PLAINTIFFS' EXHIBIT

P222

MONTANA

Key Messages

Temperatures in Montana have risen almost 2.5°F since the beginning of the 20th century, higher than the warming for the contiguous United States as a whole. This increase is most evident in winter warming, characterized by fewer very cold days since 1990. Under a higher emissions pathway, historically unprecedented warming is projected during this century.

Montana's mountains and river systems provide critical water resources for the state, as well as other downstream states. Projected increases in spring precipitation may have both positive (increased water supplies) and negative (increased flooding) impacts.

Higher temperatures, and possible decreased summer precipitation, will increase the rate of soil moisture loss during dry spells, leading to an increase in the intensity of naturally occurring droughts. The frequency and severity of wildfires are projected to increase in Montana.

Montana, the fourth largest U.S. state in land area, has large climatic variations due to its geographic diversity and altitudinal range. The central and eastern portions of the state are part of the Northern Great Plains, which experience warm summers and cold winters. The western part of the state is mountainous, with snowy winters and cool summers. Elevations across the state range from about 1,800 to 12,800 feet, leading to large variations in temperature. Average (1991–2020 normals) January temperatures at valley and plains locations range from less than 12°F in the northeast to greater than 25°F in some south-central and far western portions of the state, while average July temperatures range from less than 64°F in the western mountains to greater than 72°F in the southeastern plains.

Temperatures in Montana have risen almost 2.5°F since the beginning of the 20th century, higher than the warming for the contiguous United States as a whole. The first 21 years of this century represent the warmest period on record for Montana (Figure 1). Temperatures have warmed in all seasons and in most areas of the state.

Observed and Projected Temperature Change

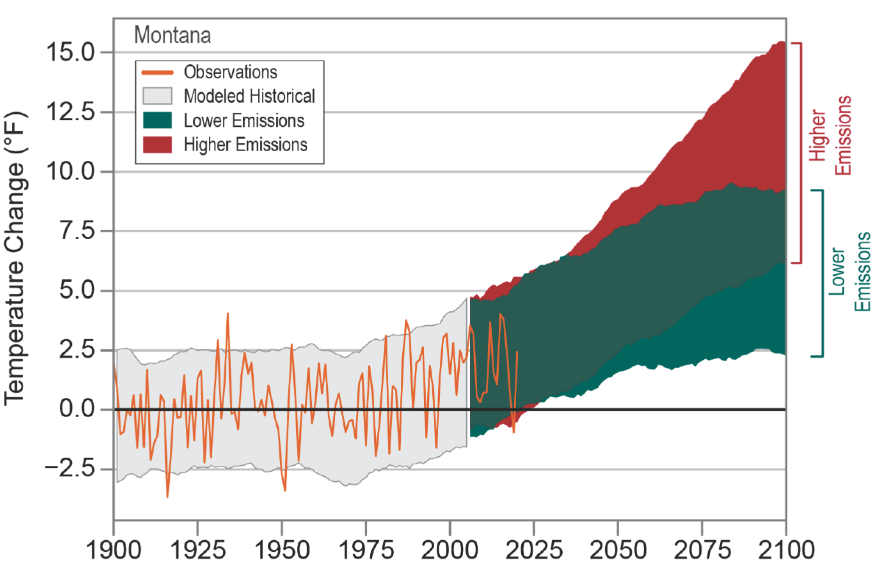

Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Montana. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Montana (orange line) have risen almost 2.5°F since the beginning of the 20th century, higher than the warming for the contiguous United States as a whole. 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.

