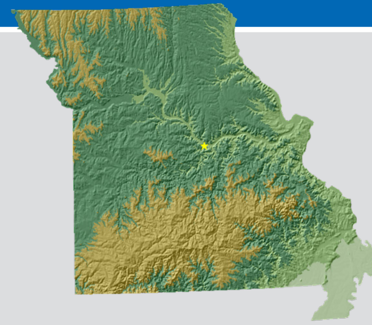


MISSOURI

Key Messages

Temperatures in Missouri have risen almost 1°F since the beginning of the 20th century. Winter warming is reflected in a below average occurrence of very cold nights since 1990. Under a higher emissions pathway, historically unprecedented warming is projected during this century.

Missouri has experienced an increase in extreme precipitation events, a trend that is projected to continue. Future increases in winter precipitation will pose a continued risk of spring planting delays and increased flooding along rivers and streams.

Severe drought, a natural part of Missouri's climate, is a risk to this agriculture-dependent state. Future increases in evaporation rates due to higher temperatures may increase the intensity of naturally occurring droughts.

Missouri's location in the interior of North America and the lack of mountain barriers to the north and south expose the state to incursions of cold arctic air masses in the winter and warm, moist air masses from the Gulf of Mexico in the summer. Annual average temperatures across the state vary by about 10°F from north to south. The hottest year on record was 2012, with an annual average temperature of 58.5°F, which is 3.9°F higher than the long-term (1895–2020) average.

Since the beginning of the 20th century, temperatures in Missouri have risen almost 1°F (Figure 1), **and temperatures in the 2000s have been higher than in any other historical period with the exception of comparable temperatures in the early 1930s Dust Bowl era**. This warming has been concentrated in the winter and spring. Summer temperatures have recently been slightly above the long-term average but below levels experienced during the 1930s, a feature characteristic of much of the Midwest (Figure 2a). Due to extreme drought and poor land management practices, the summers of the 1930s remain the warmest on record. Recent summer temperatures have been characterized by much higher nighttime minimum temperatures (slightly above Dust Bowl levels; Figure 2c), while daytime maximum temperatures have been near the long-term average (Figure 2b). The

