# I calculated my own temperature averages. Why do they differ from the temperature normals?

# Why is the difference I get for the 1991-2020 normals different from what I found for the 1981-2010 normals?

## Short Answer

There are three main reasons why your temperature averages may differ from NCEI's temperature normals: differences in the data used, different approaches to handling data gaps, and homogeneity adjustments applied by NCEI. These methodological differences can result in differences as large as if not larger than 1 deg. F between a "raw" temperature average and the corresponding temperature normal from NCEI, although most are much smaller. Look at the Distribution on Page 5 as an example.

## Long Answer

First, the data you are using may differ slightly from those in NCEI's GHCN Daily dataset on which the normals are based if they were not directly taken from that dataset or taken from it at a different time.

Second, when computing monthly-mean temperature for an individual month, WMO rules allow up to ten days to be missing in any month, if more than five are not consecutive. When more than 10 days are missing, we use regression relationships with neighboring series to estimate the monthly mean temperature for that month. If you are using a different criterion for the allowed number of missing days and are not filling in missing months with the same technique, your 30-year average may differ as well.

Third, the normals are calculated from monthly temperature time series that have been adjusted for discontinuities using the Menne and Williams (2009) Pairwise Homogenization Algorithm. After identifying shifts in time series relative to those at neighboring stations, adjustments are determined by estimating the magnitude of change in pairwise difference series between the "target" series and highly correlated neighboring series that have no apparent shifts at the same time as the target station. Earlier segments of a time series are adjusted to eliminate discontinuities with subsequent segments, so that the segment after the last identified shift remains unchanged. In other words, the earlier part of the time series has been adjusted to match the climate at the end of the series.

Additional investigation is needed to understand the observed shifts in the differences between raw averages and adjusted normals from 1981-2010 to 1991-2020 an individual stations and for the network(s) overall. Following are known sources of inhomogeneities during 1981-2020 and their expected individual impacts on the data and normals.

1. All other things being equal, there is a mean negative bias with the newer ASOS instrument. As a result, the pre-ASOS would be adjusted downward by NCEI's Pairwise Homogenization Algorithm (PHA), leading to a lower temperature average in the adjusted data compared to the raw data. However, the shift relative to the current time is an accumulation of all the changes from the current time backwards, so other shifts may obscure this relationship.
2. Within the Coop Network, the transition to MMTS, which took place between the mid-1980s and mid-2000s, at least over the CONUS, leads to lower Tmax's and higher Tmin's, controlling for other factors. Thus, the presence of this transition alone would result in the pre-MMTS observations to be adjusted downward for Tmax and upward for Tmin, leading to lower Tmax normals and higher Tmin normals compared to the raw averages. Whether this transition affected the 1981-2010 or 1991-2020 normals, or both, depends on with the it occurred between 1991 and 2020 or before 1991.
3. Changes in observation times from afternoon to morning lead to lower monthly averages, so adjustments should decrease the normal relative to the raw mean. Note that there is no time of observation bias adjustments for Alaska.
4. The impact of the above factors maybe overwhelmed by siting or instrumentation type or calibration changes.
5. For any given station, multiple factors likely interact to form the net impact on the time series during 1981-2010 and 1991-2020, respectively. Several examples will be shown below.

## Additional Background Specific to ASOS Stations

In the overview paper on the USHCN version 2 (which is for CONUS stations only), the average impact of transition to ASOS for those that are part of the U.S. HCN was about -0.4°C for both Tmax and Tmin. That overview paper is here:

Menne, M. J., C. N. Williams Jr., and R. S. Vose, 2009: The U.S. Historical Climatology Network Monthly Temperature Data, Version 2. Bulletin of the American Meteorological Society, 90, 993-1008. https://doi.org/10.1175/2008BAMS2613.1

