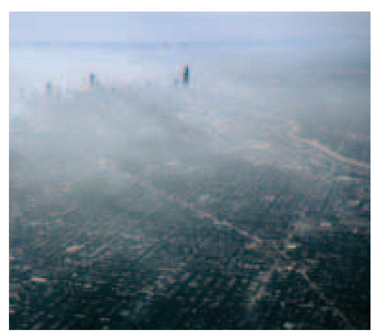
CLIMATE CHANGE
AND YOUR HEALTH

Heat in the Heartland

60 Years of Warming in the Midwest



Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

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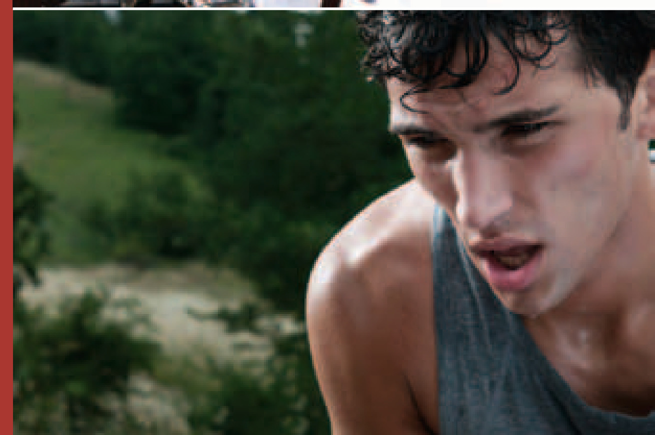

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Executive Summary

THE SUMMER OF 2011 WAS A scorcher. All but eight states reported above-average summer temperatures, and four states broke records for extreme heat. Such sticky, steamy, uncomfortable weather is poised to become even more common as our climate warms. But hot, humid days are not just uncomfortable. Extreme heat kills. From 1999 to 2003, a total of 3,442 deaths resulting from exposure to extreme heat were reported (CDC 2006a). And these figures are likely to be lower than the real toll. Medical examiners vary in the way they characterize heat-related deaths, sometimes misclassifying them as stemming from other causes (Basu and Samet 2002).

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Sweltering summer heat is not only uncomfortable but can also be lethal. Heat is actually the biggest weather-related killer in the United States, claiming, on average, more lives each year than floods, lightning, tornadoes, and hurricanes combined. High temperatures can lead to dehydration, heat exhaustion, and heatstroke, especially among vulnerable populations. These include the elderly, children, and people with preexisting medical conditions such as cardiovascular and respiratory disease, or other chronic diseases such as diabetes.

High temperatures can lead to dehydration, heat exhaustion, and deadly heatstroke. Very hot weather can also aggravate existing medical conditions, such as diabetes, respiratory disease, kidney disease, and heart disease (Basu 2009; Mastrangelo et al. 2007; Semenza et al. 1999). Urban residents, the elderly, children, agricultural workers, and people with impaired health and limited mobility are particularly susceptible to heat-related illness and death (Basu 2009; O'Neill and Ebi 2009; CDC 2008). Air pollutants such as ozone and particulate matter may also work in concert with heat, exacerbating its health effects (Basu 2009).

Dangerous heat is not just a future concern.[1] Some 71 percent of respondents to a March 2012 poll of voters in Green Bay, WI, and Grand Rapids, MI, believed that weather patterns in their area have changed in recent years (Mellman Group 2012).

Through original research, we found that hot summer weather and heat waves have indeed become more common, on average, in the nation's heartland over the last six decades. In other words, many baby boomers living in the Midwest have already faced these changes during their lifetimes.

We focused on the Midwest because it has many large population centers and is projected to see an increase in heat waves as the climate warms (O'Neill and Ebi 2009; Meehl and Tebaldi 2004). With its highly variable climate, the Midwest is also one of the most sensitive regions when it comes to human responses to excessive heat.

Heat waves have become more common over the last six decades, on average, in the five large midwestern cities we studied. Scientists project that this trend will worsen over the next century.

To better understand weather trends across this region, we analyzed weather in five major urban areas and five nearby smaller cities: Chicago and Peoria, IL; Cincinnati and Toledo, OH; Detroit, MI; Lexington, KY; Minneapolis and Rochester, MN; and St. Louis and Columbia, MO. We examined changes in summertime weather patterns using information dating back to the 1940s and 1950s, when complete digital weather records became available in those cities.

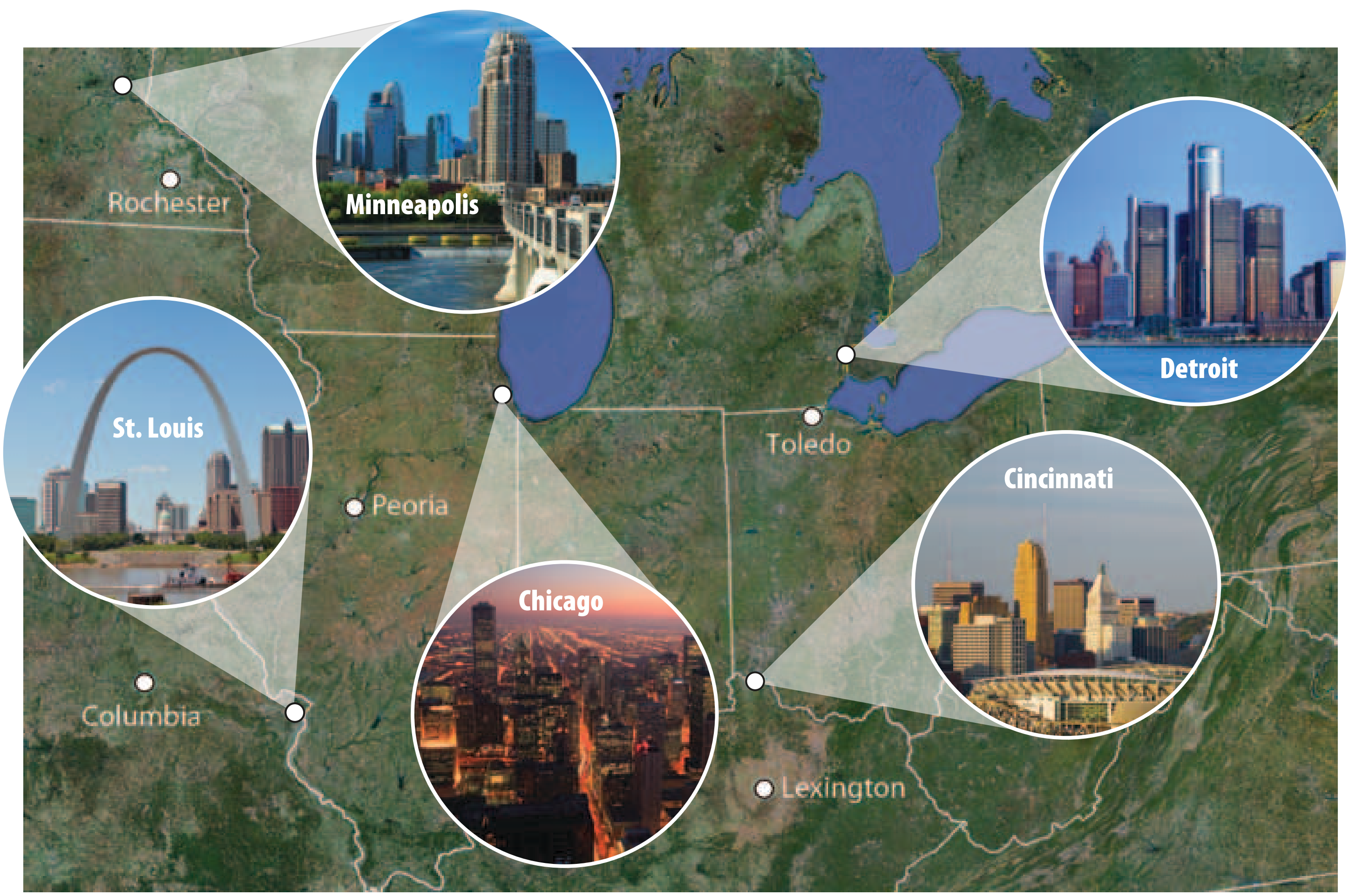
We focused on weather systems called air masses: vast bodies of air that define the weather around us. We explored whether the number of days with dangerously hot summer air masses, which are linked to human health risks, as well as cool, dry summer air masses has changed over the last 60 years.

We also examined how average daytime and nighttime temperatures and humidity levels within these weather systems have changed over time. We did so because high temperature, lack of cooling relief at night, and high humidity all contribute to heat-related illness (Poumadere et al. 2005; Wexler 2002).

We aimed not only to understand how summer weather has changed in the Midwest, but also to shed light on the importance of city-level efforts to minimize the health risks of future climate change.

Key findings of our research include:

- Dangerously hot summer days are becoming more common across the Midwest. This trend poses growing risks for public health and well-being.
- The characteristics of this dangerous weather are also changing. Hot air masses have become hotter and more humid during nighttime hours, for example. In some cities, nighttime summer temperatures within some types of air masses rose as much as 4° to 5°F over six decades.
- The number of hot, humid days has increased, on average, across the Midwest since the 1940s and 1950s, while hot, dry days have become hotter.
- Heat waves lasting three days or longer have also become more common over the last six decades.



We drew on weather data from the 1940s and 1950s to the present to determine how changes in summer heat have already affected the more than 65 million people who live in the Midwest. We targeted five large cities—Chicago, Cincinnati, Detroit, Minneapolis, and St. Louis—to gain a deeper understanding of the local effects of extreme heat, which can inform efforts to minimize health risks.

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Dangerously hot summer days are becoming more common, and summer nights hotter and more humid, across the Midwest, on average. These trends pose growing risks to public health and well-being. (Above left: Minneapolis. Above right: Chicago.)

Today St. Louis has about four more dangerous three-day heat waves each year than it did in the 1940s, for example.

- Relief from heat is harder to find. All the cities we studied now have fewer cool, dry days in the summer.
- While urban heat island effects play a role in higher air temperatures in large midwestern cities, smaller cities recorded similar increases in the number of hot summer days. This suggests that higher summer temperatures are not due solely to such effects.

Implications of Our Findings

These findings suggest several implications for public health. The weather types that have become more common in the Midwest—very hot, humid air masses, and hot, dry air masses—are associated with heat-related illness and death (National Weather Service 2005; Sheridan and Kalkstein 2004; Ebi et al. 2004). Very hot, humid air masses increase the risk of hyperthermia—elevated body temperature—while hot, dry air masses raise the risk of dehydration (Vanos et al. 2010; Epstein and Moran 2006; Mairiaux, Malchaire, and Candas 1987).

Heat waves, which are also becoming more common, further affect human health (Sheridan and Kalkstein 2010). Rising overnight temperatures are also problematic, because a lack of nighttime relief increases the risk of heat-related complications (Poumadere et al. 2005).

We cannot ignore the potential consequences of climate change, including the risk of deadly heat waves. We must invest in preventive measures to protect public health and save lives during extreme heat events. As this report shows, the cities we studied are already taking steps to minimize the health effects of dangerous hot weather. However, many other cities are still woefully unprepared.

We must also take aggressive action to reduce heat-trapping emissions from the burning of fossil fuels. If we do not, temperatures will likely continue to rise (National Research Council 2011), and we will have to cope with the effects of extreme heat on our daily lives, our health, and our economy for decades to come.

We need strategies to both build climate-resilient communities and reduce the global warming emissions that are driving climate change. Our health and well-being—and those of our children—depend on it.

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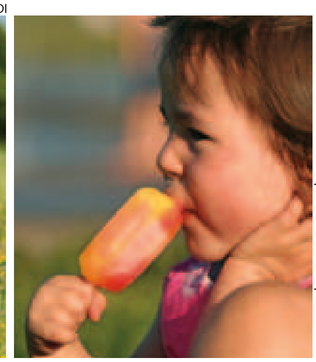

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Without aggressive action to reduce global warming emissions, the world our children live in will most likely be much hotter.

Introduction

THE SUMMER OF 2011 WAS A scorcher. It was the hottest summer since the infamous Dust Bowl era of the 1930s, with 42 states reporting above-normal temperatures, and four states breaking records for extreme heat (National Climatic Data Center 2011).

Such weather isn't just uncomfortable. Extreme heat kills. From 1999 to 2003, 3,442 deaths resulting from exposure to extreme heat were reported (CDC 2006a).

Heat waves in the recent past have struck the Midwest hard. For example, heat waves in St. Louis and Kansas City, MO, in July 1980 caused a 57 percent and 64 percent increase in deaths, respectively (Jones et al. 1982). A heat wave in Milwaukee that year contributed to 91 deaths (Weisskopt et al. 2002).

