Indicator: US and Global Mean Temperature and Precipitation (351)

Air temperature and precipitation are the two main properties of climate and the most easily measured, directly observable, and geographically consistent indicators of climate change. Both indicators significantly impact ecological condition and human health.

Trends in global temperature and precipitation provide a context for interpreting trends in temperature and precipitation in the U.S. Instrumental records from land stations and ships indicate that global mean surface temperature warmed by about 0.6ºC +/- 0.2ºC during the 20th century (Figure 351-1, bottom). The warming trend is spatially widespread and is consistent with the global retreat of mountain glaciers, reduction in snow-cover extent, the earlier spring melting of ice on rivers and lakes, and increases in sea-surface temperatures and ocean heat content (NRC, 2001). Global mean precipitation also has increased (Figure 351-2, bottom). Precipitation over land has increased by about 2 percent globally since 1901, but the trends vary spatially and temporally. For example, instrumental records show a 5 to 10 percent increase in precipitation over land in northern mid-high latitudes, except over eastern Asia. In contrast, land-surface precipitation over the sub-tropics decreased about 3 percent during the 20th century, a trend that has weakened in recent decades (IPCC, 2001).

This indicator shows trends in actual temperatures and temperature anomalies and trends in precipitation and precipitation anomalies based on instrumental records of temperature and precipitation over the United States from 1901 to the present (with the exception of Alaska and Hawaii, where records began in 1918 and 1905, respectively).

Temperature anomalies (in degrees centigrade) represent the difference between the average temperature for a given month and the 1961-1990 mean. Precipitation anomalies represent the difference between the total precipitation for a given month and the 1961-1990 mean. The precipitation anomalies are converted to percent departures from average using the 1961-1990 means. Annual time series reflect the average (temperature anomaly) or total (precipitation anomaly) of the monthly time series.

What the Data Show

Across the contiguous United States, temperatures rose linearly at a rate of 0.06°C (0.1°F) per decade since 1901, increasing to 0.33°C (0.6°F) per decade since 1976 (Figure 351-1). The last five five-year periods (1999–2003, 1998–2002, 1997–2001, 1996–2000,1995–99) were the warmest in the last 109 yr of national records (compared to the 1961-1990 mean). The most recent six-year-(1998–2003), seven-year (1997–2003), eight-year (1996–2003), nine-year (1995–2003), and ten-year (1994–2003) periods also are the warmest on record for the United States (Levinson and Waple, 2004).

Most regions of the US have warmed by at least 0.6ºC (1ºF) since 1901 although the Southeast (climate region 2) has cooled (Figure 351-1). Warming in excess 1°C (1.8°F) has occurred in the West (climate region 8) and Alaska (climate region 10).

Total annual precipitation over the contiguous U.S has increased by 6.1 percent in the last century, although there is significant regional variability (Figure 351-2). (The precipitation trend based on linear regression shows an increase in precipitation of 4.5 mm/decade.) Precipitation has increased by at least 10% in the East North Central (climate region 5) and the South (climate region 4). Decreases in precipitation have been observed in the Southwest (climate region 7) and Hawaii (climate region 11).

Indicator Limitations

- Biases may have occurred as a result of changes over time in instrumentation, measuring techniques, and the exposure and location of the instruments.

- Uncertainites in both the temperature and precipitation data increase as one goes back in time, particularly in the west, where there are fewer stations early in the record.

Data Sources

The US Historical Climate Network (USHCN)

- NOAA's National Climate Data Center (NCDC): http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html

- DOE's Carbon Dioxide Information and Analysis Center (CDIAC): http://cdiac.ornl.gov/r3d/ushcn/ushcn.html#TOP

References

IPCC, 2001a: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

NRC (National Research Council), 2001. Climate Change Science: An Analysis of Some Key Questions. Committee on the Science of Climate Change. National Academy Press, Washington, DC, 29 pp.

Levinson, D. H., and A. M. Waple, 2004: State of the Climate 2003. *Bull. Amer. Meteor. Soc.*, **85** (June), S1–S72.

