yield. **Heavy precipitation events are also projected to increase**, leading to increased runoff and flooding which can reduce water quality and erode soils.

The intensity of droughts is projected to increase. Droughts are a natural part of the climate system and because precipitation increases are projected to occur during the cooler months, North Dakota will remain vulnerable to periodic drought. Higher temperatures will increase the rate of depletion of soil moisture during dry conditions in the warm season, leading to more serious conditions during future droughts. Mid-summer through early fall wildfires may also become more common.

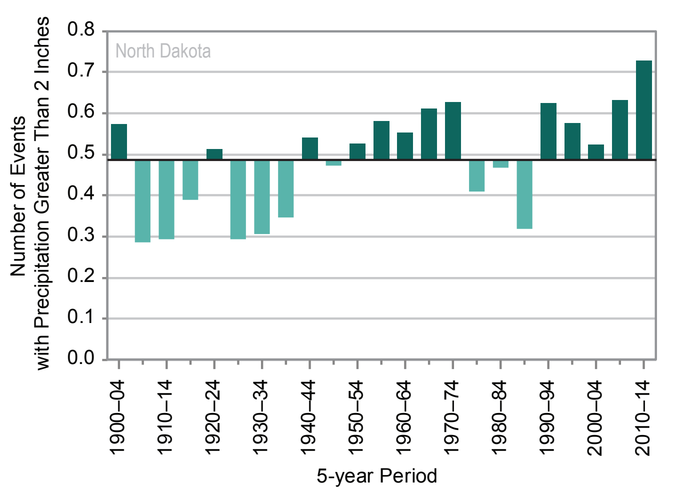


Figure 6: The observed number of extreme precipitation events (annual number of days with precipitation greater than 2 inches) for 1900–2014, averaged over 5-year periods; these values are averages from 11 long-term reporting stations. In an average year, 50% of stations will experience a day with 2 inches or more of precipitation. Since 1990, North Dakota has experienced an above average number of extreme rain events. Source: CICS-NC and NOAA NCEI.

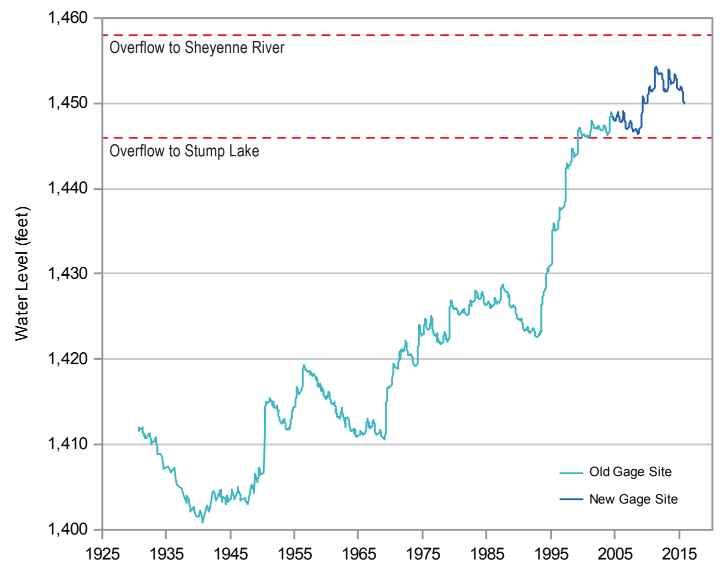


Figure 7: Time series of the water level of Devils Lake at Creel Bay. Lake levels have fluctuated over time, but have been steadily rising overall since the 1940s. Water began spilling from Devils Lake to Stump Lake in 1999, and in 2007 Devils Lake and Stump Lake essentially became one continuous body of water. If lake levels continue to rise, an uncontrolled natural spill to the Sheyenne River could occur. Source: USGS.