One of the most infamous U.S. heat waves occurred in July 1995, when record-setting temperatures gripped Chicago. More than 700 deaths in the city were eventually attributed to that extreme heat event (Palecki et al. 2001). Hospitals faced 1,072 more admissions than average—mostly for dehydration, heatstroke, and heat exhaustion (Semenza et al. 1999).[2]

Such a tragedy occurred again on an even larger scale in the summer of 2003, when a heat wave and resulting wildfires in Western Europe killed as many as 70,000 people (Robine et al. 2008). Another extreme heat event in 2010 led to an estimated 55,000 deaths across Russia (Barriopedro et al. 2011).

Such tragedies could become more common as the planet warms, especially if heat-trapping emissions from sources such as vehicles, power plants, and deforestation continue to climb. Climate models project that some regions will see more intense, more frequent, and longer-lasting extreme heat events in the second half of this century (O'Neill and Ebi 2009; Meehl and Tebaldi 2004).

To uncover trends that may already be occurring, we investigated whether the number of dangerously hot summer days—as well as cool, dry summer days—has changed over time in five large midwestern cities and five smaller cities over the past six decades. We focused on the Midwest because it has numerous major population centers, and is projected to face more heat waves as the climate warms (O'Neill and Ebi 2009; Meehl and Tebaldi 2004).

This report presents the results of our original research. We did not design our study to determine whether the trends we found stem from human-caused climate change. However, the results from these 10 cities can inform efforts to cope with the health risks of future climate change. Toward that end, we also examined what the five large midwestern cities are already doing to prepare for dangerous summer heat events.

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In summer 2010, large portions of western Russia, including Moscow, endured an intense heat wave that—along with wildfires that blanketed the city with toxic smog—killed tens of thousands of people nationwide. Continued emissions of heat-trapping gases are projected to make heat waves more likely in the future. Above, people wear face masks to protect their lungs while visiting Moscow's Red Square.

Heat waves in the recent past have struck the Midwest hard. Such weather isn't just uncomfortable—extreme heat kills.

Weather 101

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What Is Weather?

Weather is the short-term state of the lower atmosphere, or troposphere—the air mass that surrounds us. Weather includes day-to-day temperature, precipitation, wind, and cloud cover. Climate, in contrast, refers to average atmospheric conditions over decades or longer (NASA 2005).

What Is a Heat Wave?

The National Weather Service usually defines heat waves as periods of abnormally and uncomfortably hot and unusually humid weather (National Weather Service 2009a).

The weather service issues *heat advisories* and *excessive heat warnings* when predicting unusual periods of hot weather.

However, there is no universal definition for heat wave: it typically reflects not only weather patterns but also a population's ability to cope with a temperature spike. What people might call a heat wave in New England, for instance, probably would not qualify as such in sizzling southern Arizona.

What Is the Heat Index?

The heat index describes how hot it really feels, given relative humidity as well as air temperature. If the air temperature is 96°F and the relative humidity is 65 percent, the heat index is an oppressive 121°F (Figure 1) (National Weather Service 2012a).

Relative humidity is the amount of water vapor in the air at a certain temperature, compared with how much the air could hold at that temperature (National Weather Service 2009b). When humidity is very high, perspiration does not evaporate, and the human body gets little, if any, relief from the heat (Hajat, O'Connor, and Kosatsky 2010).

What Is Dew Point Temperature?

Dew point is a measure of atmospheric moisture: a higher dew point indicates that more moisture is present in the air. The dew point temperature is the level to which air must cool to become saturated with moisture, at which point it condenses on surfaces (National Weather Service 2009). Dew point temperature is familiar to anyone who has seen temperatures fall overnight to the point where dew forms on leaves and car windows.

What Is an Air Mass?

An air mass is a large volume of air—usually hundreds to thousands of miles across—with similar temperature and humidity levels throughout. Air masses tend to take on the characteristics of the areas where they form. However, their properties can change as they move across areas with different surface conditions (Figure 2, p. 8) (National Weather Service 2010; Ritter 2010).

For example, a moist tropical air mass is hotter and more humid in the southeastern United States, nearer its source region, than it is in the northeastern United States (see box, p. 8). A moist tropical air mass is similarly warmer at all locations in July than it is in January (Sheridan 2002). This report focuses on air masses typically associated with Midwest summer heat waves.

The heat index describes how hot it really feels, given relative humidity and temperature. When humidity is very high, perspiration does not evaporate and the body gets little relief from the heat.

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The infamous Chicago heat wave of July 1995, which blanketed the city in sweltering smog, led to more than 700 deaths and 1,072 hospital admissions. Scientists project that such lethal heat waves will become more common unless we take strong immediate steps to reduce our global warming emissions.

FIGURE 1. The Heat Index

Relative humidity (%)

Air temperature (°F)

°F	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
108	130	137											
106	124	130	137										
104	119	124	131	137									
102	114	119	124	130	137								
100	109	114	118	124	129	136							
98	105	109	113	117	123	126	131						
96	101	104	108	112	116	121	126	132					
94	97	100	102	106	108	114	119	124	129	136			
92	94	96	99	101	105	108	112	116	121	126	131		
90	91	93	95	97	100	103	105	109	113	117	122	127	132
88	88	89	91	93	95	98	100	103	106	110	113	117	121
86	85	87	88	89	91	93	95	97	100	102	105	108	112
84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95
80	80	80	81	81	82	82	83	84	84	85	86	86	87

The heat index describes how hot it feels, given relative humidity as well as air temperature. When humidity is very high, perspiration does not evaporate, and the human body gets little, if any, relief from the heat. Hot air masses have become hotter and more humid during nighttime hours over the last six decades in the Midwest—a recipe for a rising heat index.

Types of Air Masses

Dry Polar
This type of air mass, with cold and dry air, usually maintains the lowest temperatures and humidity along with clear skies. Dry polar air masses usually advance into the Midwest from northern regions such as Canada, on a north, northwest, or northeast wind.

Dry Moderate
This type of air mass usually has milder temperatures than dry polar yet is still dry (low humidity). Dry moderate air can occur when another type of air mass traverses dry land.

FIGURE 2. **Source Regions and Movements of Air Masses**

An air mass is a vast body of air overhead that defines the weather around us. It can extend for hundreds or thousands of miles, and has similar temperature and humidity properties throughout. The arrows indicate common movements of air masses from their source regions. The moist tropical (MT) and dry tropical (DT) air masses are most associated with increased health risks.

Dry Tropical
This type of air mass is associated with the hottest yet very dry conditions, with very clear skies. It is common in large continental areas lacking water bodies.

Dry tropical air masses can advance into the Midwest from desert regions in the U.S. Southwest and Mexico, or beneath high-pressure weather systems. Of all the types of air masses cited here, dry tropical days occur least frequently in the Midwest.

Moist Polar
Typical conditions are cloudy, humid, and cool, sometimes with light precipitation. Moist polar air is present when an air mass has recently moved in from a cool ocean or large lake. In the Midwest, dry polar air flowing over the Great Lakes can pick up moisture and turn into a moist polar air mass.

Moist Moderate
This type of air mass is considerably warmer and more humid than moist polar. Conditions tend to be cloudy and overcast, with light precipitation. It can occur when warm air meets cool air just north of a warm front, creating moderate conditions.

Moist Tropical
This is the warmest and most humid type of air mass, and thus creates the most discomfort. In the Midwest, it is commonly transported from the tropical Atlantic and the Gulf of Mexico, or occurs after a warm front passes.

Moist Tropical+
The most oppressive subset of moist tropical air, this air mass is most often associated with heat-related mortality. It is present when both morning and afternoon temperatures are above the mean on a moist tropical day.

How We Analyzed Summer Weather Trends in the Midwest

TO UNDERSTAND CHANGES IN weather patterns and what might be driving those changes, we focused on weather systems known as air masses (see "Weather 101"). By evaluating air masses instead of simply temperatures, we were able to provide a more detailed picture of the changes in weather patterns that have actually been experienced by Midwesterners over the last 60 years.

We analyzed some 60 years of data on air masses in five large midwestern cities: Chicago, Cincinnati, Detroit, Minneapolis, and St. Louis. We chose those cities to represent both the northern and southern Midwest, and to reflect proximity to the Great Lakes as well as more continental locations.

We also analyzed information on air masses in five small cities within 150 miles of the larger cities, to determine whether urban heat island effects were playing a significant role in any temperature trends. These smaller cities included Peoria, IL (paired with Chicago), Lexington, KY (Cincinnati), Toledo, OH (Detroit), Rochester, MN (Minneapolis), and Columbia, MO (St. Louis).[3] Because air masses cover hundreds or even thousands of square miles, each smaller locale has weather similar to that of its larger counterpart.[4]

Much can change in 60 years, including weather. We analyzed some 60 years of data on summer weather in five large midwestern cities: Chicago, Cincinnati, Detroit, Minneapolis, and St. Louis. We found that the types of hot weather that undermine human health (dry tropical and moist tropical+) have become more common, on average. Meanwhile cool, dry summer days (dry polar), which often bring refreshing relief from summer heat, are becoming less common.

Dry tropical (hot and dry) and moist tropical+ (very hot and humid) air masses are linked to a greater risk of heat-related deaths.

With our focus on extreme heat, we limited our study period to June, July, and August. We analyzed data on afternoon and nighttime air and dew point temperatures, air pressure, cloud cover, and wind velocity obtained and recorded at one airport weather station per city.[5] Temperatures were used as a proxy for short-term daytime and nighttime exposure.

We obtained this information from the National Climatic Data Center, whose complete digital records begin at different years for different cities: 1948 for Chicago, 1948 for Cincinnati, 1959 for Detroit, 1945 for Minneapolis, and 1946 for St. Louis. We analyzed these records through 2011. Incorporating all the variables, we used a well-known weather model, the spatial synoptic classification or SSC, to classify each day's weather into one of six types of air masses (Greene et al. 2011; Sheridan and Dolney 2003; Sheridan 2002).[6]

We then focused our analysis on three types of air masses: very hot and humid (an extreme subset of moist tropical known as moist tropical+), hot and dry (dry tropical), and cool and dry (dry polar). The dry tropical and moist tropical+ air masses are most important for human health, as they are linked to a greater risk

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Urban centers tend to be hotter than surrounding areas. Heat absorption by paved surfaces, a lack of cooling vegetation, and intense heat-emitting activities, such as transportation and industrial processes, combine to produce the urban heat island effect.

of heat-related deaths (National Weather Service 2005; Ebi et al. 2004; Sheridan and Kalkstein 2004).

The frequency of a given type of air mass—the number of days that it is present—varies in each city from year to year. Examining the 60-year record allowed us to assess trends over time.

We also wanted to determine if stretches of dangerously hot days have become more or less common. Research has shown that a run of several days of oppressive heat affects human health (Kalkstein et al. 2011). Studies have also linked at least three consecutive days of elevated temperature and humidity to greater mortality (Basu and Samet 2002).

To evaluate the most dangerous heat waves, we investigated whether three-day-or-longer runs of very hot, humid (moist tropical+) and hot, dry (dry tropical) air masses have become more common.[7] (We did not analyze three-day-or-longer heat waves for the smaller cities because of time and resource constraints.)

Finally, we investigated whether each type of air mass has become warmer or more humid, as represented by dew point temperature, in each city, to gain a sense of trends in relative humidity. Specifically, we looked at the 3:00 a.m. and 3:00 p.m. air temperature and dew point temperature (representing nighttime and daytime values) for each type of air mass during each summer day on record.

Accounting for Urban Heat Island Effects

In rural areas, trees and other vegetation provide shade and help cool the air as plants release water vapor. In urban areas, cooling vegetation is often in short supply. Tall buildings, roads, and other paved surfaces in cities also absorb and retain more heat than do the flat open spaces and plant life of more rural locales, and cities release that trapped heat more slowly throughout the night (Environmental Protection Agency 2012a).

A city's buzzing human activities—such as transportation, industrial processes, and the operation of numerous home appliances—emit heat (Environmental Protection Agency 2012b). Urban architecture can also influence wind flow and energy absorption. The difference in nighttime temperatures between a large city and its surroundings can therefore be as much as 21.6°F (Oke 1988).

We paired each larger city with a nearby smaller city to help distinguish between urban heat island effects and other causes of trends in temperature and humidity.

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To determine whether heat trends simply reflected urban heat island effects, we collected data on five small cities at least 10 miles from the five larger cities. Although there were some differences between large and small cities, several common patterns emerged, suggesting a contribution from regional climate change, not simply urban heat island effects.

