> estimates of national-scale temperature. NCDC builds its current operational contiguous U.S. (CONUS) temperature from a divisional dataset based on 5-km resolution gridded temperature data. This dataset, called *nClimDiv,* replaced the previous operational dataset, the U.S. Historical Climatology Network (USHCN), in March 2014. [41]

Surprisingly, NOAA, NCDC, and NCEI do not use or cite the high-quality temperature data produced by the USCRN in any public reports.[42] Instead, they use *n*ClimDiv data, which contains all of the poorly sited USHCN stations, in addition to thousands of other stations that likely have the same set of station siting problems. NOAA / NCDC claims they then "adjust" the *n*ClimDiv data to closely match the data from the USCRN. This "Band-Aid" approach does little to address problems that have been identified, and instead creates a dataset rife with multitudes of adjustments that may or may not fairly represent long-term temperature trends. Moreover, this approach does not address problems with individual station records, such as heat sink effects and biased temperature readings.

Furthermore, adjusting the *n*ClimDiv data to closely match the data from the USCRN only affects 17 years of data, failing to address any data produced before USCRN became operational in 2005. This means all of the temperature data showing climate warming in the 20th century was not adjusted in the same manner as data gathered after 2005, creating a disjointed U.S. climate dataset.

Ironically, monthly data from the USCRN in Figure 14 show significantly oscillating temperature changes, with little to indicate a warming trend from 2005 to 2022. In fact, the graphic clearly shows the United States to be cooler in May 2022 compared to January 2005.[43]

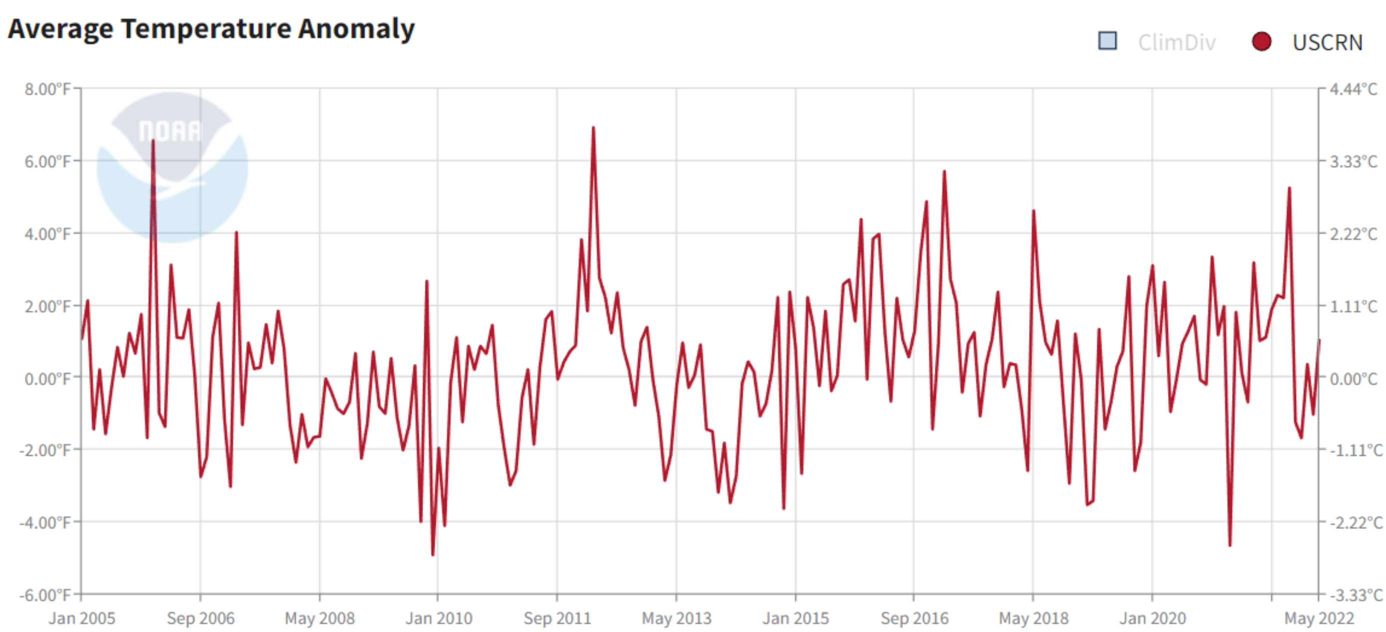


Figure 14: Screen capture of USCRN monthly average temperature data. Source: NCDC / NOAA.

