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 Hawaiʻi (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_2 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 ºC higher by the end of the century.

SSP2-4.5 This is a “middle of the road” scenario. CO_2 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 ºC by the end of the century.

SSP3-7.0 On this path, emissions and temperatures rise steadily and CO_2 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 ºC.

SSP5-8.5 This can be considered a worst-case scenario. Current CO_2 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 ºC higher.

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

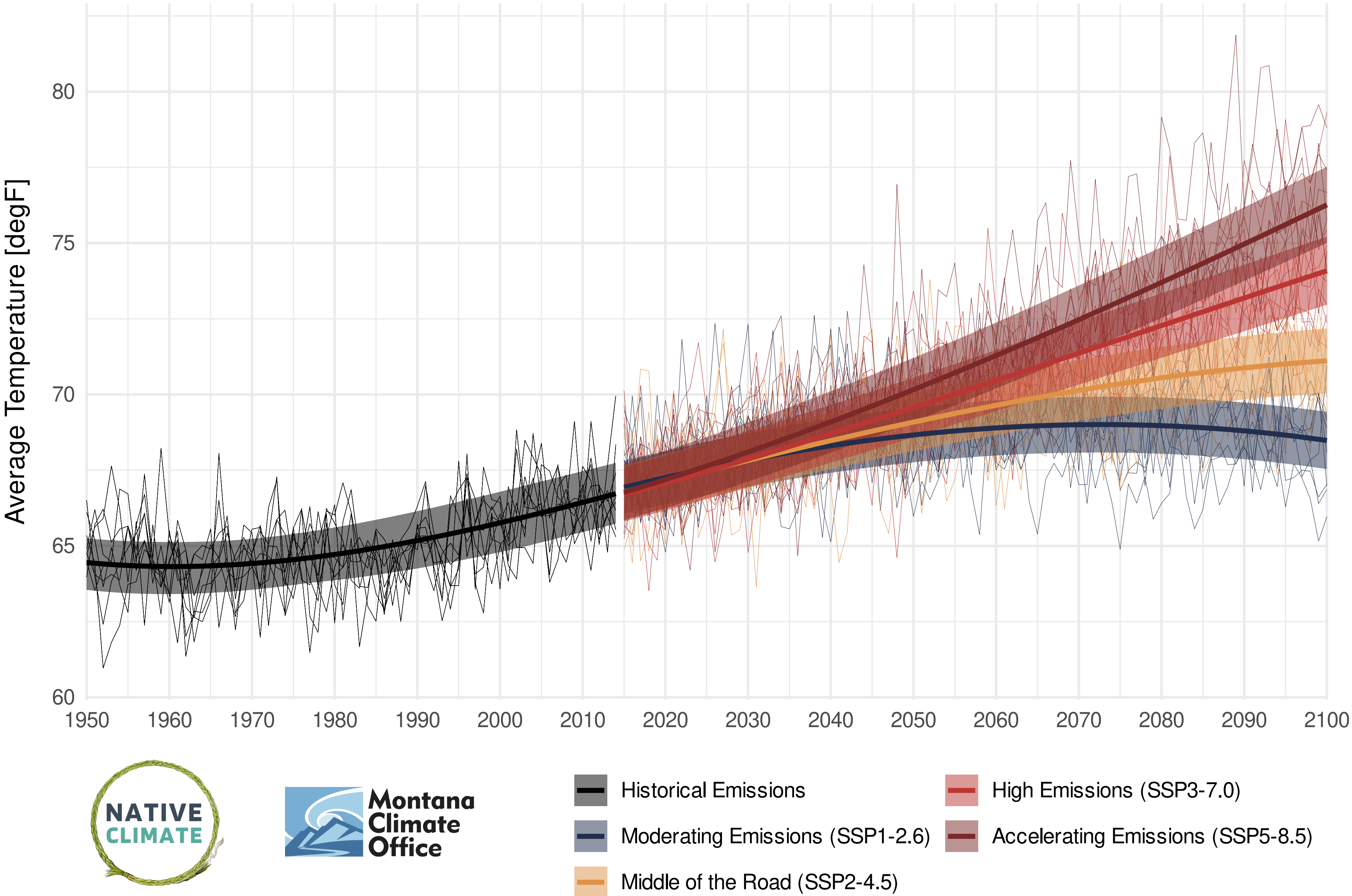
Variable	Units	Description
Average Temperature	ºF	Annual average daily temperature
Growing Degree Days	Fahrenheit GDDs	Heat accumulation (warmth) above 50 ºF, in units of Fahrenheit Growing Degree Days. Appropriate for corn agriculture.
Frost Free Days	count	Number of days per year with minimum daily temperatures greater than 32 ºF
Annual Precipitation	inches	Total annual precipitation
Annual Frozen Precipitation	inches	Total annual precipitation on days with a minimum temperature of at most 32 ºF
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

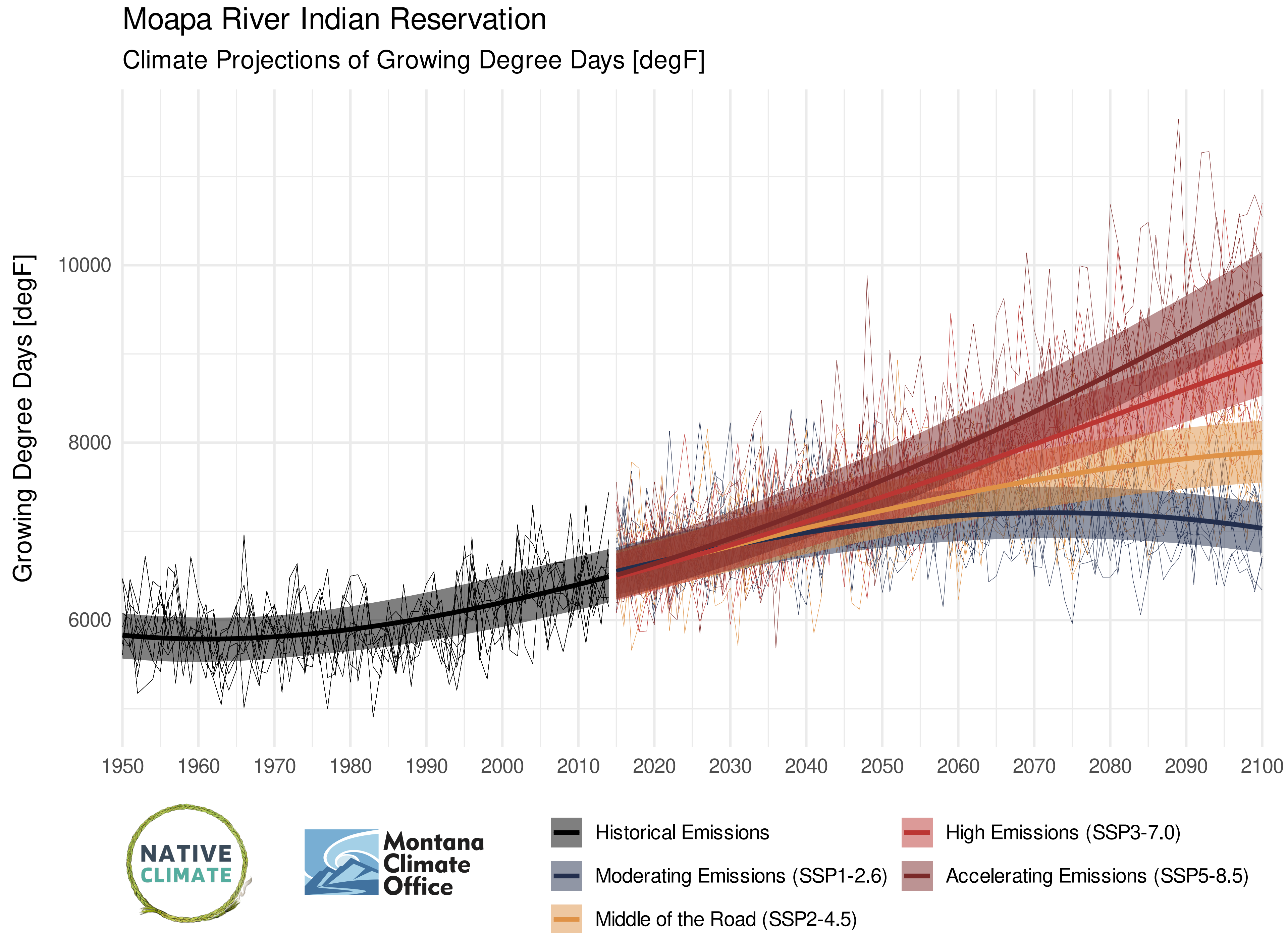
Variable	Units	Description
Maximum 3-Day Precipitation	inches	Maximum total precipitation over a three-day period each year
Average Precipitation on Wet Days	inches	Average daily precipitation on days with precipitation
Average Precipitation on Wet Days (trace)	inches	Average daily precipitation on days 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 >= 100 ºF	count	Number of days per year where the daily high temperature is at least 100 ºF
Number of Days with Heat Index Hazard	count	Number of days per year at each of the National Atmospheric and Oceanographic Organization's (NOAA) heat index hazard levels. *Caution*: fatigue is possible with prolonged exposure and activity; continuing activity could result in heat cramps. *Extreme caution*: heat cramps and heat exhaustion are possible; continuing activity could result in heat stroke. *Danger*: heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity. *Extreme danger*: heat stroke is imminent.
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 ºF
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 ºF
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. Code for producing all data supplied here is freely available on Github: https://github.com/native-climate/cmip6-reservations.