Those CONUS results are consistent with Guttman and Baker, 1996 (see link below), namely, that all things being equal with siting, etc., the ASOS temperature instrument (HO88) reads lower, on average, then the prior pre-ASOS instrument (HO83), but site changes can overwhelm the signal associated with the instrument change. Of course, since then, other temperature instrument changes have taken place both generally and at specific locations. The Goodman and Baker paper can be found here:

Guttman, N. B., and C. B. Baker, 1996: Exploratory Analysis of the Difference between Temperature Observations Recorded by ASOS and Conventional Methods. Bulletin of the American Meteorological Society, 77, 2865–2874. https://doi.org/10.1175/1520-0477(1996)077%3C2865:EAOTDB%3E2.0.CO;2

## Some Examples

Dayton, OH (KDAY) maximum temperatures were adjusted several time during and before 1991-2020 in response to statistically significant differences compared to a number of surrounding stations without such shifts at those times. Of the four shifts in the graph bellow for January monthly temperature, the overall time series warms in this case in order to homogenize to the current climate. Three of the four shifts in the range of 0.3 F to 1.9 F corresponded to known station changes, although the cause of the change from 2012 to 2013 was not identified in the station metadata.

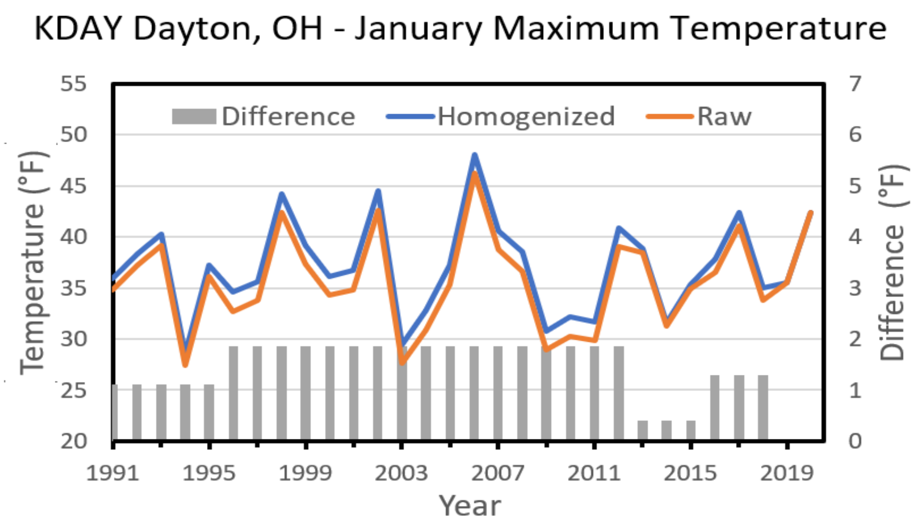


Figure 1. A graph of January monthly maximum temperature from Dayton, Ohio, for 1991-2020 displaying raw (red) and homogenized (blue) time series, along with their differences displayed as gray bars assigned to values according to the right axis.

Interestingly, on an annual basis, the large increase in temperature normals in an absolute sense between 1981-2010 and 1991-2020 reflects these homogenization changes since the last normals were release; 1981-2010 is now warmer by +1.3°F for minimum and +2.0°F for maximum temperatures. Therefore, if the comparison is made between a newly calculated 1981-2010 normals adjusted for all inhomogeneities known now versus 1991-2020, the change in the new normals versus the recalculated 1981-2010 normals is reduced to +0.4°F for minimum and +0.3°F for maximum temperatures.

La Crosse, WI (KLSE) displays a similar types of homogeneity changes in its history, and so also shows a large warming between its 1981-2010 and 1991-2020 maximum temperature normals. Once the change in the old 1981-2010 normals versus the newly homogenized 1981-2010 normals are recognized (+1.1°F for minimum and +1.5°F for maximum temperature), the changes in the new 1991-2020 normals versus the recalculated 1981-2010 normals are reduced to +0.2°F and +0.1°F, respectively.