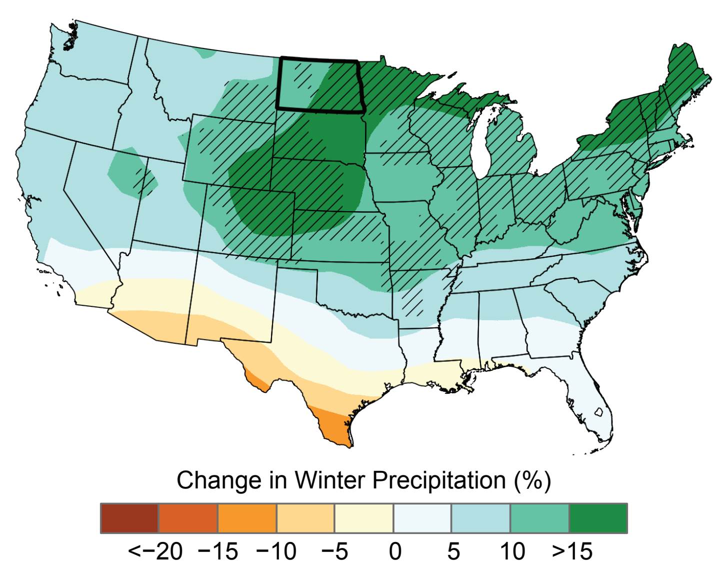
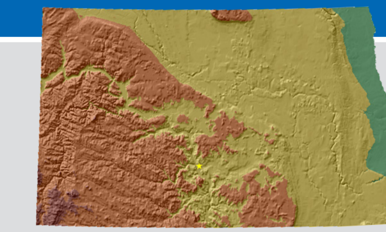


Figure 8: Projected change in winter precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Winter precipitation is projected to increase in the range of 10%–20% by 2050. Spring precipitation is also projected to increase in North Dakota. North Dakota is part of a large area in the northern and central United States with projected increases. Source: CICS-NC, NOAA NCEI, and NEMAC.

WWW.NCEI.NOAA.GOV | HTTPS://STATESUMMARIES.NCICS.ORG/ND | LEAD AUTHORS: REBEKAH FRANKSON, KENNETH KUNKEL | CONTRIBUTORS: LAURA STEVENS, DAVID EASTERLING, MARTHA SHULSKI, ADNAN AKYUZ



NORTH DAKOTA

Key Messages

North Dakota has experienced one of the largest temperature increases of any contiguous U.S. state, with annual average temperatures increasing at a rate of 0.26°F per decade. This increase is most evident in winter warming, which has been characterized by the much below average occurrence of extremely cold days since 1980. Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century.

Higher temperatures will increase the rate of warm season soil moisture depletion, leading to more serious conditions during future naturally occurring droughts.

Precipitation is projected to increase during the colder part of the year. Heavy precipitation events are also projected to increase.

North Dakota lies in the northern Great Plains, straddling the transition from the moist eastern United States to the semi-arid western United States. Due to its location in the center of the North American continent, the state has a continental climate and experiences wide temperature extremes. Average January temperatures range from 0°F in the northeast to 15°F in the southwest, while average July temperatures range from 65°F in the northeast to 72°F in the south. Temperatures of 100°F or more occur nearly every year and are most prevalent in the drier southwestern and south-central regions. The lack of mountain ranges to the north allows arctic air masses to enter the state frequently during the winter, bringing bitter cold spells.

The 2000s have been one of the warmest periods on record for North Dakota, with several very warm years comparable to the extreme heat of the 1930s Dust Bowl era when extreme drought and poor land management likely exacerbated the hot summer temperatures (Figure 1). Over the last 130 years, North Dakota's annual average temperature has increased 0.26°F per decade, one of the fastest increases of any state in the contiguous United States. This warming has been concentrated in the winter and spring while summers have not warmed substantially in the state, a feature characteristic of much of the Great Plains and Midwest. This is reflected in a below average occurrence of very hot days (days with maximum temperature greater than