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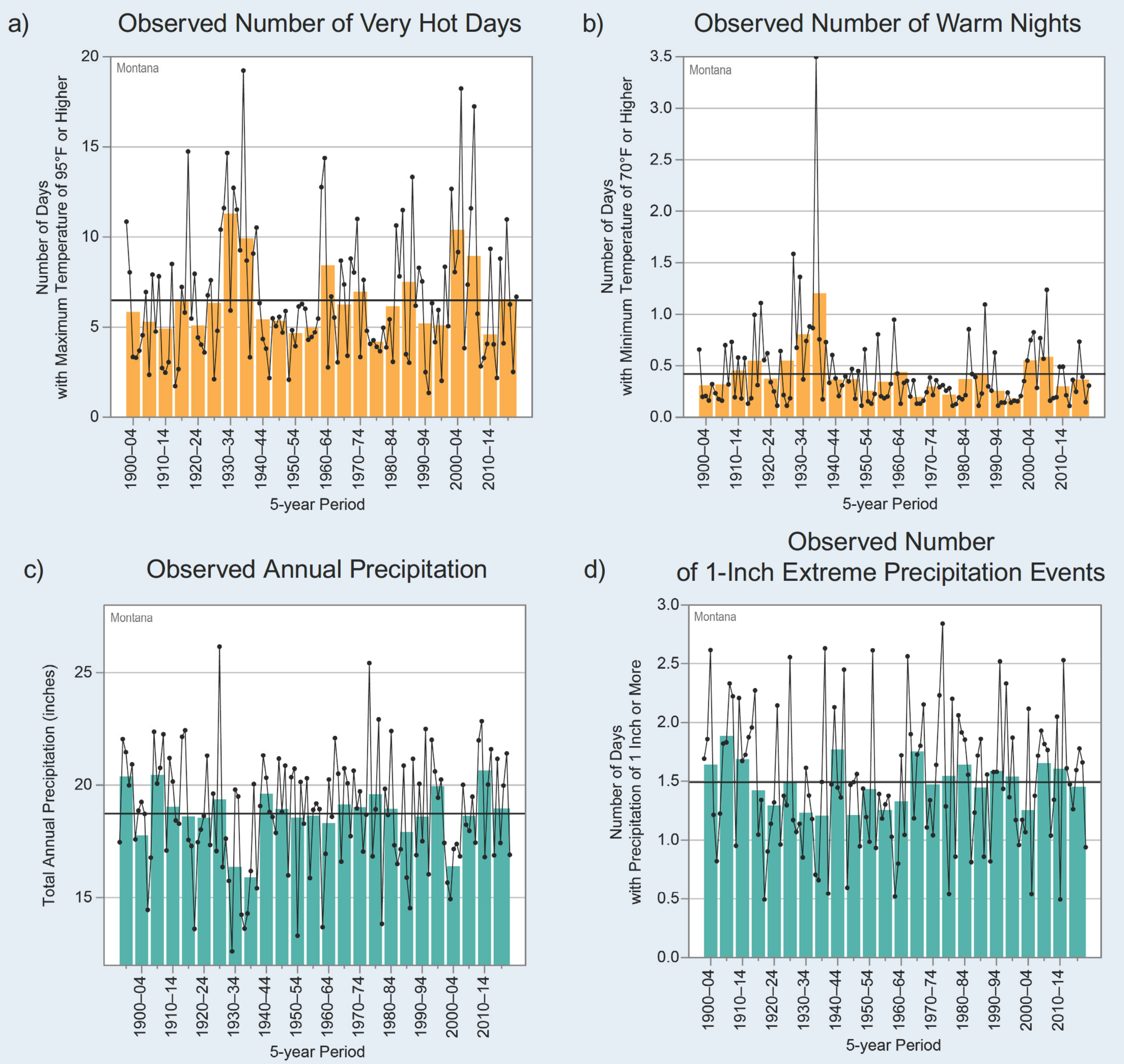

Figure 2: Observed (a) annual number of very hot days (maximum temperature of 95°F or higher), (b) annual number of warm nights (minimum temperature of 70°F or higher), (c) total annual precipitation, and (d) annual number of 1-inch extreme precipitation (days with precipitation of 1 inch or more) for Montana from (a, b, d) 1900 to 2020 and (c) 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) 6.5 days, (b) 0.4 nights, (c) 18.7 inches, (d) 1.5 days. (Note that for Figures 2a, 2b, and 2d, the average for individual reporting stations varies greatly because of the state's large elevation range.) The highest number of very hot days and warm nights occurred during the 1930s and early 2000s. Annual precipitation varies widely and shows no overall trend. The number of 1-inch extreme precipitation events has generally been near average since 1970; a typical station experiences 1 to 2 events per year. Sources: CISESS and NOAA NCEI. Data: (a, b) GHCN-Daily from 16 long-term stations; (c) nClimDiv; (d) GHCN-Daily from 20 long-term stations.

