

## Heat Waves

**1 Describe the physical, chemical, or biological measurements upon which this indicator is based. Are these measurements widely accepted as scientifically and technically valid? Explain.**

This indicator is based on measurements from the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS) Cooperative Observer Program (COOP). NOAA's COOP data set is the core climate network of the United States (Kunkel et al., 2005). Data collected by COOP are referred to as U.S. Daily Surface Data or Summary of the Day data. Cooperative observers include state universities, state and federal agencies, and private individuals whose stations are managed and maintained by NWS. Each station records a minimum of one variable. Variables from the COOP data set that are relevant to this indicator include observations of daily maximum and minimum temperatures. General information about the NWS COOP data set is available at: [www.nws.noaa.gov/os/coop/what-is-coop.html](http://www.nws.noaa.gov/os/coop/what-is-coop.html).

**2 Describe the sampling design and/or monitoring plan used to collect the data over time and space. Is it based on sound scientific principles? Explain.**

Systematic collection of weather data in the United States began in the 1800s. Since then, observations have been recorded from 23,000 stations. At any given time, observations are recorded from approximately 8,000 stations. Observations are made on a 24-hour basis, and the maximum and minimum temperatures are recorded for each 24-hour time span. Daily maximum and minimum temperature data used in this indicator represent only the contiguous 48 states; however, the data set has broader regional coverage. Observers are trained to collect data, and equipment to gather these data is provided and maintained by the NWS.

**3 Describe the conceptual model used to transform these measurements into an indicator. Is this model widely accepted as a scientifically sound representation of the phenomenon it indicates? Explain.**

Data from the COOP data set have been used to calculate annual values for a U.S. Annual Heat Wave Index. In this indicator, heat waves are defined as warm periods of at least four days with an average temperature (that is, averaged over all four days) exceeding the threshold for a 1 in 10 year occurrence (Kunkel et al, 1999). The Annual U.S. Heat Wave Index is a frequency measure of the number of heat waves that occur each year. A complete explanation of trend analysis in the annual average heat wave index values, especially trends occurring since 1960, can be found in Appendix A, Example 2, of U.S. Climate Change Science Program (2008).

Figures 2 and 3 of this indicator show the percentage of the area of the contiguous 48 states in any given year that experienced daytime temperatures much above normal daily highs and nighttime temperatures much above normal daily lows, respectively. This part of the analysis

was originally reported in U.S. Climate Change Science Program (2008), although that report does not define what is meant by “much above.” Data were adjusted to remove urban warming bias (U.S. Climate Change Science Program, 2008).

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

Sampling procedures are described in Kunkel et al. (2005) and in the full metadata for the COOP data set available at:

[www.ngdc.noaa.gov/nmmrview/xmls/fgdc.jsp?id=gov.noaa.ncdc:C00314&view=html#Metadata\\_Reference\\_Information](http://www.ngdc.noaa.gov/nmmrview/xmls/fgdc.jsp?id=gov.noaa.ncdc:C00314&view=html#Metadata_Reference_Information).

Analytical procedures are described in Kunkel et al. (1999) and Appendix A of U.S. Climate Change Science Program (2008).

Pre-1948 data from the COOP data set were digitized over the last few years. A number of other potential sources of error were corrected for during digitization, to the extent possible. These changes are described in Kunkel et al. (2005).

**5 To what extent is the complete data set accessible, including metadata, data-dictionaries, and embedded definitions? Are there confidentiality issues that may limit accessibility to the complete data set?**

Data for this indicator were provided directly by Dr. Ken Kunkel (Desert Research Institute) and Dr. David Easterling (NOAA). However, all raw COOP data are maintained in a public database by NOAA’s National Climate Data Center (NCDC). Complete data, embedded definitions, and data descriptions can be downloaded online at: [www.ncdc.noaa.gov/doclib/](http://www.ncdc.noaa.gov/doclib/). State-specific data can be found at:

[www7.ncdc.noaa.gov/IPS/coop/coop.html?jsessionid=312EC0892FFC2FBB78F63D0E3ACF6CBC](http://www7.ncdc.noaa.gov/IPS/coop/coop.html?jsessionid=312EC0892FFC2FBB78F63D0E3ACF6CBC). There are no confidentiality issues that may limit accessibility, but some portions of the data set may need to be formally requested. Complete metadata for the COOP data set can be found at: [www.ngdc.noaa.gov/nmmrview/xmls/fgdc.jsp?id=gov.noaa.ncdc:C00314&view=html](http://www.ngdc.noaa.gov/nmmrview/xmls/fgdc.jsp?id=gov.noaa.ncdc:C00314&view=html).

