

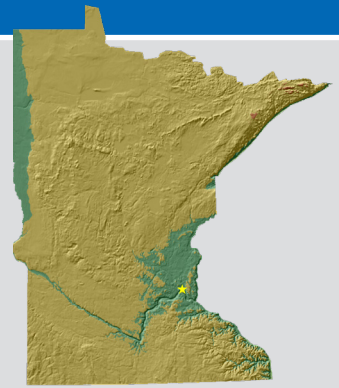
MINNESOTA

Key Messages

Temperatures in Minnesota have risen more than 2.5°F since the beginning of the 20th century. Under a higher emissions pathway, historically unprecedented warming is projected during this century. While warmer temperatures will reduce heating energy demand and lengthen the growing season, they will also increase the intensity of naturally occurring droughts.

Precipitation has increased over the last 100 years. Spring precipitation is projected to increase by about 15% to 20% by midcentury.

Extreme precipitation events are projected to increase in frequency and intensity, resulting in increased flooding and associated impacts, such as increased erosion, infrastructure damage, and agricultural losses.



Minnesota'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, resulting in large temperature variations across the seasons. Winters are cold in the south and frigid in the north, and summers are mild to occasionally hot in the south and pleasantly cool in the north. 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 that pushes northward from the Gulf of Mexico. The summer is also punctuated by periodic intrusions of cooler air from Canada, providing breaks from the heat. Temperature extremes have ranged from as low as -60°F (February 2, 1996, at Tower) to as high as 115°F (July 29, 1917, at Beardsley). Among the non-mountainous U.S. states, Minnesota has the third-largest range of highest to lowest temperatures. The state's location on the eastern edge of the transition zone between the humid climate of the eastern United States and the semiarid climate of the Great Plains also creates large differences in average precipitation across the state. Snowstorms are a normal part of the winter and early spring climate, with annual average snowfall ranging from 30 to 70 inches over most of the state, with higher values near 90 inches along the shores of Lake Superior.

Observed and Projected Temperature Change

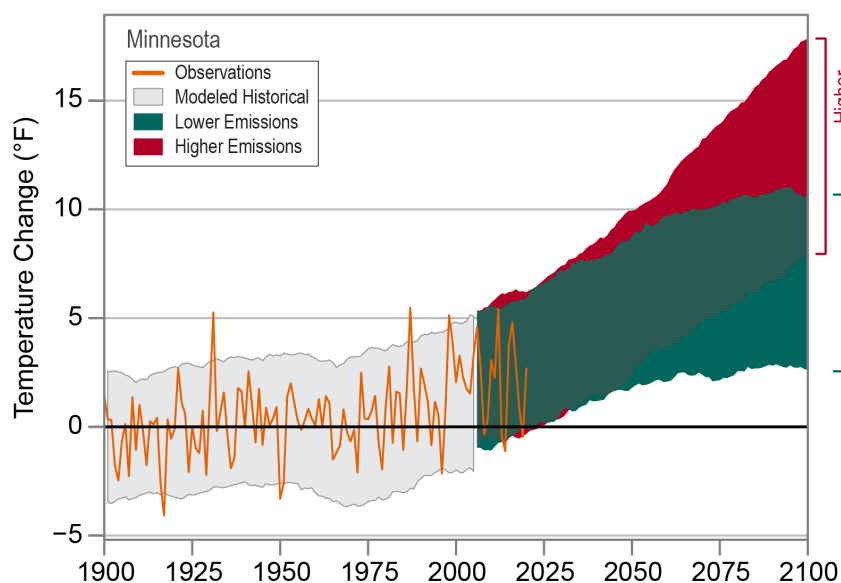


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Minnesota. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Minnesota (orange line) have risen more than 2.5°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 10°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.

