

# Understanding and Assessing Climate Change: Preparing for Nebraska's Future

## 2024 Climate Change Impact Assessment Report

### Chapter 4 - Projects of Nebraska's Future Climate





# Chapter 4

## Projections of Nebraska's Future Climate

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### Key messages

1. Significant warming is expected in all parts of Nebraska, in all seasons, through the rest of the century.
2. By 2050, Nebraska's statewide annual temperatures are projected to increase by 5°F to 6°F compared to the 1950–2014 historical period. By the end of the century, these temperatures are projected to increase by 7°F to 11.5°F compared to the historical period.
3. Summer and fall are projected to warm slightly more than winter and spring.
4. By the end of the century, Nebraska's extremely hot days (90°F or higher) will likely increase two to four times compared to the historical period. Extremely warm nights (low temperatures above 70°F) are projected to be over ten times more frequent than during the historical period.
5. Under a high-emission, fossil-fueled development scenario, Nebraska could experience over 50 days per year with a maximum temperature greater than 100°F by the end of the century.
6. Extremely cold temperatures (low temperatures below 0°F) are expected to decrease from around 20 days per year to four to seven days per year.
7. Most climate models project an increase (+10% to +35%) in winter and spring statewide precipitation and a decrease (-10% to -20%) in precipitation for summer months.
8. Very extreme precipitation events will increase in the future, with the most extreme events increasing the most.

# Introduction

Scientists use global climate models to understand how the climate has changed in the past and may change in the future. These models use mathematical equations to simulate how energy and matter interact in the atmosphere, land, and oceans. Modelers must make many choices on how these simulations are produced, including the model's resolution and how small-scale features are represented. This results in an ensemble of global simulations led by modeling groups worldwide. The Coupled Model Intercomparison Project Phase 6 (CMIP6) is the most recent generation of these simulations, which produces output for past, present, and future periods (Eyring et al., 2020).

These simulations are forced in the historical period (1950–2014) by setting observed changes in greenhouse gas emissions, solar activity, volcanoes, and land use. Future simulations (2015–2100) are forced with projections of greenhouse gas emissions, which are controlled by population growth, economic development, energy use, and technologies for efficiency and sources of energy. In CMIP6, these scenarios for future greenhouse gas emissions are referred to as shared socioeconomic pathways (SSP)

(O'Neill et al., 2014). The moderate emissions scenario (SSP2-4.5) pictures a world where socioeconomic factors follow the path of their historical trends and carbon dioxide emissions decline by mid-century. The high emissions scenario (SSP5-8.5) is a “business as usual” pathway that doubles carbon dioxide emissions by 2050 with fossil fuel and energy-driven lifestyles.

The output from global climate models provides useful estimates of future climate change. However, these simulations are typically run at resolutions from 100 to 250 km (about 60 to 150 miles), which is too coarse to provide useful regional information or to force agricultural and hydrological models. These impact models require information at much higher spatial resolutions (1 to 25 km or about 0.5 to 16 miles), so global climate model output is typically downscaled through dynamical and statistical methods. In this section of the assessment, we use the statistically downscaled climate projections from LOCA (Localized Constructed Analogs) version 2 developed by Pierce et al. (2023), which is applied to 23 CMIP6 models and produces daily maximum and minimum temperatures and precipitation at 6 km resolution.

## Temperature projections

Simulations reproduce the observed increase in annual temperature across Nebraska for the historical period (Figure 4.1). By mid-century, both emission scenarios suggest that the average temperature in Nebraska will increase by about 5°F to 6°F compared to the historical period. However, by the end of the century, the high emissions scenario produced an average of 11.5°F of warming from the historical period, around four additional degrees of warming compared to the moderate emissions scenario. This highlights the importance of reducing greenhouse emissions, allowing us to avoid the largest amounts of warming and the worst impacts of climate change.