During 2000–2007, the state experienced its highest number of very hot days since the extreme summer heat of the 1930s Dust Bowl era (Figure 2a). With an annual average temperature of 44.9°F (3.6°F above the long-term [1895–2020] average), 2015 tied with 1934 for the hottest year on record. Montana rarely experiences warm nights due to its dry air and high average elevation. The number of warm nights during the 2000s averaged about 50% higher than during the 1940s through the 1990s; the highest values on record occurred during the Dust Bowl era (Figure 2b). In addition to the overall trend of higher average

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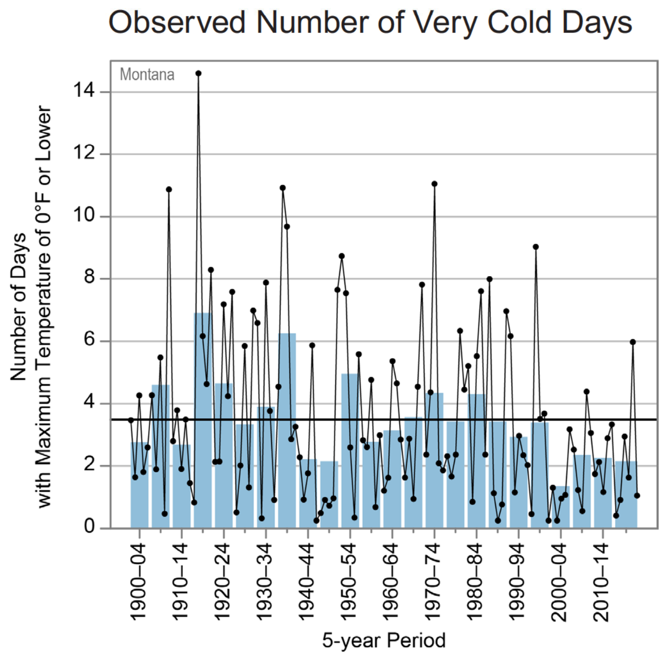

Figure 3: Observed annual number of very cold days (maximum temperature of 0°F or lower) for Montana from 1900–2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 3.5 days (note that the average for individual reporting stations varies greatly because of the state's large elevation range). The number of very cold days has been below average since 2000, indicative of winter warming in the state. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 16 long-term stations.

temperatures, the state has experienced a below average number of very cold days since 1985 (Figure 3). Additionally, the rise in winter and summer average temperatures has been quite pronounced (Figures 4a and 4b).

Montana's topographic variability causes large regional variations in precipitation, with annual totals ranging from less than 7 inches in lowland and valley locations across the southern portion of the state to more than 35 inches in the mountainous northwest. Some of the higher mountain locations can receive much more, with late-season snow depths averaging more than 40 inches of water content (Figure 5). Most of the state's precipitation falls during the summer months, although some areas in the mountains experience a peak during the winter and spring months due to abundant snowfall induced by airflow over the mountains. Statewide average precipitation has varied from a low of 12.6 inches in 1931 to a high of 26.2 inches in 1927. The wettest multiyear periods were in the late 1890s, early 1910s, and early 2010s, and the driest were in the 1930s and the early 2000s (Figure 2c). The wettest consecutive 5-year interval was 2010–2014, with an annual average of 20.7 inches, and the driest was 1933–1937, with an annual average of 15.6 inches. Annual snowfall varies across the state, with some areas in the mountains receiving more than 300 inches. The number of 1-inch extreme precipitation events has generally been near average since 1970 (Figure 2d).

