



## Native Climate CMIP6 Agricultural Climate Projections



*Native Climate* is a USDA NIFA-funded project to support climate adaptation efforts in Native American communities by building new connections between Native wisdom and Western scientific data. Through two-way information-sharing and relationship-building, Native Climate aims to make climate data more accessible and useful to Tribes, and to build awareness nationally about climate impacts and resilience on Native lands. The project is led by the Desert Research Institute in partnership with University of Nevada, Reno Tribal Extension, the Montana Climate Office at the University of Montana, University of Arizona Tribal Extension, and the USDA Climate Hubs. The project team includes Tribal natural resource managers, agriculture producers, and climate leaders along with 1994 and 1862 Tribal Extension, researchers working in Indian Country, other federal and state climate service organizations, and a group of Native American advisors. *Native Climate* is funded by the U.S. Department of Agriculture, National Institute of Food and Agriculture (USDA NIFA) and builds on the work of the [Native Waters on Arid Lands](#) project (2015–2022).

Native Climate partners at the Montana Climate Office have extracted place-based climate data for Native American, Alaska Native, and Native Hawaiian lands located in the United States. Climate data and projections for temperature, precipitation, and other metrics related to crop, livestock and forestry agriculture are shown in the accompanying graphs. The data derive from eight Coupled Model Intercomparison Project Phase 6 (CMIP6) global climate models and four socioeconomic scenarios for the period from 2015 to 2100, as well as the historical simulation for each model for the period 1950 to 2014. Raw data are extracted for the location of the reservation from the NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) dataset (NEX-GDDP-CMIP6). Further information on the NASA NEX downscaled product, including descriptions of the projected climate variables, can be found at <https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp-cmip6>.

Spatial data on Native lands were derived from the US Census TIGER/Line database, which includes all tribally controlled lands in the United States, as well as Alaska Native Village Statistical Areas (ANVSA) and State Designated Tribal Statistical Areas (SDTSA). We divided the Navajo Nation into its five agencies to better represent climate differences across the Nation. We used the recently defined climate divisions for the State of Hawai‘i ([Luo et al 2024](#)) to represent climate difference on the Hawaiian Islands.

Tabular data for all graphs included here are available in the accompanying Microsoft Excel workbook. We aggregated daily data from each model and scenario into seasonal or annual statistics (the **Annual Projections** worksheet), and then we combined the results from the eight models using a generalized additive model (the **Smoothed Projections** worksheet). We provide raw daily data for each scenario in the **Raw** worksheets.

The CMIP6 data include projections for four scenarios for how global society, demographics and economics might change over the next century, collectively called “Shared Socioeconomic

Pathways” (SSPs). The SSPs offer pathways that the world could take in the future and are used in conjunction with the “Representative Concentration Pathways” (RCPs) for greenhouse gas emissions that were included in previous CMIP projections.

The following scenarios are included in these data:

- SSP1-2.6** This is a best-case scenario. Global CO<sub>2</sub> emissions are cut severely, reaching net-zero after 2050. Societies switch to more sustainable practices, with focus shifting from economic growth to overall well-being. Investments in education and health go up, and inequality falls. Temperatures stabilize around 1.8 °C higher by the end of the century.
- SSP2-4.5** This is a “middle of the road” scenario. CO<sub>2</sub> emissions hover around current levels before starting to fall mid-century, but do not reach net-zero by 2100. Socioeconomic factors follow their historic trends, with no notable shifts. Progress toward sustainability is slow, with development and income growing unevenly. In this scenario, temperatures rise 2.7 °C by the end of the century.
- SSP3-7.0** On this path, emissions and temperatures rise steadily and CO<sub>2</sub> emissions roughly double from current levels by 2100. Countries become more competitive with one another, shifting toward national security and ensuring their own food supplies. By the end of the century, average temperatures have risen by 3.6 °C.
- SSP5-8.5** This can be considered a worst-case scenario. Current CO<sub>2</sub> emissions levels roughly double by 2050. The global economy grows quickly, but this growth is fueled by exploiting fossil fuels and energy-intensive lifestyles. By 2100, the average global temperature is 4.4 °C higher.

**We derived the following agricultural climate variables from the raw data:**

| <b>Variable</b>             | <b>Units</b>    | <b>Description</b>  |
|-----------------------------|-----------------|---|
| Average Temperature         | °F              | Annual average daily temperature  |
| Growing Degree Days         | Fahrenheit GDDs | Heat accumulation (warmth) above 50 °F, in units of Fahrenheit Growing Degree Days. Appropriate for corn agriculture. |
| Frost Free Days             | count           | Number of days per year with minimum daily temperatures greater than 32 °F  |
| Annual Precipitation        | inches          | Total annual precipitation  |
| Annual Frozen Precipitation | inches          | Total annual precipitation on days with a minimum temperature of at most 32 °F  |
| Spring Precipitation        | inches          | March–May total precipitation   |
| Summer Precipitation        | inches          | June–August total precipitation   |
| Fall Precipitation          | inches          | September–November total precipitation  |
| Winter Precipitation        | inches          | December–February total precipitation   |

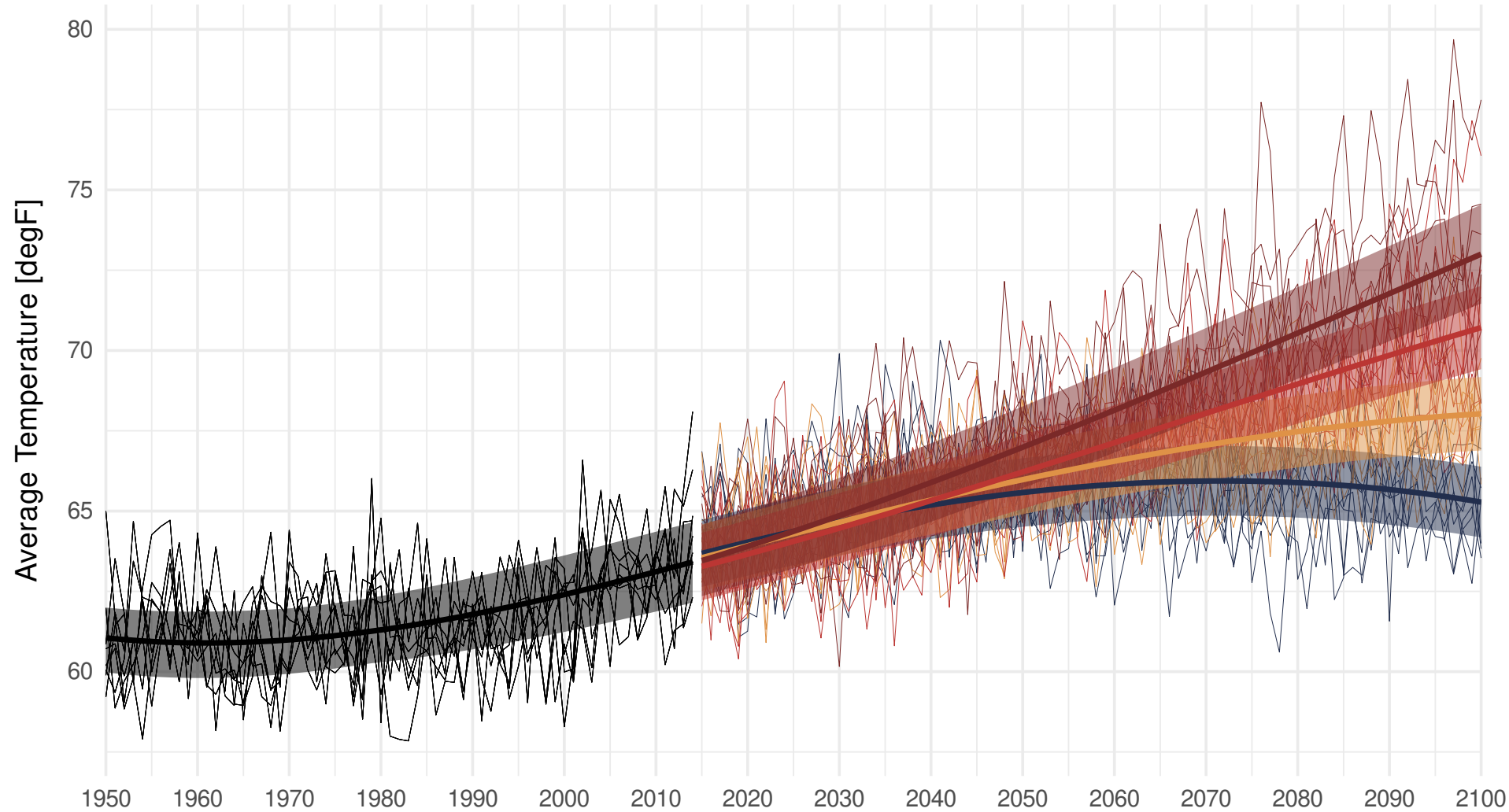
| <b>Variable</b>                           | <b>Units</b>   | <b>Description</b>   |
|---|----------------|--|
| Maximum 3-Day Precipitation               | inches         | Maximum total precipitation over a three-day period each year  |
| Average Precipitation on Wet Days         | inches         | Average daily precipitation on days with precipitation   |
| Average Precipitation on Wet Days (trace) | inches         | Average daily precipitation on days with more than 0.08 inches (2 mm) of precipitation   |
| Number of Wet Days                        | count          | Number of days per year with precipitation   |
| Number of Wet Days (trace)                | count          | Number of days per year with more than 0.08 inches (2 mm) of precipitation   |
| Number of Dry Days                        | count          | Number of days per year with no precipitation  |
| Number of Dry Days (trace)                | count          | Number of days per year with at most 0.08 inches (2 mm) of precipitation   |
| Number of Days $\geq$ 100 °F              | count          | Number of days per year where the daily high temperature is at least 100 °F  |
| Number of Days with Heat Index Hazard     | count          | <p>Number of days per year at each of the National Atmospheric and Oceanographic Organization's (NOAA) heat index hazard levels.</p> <p><i>Caution:</i> fatigue is possible with prolonged exposure and activity; continuing activity could result in heat cramps.</p> <p><i>Extreme caution:</i> heat cramps and heat exhaustion are possible; continuing activity could result in heat stroke.</p> <p><i>Danger:</i> heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.</p> <p><i>Extreme danger:</i> heat stroke is imminent.</p> |
| Average Surface Wind Speed                | miles per hour | Annual average wind speed at ten meters above the ground surface   |
| Normal First Day of Growing Season        | date           | First day of the year, prior to the normal hottest day of the year, having six consecutive days with a normal average daily temperature above 50 °F  |
| Normal Last Day of Growing Season         | date           | First day of the year, following the normal hottest day of the year, having six consecutive days with a normal average daily temperature below 50 °F   |
| Normal Length of Growing Season           | days           | Number of days between the first and last days of the growing season   |
| Day of First Snow                         | date           | First day of the year, following the normal hottest day of the year, with frozen precipitation   |

Please contact **Dr. Kyle Bocinsky, Director of Climate Extension for the Montana Climate Office** with any technical questions about these data: [kyle.bocinsky@umontana.edu](mailto:kyle.bocinsky@umontana.edu). Code for producing all data supplied here is freely available on Github: <https://github.com/native-climate/cmip6-reservations>.