We reasoned that if a large city showed a warming trend that was not apparent in the smaller city, that trend was likely largely due to urban heat island effects. If both the large and the small city recorded a similar warming trend, it was likely not due primarily to those effects.[8]

Evaluating Daytime and Nighttime Trends

Many studies that investigate how humans respond to weather use data from just one time during the day (Anderson and Bell 2009; Davis et al. 2003b). However, urban heat island effects are strongest at night (McCarthy et al. 2010; Oke 1988). And high overnight temperatures are associated with heat-related illness and death (O'Neill and Ebi 2009; Poumadere et al. 2005).

We therefore looked at air temperature and dew point temperature at 3:00 a.m. and 3:00 p.m. for each type of air mass. Other U.S. scientists have also used that approach to evaluate links between these temperatures and mortality (Davis et al. 2003a; Curriero et al. 2002).

Scientists have also used that approach to study links between heat and health in Korea, Italy, Canada, and China (Baccini et al. 2011; Lee et al. 2010; Tan et al. 2004; Sheridan and Kalkstein 2004). For example, one study used temperature measurements at 5:00 a.m. and 5:00 p.m. to analyze the relationship between extreme heat and ambulance response calls in Toronto (Dolney and Sheridan 2006).

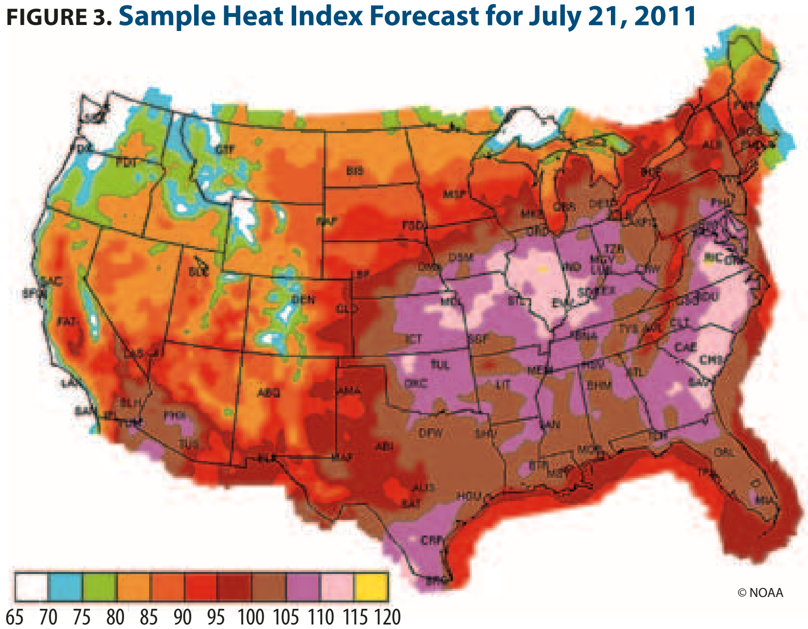
We included temperature data collected at 3:00 a.m. because high overnight temperatures are associated with heat-related illness and death.

Spotlight on 2011

In the summer of 2011, the United States was hit hard with the kind of stifling heat wave that a changing climate can bring (Figure 3).

- Forty-two states reported above-average summer temperatures, and four states broke records for high temperatures (National Climatic Data Center 2011).
- Heat and drought across the Southwest and the southern plains caused 95 deaths and some $12 billion in losses to crops and livestock (National Climatic Data Center 2012).
- During a heat wave in July, the National Weather Service issued heat advisories and warnings affecting some 140 million Americans and nearly 1 million square miles, from the central United States to the East Coast (National Climatic Data Center 2011).

FIGURE 3. Sample Heat Index Forecast for July 21, 2011



The summer of 2011 brought record-breaking heat to much of the country. On this day in July, the heat index forecast topped 105°F for much of the Midwest. In the cities we investigated, potentially dangerous hot summer days have become more common over the past six decades, on average.

Findings: The Midwest Is Heating Up

OUR INVESTIGATION UNCOVERED measurable increases in dangerously hot weather in the Midwest. People living in the region have experienced these weather changes during their lifetimes.

Specifically, we found that the air masses associated with harmful health effects—dry tropical and moist tropical+—have become more common in the Midwest over the last six decades, on average. Hot summer air masses lasting three days or longer have also become more common, on average. Meanwhile cool, dry summer days (dry polar) have become less common.

The characteristics of these types of weather have also changed. With some exceptions, hot summer air masses have become both hotter and more humid, particularly at night. Overnight temperatures under both types of hot air masses—especially hot, dry air—have risen in many cities. For example, when a dry tropical air mass is present in St. Louis, temperatures at 3:00 a.m. are 4.4°F higher today than 66 years ago.

Dew point temperatures and sometimes relative humidity have also increased significantly in most of the cities. The overnight heat index has also shown evidence of increase.

We found some differences between large and small cities, but several common patterns emerged (see below). This strongly suggests that the changes we uncovered stem from regional climate change, not simply urban heat island effects.

Changes in Summer Weather Patterns

Very Hot, Humid Days Are Occurring More Often

Findings for Large Cities

Very hot, humid air masses (moist tropical+) appear to be much more common today than in the 1940s. Cincinnati, Detroit, and St. Louis saw significant increases in the number of moist tropical+ days each summer, even though these extreme air masses remain uncommon. For example, St. Louis now has twice as many very hot, humid days (moist tropical+) as it did in the late 1940s, on average.

Findings for Small Cities

The number of days each summer of very hot, humid (moist tropical+) weather systems rose in all five small cities. These increases were statistically significant in three cities: Lexington, Peoria, and Toledo. In Lexington, for example, the number of moist tropical+ days more than doubled, from about two during a typical summer at the beginning of the study period to about five each summer in the most recent decade.

Very Hot, Dry Days Are Also Becoming More Common

Findings for Large Cities

Changes in the number of days with hot, dry (dry tropical) air masses were somewhat less consistent across the five large cities. Dry tropical days became more common in Chicago, Detroit, and Minneapolis, but this increase was statistically significant only in Detroit. In St. Louis, the frequency of dry tropical days changed little, while Cincinnati experienced a slight drop.

Findings for Small Cities

The number of days with hot, dry weather systems (dry tropical) showed some increases in the small cities, but the trend was not uniform or statistically significant. In fact, the frequency of dry tropical air masses in Rochester actually declined at a significant rate. However, overall trends suggest a shift from drier to more humid air masses in the smaller cities—similar to what we found in the large cities.

Heat Waves Are Occurring More Often

Three-day-or-longer stretches of hot air masses are also occurring much more often. St. Louis, for example, recorded an average of three three-day-or-longer runs of moist tropical+ and dry tropical air masses annually in the 1940s. That number has since more than doubled, to an average of seven such heat waves each year today.

A Closer Look at Our Trend Analysis

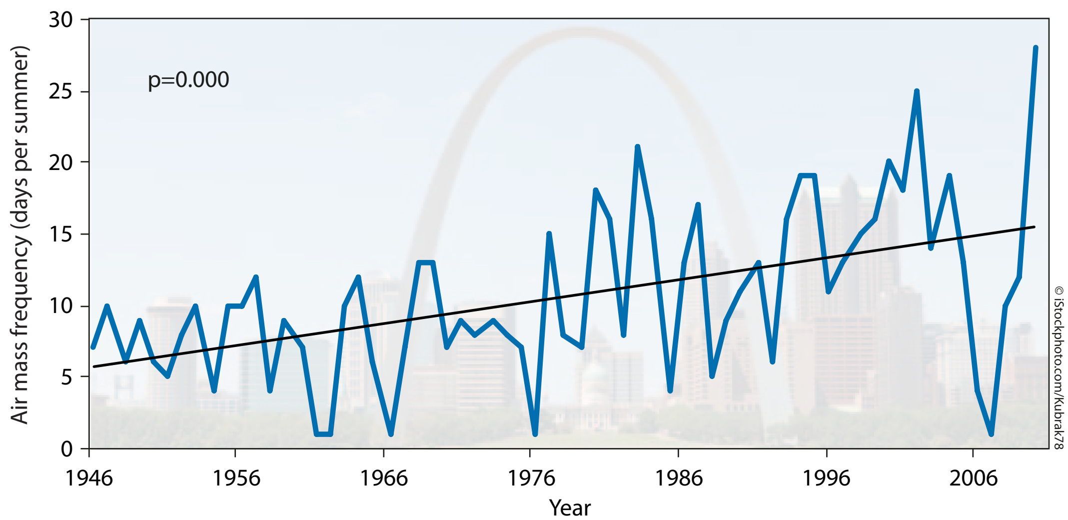
Our analysis allows us to see changes in each variable over time, giving us a trend line, or slope. In our study, the y-axis represents either the number of days each summer that an air mass occurs, or the temperature within that type of air mass. The x-axis represents time, in years. The slope of the line can tell us how much the number of days or temperature is changing over time. By multiplying the slope by the total number of years, we end up with a value that signifies the change for the entire period.

A common statistical measure known as the p-value indicates whether a trend is statistically significant. A p-value of less than 0.05 is usually considered statistically significant. Such a p-value indicates that there is less than a 5 percent likelihood that a trend is due to chance—and therefore that there is a 95 percent likelihood that the trend reflects the factor we are investigating (Ambaum 2010).

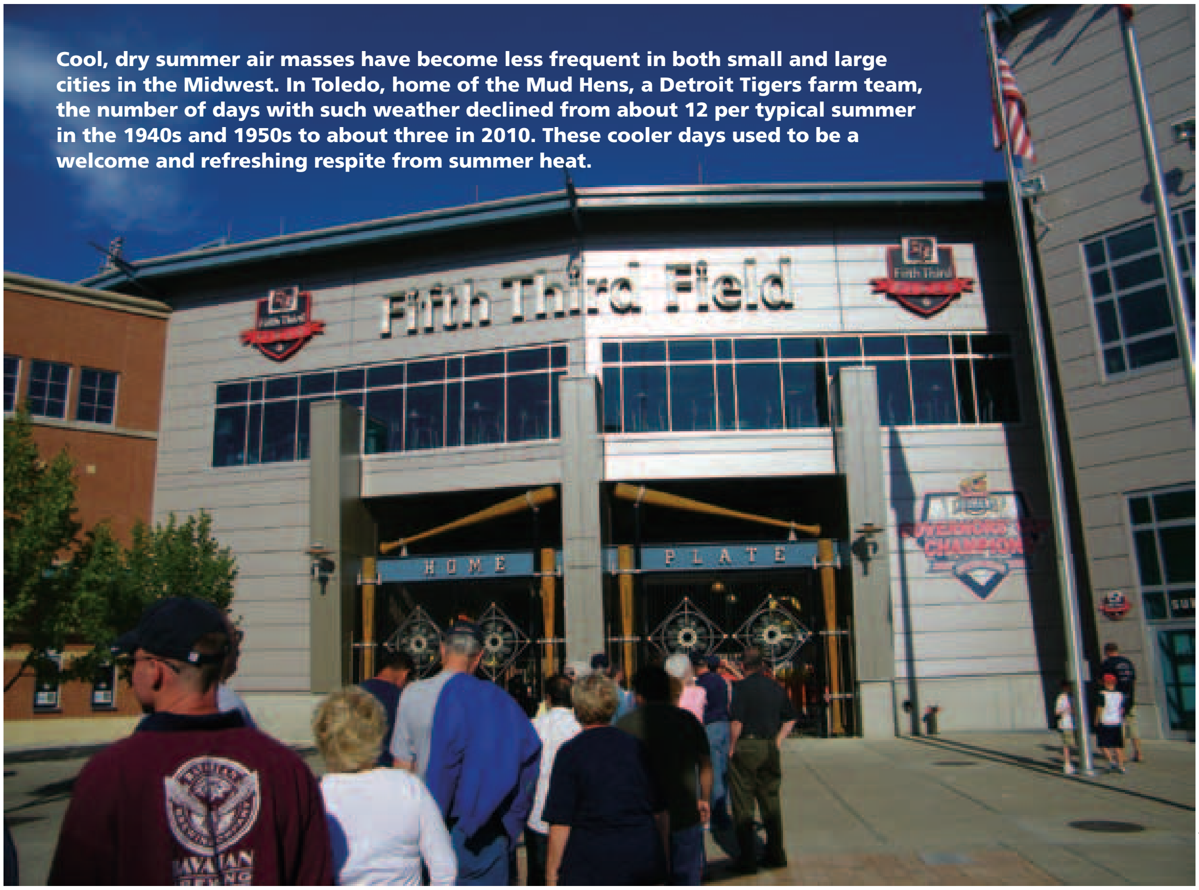
Trends with p-values from 0.05 to 0.1 are not considered statistically significant. However, such p-values indicate that there is less than a 10 percent chance that a reported trend is random, so we consider such trends important.