Graphics

Figure 351-1: Annual Mean Temperature Anomalies 1901-2003

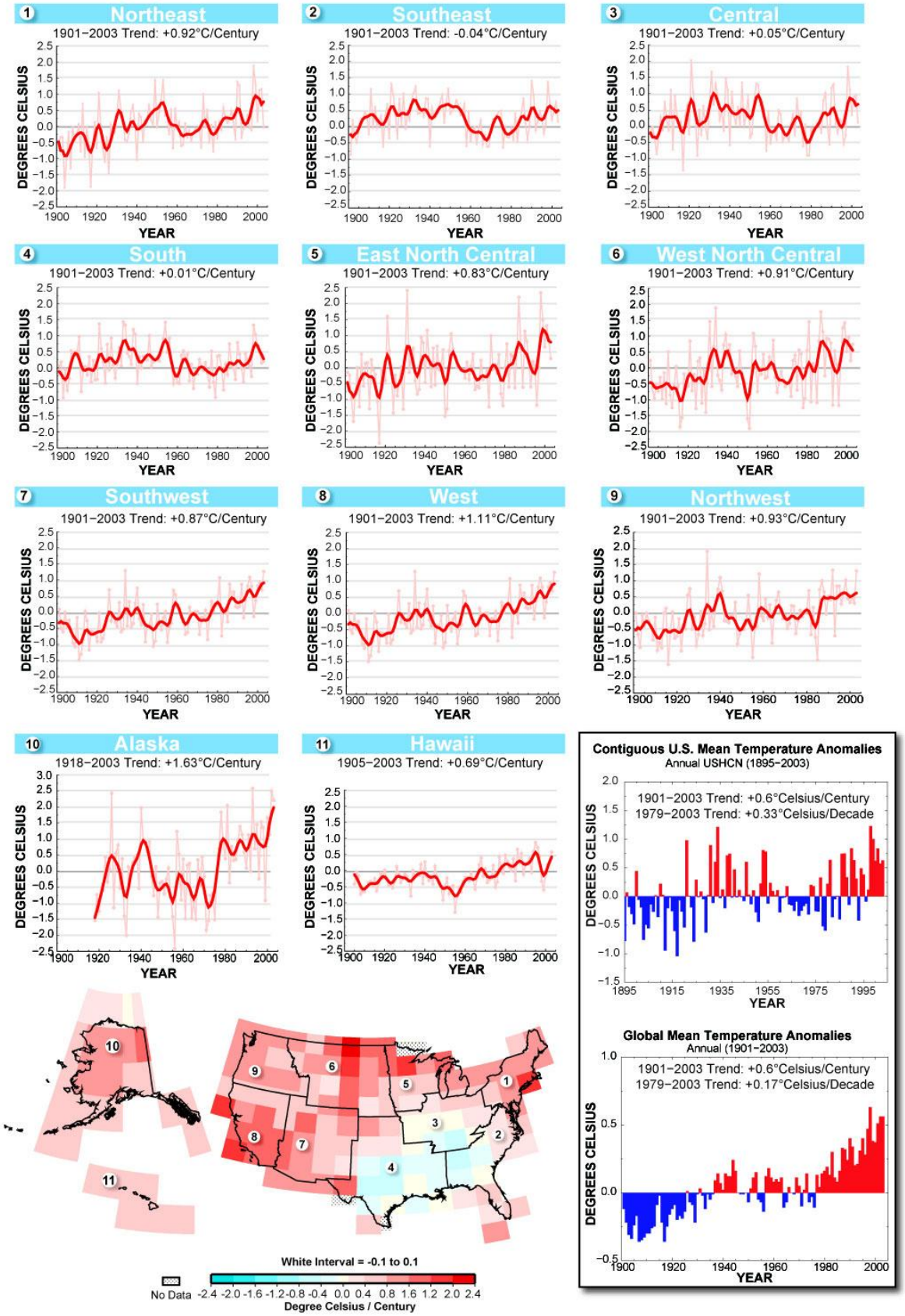
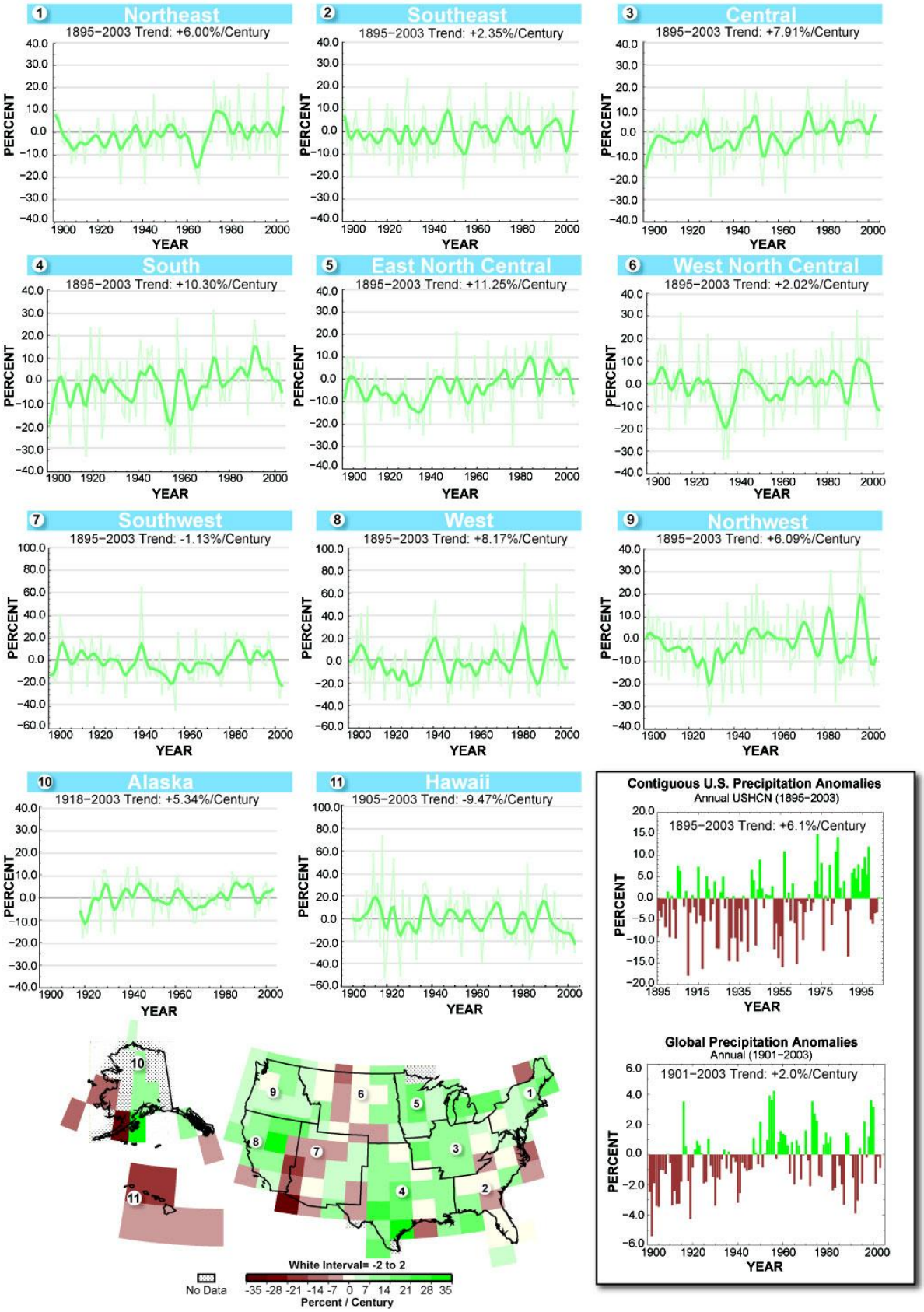