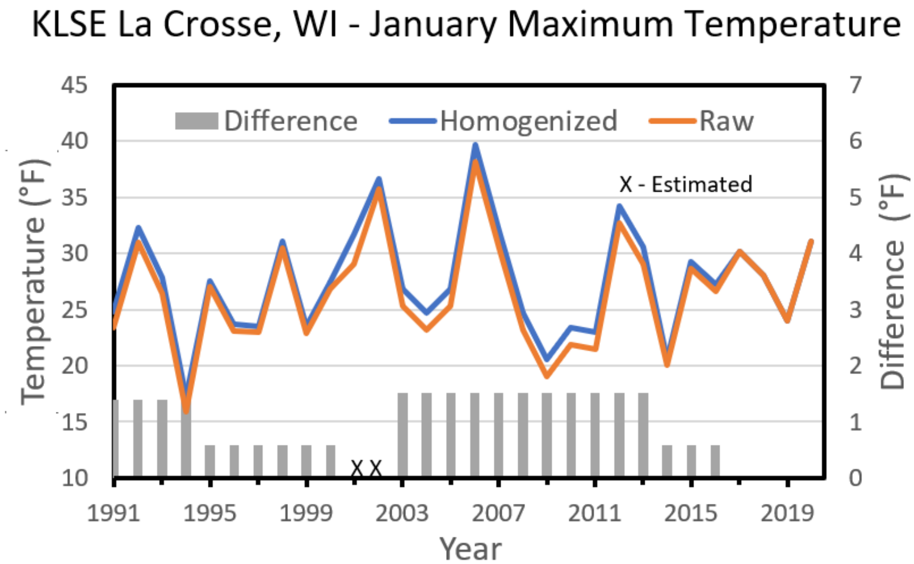


Figure 2. A graph of January monthly maximum temperature from La Crosse, WI, for 1991-2020 displaying raw (red) and homogenized (blue) time series, along with their differences displayed as gray bars assigned to values according to the right axis.

Finally, Washington-Dulles (KIAD) displays a more classic ASOS transition response with a negative shift of the record prior to 1996, and a stable record afterward. Once the change in the old 1981-2010 normals versus the newly homogenized 1981-2010 normals of -1.0°F for minimum and +0.3°F for maximum temperature are counted, the changes in the new 1991-2020 normals versus the recalculated 1981-2010 normals shift to +0.6°F and +0.8°F, respectively.

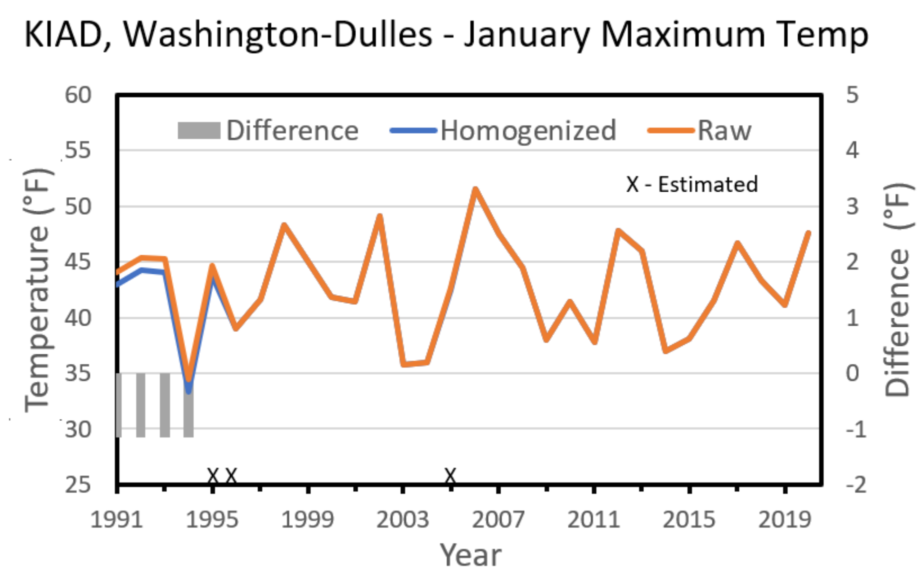


Figure 3. A graph of January monthly maximum temperature from Washington-Dulles, for 1991-2020 displaying raw (red) and homogenized (blue) time series, along with their differences displayed as gray bars assigned to values according to the right axis.