Moapa River Indian Reservation

Climate Projections of Average Temperature [degF]




Moapa River Indian Reservation
Climate Projections of Growing Degree Days [degF]
Growing Degree Days [degF]
10000
8000
6000
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
NATIVE CLIMATE
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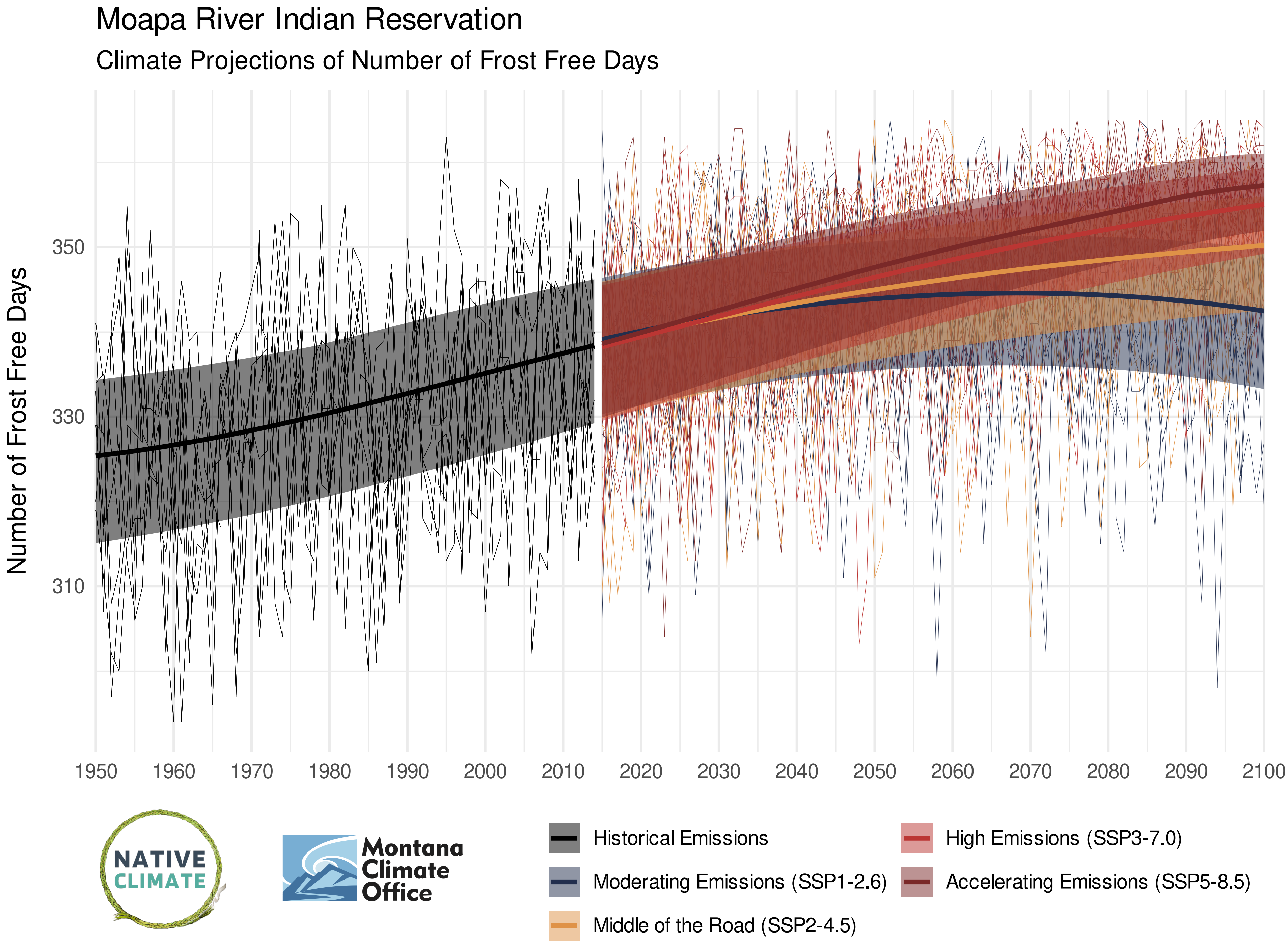
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)


Moapa River Indian Reservation
Climate Projections of Number of Frost Free Days
Number of Frost Free Days
350
330
310
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)
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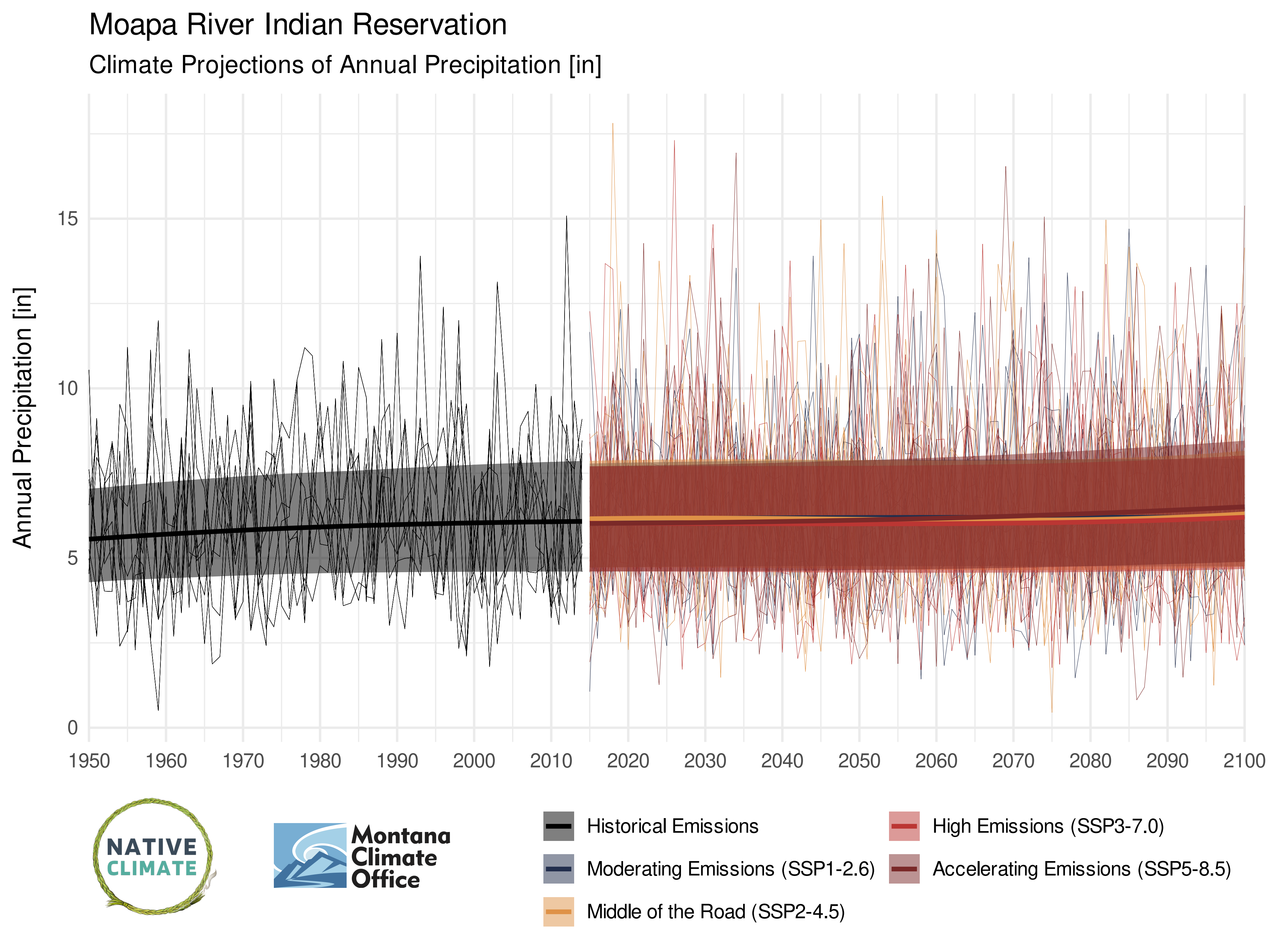
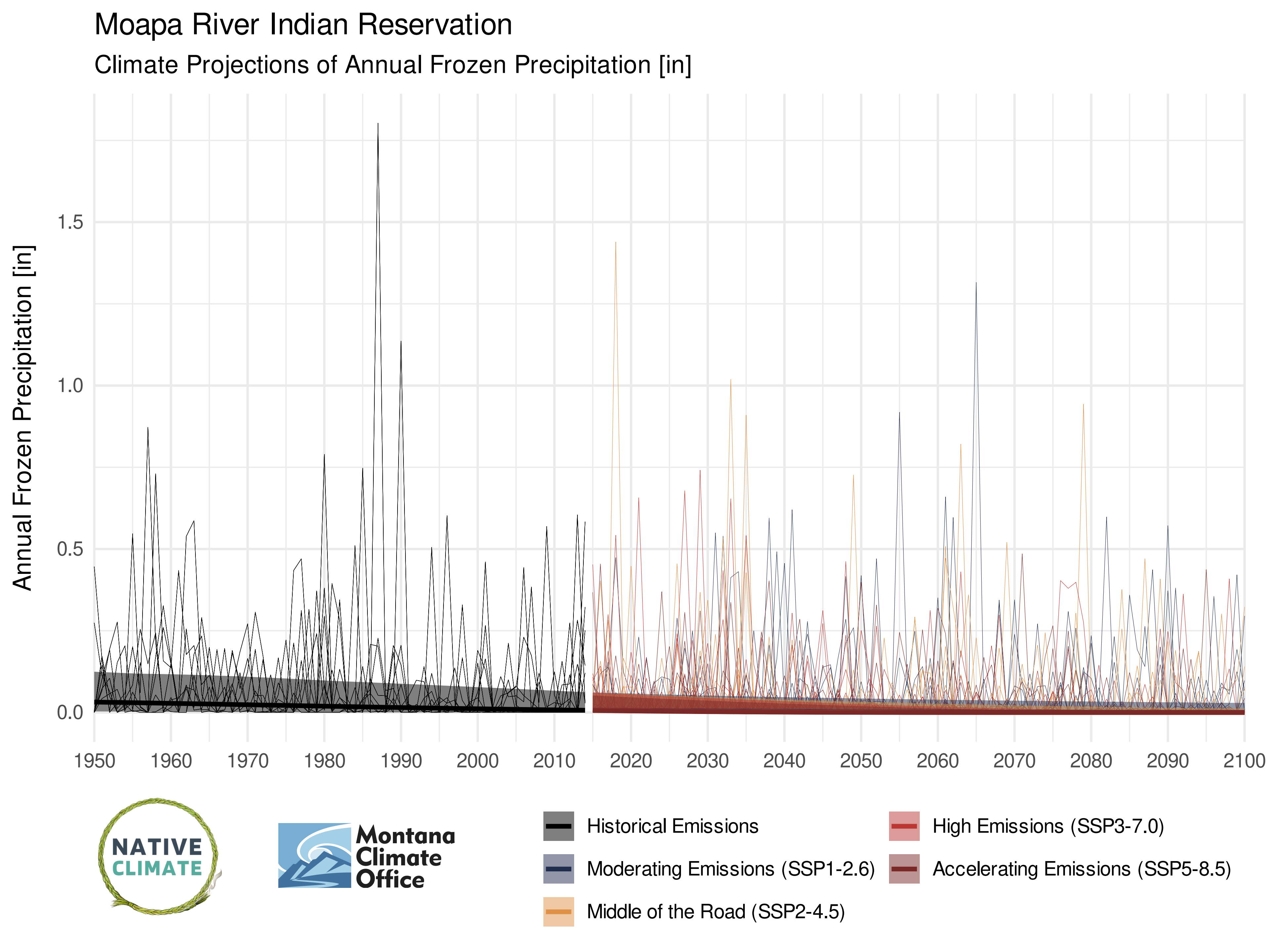
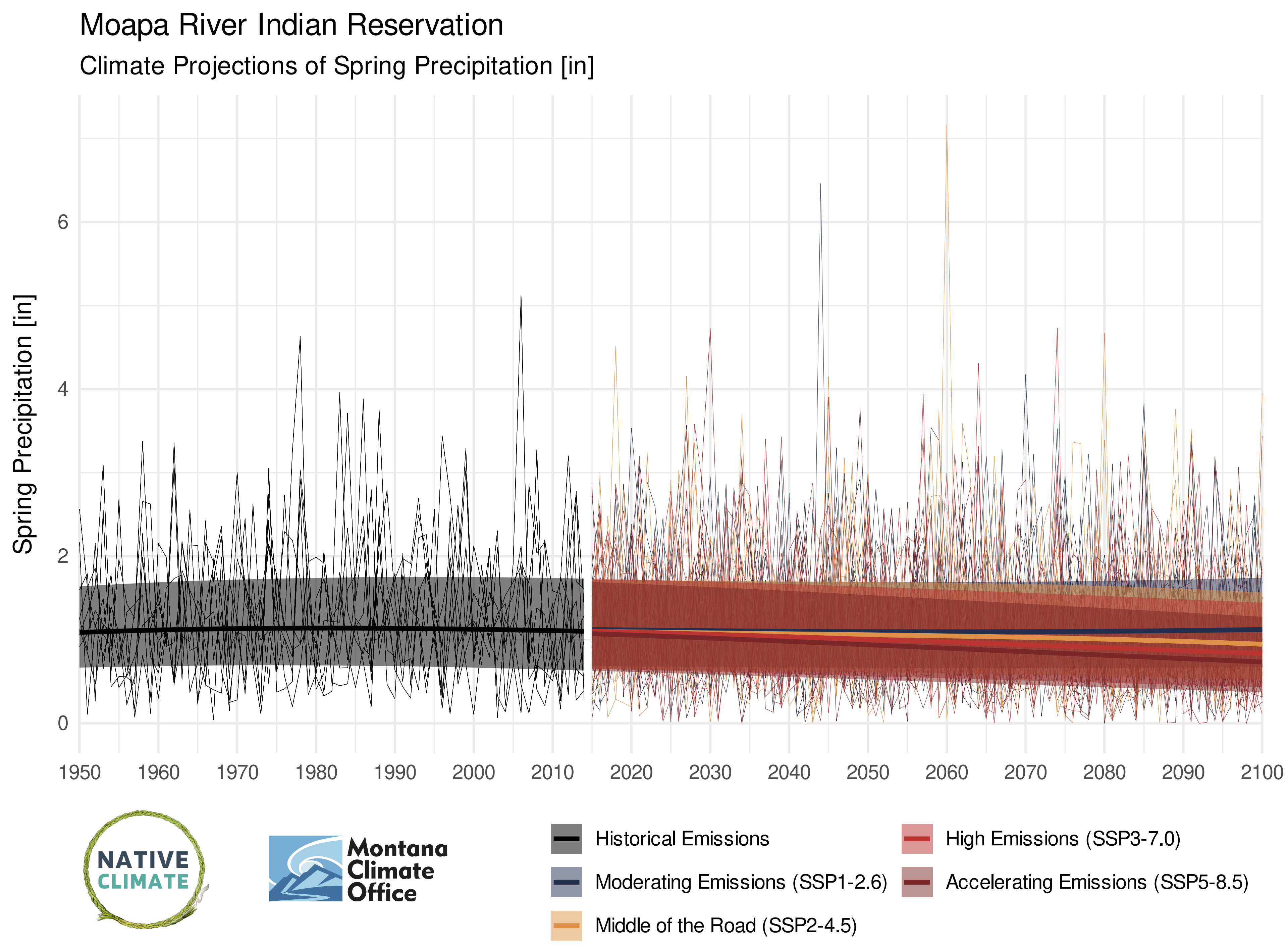

