Heat Wave

An extended period (typically two days or longer) of abnormally high temperature and humidity that causes temporary modification in lifestyle and that may have adverse health consequences for the affected population.

The SNRA Heat Wave hazard event is currently part of the SNRA's qualitatively described research base. Substantial work towards the fully quantitative analysis of the Heat Wave event within the SNRA framework has been undertaken, and the data sources and interim analysis in progress are provided below for the next analyst or project team to continue this work.

Interim estimates are provided in Table 8 at the end of this summary sheet, for the convenience of the reader or reviewer. These numbers are still under review, and may change substantially when the quantitative analysis of this hazard has been completed.

Event Background[7]

Extreme summer weather is characterized by a combination of very high temperatures and exceptionally humid conditions. When persisting over time, it is called a heat wave. The National Weather Service (NWS) defines a heat wave as a period of time (typically two days or longer) where the temperature is abnormally hot and unusually humid.[8] The Environmental Protection Agency expands on the definition, noting that an excessive heat event (EHE) can be defined in different ways based on location:

> Because how hot it feels depends on the interaction of multiple meteorological variables (e.g., temperature, humidity, cloud cover), EHE criteria typically shift by location and time of year. In other words, Boston, Philadelphia, Miami, Dallas, Chicago, San Diego, and Seattle are likely to have different EHE criteria at any point in the summer to reflect different local standards for unusually hot summertime weather. In addition, these criteria are likely to change for each city over the summer. As a result, reliable fixed absolute criteria, e.g., a summer day with a maximum temperature of at least 90°F, are unlikely to be specified.[9]

Research shows that behavioral, cultural, physical, and social adaptations are made in regions where summers are consistently hot and humid.[10,11] Thus, thresholds for what is considered a heat wave may need to be set higher in those areas. One proposed definition suggests that a heat wave for a given location is a period of at least 48 hours during which both the overnight lows and daytime highs do not fall below the NWS heat stress thresholds of 80°F and 105°F

---

[7] This section is substantially adapted from Chapter 8, Federal Emergency Management Administration (1997), Multi-Hazard Identification and Risk Assessment (MHIRA): A Cornerstone of the National Mitigation Strategy: FEMA Mitigation Directorate, at https://www.fema.gov/media-library/assets/documents/7251?id=2214 (retrieved April 2013); and U.S. Environmental Protection Agency, U.S. Centers for Disease Control and Prevention, National Weather Service, Federal Emergency Management Agency (2006, June). Excessive Heat Event Guidebook, EPA 430-B-06-005, at http://www.epa.gov/heatisland/about/pdf/EHEguide_final.pdf (retrieved December 2012).

[8] National Weather Service, Glossary [electronic resource]: http://w1.weather.gov/glossary/index.php?letter=h (retrieved December 2012).

[9] U.S. Environmental Protection Agency, U.S. Centers for Disease Control and Prevention, National Weather Service, Federal Emergency Management Agency (2006, June). Excessive Heat Event Guidebook, EPA 430-B-06-005; page 9. At http://www.epa.gov/heatisland/about/pdf/EHEguide_final.pdf (retrieved December 2012).

[10] Robinson, P. J. "On the Definition of a Heat Wave," Journal of Applied Meteorology 40 (2001): 763.

[11] Chestnut, L. G. and others. "Analysis of Differences in Hot-Weather-Related Mortality Across 44 U.S. Metropolitan Areas," Environmental Science & Policy 1 (1998): 59.

respectively, except where more than one percent of annual heat index observations exceed the NWS thresholds. In those locations (typically, the South and Southwest), the one percent high and low values would be used.[12]

There appears to be a strong relationship between heat-wave-related mortality and geographic region. Generally, the greatest levels of heat-wave-related mortality have occurred in metropolitan areas of the Northeast (e.g., Baltimore, Boston, and New York) and the Midwest (e.g., Chicago, Kansas City, and Minneapolis). These regions have mortality ranges of 2.5 - 5 heat-related deaths per 100,000. Southern (Atlanta, Houston, and Miami) and Western (Phoenix, Salt Lake City, and San Diego) metropolitan areas have significantly lower rates, less than one death per 100,000.[13,14]

To account for the interactions of heat stress and local adaptation, some have suggested sequentially defining heat events. For example, to address periods that may appear to be heat waves but that do not meet threshold criteria, *warm spell* and *hot spell* have been used.[15] An alternative that builds from the existing definition uses heatwave, severe heatwave, and extreme heatwave. A *heatwave* occurs when heat index thresholds are exceeded for two days (the current NWS definition). The intensity may be viewed as uncomfortable, but there is little social impact or adaptation. A *severe heatwave* would cause some social adaptation, with vulnerable population sectors (e.g., the aged, poor, or socially isolated) most affected. Finally, *extreme heatwaves* are characterized by cascading failures of the power, transportation, and health systems that usually protect the larger population.[16]