Given that NOAA / NCEI is eschewing the high-quality unadjusted data from USCRN in favor of the adjusted and biased *n*ClimDiv data, the need for a new Surface Stations survey emerged.

THE 2022 SURFACE STATIONS SURVEY

The introduction of the new *n*ClimDiv methodology necessitated a reevaluation of stations used to collect temperature data in the United States. With thousands of new stations added to the network, it is important to determine whether the GHCN stations—now constituting the vast majority of the network—suffer from the same problems that have historically plagued the USHCN.

Project Goals

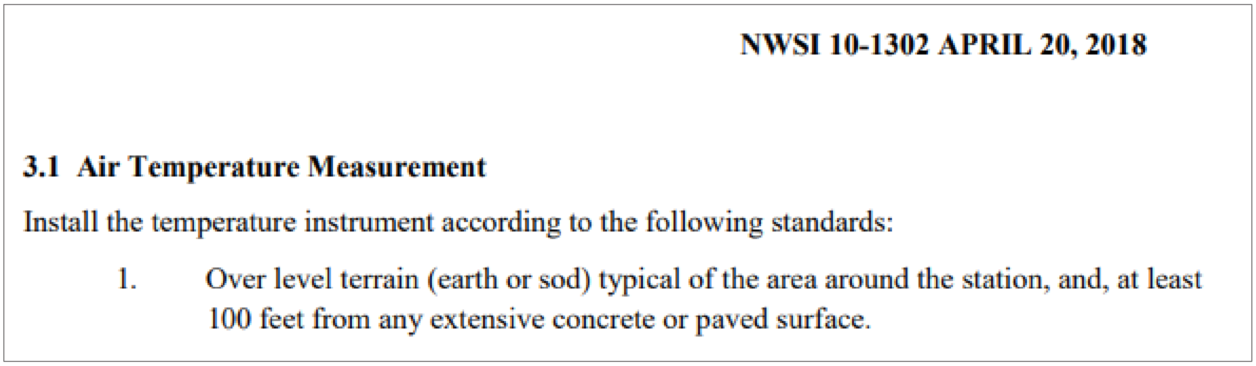
1. Photographically review as many of the USHCN stations cited in the original 2009 survey as possible.
2. Note differences between 2009 and 2022 with emphasis on closures, moves, and equipment changes.
3. Determine if station ratings have changed due to additional encroachments or station moves.
4. Expand the photographic survey to look at GHCN stations where possible to determine if GHCN stations have the same type of problems that plagued the USHCN.
5. Note the most egregious station siting violations, and bring those to the attention of the NWS manager in charge.
6. Publish the photographic survey for USHCN before and after, plus new GHCN stations.
7. Examine station continuity data for the entire GHCN network to determine how much change has occurred over time.
8. Establish conclusions from the new survey.
9. Make recommendations for the future.

Survey Methods

Like the 2009 Surface Stations project, the 2022 Surface Stations survey uses photographic documentation combined with GPS and Google Earth Pro location assistance. Anthony Watts and a team of volunteers conducted all in-person site visits, following the process below:

1. Determine station type (USHCN or GHCN) from the NOAA HOMR Station Database.
2. Determine if station has been moved or closed from NOAA HOMR Station Database remarks section.
3. If open, determine station GPS location coordinates from the NOAA HOMR Station Database.
4. Extract GPS coordinates from NOAA HOMR Station Database, insert into Google Earth Pro for location and driving directions.
5. Note if the station location has any likely restrictions, such as fences or gates.
6. Avoid surveying stations on private property unless they are visible from a public street.
7. Drive to station, photograph from four compass points if possible, plus one or two overall photographs to determine the character of the site.
8. Make observations and note anything out of the ordinary.
9. Submit photographs by e-mail to report author.
10. Author to compare station photographs and Google Earth measurements to NOAA/NWS official publication on station placement, NWSI 10-1302, dated April 20, 2018.[44]
11. Author to determine if the station complies with published NOAA standards.