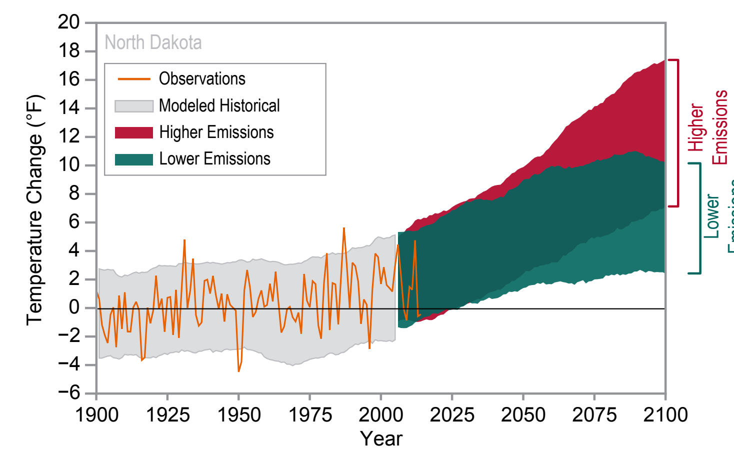


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for North Dakota. Observed data are for 1900–2014. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions)[1]. Temperatures in North Dakota (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 the 21st century. Less warming is expected under a lower emissions future (the coldest years being about 2°F warmer than the long-term average; green shading) and more warming under a higher emissions future (the hottest years being about 11°F warmer than the hottest year in the historical record; red shading). Source: CICS-NC and NOAA NCEI.

[1]Technical details on models and projections are provided in an appendix, available online at: https://statesummaries.ncics.org/nd.

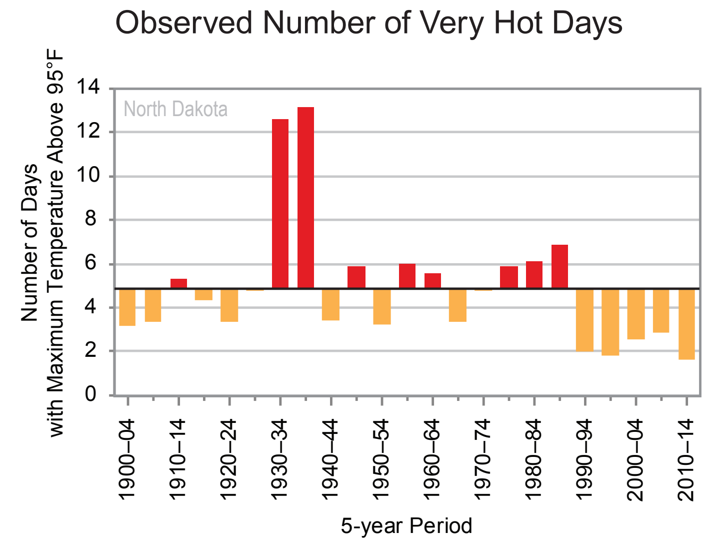


Figure 2: The observed number of very hot days (annual number of days with maximum temperature above 95°F) for 1900–2014, averaged over 5-year periods; these values are averages from 16 long-term reporting stations. The dark horizontal line represents the long-term average. The 1930s were North Dakota's hottest period over the past century. From 1930 to 1939, the number of extremely hot days was more than double the long-term average. Since 1990, however, the number of very hot days has been below the long-term average. Source: CICS-NC and NOAA NCEI.

95°F) in recent years (Figure 2) and no overall trend in warm nights (days with minimum temperature greater than 70°F) since the beginning of the 20th century (Figure 3). The winter warming trend is reflected in a below average number of very cold days (days with maximum temperature less than 0°F) since 2000 (Figure 4). Additionally, over the past 130 years, winter temperatures have increased by 4.4°F per century, more than three times as much as the summer trend of 1.4°F per century during the same time period.

