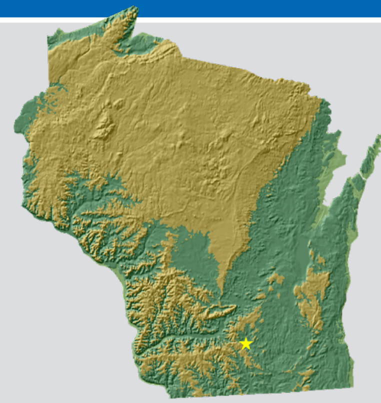
WISCONSIN



Key Messages

Temperatures in Wisconsin have risen more than 2°F since the beginning of the 20th century. Under a higher emissions pathway, historically unprecedented warming is projected during this century. Extreme heat is a particular concern for densely populated urban areas such as Milwaukee, where high temperatures and high humidity can cause dangerous conditions.

Wisconsin has experienced an increase in both annual precipitation and extreme precipitation events, and these increases are projected to continue. Projected increases in winter and spring precipitation will pose a continuing risk of spring planting delays, as well as an increased risk of flooding. Snowfall is projected to decline due to warmer temperatures.

Severe drought, a natural part of Wisconsin's climate, is a risk to this agriculture-dependent state. The intensity of naturally occurring droughts may increase due to earlier snowmelt, a greater frequency of dry days, and higher temperatures, which increase the rate of soil moisture depletion during dry spells.

Changes in seasonal and multiyear precipitation, evaporation, and temperature can affect water levels in the Great Lakes, causing serious environmental and socioeconomic impacts.

Wisconsin's location in the interior of North America and the lack of mountains to the north and south expose the state to incursions of bitterly cold air masses from the Arctic in the winter and warm, humid air masses from the Gulf of Mexico in the summer, causing a large range of temperatures across the state. The southern part of the state experiences cold winters and mild to hot summers, while the northern part of the state experiences frigid winters and generally cool summers with brief bouts of excessive heat. The winter season is dominated by dry and cold air, with occasional intrusions of milder air from the west and south. The summer is characterized by frequent warm air masses, either hot and dry continental air masses from the arid west and southwest or warm and moist air from the south. However, periodic intrusions of cooler air from Canada provide breaks from summer heat. The state has borders along Lake Superior to the north and Lake Michigan to the east, and the proximity to the lakes provides a moderating effect on temperatures for locations along the shorelines. Annual average temperatures vary from 39°F in the north to 50°F in the south.

Observed and Projected Temperature Change

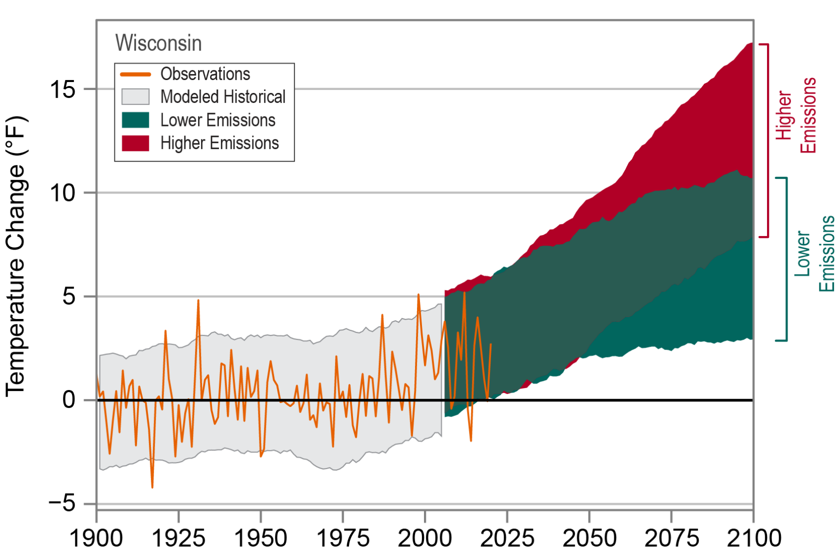


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Wisconsin. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Wisconsin (orange line) have risen more than 2°F since the beginning of the 20th century. Shading indicates the range of annual temperatures from the set of models. Observed temperatures are generally within the envelope of model simulations of the historical period (gray shading). Historically unprecedented warming is projected during this century. Less warming is expected under a lower emissions future (the coldest end-of-century projections being about 2°F warmer than the historical average; green shading) and more warming under a higher emissions future (the hottest end-of-century projections being about 12°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.