Figure 15 illustrates the station siting compliance standards from NWSI 10-302.



NWSI 10-1302 APRIL 20, 2018

3.1 Air Temperature Measurement

Install the temperature instrument according to the following standards:

1. Over level terrain (earth or sod) typical of the area around the station, and, at least 100 feet from any extensive concrete or paved surface.

Figure 15: Screen capture of section 3.1.1 of NOAA / NWS publication 10-1302, "REQUIREMENTS AND STANDARDS FOR NWS CLIMATE OBSERVATIONS," citing 100 feet of separation between the temperature sensor and concrete of paved surfaces. Source: NOAA / NWS.

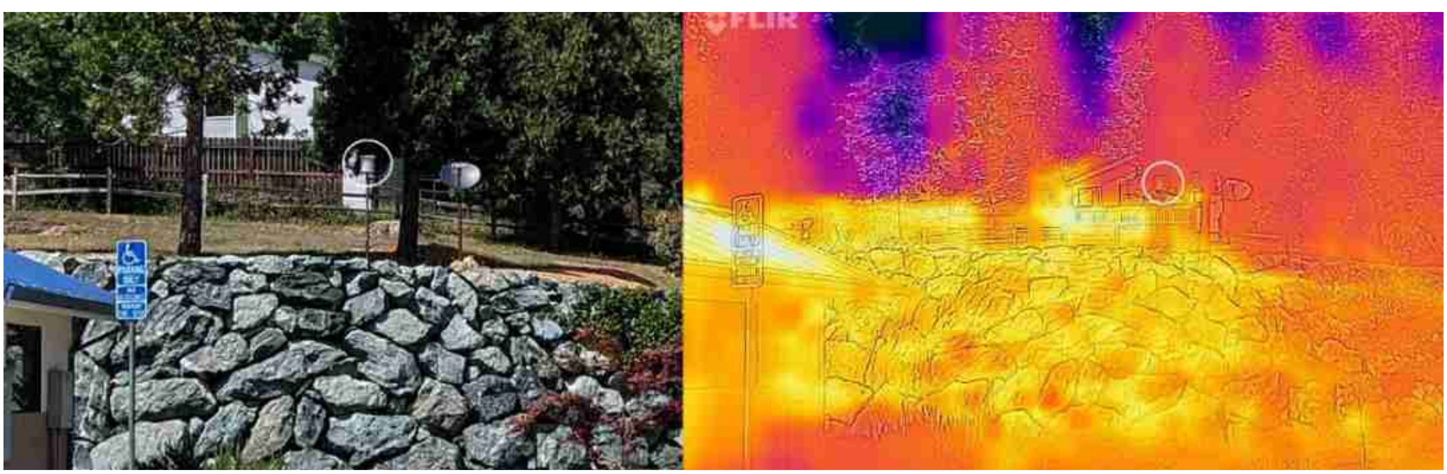
2022 SURFACE STATIONS SURVEY: EXAMPLES OF SITING ISSUES, GOOD AND BAD

This section presents photographic examples of USHCN and GHCN station siting. The majority of stations are not in compliance with NWS publication 10-1302, but examples of those in compliance are also given. Station locations, observed issues, and explanations are given in the image captions.

Visible and infrared photos of MMTS placement near roof and large parking lot at Woodland, CA, GHCN Station at the Yolo County Office of Weights and Measures. Source: Anthony Watts.

Visible and infrared photos of MMTS placement near sunlit wall and large parking lot at Arco, ID, GHCN Station. Source: Anthony Watts.

MMTS placement in COOP observer’s yard next to an ODOT maintenance facility in Basque, OR. Note the very large asphalt parking lot in the aerial photo and the yellow marker indicating the MMTS placement. Basque is an isolated small town, with the next town 30 miles away. It would be categorized as exceptionally rural, yet the GHCN thermometer is placed directly next to the largest heat sink. Source: Anthony Watts, Google Earth.