Moapa River Indian Reservation
Climate Projections of Annual Precipitation [in]
Annual Precipitation [in]
0
5
10
15
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
NATIVE CLIMATE
Montana Climate Office
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)

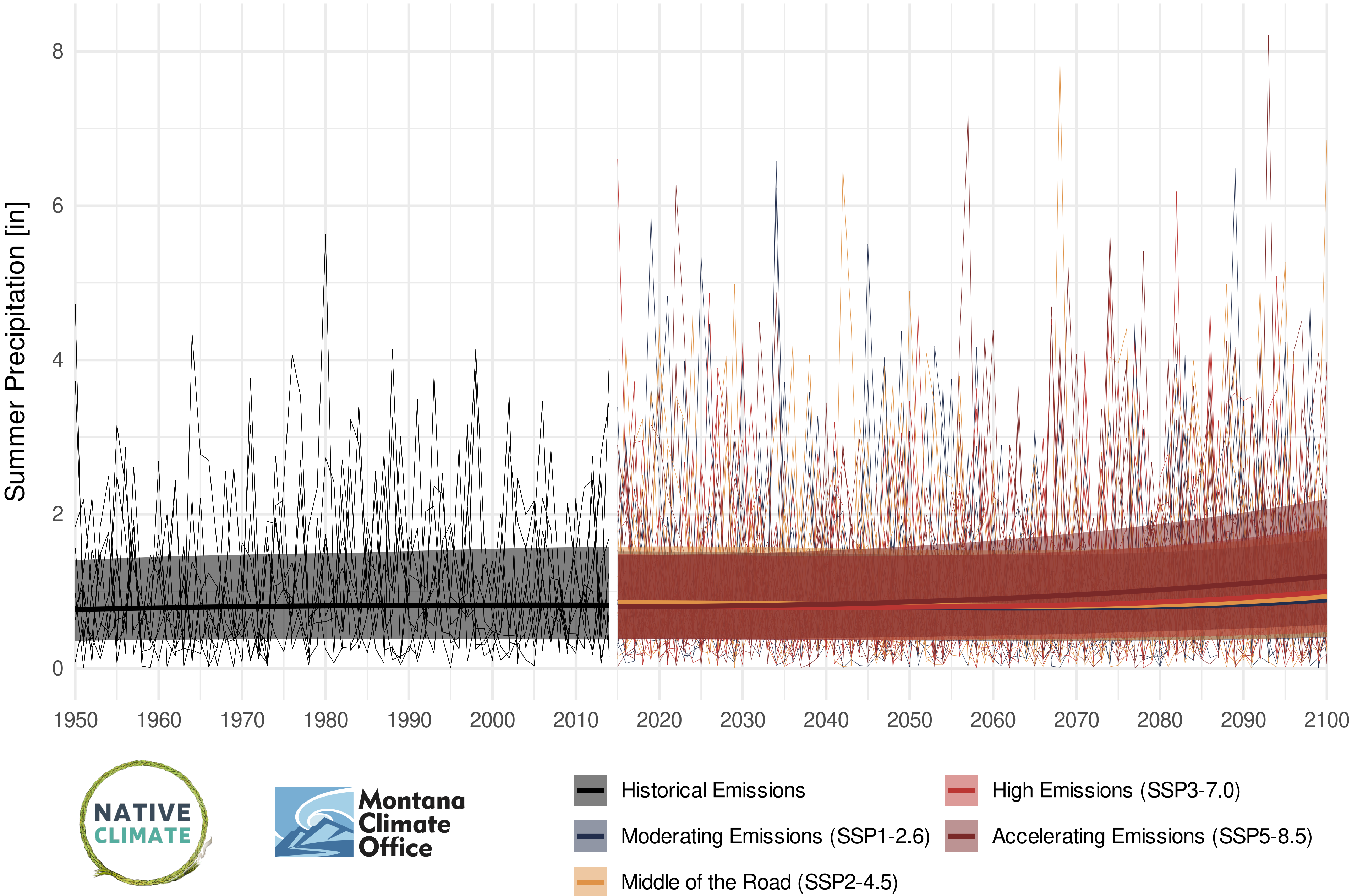


Moapa River Indian Reservation
Climate Projections of Annual Frozen Precipitation [in]
Annual Frozen Precipitation [in]
0.0
0.5
1.0
1.5
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
NATIVE CLIMATE
Montana Climate Office
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)


Moapa River Indian Reservation
Climate Projections of Spring Precipitation [in]
Spring Precipitation [in]
0
2
4
6
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
NATIVE CLIMATE
Montana Climate Office
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)

Moapa River Indian Reservation

Climate Projections of Summer Precipitation [in]