During the summer months, the state experiences frequent thunderstorms, which can produce hail, lightning, and strong winds. Tornadoes are infrequent and occur almost entirely in the eastern third of the state. Montana's northern location and lack of mountain barriers to the north makes it highly susceptible to the impacts of winter storm systems, including heavy snows, high winds, and low wind chill temperatures. Blizzards are most common in the northeastern part of the state, occurring about five times per year. The eastern part of the state can experience bitterly cold temperatures, occasionally lower than −30°F. The state's record low of −70°F, observed at Rogers Pass (1954), is the lowest of the contiguous 48 states. Alternatively, the state is prone to summer hot spells, with an all-time high temperature of 117°F, observed at Medicine Lake and Glendive (1937 and 1893, respectively). This record bests those of more obvious states, such as Florida, and is a result of the dry air and downslope winds in the lower elevations of the eastern plains.

Chinook winds—warm and dry winds common along the eastern slopes of the Rocky Mountains—are a hazard to Montana during the winter months and often bring large temperature increases. Over January 14–15, 1972, chinook winds caused the temperature in Loma to increase from −54°F to 49°F (a 103°F change), the largest 24-hour temperature change in U.S. history. Although these winds can bring pleasant warmer temperatures during the winter months, they can be accompanied by strong gusts and dangerous crosswinds, resulting in property damage and quickly melting snow cover, even in mid-winter.

Because Montana serves as a major water source for other states, changes in precipitation can have broad impacts beyond its boundaries. Water from the state's rivers flows into the Atlantic Ocean via the Gulf of Mexico (Missouri River system), the Arctic Ocean via Hudson Bay (Belly, Saint Mary, and Waterton Rivers), and the Pacific Ocean (Columbia River system), making Montana one of

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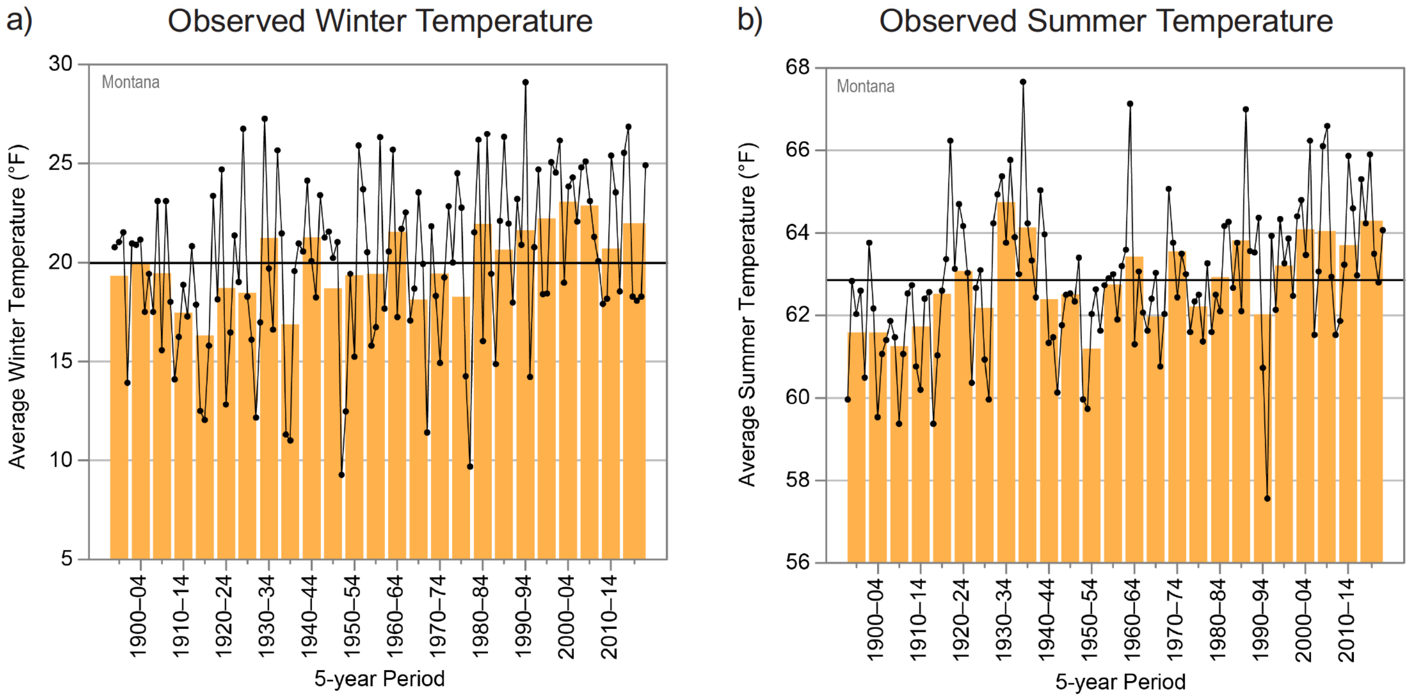