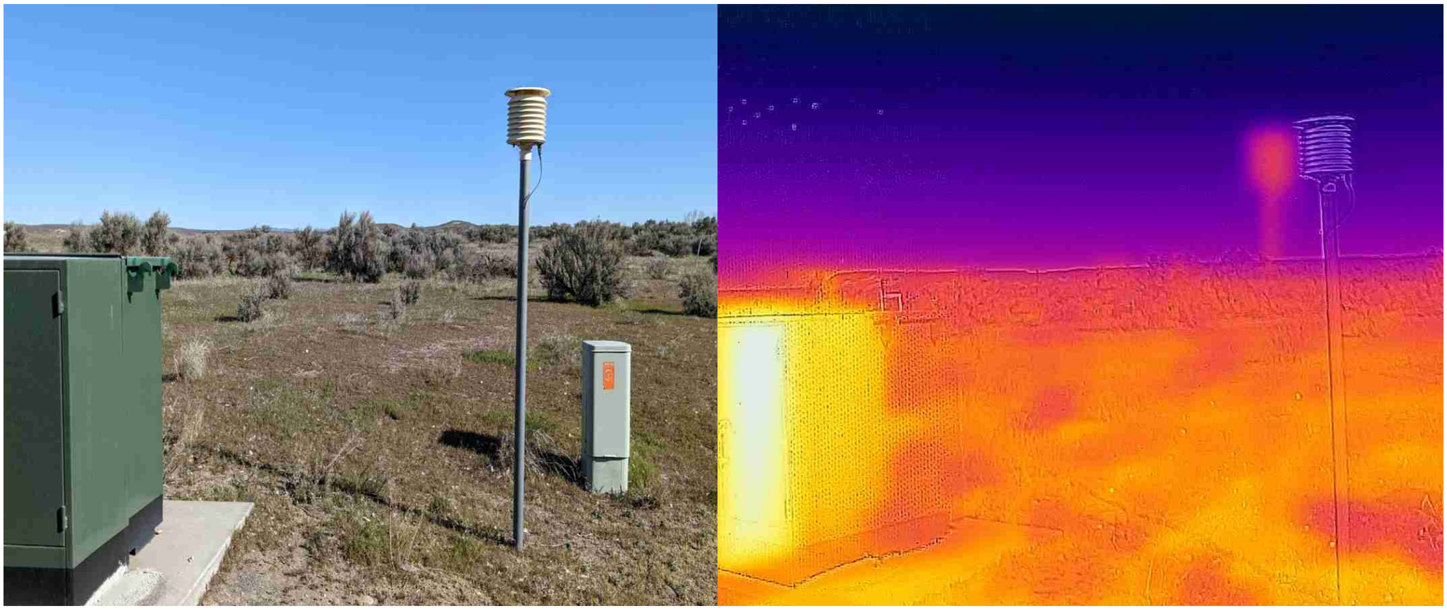
Visible and infrared MMTS placement near large sunlit rock wall and large parking lot at Colfax, CA, USHCN Station. MMTS temperature sensor is circled in both photos. The previous placement was in a grass field before the fire station was renovated. Source: Anthony Watts.

Visible and infrared photos of MMTS placement near large sunlit wall and electric power generation plant at Dillon, MT, USHCN Station at Western Montana University. Source: Anthony Watts.