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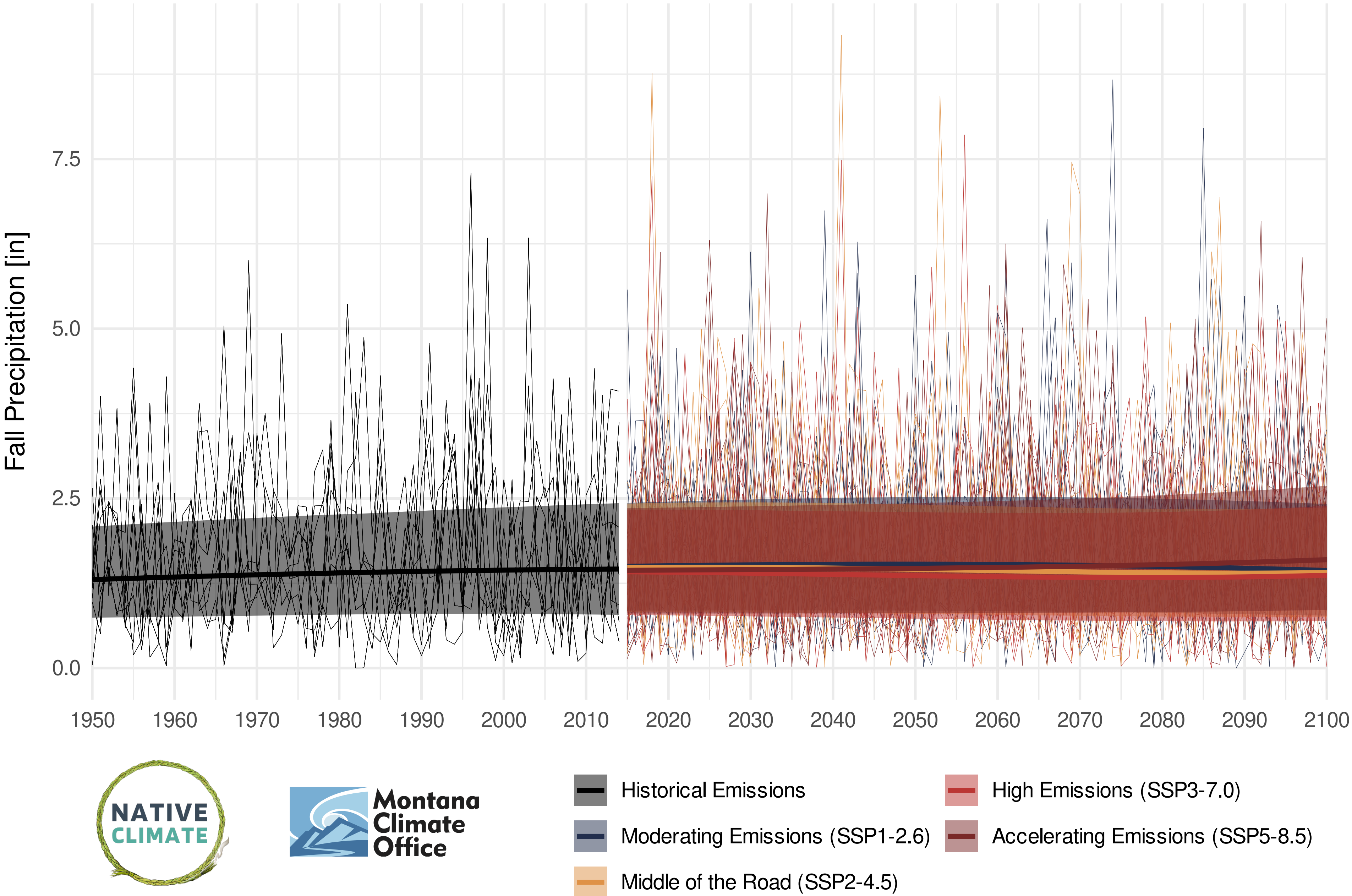
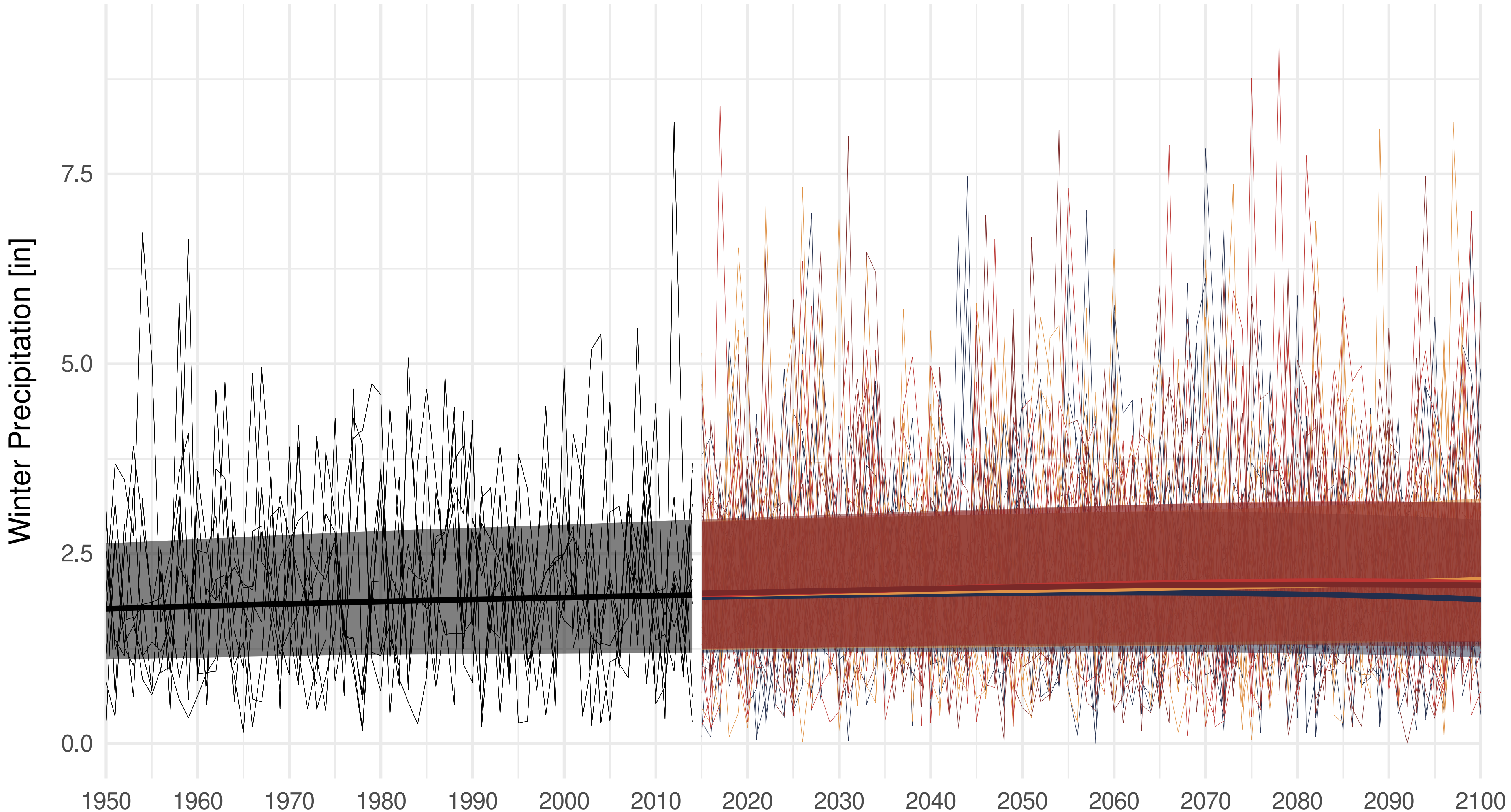
Climate Projections of Fall Precipitation [in]



Moapa River Indian Reservation

Climate Projections of Winter Precipitation [in]



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Historical Emissions

Moderating Emissions (SSP1-2.6)

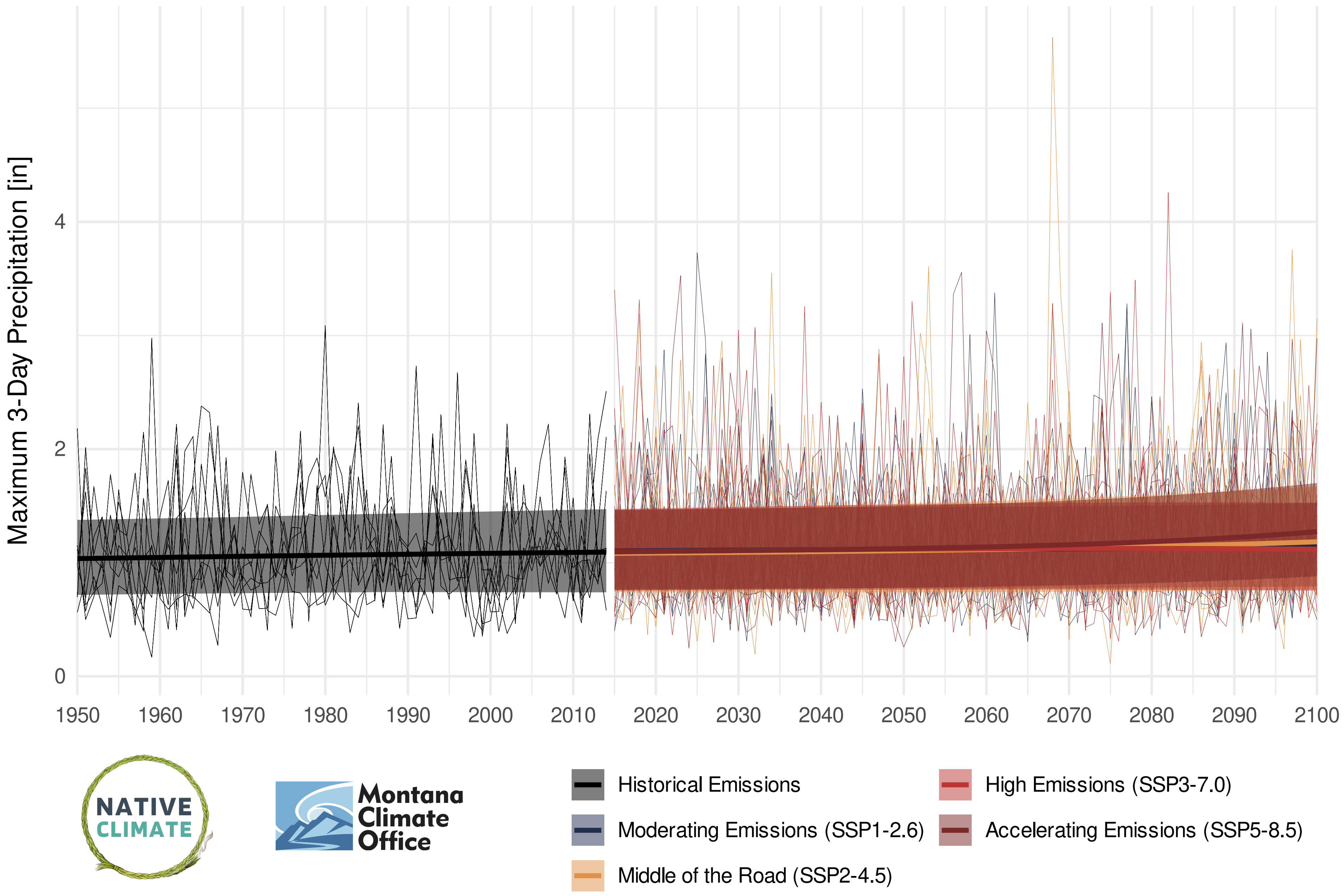
Middle of the Road (SSP2-4.5)

High Emissions (SSP3-7.0)

Accelerating Emissions (SSP5-8.5)

Moapa River Indian Reservation

Climate Projections of Maximum 3-Day Precipitation [in]