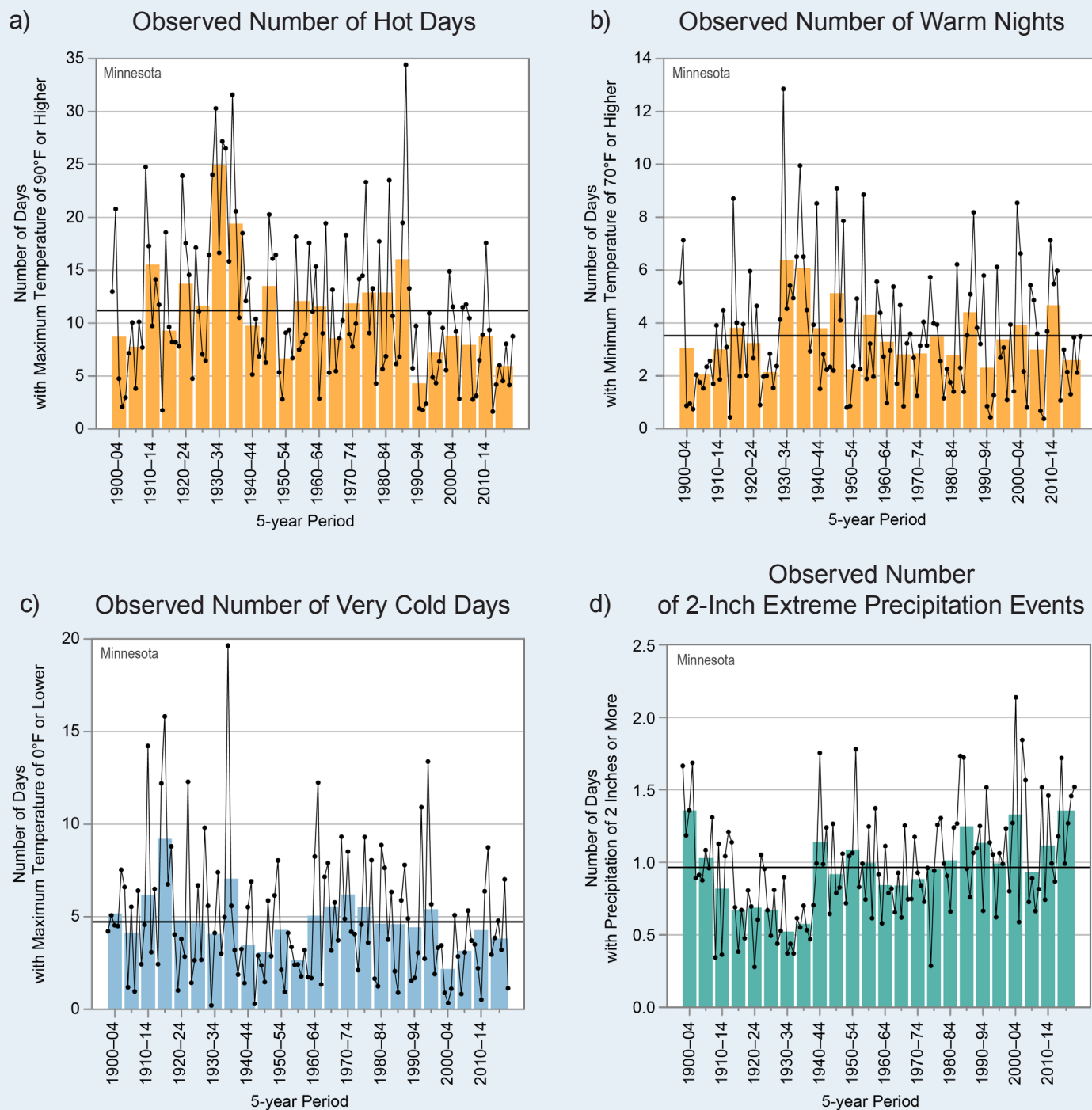


Figure 2: Observed annual number of (a) hot days (maximum temperature of 90°F or higher), (b) warm nights (minimum temperature of 70°F or higher), (c) very cold days (maximum temperature of 0°F or lower), and (d) 2-inch extreme precipitation events (days with precipitation of 2 inches or more) for Minnesota 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 lines show the long-term (entire period) averages: (a) 11 days, (b) 3.5 nights, (c) 4.7 days, (d) 1.0 days. Since 1990, Minnesota has experienced a below average number of hot days. The number of warm nights peaked during the 1930s and shows no long-term trend. Since 1980, the number of very cold days has been near or below average. The number of 2-inch extreme precipitation events was above the long-term average during the most recent 6-year period (2015–2020); a typical station experiences about 1 event per year. Sources: CISESS and NOAA NCEI. Data: (a, b, c) GHCN-Daily from 21 long-term stations; (d) GHCN-Daily from 25 long-term stations.

Temperatures in Minnesota have risen more than 2.5°F since the beginning of the 20th century (Figure 1). Since 1998, Minnesota has experienced 8 of its 10 warmest years on record. This warming has been concentrated in the winter, while summers have not warmed as much. Summer warming has been mostly due to an increase in nighttime temperatures, with the coolest nights of summer becoming warmer. By contrast, summer daytime high temperatures have increased very little, which is reflected in a below average occurrence of hot days (Figure 2a). There is no overall trend in warm nights (Figure 2b). The winter warming trend is reflected in a below average number of very cold days since 2000, with a historic low occurring during the 2000–2004 period (Figure 2c). In addition, the ice-out date for Lake Osakis has been earlier than April 16 for 11 years since 2000 (Figure 3).