The highest annual temperature in Nebraska's history was 52.7°F, which occurred in 1934 at the beginning of the Dust Bowl. These projections suggest that by the end of the century, the statewide average temperature

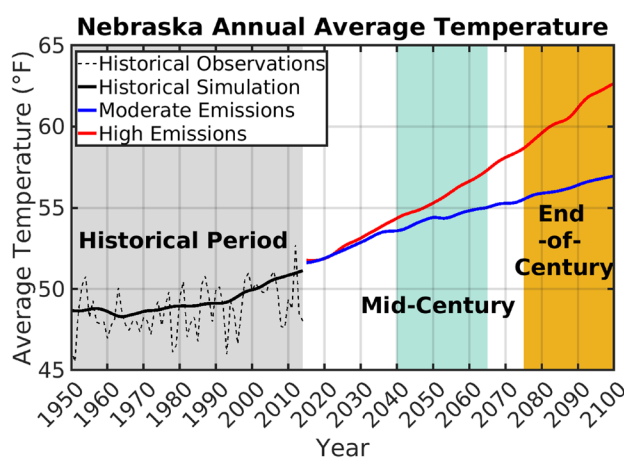


Figure 4.1. Annual temperatures averaged across Nebraska for the historical period (black lines) and two emissions scenarios: moderate emissions (blue line) and high emissions (red line).

will be 3°F to 7°F warmer than this extreme period in Nebraska's history. During the historical period, the average temperature of Oklahoma was approximately 60°F, which will be comparable to the average temperature of Nebraska by the end of the century

under the high emissions scenario (NOAA NCEI, 2024a).

Nebraska will warm across all seasons in the coming century (Figures 4.2, 4.3, 4.4, and 4.5). Warming is projected to be uniform across the state, with

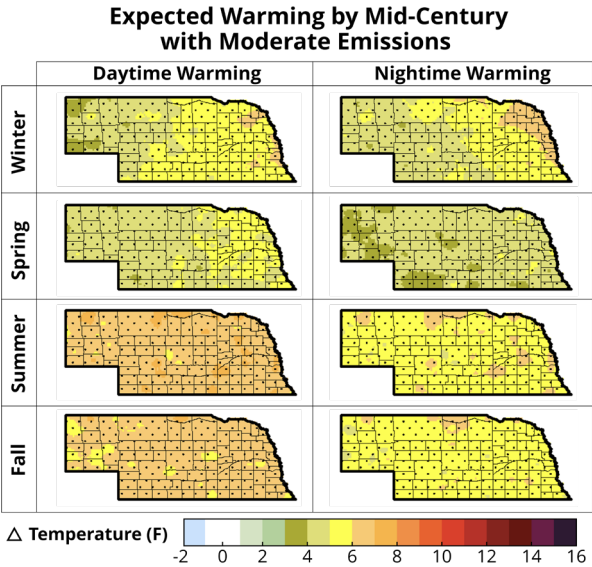


Figure 4.2. These maps show the expected warming by the middle of the century compared with the historical period for the moderate emissions scenario. Stippling indicates regions where 80% of the downscaled models agree on the direction of temperature change.

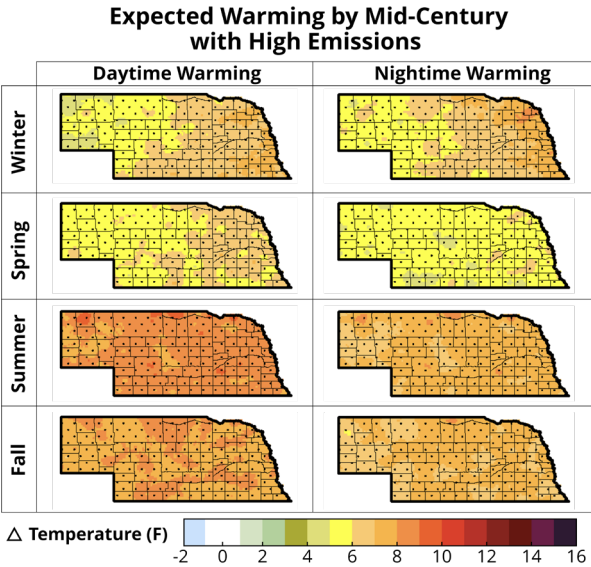


Figure 4.3. These maps show the expected warming by the middle of the century compared with the historical period for the high emissions scenario. Stippling indicates regions where 80% of the downscaled models agree on the direction of temperature change.