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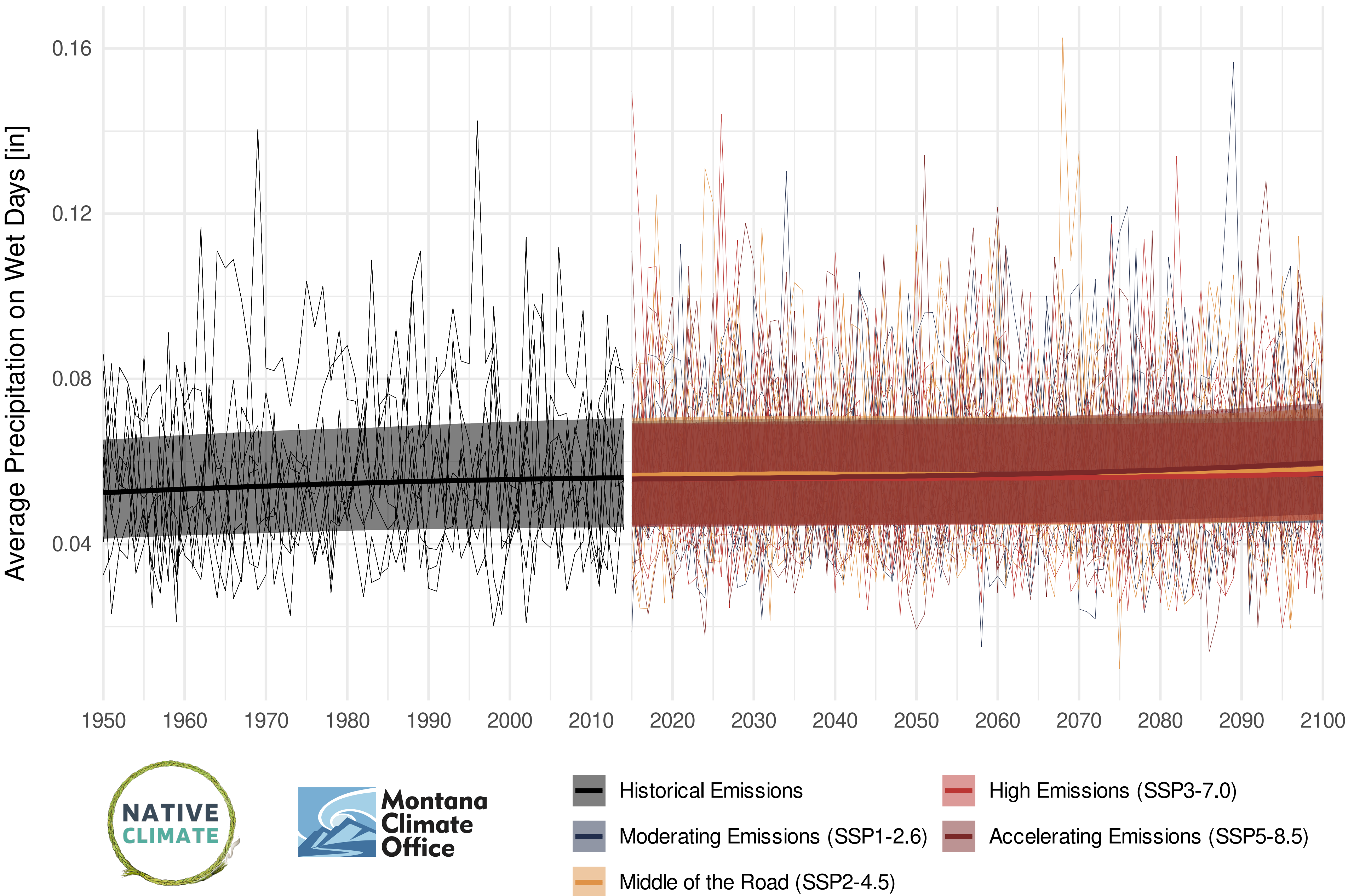
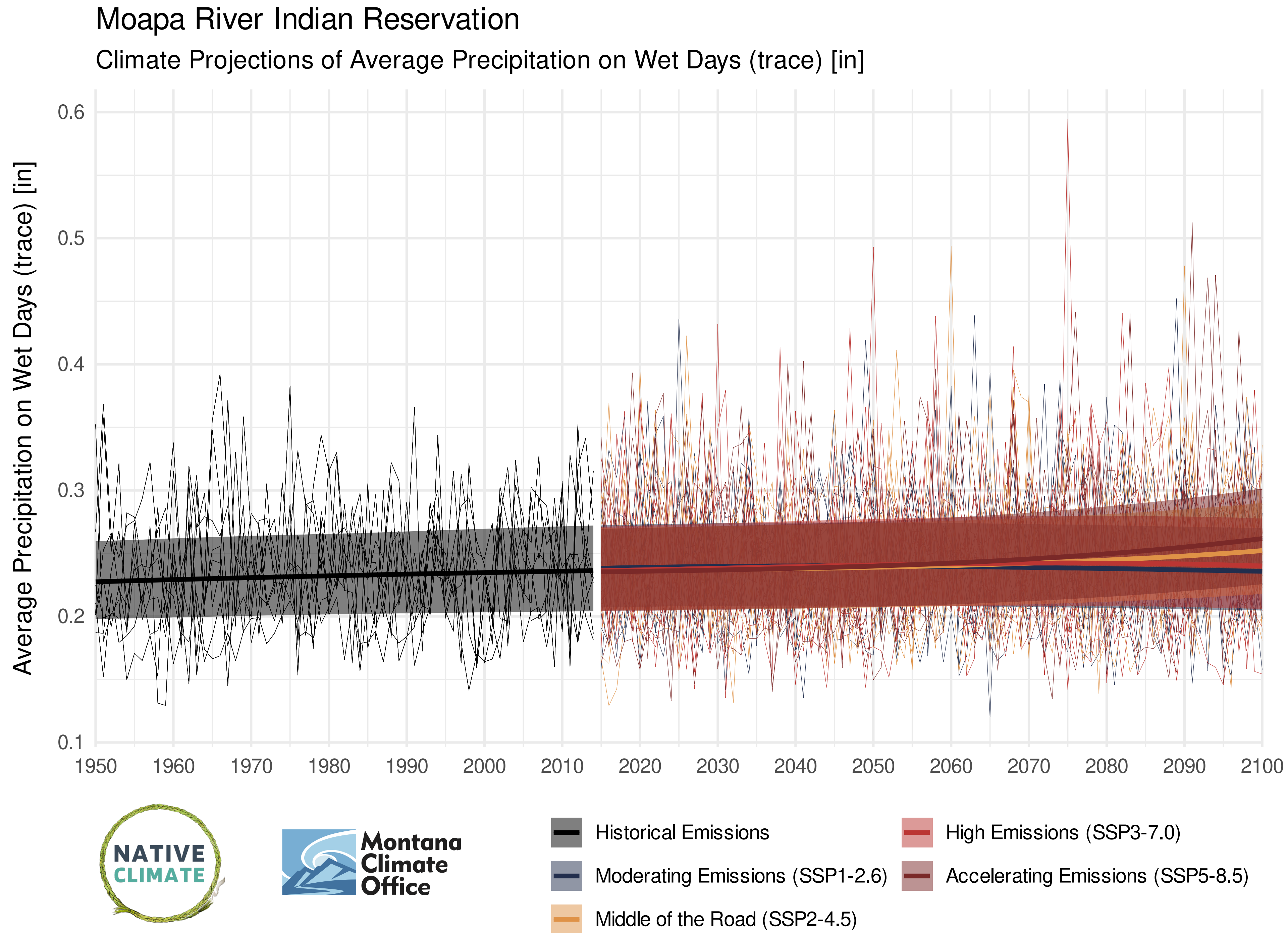
Climate Projections of Average Precipitation on Wet Days [in]





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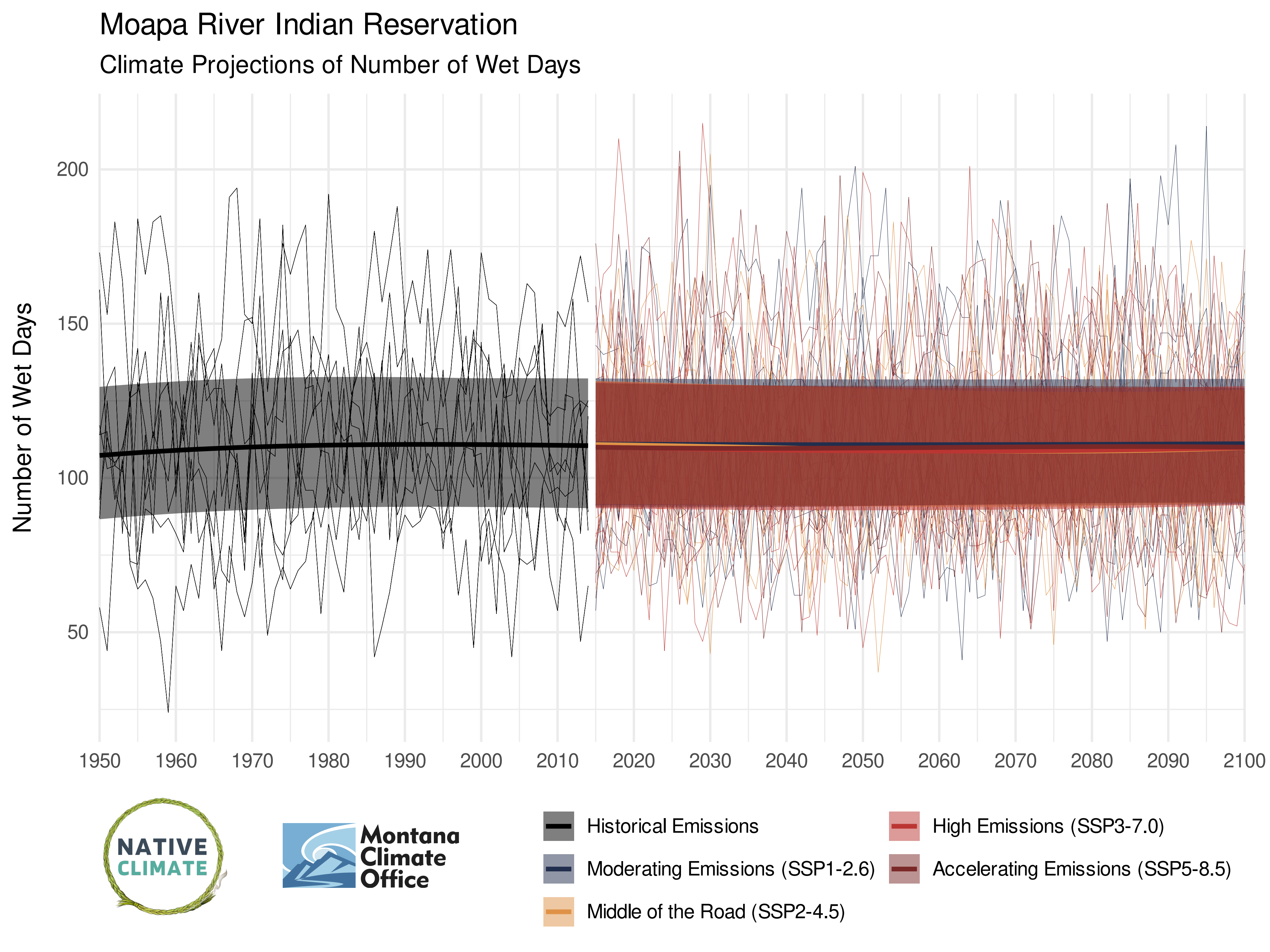