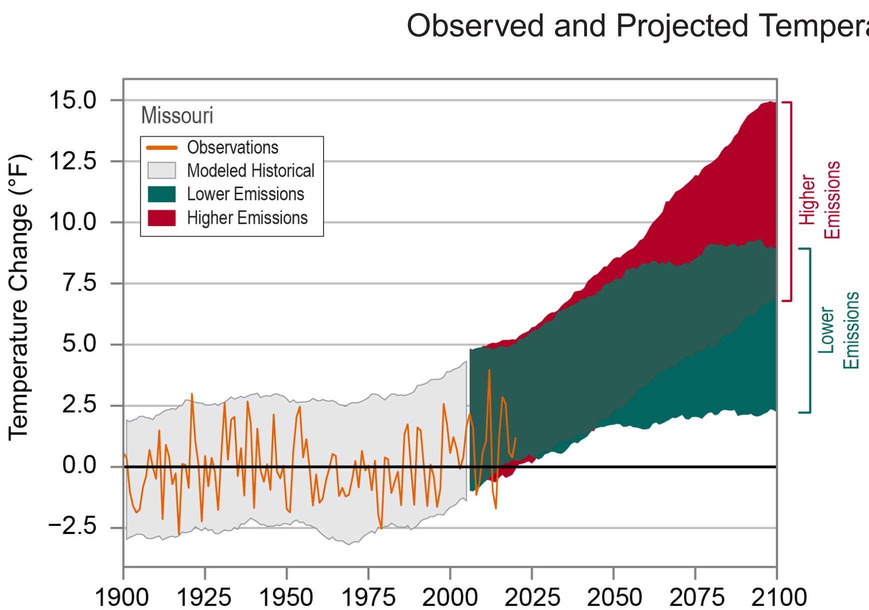
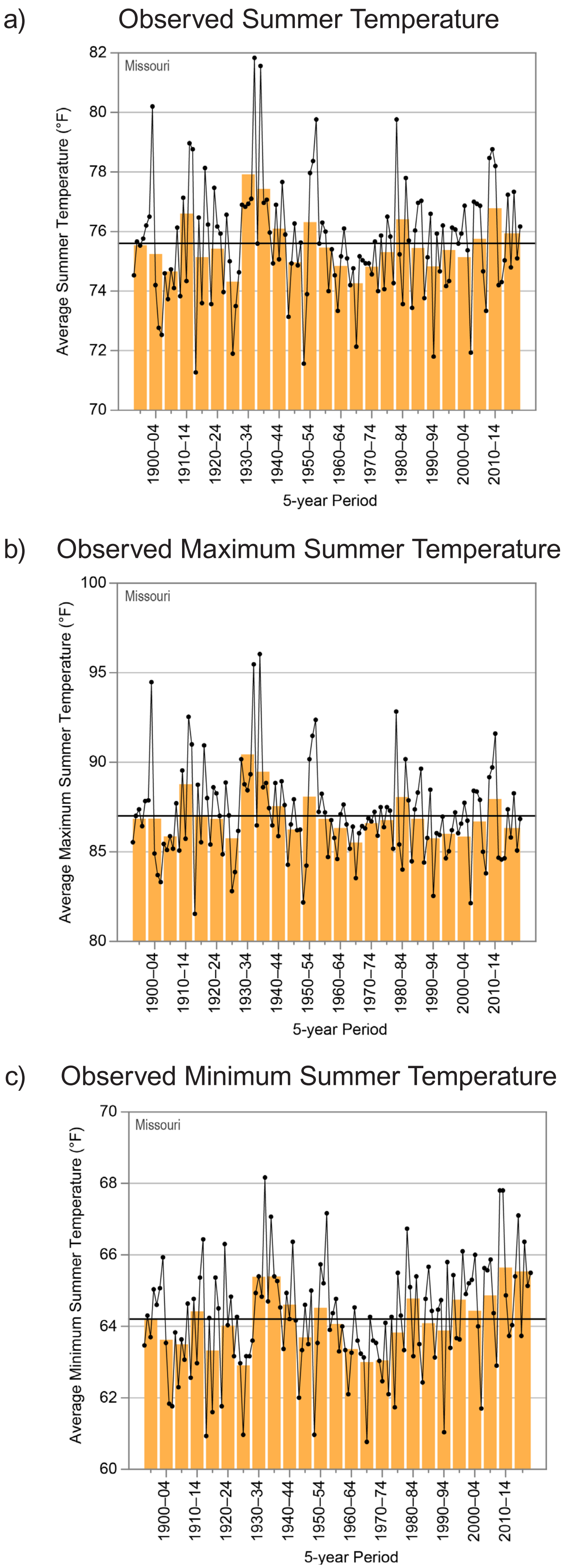


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Missouri. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Missouri (orange line) have risen almost 1°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 11°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.



state has also experienced a below average number of extremely hot days (Figure 3a). In addition to the overall trend of higher average temperatures, the state has seen an above average number of very warm nights (Figure 4). At St. Louis Lambert International Airport, the number of very warm nights has increased from 13 per year during 1961–1990 to 20 per year during 1991–2020. There is also an upward trend in summer humidity since the mid-20th century. The winter warming trend is reflected in a below average number of very cold nights since 1990 (Figure 3b).

Annual average precipitation varies widely across the state, from a low of 35 inches in the northwest to a high of 55 inches in the southeast. The northern part of the state receives more snowfall, with an annual average of more than 20 inches compared to less than 5 inches in the south. Statewide, total annual precipitation has ranged from a low of 25.1 inches in 1953 to a high of 57.1 inches in 1973. The driest consecutive 5-year interval was 1952–1956, and the wettest was 2007–2011 (Figure 3c). Summer precipitation exhibits no overall trend (Figure 3d). For large portions of the state, more than 40% of the total annual precipitation occurs on the 10 wettest days of the year.

