Heat-Related Deaths

Identification

1. Indicator Description

Extreme heat events (i.e., heat waves) have become more frequent in the United States in recent decades (see the High and Low Temperatures indicator), and studies project that the frequency, duration, and intensity of extreme heat events will continue to increase as a consequence of climate change (Melillo et al., 2014). When people are exposed to extreme heat, they can suffer from potentially deadly heat-related illnesses such as heat exhaustion and heat stroke. Additionally, the incidence of deaths due to cardiovascular disease (CVD) has been shown to increase with temperature, particularly among older adults and other vulnerable populations such as non-Hispanic blacks (Berko et al., 2014; Zanobetti et al., 2012). Thus, as extreme heat events increase, the risk of heat-related deaths and illness is also expected to increase (IPCC, 2014; Sarofim et al., 2016). Tracking the rate of reported overall heat-related deaths and heat-related CVD deaths over time provides a measure of how climate change may affect human well-being.

Components of this indicator include:

- The rate of U.S. annual deaths between 1979 and 2014 for which heat was classified on death certificates as the underlying (direct) cause (Figure 1, orange line).
- The rate of U.S. summer deaths between 1999 and 2014 for which heat was classified as either the underlying cause or a contributing factor (Figure 1, blue line).
- The rate of U.S. summer deaths between 1999 and 2014 for which cardiovascular disease was classified as the underlying cause and heat was listed as a contributing factor (Figure 2). Rates are shown for three groups: the general population, individuals age 65 and older, and non-Hispanic black individuals.

2. Revision History

April 2010:	Indicator published.
December 2012:	Updated indicator with data through 2009. Added contributing factors analysis to complement the existing time series, converted the measure from counts to crude rates, and added an example figure.
May 2014:	Updated indicator with data through 2010.
June 2015:	Updated indicator on EPA's website with data through 2013.
August 2016:	Updated indicator with data through 2014. Added Figure 2 to show heat-related CVD death rates.

Data Sources

3. Data Sources

This indicator is based on data from the U.S. Centers for Disease Control and Prevention's (CDC's) National Vital Statistics System (NVSS), which compiles information from death certificates for nearly every death in the United States. The NVSS is the most comprehensive source of mortality data for the population of the United States. The CDC provided analysis of NVSS data.

Mortality data for the illustrative example figure came from CDC's National Center for Health Statistics (NCHS). The estimate of deaths in excess of the average daily death rate is from the National Research Council's report on climate stabilization targets (NRC, 2011), which cites the peer-reviewed publication Kaiser et al. (2007).

For reference, the illustrative example also shows daily maximum temperature data from the weather station at the Chicago O'Hare International Airport (GHCND:USW00094846).

4. Data Availability

Underlying Causes

The long-term time series (1979–2014) in Figure 1 is based on CDC's Compressed Mortality File, which can be accessed through the CDC WONDER online database at: http://wonder.cdc.gov/mortSQL.html (CDC, 2016a). CDC WONDER provides free public access to mortality statistics, allowing users to query data for the nation as a whole or by state or region, demographic group (age, sex, race), or International Classification of Diseases (ICD) code. Users can obtain the data for this indicator by accessing CDC WONDER and querying the ICD codes listed in Section 5 for the entire U.S. population.

Underlying and Contributing Causes

The 1999–2014 time series in Figure 1 is based on an analysis developed by the National Environmental Public Health Tracking (EPHT) Program, which CDC coordinates. Monthly totals by state are available online at: http://ephtracking.cdc.gov/showIndicatorPages.action. CDC staff from the National Center for Environmental Health (NCEH) EPHT branch provided national totals to EPA (CDC, 2016c).

Users can query underlying and contributing causes of death through CDC WONDER's Multiple Causes of Death file (http://wonder.cdc.gov/mcd-icd10.html), but note that EPHT performed additional steps for Figure 1 that cannot be recreated through the publicly available data portal (see Section 6).