Total annual precipitation in Minnesota has been above the long-term (1895–2020) average since 1990 (Figure 4). The number of 2-inch extreme precipitation events has been mostly above average since 1985, with the 2015–2020 period having the highest recorded multiyear average (Figure 2d). Annual average precipitation, including rainfall and the water equivalent found in snowfall, ranges from 23 inches in the far northwest to more than 35 inches in the southeast. Nearly two-thirds of annual precipitation falls during the growing season (May through September). However, occasional drought is a natural feature of the climate, occurring when anomalous circulation patterns bring in dry air from the interior of North America.

Between 2000 and 2012, extreme weather events (including extreme drought, summer heat waves, severe storms, heavy rain and flooding, and tornadoes) caused more than \$4 billion in property damages. In general, thunderstorms cause more property damage in Minnesota than any other type of extreme event. The annual frequency of thunderstorm days is roughly 45 days in the southern part of the state and 30 days along the northern border. Due to Minnesota's northern location, heat waves are infrequent but can have severe consequences for populations less acclimatized to these events. Between 1995 and 2012, excessive heat events occurred most frequently in the central and southern counties (Figure 5). Since 2000, the number of very heavy rains (6 inches or more in a day) has been 2 to 3 times higher than in the 20th century.

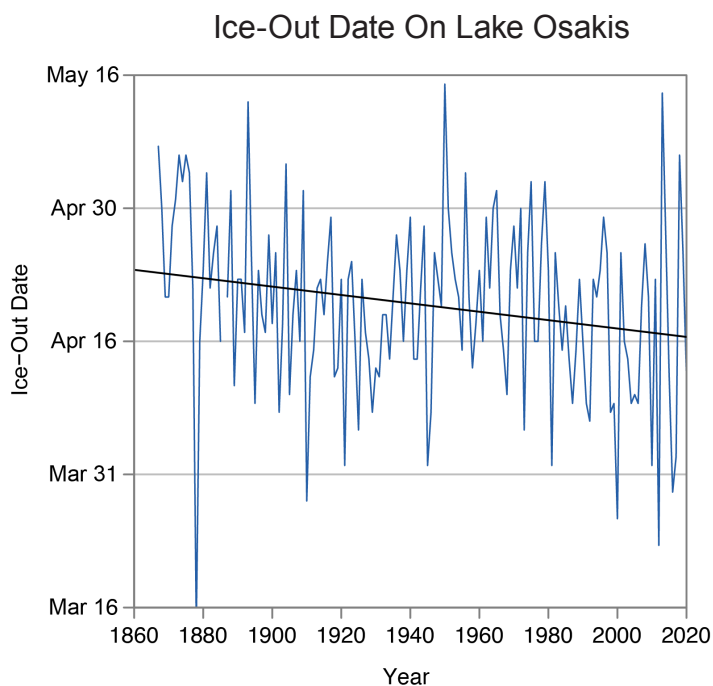


Figure 3: Annual changes in ice-out dates for Lake Osakis (blue line) from 1867 to 2020. The black line shows the long-term trend. Lake Osakis ice-out dates have been getting earlier over the last few decades, with 3 of the 5 earliest dates occurring since 2000. Source: Minnesota Department of Natural Resources.

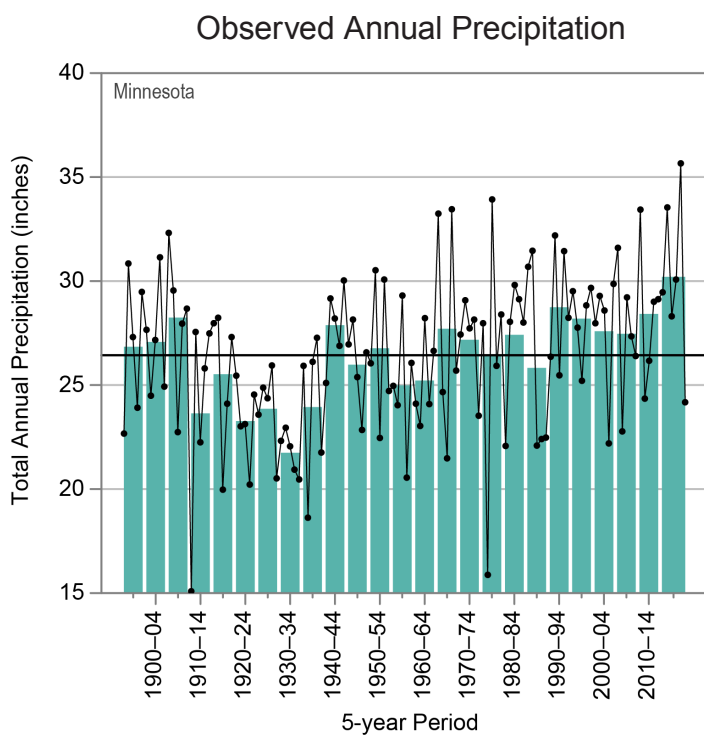
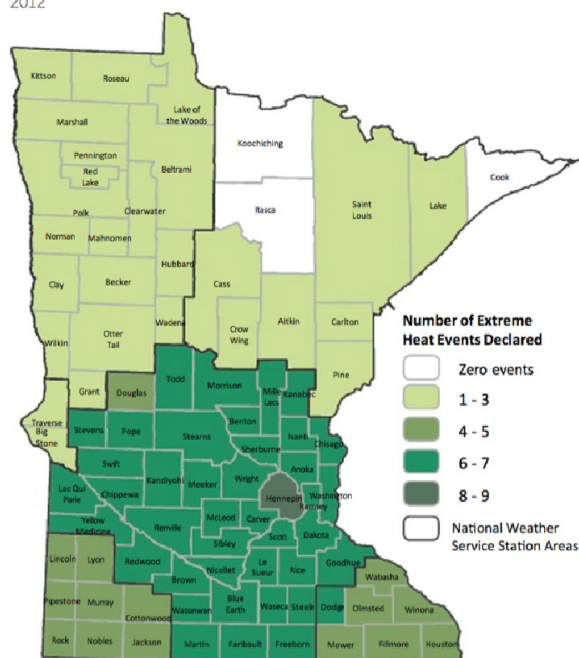