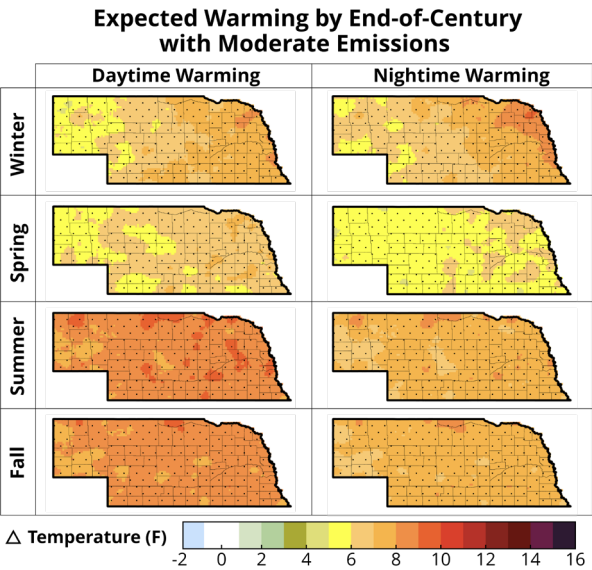


Figure 4.4. These maps show the expected warming by the end of the century compared with the historical period for the moderate emissions scenario. Stippling indicates regions where 80% of the downscaled models agree on the direction of temperature change.

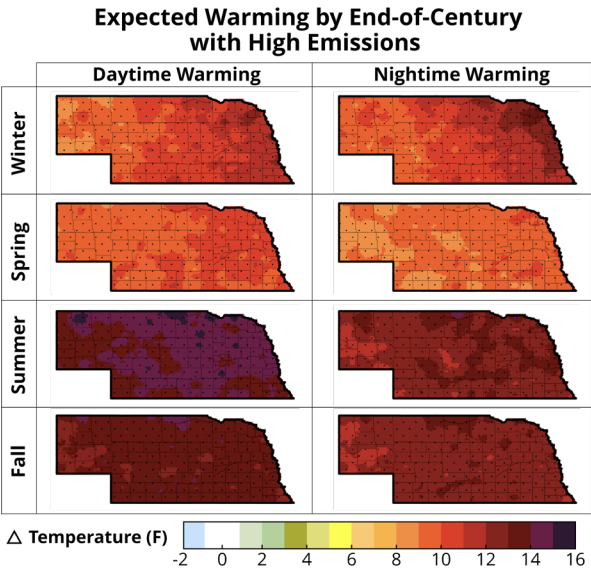


Figure 4.5. These maps show the expected warming by the end of the century compared with the historical period for the high emissions scenario. Stippling indicates regions where 80% of the downscaled models agree on the direction of temperature change.



a slightly increased warming toward the east. Summer and fall are the seasons with the largest amount of warming. During spring and summer, daytime temperatures increase more than nighttime, but the opposite is seen in fall and winter.

These changes in average temperature will increase the magnitude and frequency of extreme weather events. By the end of the century, Nebraska could experience two to four times more days over 90°F than in the historical period. Days with temperatures above 100°F were observed on average less than 10 days per year across Nebraska during the historical period. Under the high emissions scenario, Nebraska could experience over 50 days per year with these extremely high daytime temperatures by the end of the century (Figure 4.6).

Extreme nighttime temperatures are also expected to change, especially toward the southeastern part of the state (Figure 4.7). During the historical period,

most of the state experienced less than five days per year with temperatures that did not fall below 70°F. This is projected to increase to a statewide average of 60 days per year with minimum temperatures above 70°F, with the southeastern part of the state experiencing around 100 days per year with these extremely warm nighttime temperatures by the end of the century. Cool nighttime temperatures are critical for agriculture and human health, so this increase in both emissions scenarios is highly important.