Underlying and Contributing Causes: Cardiovascular Disease

The 1999–2014 trend lines for heat-related CVD deaths in Figure 2 are based on underlying causes (diseases of the circulatory system) and contributing causes (heat) data from CDC's Multiple Cause of Death file, which can be accessed through the CDC WONDER online database at: http://wonder.cdc.gov/mcd-icd10.html (CDC, 2016b).

Death Certificates

Individual-level data (i.e., individual death certificates) are not publicly available due to confidentiality issues.

Chicago Heat Wave Example

Data for the example figure are based on CDC's Compressed Mortality File, which can be accessed through the CDC WONDER online database at: www.cdc.gov/nchs/data_access/cmf.htm. The analysis was obtained from Kaiser et al. (2007). Daily maximum temperature data for 1995 from the Chicago O'Hare International Airport weather station are available from the National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Information (NCEI) at: www.ncdc.noaa.gov/cdo-web.

Methodology

5. Data Collection

This indicator is based on causes of death as reported on death certificates. A death certificate typically provides space to designate an immediate cause of death along with up to 20 contributing causes, one of which will be identified as the underlying cause of death. The World Health Organization (WHO) defines the underlying cause of death as "the disease or injury which initiated the train of events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury."

Causes of death are certified by a physician, medical examiner, or coroner, and are classified according to a standard set of codes called the ICD. Deaths for 1979 through 1998 are classified using the Ninth Revision of ICD (ICD-9). Deaths for 1999 and beyond are classified using the Tenth Revision (ICD-10).

Although causes of death rely to some degree on the judgment of the physician, medical examiner, or coroner, the "measurements" for this indicator are expected to be generally reliable based on the medical knowledge required of the "measurer" and the use of a standard classification scheme based on widely accepted scientific definitions. When more than one cause or condition is entered, the underlying cause is determined by the sequence of conditions on the certificate, provisions of the ICD, and associated selection rules and modifications.

Mortality data are collected for the entire population and, therefore, are not subject to sampling design error. For virtually every death that occurs in the United States, a physician, medical examiner, or coroner certifies the causes of death on an official death certificate. State registries collect these death certificates and report causes of death to the NVSS. NVSS's shared relationships, standards, and procedures form the mechanism by which the CDC collects and disseminates the nation's official vital statistics.

Standard forms for the collection of data and model procedures for the uniform registration of death events have been developed and recommended for state use through cooperative activities of the states and CDC's NCHS. All states collect a minimum data set specified by NCHS, including underlying causes of death and basic demographic data (e.g., age, race, and ethnicity). CDC has published procedures for collecting vital statistics data (CDC, 1995).

This indicator excludes deaths to foreign residents and deaths to U.S. residents who died abroad.

General information regarding data collection procedures can be found in the Model State Vital Statistics Act and Regulations (CDC, 1995). For additional documentation on the CDC WONDER database (EPA's data source for part of this indicator) and its underlying sources, see: http://wonder.cdc.gov/wonder/help/cmf.html.

CDC has posted a recommended standard certificate of death online at: www.cdc.gov/nchs/data/dvs/DEATH11-03final-ACC.pdf. For a complete list and description of the ICD codes used to classify causes of death, see: www.who.int/classifications/icd/en.

Chicago Heat Wave Example

The mortality data set shown in the example figure includes the entire Standard Metropolitan Statistical Area for Chicago, a region that contains Cook County plus a number of counties in Illinois and Indiana, from June 1 to August 31, 1995.

In the text box above the example figure, values reflect data from Cook County only. The number of deaths classified as "heat-related" on Cook County death certificates between July 11 and July 27, 1995, was reported to CDC by the Cook County Medical Examiner's Office. More information is available in CDC's Morbidity and Mortality Weekly Report (www.cdc.gov/MMWR/preview/mmwrhtml/00038443.htm). Deaths in excess of the average daily death rate for Cook County were determined from death certificates obtained from the Illinois Department of Public Health (Kaiser et al., 2007).

6. Indicator Derivation

This indicator reports annual rates of deaths per million population that have been classified with ICD codes related to exposure to natural sources of heat. The NVSS collects data on virtually all deaths that occur in the United States, meaning the data collection mechanism already covers the entire target population. Thus, it was not necessary to extrapolate the results on a spatial or population basis. No attempt has been made to reconstruct trends prior to the onset of comprehensive data collection, and no attempt has been made to project data forward into the future.

