United States Climate Normals, 1971-2000
Inhomogeneity Adjustment Methodology

National Climatic Data Center/NESDIS/NOAA
March 20, 2002

A climate normal is defined, by convention, as the arithmetic mean of a climatological element computed over three consecutive decades (WMO, 1989). Ideally, the data record for such a 30-year period should be free of any inconsistencies (*e.g.*, due to changes in station location, instrumentation, time of observation, surrounding environment, observing practice, sensor drift, *etc.*) and be serially complete (*i.e.*, no missing values). When present, inconsistencies can lead to a non-climatic bias in one period of a station's record relative to another. In that case, the data record is said to be *inhomogeneous*. Since records are frequently characterized by data inhomogeneities, statistical methods have been developed to identify and account for them. In the application of these methods, adjustments are made so that earlier periods in the data record more closely conform to the most recent period. Additionally, techniques have been developed to estimate values for missing observations. After such adjustments are made, the climate record is said to be *homogeneous* and serially complete. This adjusted record is characterized by variations and trends caused solely by variations and trends in weather and climate. The climate normal is then simply calculated as the average of the 30 values for each month observed over a normals period like 1971 to 2000. By using appropriately adjusted data records, the 30-year mean value will more closely reflect the average climatic conditions at a given station with respect to the instrumentation and siting conditions present at the end of the normals period.

A common approach to identifying data inhomogeneities is to compare the temperature series for a given station to neighboring observations by forming a difference series between a candidate's temperature series and the average from surrounding stations (the reference series). An example of this is shown in Figure 1 for Phoenix, Arizona (PHX; Sky Harbor Airport, Cooperative Number 026481). Panel A shows the time series of maximum monthly temperature departures for the 1990s for the candidate station (PHX; solid line) and the corresponding reference series (dashed line). Like many First-Order stations, PHX experienced a changeover to Automated Surface Observing System (ASOS) instrumentation in the 1990s, resulting in both instrumentation and siting changes. The difference between standardized monthly temperature anomalies at PHX and its reference series (Panel B) shows an apparent change in mean level coincident with ASOS commissioning. This inhomogeneity is statistically significant according to the maximum likelihood ratio test as shown in Panel C.

The goal in performing homogeneity adjustments is to produce a time series that is representative of the current observing practices, since these are the conditions under which future observations will be compared. As the PHX case illustrates, the changeover to ASOS can result in observations that are detectably cooler than those taken using previous instrumentation and siting conditions. Using an adjusted series, the current normals should reflect what is currently being observed by ASOS, not some integration of ASOS and past observing systems and locations. In other words, forecast production, verification, validation, and any other use of the normals (*e.g.*, Heating Degree Days calculation) are all linked to what is currently being observed, and any bias relative to the present observational system is removed.

As mentioned above, the data adjustments performed for the normals were based on comparison of the time series for the candidate station and a reference time series derived as a function of surrounding stations (*see* Peterson and Easterling (1994) for a description of reference series). The two time series were differenced, and the resulting difference time series examined for evidence of discontinuities resulting from a change in the relationship between the two time series. Since the reference series is produced from a number of surrounding observing stations (reference stations), the effect of individual inhomogeneities from any one reference station is minimized and the reference time series is considered to be homogeneous (all variations and trends are, for all intents and purposes, a result of variations in weather and climate rather than instrument changes, moves, *etc.*).

In the case of Phoenix, as with all normals temperature stations, the data adjustments were performed independently for both maximum and minimum temperature, as shown in Figure 2. For the most part, the adjustment is downward at Phoenix in the years prior to introduction of ASOS. As would be expected, the average of the 30-year adjusted series is cooler than the original series since values in the pre-ASOS period were lowered to conform to the cooler bias of the ASOS era.