For more information on the Native Climate project, please visit: <https://native-climate.com> or contact Dr. Maureen McCarthy at: [maureen.mccarthy@dri.edu](mailto:maureen.mccarthy@dri.edu)

# Cheyenne and Arapaho OTSA

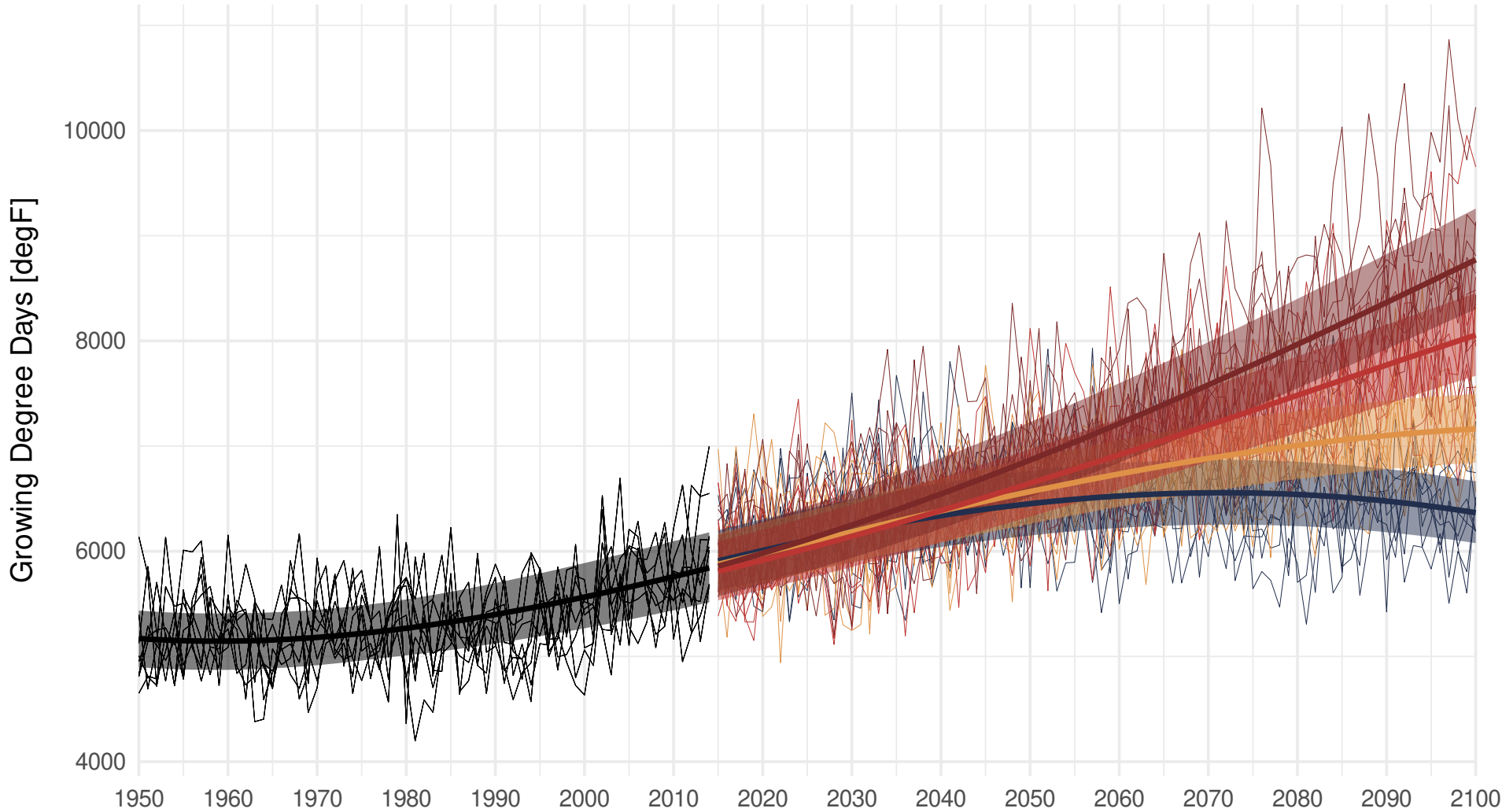
## Climate Projections of Average Temperature [degF]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

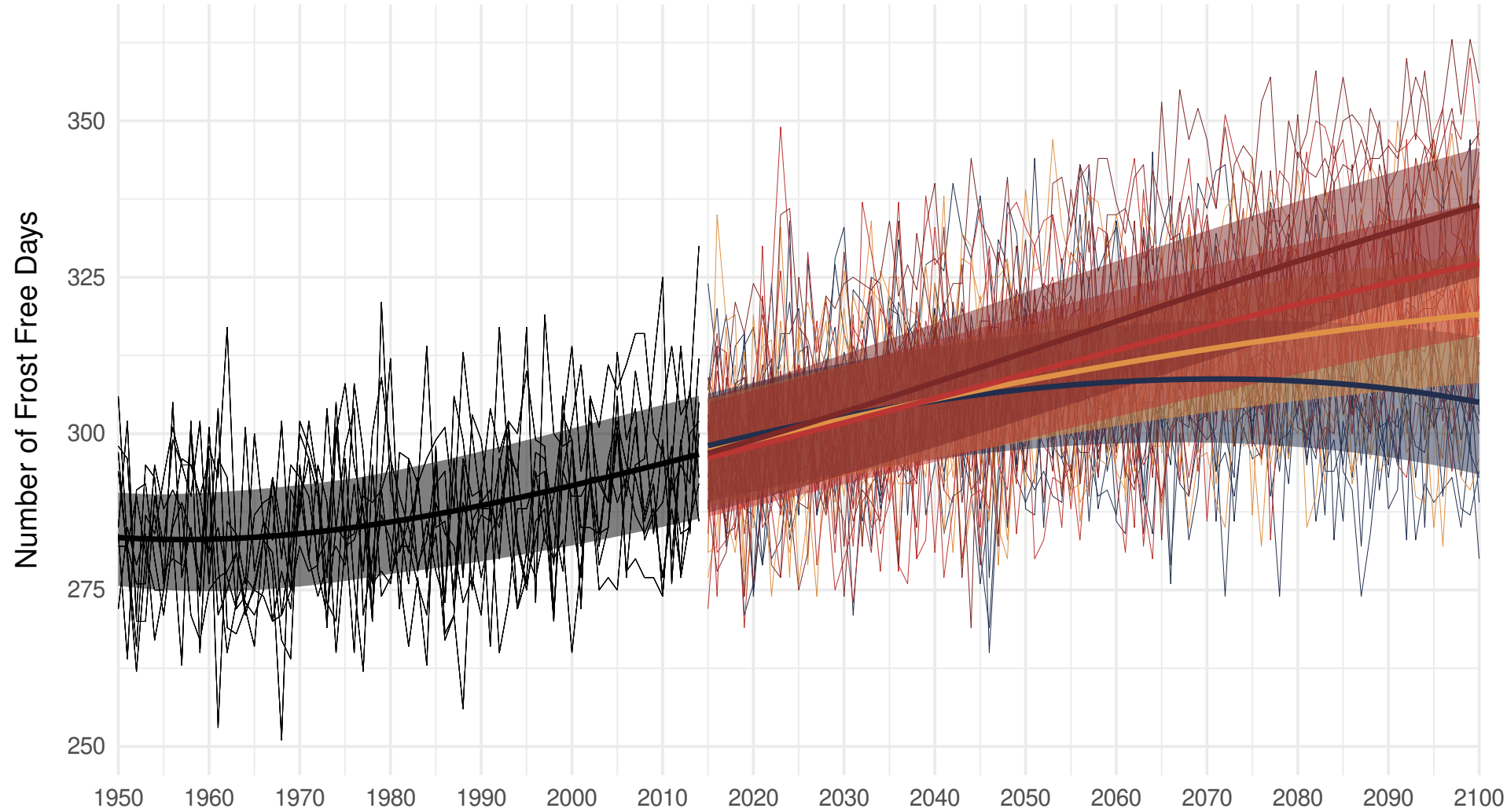
## Climate Projections of Growing Degree Days [degF]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

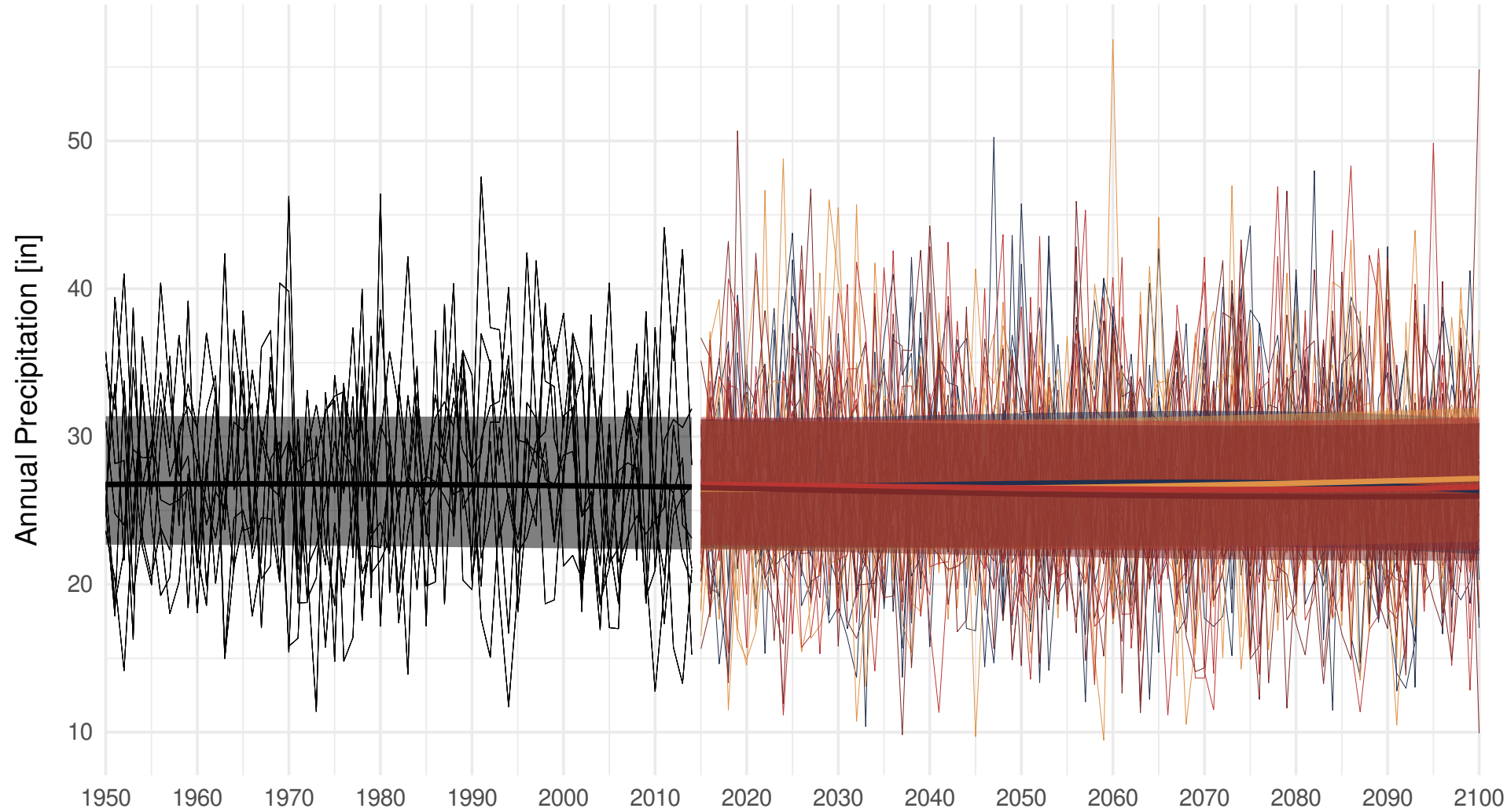
## Climate Projections of Number of Frost Free Days