Moapa River Indian Reservation
Climate Projections of Number of Wet Days
Number of Wet Days
200
150
100
50
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)
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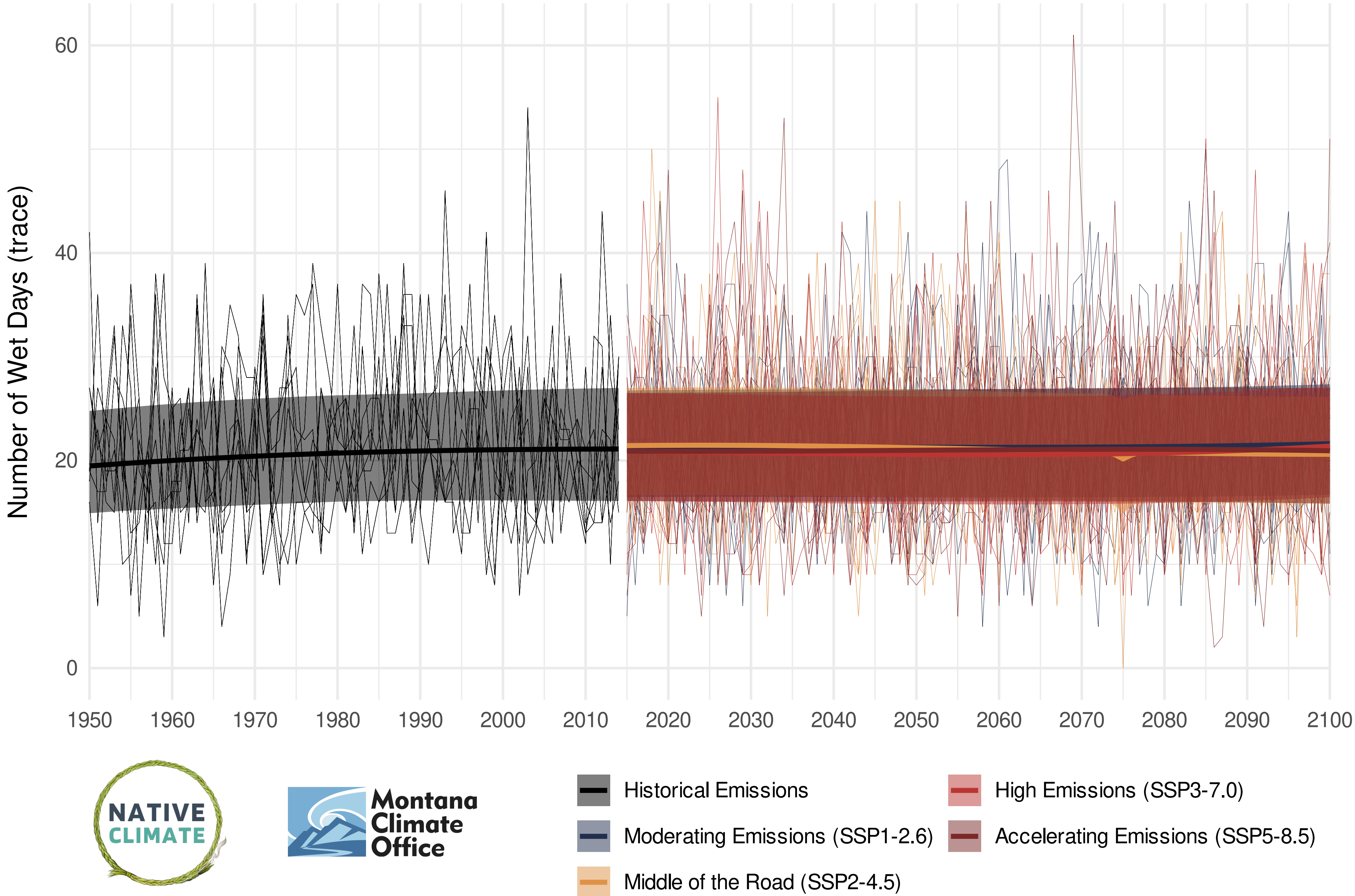
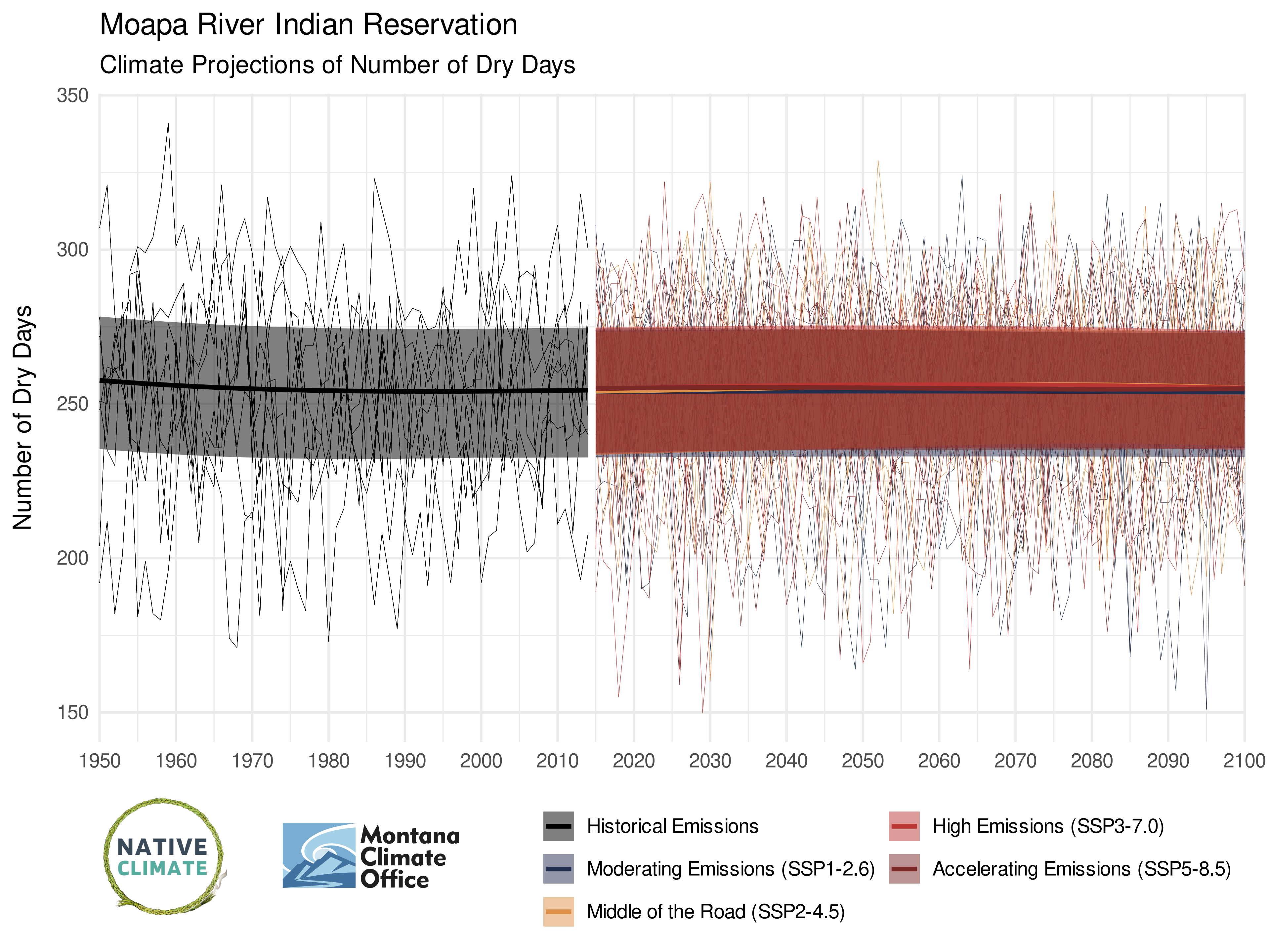
Moapa River Indian Reservation

Climate Projections of Number of Wet Days (trace)




Moapa River Indian Reservation
Climate Projections of Number of Dry Days
Number of Dry Days
350
300
250
200
150
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Historical Emissions
Moderating Emissions (SSP1-2.6)
Middle of the Road (SSP2-4.5)
High Emissions (SSP3-7.0)
Accelerating Emissions (SSP5-8.5)
NATIVE CLIMATE
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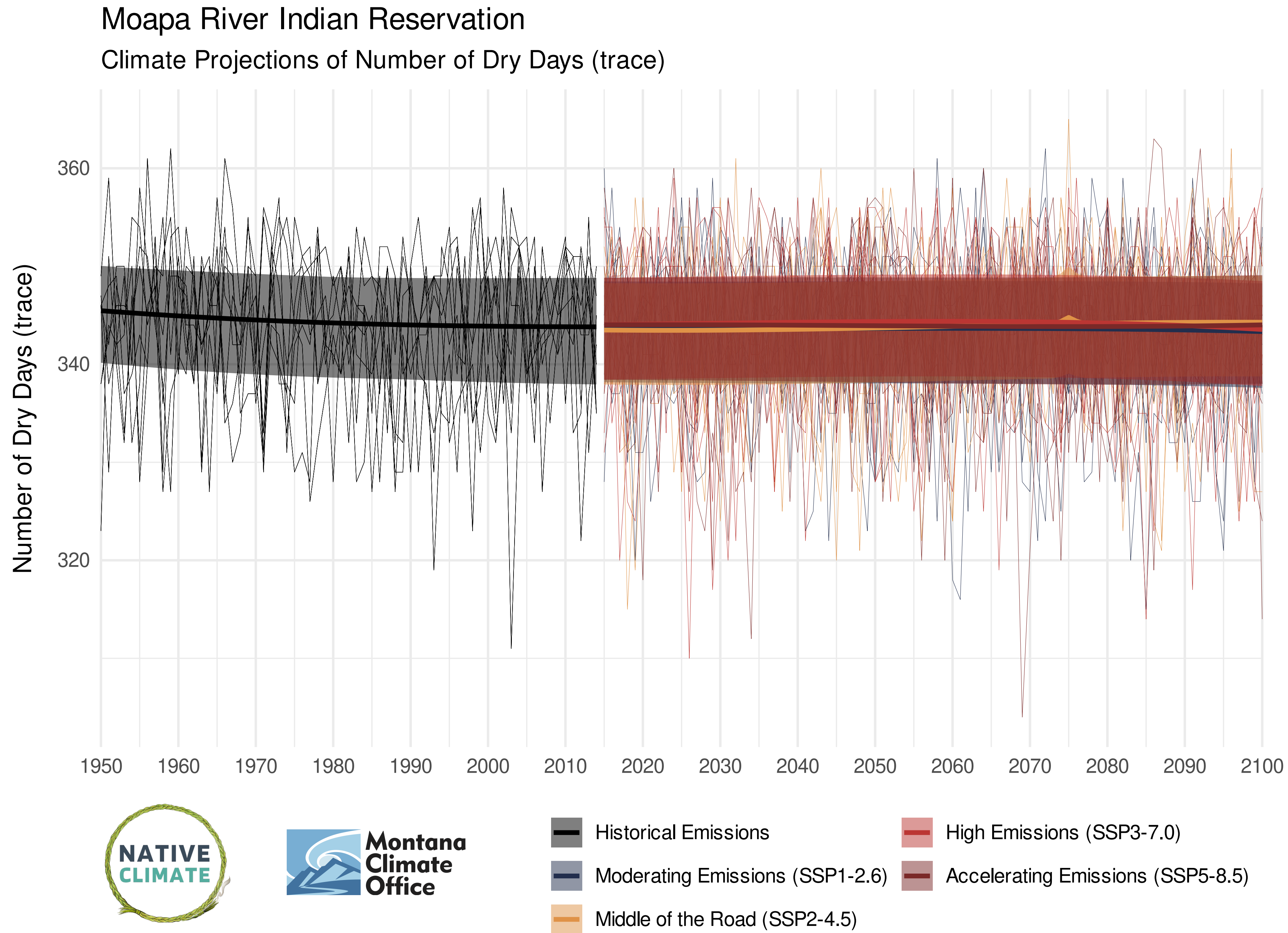