While the largest discontinuity evident at Phoenix is related to the introduction of ASOS, **any** discontinuity identified through examination of the difference time series is assumed to be a change at the candidate station. These discontinuities were identified using a statistical approach described by Easterling and Peterson (1995). An offset value (change) is based on the change in the mean of the difference series before and after the discontinuity. This offset value was then used to adjust the candidate time series simply by adding the value to the candidate time series beginning at the identified discontinuity date and moving backward through time to either the next discontinuity or the beginning of the time series, whichever comes first. Thus, for example, if the ASOS was installed at a station in 1995, and an offset value of, say, -1.5°F was found (meaning that the ASOS was cooler than previous instruments), then the offset would be applied for observations prior to 1995. This adjustment makes the time series before ASOS consistent with the current ASOS observing site. Once the candidate time series has been adjusted for all discontinuities found during the thirty-year normals period (1971-2000), then the resulting normals are consistent with what is currently being observed.

Easterling, D.R, and T.C. Peterson, 1995: A new method for detecting and adjusting for undocumented discontinuities in climatological time series. *Internation. Journal of Climatology*, **15**, 369-377.

Peterson, T.C., and D.R. Easterling, 1994: Creation of homogeneous composite climatological reference series. *Internation Journal of Climatology*, 14, 671-679.

World Meteorological Organization, 1989: Calculation of Monthly and Annual 30-Year Standard Normals, *WCDP-No. 10, WMO-TD/No. 341*, Geneva: World Meteorological Organization.

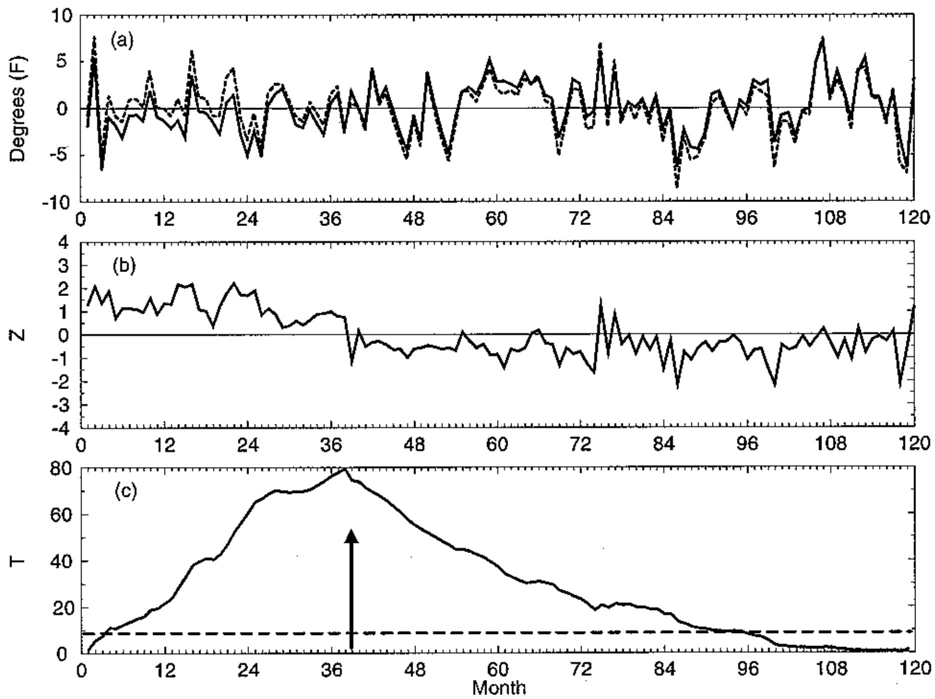

Figure 1. (a) Time series of monthly maximum temperature departures from January 1991 through December 2000 at Phoenix, Arizona (solid line) and for the reference series comprised of surrounding stations (dashed line).
(b) Standardized difference (z) between the candidate and reference series.
(c) Time series of the maximum likelihood ratio test statistic, T, for a change in mean level. The dashed line is the magnitude for the 95% critical values for a time series with 120 observations. The date of ASOS commissioning is noted by the arrow in early 1994.