Annual precipitation ranges from less than 14 inches in the northwest to 22 inches in the southeast. Statewide average annual precipitation varies from year to year, ranging from a low of 8.81 inches in 1936 to a high of 23.48 inches in 2010. The wettest multi-year periods were in the early 1940s, 1990s, and 2010s, and the driest in the 1930s. The wettest 5-year period was 2007–2011 and the driest was 1933–1937 (Figure 5). Most of the state's precipitation falls during the summer months when thunderstorm activity is highest. The most severe of these storms can produce hail, tornadoes, or damaging straight-line winds exceeding 75mph. **The frequency of heavy rain events has increased** (Figure 6). Since 1990, the number of such events has been above average, peaking during the most recent 5-year period (2010–2014).

Compared to other northern states, North Dakota receives less snowfall, averaging 25 to 45 inches annually. However, due to the state's northern location, winter storm systems can be accompanied by exceptionally severe conditions, including heavy snows, high winds, and low wind chill temperatures. The probability of a blizzard occurring in any given year is greater than 50% for the state, one of the highest in the nation. During the winter of 1996–1997, North Dakota experienced nine blizzards and four winter storms which produced seasonal snowfalls of over 100 inches in some parts of the state.

The Red River Valley is one of the most flood-prone areas in the United States due to the river's low gradient and northward flow. The spring thaw causes snow and river ice in the south to melt prior to the downstream river channel to the north. This creates natural ice jams, flooding of the upstream river, and backfill of runoff into the river's tributaries. In addition to snowmelt, recharge of soil moisture due to fall precipitation and direct runoff of spring rainfall from saturated soils contribute to spring floods. Based on more than 100 years of river stage data collected in Fargo, the Red River has exceeded major flood stages 16 times. In the spring of 1997, the melting of record snowfall caused record floods along the river; this record was exceeded in the 2009 floods, when the river at Fargo reached the highest level in recorded history. Another flood-prone area in the state is Devils Lake. The rising water of Devils Lake and Stump Lake has destroyed hundreds of homes and businesses and inundated thousands of acres of productive farmland. Since 1993, the state of North Dakota and the U.S. Government has spent more than $450 million in flood-mitigation efforts in the region. If lake levels continue to rise, an uncontrolled natural spill to the Sheyenne River could occur, potentially causing extensive downstream flooding, channel erosion, and water quality degradation (Figure 7).

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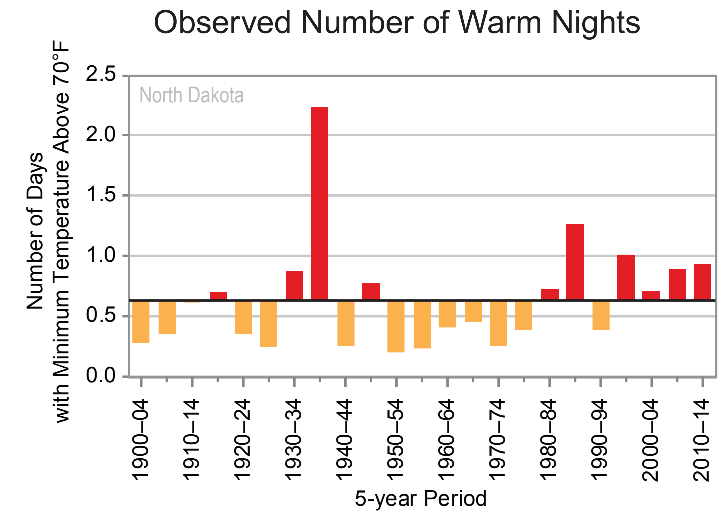

Figure 3: The observed number of warm nights (annual number of days with minimum temperature above 70°F) for 1900–2014, averaged over 5-year periods; these values are averages from 16 long-term reporting stations. The dark horizontal line represents the long-term average. The late 1930s had the highest frequency of warm nights, more than three times the long-term average. Over the past two decades, North Dakota has experienced an above average number of warm nights. Source: CICS-NC and NOAA NCEI.