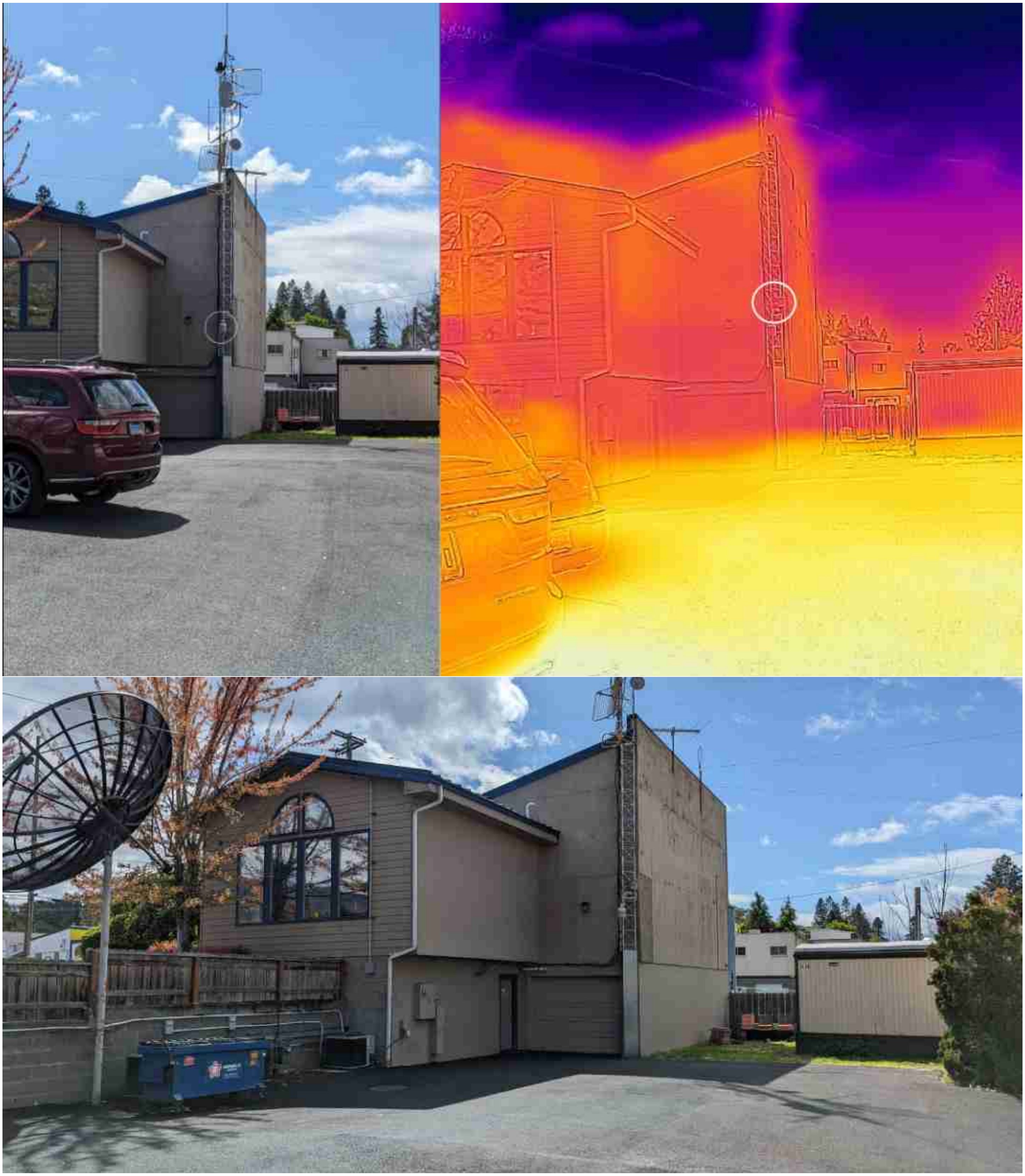
MMTS and CRS placement in a large grass field at USDA Agricultural Research Farm in Dubois, ID. This station is properly sited, and is one of two Class 1 rated stations located in the 2022 survey. Source: Anthony Watts.

CRS placement at rear of Cooperative Observer’s residence at Elkton, ID. Note the deterioration of the CRS, including rot, mold, and peeling paint. Observations are still taken daily here. Source: Anthony Watts.

MMTS placement near a building and five air conditioner units at a WWTP, a GHCN station in Fort Pierce, FL. The a/c units produce waste heat, which can easily bias the sensor warmer. Source: Tim Benson.



MMTS placement near a ground mounted power transformer at USHCN station in Glens Ferry, OR. This station was surveyed as part of the original 2009 report and was identified as being biased, but has not been corrected as of 2022. Source: Anthony Watts.



Visible and infrared photo of MMTS placement on tower above a parking lot at Grants Pass, OR, USHCN station. In the bottom photo, air conditioner units that produce warm exhaust that rises can be seen. This is a Class 5 station, wholly unsuitable for climate measurements, and likely the worst station in the entire 2022 survey. Source: Anthony Watts.

Visible and infrared photos of MMTS placement near airport ramp tarmac at GHCN station in Lakeland, FL. Source: Anthony Watts.