Figure 351-2: Annual Precipitation Anomalies 1895-2003



R.O.E. Indicator QA/QC

Data Set Name: U.S. AND GLOBAL MEAN TEMPERATURE AND PRECIPITATION
Indicator Number: 351 (114471)
Data Set Source: The U.S. Historical Climate Network and Global Historical Climate Network
Data Collection Date: 1901-2003
Data Collection Frequency: monthly
Data Set Description: Changes/Trends in Anomalies of US and Global Mean Temperature and Precipitation
Primary ROE Question: What are the trends in the critical physical and chemical attributes of the Nation's ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. The U.S. Historical Climatology Network (USHCN, Karl et al. 1990) is a high-quality moderate sized data set of monthly averaged maximum, minimum, and mean temperature and total monthly precipitation developed to assist in the detection of regional climate change.

References: http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html and http://cdiac.esd.ornl.gov/epubs/ndp019/ndp019.html

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. One of the objectives in establishing the U.S. HCN was to detect secular changes of regional rather than local climate. Therefore, only those stations that were not believed to be influenced to any substantial degree by artificial changes of local environments were included in the network. Some of the stations in the U.S. HCN are first order weather stations, but the majority were selected from U.S. cooperative weather stations (approximately 5000 in the United States). To be included in the U.S. HCN, a station had to be active (in 1987), have at least 80 years of mean monthly temperature and total monthly precipitation data, and have experienced few station changes. An additional criterion that was used in selecting the 1221 U.S. HCN stations, which sometimes compromised the preceding criteria, was the desire to have a uniform distribution of stations across the United States.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?
Yes. These data have been adjusted to remove biases introduced by station moves, instrument changes, time-of-observation differences, and urbanization effects.

References: - Easterling, D.R., and T.C. Peterson, 1995: A new method of detecting undocumented discontinuities in climatological time series, Int. J. of Climatol., 15, 369-377. - Karl, and C.N. Williams, 1987: An approach to adjusting climatological time series for discontinous inhomogeneities. J. Climate Appl. Meteor., 26, 1744-1763. - Karl, C.N. Williams Jr., and P.J. Young, 1986: A model to estimate the time of observation bias associated with monthly mean maximum, minimum, and mean temperatures for the United States J. Climate Appl. Meteor., 25, 145-160. - Karl, H. Diaz, and G. Kukla, 1988: Urbanization: Its detection in the U.S. climate record. J. Climate Appl. Meteor., 1, 1099-1123. - Quayle, R.G., D.R. Easterling, T.R. Karl, and P.Y. Hughes, 1991: Effects of recent thermometer changes in the cooperative station network. Bull. Amer. Meteor. Soc., 72, 1718-1723.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

The indicator provides a century long record of observed temperatures and precipitation throughout the United States. The USHCN is comprised of 1221 high-quality stations from the U.S. Cooperative Observing Network within the 48 contiguous United States. The data set is comprised of monthly averaged maximum, minimum, and mean temperature and total monthly precipitation. The data for Alaska and Hawaii originate from the Global Historical Climate Network dataset (GHCN) (comprised of over 14,000 individual station monthly records) which undergoes the same quality control measures as the USHCN. However these data are analyzed to produce 5x5 degree grid box data, whereas it was determined that a 2.5 degrees X 3.5 degree grid box was optimal for analysis of the USHCN data within the contiguous U.S. See: http://www.ncdc.noaa.gov/oa/climate/research/ushcn/gridbox.html

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

The network covers the entire United States, including sensitive populations and ecosystems.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

The mean temperature and precipitation trends provide an unambiguous indicator of climate change in the United States.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

See: http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

The USHCN was developed and is maintained at NOAA's National Climatic Data Center (NCDC) and the Carbon Dioxide Information and Analysis Center (CDIAC) of Oak Ridge National Laboratory through a cooperative agreement between the NCDC and the U.S. Department of Energy. Currently it is distributed by NCDC and by CDIAC on various computer media including anonymous ftp. There are no confidentiality issues that may limit accessibility. Link to data online: ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/
http://cdiac.esd.ornl.gov/epubs/ndp019/ushcn_r3.html