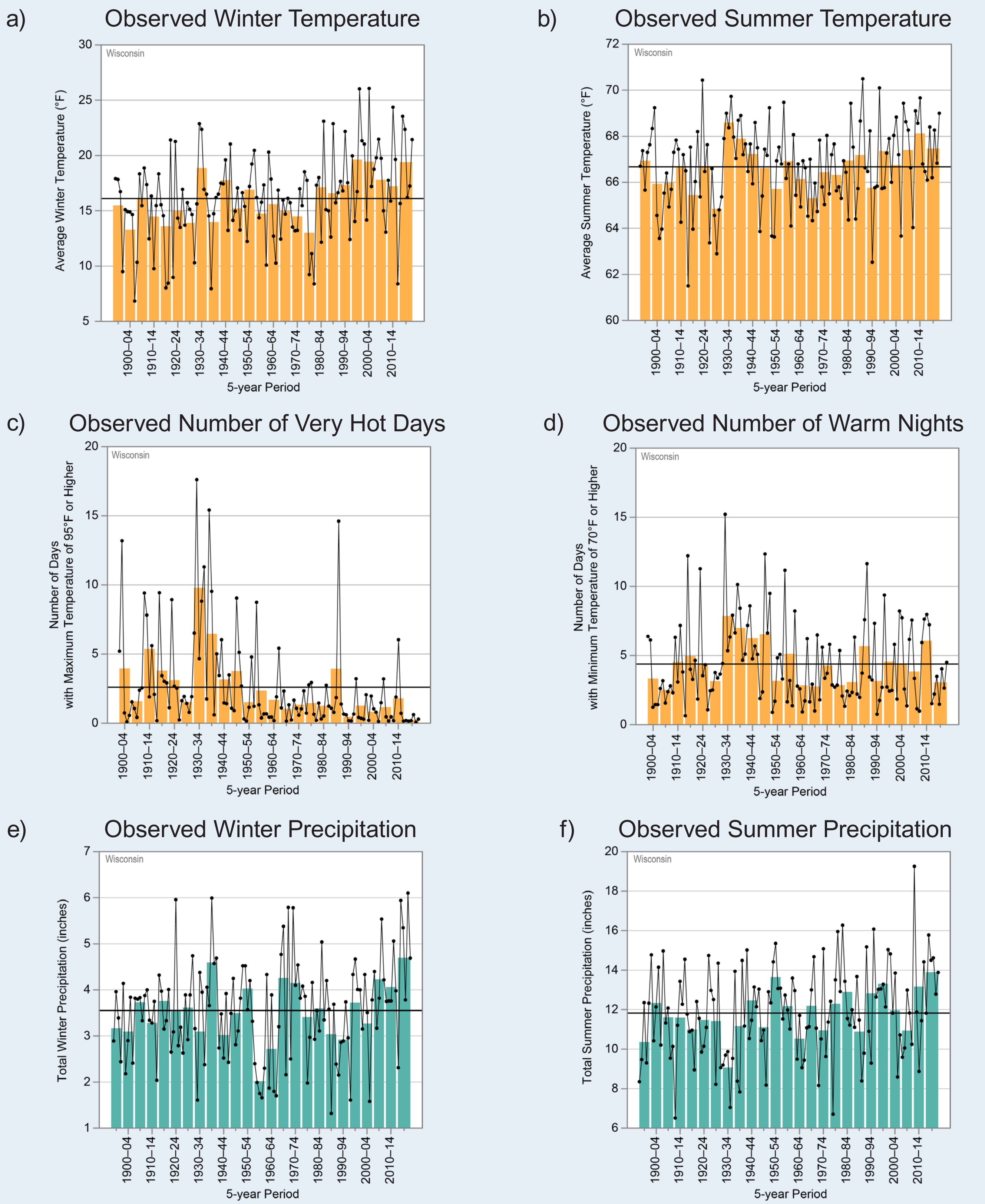


Figure 2: Observed (a) winter (December–February) average temperature, (b) summer (June–August) average temperature, (c) annual number of very hot days (maximum temperature of 95°F or higher), (d) annual number of warm nights (minimum temperature of 70°F or higher), (e) total winter precipitation, and (f) total summer precipitation for Wisconsin from (a, b, e, f) 1895–2020 and (c, d) 1900–2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black lines show the long-term (entire period) averages: (a) 16.1°F, (b) 66.7°F, (c) 2.6 days, (d) 4.4 nights, (e) 3.6 inches, (f) 11.8 inches. Winter and summer temperatures have generally been above average since 1980. Due to extreme drought and poor land management practices, the summers of the 1930s remain the warmest on record. The number of very hot days has been below average since 1950 (excluding the 1985–1989 period), indicating a lack of summer warming, while the number of warm nights has fluctuated around the average since 1995. Winter and summer precipitation has been above average since 2005 and 2010, respectively. Sources: CISESS and NOAA NCEI. Data: (a, b, e, f) nClimDiv; (c, d) GHCN-Daily from 25 long-term stations.

Since the beginning of the 20th century, temperatures in Wisconsin have risen more than 2°F, and temperatures in the 2000s have been warmer than in any other historical period (Figure 1). The hottest 5-year period on record was 2000–2004. The hottest year was 2012, with a statewide average temperature of 47.4°F, which is 5°F above the long-term average. Like much of the Midwest, this warming has been concentrated in the winter and spring, while summers have warmed less (Figures 2a and 2b). Warmer spring temperatures present the additional threat of frost-freeze damage to early-budding fruit trees. In 2012, a "killer frost" closely followed an abnormally warm March, resulting in significant damage to fruit crops. The lack of summer warming is reflected in a