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

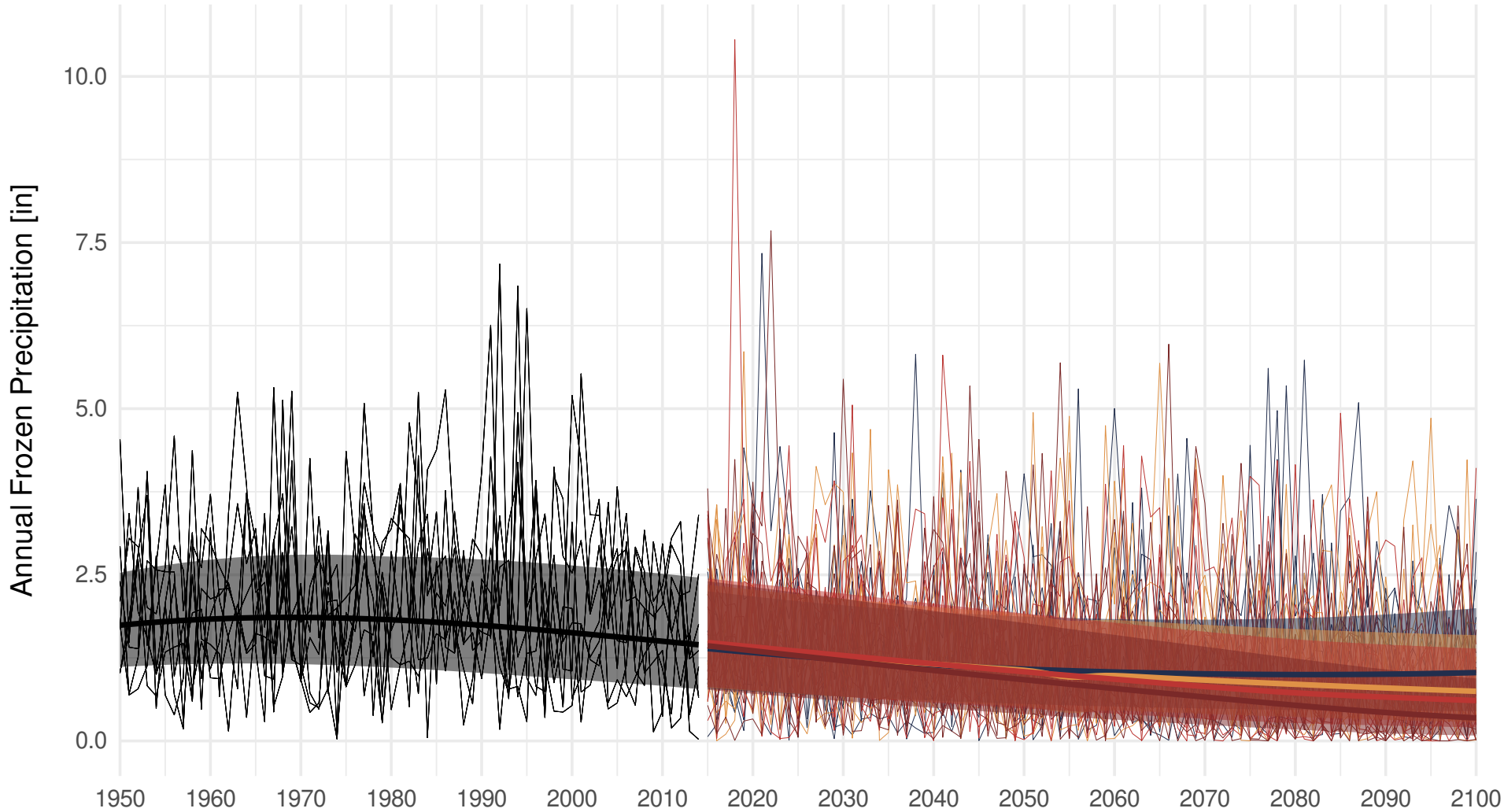
## Climate Projections of Annual Precipitation [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

## Climate Projections of Annual Frozen Precipitation [in]

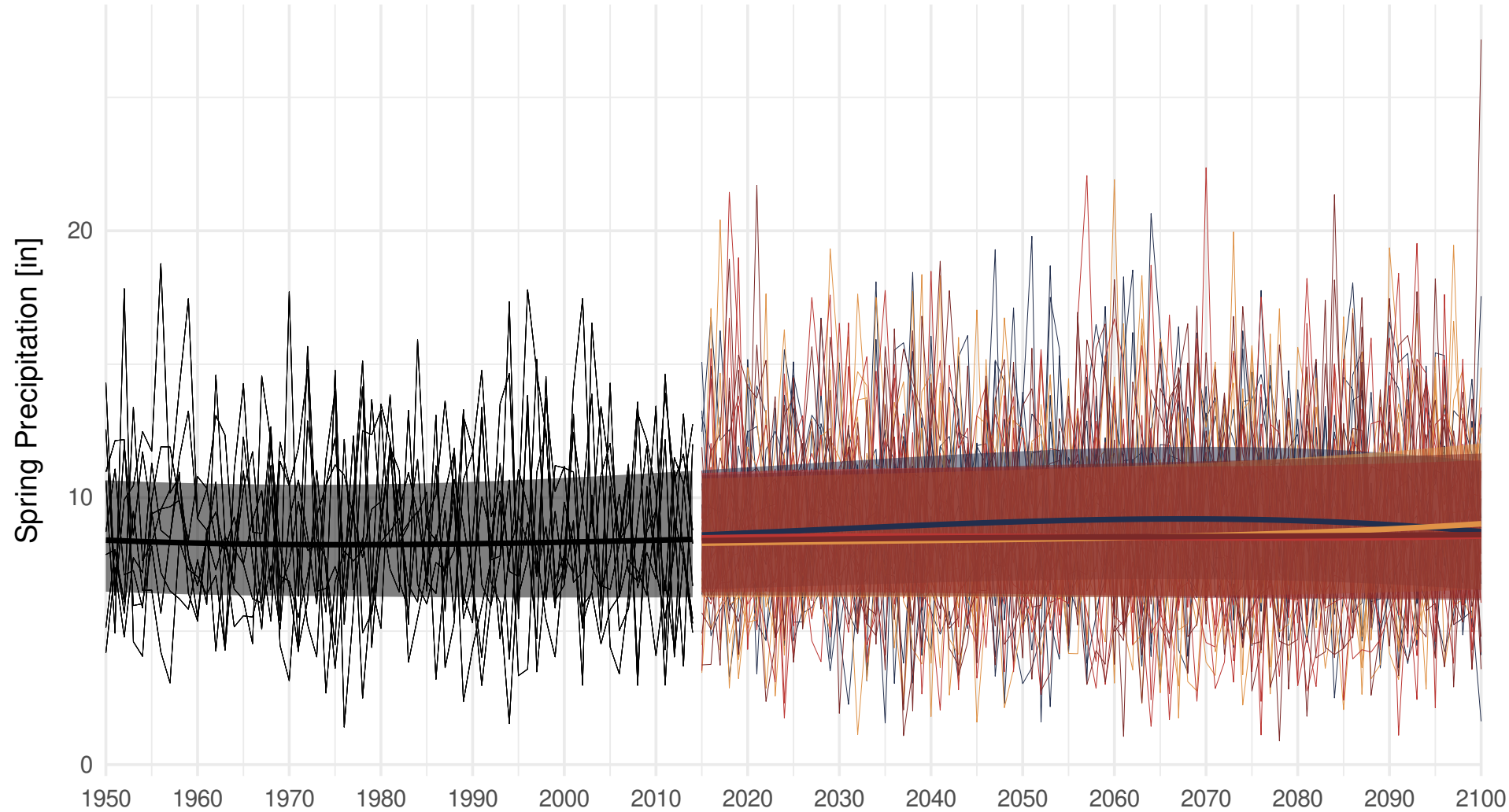


- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)



# Cheyenne and Arapaho OTSA

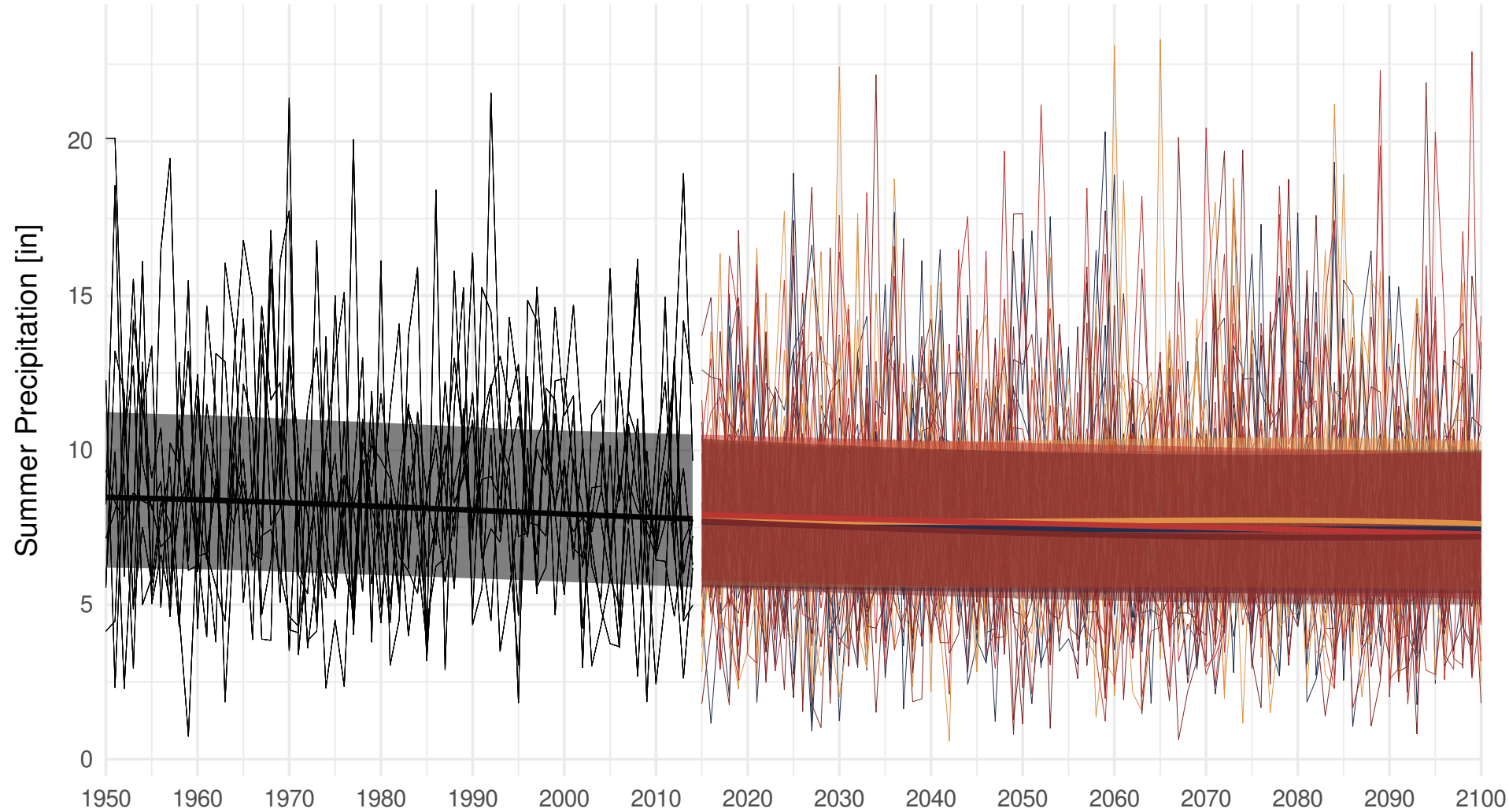
## Climate Projections of Spring Precipitation [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