Underlying Causes

The long-term trend line in Figure 1 reports the rate of deaths per year for which the underlying cause had one of the following ICD codes:

- ICD-9 code E900: "excessive heat—hyperthermia"—specifically subpart E900.0: "due to weather conditions."
- ICD-10 code X30: "exposure to excessive natural heat—hyperthermia."

This component of the indicator is reported for the entire year. EPA developed this analysis based on the publicly available data compiled by CDC WONDER. EPA chose to use crude death rates rather than death counts because rates account for changes in total population over time. Population figures are obtained from CDC WONDER.

Underlying and Contributing Causes

The "underlying and contributing causes" trend line in Figure 1 reports the rate of deaths for which either the underlying cause or the contributing causes had one or more of the following ICD codes:

- ICD-10 code X30: "exposure to excessive natural heat—hyperthermia."
- ICD-10 codes T67.0 through T67.9: "effects of heat and light." Note that the T67 series is used only for contributing causes—never for the underlying cause.

To reduce the chances of including deaths that were incorrectly classified, EPHT did not count the following deaths:

- Deaths occurring during colder months (October through April). Thus, the analysis is limited to May–September.
- Any deaths for which the ICD-10 code W92, "exposure to excessive heat of man-made origin," appears in any cause field. This step removes certain occupational-related deaths.

Foreign residents were excluded. EPHT obtained death counts directly from NVSS, rather than using the processed data available through CDC WONDER. EPHT has not yet applied its methods to data prior to 1999. For a more detailed description of EPHT's analytical methods, see the indicator documentation at: http://ephtracking.cdc.gov/showIndicatorPages.action. Crude death rates were calculated in the same manner as with the underlying causes time series.

Underlying and Contributing Causes: Cardiovascular Disease

The lines in Figure 2 report crude rates of deaths for which diseases of the circulatory system were listed as the underlying cause of death and heat was listed as a contributing factor. The underlying causes of death for Figure 2 include the following ICD codes:

- ICD-10 codes I00 through I02: "acute rheumatic fever."
- ICD-10 codes I05 through I09: "chronic rheumatic heart diseases."
- ICD-10 codes I10 through I15: "hypertensive diseases."
- ICD-10 codes I20 through I25: "ischaemic heart disease."
- ICD-10 codes I26 through I28: "pulmonary heart disease and diseases of pulmonary circulation."
- ICD-10 codes I30 through I51: "other forms of heart disease."
- ICD-10 codes I60 through I69: "cerebrovascular disease."
- ICD-10 codes I70 through I78: "diseases of arteries, arterioles and capillaries."
- ICD-10 codes I80 through I89: "diseases of veins, lymphatic vessels and lymph nodes."

- ICD-10 codes I95 through I99: “other and unspecified disorders of the circulatory system.”

To associate diseases of the circulatory system (underlying cause) with heat, the following ICD codes were evaluated as a contributing cause for each death:

- ICD-10 code X30: “exposure to excessive natural heat—hyperthermia.”
- ICD-10 codes T67.0 through T67.9: “effects of heat and light.”

Figure 2 presents data for three demographic groups: the general population, individuals age 65+, and non-Hispanic blacks. Specific query parameters were as follows:

- General population: all races and all age groups.
- Age 65+: all races and the following age groups: 65-74 years, 75-84 years, and 85+ years.
- Non-Hispanic blacks: all age groups, Black or African American race, and Not Hispanic or Latino origin.

CDC provided monthly data for the general population and age 65+ groups for Figure 2; EPA queried the data for non-Hispanic blacks directly from: http://wonder.cdc.gov/mcd-icd10.html. To reduce the chances of including deaths that were incorrectly classified, and to be consistent with the “underlying and contributing causes” analysis in Figure 1, EPA removed deaths occurring during colder months (October through April). Thus, the analysis is limited to May–September.