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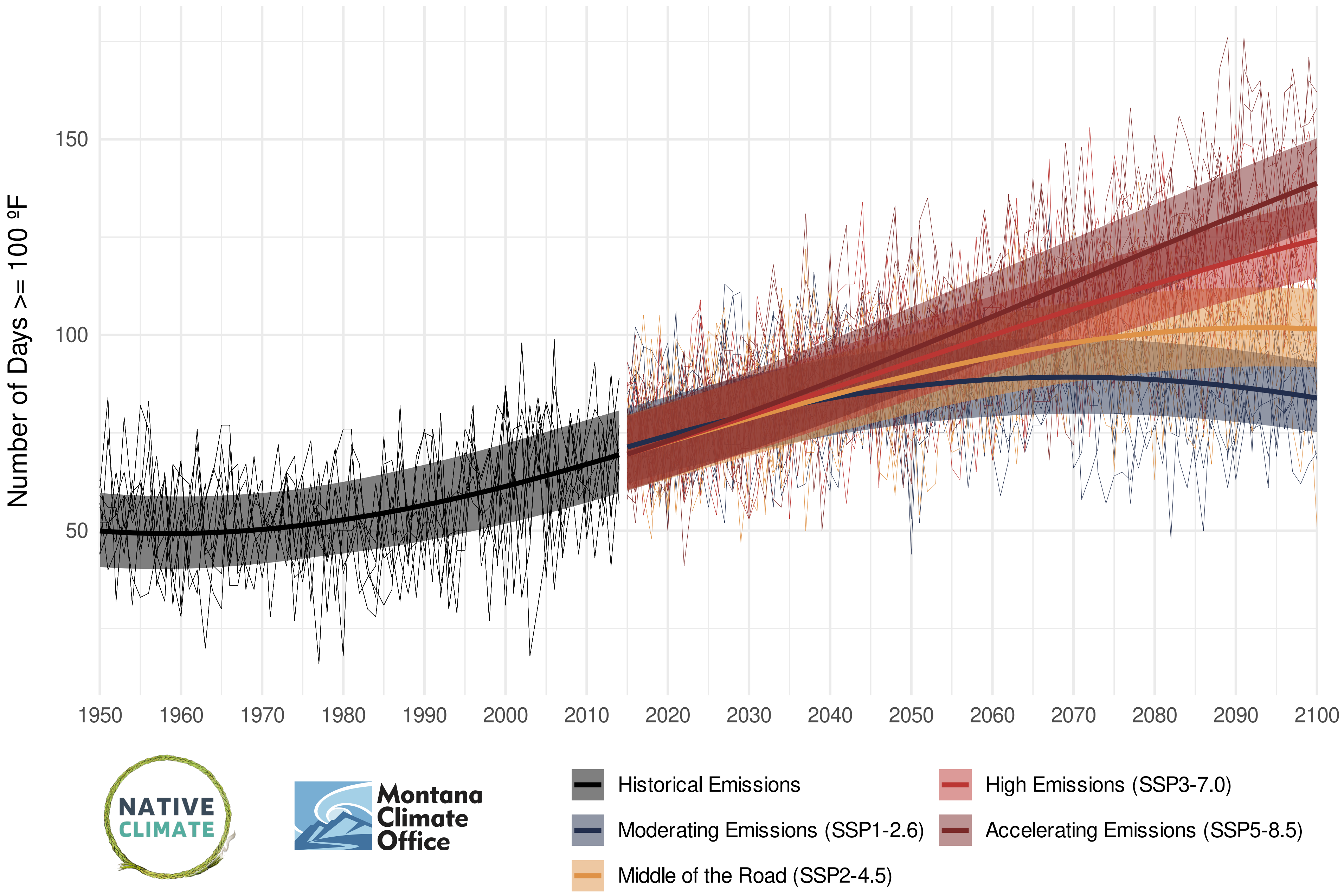
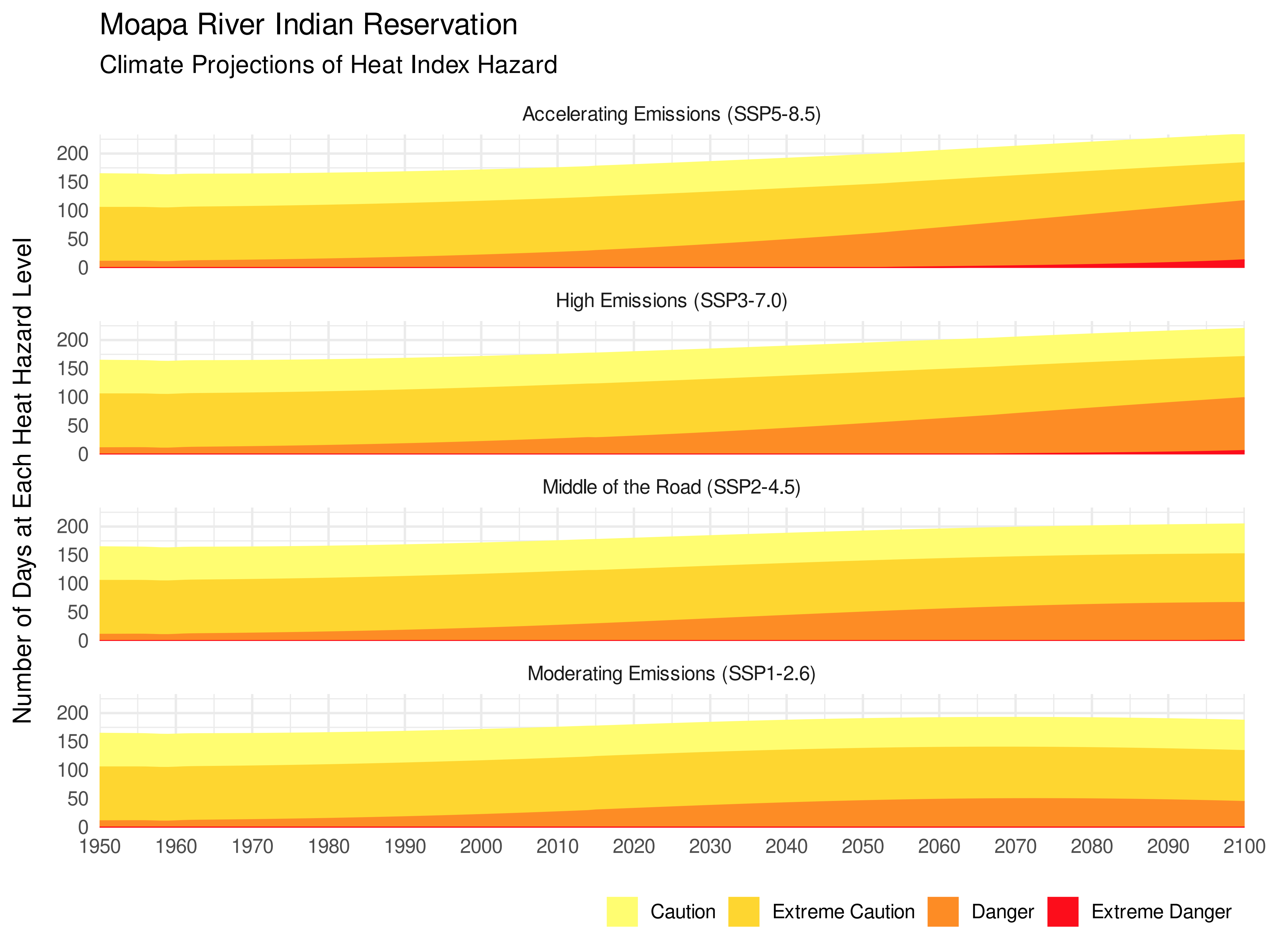
Moapa River Indian Reservation

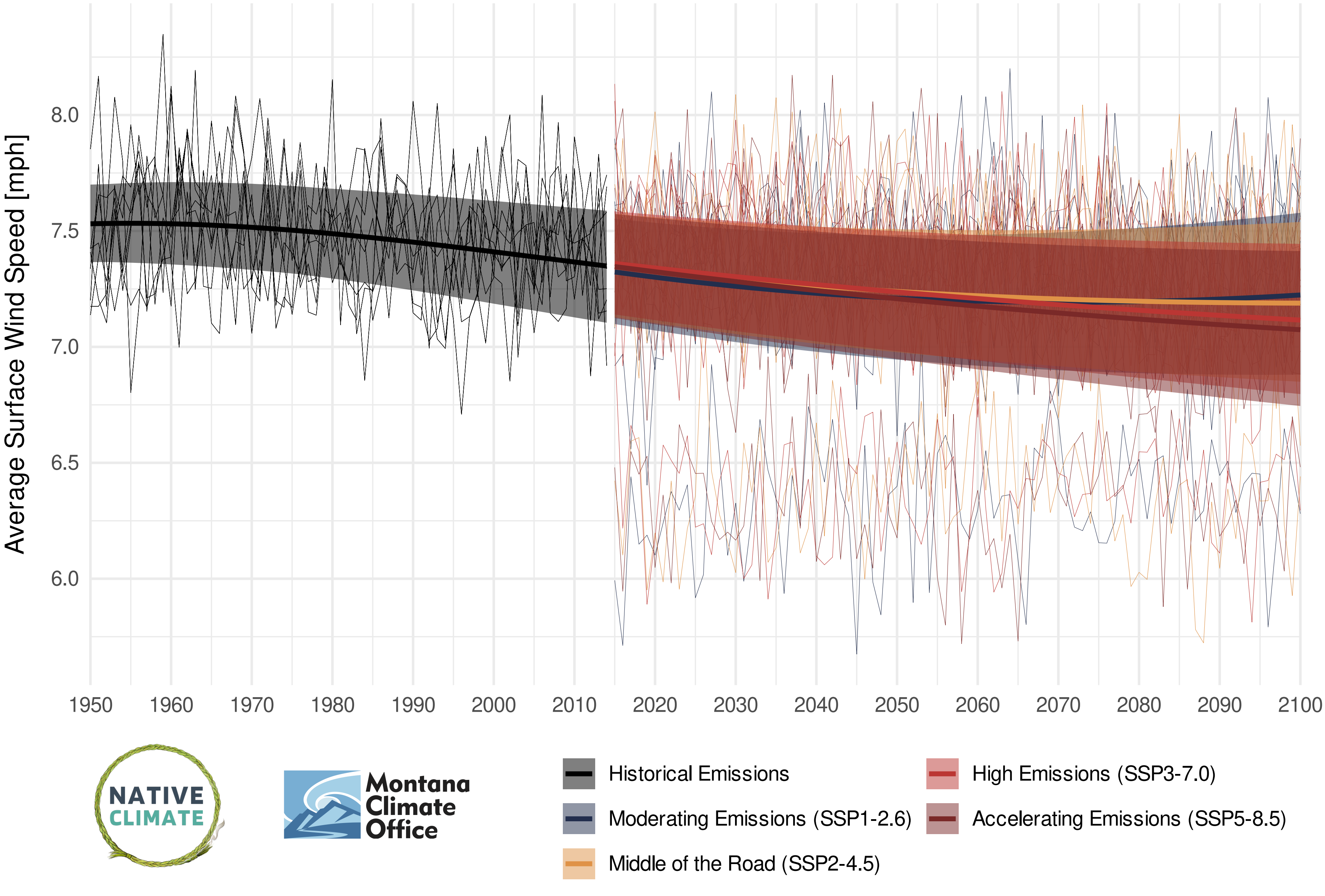
Climate Projections of Number of Days >= 100 ºF




Moapa River Indian Reservation
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)
Number of Days at Each Heat Hazard Level
0
50
100
150
200
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Caution
Extreme Caution
Danger
Extreme Danger