below average occurrence of very hot days (Figure 2c) and no overall trend in warm nights (Figure 2d). The number of very cold days has been near or below average since 2000, reflecting a winter warming trend (Figure 3). The increase in winter temperatures has also reduced lake ice cover. Ice coverage in the Great Lakes has been declining since the 1970s. For example, the annual average maximum ice coverage during 2003–2013 was less than 43%, compared to the 1962–2013 average of 52%. Ice-cover duration on Lake Mendota has exhibited a consistent downward trend since the late 19th century (Figure 4).

Precipitation varies widely from year to year (Figure 5), and most of the state's precipitation falls during the warmer half of the year. Statewide total annual precipitation has ranged from a low of 20.5 inches in 1910 to a high of 44.6 inches in 2019. **Recently, Wisconsin has experienced some unusually wet years in addition to 2019. The third-wettest year on record was 2018 (39.7 inches), and 2016, 2010, 2017, and 2014 were the fourth-, fifth-, tenth-, and eleventh-wettest, respectively**. **The driest multiyear periods were in the late 1890s, early 1930s, and late 1950s, and the wettest were in the early 1990s and 2010s**. The driest consecutive 5-year interval was 1929–1933, and the wettest was 2015–2019. Total winter precipitation and total summer precipitation have been mostly above average over the last 26 years (Figures 2e and 2f). The frequency of 2-inch extreme precipitation events has increased, with the highest number occurring during the 2015–2020 period (Figure 6). Snowfall varies from about 30 inches annually in the south to more than 100 inches along the Gogebic Range. This heavy snowfall along the Gogebic Range is partially due to lake-effect snow events on the south shore of Lake Superior, which has experienced significant upward trends in annual snowfall totals. These upward trends are attributed to warmer air temperatures, which create more moisture