Extremely cold winter temperatures are important for controlling pest populations. During the historical period, Nebraska observed around 20 days per year with a minimum temperature below 0°F. By the end of the century, under the moderate emissions scenario, these extremely cold days decreased to approximately seven days per year, with an average of four days per year occurring during the high emissions scenario (Figure 4.7).

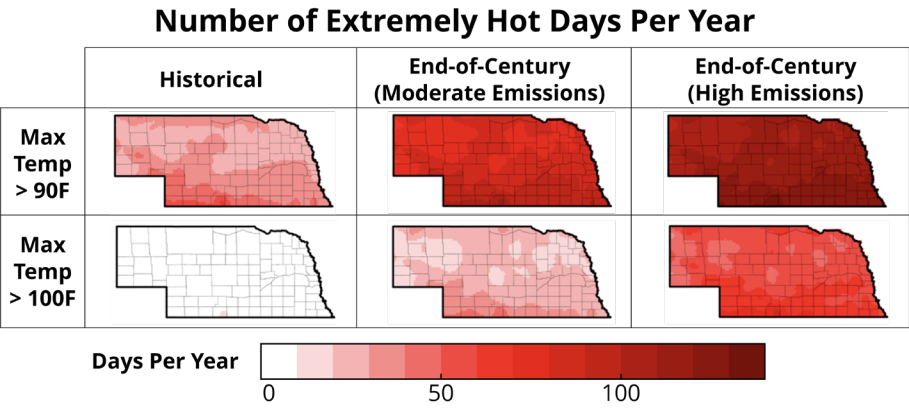


Figure 4.6. The number of extremely hot days is projected to increase under both emissions scenarios.

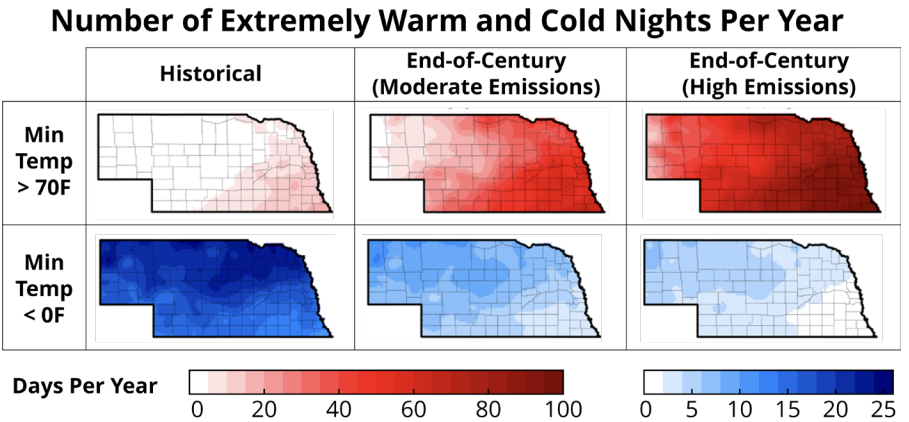


Figure 4.7. The number of extremely warm nights per year (top) is projected to increase, and the number of extremely cold nights per year (bottom) is projected to decrease under both emissions scenarios.

# Precipitation projections

The projections of annual precipitation change in Nebraska are more uncertain than those of temperature change. Global climate models consistently project that the northernmost U.S. states will see overall higher annual precipitation in the future and that the Southwest and Mexico will see lower annual precipitation in the future (Figure 4.8). Since Nebraska is in the transition zone between these regions, projecting the annual change in precipitation is difficult. The downscaled precipitation allows us to see more robust signals across different seasons. Nebraska is projected to have a robust increase in precipitation during winter and spring and experience a decrease in precipitation during the summer months by the middle of the century (Figure 4.9) and the end of the century (Figure 4.10). The magnitude of these patterns is much larger in the high emissions scenario than in the moderate emissions scenario.

Extreme precipitation events are projected to increase significantly (Figure 4.11), including flooding and runoff. These events will likely remain most common in the state's southeastern part. The most extreme events (for example, days with more than four inches of precipitation) are projected to increase in frequency more than less extreme events.

