Introduction to Extreme Heat Events
Extreme heat events can cause a number of health-related problems, including an increase in deaths (mortality) and nonfatal outcomes (morbidity). Yet, almost all of the negative health outcomes from extreme heat can be prevented by taking appropriate measures to ensure that the public stays cool and hydrated during an extreme heat event. As more counties and cities begin to prepare for extreme heat, it is hoped that Minnesota will experience fewer heat-related deaths and illnesses.

Why care about extreme heat events?

Although most heat-related deaths and illnesses are preventable, a significant number of people die and suffer from extreme heat events every year in the U.S. From 1979 to 2003, more people in the U.S. died from extreme heat than from hurricanes, lightning, tornadoes, floods, and earthquakes combined. From 1999-2003, about 3,442 deaths resulted from exposure to extreme heat in the U.S.

The magnitude of deaths and illnesses from extreme heat events is often underreported and little understood by the general public. Extreme heat events do not typically make the news headlines compared to other extreme weather events, such as tornadoes and floods, and they do not leave a lasting trail of infrastructural damage that continuously reminds people of their impact. Therefore, extreme heat events have been called the “silent killers.” However, in recent years there have been several notable heat waves that have caused a catastrophic number of deaths. In the historic 2003 European heat wave, about 14,800 people in France and about 50,000 people in Europe died from heat-related illnesses. In 2010, Russia experienced a heat wave that caused an estimated 4,824 excess deaths in July in Moscow alone. The United Nation News Centre reported that this Russian heat wave caused about 56,000 total fatalities across the country, likely a result of the combination of extreme heat, smog, and smoke from wildfires. Closer to home, more than 700 deaths have been attributed to the 1995 Chicago heat wave.

Extreme heat events occur in Minnesota; however, it is difficult to know the exact number of deaths and illnesses due to extreme heat events because Minnesota does not have an official reporting system for deaths and illnesses attributable to extreme heat. A review of mortality records for deaths occurring in the months of May through September indicates that 35 deaths were directly attributable to extreme heat in Minnesota during the years 2000-2010. This count likely underestimates the full burden of extreme heat on mortality, since it only captures deaths in which exposure to excess heat is explicitly listed as a cause of death on the death certificate. Because heat-related illnesses can cause various symptoms and exacerbate a wide variety of existing medical conditions, the cause of death can be difficult to establish if not witnessed by a physician. Additionally, this count does not include data from summer 2011 when Minnesota experienced five separate extreme heat events, one of which broke several records for dew point temperature. Regarding morbidity, the number of people in Minnesota who have been afflicted with heat-related illnesses is unknown, but likely to be much higher than mortality numbers.

Minnesota is warming

Minnesota is getting hotter and more humid, which may increase the number of extreme heat events. Decadal trends assessed by the State Climatology Office, suggest that Minnesota’s average temperature is increasing and the number of days with a dew point temperature greater than or equal to 70°F is increasing.
The chart below shows Minnesota’s annual average temperature (red line), which demonstrates the wide fluctuation in temperature from year to year, and the 10-year running average temperature (blue stars) from the late 1890s to 2010. The 10-year running average temperature shows an upward trend in temperature starting in the 1980s.\textsuperscript{11}

There are three significant trends in this overall warming:\textsuperscript{12}

1. Temperature increases vary by season, with winters temperatures rising about twice as fast as annual average temperatures.

2. Minimum or ‘overnight low’ temperatures have been rising faster than the maximum temperature.

3. Temperature increases vary by geography. Since the early 1980s, the temperature has risen slightly over 1°F in the south of Minnesota to a little over 2°F in much of the north.

Climate change projections developed by various researchers concur with the observed trends. Climate models project that future temperatures in Minnesota will increase from 2-3°C (3.6-5.4°F) by 2069.\textsuperscript{13,14} Exact predictions vary with the choice of climate model, assumptions about emission changes, and other model parameters. Regardless of these differences, climate model projections have consistently pointed to increased temperatures in Minnesota in the future.

Also, Minnesota has observed an increasing number of days with high dew point temperatures. The dew point temperature is the temperature to which the air must be cooled at constant pressure for it to become saturated.\textsuperscript{15} The higher the dew point temperature, the greater the amount of moisture in the air. Some people may be more familiar with the term ‘relative humidity’ to describe the amount of moisture in the air. Relative humidity is the ratio of the amount of water vapor in the air at a specific temperature to the maximum amount that the air could hold at that temperature (e.g., dew point temperature),
expressed as a percentage. The same amount of water vapor in the air will yield a different percentage of relative humidity if the air temperature changes; whereas, the dew point temperature will stay the same for the same amount of water vapor. The dew point temperature is always lower than or equal to the air temperature. When the dew point temperature equals the air temperature, the relative humidity is 100% (i.e., the air is saturated). During the summer, the dew point temperature, not the relative humidity, is usually a better measure of how humid it feels outside.