Because agriculture is an important sector of Missouri's economy, **the state is particularly vulnerable to extreme precipitation conditions**. Both floods and droughts can result in billions of dollars in losses. In 2012, a severe drought across the Midwest had large impacts on Missouri. Rainfall for the critical growth period of May–July totaled only 5.8 inches, several inches below average, resulting in the third-driest growth period (after 1901 and 1936) in 126 years of record keeping. The drought was the worst Missouri had seen in 30 years. By the end of July, all 114 counties had been declared disaster areas.

Figure 2: Observed (a) summer (June–August) average temperature, (b) summer average maximum temperature, and (c) summer average minimum temperature for Missouri 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 lines show the long-term (entire period) averages: (a) 75.6°F, (b) 87.0, (c) 64.2°F. Missouri experienced its highest summertime temperatures during the extreme heat of the 1930s Dust Bowl era. Since 2010, summer temperatures have been above average because average nighttime lows have been the highest on record, even higher than the 1930s. Sources: CISESS and NOAA NCEI. Data: nClimDiv.

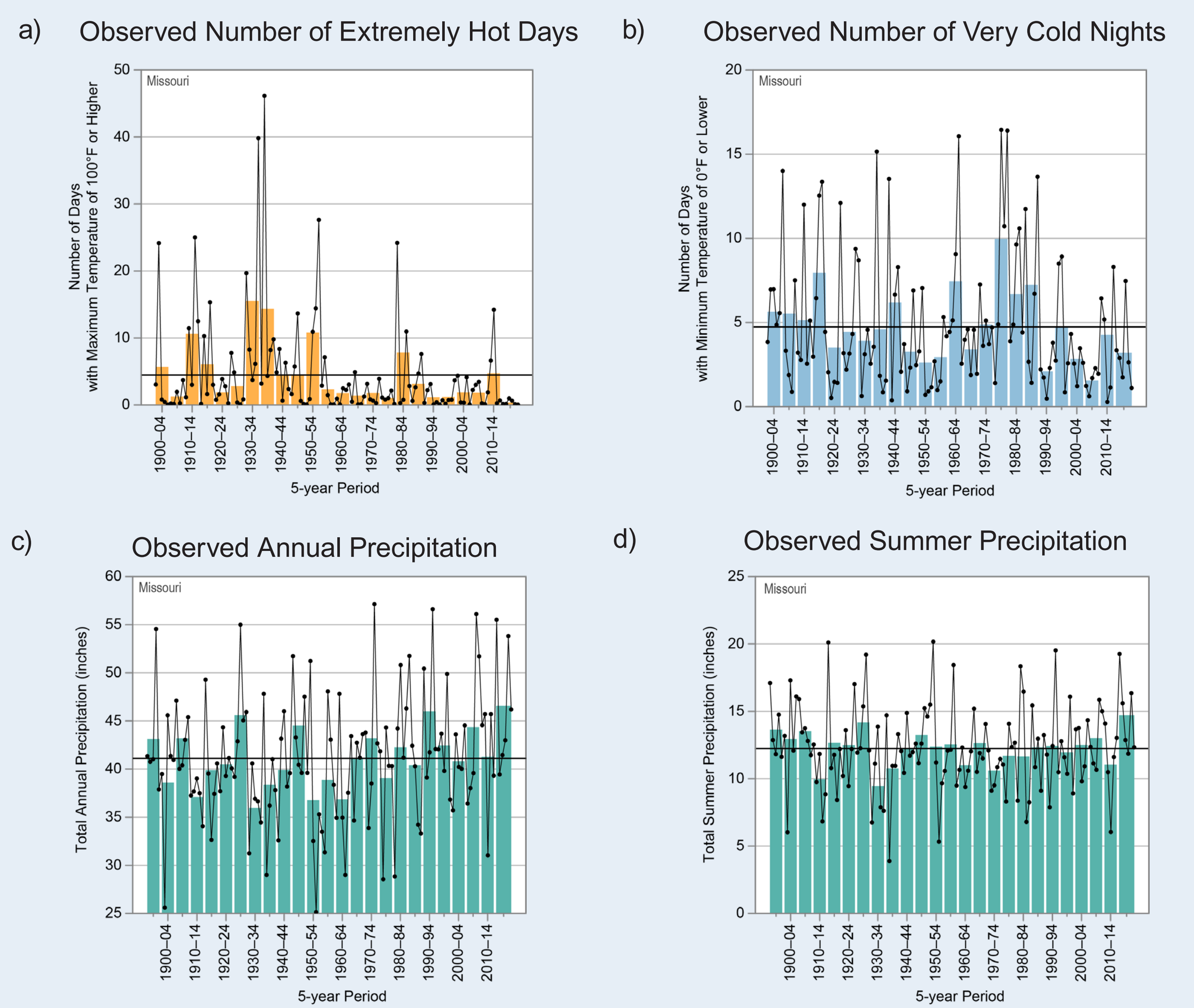


Figure 3: Observed (a) annual number of extremely hot days (maximum temperature of 100°F or higher), (b) annual number of very cold nights (minimum temperature of 0°F or lower), (c) total annual precipitation, and (d) total summer (June–August) precipitation for Missouri from (a, b) 1900 to 2020 and (c, d) 1895 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) 4.5 days, (b) 4.7 nights, (c) 41.0 