Figure 4: Observed (a) winter (December–February) and (b) summer (June–August) average temperature for Montana from (a) 1895–96 to 2019–20 and (b) 1895 to 2020. Dots show annual values. Bars show averages over 5-year periods (first bar in Figure 4a is a 4-winter average, last bar in Figures 4a and 4b is a 6-winter and 6-summer average, respectively). The horizontal black lines show the long-term (entire period) averages of (a) 20.0°F and (b) 62.9°F. Since 1980, Montana has experienced above average winter temperatures. Since 1995, summer temperatures have been above average but have not surpassed the record high of the 1930 to 1934 period. Sources: CISESS and NOAA NCEI. Data: nClimDiv.

the few regions globally whose waters feed three oceans. Streamflow in these rivers relies on meltwater from the snowpack in the late spring and summer.

Extreme precipitation events during the spring thaw can cause severe flooding. In 1964, a cool spring delayed melting of the snowpack. From June 8 to 9, heavy rains fell on the above average snowpack, with some areas receiving more than 10 inches in 36 hours. This was one of the worst flash floods in the state's history, causing at least 28 deaths and damages of more than $50 million. In 2011, heavy spring rains, along with an extremely heavy snowpack, caused significant flooding across the state. Multiple stations reported more than 10 inches of rain during the month of May, making it the second-wettest May in Montana's history, with many rivers hitting record levels. Below normal temperatures in the area caused pieces of floating ice to accumulate in some streams and rivers, leading to ice jams that obstructed streamflow and resulted in additional flooding. By mid-June, 31 of the state's 56 counties and 4 of the state's 7 reservations were declared disaster areas. Total damages across the state were estimated at more than $50 million. Ice jam flooding can also occur during rapid spring warming.

As an agriculturally dependent state, Montana is particularly vulnerable to drought. The Dust Bowl is by far the most famous drought of the past 100 years, but recent severe droughts are also noteworthy. In 2012, the state experienced the driest July–September period in the historical record, dating back to 1895. By October 2012, much of the southern half of the state was in severe drought. The drought provided ideal conditions for wildfires and resulted in more than 2,000 fires burning more than 1.2 million acres. Warmer temperatures are increasing the risk of flash droughts, such as a severe event that occurred during the 2017 summer.

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 the 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 heat wave intensity are projected, but the intensity of cold waves is projected to decrease. **Projected rising temperatures**

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will also raise the snow line—the average lowest elevation at which snow falls. This will increase the likelihood that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at those lower mountain elevations that are now on the margins of reliable snowpack accumulation. **Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water availability during the summer months**.

Although projections of overall annual precipitation are uncertain, winter and spring precipitation is projected to increase (Figure 6). Rising temperatures will affect snowmelt patterns, shifting runoff to earlier in the year. Heavy spring precipitation could increase the potential for flooding. Increased spring precipitation can have both positive and negative impacts on Montana's agricultural economy, improving soil moisture but potentially delaying planting and resulting in yield losses. Changes in snowmelt patterns could also affect other water-reliant industries, such as mining and tourism.