Figure 4: Observed total annual precipitation for Minnesota from 1895 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 26.4 inches. The driest multiyear periods were in the 1910s through the 1930s, and the wettest were from the 1990s to the present. The driest consecutive 5-year interval was 1932–1936, and the wettest was 2015–2019. Sources: CISESS and NOAA NCEI. Data: nClimDiv.

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. Increases in the number of extremely hot days and decreases in the number of extremely cold days are projected to accompany the overall warming.

Number of Extreme Heat Events by County 1995-2012

FIGURE IV-3: NUMBER OF EXTREME HEAT EVENTS BY COUNTY 1995-2012



Data source: NOAA National Climatic Data Center (NCDC, 2013).

Figure 5: Total number of extreme heat events by county for Minnesota from 1995 to 2012. Excessive heat events occurred more frequently in counties located in central and southern Minnesota. Source: Minnesota Climate Change Vulnerability Assessment. Data: NCEI Storm Events Database. Used with permission of Minnesota Department of Health.

Annual average precipitation is projected to increase, with increases most likely occurring in winter and spring (Figure 6). Minnesota is part of a large area of the Northern Hemisphere in the higher mid-latitudes projected to see increases. Increases in intense rainfall are also expected. Despite these increases in precipitation, it is possible that future droughts will be more intense because of higher temperatures, which will increase the rate of soil moisture loss. In 2007, 24 counties in Minnesota received federal drought designations, while 7 counties were declared flood disasters. And in 2012, 55 counties received drought designations, while 11 counties were declared flood emergencies. Recent events demonstrate the likelihood of simultaneous increases in both flooding and drought severity within the state.

Projected Change in Spring Precipitation

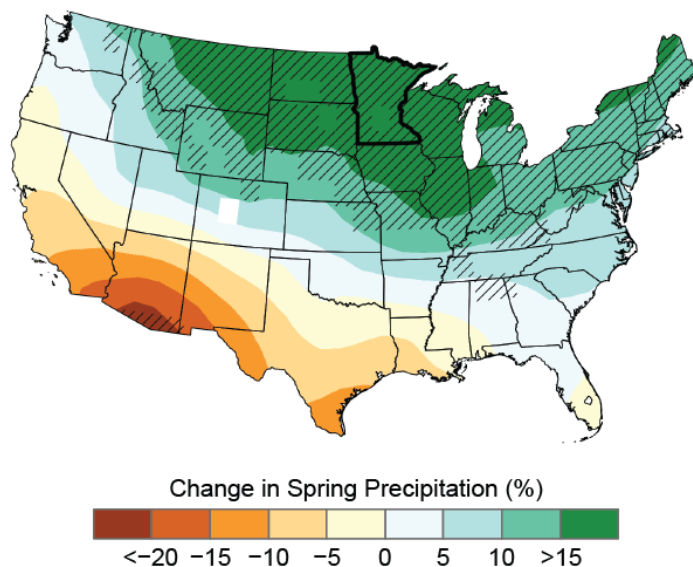


Figure 6: Projected changes in total spring (March–May) precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. The white-out area indicates that the climate models are uncertain about the direction of change. Hatching represents areas where the majority of climate models indicate a statistically significant change. Minnesota is part of a large area of projected increases across the northern United States. Sources: CIESSE and NEMAC. Data: CMIP5.

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