inches, (d) 12.2 inches. The number of extremely hot days and very cold nights has been mostly below average since 1990. Due to extreme drought and poor land management practices, the summers of the 1930s remain the warmest on record. Annual precipitation has been generally above average since 1990, while summer precipitation has been variable, with no extended periods of above or below average levels. The driest consecutive 5-year interval was 1952–1956, and the wettest was 2007–2011. Sources: CISESS and NOAA NCEI. Data: (a, b) GHCN-Daily from 19 long-term stations; (c, d) nClimDiv.

Missouri has experienced an increase in the number of extreme precipitation events (Figure 5), **and the state's position in the lower river basins of several large midwestern rivers makes downstream flooding an extreme hazard**. Missouri ranked fourth in state losses due to flooding during 1955–1997. One of the most severe climate events in the state's history was the 1993 Mississippi River flood. Near St. Louis, the Mississippi River crested at 49.6 feet, almost 20 feet above flood stage and 6 feet higher than the previous peak in April 1973. The flooding resulted in billions of dollars in damages to homes, businesses, agriculture, and infrastructure. In 2011, the state experienced flooding along both the Mississippi and Missouri Rivers. A wet April along the Ohio River valley and record snowmelt in the upper Mississippi River basin caused record swelling along both the Ohio and Mississippi Rivers. To save the town of Cairo, Illinois, a levee was destroyed near Birds Point, flooding hundreds of thousands of acres of Missouri farmland. Property and crop damages