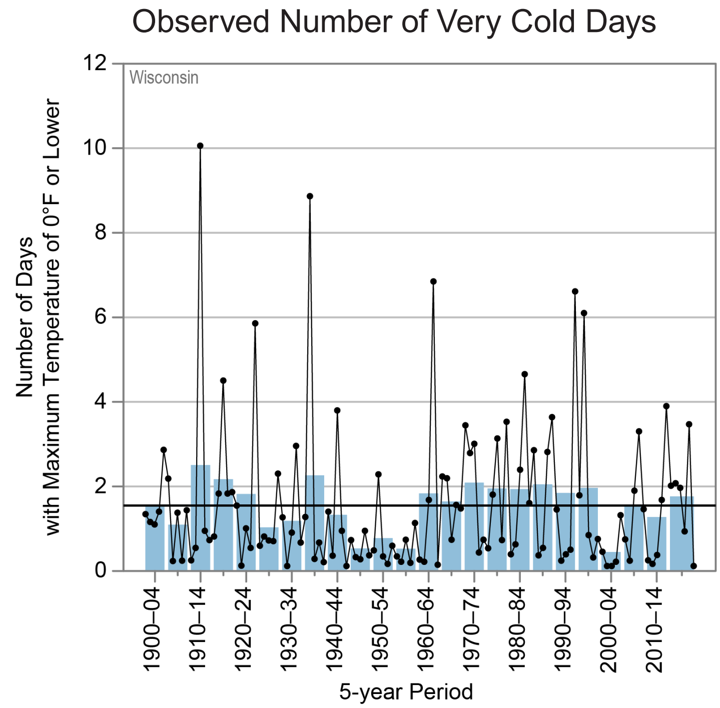


Figure 3: Observed annual number of very cold days (maximum temperature of 0°F or lower) for Wisconsin from 1900 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 1.6 days. The number of very cold days has varied widely across the historical record. Wisconsin experienced the fewest number of very cold days during the 2000–2004 period, indicative of overall winter warming in the region. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 25 long-term stations.

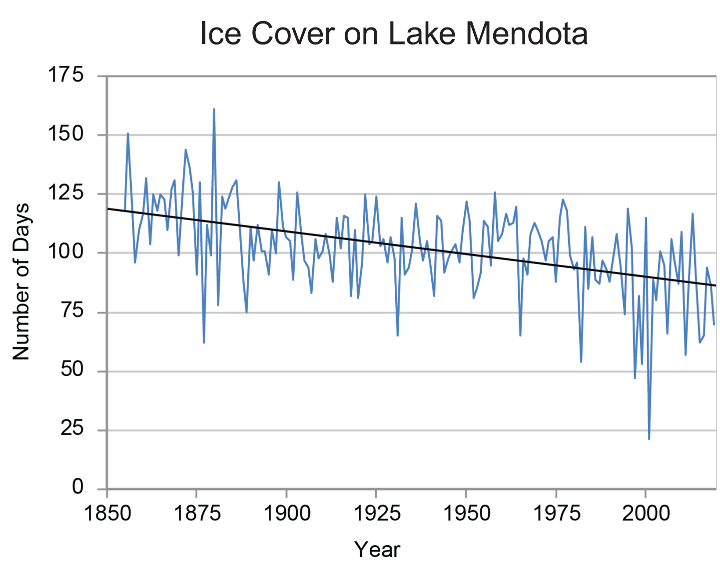


Figure 4: Annual changes in ice-cover duration (blue line) for Lake Mendota from 1855 to 2020. The total duration of ice cover exhibits a consistent downward trend (black line), decreasing from about 120 days in the late 19th century to fewer than 100 days in most years since 1990. Source: Wisconsin State Climatology Office.