Figure 4 depicts an example from our findings: the number of days each summer that a moist tropical+ air mass was present over St. Louis from 1946 to 2011. The strong positive slope indicates an overall increase in the number of such days—about 10 over the study period. With a p-value of 0.000 (less than 0.05), this increase is statistically significant.[9] The full results for all 10 cities can be found in the online technical appendix.

FIGURE 4. Frequency of Moist Tropical+ Air Masses in St. Louis from 1946 to 2011



St. Louis experienced an average of three annual three-day-or-longer runs of dangerously hot air masses in the 1940s. That number has more than doubled, to an average of seven such heat waves today.



Cool, dry summer air masses have become less frequent in both small and large cities in the Midwest. In Toledo, home of the Mud Hens, a Detroit Tigers farm team, the number of days with such weather declined from about 12 per typical summer in the 1940s and 1950s to about three in 2010. These cooler days used to be a welcome and refreshing respite from summer heat.

Our investigation uncovered measurable increases in dangerously hot weather in the Midwest. People living in the region have experienced these weather changes during their lifetimes.

The Number of Cool Summer Days Is Declining

Findings for Large Cities

The incidence of cool, dry summer (dry polar) air masses fell over time in all five large cities. And in every city except Cincinnati, that decrease was statistically significant. In Chicago, for instance, the number of dry polar days each year dropped by one day every decade, for a 40 percent overall drop in the number of such days annually from 1948 to today. And the yearly frequency of dry polar days in Detroit dropped more than two each decade, so the city now averages 10.5 fewer cool, dry days each summer than in 1959. With fewer cool summer days on the calendar, residents experience less relief from hot weather.

Findings for Small Cities

Cool, dry summer (dry polar) air masses became less common in all the small cities except Rochester. In Toledo, the number of dry polar days declined from about 12 per typical summer in the 1940s and 1950s to about three in 2010.

Changes in Overnight Temperature, Humidity, and Heat Index

Overnight Temperatures Are Rising

Findings for Large Cities

Overnight (3:00 a.m.) temperatures showed much stronger trends than afternoon (3:00 p.m.) temperatures. In most large cities, afternoon temperatures associated with a given type of air mass did not rise much over time, and some cooled slightly. Overnight temperatures, in contrast, increased notably.

In Detroit and St. Louis, dry polar, dry tropical, and moist tropical+ air masses all warmed, and these increases were statistically significant. In four of the five cities, the already very hot and humid moist tropical+

air mass became significantly warmer. The only exception occurred in Cincinnati, where, for reasons that are unclear, temperatures of all these air masses changed little, in both the afternoon and overnight.

Some cities saw marked trends in overnight temperatures. For example, in Detroit, average overnight temperatures on hot, dry (dry tropical) days warmed 4.3°F over a 52-year period. And Detroit was not an isolated example. In St. Louis, average overnight dry tropical temperatures rose about 4.4°F.

Overnight increases for moist tropical+ air were somewhat smaller but still notable, given that this type of weather already has the warmest overnight temperatures. Each city except Cincinnati showed statistically significant increases in moist tropical+ overnight temperatures: 1.7°F in Chicago, 2.1°F in Detroit, 1.6°F in Minneapolis, and 2.1°F in St. Louis.

What's more, differences between daytime and nighttime temperatures appear to be narrowing in most cities. This trend may be important in understanding the impact of high heat on human health, both now and in the future, as a lack of nighttime heat relief has been linked to increases in heat-related illness (O'Neill and Ebi 2009; Poumadere et al. 2005).

Findings for Small Cities

As in the larger cities, nighttime air masses in the small cities have generally become hotter over time. Overall, very hot and humid (moist tropical+), hot and dry (dry tropical), and cool and dry (dry polar) air masses in the small cities warmed notably in the nighttime, but not in the afternoon.

In Columbia, overnight temperatures rose for the cooler dry polar and the hotter dry tropical air masses. In Lexington, Peoria, and Toledo, overnight temperatures increased for all three air masses. Some of these increases were sizable. In Columbia, where the airport is in an agricultural region well outside the city, average overnight temperatures during dry tropical weather rose 3.7°F over 66 years.

Nighttime Dew Point Temperatures Are Rising

Findings for Large Cities

Overnight dew point temperatures for hot air masses tended to increase over time. For example, Detroit and Minneapolis both saw an increase in overnight dew point temperatures for moist tropical+ air masses. In St. Louis, overnight dew point temperatures for dry tropical weather rose by more than 7°F. That change contributed to a notable rise in overnight relative humidity during such weather, from 63 to 71 percent on average.

As with temperature trends, afternoon dew point temperatures did not change significantly over time. The exceptions were an increase in the dew point temperature for dry tropical weather in St. Louis, and a decrease in the dew point temperature for dry tropical weather in Detroit.

If the moisture content of dry tropical air masses increases, some may cross the threshold into the moist tropical category. This can occur if warmer air, which can hold more water vapor, becomes more common.[10]

If dry tropical air masses are becoming moister, as rising dew point temperatures suggest, then moist tropical+ days should become more common, at the expense of dry tropical days. That may explain why the frequency of moist tropical+ air masses is rising more rapidly than that of other types of air masses, and why dry tropical air masses are becoming slightly less common.

Findings for Small Cities

As in large cities, the moisture content of nighttime air masses in small cities has generally increased since the 1940s and 1950s. In Toledo, overnight dew point temperatures of dry tropical air masses rose about 5°F over a roughly 55-year period, while overnight air temperatures rose by about 3.8°F. These changes correspond to an increase in overnight relative humidity of 3.5 percent in these typically dry air masses.

© Rebecca Koenig

Very hot, humid weather increases the risk of hyperthermia—elevated body temperature—which can result in disability or death. When humidity is very high, body sweat does not evaporate, and people obtain little or no relief from the heat. In St. Louis, for example (shown above at the city's Gateway bus and train station), overnight relative humidity under dry tropical air masses rose from 63 percent to 71 percent from 1946 to today, reducing nighttime relief from extreme heat.

The Heat Index Also Rises

Temperature and relative humidity both affect the heat index, a measure of how hot the air actually feels. To investigate this measure, we evaluated changes in the overnight heat indices of Chicago and St. Louis on very hot, humid (moist tropical+) and hot, dry (dry tropical) days.

In Chicago, the average heat index rose 2.6°F on moist tropical+ days, and 0.1°F on dry tropical days. In St. Louis, the average heat index rose 3.8°F on moist tropical+ days, and 4.4°F on dry tropical days.

These sizable increases could affect people's health. In St. Louis, the mean overnight heat index averages near 80°F for both types of hot air masses, affording little heat relief. Scientists have linked both high night-time temperatures and high relative humidity to increases in heat-related illness and death (O'Neill and Ebi 2009; Poumadere et al. 2005).

What the Future Could Bring

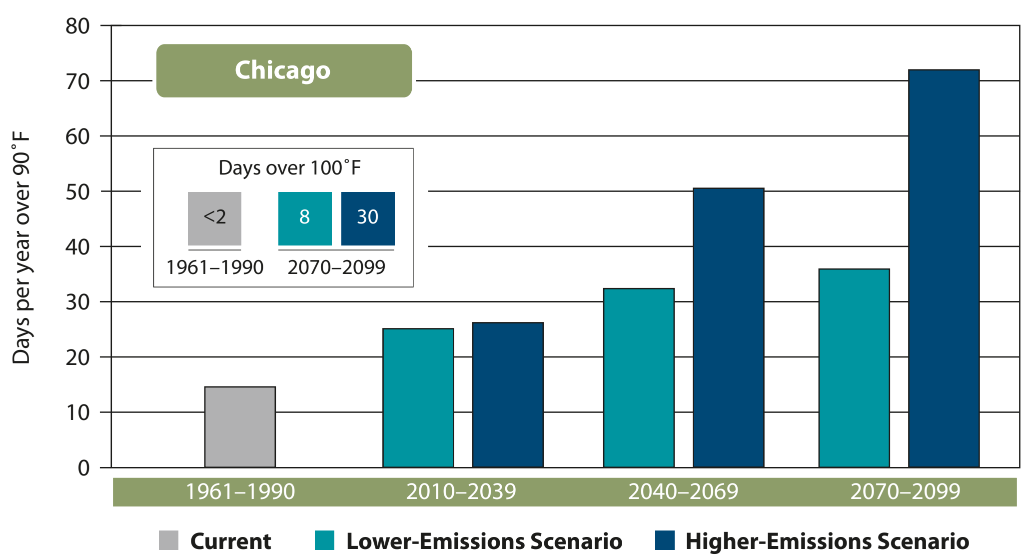
If global warming emissions continue at their current pace, the Midwest could face even hotter summers.[11] An earlier UCS report projected how many days with temperatures above 90°F and 100°F the cities in our study could face under this scenario (UCS 2009a). For example, Chicago could see more than 70 days with temperatures above 90°F each year toward the end of this century, on average (Figure 5). Under a lower-emissions scenario, and therefore more modest global and regional warming, the number of such days would drop by half.

Scientists also expect the number of dangerously hot days over 100°F in Chicago to increase dramatically under the higher-emissions scenario, producing a month of such days. They also project average summer temperatures to rise more than 3°F over the next several decades, and by an extraordinary 13°F toward the end of the century. Under a lower-emissions scenario, that increase would drop by half.

All the cities in our study can expect to see the number of hot days each year rise over the coming century. For example, St. Louis will face more than 100 days each year above 90°F by the end of the century under a higher-emissions scenario, according to the UCS report. This number drops to slightly more than 60 days under a lower-emissions scenario—highlighting the importance of the choices we make.

Other measures of dangerous heat suggest a similar future for the Midwest. For example, heat waves similar to that in Europe in 2003, which claimed thousands of lives, could occur every other year in the Midwest by the end of century under a higher-emissions scenario (USGCRP 2009).[12]

FIGURE 5. A Future with More Days above 90°F



A previous UCS analysis considered two possible futures: one with fewer heat-trapping emissions, and one with more. Under a high-emissions scenario, midwestern cities such as Chicago will face many more summer days above 90°F. The number of such days is also projected to rise across the region under a lower-emissions scenario, but less markedly (Union of Concerned Scientists 2009a).

The Impact of Dangerous Summer Weather on Health

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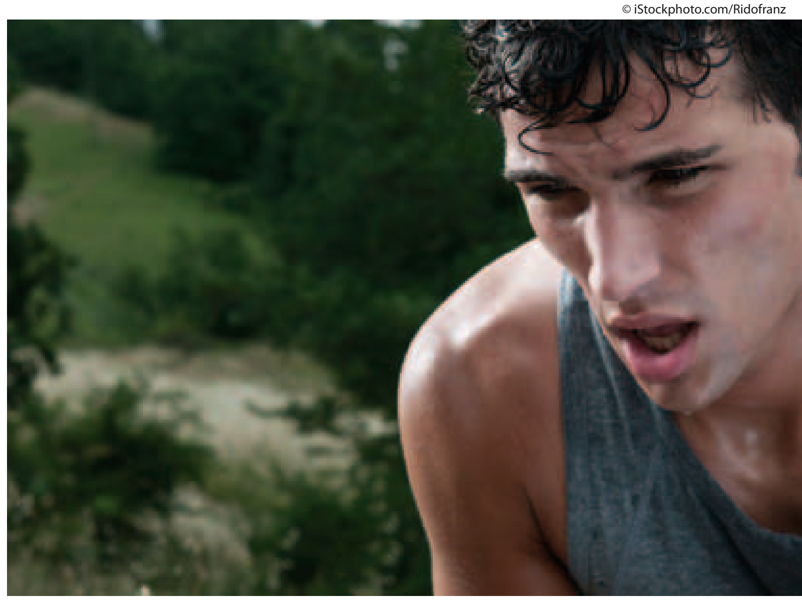


Heat poses more risk for the elderly and the immobile, especially if they already have diabetes, respiratory disease, kidney disease, or heart disease. Many elderly people try to endure heat waves in unsafe conditions without fully understanding their dangers. As the U.S. population ages, heat-related illnesses and deaths are expected to become more prevalent. Extreme heat also poses a particular danger to athletes and outdoor workers, who may disregard warnings about heat-related illness.

HIGH TEMPERATURES AND HUmidity levels pose serious threats to public health. Very hot, humid weather increases the risk of hyperthermia—elevated body temperature—and hot, dry weather raises the risk of dehydration (Vanos et al. 2010; Epstein and Moran 2006; Mairiaux, Malchaire, and Candas 1987). The impact of heat on people's well-being depends on their exposure to high temperatures or prolonged periods of intense heat, their underlying health, and their economic and social vulnerability, as well as how much their region has invested in measures to help residents cope with heat.