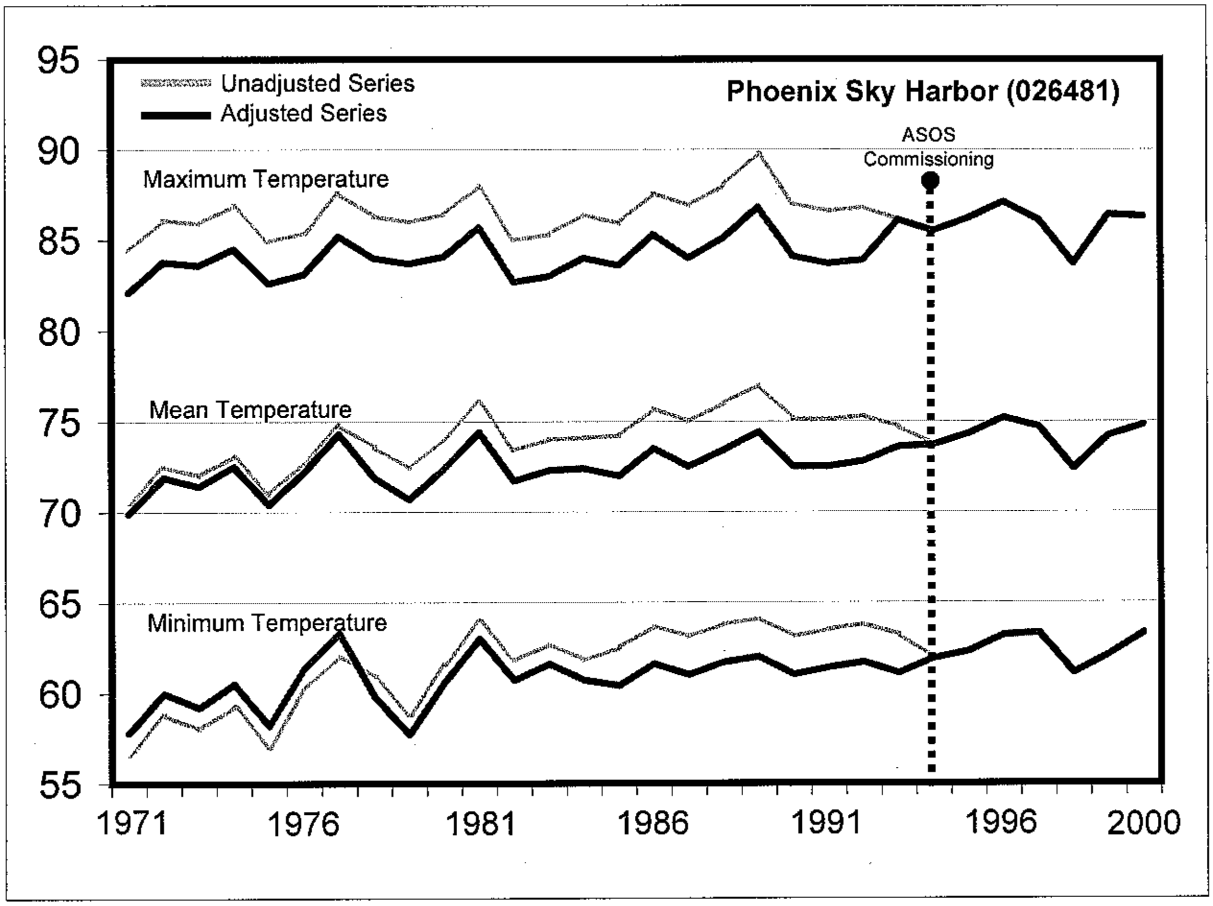

Figure 2. Monthly temperature values for Phoenix, Arizona, January 1971 through December 2000. The unadjusted series are shown in gray, while the inhomogeneity-adjusted series are shown in black. ASOS commissioning is noted with a dashed vertical line. Temperature values are in degrees Fahrenheit.