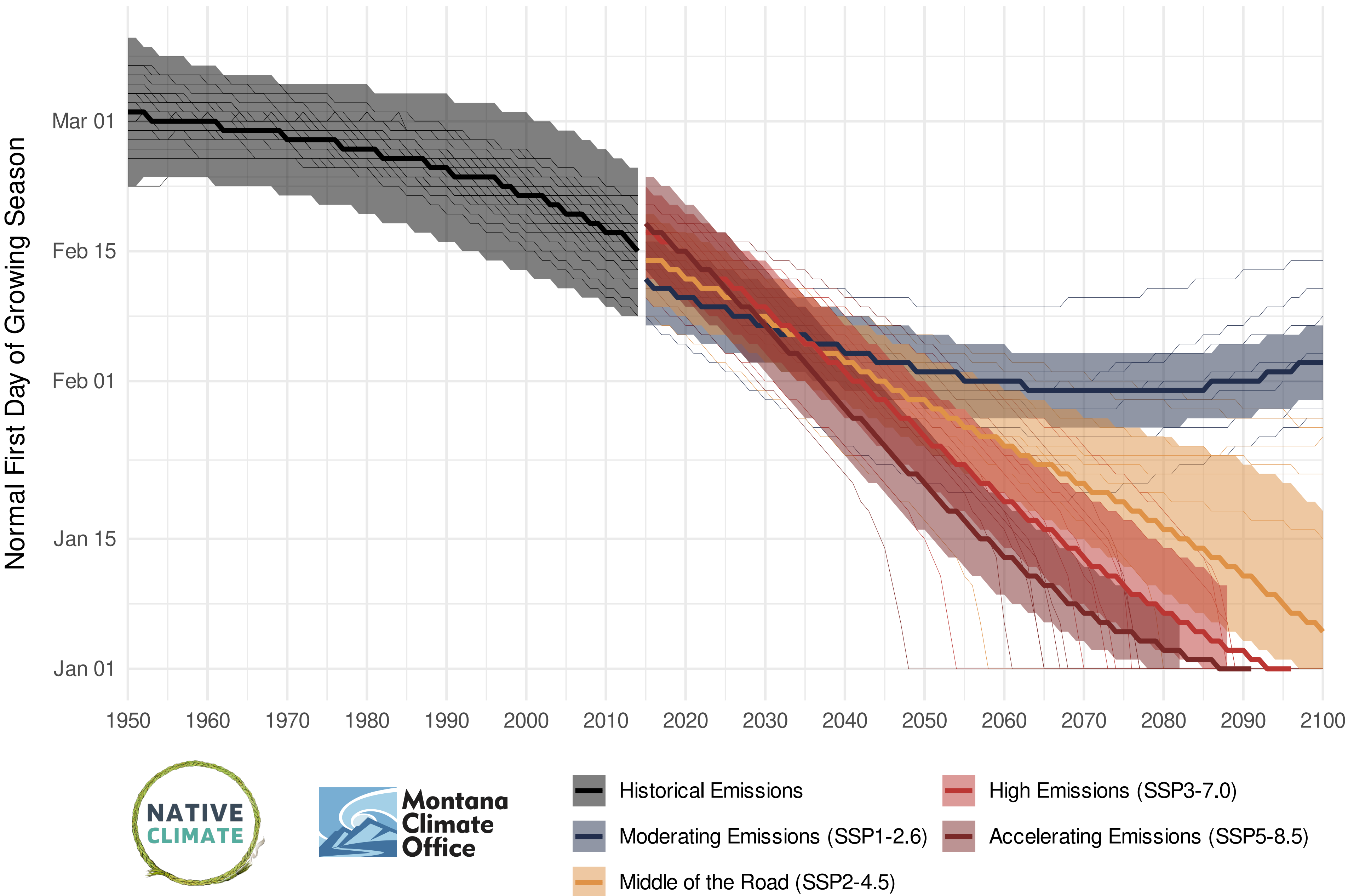
Moapa River Indian Reservation

Climate Projections of Average Surface Wind Speed [mph]



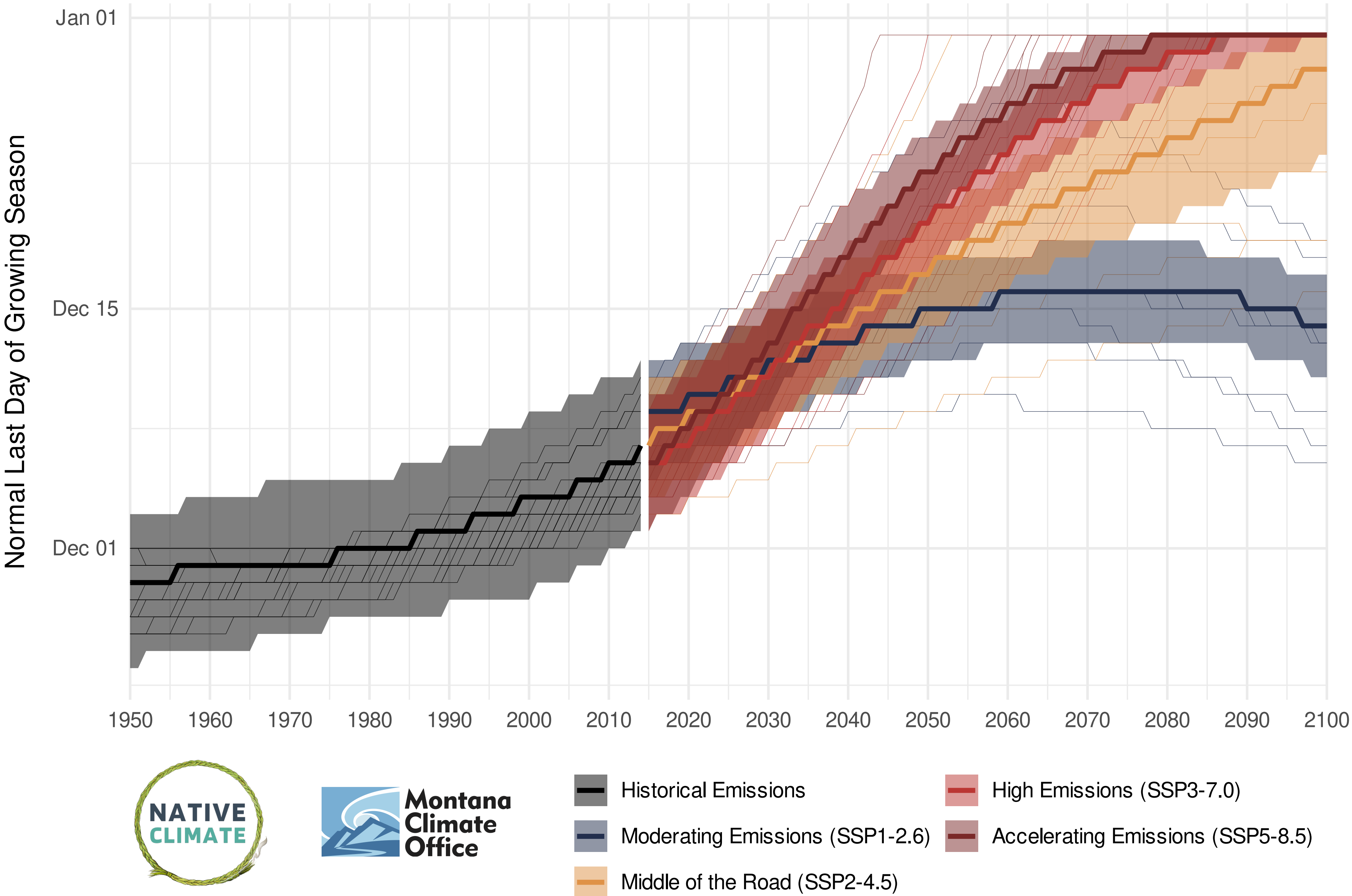
Moapa River Indian Reservation

Climate Projections of Normal First Day of Growing Season



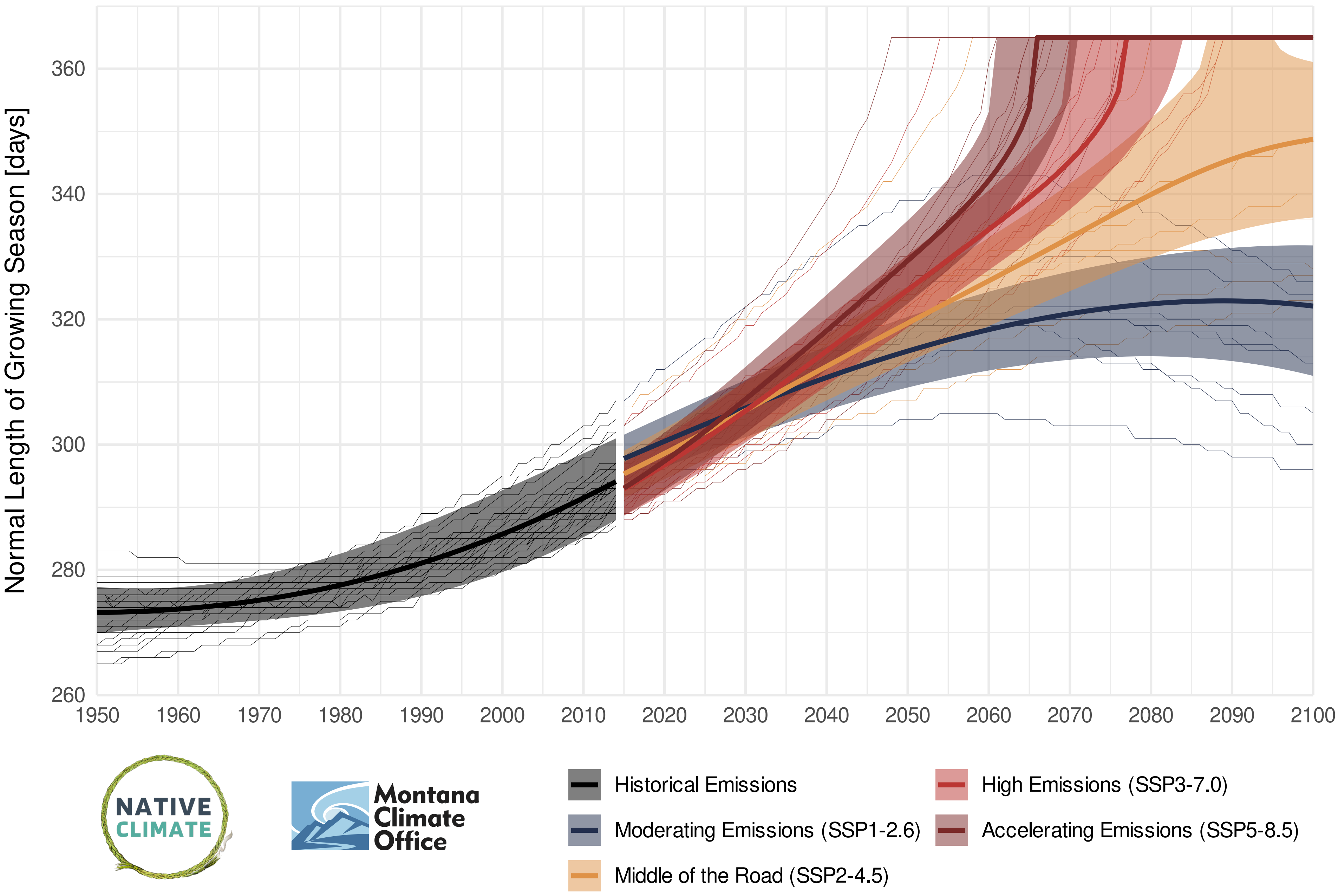
Moapa River Indian Reservation

Climate Projections of Normal Last Day of Growing Season



Moapa River Indian Reservation

Climate Projections of Normal Length of Growing Season [days]



Moapa River Indian Reservation

Climate Projections of Day of First Snow