The number of days between precipitation events is also projected to increase across the state (Figure 4.12). The maximum number of consecutive dry days per year (one indicator of drought) may increase by 5% to 10% by the end of the century, especially across the eastern part of the state. The increase in extreme precipitation combined with longer dry spells has important implications for flash drought and flooding events.

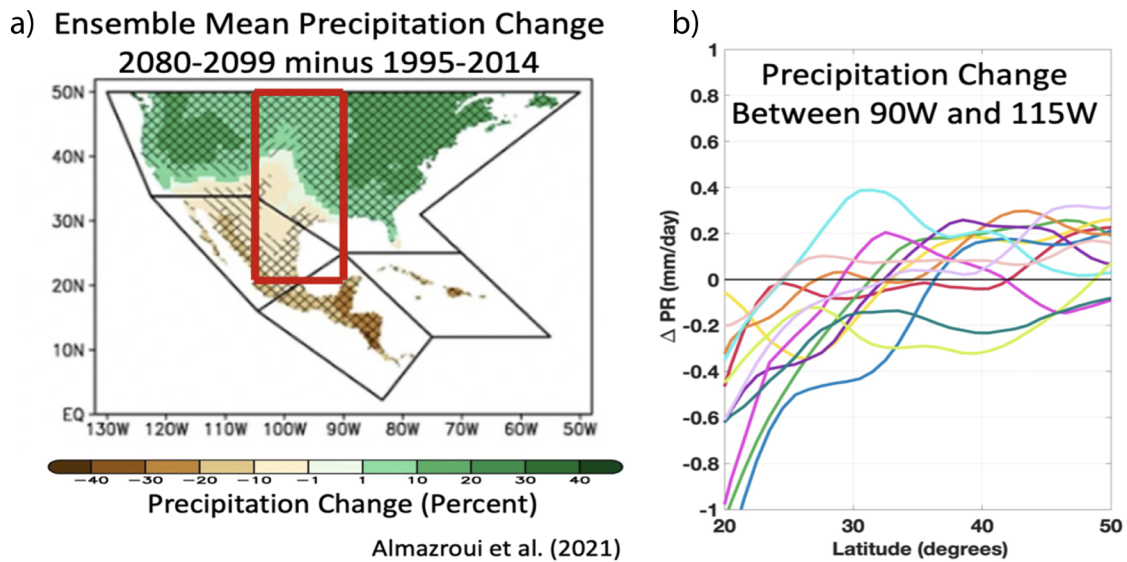


Figure 4.8. (a) The spatial distribution of changes in annual mean precipitation (%) for the end of the century under the high emissions scenario (left) in an ensemble of CMIP6 models. The backslash and forward slash indicate the grid boxes showing significant and robust changes, respectively, while hatching represents the grid boxes having both significant and robust changes (Source: Almazroui, 2021). (b) The precipitation change, averaged in the east-west direction between 90W and 115W (red box), for a selection of CMIP6 models (right) shows model uncertainty in the transition between the drying south and wetting north.