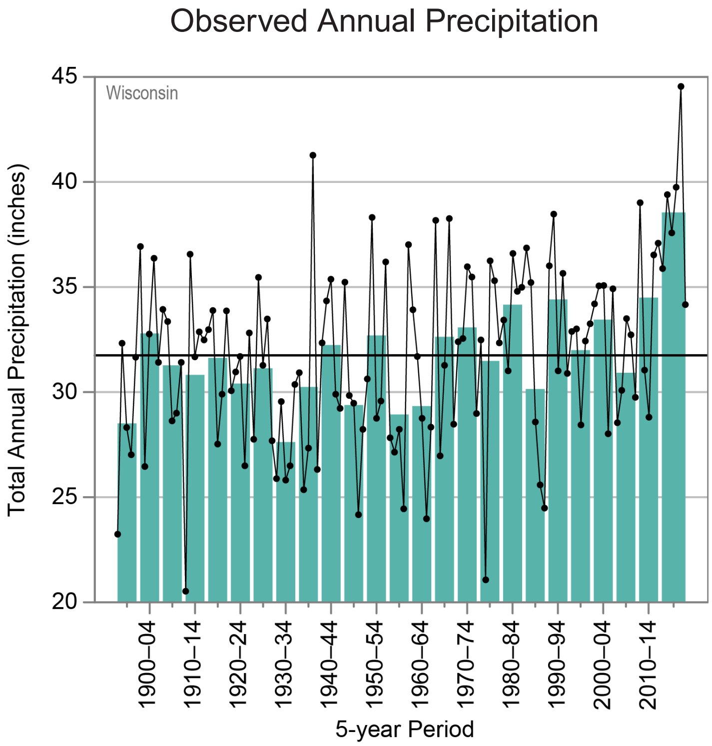


Figure 5: Observed total annual precipitation for Wisconsin from 1895 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 31.8 inches. Annual precipitation varies widely, but recent years have seen totals well above average. The wettest consecutive 5-year interval was 2015–2019, with an annual average of 39.4 inches, while the driest was 1929–1933, with an annual average of only 27.1 inches. Sources: CISESS and NOAA NCEI. Data: nClimDiv.

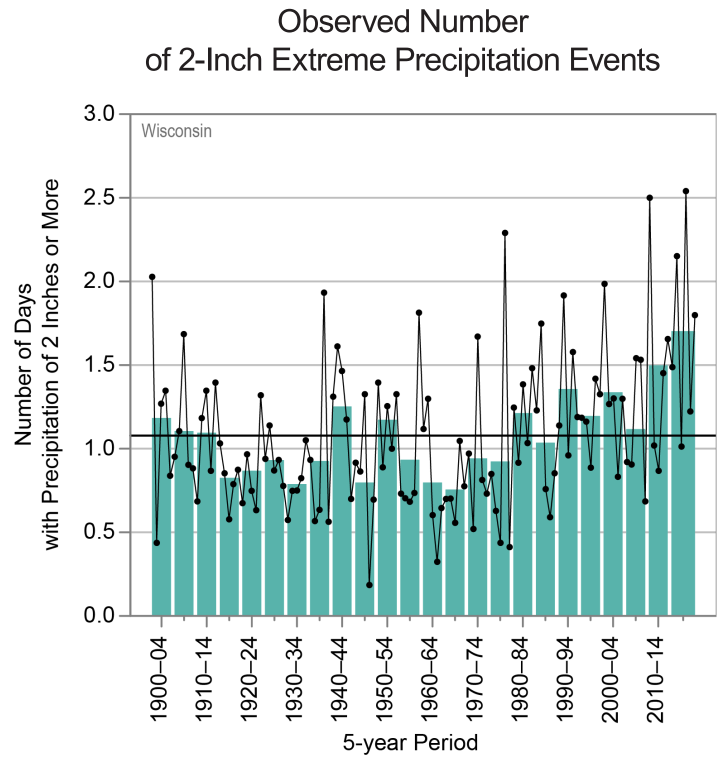


Figure 6: Observed annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more) for Wisconsin from 1900 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 1.1 days. A typical reporting station experiences 1 event per year. Since 1990, Wisconsin has experienced an increasing number of 2-inch extreme precipitation events. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 30 long-term stations.

availability due to warmer surface water temperatures and reduced lake ice coverage. Annual snowfall totals have also increased over the rest of Wisconsin since 1930.

Many rivers border and run through Wisconsin, and due to both ice jams and heavy precipitation, the state is susceptible to both groundwater flooding and river flooding. Heavy rain and snow during the fall and winter of 2007–2008 led to elevated water tables by the summer of 2008. The elevated water tables, combined with increased summer precipitation, caused flooding to persist for 6 months and resulted in approximately $17 million in agricultural and property damages from groundwater flooding alone. In addition, during June 5–12, 2008, a series of storms brought heavy rain to southern Wisconsin, with multiple stations reporting more than 10 inches. The rain caused severe flooding, totaling more than a billion dollars in damages.