## Overall Effects of Homogenization

While it may seem likely even inevitable that the homogenization impact on normals would be overwhelmingly in the positive direction, this is simply not the case. Of the subset of normals for NWS station list of 760, 739 had information from the last normals period to allow a comparison of 1981-2010 normals calculated in 2011 versus the same 1981-2010 period normals calculated now after ten additional years of homogenization. Of these, the average shift is only +0.1°F for minimum temperature normals, with a symmetrical distribution around zero (Figure 4). There is no significant bias in the overall impact of homogenization on the resulting normals, and these corrections serve to create normals that more closely match the current climate at a location.

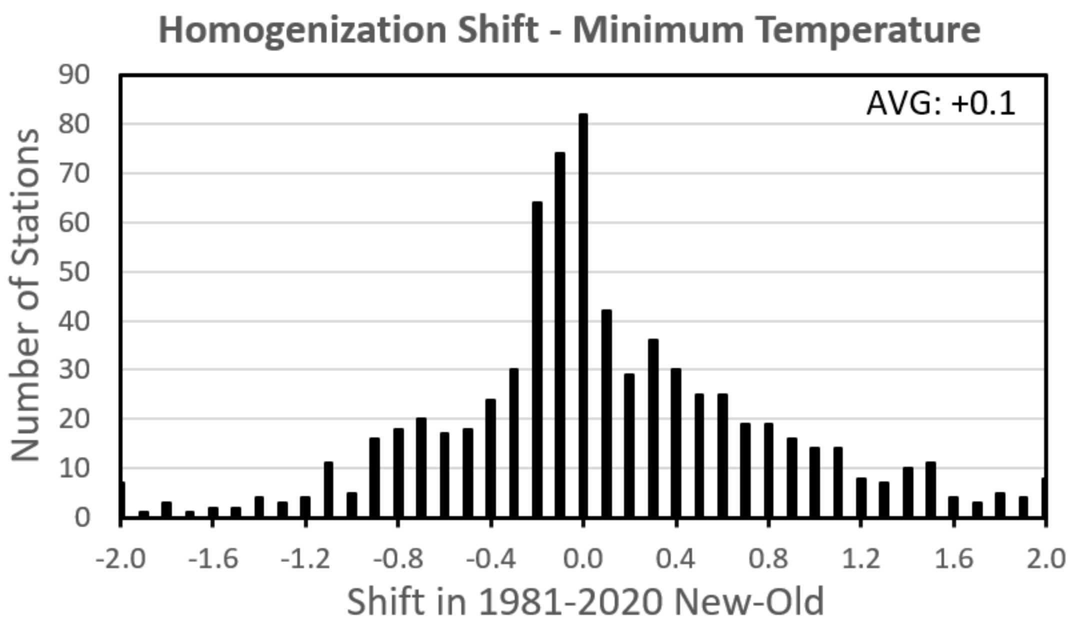


Figure 4. Histogram of homogeneity caused shifts in 1981-2010 normals as of February 2021.

While the impacts of homogenization vary from station to station, it is interesting to note that subtracting the updated 1981-2020 from the new 1991-2020 normals results in average for the 739 selected stations of +0.53°F between the two periods for minimum temperature, and +0.55°F for maximum temperature. It is always essential to compare apples to apples, which in this case means updating the 1981-2010 normals first before performing a comparison to 1991-2020. These changes are displayed on maps of the contiguous United States at the comparison tab on the normals web page at:
https://www.ncei.noaa.gov/products/us-climate-normals

In conclusion, while it may be concerning to see new temperature normals that are above or below numerical expectations based on raw data, the 1991-2020 U.S. Climate Normals are presenting the current climate truly so that departures can be calculated and characteristics understood.