The intensity of future droughts is projected to increase. Even if overall precipitation increases, rising temperatures will increase the rate of soil moisture loss during dry spells. In addition, while fall, winter, and spring precipitation is projected to increase, a majority of climate models project summer decreases. Thus, summer droughts are likely to become more intense, potentially leading to increases in the frequency and severity of wildfires.

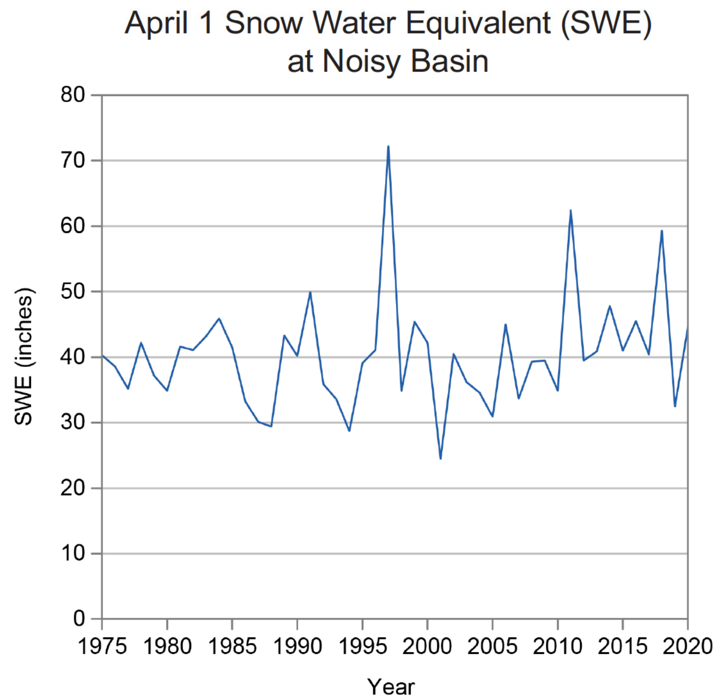

Figure 5: Variations in the April 1 snow water equivalent (SWE) at the Noisy Basin, Montana, SNOTEL site from 1975 to 2020. SWE, the amount of water contained within the snowpack, varies widely from year to year. In 2011, the April 1 snowpack reached the greatest depths since 1997. Melting of this snowpack led to severe flooding across the Northern Great Plains in the summer of 2011. Source: NRCS NWCC.

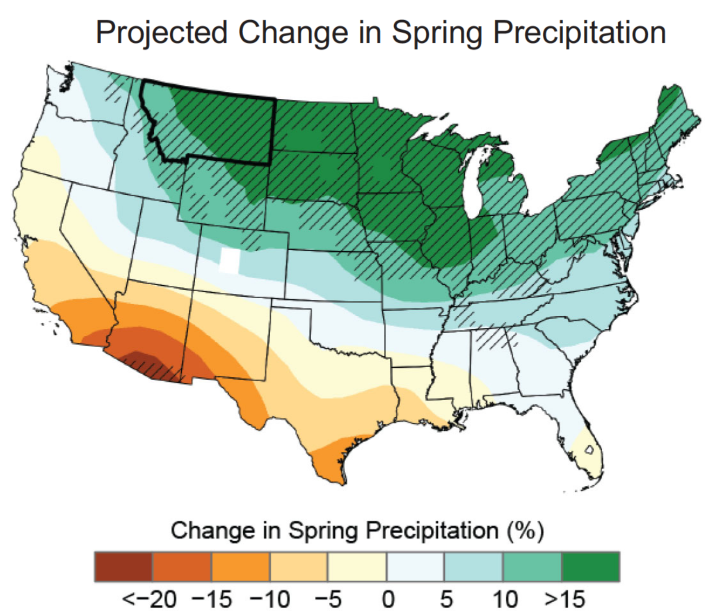

Figure 6: Projected changes in total spring (March–May) precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. The whited-out area indicates that the climate models are uncertain about the direction of change. Hatching represents areas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

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

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