Chicago Heat Wave Example

The authors of Kaiser et al. (2007) determined that the Chicago area had 692 deaths in excess of the background death rate between June 21 and August 10, 1995. This analysis excluded deaths from accidental causes but included 183 deaths from “mortality displacement,” which refers to a decrease in the deaths of individuals who would have died during this period in any case but whose deaths were accelerated by a few days due to the heat wave. This implies that the actual number of excess deaths during the period of the heat wave itself (July 11–27) was higher than 692, but was compensated for by reduced daily death rates in the week after July 27. Thus the value for excess deaths in Cook County for the period of July 11–27 is reported as approximately 700 in the text box above the example figure.

7. Quality Assurance and Quality Control

Vital statistics regulations have been developed to serve as a detailed guide to state and local registration officials who administer the NVSS. These regulations provide specific instructions to protect the integrity and quality of the data collected. This quality assurance information can be found in CDC (1995).

For the “underlying and contributing causes” component of this indicator, extra steps have been taken to remove certain deaths that could potentially reflect a misclassification (see Section 6). These criteria generally excluded only a small number of deaths.

Analysis

8. Comparability Over Time and Space

When plotting the long-term data in Figure 1, EPA inserted a break in the line between 1998 and 1999 to reflect the transition from ICD-9 codes to ICD-10 codes. The change in codes makes it difficult to accurately compare pre-1999 data with data from 1999 and later. Otherwise, all methods have been applied consistently over time and space. ICD codes allow physicians and other medical professionals across the country to use a standard scheme for classifying causes of deaths.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from this indicator are as follows:

1. It has been well-documented that many deaths associated with extreme heat are not identified as such by the medical examiner and might not be correctly coded on the death certificate. In many cases, they might just classify the cause of death as a cardiovascular or respiratory disease. They might not know for certain whether heat was a contributing factor, particularly if the death did not occur during a well-publicized heat wave. By studying how daily death rates vary with temperature in selected cities, scientists have found that extreme heat contributes to far more deaths than the official death certificates would suggest (Medina-Ramón and Schwartz, 2007). That is because the stress of a hot day can increase the chance of dying from a heart attack, other heart conditions, and respiratory diseases such as pneumonia (Kaiser et al., 2007). These causes of death are much more common than heat-related illnesses such as heat stroke. Thus, this indicator very likely underestimates the number of deaths caused by exposure to heat. However, it does serve as a reportable national measure of overall deaths and CVD deaths attributable to heat.

2. ICD-9 codes were used to specify underlying cause of death for the years 1979 to 1998. Beginning in 1999, cause of death was specified with ICD-10 codes. The two revisions differ substantially, so data from before 1999 cannot easily be compared with data from 1999 and later.

3. The fact that a death is classified as “heat-related” does not mean that high temperatures were the only factor that caused the death. Pre-existing medical conditions can greatly increase an individual’s vulnerability to heat.

4. Heat waves are not the only factor that can affect trends in “heat-related” deaths. Other factors include the vulnerability of the population, the extent to which people have adapted to higher temperatures, the local climate and topography, and the steps people have taken to manage heat emergencies effectively. In particular, heat-response measures can make a big difference in death rates. Response measures can include early warning and surveillance systems, air conditioning, increased access to cooling centers, health care, public education, infrastructure standards, and air quality management. For example, after a 1995 heat wave, the city of Milwaukee developed a plan for responding to extreme heat conditions in the future. During a 1999 heat wave, this plan cut heat-related deaths nearly in half compared with what was expected (Weisskopf et al., 2002).

Other studies may shed some light on the extent of undercounting inherent in this data set. As described in Sarofim et al. (2016), some statistical approaches estimate that more than 1,300 deaths per year in the United States are due to extreme heat, compared with about 600 deaths per year in the "underlying and contributing causes" data set shown in Figure 1. The Chicago heat wave example shows that a single extreme heat event likely caused about 700 deaths that would not otherwise have occurred during that time period, even though only 465 deaths were attributed to extreme heat on death certificates during that period.