Due to the state's northerly location and proximity to the winter storm track, severe winter storms are a regular occurrence. During February 1–2, 2011, southern Wisconsin experienced blizzard conditions from a powerful storm tracking south of the state. Snow accumulations ranged from 12 to 26 inches, with wind gusts of 45 to 60 mph. One of Wisconsin's worst natural disasters was a devastating ice storm in the south-central and southeastern portion of the state during March 4–5, 1976. Ice accumulations of up to 5 inches were reported, downing thousands of power lines and snapping many trees and utility poles. Some rural areas were without power for 10 days.

Severe thunderstorms are a threat to the state, particularly during the spring and summer months. A strong derecho during May 30–31, 1998, caused wind gusts of 70 to 100 mph, with some areas reporting winds of up to 128 mph. More than 250,000 people lost power, and damages were estimated at more than $60 million. Although tornadoes are not as common in Wisconsin as in other midwestern states, they can occasionally occur and cause loss of life. The state averaged 23 tornadoes annually during 1980–2020, with a record of 62 in 2005. On August 25, 2005, twenty-seven tornadoes occurred in southern Wisconsin, the state's highest confirmed number of tornadoes in a single day. Among those tornadoes, an F3 tornado traveled about 20 miles into Jefferson County from Dane County, passing through Stoughton with maximum intensity and a width of one-half mile. It destroyed or damaged 240 houses, resulted in property damages of more than $40 million, and killed 1 person and injured 23 more. On April 10, 2011, severe thunderstorms caused the largest single outbreak of tornadoes in northeastern Wisconsin; 4 of the 15 tornadoes were classified as strong (EF2 and EF3). Fortunately, the tornadoes impacted relatively rural areas, limiting damages to slightly more than $10 million.

Water levels in the Great Lakes have fluctuated over a range of 3 to 6 feet since the late 19th century (Figure 7). Higher lake levels were generally noted in the late 19th century, the early 20th century, and the 1940s, 1950s, 1980s, and the late 2010s. Lower lake levels were observed in the 1920s and 1930s and again in the 1960s. For Lake Michigan–Huron, lower levels occurred during the first decade of this century. Lake levels have risen rapidly since 2013, with the highest levels since 1886 observed in 2020.

Under a higher emissions pathway, historically unprecedented warming is projected during this century (Figure 1). Even under a lower emissions pathway, annual average temperatures are projected to most likely exceed historical record levels by the middle of this century. However, a large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Extreme heat is a particular concern when high temperatures combine