MMTS placement at Lava Hot Springs, ID, GHCN station. This is a tourist attraction where the MMTS sensor was placed into a natural hole in the ground where hot water for bathing and swimming emanates from the natural depression in the ground. In addition, the MMTS is next to a parking lot, a stone wall, and a sidewalk, all of which are heat sinks. The nearby electrical panel may generate heat. Because the MMTS is below average ground level in the natural depression, it is also wind-sheltered, which prevents atmospheric mixing and thus will not be representative of temperatures in the nearby landscape. Source: Anthony Watts.

This is the official USHCN station for New Orleans, LA, located at Audubon Park. The NWS is quite proud of it, displaying placards on station history and stylish iron fencing complete with the fleur-de-lis designs to help it blend into the architecture of the region. However, the NWS poured a concrete slab directly under the MMTS, and the station is just feet away from an industrial facility. Source: Linnea Lueken.

MMTS at a WWTP in Ocala, FL, a USHCN station. The station siting is reasonably good, likely a Class 2 station, but is marred by the lack of maintenance of the MMTS, as seen in the close-up. Mold growing on the MMTS darkens it, absorbing more sunlight, making it warmer. Source: Anthony Watts.

USHCN station at Paso Robles, CA, on Paso Robles Boulevard. Note it is located between U.S. Route 101 and is directly over a concrete slab. This is a Class 5 station that is saturated with heat sinks. Source: Dacre Bush / Google Earth Street View.

GHCN station at the rear of the Pocatello, ID, National Weather Service Forecast Office. Note the bank of a/c units on the right, the MMTS (circled in red) and the airport tarmac in the background. Source: Anthony Watts.

Visible and infrared photos of GHCN station located at the FBO office at Punta Gorda Airport, FL. The station is surrounded by heat sinks. Source: Anthony Watts.

Visible and infrared photos of MMTS placement of GHCN station for Shoshone, ID, next to a junk yard at the city maintenance facility. The station is surrounded by heat sinks. Source: Anthony Watts.

MMTS placement at USHCN station in Spanish Fork, UT. Note the a/c unit and the power substation. Also note the proximity of the roof, due to the thermometer's elevation. The location is at a power generation facility. Source: Steve Randle and Ron Broadaway.

MMTS placement at the airport fire station in Tallahassee, FL, a GHCN station. Note the proximity of multiple heat sources and sinks. Source: Anthony Watts.

USHCN station at WWTP in Tifton, GA. Note the MMTS is directly over a sidewalk, near a brick wall, and near a/c units. This is a Class 5 station. Note in the second photo the discoloration of the MMTS, making it darker, prone to absorb more sunlight, and subsequently warmer. Source: Alan Watt.

Visible and infrared photos of USHCN station in Troy, AL, at a radio station parking lot. Multiple heat sinks and sources are visible within feet of the sensor, including a/c units, asphalt, and concrete. The MMTS is mounted on top of a brick retaining wall. Previously, it was placed in the grass near the satellite dish. Source: Anthony Watts.

MMTS placement at the Storey County Volunteer Fire Department in Virginia City, NV. This is a GHCN station with records dating back to 1887. Note in the close-up photo, the top solar shield cap of the MMTS is missing. Multiple heat sinks are in proximity to the sensor, including asphalt, concrete, a barbecue grill, two a/c units, a generator, and multiple structures providing wind sheltering. Source: Anthony Watts.

MMTS placement at the Auburn, CA, post office, a GHCN station. Note the multiple heat sinks near the sensor, which is surrounded by asphalt, concrete, and brick buildings. Source: Anthony Watts.

MMTS and CRS, at a GHCN station in the Paris, TX, city maintenance yard. Heat sinks surround this station. Source: H. Sterling Burnett.

USHCN Station at Sandpoint, ID, showing the original location in a grassy area, at the Agricultural Experiment Station, and then after, where the MMTS has been placed in the parking lot of the Sandpoint airport. The Agricultural Experiment Station was closed, and to get a continuity of temperature readings, the NWS relocated the MMTS to the office of Granite Aviation, which provides daily readings. The new location is only feet from automobile radiators, and entirely surrounded by asphalt due to the parking lot and the airport tarmac. It is a prime example of the NWS preferring a continuity of the record over the quality of the record. Source: Google Earth and Jim Lynch.