Heat Wave Characteristics

Independent of how the heat wave was defined, research indicates that communities typically face one to two heat waves per year, with little regional variation. Most heat waves last two to three days; heat waves lasting seven to ten days are very rare.[17, 18]

Heat wave mortality rates are influenced by a heat wave's intensity, duration, and occurrence during the season. As one might expect, long duration events with an intense heat/humidity combination increase the relative risk of mortality. Early and first in-season heat waves generate higher mortality rates than subsequent and later in-season heat waves.[19]

Each year, many areas of the United States experience periods of prolonged high temperatures combined with high humidity. In susceptible areas, people usually are aware of the hazard, anticipate it, and are accustomed to avoiding its potentially dangerous effects. However, extreme summer heat does strike areas not accustomed to the phenomenon, where people tend to be less prepared.

---

[12] Robinson, "On the Analysis of a Heat Wave," 762.
[13] Chestnut, "Analysis of Differences…," 63.
[14] Anderson, G. B. and Bell, M. L. "Heat Waves in the United States: Mortality Risk during Heat Waves and effect Modification by Heat Wave Characteristics in 43 U.S. Communities," Environmental Health Perspectives 119, no. 2 (2011): 212.
[15] Robinson, "On the Analysis of a Heat Wave," 766.
[16] Nairn, J. and Fawcett, R. Defining Heatwaves: Heatwave Defined as a Heat Impact Event Servicing All Community and Business Sectors in Australia, CAWCR Technical Report No. 060 (Kent Town, South Australia: Bureau of Meteorology, 2013), 13.
[17] Anderson, "Heat Waves in the United States:…," 212.
[18] Robinson, "On the Analysis of a Heat Wave," 766-767.
[19] Anderson, "Heat Waves in the United States:…," 212-216.

Extreme heat events are a public health threat because they often increase the number of daily deaths (mortality) and other non-fatal adverse health outcomes (morbidity) in affected populations. The major threat of extreme summer weather is heatstroke, a medical emergency that can be fatal.

Heat waves pose the greatest danger to outdoor laborers, the elderly, children, people having physical challenges or mental impairments, and people residing in homes without air conditioning. Specific high-risk groups typically experience a disproportionate number of health impacts from extreme hot weather conditions. The following populations have physical, social, and economic factors that put them at high risk:

- Older persons (age > 65)
- Infants (age < 1)
- The homeless
- The poor
- People who are socially isolated
- People with mobility restrictions or mental impairments
- People taking certain medications (e.g., for high blood pressure, depression, insomnia)
- People engaged in vigorous outdoor exercise or work
- People under the influence of drugs or alcohol.

While the SNRA considers heat waves as contingent risks (incidents discrete in time) rather than persistent risks (total annualized loss), current estimates of average annual fatalities due to extreme heat events in the United States range from 1,000-2,000 fatalities and upward,[20] making extreme heat one of the largest non-disease causes of deaths in the U.S.

The combined effects of high temperatures and high humidity are more intense in urban centers than in rural areas, and most heat wave deaths occur in urban areas. One reason is the relative poverty of some urban areas: low-income people are less able to afford cooling devices, and the energy needed to operate them. Other reasons include specific environmental factors of urban areas. Poor air quality may exacerbate severe conditions. The masses of stone, brick, concrete, and asphalt that are typical of urban architecture absorb radiant heat energy from the sun during the day and radiate that heat during nights that would otherwise be cooler. Tall city buildings may effectively decrease wind velocity, thereby decreasing the contribution of moving air to evaporative and convective cooling.

The heat waves of 1995 caused hundreds of fatalities in the Chicago metropolitan area. Many deaths were among low-income elderly in residential units not equipped with air conditioning. Local utilities were forced to impose controlled power outages because of excessive energy demands, and water suppliers reported very low levels of water in storage.

The primary economic losses from heat waves are agricultural. Except for the August 1995 heat wave/drought, which is not otherwise counted, agricultural losses from heat wave/drought

[20] EPA/CDC/NWS/FEMA (2006), pp 7, 12-13 (both counts of combined metropolitan areas are a floor of fatalities in the Nation as a whole).

historical incident records are considered under the Drought national-level event to avoid double-counting. However, extreme heat can also cause damage to physical infrastructure, including roads, bridges, and railroads. High temperatures can be partially responsible for deflection of rails, raising the risk of railroad accidents.

Concern over the potential future health impacts of heat waves follows research conclusions that excessive heat events may become more frequent, more severe, or both in the United States.[21]

While droughts and heat waves can occur at the same time, they are separate meteorological events and have been assessed independently in the SNRA.[22] For further information on droughts, please see the Drought risk summary sheet.

Assumptions

The Spatial Hazard Events and Losses Database for the United States (SHELDUS)[23] was used to conduct the assessment. SHELDUS is a county-level hazard data set maintained by the University of South Carolina. The selected time period was from1990 to 2011. It was decided by the SNRA project team that a narrower time period was appropriate and consistent with the assessment conducted on wildfires for the SNRA. At this point, however, it is possible to use data from 1967 – 2011.