## Expected Precipitation Change by Mid-Century

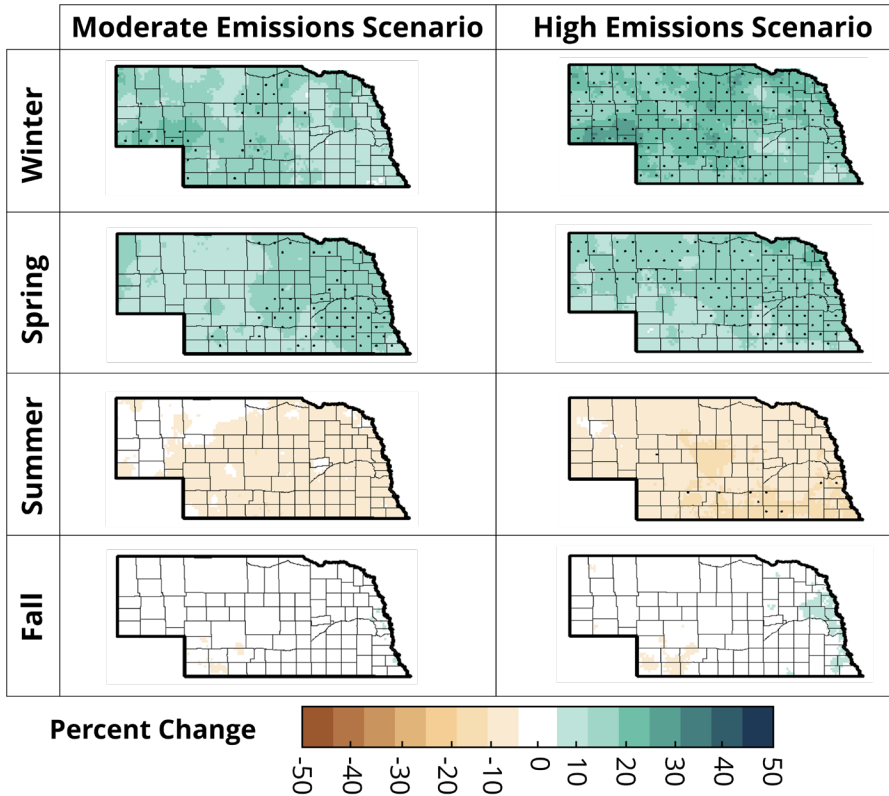


Figure 4.9. These maps show the expected change in precipitation by the end of the century compared with the historical period for the moderate (left) and high (right) emissions scenarios. Stippling indicates regions where 80% of the downscaled models agree on the direction of precipitation change.

## Expected Precipitation Change by End-of-Century

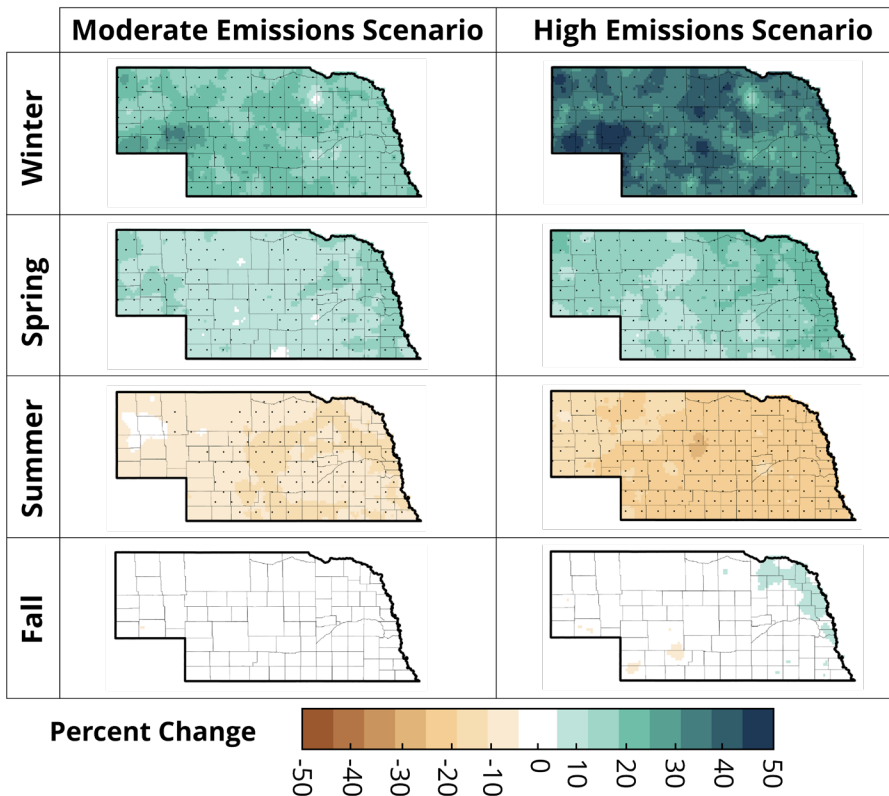


Figure 4.10. These maps show the expected change in precipitation by the end of the century compared with the historical period for the moderate (left) and high (right) emissions scenarios. Stippling indicates regions where 80% of the downscaled models agree on the direction of precipitation change.