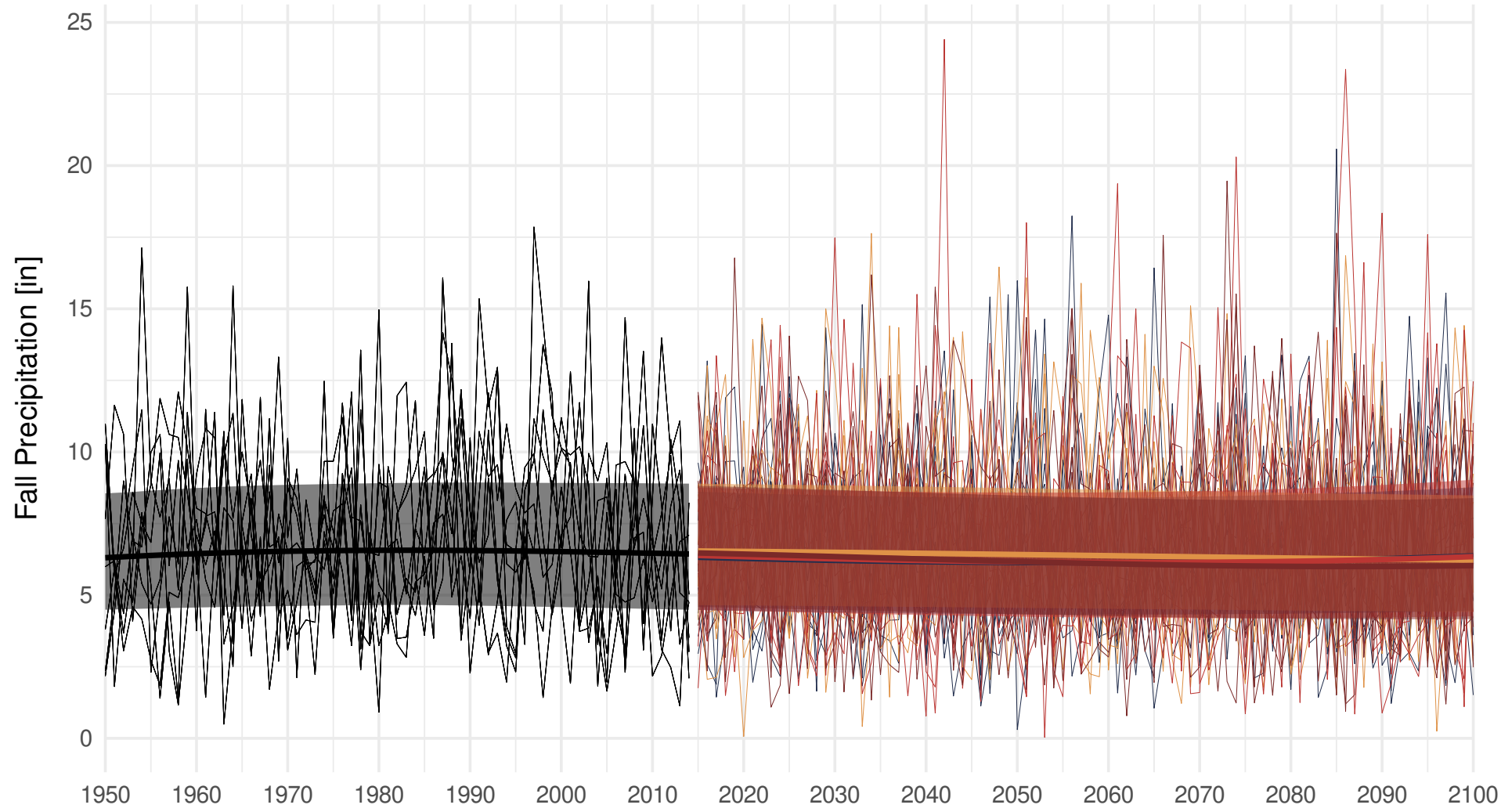
## Climate Projections of Summer Precipitation [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

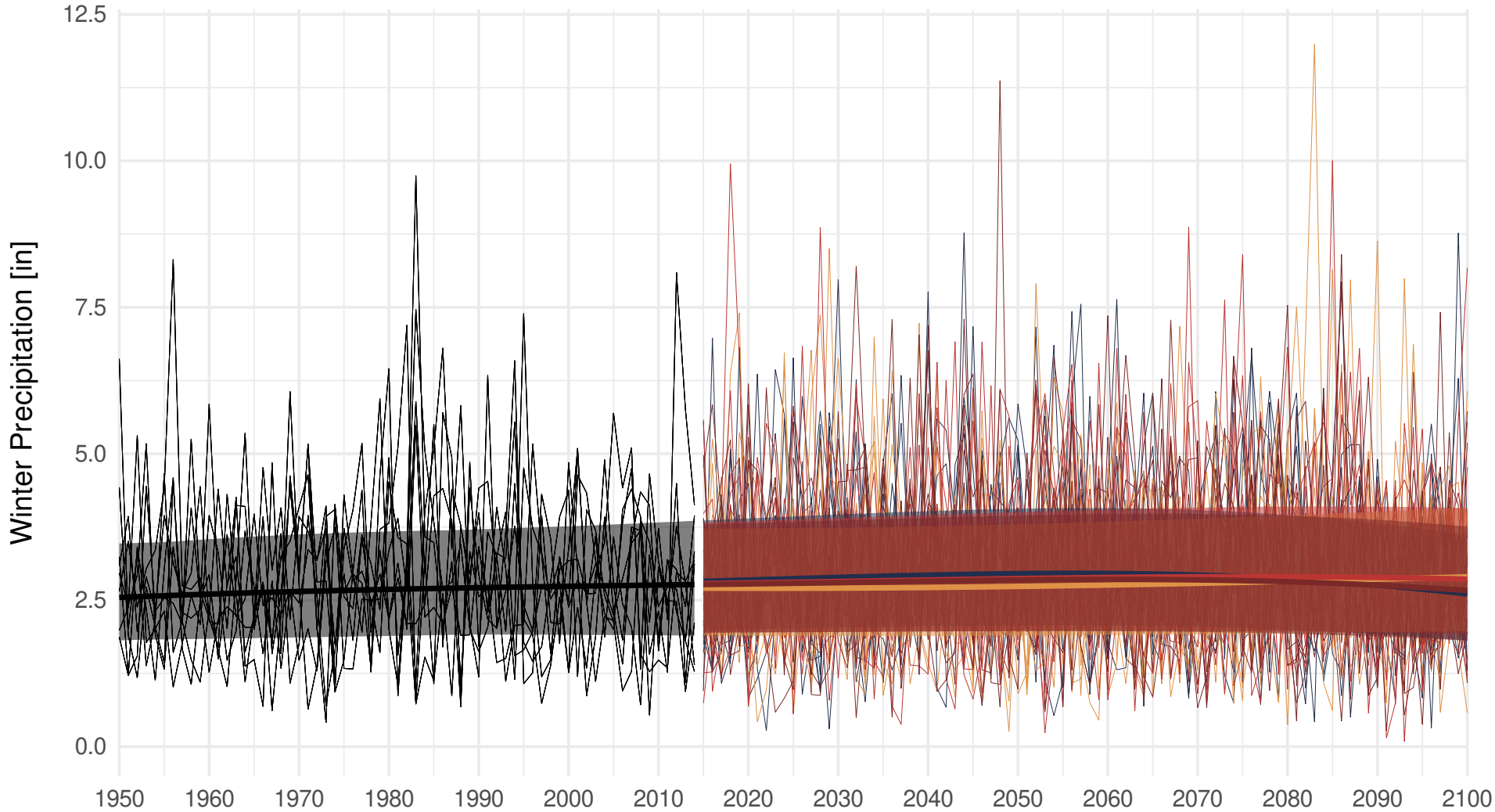
## Climate Projections of Fall Precipitation [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

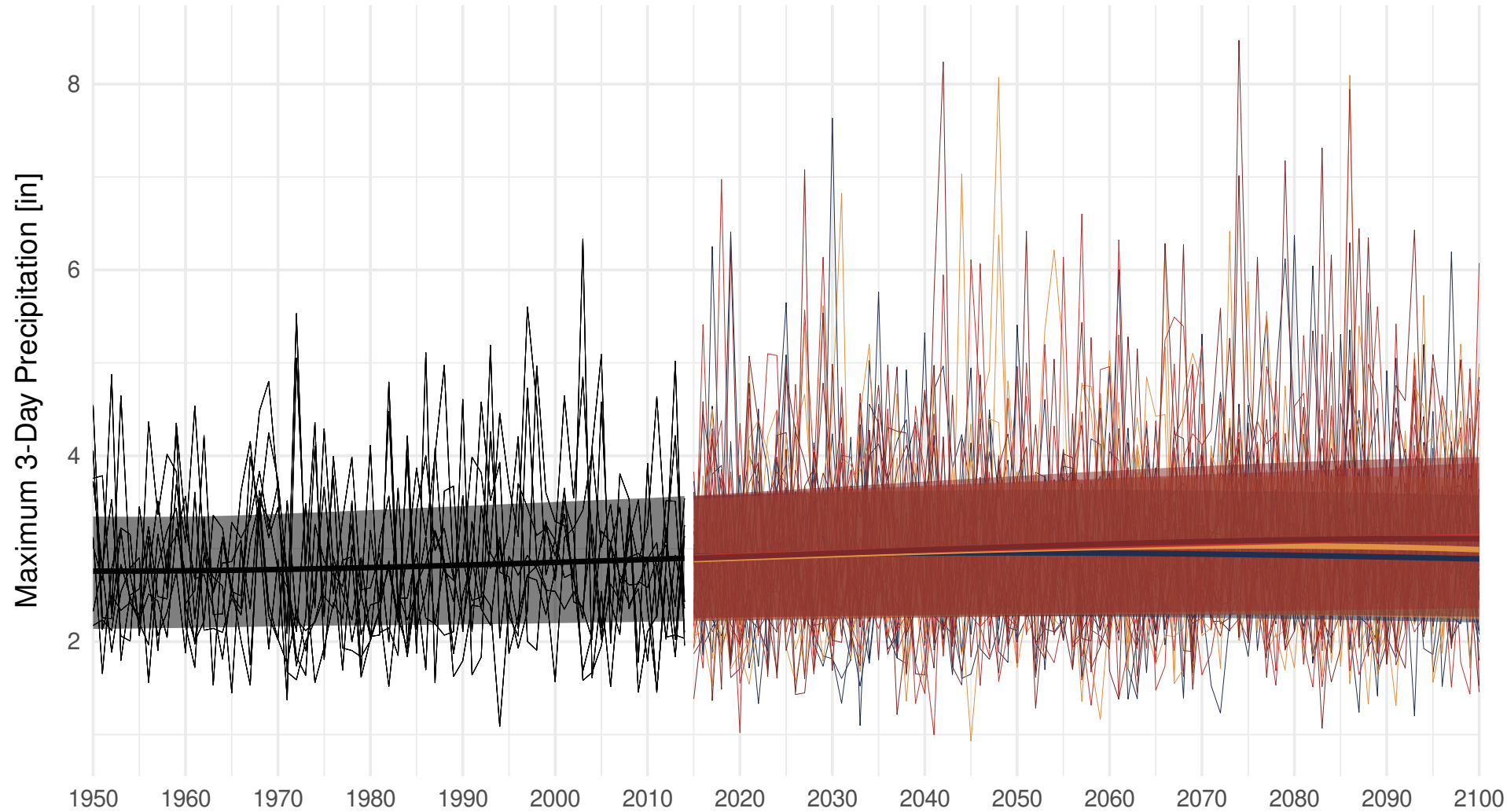
## Climate Projections of Winter Precipitation [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

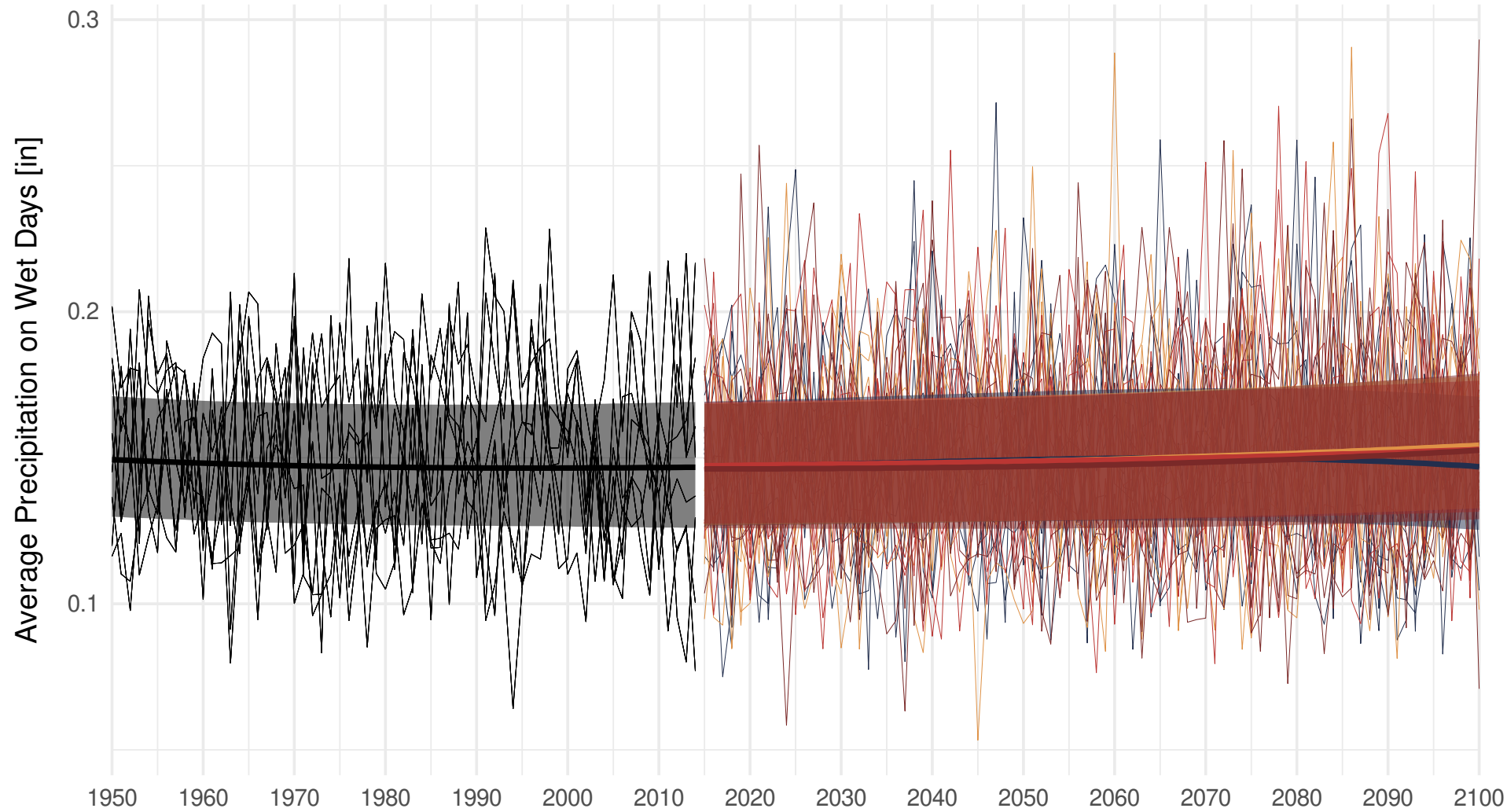
## Climate Projections of Maximum 3-Day Precipitation [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