Some groups are especially vulnerable to the dangers of hot weather. Heat is a particular hazard for people who are physically active, including both indoor workers with minimal access to cooling systems and outdoor workers (Hanna et al. 2011). People who play outdoor sports are also at risk when the temperature climbs. Heat stress is much more likely to occur in motivated and elite athletes who disregard heat warnings to train and compete (Vanos et al. 2012).

The elderly are also at greater risk of heat-related health complications (Basu, Dominici, and Samet 2005; Diaz et al. 2002). Older individuals are at higher risk partly because extreme heat can aggravate existing medical conditions such as diabetes, respiratory disease, kidney disease, and heart disease (Mastrangelo et al. 2007; Semenza et al. 1999).

The share of U.S. residents over age 65 is climbing, from roughly 13 percent today to a predicted 20 percent by 2030. As the population ages, we can expect more heat-related illnesses and even deaths (O'Neill and Ebi 2009). One study of mortality from heat waves in St. Louis from the 1930s through the 1960s found that people aged 40 to 80 had the greatest risk of dying in a 1936 heat wave. During a 1966 heat wave,

CONTINUED ON P. 20

City-by-City Results

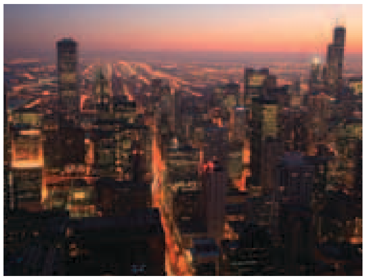
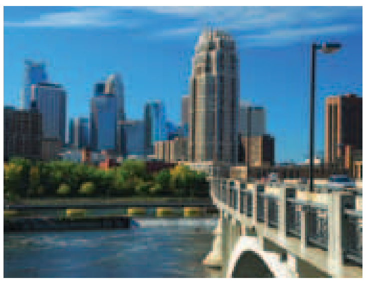
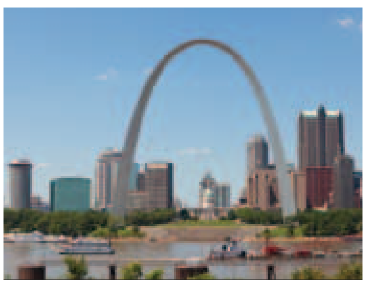
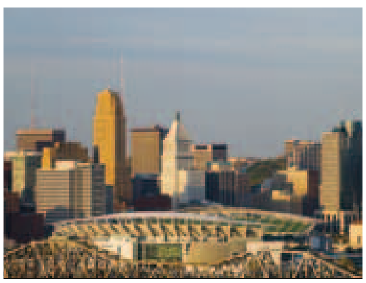
In this chart we identified statistically significant values at *p<0.05 and ^p<0.10. Note that for some cities, proper statistical tests could not be performed on dry tropical air masses because the frequencies were too low.

DAILY SUMMER WEATHER TRENDS

Very hot, humid days and hot, dry days are both dangerous to human health, while cool, dry days bring relief from the summer heat and humidity.

NIGHTTIME SUMMER

High nighttime temperatures bring no relief from the heat, heat-related

City	Photo	Very Hot, Humid Days	Hot, Dry Days	Cool, Dry Days	Temperature and Humidity Changes in Very Hot, Humid Nights: Temperature	Temperature and Humidity Changes in Very Hot, Humid Nights: Dew Point
Chicago, IL 1948–2011 (63 years)		Increased 62% 2.5 Days	Increased 79% 1.5 Days	Decreased* 44% 7+ Days	Increased^ 1.7°F	Increased 0.8°F
Detroit, MI 1959–2011 (52 years)		Increased^ 172% 3.5 Days	Increased^ 338% 3 Days	Decreased* 70% 10.5 Days	Increased* 2.1°F	Increased* 2.5°F
Minneapolis, MN 1945–2011 (66 years)		Increased 55% 1.5 Days	Increased 45% 3 Days	Decreased^ 32% 4.5 Days	Increased^ 1.6°F	Increased* 2.2°F
St. Louis, MO 1946–2011 (65 years)		Increased* 200% 10 Days	No Change	Decreased* 43% 4 Days	Increased* 2.1°F	Increased 0.6°F
Cincinnati, OH 1948–2011 (63 years)		Increased^ 208% 2 Days	Decreased 45% 2 Days	Decreased 26% 2 Days	Increased 0.2°F	Decreased 0.7°F

Photos: (Chicago) © iStockphoto.com/Veni; (Detroit) © iStockphoto.com/DenisTangneyJr; (Minneapolis) © iStockphoto.com/Davel5957; (St. Louis) © iStockphoto.com/Kubrak78; (Cincinnati) © iStockphoto.com/Davel5957

+ 45–99% / – 45–99% | +100–199% | + ≥ 200% | Decrease in Cool Days

+ < 1°F / – < 1°F | + 1°–2.9°F / – 1°–2.9°F

WEATHER TRENDS

and high relative humidity putting people at risk for illness and death.

THREE-DAY HEAT WAVE TRENDS

Three consecutive days of high heat and humidity can increase heat-related illness and death.

Temperature and Humidity Changes in Hot, Dry Nights: Temperature	Temperature and Humidity Changes in Hot, Dry Nights: Dew Point	Average Increase in Heat Waves Harmful to Human Health
Increased 2.6°F	Increased 2.8°F	Increased 1 per year
Increased* 4.3°F	Increased 1°F	Increased 2 per year
Decreased 0.8°F	Decreased 1.4°F	Increased 1 per year
Increased* 4.4°F	Increased* 7.7°F	Increased* 4 per year
Increased 0.6°F	Decreased 1.1°F	No Change

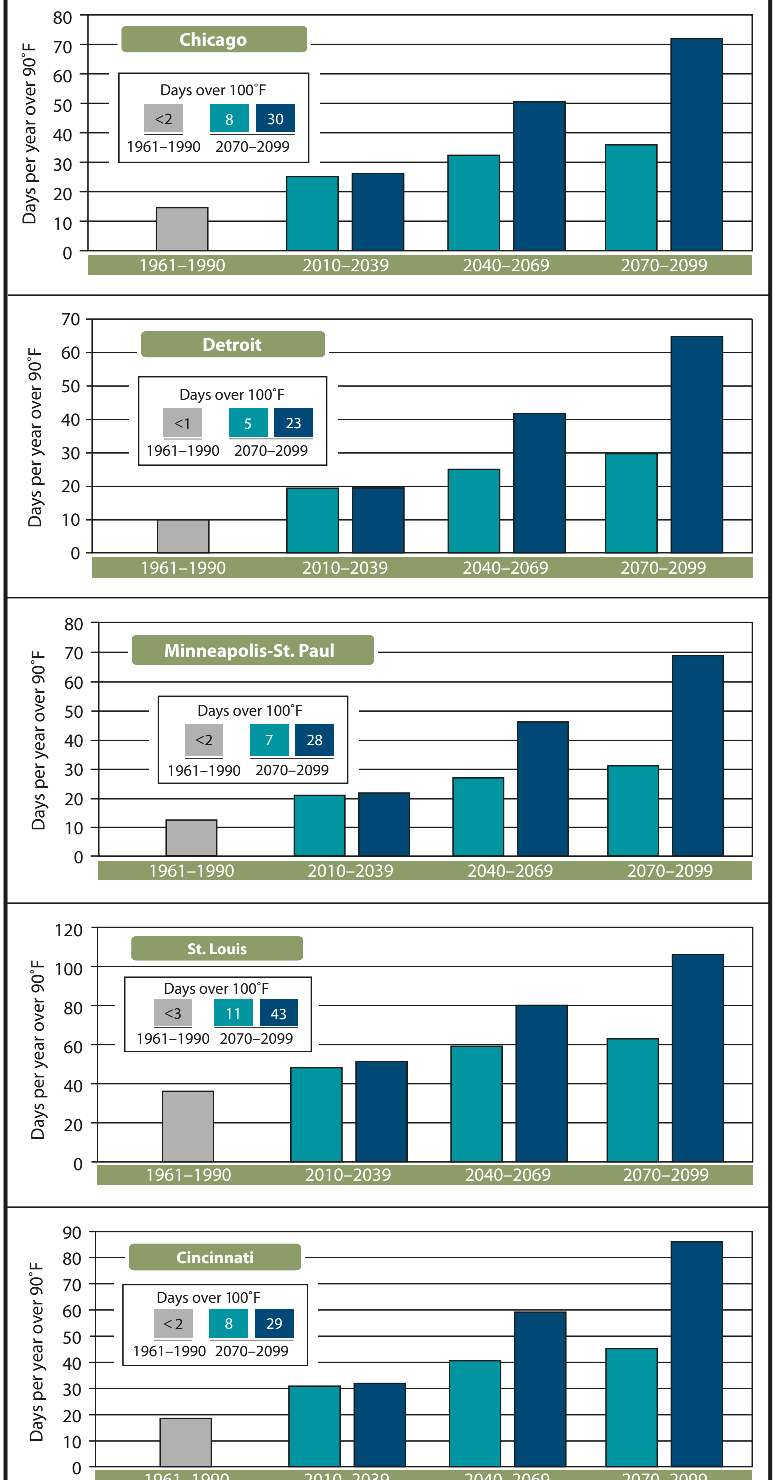
* + > 3°F

* ≥ 1

WHAT THE FUTURE MIGHT LOOK LIKE

Assuming current carbon emissions trends continue (equivalent to the higher-emissions scenario), the Midwest will likely face scorching summer days with temperatures that soar above 90°F—and even 100°F—late in this century. If carbon emissions are significantly curtailed (lower-emissions scenario), far fewer summer days will be extremely hot.

The data for this section were compiled from other sources. This report's original research does not include projections of potential future climate changes.



Source: UCS 2009a-e.

Current   Lower-Emissions Scenario   Higher-Emissions Scenario

© Erin Nekervis

Low-income urban residents and members of minority groups are more likely to live in neighborhoods with high population density, little open space, and sparse vegetation—conditions that can make neighborhoods even warmer. These problems are compounded when residents cannot afford air conditioning, increasing their risk of heat-related illness and death.

CONTINUED FROM P. 17

however, the majority of heat-related deaths occurred among people aged 60 to 90, likely reflecting the increase in life expectancy over the decades (Basu and Samet 2002; Bridger, Ellis, and Taylor 1976).

Urban residents are particularly vulnerable to the effects of heat, thanks to urban heat island effects, and low-income urban residents may be even more susceptible to stress from hot-weather events. People of lower socioeconomic status and members of minority groups are more likely to live in neighborhoods with high population density, little open space, and sparse vegetation (Basu and Samet 2002; Buechley, Van Bruggen, and Truppi 1972). Those conditions combine to make urban neighborhoods even warmer than their surroundings (Harlan et al. 2006). People of lower socioeconomic status are also less likely to own air conditioners, or may not use them because of the cost of electricity, increasing their risk of heat-related death (Curriero et al. 2002).

According to the United Nations, some 85 percent of Americans will live in urban areas by 2020, and the urban population will climb to 90 percent by 2050 (United Nations 2011). This trend toward city living will only add to the health effects of heat waves (Shahmohamadi et al. 2011; Hobbs and Damon 1996). Still, city dwellers are not the only people at risk from dangerously hot weather. Heat waves are projected to become more common in both towns and cities across the nation—particularly in the Northeast and Midwest (O'Neill and Ebi 2009).

Quantifying the Health Effects of Extreme Heat

In the public health community, epidemiologists study the cause of disease (in this case, heat-related illness and death) by designing studies that can assess the relationship between an exposure metric (e.g., ambient temperature, heat wave) and a specific outcome (e.g., heat-related hospitalizations, emergency room visits, deaths). As discussed later, heat can be associated with elevated mortality from a variety of causes, so health studies often evaluate "all-cause" or "cause-specific" (e.g., cardiovascular) mortality in addition to causes specific to heat exposure.

The hundreds of studies examining heat-related health concerns do not use a standard metric for exposure to high temperature, nor do analysts regard one metric as better than another (Barnett, Tong, and

Projected Deaths Each Year from Extreme Summertime Heat

	2020–2029	2045–2055	2090–2099
Chicago	143	185	300
Cincinnati	19	23	31
Detroit	255	291	701
Minneapolis	119	112	142
St. Louis	67	109	189

Source: Greene et al. 2011.