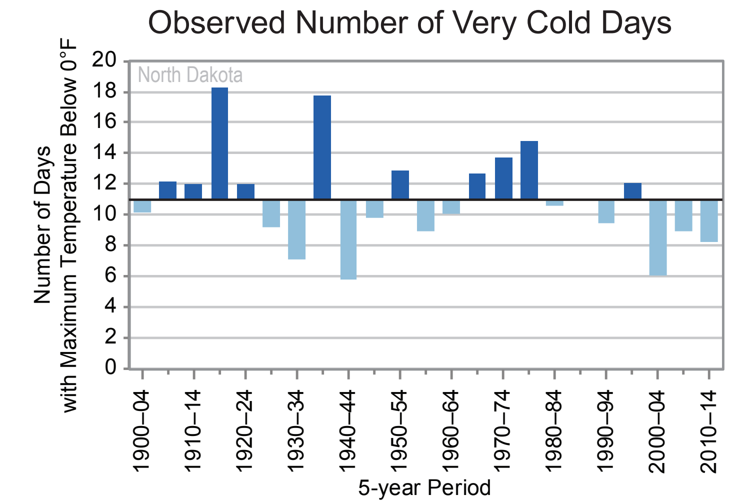

Figure 4: The observed number of very cold days (annual number of days with maximum temperature below 0°F) for 1900–2014, averaged over 5-year periods; these values are averages from 16 long-term reporting stations. The dark horizontal line represents the long-term average. Since 2000, North Dakota has experienced a below normal number of extremely cold days, indicative of overall winter warming in the region. Source: CICS-NC and NOAA NCEI.

Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century (Figure 1). Even under a lower pathway of greenhouse gas emissions, average annual temperatures are projected to most likely exceed historical occurrences by the middle of the 21st century. However, there is a large range of temperature increases under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records (Figure 1). Although there has not been an increase in hot summer temperatures, continued overall warming is expected to eventually lead to an increase in the intensity of heat waves, while cold wave intensity is projected to decrease.

Even though the current observed records do not show a positive trend in cold season precipitation so far, projections suggest that winter precipitation will increase (Figure 8), even under a lower emissions pathway. Increased cold season precipitation can have both positive and negative impacts on North Dakota's agricultural economy, improving soil moisture but potentially delaying planting and resulting in loss of

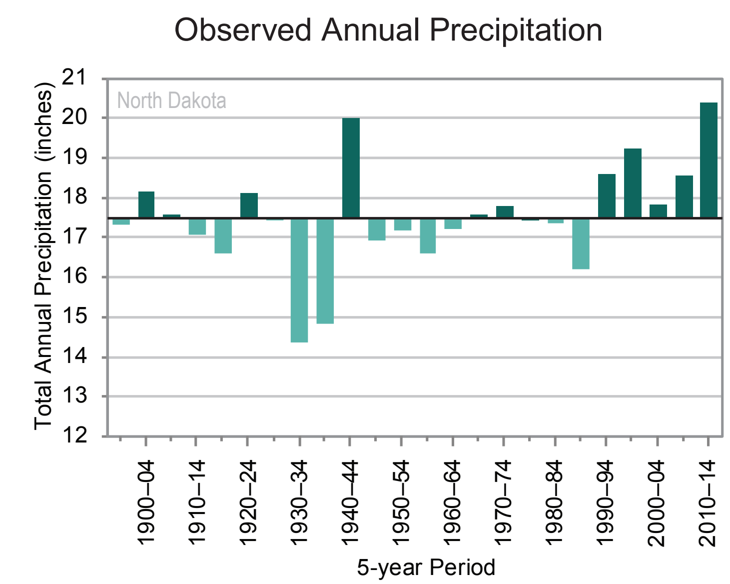

Figure 5: The observed spring and summer precipitation for 1895–2014, averaged over 5-year periods; these values are averages from NCEI's version 2 climate division dataset. The dark horizontal line represents the long-term average. Annual precipitation varies widely, but recent years have seen above average precipitation. The wettest 5-year period on record is 2007–2011, averaging 20.38 inches, while the driest period on record (1933–1937) averaged 14.36 inches. Source: CICS-NC and NOAA NCEI.