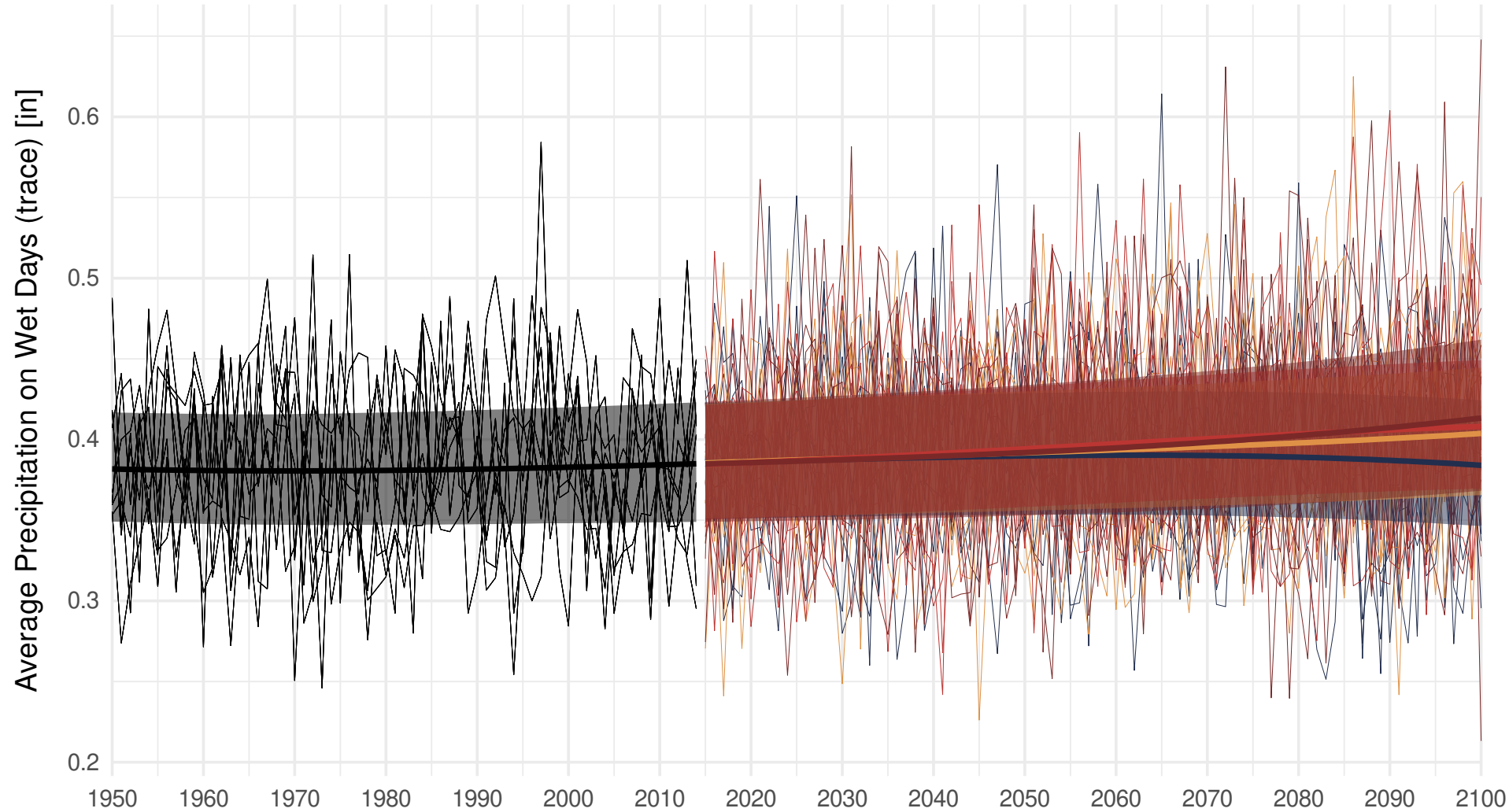
## Climate Projections of Average Precipitation on Wet Days [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

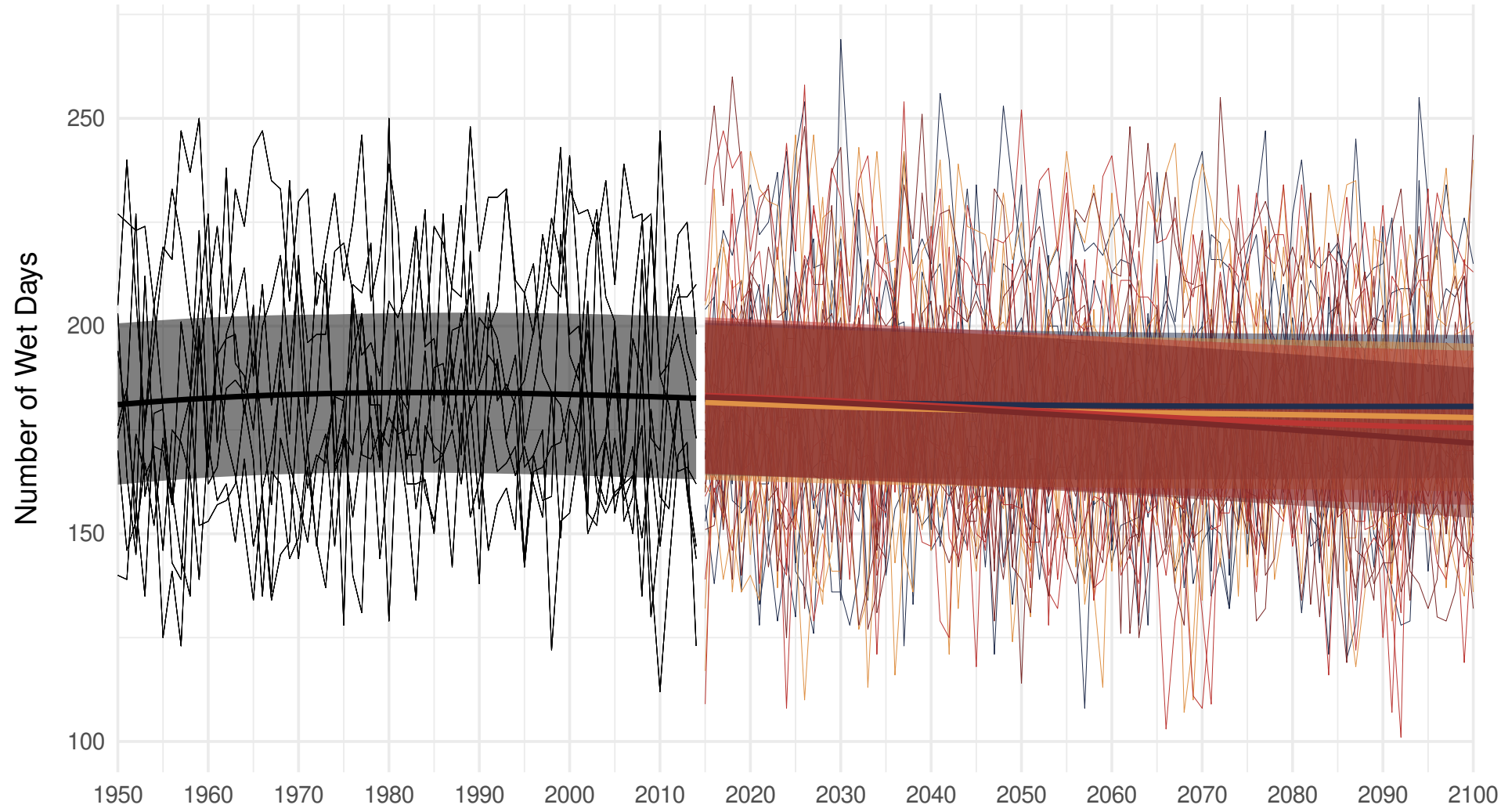
Climate Projections of Average Precipitation on Wet Days (trace) [in]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

## Climate Projections of Number of Wet Days

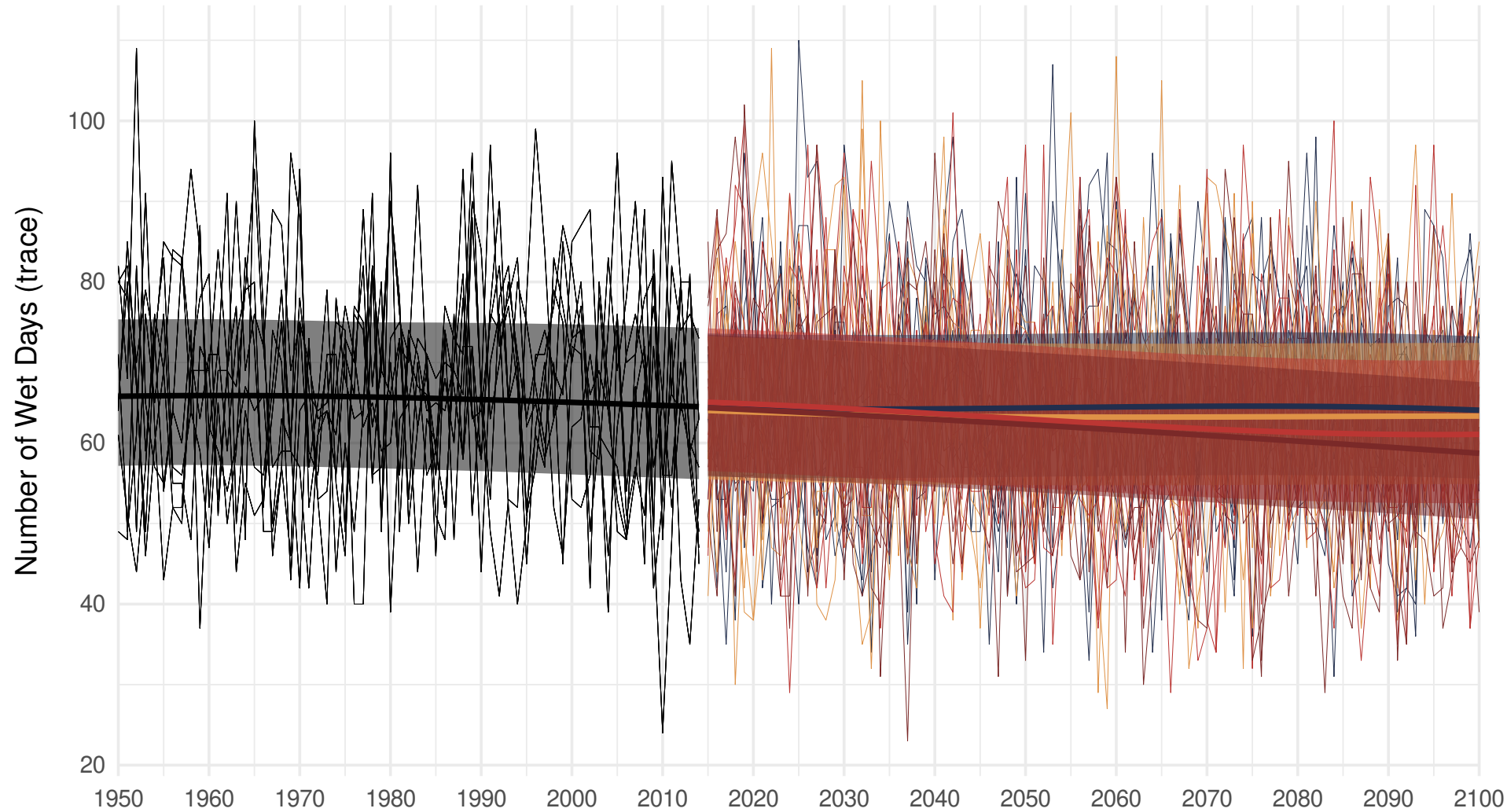


- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)