## Expected Frequency of Extreme Precipitation

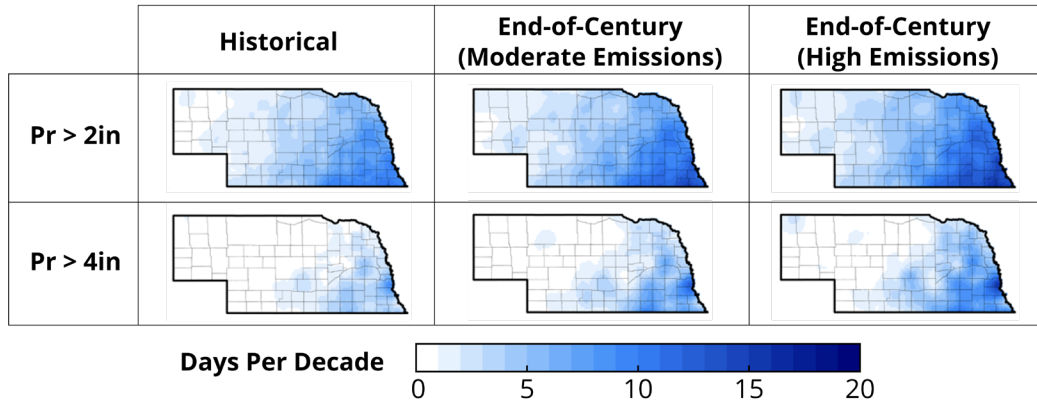


Figure 4.11. The number of days with extreme precipitation is projected to increase under both emissions scenarios.

## Maximum Consecutive Dry Days Per Year

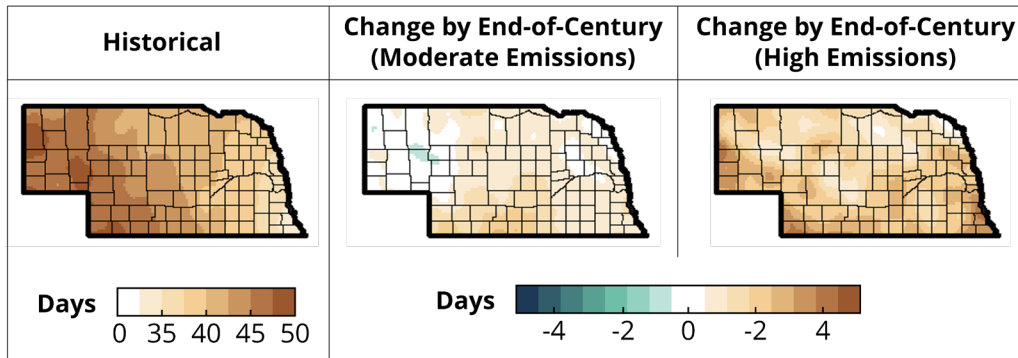


Figure 4.12. The maximum length of consecutive dry days per year is projected to increase under both emissions scenarios.

## Gaps and needs

- » **Decrease carbon emissions.** Every change described in this section is smaller in magnitude in the moderate emissions scenario than in the high emissions scenario. Decreasing greenhouse gas emissions can avoid climate change's most significant changes and impacts.
- » **Increased observations of climate indicators.** Continued investment and extension of instrumentation across the state will allow monitoring of Nebraska's changing climate, provide vital information to better understand key climate processes, and reduce model uncertainty. This can also include opportunities for citizen science monitoring.
- » **Higher-resolution regional climate simulations.** The limitations of statistical downscaling constrain the analysis in this report. For example, daily temperature and precipitation are commonly produced through this methodology, while moisture and winds are not. Producing regional simulations using models that better capture the dynamics of the climate system will allow us to provide more detailed information in our projections that can be used to help make decisions as communities prepare to adapt to changes in Nebraska's climate.