Higher summer temperatures and heat waves are projected to increase as our climate warms. One recent study projected a notable rise in heat-related deaths across the Midwest over the course of the twenty-first century under a higher-emissions scenario (A1FI), as indicated above.

FIGURE 6. **Heat Disorders**

Heat index	*Possible heat disorders for people in higher-risk groups*
Extreme Danger 130°F or higher	Heatstroke/sunstroke highly likely with continued exposure.
Danger 105°F to 130°F	Sunstroke, heat cramps, or heat exhaustion likely, and heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution 90°F to 105°F	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and/or physical activity.
Caution 80°F to 90°F	Fatigue possible with prolonged exposure and/or physical activity.

Source: National Weather Service, online at *http://www.nws.noaa.gov/om/brochures/heat_wave.shtml.*

The heat index describes how hot it really feels, given relative humidity as well as air temperature. As the heat index rises, so does the risk of heat-related illness and death.

Clements 2010). However, researchers often use air temperature and relative humidity level, or dew point temperature, as an indicator of heat stress (Basu and Samet 2002).

Heat-Related Mortality

Evaluating heat-related mortality is challenging. The Ad Hoc Committee of the National Association of Medical Examiners recommends attributing a death to heatstroke or hyperthermia if body temperature was at least 105°F at the time of death, or the deceased person showed changes in mental status and had elevated levels of liver and muscle enzymes (Donoghue et al. 1997).

However, despite this recommendation, examiners often report cardiovascular, respiratory, and cerebrovascular diseases as the underlying cause of death even when heat was an important contributing factor (Basu and Samet 2002). As much as a three-day lag between heat events and deaths may also occur, further complicating classification of death (Martin et al. 2011; Anderson and Bell 2009; Basu and Samet 2002).

If our current rate of heat-trapping emissions continues, the Centers for Disease Control (CDC) predicts that annual heat-related deaths will reach 3,000 to 5,000 by 2050 (CDC 2009). *(Note: The CDC bases these projections on the A1FI scenario for heat-trapping emissions of the Intergovernmental Panel on Climate Change.)* People in the northernmost cities, who are not as acclimated to dramatic increases in air temperature, are more vulnerable to extreme heat (Curriero 2002). People living in areas that regularly see high summertime temperatures, and those who live closer to the equator, are usually better able to withstand high heat (Hajat and Kosatky 2010).

The share of U.S. residents over age 65 is climbing, from roughly 13 percent today to a predicted 20 percent by 2030. As the population ages, we can expect more heat-related illnesses and even deaths.

Heat-Related Illnesses

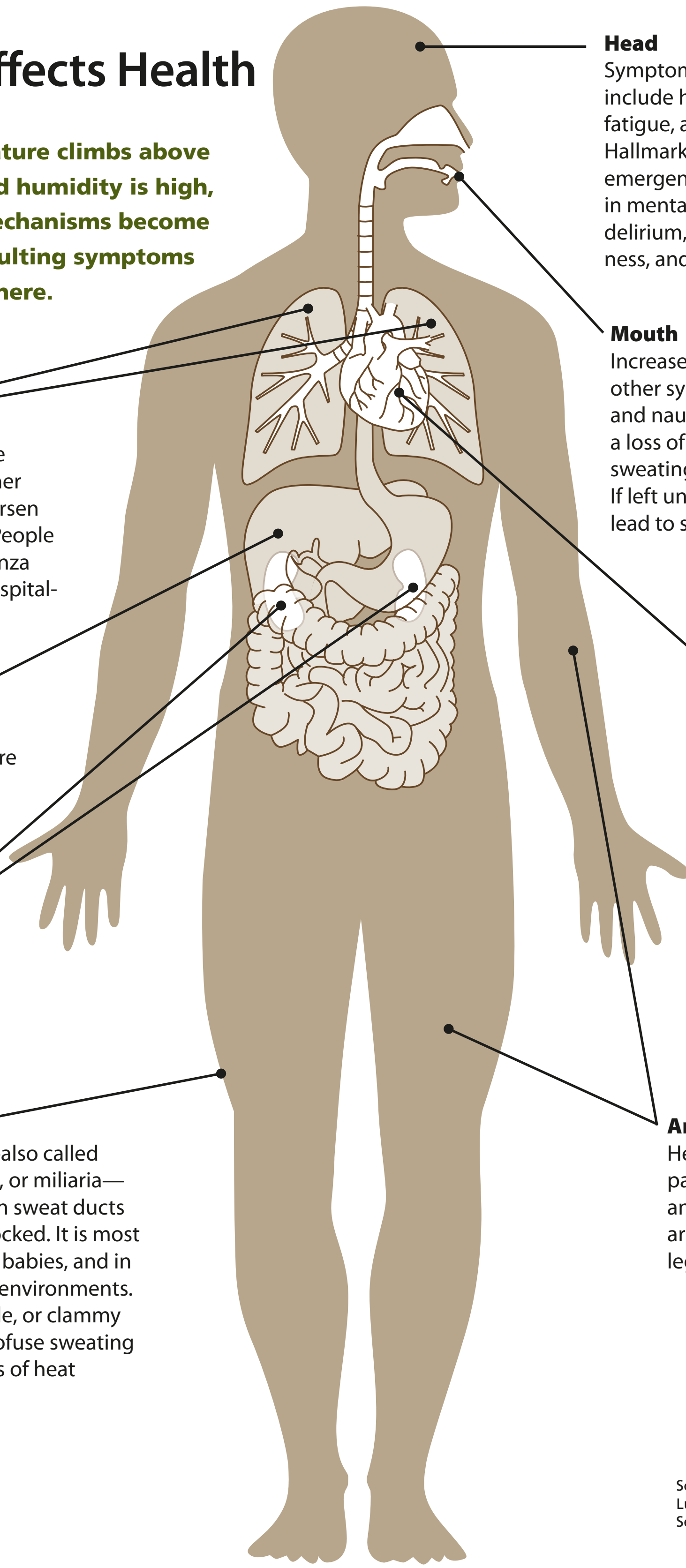
Heat-related illnesses occur along a spectrum, from relatively minor heat rash to potentially deadly heatstroke (Figure 6). People suffer heat-related illness when the body's normal temperature control system is unable to effectively regulate its internal temperature (Bouchama and Knochel 2002).

Heat cramps, heat exhaustion, and heatstroke are the conditions most likely to send people to the emergency room when temperatures rise. Heat cramps occur when heavy sweating and water intake upset the body's salt balance, causing cramping of the muscles in the legs, arms, and abdomen. Heat exhaustion causes profuse sweating, nausea, and confusion, although it is milder than heatstroke, and is typically associated with a core body temperature of 98.6°F to 104°F. Although these symptoms can be alarming, heat exhaustion is not necessarily life threatening unless it progresses (Glazer 2005).

Heat exhaustion can sometimes progress to heatstroke. More commonly, heatstroke comes on suddenly,

How Heat Affects Health

When the air temperature climbs above body temperature and humidity is high, the body's cooling mechanisms become less effective. The resulting symptoms include those shown here.



Head
Symptoms of heat exhaustion can include headache, dizziness, irritability, fatigue, and loss of coordination. Hallmarks of heatstroke—a medical emergency—include marked changes in mental status, such as confusion, delirium, irritability, loss of consciousness, and seizures.

Mouth
Increased thirst, dry mouth, and other symptoms such as weakness and nausea often signal dehydration—a loss of water or salts because of heavy sweating or inadequate fluid intake. If left untreated, dehydration can lead to serious health effects.

Lungs
Asthma, chronic obstructive pulmonary disease, and other respiratory diseases can worsen when temperatures spike. People with pneumonia and influenza are also at greater risk of hospitalization during a heat wave.

Heart
Your heart has to work harder to keep your body from overheating when outside temperatures rise. Tachycardia (rapid heartbeat) can occur with heat exhaustion, and cardiac arrhythmias (abnormal or irregular heart rhythms) can occur with heatstroke. Patients with a history of cardiovascular disease and high blood pressure are at greater risk of hospitalization during heat waves.

Liver
Heatstroke can injure the liver.

Kidneys
Heatstroke can lead to kidney failure.

Skin
Heat rash—also called prickly heat, or miliaria—occurs when sweat ducts become blocked. It is most common in babies, and in hot, humid environments. Flushed, pale, or clammy skin and profuse sweating can be signs of heat exhaustion.

Arms and Legs
Heat cramps can cause painful muscle spasms and cramping in the arms, shoulders, and legs.

Source: Becker and Steward 2011; Glazer 2005; Lugo-Amador, Rothenhaus, and Mouyer 2004; Semenza et al. 1999.

Illustration: Amanda Wait & Annie Bissett/Nonprofitdesign.com without the warning signs of heat exhaustion. But no matter how it starts, heatstroke is an emergency. After prolonged exposure to extreme heat, the body can completely stop sweating. Unable to cool itself through perspiration, the body's core temperature can climb above 105°F. Blood pressure drops and pulse speeds up. Without emergency treatment, this dangerously elevated body temperature leads to enzyme malfunction, organ damage, and death (Stonehill 1972).

Factors beyond the direct physical effects of high temperatures can increase the risk of heat-related illness. Nighttime temperatures are one such factor. When temperatures remain high into the night, people have no relief from hot daytime weather and are at greater risk for heat-related illness and death (O'Neill and Ebi 2009; Poumadere et al. 2005).

Ozone also increases the risk of heat-related health complications. Ozone exacerbates lung diseases such as asthma, and can cause breathing difficulties even in healthy people (UCS 2011; Ito, De Leon, and Lippman 2005; Cody et al. 1992). Ozone pollution is expected to rise along with temperatures over much of the United States (Jacob and Winner 2009).

Climate Change and Hot Weather

Average U.S. temperatures have already increased by 2°F over the past 50 years as carbon dioxide and other heat-trapping emissions have accumulated in the atmosphere. And they are projected to rise another 7° to 11°F by the end of this century under a high-carbon-emissions scenario, and 4° to 6.5°F under a low-emissions scenario. These increases are likely to affect weather, ecosystems, and public health markedly (Karl, Melillo, and Peterson 2009).

Each new decade since the 1970s has been hotter than the last, with 2000 to 2010 the hottest on record so far (Arndt 2010; NASA 2010). In the 1950s, record low temperatures were just as likely to occur as record highs. During the last 10 years, in contrast, the United States has experienced twice as many record highs as record lows. By 2050, scientists project that record highs will outnumber record lows by 20 to 1 (Meehl et al. 2009).

Measured and projected changes in temperature beyond these averages promise to affect public health more directly. Notably, average global nighttime temperatures have risen more rapidly than average daytime temperatures (Gershunov, Cayan, and Iacobellis 2009; Alexander et al. 2006). That means dwellings cool more slowly during the night, and people get less relief from extreme heat.

Heat waves, too, are becoming more common. Over the past few decades, the number of extreme heat events has increased both in the United States and around the world (IPCC 2012; IPCC 2007). According to a U.S. government report, high-humidity heat waves have become both more frequent and more intense in the last 30 to 40 years (Karl, Melillo, and Peterson 2009).