SHELDUS provides data based on reports from individual counties, so the SNRA project team had to aggregate data in order to account for the accurate amount of economic loss, fatalities, and injuries. Events in the data set were combined into a single heat wave event if the entries had the same beginning and end date. There were 566 unique heat wave events during the time period from 1990 to 2011. Of the 566, six met the consequence threshold of 100 fatalities.

The SNRA project team chose to use 100 fatalities per event that are attributed to heat as a minimum threshold.

Frequency

The best-estimate frequency is the average frequency of occurrence of heat waves in the selected 21 year period. The low frequency is the inverse of the longest time interval between heat waves in this set (in days, measured from the start of the event); the high frequency is the highest number of heat wave events that occurred in one year.

Health and Safety

There were three events in 1999 that met the threshold of 100 or more fatalities, which happened during a long-term heat wave that struck the central United States in July 1999. The shortest period of time between each significant event determined the upper bound of the frequencies.

[21] EPA/CDC/NWS/FEMA (2006), p 5.

[22] To avoid double counting, for heat wave/drought historical records in the SHELDUS database which overlapped in time (e.g., when aggregated for each of the two events according to its threshold criteria), human fatality and injury and property damage amounts were counted under the Heat Wave event, while crop damage amounts were counted under the Drought event.

[23] Hazards & Vulnerability Research Institute (2011). The Spatial Hazard Events and Losses Database for the United States (SHELDUS), version 8.0 [online database]. Columbia, SC: University of South Carolina. Available from http://www.sheldus.org.

Direct Economic Loss

Except for heat incidents overlapping in time with those counted for the drought national-level event, and for which crop losses were subtracted to avoid double counting, property loss and crop loss for counted incidents were combined to reflect total direct economic loss (see Table 7 below). All values are adjusted for inflation and represent the economic loss in 2011 dollars.

Social

SHELDUS does not provide data on social displacement. Although temporary relocation of large numbers of at-risk persons to cooling centers and public facilities with air conditioning is a pillar of current community heat wave emergency response, collated estimates of numbers of persons leaving their homes for extended periods in historical heat wave incidents could not be found in the literature. This field requires further research.

Psychological

In the absence of estimates for what the project team expected would be a non-negligible level of social displacement, the SNRA measure of psychological distress, which uses social displacement as a key input, could not be calculated.

Environmental

The environmental consequence estimate, which was assessed for the 24 original national-level events of the 2011 SNRA by subject matter experts from the U.S. Environmental Protection Agency (EPA), could not be assessed for the heat wave event added to the SNRA in calendar year 2012.

Potential Mitigating Factors

Mitigation efforts to reduce the frequent severity of heat waves are related to a reduction in the burning of hydrocarbons through a decreased global dependence on fossil fuels. These mitigation efforts are focused on reduced occurrence and decreased severity rather than individual measures that can be taken to reduce heat-related mortality (e.g., use of air conditioners, limiting element exposure).

Table 7: Heat Wave Events

Date	Fatalities[†]	Injuries	Total Loss (Property + Crop Loss) Adjusted for Inflation in 2011 Terms
7/15/1995	859	617	$17,196,587
8/3/1995	145	150	$588,681,793
7/5/1999	161	824	$0
7/23/1999	136	576	$4,472,369
7/31/1999	131	11	$67,763
8/1/2006	117	365	$11,196

Table 8: Summary of Interim Data[24]

Category	Description	Metric	Low	Best	High
Health and Safety	Fatalities[25]	Number of Fatalities	117[26]	258	859
	Injuries and Illnesses[27]	Number of Injuries or Illnesses	11	424	824
Economic	Direct Economic Loss	U.S. Dollars	$0	$102 Million	$589 Million
	Indirect Economic Loss	U.S. Dollars	N/A		
Social	Social Displacement	Displaced from Homes ≥ 2 Days	N/A	N/A	N/A
Psychological	Psychological Distress	Qualitative Bins	N/A		
Environmental	Environmental Impact	Qualitative Bins	N/A		
Likelihood	Frequency of Events	Frequency of Events[28]	TBD		

[24] The quantitative analysis for this hazard event is still in progress. The above estimates from the data that have been collected and analyzed to date are provided for convenience, but they should NOT be considered as final SNRA estimates.
[25] Minimum, mean, and maximum values of fatalities for historical events in the SHELDUS database meeting threshold criteria. See Methodology and Assumptions for details.
[26] 100 is the minimum number of fatalities because it represents the minimum consequence threshold for a national level event.
[27] Minimum, mean, and maximum values of Total Affected of the subset of events reporting this measure. See Methodology and Assumptions for details.
[28] Minimum, mean and maximum frequencies. See Methodology and Assumptions for details.