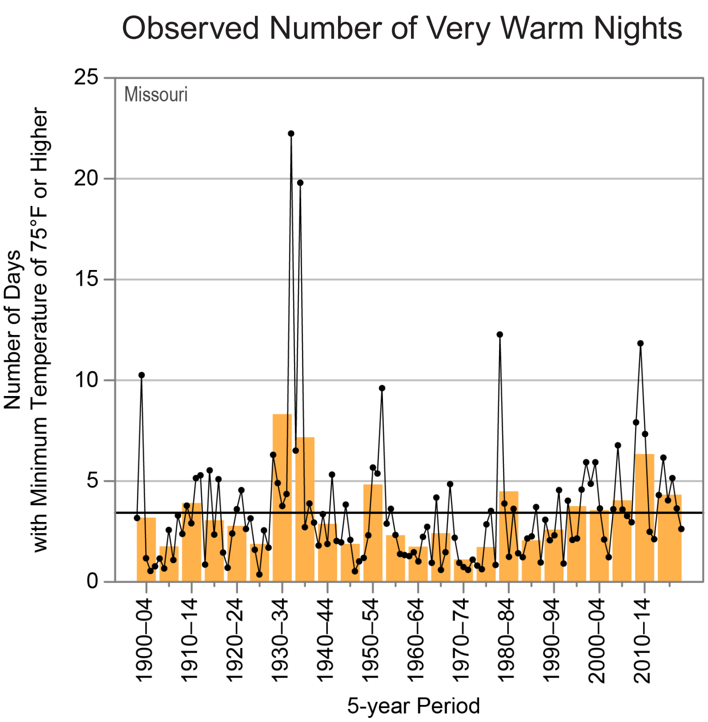


Figure 4: Observed annual number of very warm nights (minimum temperature of 75°F or higher) for Missouri from 1900 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 3.4 nights. During the 1930s, Missouri experienced a high frequency of very warm nights. This was followed by a cool period during the 1960s and 1970s. The 2010–2014 period had the highest number of very warm nights since the extreme heat of the 1930s. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 19 long-term stations.

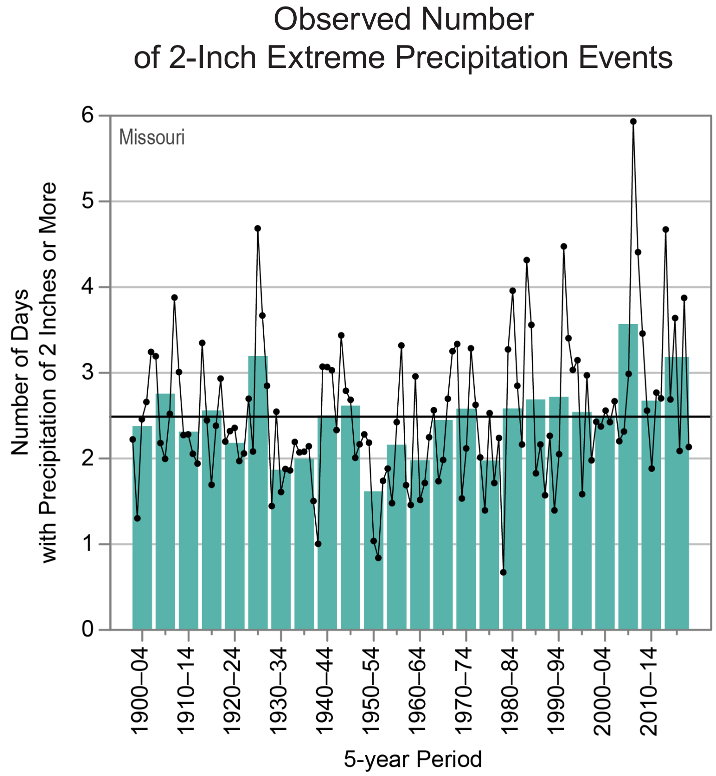


Figure 5: Observed annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more) for Missouri from 1900 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 2.5 days. A typical reporting station experiences 2 to 3 events per year. Since 2005, Missouri has experienced an above average number of 2-inch extreme precipitation events, with the highest number occurring during the 2005–2009 period, when a typical station experienced 3 to 4 events per year. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 25 long-term stations.

were estimated to be more than $300 million. In June of that year, runoff from a record winter snowpack in the northern Rockies, combined with heavy rains, caused major flooding along the entire length of the Missouri River. In mid-March 2019, a major storm and associated snowmelt resulted in historic Midwest flooding, the worst since 1993, inundating millions of acres of farmland and numerous cities and towns and causing widespread damage to roads, bridges, levees, and dams. Additional persistent, heavy rainfall pushed rivers to similar levels in early June 2019.