# Cheyenne and Arapaho OTSA

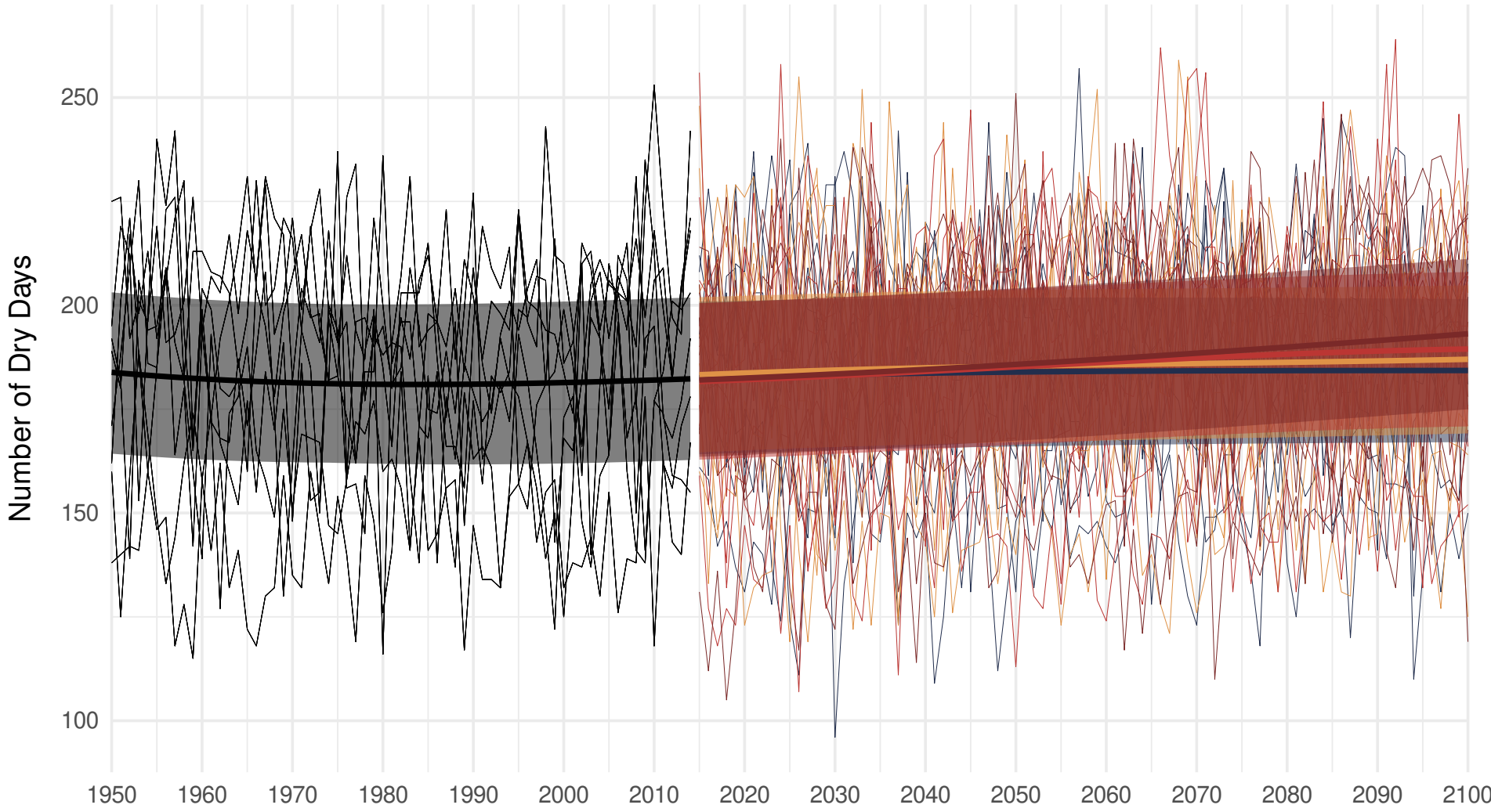
## Climate Projections of Number of Wet Days (trace)



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

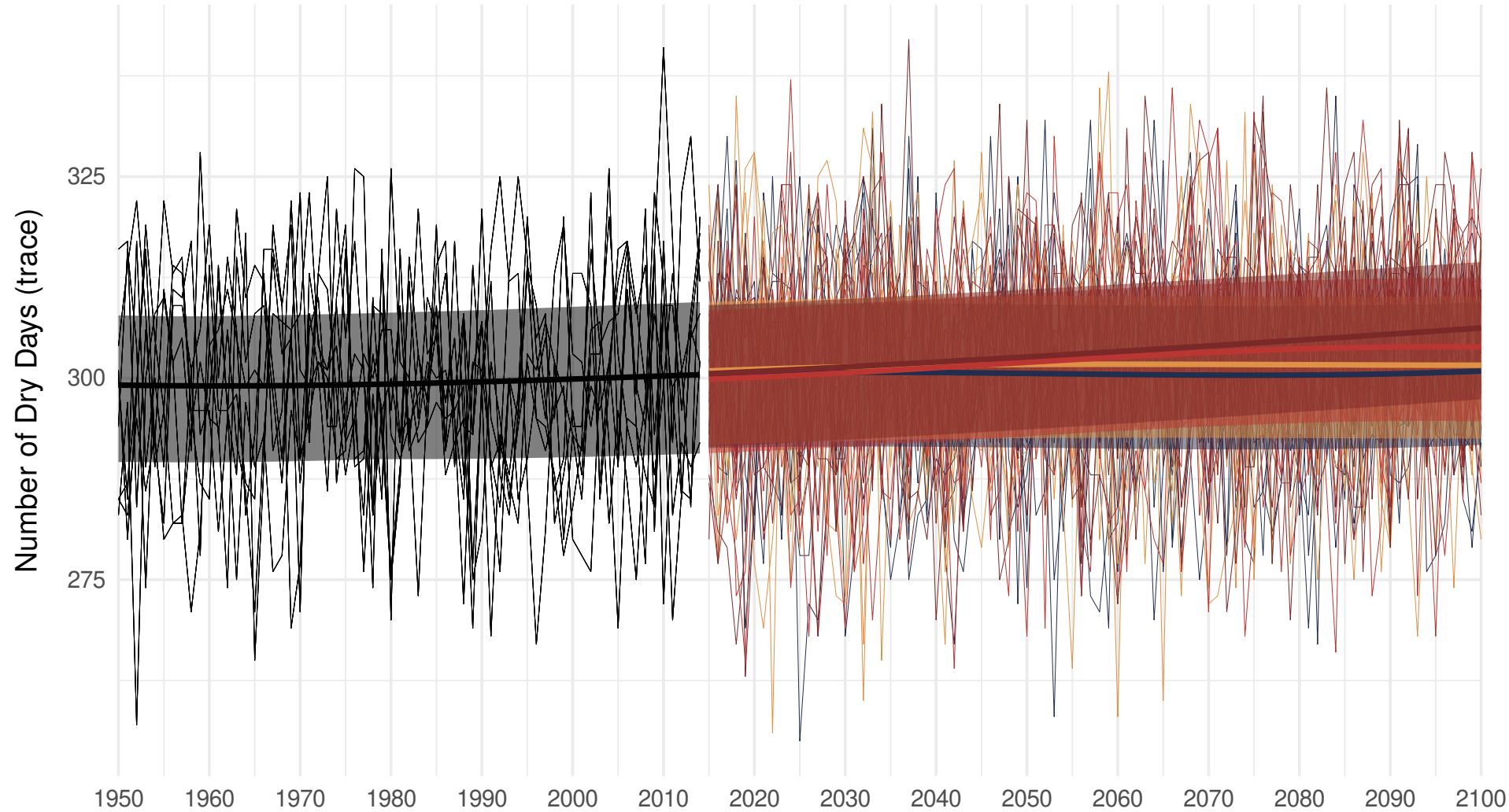
## Climate Projections of Number of Dry Days



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

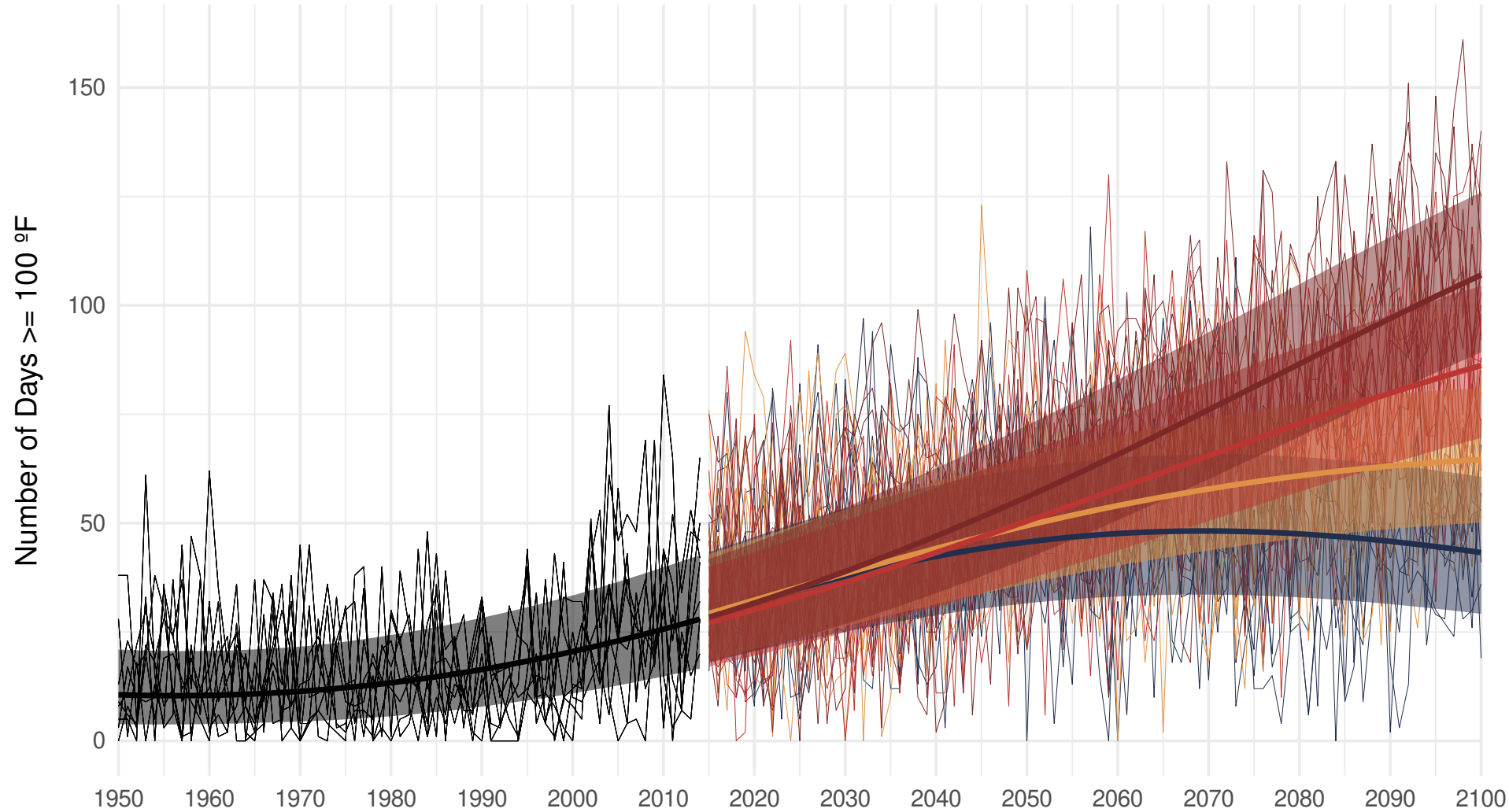
## Climate Projections of Number of Dry Days (trace)