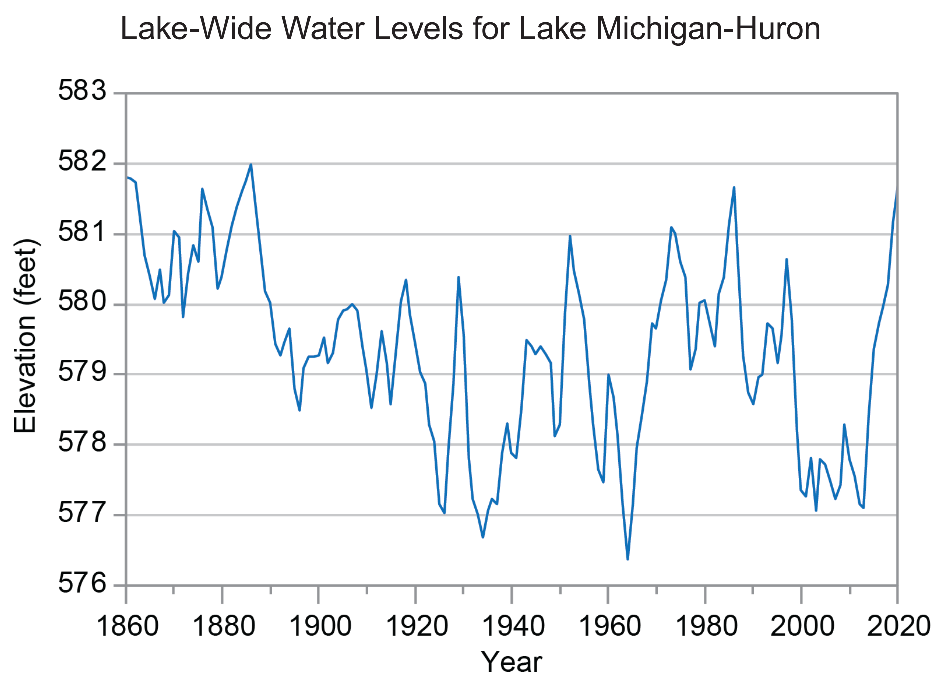


Figure 7: Annual time series of the average water levels for Lake Michigan–Huron from 1860 to 2020. Water levels in the Great Lakes have fluctuated widely over the years. Lake Michigan–Huron levels were very low during 2000–2013 but have since risen rapidly to the highest levels since 1886. Source: NOAA GLERL.

with high humidity to create dangerous heat index values, resulting in risks to human health. Urban areas are especially vulnerable to extreme heat, due to the urban heat island effect and high social vulnerability. Future heat waves are projected to be more intense, and cold waves are projected to be less intense. Winter ice cover on the Great Lakes is projected to decrease.

Precipitation is projected to increase for Wisconsin, with the most likely increases occurring during the winter and spring (Figure 8), **but snowfall is projected to decline due to warmer temperatures**. Additionally, extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods. Above normal precipitation enhances the risk of springtime flooding, which could pose a threat to Wisconsin's agricultural industry by delaying planting and causing yield losses.

The intensity of future droughts is projected to increase. Even if precipitation increases in the future, rising temperatures will increase the rate of soil moisture loss during dry periods. Thus, future summer droughts, a natural part of Wisconsin's climate, are likely to be more intense.

Changes in seasonal and multiyear precipitation, evaporation, and temperature can affect water levels in the Great Lakes, causing serious environmental and socioeconomic impacts. During the 1980s, high lake levels resulted in the destruction of beaches, the erosion of shorelines, and the flooding and destruction of near-shore structures. Low lake levels can affect the supply and quality of water, restrict shipping, and result in the loss of wetlands. Future changes in lake levels are uncertain and the subject of research. Reduced winter ice cover from warmer temperatures leaves shores vulnerable to erosion and flooding.

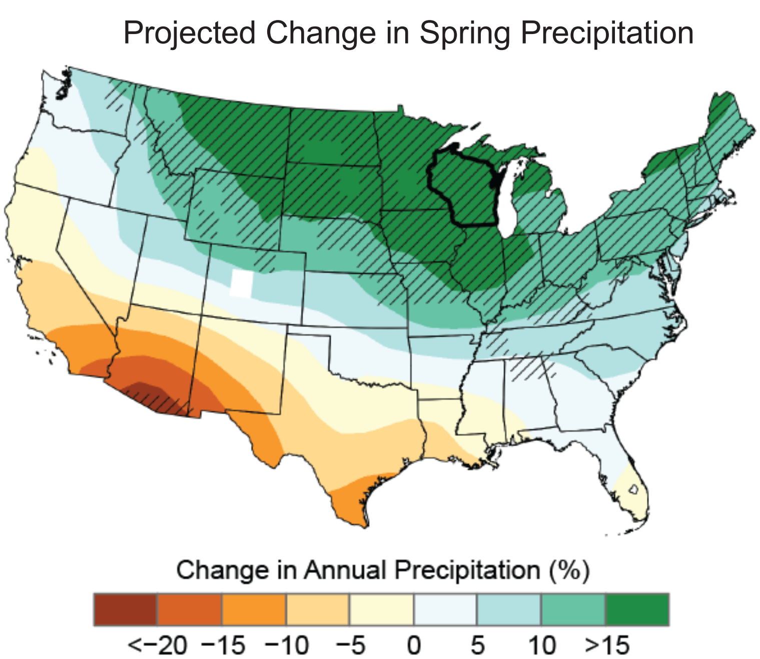


Figure 8: Projected changes in total spring (March–May) precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. The whited-out area indicates that the climate models are uncertain about the direction of change. Hatching represents areas where the majority of climate models indicate a statistically significant change. Wisconsin is part of a large area of projected increases in the Northeast and Midwest. Sources: CISESS and NEMAC. Data: CMIP5.

Technical details on observations and projections are available online at https://statesummaries.ncics.org/technicaldetails.