Severe thunderstorms are common in Missouri. During the summer, the state's lack of geographic barriers allows cold, dry air from the north to collide with warm, moist air from the Gulf of Mexico, triggering severe thunderstorms that can produce high winds, heavy rain, tornadoes, and hail. On April 10, 2001, a strong thunderstorm produced catastrophic hail damage across the I-70 corridor. The storm produced hail as large as 3 inches in diameter, and damages in the Kansas City and St. Louis areas were estimated at more than $1 billion. **Missouri has a long and deadly history of tornadic storms**. On May 22, 2011, an EF5 tornado with winds exceeding 200 mph hit the city of Joplin, killing more than 150 people and causing billions of dollars in damages. This was the deadliest tornado in Missouri history. On March 18, 1925, the Tri-State Tornado, the deadliest tornado in U.S. history, tracked more than 200 miles from southeastern Missouri, across southern Illinois, and into Indiana. In Missouri, the storm killed at least 11 people and caused extensive property damage, including the near complete destruction of the town of Annapolis.

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. In southern Missouri, the annual number of consecutive days with temperatures exceeding 95°F is projected to increase by up to 20 days. Temperature increases will cause future heat waves to be more intense, a concern for this region, which already experiences hot and humid conditions. Extreme heat is a particular concern for urban areas, such as St. Louis and Kansas City, where the urban heat island effect raises summer temperatures. During July 9–14, 1966, St. Louis experienced a severe heat wave that caused many deaths. In addition to daytime highs between 101°F and 106°F at St. Louis Lambert International Airport, nighttime temperatures never dropped below 77°F, and on July 12, the low was only 84°F. If the warming trend continues, future heat waves are likely to be more intense, and cold wave intensity is projected to decrease.

Although projections of overall annual precipitation are uncertain, winter and spring precipitation is projected to increase (Figure 6), while summer precipitation may decrease. Additionally, the frequency and intensity of extreme precipitation events are projected to increase, potentially increasing the frequency and intensity of floods. Springtime flooding in particular could pose a threat to Missouri's important agricultural economy by delaying planting and resulting in yield losses.

The intensity of droughts is projected to increase. Even if precipitation increases in the future, rising temperatures will increase evaporation rates, resulting in more rapid loss of soil moisture. Thus, future summer droughts, a natural part of Missouri's climate, are likely to become more intense.

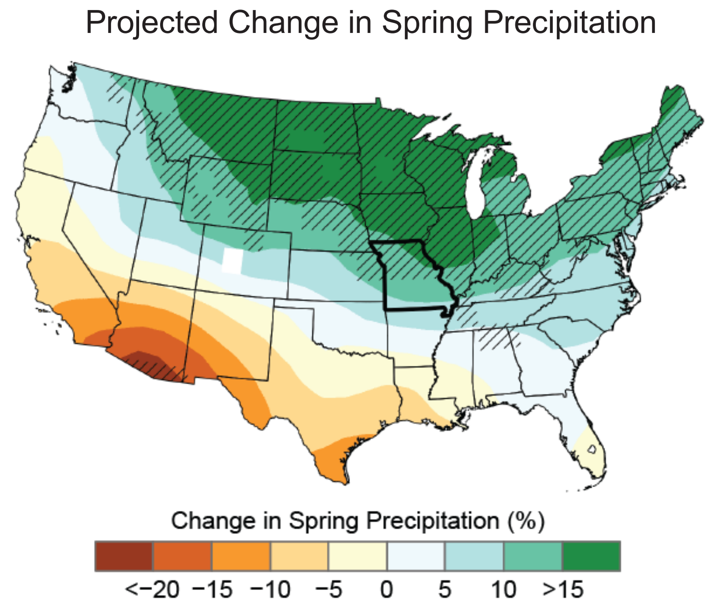


Figure 6: Projected changes in total spring (March–May) precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. The whited-out area indicates that the climate models are uncertain about the direction of change. Hatching represents areas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