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. Appropriate README files are appended to the data so that they are discernible for analysis. See: ftp://ftp.ncdc.noaa.gov/pub/data/ushcn/README.TXT
T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

Both the National Climatic Data Center and the Carbon Dioxide Information and Analysis Center publish extensive documentation about the USHCN dataset. See:
http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html and
http://cdiac.esd.ornl.gov/epubs/ndp019/ndp019.html

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Anomalies and Trends for the contiguous US were calculated from the US Historical Climatology Network database (Karl et al. 1990). The Anomaly Method was used for calculating station anomalies (base period 1961-1990 minimum 25 of 30 years of data required) on a month by month basis, and the station anomalies were then averaged within 3.5X2.5 degree grid cells. In obtaining regional time series, the grid cell anomalies were averaged (using cosine weighting) across all grid cells within regions. For grid cells that were only partially contained within a region, the grid cell anomaly was also weighted by the proportion of the grid cell within the region. Annual time series are the average (temperature) or total (precipitation) of the monthly time series. Precipitation anomalies were converted to percent departures from average using the 1961-1990 means. Grid cell trends were calculated using least squares regression after the annual time series were computed for each grid box. The Global Historical Climatology Network database (Peterson and Vose, 1997) was the source of data for Alaska and Hawaii anomaly and trend calculations as well as for global calculations. The global temperature temperature trends were taken from the merged land air and sea surface temperature dataset consisting of a combination of GHCN and COADS data. Global precipitation is from GHCN only. Station anomalies for precipitation were calculated using the Anomaly Method (base period 1961-1990 minimum 25 of 30 years of data required), while station temperature anomalies were calculated using the First Difference Method (Peterson et al. 1998) on a month by month basis. Station anomalies for precipitation and temperature were averaged within 5X5 degree grid cells and the monthly grid cell values averaged (temperature) or totaled (precipitation) into annual anomalies. Precipitation anomalies were converted to percent departures from average using the 1961-1990 means. Statewide and global time series and grid cell trends were calculated in the manner described for the contiguous US. Trends were calculated only in those grid cells for which there were at least 68 years of data in the 103-year period. A summary of the data set and methods (for the Global data, i.e. Alaska and Hawaii) used in development can be found at http://www.ncdc.noaa.gov/gcag/gcagmerged.html

Additional references: - Karl, T.R., C.N. Williams, Jr., F.T. Quinlan, and T.A. Boden, 1990: United States Historical Climatology Network (HCN) Serial Temperature and Precipitation Data, Environmental Science Division, Publication No. 3404, Carbon Dioxide Information and Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN, 389 pp. - Peterson, T.C., T.R. Karl, P.F. Jamason, R. Knight, and D.R. Easterling, 1998: The first difference method: maximizing station density for the calculation of long-term global temperature change. Journal of Geophysical Research, Atmospheres , 103 (D20), 25967-25974. - Peterson, T.C., and R.S. Vose, 1997: An overview of the Global Historical Climatology Network temperature data base. Bulletin of the American Meteorological Society , 78 (12), 2837-2849.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Not presently. During the first half of 2005, it is likely that NOAA's National Climatic Data Center will begin putting error bars on temperature time series, but techniques for doing this for precipitation have not been developed.

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Balling and Idso (2002) compare the USHCN data with several surface and upper-air datasets and show that the effects of the various USHCN adjustments produce a significantly more positive, and likely spurious, trend in the USHCN data. However, in a subsequent analysis Vose et al. (2003) found that USHCN station history information is reasonably complete and that the bias adjustment models have low residual errors. References: Balling Jr., R.C. and Idso, C.D. 2002. Analysis of adjustments to the United States Historical Climatology Network (USHCN) temperature database. Geophysical Research Letters R. S. Vose, C. N. Williams Jr., T. C. Peterson, T. R. Karl, and D. R. Easterling, 2003: An evaluation of the time of observation bias adjustment in the U.S. Historical Climatology Network. Geophysical Research Letters.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

There are data gaps, particularly in the earlier years of the time series that increase the uncertainty but these are not sufficient to mislead the user about the fundamental trends.