People accustom to continental climates (e.g., Minnesotans and Midwesterners generally) often begin to feel uncomfortable when the dew point temperature reaches between 65 and 69°F. Most inhabitants of these areas will consider dew points above 75 °F extremely uncomfortable or oppressive. Higher dew point temperatures and humidity directly impact people’s health by making it more difficult for people to cool themselves. The human body cools itself through four different mechanisms: radiation, evaporation, convection and conduction. See Chapter 4, “Definitions,” for a description of the four mechanisms. One of the main cooling mechanisms used during the summer is evaporation. The body perspires and the perspiration evaporates into the air, cooling the body. When evaporation is inhibited by additional humidity, perspiration does not evaporate easily off the skin, which reduces the ability of people to cool themselves.

High dew point and air temperatures combine to create dangerous conditions for human health. The heat index uses air temperature and relative humidity to determine how humans perceive ambient temperature. When humidity is high, the air temperature can be lower and still negatively affect human health. For a more detailed description of the heat index and combinations of temperature and humidity that are harmful to human health, see Appendix A.
The chart “Twin Cities Annual Number of Days Where Dewpoint Temperatures => 70 degrees F” shows the trend line (dashed red line) of the number of days where the maximum dew point was greater than or equal to 70°F in the Twin Cities from 1945 to 2010. The slope of the line suggests that the number of days with a dew point temperature greater than or equal to 70°F may be increasing by 0.53 days per decade. The dashed blue line suggests that the numbers of days with a dew point at 1800 hours (i.e., 6PM) equal to or greater than 70°F may be increasing 0.16 days per decade. Dew point temperatures were historically collected only at 1800 hours because dew point temperature was collected manually and 1800 hours was often the time of day with the highest dew point.

Prior to 2011, the highest dew point temperature ever recorded in the Twin Cities was 81°F on July 30, 1999. On July 19, 2011, the dew point temperature reached 82°F in the Twin Cities. On that same day, the state record dew point temperature was reached in Moorhead, Minnesota with a dew point temperature of 88°F. The only other spot in the Western Hemisphere with a dew point temperature in the 80s that day was in the Amazon Jungle in South America.

Researchers of a report focusing on predicting climate changes in the Great Lake region ran a global climate model to estimate temperature extremes in the Great Lakes region through 2100. The climate model predicted that the number of hot days each summer would increase throughout the period, with many years during the last few decades of the century likely to experience 40 or more days exceeding 90°F (32°C). The report surmised that the health impacts of increased days with hotter temperatures are likely to be greatest in urban areas, especially in cities such as Minneapolis/St. Paul, where extremely high temperatures have historically been rare.

Based on observed and predicted trends, extreme heat events have a high probability of occurring more frequently in Minnesota. Despite the likely increase in extreme heat events, many counties and cities in Minnesota are not prepared to deal with extreme heat events. Lessening the impact of extreme heat events requires improving the awareness of public health officials and the general public about the health risks of extreme heat events and developing and implementing effective extreme heat notification and response plans.

**Defining extreme heat events**

Extreme heat events are characterized by weather that is substantially hotter and/or more humid than average for a particular location at a particular time, especially in the spring and summer. Given the differences between average annual temperatures in St. Paul, Minnesota (45°F), for example, versus the average annual temperatures in Atlanta, Georgia (61°F), it is easy to see that an extreme heat event in Minnesota might not register as an extreme heat event in Georgia.

How hot it feels depends on location, time of year, and the interaction of multiple meteorological variables (e.g., temperature, humidity, cloud cover, wind). Hotter temperatures earlier in the spring are likely to have more detrimental health impacts than the same temperatures later in the summer because people have not had time to gradually adjust to the warmer temperatures. Definitions of an extreme heat event can shift based on location and time of year. Thus, definitions of an extreme heat event need to be sensitive to the variables important for a particular location.
Defining an extreme heat event is important for two reasons. First, the National Weather Service (NWS) needs a definition of extreme heat in order to issue a heat advisory, watch or warning. Second, local jurisdictions need to define an extreme heat event locally to determine if and when a heat response plan should be implemented. The following section describes the NWS stations that cover Minnesota and how the NWS defines extreme heat events. Chapter 3, “Preparing Minnesota for Extreme Heat Events,” describes how local jurisdictions define extreme heat events for the purposes of implementing their response plan. Timely forecasting of extreme heat events, transferring the forecast information to the agency responsible for the heat response plan and deciding when to implement the response plan are the first crucial steps in preventing heat-related morbidity and mortality.

There are six NWS stations serving Minnesota. Each NWS station releases heat advisories, watches, and warnings depending on the weather in its own service area. Below is a map of the stations. Note that in some cases, the NWS station serving Minnesota communities may be located in another state.