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

Climate Projections of Number of Days  $\geq 100$  °F

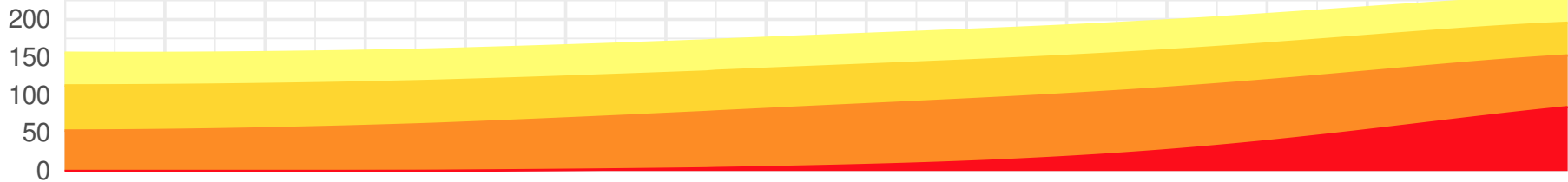


- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

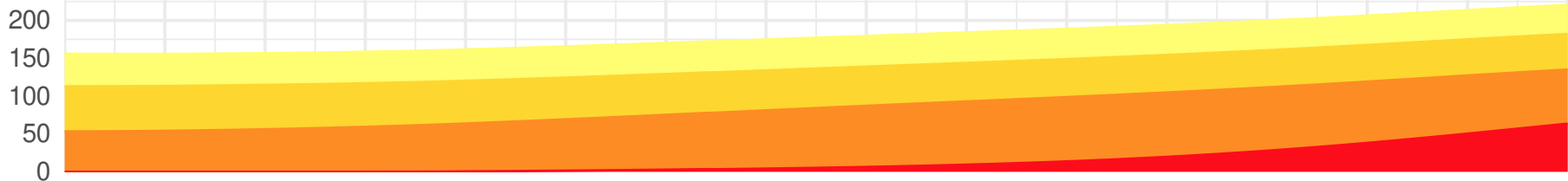
# Cheyenne and Arapaho OTSA

## Climate Projections of Heat Index Hazard

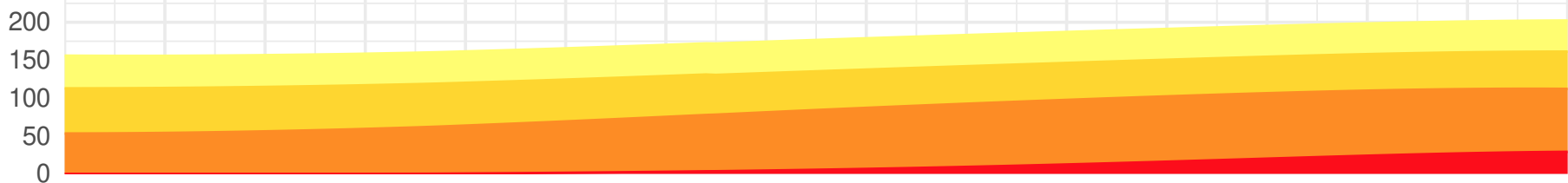
Accelerating Emissions (SSP5-8.5)



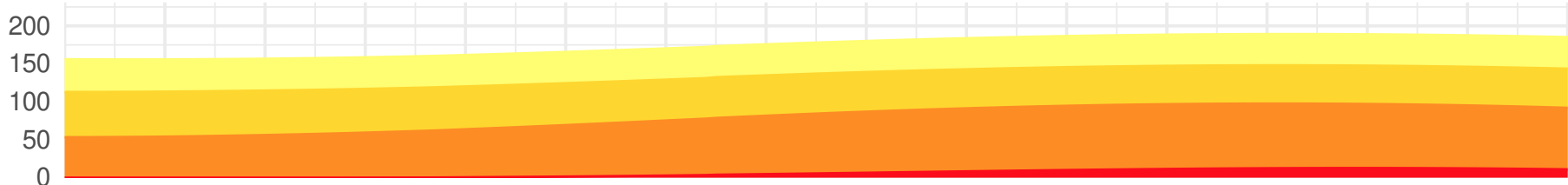
High Emissions (SSP3-7.0)



Middle of the Road (SSP2-4.5)



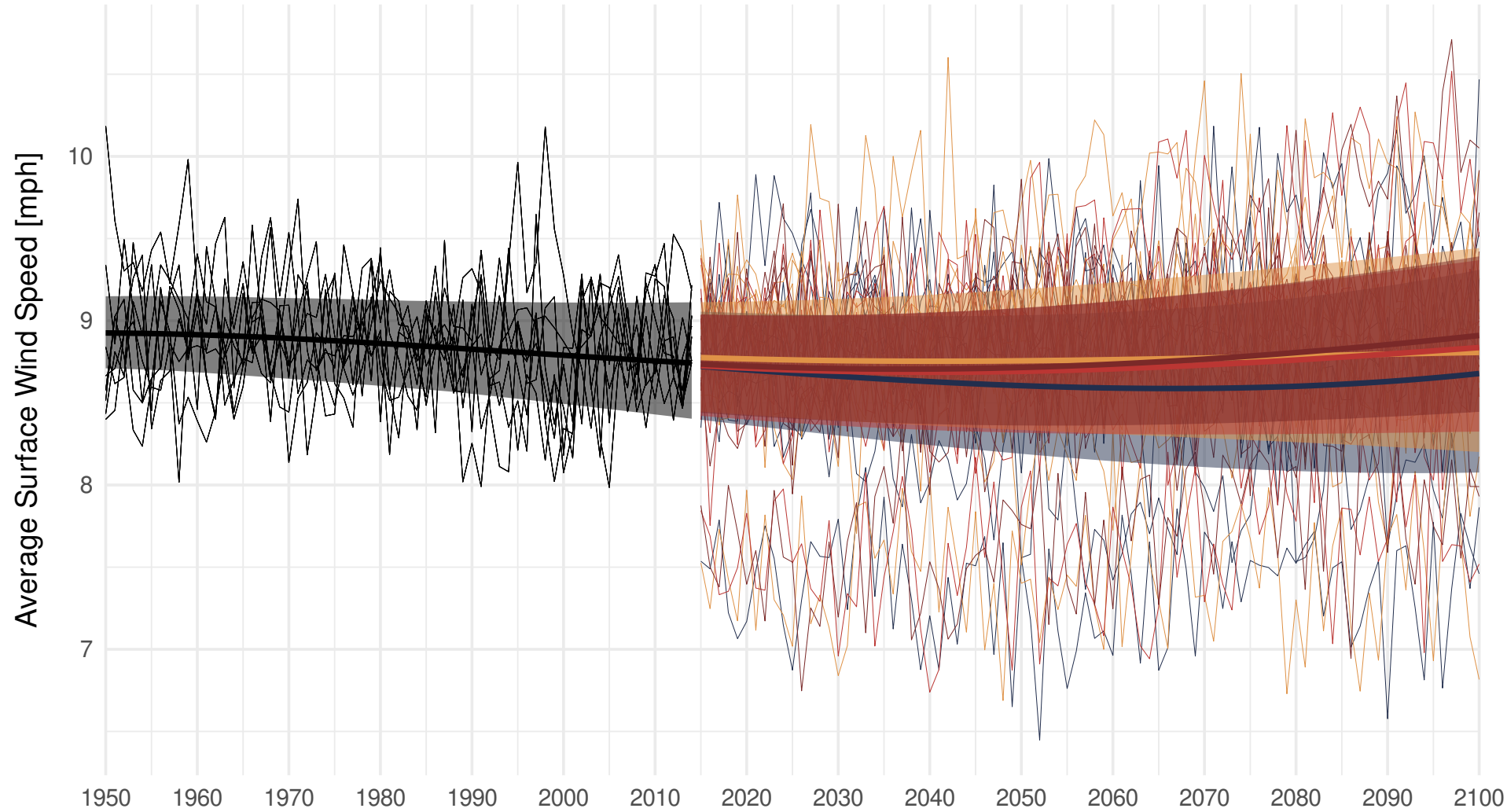
Moderating Emissions (SSP1-2.6)



Caution Extreme Caution Danger Extreme Danger

# Cheyenne and Arapaho OTSA

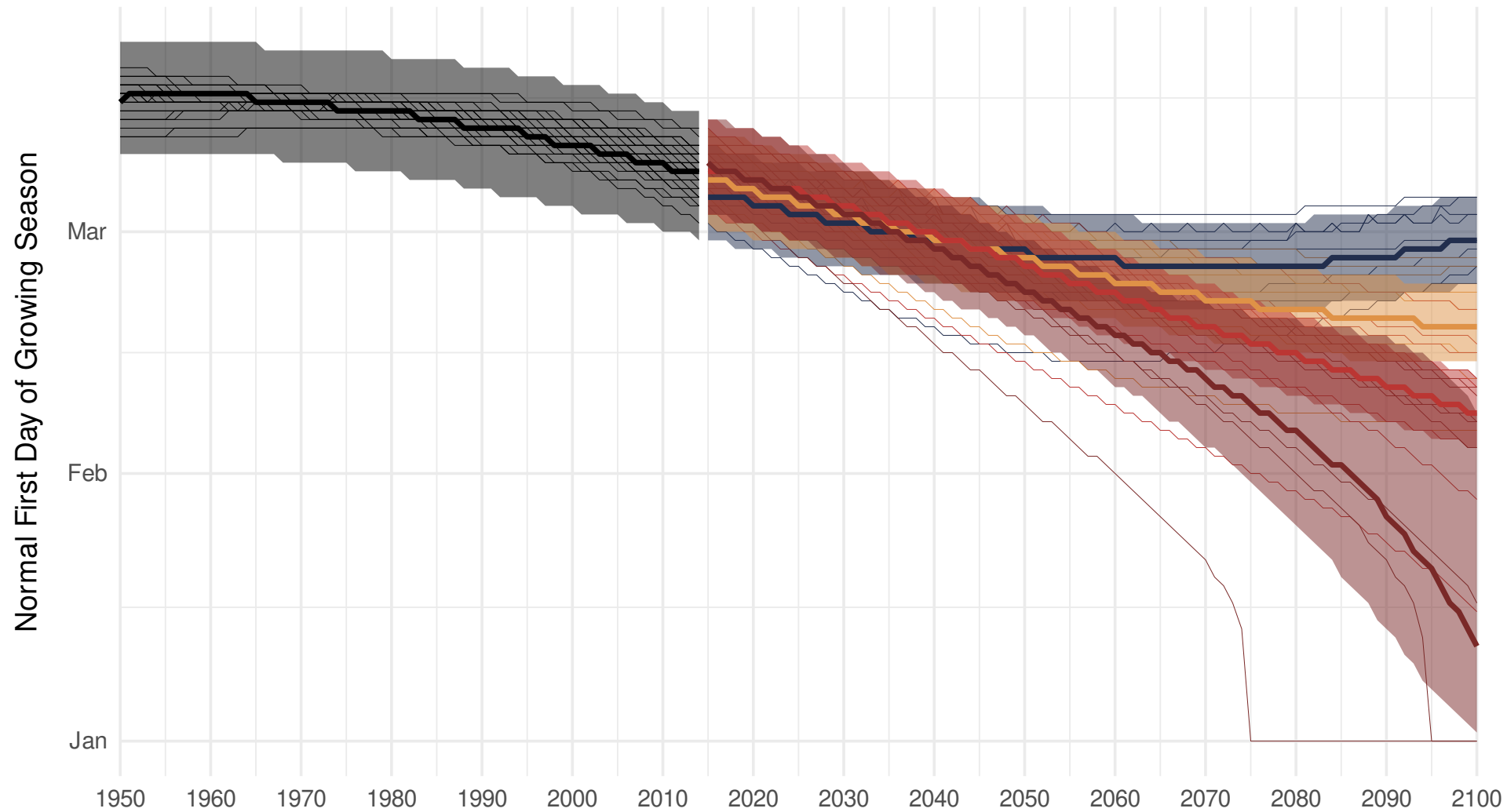
## Climate Projections of Average Surface Wind Speed [mph]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