10. Sources of Uncertainty

Uncertainty estimates are not available for this indicator. Because statistics have been gathered from virtually the entire target population (i.e., all deaths in a given year), these data are not subject to the same kinds of errors and uncertainties that would be inherent in a probabilistic survey or other type of representative sampling program.

Some uncertainty could be introduced as a result of the professional judgment required of the medical professionals filling out the death certificates, which could potentially result in misclassification or underreporting in some number of cases—probably a small number of cases, but still worth noting.

11. Sources of Variability

There is substantial year-to-year variability within the data, due in part to the influence of a few large events. Many of the spikes apparent in Figures 1 and 2 can be attributed to specific severe heat waves occurring in large urban areas.

12. Statistical/Trend Analysis

This indicator does not report on the slope of the apparent trends in heat-related deaths, nor does it calculate the statistical significance of these trends.

References

Berko, J., D.D. Ingram, S. Saha, and J.D. Parker. 2014. Deaths attributed to heat, cold, and other weather events in the United States, 2006–2010. National Health Statistics Reports, Number 76. National Center for Health Statistics. www.cdc.gov/nchs/data/nhsr/nhsr076.pdf.

CDC (U.S. Centers for Disease Control and Prevention). 1995. Model State Vital Statistics Act and Regulations (revised April 1995). DHHS publication no. (PHS) 95-1115. www.cdc.gov/nchs/data/misc/mvsact92aacc.pdf.

CDC. 2016a. CDC Wide-ranging Online Data for Epidemiologic Research (WONDER). Compressed mortality file, underlying cause of death. 1999–2014 (with ICD-10 codes) and 1979–1998 (with ICD-9 codes). Accessed February 2016. http://wonder.cdc.gov/mortSQL.html.

CDC. 2016b. CDC Wide-ranging Online Data for Epidemiologic Research (WONDER). Multiple cause of death file. 1999–2014 (with ICD-10 codes). Accessed July 2016. http://wonder.cdc.gov/mcd-icd10.html.

CDC. 2016c. Indicator: Heat-related mortality. National Center for Health Statistics. Annual national totals provided by National Center for Environmental Health staff in June 2016. http://ephtracking.cdc.gov/showIndicatorPages.action.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate change 2014: Impacts, adaptation, and vulnerability. Working Group II contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. http://ipcc.ch/report/ar5/wg2.

Kaiser, R., A. Le Tertre, J. Schwartz, C.A. Gotway, W.R. Daley, and C.H. Rubin. 2007. The effect of the 1995 heat wave in Chicago on all-cause and cause-specific mortality. Am. J. Public Health 97(Supplement 1):S158–S162.

Medina-Ramón, M., and J. Schwartz. 2007. Temperature, temperature extremes, and mortality: A study of acclimatization and effect modification in 50 U.S. cities. Occup. Environ. Med. 64(12):827–833.

Melillo, J.M., T.C. Richmond, and G.W. Yohe (eds.). 2014. Climate change impacts in the United States: The third National Climate Assessment. U.S. Global Change Research Program. http://nca2014.globalchange.gov.

NRC (National Research Council). 2011. Climate stabilization targets: Emissions, concentrations, and impacts over decades to millennia. Washington, DC: National Academies Press.

Sarofim, M.C., S. Saha, M.D. Hawkins, D.M. Mills, J. Hess, R. Horton, P. Kinney, J. Schwartz, and A. St. Juliana. 2016. Chapter 2: Temperature-related death and illness. The impacts of climate change on human health in the United States: A scientific assessment. U.S. Global Change Research Program. https://health2016.globalchange.gov.

Weisskopf, M.G., H.A. Anderson, S. Foldy, L.P. Hanrahan, K. Blair, T.J. Torok, and P.D. Rumm. 2002. Heat wave morbidity and mortality, Milwaukee, Wis, 1999 vs. 1995: An improved response? Am. J. Public Health 92:830–833.

Zanobetti, A., M.S. O'Neill, C.J. Gronlund, and J.D. Schwartz. 2012. Summer temperature variability and long-term survival among elderly people with chronic disease. P Natl. Acad. Sci. USA 109(17):6608–6613.