In the years to come, an entirely new heat regime is likely to emerge in many parts of the world. In Chicago, for instance, events similar in magnitude to the deadly 1995 heat wave are projected to occur every other year, even if we reduce our carbon emissions (Figures 7 and 8, p. 24). If we do not curb those

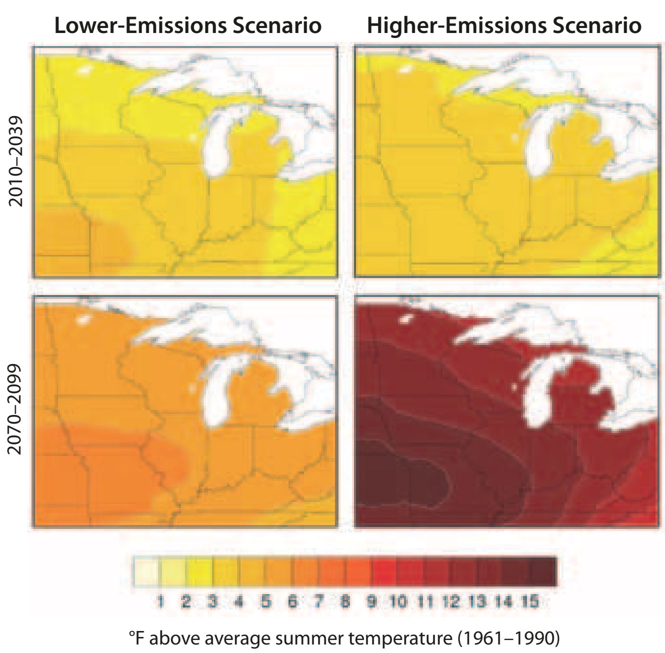
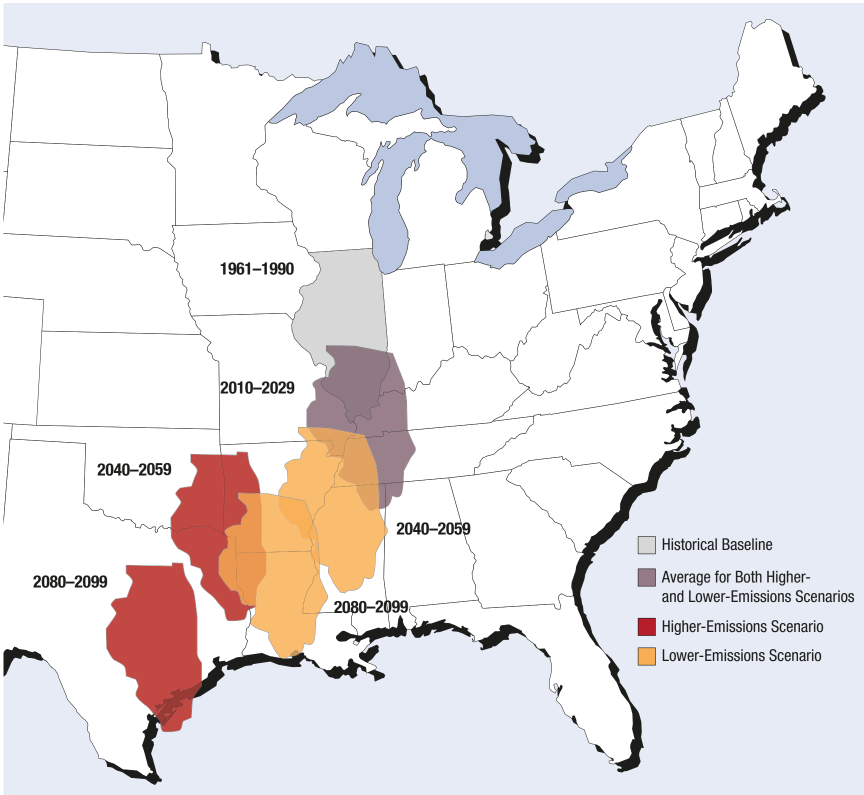


FIGURE 7. Scorching Summers Become the Norm

If our heat-trapping emissions continue to rise at current rates, summers in the Midwest are projected to become much hotter. Under a high-emissions (A1FI) scenario (right), average summer temperatures are projected to rise by more than 3°F over the next several decades, and by an extraordinary 14°F toward the end of this century. Under a lower-emissions (B1) scenario (left), that increase would be halved. (For more information, see *www.ucsusa.org/mwclimate*.)

FIGURE 8. **Southern Weather Comes to Illinois**



Scientists project that Illinois will face hotter temperatures and less summer rain under continued climate change. The red outlines show the kind of southern summers Illinois could see during this century under a higher-emissions (A1FI) scenario. Analysts expect the state to face hotter summers even under a lower-emissions (B1) scenario, as the yellow outlines illustrate.

Source: UCS 2009a.

emissions, such extreme events are likely to strike roughly three times each year (Hayhoe et al. 2009).

The Midwest is not the only region at risk. In the Northeast, for example, if we continue on a path of high heat-trapping emissions, Boston is projected to face more than 60 days over 90°F each year by the end of the century, and more than 20 days over 100°F. And, if we continue with high carbon emissions, many southern states are expected to have twice as many days each year above 90°F by the end of this century as at the end of the twentieth century (Karl, Melillo, and Peterson 2009).[13]

Climate change may already be affecting many aspects of weather, including temperature and precipitation, and causing increases in extreme weather-related events such as droughts and wildfires. Some studies have started to detect changes in heat extremes that are consistent with long-term climate change. Determining the cause and effect of a specific instance of extreme weather remains an emerging area of research. Nevertheless, scientists are pioneering ways to link specific heat waves—particularly those that break all-time records—to large-scale climate change.

Scientists investigating the 2003 European heat wave, for instance, concluded with high confidence that climate change from human activities had doubled the risk of an extreme heat event of that magnitude (Stott, Stone, and Allen 2004). Similarly, after a heat wave around Moscow in July 2010, researchers found that there was only a 20 percent chance that the heat wave would have occurred without climate change (Rahmstorf and Coumou 2011).

Ozone pollution—which is expected to rise along with temperatures over much of the United States—increases the risk of heat-related health complications by exacerbating lung diseases such as asthma and causing breathing difficulties even in healthy people.

Building Resilient Communities

A LARGE BODY OF SCIENTIFIC EVIdence indicates that carbon emitted from human activities such as burning fossil fuels and cutting down forests is very likely raising our planet's temperature (IPCC 2007). As this study shows, hot summer days and heat waves have already become more common across the Midwest. In that region and beyond, communities must find ways to adapt to these dangerous weather conditions.

While several major cities, including Chicago, have implemented climate action plans or emergency-response plans for extreme heat, the latter idea is still very new to most communities. A 2010 survey of 70 communities across the country found that just 30 had programs to prevent heat-related illness and death during heat waves (O'Neill et al. 2010).[14] Many of these communities cited local leadership as driving these programs. Lack of informed local leadership, along with a shortage of resources, are the likely reasons many communities have failed to develop such programs.

Although communities have been slow to adopt them, formal heat-response plans are effective in reducing deaths from heat waves. After the 1995 Chicago heat wave, for example, the city developed a plan that researchers believe reduced heat-related deaths during another heat wave in 1999 (Luber and McGeehin 2008).

Of course, communities can go only so far to protect their residents. Residents must also change their behavior to stay safe during extreme heat events, such as by drinking plenty of water, spending at least a few hours a day in air conditioning, and avoiding direct sunshine, alcoholic beverages, and strenuous activity (Environmental Protection Agency 2006). However, much of the public still fails to recognize the dangers of heat waves, and many at-risk individuals do not take precautionary measures. Heat action plans must therefore include outreach and education (Luber and McGeehin 2008).

How Communities Can Protect Health during Extreme Heat

The Environmental Protection Agency's *Excessive Heat Events Guidebook* outlines several steps that officials can take to minimize the health effects of such events (Environmental Protection Agency 2006). These steps include:

- Communicating the danger of extreme heat by ensuring real-time public access to information on the risks and appropriate responses, through broadcast media, websites, and toll-free phone lines
- Establishing and facilitating access to air-conditioned public shelters

Building resilience in the face of extreme heat requires commitment and collaboration. For example, planners can reduce the urban heat island effect by expanding green spaces such as parks and rooftop gardens (Chicago, left). Officials can also develop heat-response plans that include educating and checking on residents and setting up cooling centers, such as at Detroit's Farwell Recreation Center (center, during a 2010 heat wave). Residents can also take proactive steps, such as drinking plenty of water, spending at least a few hours a day in air conditioning, and avoiding strenuous activity.

Photos (L to R): © City of Chicago; © Detroit Free Press/Andrew J. Jackson; © iStockphoto.com/LSOphoto

Tools and Programs for Adapting to Climate Change

Federal agencies and other organizations are providing resources and developing tools and programs to help communities prepare for dangerous heat events.

Federal Initiatives

- The White House Climate Change Adaptation Task Force, composed of representatives from more than 20 federal agencies, is developing recommendations on how the government can strengthen its programs to better prepare the nation for the effects of climate change (*Whitehouse.gov* 2012).
- The CDC's National Environmental Health Tracking Program collects data on the health effects of multiple hazards, from asthma to air pollution. The CDC recently added a component that will allow users to find information on climate change and health, such as temperature, heat-related death, and heat vulnerability.[15] The CDC's Climate-Ready States and Cities Initiative is also helping state and city health departments prepare for and respond to the health effects of climate change (CDC 2012).
- The National Weather Service has developed a Heat/Health Watch Warning System to alert citizens to dangerous heat events up to five days in advance.[16] The National Weather Service first tested the system in Philadelphia, then expanded it to 30 cities, and now plans to extend it to all cities with populations of 500,000 or more (Kalkstein 2009; National Weather Service 2005).
- The Environmental Protection Agency released its *Excessive Heat Events Guidebook* in 2006 with the National Oceanic and Atmospheric Administration, the Federal Emergency Management Agency, and the CDC. The guidebook gives public health officials information on the impact of such events so they can assess local health risks. The guidebook also offers a menu of steps that officials can include in programs to respond to such events.
- The Global Change Research Act of 1990 requires the federal government to produce a National Climate Assessment—a status report on climate change science and its effects—every four years. The report is based on observations across the county, and informs efforts to mitigate and adapt to climate change (*Globalchange.gov* 2012).

Other National, State, and Local Initiatives

- The Geospatial Emergency Management Support System, developed by researchers, integrates maps, real-time weather data, and other information to help policy makers track the local effects of climate change and identify populations most vulnerable to them (Houghton et al. 2012).
- The nonprofit ICLEI–Local Governments for Sustainability has developed the Climate and Air Pollution Planning Assistant, a tool to help local governments identify opportunities for reducing global warming emissions (ICLEI 2012a).
- The Climate Resilient Communities Program, also developed by ICLEI–Local Governments for Sustainability, provides real-world examples, training and networking, and technical guidance to help local governments enhance their ability to cope with climate change, including heat waves (ICLEI 2012b).
- The National Association of County and City Health Officials (NACCHO) works with local governments to address the public health effects of climate change by improving coordination and communication. NACCHO is conducting one-year demonstration projects in six U.S. states, including communities in Illinois and Minnesota (NACCHO 2012).
- The Association of State and Territorial Health Officials has developed a Climate Change Collaborative to research, develop, and compile promising practices, success stories, and tools to help state and territorial health agencies mitigate and prepare for climate change.
- The Resource Innovation Group, affiliated with the Center for Sustainable Communities at Willamette University, has developed guidebooks for integrating planning for climate change into the work of county, regional, and tribal public health agencies (Resource Innovation Group 2012). The guidebooks include *Public Health and Climate Change: A Guide for Increasing the Capacity of Local Public Health Departments* and *Ready for Change: Preparing Public Health Agencies for the Impacts of Climate Change*
- The Georgetown Climate Center at Georgetown University has created a clearinghouse for climate action and adaptation plans from communities across the country. The clearinghouse, aimed at policy makers, public health professionals, and urban planners, features plans from Midwest states such as Michigan, Wisconsin, and Illinois (Georgetown Climate Center 2012).

- Directly assessing and, if needed, intervening on behalf of those at greatest risk, including homeless individuals, older people, and those with known medical conditions
- Establishing systems to alert public health officials about high-risk individuals or those in distress during an extreme heat event, such as lists of these residents and telephone hotlines they can call

While all communities can benefit from these tools and planning initiatives, urban neighborhoods are uniquely susceptible to extreme heat. Officials, urban planners, and architects should make special efforts to mitigate rising temperatures in these neighborhoods, such as by expanding the amount of vegetation in public spaces, adopting standards for reflective roofing and paving materials, and lowering global warming emissions (Harlan et al. 2006).

Climate change affects each city and state in unique ways, and policy makers must be aware of local patterns (Grimmond et al. 2010). Successful heat-response plans require collaboration among many agencies and organizations, city-specific criteria on the risks of extreme heat and methods to reach residents most at risk, and a communication plan. Developing such comprehensive plans will require effort and funding, but they are vital to preparing for the extreme temperatures to come (Luber and McGeehin 2008).

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As part of the St. Louis heat-response team, Mayor Francis Slay went door to door with other city officials during the heat wave of summer 2011, checking on residents and offering resources to help them stay cool.

How Midwest Cities Are Taking Action

Chicago

ACTION PLANS AND RESOURCES

Chicago has developed an Extreme Weather Operations Plan, which the Office of Emergency Management and Communications reviews annually and updates as needed in coordination with other agencies.[17] The plan calls for a range of actions during extreme heat events, including:

- Opening 24-hour cooling centers
- Conducting police checks of seniors and at-risk individuals
- Inspecting high-risk buildings (i.e., buildings with no air conditioning) to ensure that windows and ventilation systems are operating properly

OTHER INITIATIVES

As part of the Keep Cool Illinois campaign, the state has designated more than 120 facilities—including 26 in Chicago—for use as cooling centers. Open from 8:30 a.m. to 5:00 p.m. Monday through Friday, these facilities offer residents a cool, comfortable place to stay on hot summer days.[18]

Chicago is a national leader in climate change preparation and mitigation. The city's Climate Action Plan includes many steps to save lives in a heat emergency.