**6 Are the descriptions of the study or survey design clear, complete, and sufficient to enable the study or survey to be reproduced? Explain.**

As described in the response to Question 5, all raw data in the COOP data set are publicly available, although significant data aggregation would have to be undertaken to reproduce the indicator data set. Information to reproduce Figure 1 of this indicator (the U.S. Annual Heat Wave Index) can be found in Kunkel et al. (1999) (and references therein) and U.S. Climate Change Science Program (2008) (full report and Appendix A, Example 2). Information to reconstruct Figures 2 and 3 of this indicator is somewhat more limited; the available information can be found in U.S. Climate Change Science Program (2008).

**7 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?**

The NWS has documented COOP methods, including training manuals and maintenance of equipment, at: [www.nws.noaa.gov/os/coop/training.htm](http://www.nws.noaa.gov/os/coop/training.htm). Quality control of the underlying data set is also discussed at: [www.ngdc.noaa.gov/nmmrview/xmls/fgdc.jsp?id=gov.noaa.ncdc:C00314&view=html#quality](http://www.ngdc.noaa.gov/nmmrview/xmls/fgdc.jsp?id=gov.noaa.ncdc:C00314&view=html#quality). Additionally, early data in the COOP data set have recently been digitized from hard copy. Quality control associated with digitization and other potential sources of error are discussed in Kunkel et al. (2005).

**8 What statistical methods, if any, have 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)? Are these methods scientifically appropriate?**

Certain statistical methods are used to determine trends in the U.S. heat wave index data. These trends are based on data collected from stations spread throughout the contiguous United States. Long-term collection stations have been carefully selected from the full set of all collection stations to provide an accurate representation of the United States (Kunkel et al., 1999). Statistical methods used to analyze trends in U.S. annual heat wave index are presented in Appendix A, Example 2, of U.S. Climate Change Science Program (2008).

**9 What uncertainty measurements or estimates are available for the indicator and/or the underlying data set?**

Error estimates have been developed for certain segments of the data set, such as the pre-1948 COOP data. However, error estimates do not appear to be available for the data set as a whole. Uncertainty measurements are not included with the publication of the U.S. Annual Heat Wave Index and the area of the U.S. hot daily highs and hot daily lows. Error measurements for the pre-1948 COOP data set are discussed in detail in Kunkel et al. (2005).

**10 To what extent do uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?**

Heat wave trends are somewhat difficult to analyze because of the presence of several outlying values in the 1930s and inter-annual variability which may frustrate attempts to fit a linear trend to the whole series. However, standard statistical treatments can be applied to assess a highly statistically significant linear trend from 1960 to 2008. Periodic re-analysis and quality control of subsets of the COOP data set has improved the quality of the data and reduced error overall. Improvement of the pre-1948 data set is described in Kunkel et al. (2005).

**11 Describe any limitations or gaps in the data that may mislead a user about fundamental trends in the indicator over space or over the time period for which data are available.**

Limitations to this indicator include the following:

1. Biases may have occurred as a result of changes over time in instrumentation, measuring procedures, and the exposure and location of the instruments.
2. Observer errors, such as errors in reading instruments or writing observations on the form, are present in the earlier part of this data set. Additionally, uncertainty may be introduced into this data set when hard copies of data are digitized. As a result of these and other reasons, uncertainties in the temperature data increase as one goes back in time, particularly given that there are fewer stations early in the record. However, NOAA does not believe these uncertainties are sufficient to mislead the user about fundamental trends in the data. More information about limitations of early COOP data can be found in Kunkel et al. (2005).

**12 References**

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Kunkel, K.E., D.R. Easterling, K. Hubbard, K. Redmond, K. Andsager, M.C. Kruk, and M.L. Spinar. 2005. Quality control of pre-1948 Cooperative Observer Network data. *J. Atmos. Oceanic Technol.* 22:1691–1705.

U.S. Climate Change Science Program. 2008. Synthesis and Assessment Product 3.3: Weather and climate extremes in a changing climate. <[www.climatechange.gov/Library/sap/sap3-3/final-report/sap3-3-final-Chapter2.pdf](http://www.climatechange.gov/Library/sap/sap3-3/final-report/sap3-3-final-Chapter2.pdf)>