The NWS defines extreme heat events differently depending on location. One way the NWS defines an extreme heat event is by using NWS’s current and forecasted weather reports along with site-specific, weather-based mortality algorithms to identify extreme heat conditions. The NWS Chanhassen office uses the Synoptic Health Watch-Warning Network based on work by Dr. Laurence Kalkstein of the University of Miami and Dr. Scott Sheridan of Kent State University. The network is based on “evaluating the negative health impact of oppressive air masses, as expressed by excess mortality, in each locality. NWS forecast data are compared to historical meteorological conditions that have led to such mortality increases, and advisories, watches, and warnings are indicated accordingly.” The network was mainly composed for large cities, which are prone to holding onto heat through the nighttime hours, and thus do not experience a reprieve from the heat.
The NWS Chanhassen office issues watches and warnings for Hennepin and Ramsey Counties and will only issue a watch or warning if both meteorological conditions and the projected mortality data (derived from the Synoptic Health Watch-Warning Network) indicate an extreme heat event. For other areas of Minnesota, heat advisories, watches and warnings are issued based on a set of temperature thresholds over a certain period of time. See Table 1 below for definitions of heat advisories, watches and warnings for Hennepin and Ramsey Counties and all other counties in Minnesota.

<table>
<thead>
<tr>
<th>Table 1: Definitions of heat watch, advisory, and warning¹</th>
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<tr>
<td><strong>Excessive Heat Watch</strong></td>
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<td>Excessive Heat Watches are issued when conditions are favorable for an excessive heat event in the next 12 to 72 hours. A Watch is used when the risk of a heat wave has increased but its occurrence and timing is still uncertain. A watch provides enough lead time so that those who need to prepare can do so, such as city officials who have extreme heat response plans.</td>
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<td>In Hennepin and Ramsey counties a heat watch is defined as: Maximum heat index at Minneapolis/St. Paul International Airport is expected to reach 100°F or greater for 1 day, or the maximum heat index is expected to reach 100°F or greater and an overnight low temperature no cooler than 75°F for 2 days in a row. In addition, the Heat Watch/Warning System must recommend a watch.</td>
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<td>Outside Hennepin and Ramsey counties a heat watch is defined as: Maximum heat index reaches 105°F or greater and a minimum heat index of 75°F or greater for at least 48 hours.</td>
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<td><strong>Heat Advisory</strong></td>
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<td>Heat Advisories are issued when an extreme heat event is expected in the next 48 hours. These statements are issued when an extreme heat event is occurring, is imminent, or has a very high probability of occurring. An advisory is for less serious conditions that cause significant discomfort or inconvenience and, if caution is not taken, could lead to a threat to life and/or property.</td>
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<td>In Hennepin and Ramsey counties a heat advisory is defined as: Maximum heat index at Minneapolis/St. Paul International Airport is expected to reach 95°F or greater for 1 day, or the maximum heat index is expected to reach 95°F or greater and an overnight low temperature no cooler than 75°F for 2 days in a row.</td>
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<td>Outside Hennepin and Ramsey counties a heat advisory is defined as: Maximum heat index reaches 100°F and/or the maximum temperature reaches 95°F or higher.</td>
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<td><strong>Excessive Heat Warning</strong></td>
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<td>Excessive Heat Warnings are issued when an extreme heat event is expected in the next 48 hours. These statements are issued when an extreme heat event is occurring, is imminent, or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property.</td>
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<tr>
<td>In Hennepin and Ramsey counties a heat warning is defined as: Maximum heat index at Minneapolis/St. Paul International Airport reaches 100°F or greater for at least 1 day. In addition, the Heat Watch/Warning System, a tool develop based on research, must recommend a warning. A warning may also be issued if advisory criteria are expected for 4 days in a row.</td>
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<tr>
<td>Outside Hennepin and Ramsey counties a heat warning is defined as: Maximum heat index reaches 105°F or greater and a minimum heat index of 75°F or greater for at least 48 hours. A warning may also be issued if advisory criteria are expected for 4 days in a row.</td>
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¹ National Weather Service (2012)
Definitions of extreme heat events should be reviewed regularly to ensure that they are and continue to be applicable to the locality and responsive to actual health impacts. As average temperatures in Minnesota continue to climb, Minnesotans may start to acclimate to warmer summers. The NWS may consider revising its heat advisory, watch and warning definitions every few years based on more current historical meteorological conditions and evidence of heat-attributable adverse health impacts.

Local government staff, public health professionals and other organizations that participate in planning and/or providing services for preventing heat-related illnesses should identify the NWS station for their jurisdiction and build relationships with the NWS staff to ensure receiving the most current information available on predicted extreme heat events.

Minnesota recently broke several heat-related records. During the summer of 2011, there were five heat episodes in Minnesota that were worthy of issuing heat advisories or warnings. The worst heat event occurred during the heat wave of July 16-20, 2011. On July 19, a record state dew point temperature was set in Moorhead at 88°F. The air temperature was 93°F, creating conditions that made it feel like almost 130°F. On that same day, the Twin Cities experienced an all-time high dew point of 82°F with an air temperature of 95°F. The combined hot air and high dew point temperatures created a heat index of almost 119°F.26