Photo: (Chicago) © iStockphoto.com/Veni

Cincinnati

ACTION PLANS AND RESOURCES

Cincinnati does not have an official heat action plan, although the city has taken some steps to deal with heat waves:

- The Cincinnati Health Department (CHD) monitors daily weather forecasts, issues heat alerts, and designates heat emergencies.
- The Cincinnati Drug and Poison Information Center also issues special health alerts during extreme heat events.
- The city opens recreation centers to serve as cooling centers during periods of excessive heat.
- The CHD and the CDC studied the risk factors for death during heat waves. The researchers found that people taking medications and people with mental illness were especially vulnerable to extreme heat (Kaiser et al. 2001). As a result, the CHD has specifically targeted these groups for special outreach efforts during heat waves.

OTHER INITIATIVES

Ohio does not prohibit public utilities from turning off gas or electricity when they are the sole power source for cooling during periods of extreme heat. However, the state does require a 30-day delay in a utility disconnection, if a medical professional certifies that that step would endanger an individual's health.[19]

Detroit

ACTION PLANS AND RESOURCES

The city divides heat awareness plans and activities between the Department of Health and Wellness Promotion, the Office of Homeland Security and Emergency Management, and the Recreation Department. The American Red Cross, the Salvation Army, and community volunteers help implement the plan.

- When the National Weather Service identifies an extreme heat event, the health department sends out advisories and coordinates the opening of recreation and other cooling centers.
- The health department's All Hazard Plan, Emergency Management's Emergency Operations Plan, and the Recreation Department's protocol for opening cooling centers take effect during heat emergencies.
- Local media help publicize the cooling centers and other resources for coping with heat events.

OTHER INITIATIVES

The Metro-Detroit Climate Justice Task Force, composed of volunteers from the academic, social service, and government sectors, formed in 2011 to raise awareness of the risks of heat-related illness, and to provide resources to at-risk populations. Most recently, Detroiters Working for Environmental Justice, in partnership with Detroit Homeland Security and other entities, has formed the Detroit Climate Action Collaborative to build public awareness of climate change and its effects on residents.[20]

Photos: (Cincinnati) © iStockphoto.com/Davel5957; (Detroit) © iStockphoto.com/DenisTangneyJr

Minneapolis

ACTION PLANS AND RESOURCES

Minneapolis relies on the Extreme Weather Annex of its Emergency Operations Plan when the National Weather Service issues a heat advisory or heat warning.

- The city's Heat Health Watch website posts such advisories and warnings.[21]
- Minneapolis officials conduct door-to-door wellness checks during such events, and post a list of public air-conditioned buildings for use by people who do not have air conditioning in their homes.[22] Officials are developing a plan for pets.
- The local Department of Health and Family Support works closely with Regulatory Services and Emergency Preparedness and the Minnesota Department of Health to help residents prepare for extreme heat events.

OTHER INITIATIVES

Under state law, public utilities cannot turn off electricity or water when the National Weather Service has issued an excessive heat watch, heat advisory, or excessive heat warning.[23]

The state has also developed an Extreme Heat Tool Kit that includes population-based maps that local officials can use to target at-risk populations.[24]

St. Louis

ACTION PLANS AND RESOURCES

The city of St. Louis Health Department has an Extreme Temperature Plan.[25] As part of the plan, monitoring morbidity and mortality, weather surveillance procedures, and other organizational collaborations are identified.[26]

After a heat wave in 1980, local officials and community organizations formed Operation Weather Survival (OWS) to prevent illness and death from extreme heat or cold weather.[27] The OWS monitors weather forecasts and uses email and telephone calls to alert members of heat warnings and advisories. The group also provides and installs air conditioners for medically needy individuals.[28]

OTHER INITIATIVES

The state's Ready in 3 program helps residents prepare for emergency events, including heat waves.[29] The Missouri Department of Health and Senior Services also offers cooling centers across the state during extreme heat events.[30]

Missouri does not prohibit public utilities from turning off gas or electricity when they are the sole power source for cooling during periods of extreme heat.[31] However, the state does provide guidance to households threatened with disconnection on seeking assistance for energy bills.[32]

All communities can benefit from specially designed tools and planning initiatives to deal with the heat. Urban neighborhoods, however, are uniquely susceptible to extreme heat and special efforts are needed to protect these residents.

Where Do We Go from Here?

(L to R): © iStockphoto.com/bowdenimages; © Dori (dori@merr.info)

A midwestern landscape (right) shows wind turbines scattered across farm fields. By shifting to renewable energy sources like wind and dramatically limiting our use of fossil fuels, we can curb some of the extreme effects of climate change and help minimize health risks from hot weather. The energy choices we make today will shape the world we and our children live in tomorrow.

EXTREME HEAT EVENTS BECAME more intense and more common in the Midwest over the past six decades. Midwesterners have experienced these changes in weather during their lifetimes. While we did not design our study to determine whether such changes stem from human activities, our findings are consistent with projected warming trends.

A previous UCS report showed that the risk of dangerously hot weather in the Midwest is likely to grow as we continue to release heat-trapping emissions and the climate warms. Under a higher-emissions scenario, nine major cities—including the five in this report—are projected to see at least 60 days over 90°F each year, and 20 days topping 100°F, by the last 30 years of this century (Hayhoe et al. 2009).

Scientists also project that heat waves in North America and Europe will become more intense, more frequent, and longer-lasting (IPCC 2012). Under a lower-emissions scenario, the Midwest can expect a heat wave comparable to the devastating 2003 European heat wave every decade by the last 30 years of the century—or every other year under a higher-emissions scenario (Hayhoe et al. 2009).

Over the very long term, climate change could make outdoor temperatures unbearable—and possibly lethal—during the hottest months in many parts of the world (Sherwood and Huber 2010). The choices we make today will determine which of these scenarios occurs.

While our analysis shows that dangerous summer air masses have become more common, this is only one of the public health risks associated with global warming. Many more are expected, including worsening ozone pollution, degraded water quality, more outbreaks of waterborne diseases, more bacterial and viral diseases transmitted by mosquitoes, ticks, and fleas, and droughts, floods, and related crop failures (UCS 2011).

Local preparedness is critical to protecting public health and saving lives during extreme heat events (Union of Concerned Scientists 2012). However, we also need a comprehensive national strategy to create climate-resilient communities and reduce the heat-trapping emissions that are driving climate change.

We can choose to significantly lower our global warming emissions. By shifting to renewable energy sources and dramatically limiting our use of fossil fuels, we can avoid some of the most extreme climate change. We can also make choices—both as individuals and as a society—that minimize our future health risks from dangerously hot weather.

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Endnotes

1 In this report, "dangerous" refers to dry tropical and moist tropical+ air masses, which have been linked to heat-related illness and mortality (National Weather Service 2005; Ebi et al. 2004; Sheridan and Kalkstein 2004).

2 The Office of Climate, Water and Weather Services and the National Climatic Data Center compile the number of fatalities, injuries, and damages caused by weather-related hazard using reports from National Weather Service offices in the 50 states, Puerto Rico, Guam, and the Virgin Islands.

3 We also evaluated a second small city paired with Chicago: Rockford, IL. The results were inconclusive, and showed little trend of any sort. The technical appendix includes full results for Rockford.

4 For more detail on our approach and results, see the technical appendix, online at *www.ucsusa.org/heatintheheartland.*

5 We used information from airport weather stations because they provide the hourly data needed to determine types of air masses. Because air masses cover an extensive area, data from such stations accurately reflect conditions in city centers even if they are located outside them.

We analyzed dew point temperatures because they are used to classify air masses. Trends in both air temperature and dew point can reveal trends in relative humidity. If the dew point is rising faster than the air temperature, relative humidity is also rising. If air temperature is falling faster than dew point, relative humidity is again rising.

6 Because our data extend back only to the late 1940s, our analysis does not capture the warm decade of the 1930s, which may have influenced trends over the last century. However, both the 1920s and 1940s were relatively cool, so the 1930s likely represents an anomalous period. More recent trends may also be more relevant (USGCRP 2009).

7 A three-day-or-longer run of moist tropical+ and dry tropical days could occur in any combination. For example, three days in a row of dry tropical count as a single run, as do three consecutive days of dry tropical, dry tropical, and moist tropical+, with each occurring on a single day. Each three-day-or-longer stretch of oppressive air mass days counts as a single run. A four-day stretch, therefore, is counted as two consecutive three-day runs (days 1-2-3 plus days 2-3-4), and a five-day run is counted as three consecutive three-day runs (days 1-2-3, days 2-3-4, and days 3-4-5).

8 Although we designed our methodology to control for urban heat island effects, we cannot completely rule out some contribution from such effects.

9 For more such graphs, see the technical appendix, online at *www.ucsusa.org/heatintheheartland.*

10 Moisture content rises with air temperature (Held 1993; Kalkstein et al. 1990). However, this can occur only if a water source, such as a body of water or a moist surface, is available for evaporation,

11 The Intergovernmental Panel on Climate Change (IPCC) has developed a set of possible futures, or scenarios, that project global emissions of heat-trapping gases based on a range of variables, including population growth, energy use, and other choices. Reports in the UCS series *Confronting Climate Change in the Midwest*, including this report, use the IPCC's A1FI and B1 scenarios to represent higher- and lower-emissions choices during this century. The B1 scenario projects lower emissions than A1FI, and therefore more modest increases in global and regional temperatures. A1FI projects the highest emissions and temperature increases among the IPCC scenarios. For more on the scenarios, see IPCC 2000. For more on *Confronting Climate Change in the Midwest* reports, see *www.ucsusa.org/global_warming/science_and_impacts/impacts/climate-change-midwest.html*.

12 In the cited report, the higher-emissions scenario is SRES A2 from the IPCC.

13 The higher-emissions scenario described here is the SRES A2 scenario from the IPCC.

14 Only 25 percent of communities that received this survey responded, making it difficult to generalize about the state of heat wave preparedness across the country. However, the authors concluded that many U.S. communities lack comprehensive programs to prepare for heat events.

15 For more information on this program, see *ephtracking.cdc.gov/showClimateChangeTracking.action*, accessed April 11, 2012.

16 The National Weather Service developed this system with Larry Kalkstein, a coauthor of this report.

17 For more information on the Extreme Weather Operations Plan, part of the city's Climate Action Plan, see *www.chicagoclimateaction.org/pages/adaptation/49.php*, accessed April 13, 2012.

18 See *www2.illinois.gov/keepcool/Pages/default.aspx*, accessed April 20, 2012.

19 See *liheap.ncat.org/Disconnect/disconnect.htm*, accessed April 20, 2012.

20 See *www.dwej.org/facts.htm*, accessed April 18, 2012.

21 See *www.minneapolismn.gov/news/news_20110607beattheheat*, accessed April 13, 2012.

22 See *www.minneapolismn.gov/www/groups/public/@health/documents/webcontent/convert_284825.pdf*, accessed April 13, 2012.

23 See *liheap.ncat.org/Disconnect/disconnect.htm*, accessed April 20, 2012.

24 See *http://www.health.state.mn.us/macros/search/index.html?q=heat+tool+kit&cx=001025453661958716519%3Aj2323tveixc&cof=FORID%3A10&ie=UTF-8&submit=Search.*

25 Jackson, L. 2012. Personal communication, May 17. Lillie Jackson is an epidemiologist with the St. Louis Department of Health.

26 See *www.crh.noaa.gov/Image/lsx/wcm/coolingsites2010.pdf*, accessed April 13, 2012.

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31 See *liheap.ncat.org/Disconnect/disconnect.htm*, accessed April 20, 2012.

32 See *www.ameren.com/sites/aue/DollarMore/Documents/AssistanceGuide.pdf*, accessed May 17, 2012.

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CLIMATE CHANGE AND YOUR HEALTH

Hot, humid days are not just uncomfortable. Extreme heat kills. High temperatures can lead to dehydration, heat exhaustion, and deadly heatstroke. As temperatures rise, public health officials face a difficult challenge.

Heat in the Heartland: 60 Years of Warming in the Midwest analyzes six decades of summer weather in cities in Illinois, Michigan, Minnesota, Missouri, and Ohio. The findings show that many Midwesterners are already living with more hot and humid summer days, hotter and more humid summer nights, and more dangerous heat waves—as well as fewer cool days to bring relief from the heat. Extreme heat is not only tomorrow's problem: it is already affecting Americans across the Midwest.

The United States has the technology to reduce harmful global warming emissions, and the knowledge to protect the public from extreme heat. In fact, as this report shows, Midwest cities are already taking some lifesaving steps. The choices we make today to adapt and prepare for a warming world will affect the health and well-being of ourselves, our children, and our descendants long into the future.

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