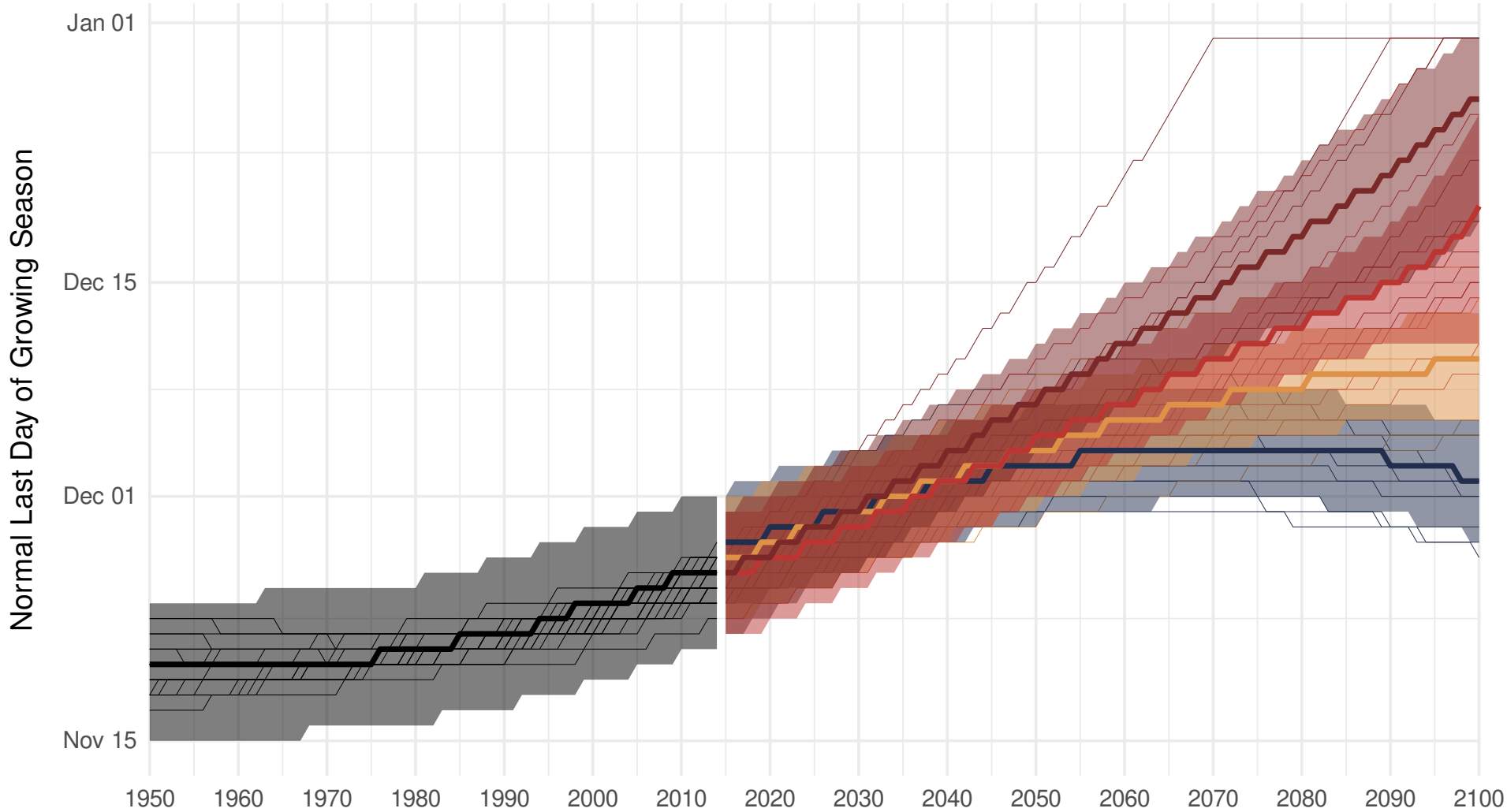
## Climate Projections of Normal First Day of Growing Season



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

## Climate Projections of Normal Last Day of Growing Season

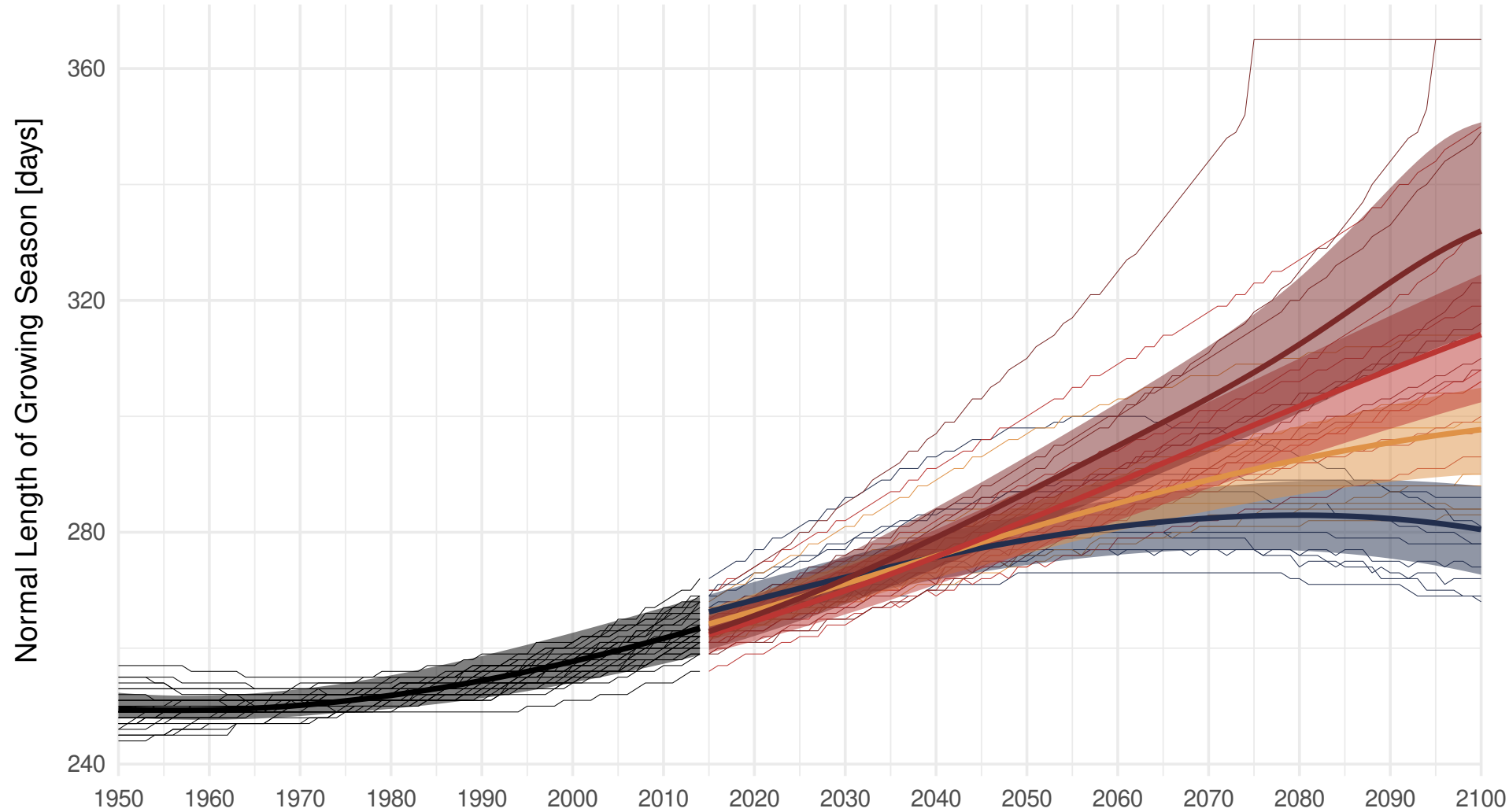


- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)



# Cheyenne and Arapaho OTSA

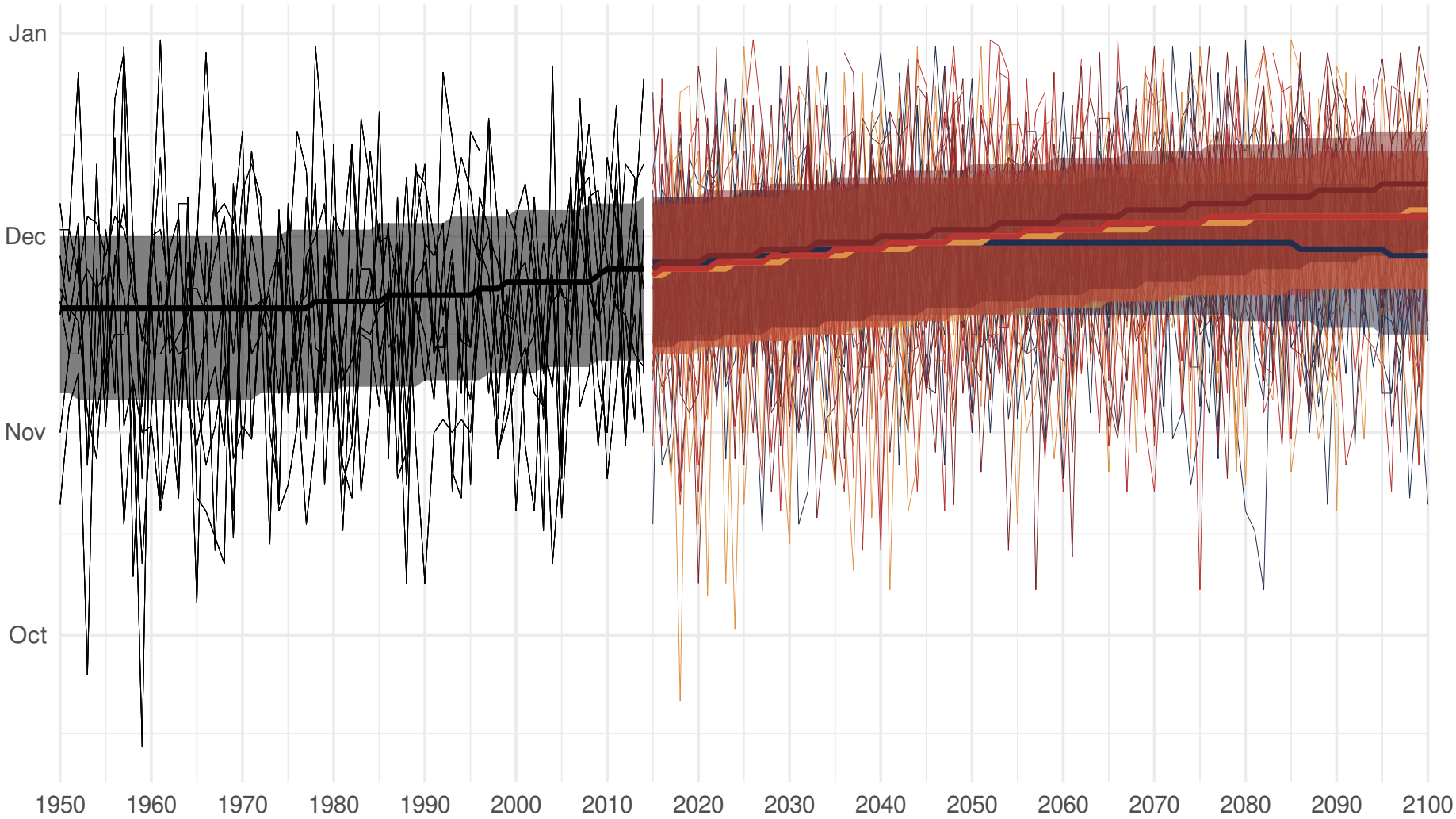
## Climate Projections of Normal Length of Growing Season [days]



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)

# Cheyenne and Arapaho OTSA

## Climate Projections of Day of First Snow



- Historical Emissions
- Moderating Emissions (SSP1-2.6)
- Middle of the Road (SSP2-4.5)
- High Emissions (SSP3-7.0)
- Accelerating Emissions (SSP5-8.5)