Climate Change Trends for Planning at Sand Creek Massacre National Historic Site

Prepared by Nicholas Fisichelli, NPS Climate Change Response Program April 18, 2013

Climate change and National Parks

Climate change, in conjunction with other stressors, is impacting all aspects of park management from natural and cultural resources to park operations and visitor experience. Effective planning and management must be grounded in our comprehension of past dynamics as well as the realization that future conditions may shift beyond the range of variability observed in historical data. Climate change will manifest itself not only as shifts in mean conditions (e.g., increasing mean annual temperature) but also as changes in climate variability (e.g., more intense storms and droughts). Put another way, land managers are dealing with both rapid directional change and tremendous uncertainty. Understanding climate change projections and associated levels of uncertainty will facilitate planning actions that are robust regardless of the precise magnitude of change experienced in the coming decades.

Historical and Projected National and Regional Climate Trends

Text and figures in this section are directly from the National Climate Assessment (http://ncadac.globalchange.gov/)

Historical Temperature Trends

"U.S. average temperature has increased by about 1.5°F since record keeping began in 1895; more than 80% of this increase has occurred since 1980 (Figure 1). The most recent decade was the nation's warmest on record and U.S. temperatures are expected to continue to rise. Because human-induced warming is superimposed on a naturally varying climate, the temperature rise has not been, and will not be, smooth across the country or over time… The cooling in mid-century that was especially prevalent over the eastern half of the U.S. may have stemmed partly from the cooling effects of sulfate particles from coal burning power plants (Leibensperger et al. 2012), before these sulfur emissions were regulated to address health and acid rain concerns... Since 1991, temperatures have averaged 1°F to 1.5°F higher than 1901-1960 over most of the U.S., except for the Southeast, where the warming has been less than 1°F. On a seasonal basis, long-term warming has been greatest in winter and spring."

Historical Precipitation Change

"Precipitation averaged over the entire U.S. has increased during the period since 1900 (+5%), but regionally some areas have had increases greater than the national average, and some areas have had decreases (Figure 1). The largest increases have been in the Midwest, southern Great Plains, and Northeast. Portions of the Southeast, the Southwest, and the Rocky Mountain states have experienced decreases."

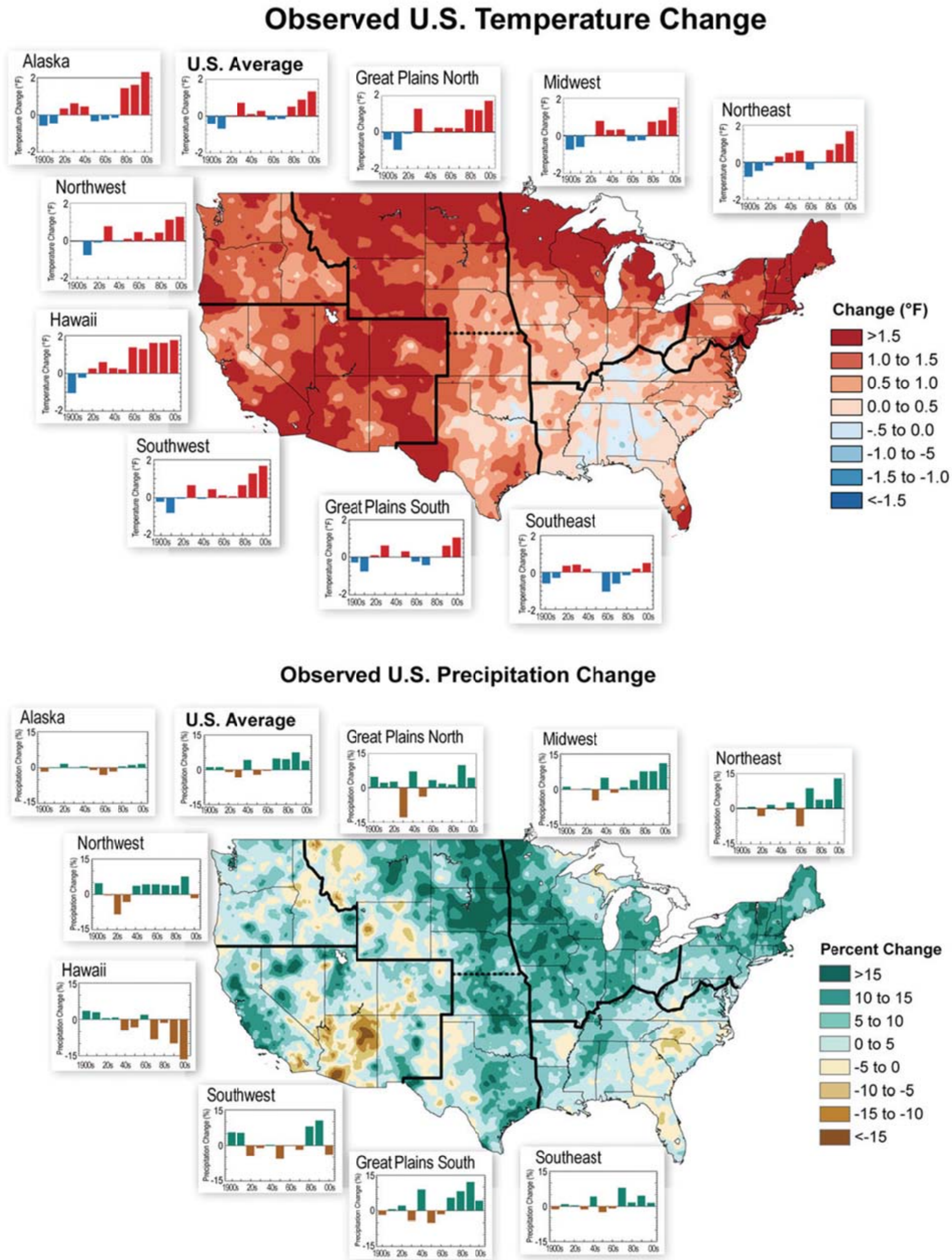


Figure 1. Observed U.S. temperature and precipitation changes. The colors on the maps show changes over the past 20 years (1991-2011) compared to the 1901-1960 average. The bars on the graphs show the average changes by decade for 1901-2011 (relative to the 1901-1960 average) for each region. The period from 2001 to 2011 was warmer than any previous decade in every region. (Figure source: NOAA NCDC / CICS-NC. Data from NOAA NCDC.)

Projected 21st Century Temperature Change

Warming patterns of the past several decades are projected to continue across the entire country. “In the next few decades, this warming will be roughly 2°F to 4°F in most areas. By the end of the century, U.S. warming is projected to correspond closely to the level of global emissions: roughly 3°F to 5°F under lower greenhouse gas emissions scenarios (B1) involving substantial reductions in emissions, and 5°F to 10°F for higher emissions scenarios (A2) that assume continued increases in emissions (Figure 2). The largest temperature increases are projected for the upper Midwest and Alaska.” (It is important to note that the recent trajectory of atmospheric greenhouse gas emissions is above that of the A2 higher emissions scenario (Friedlingstein et al. 2010).)

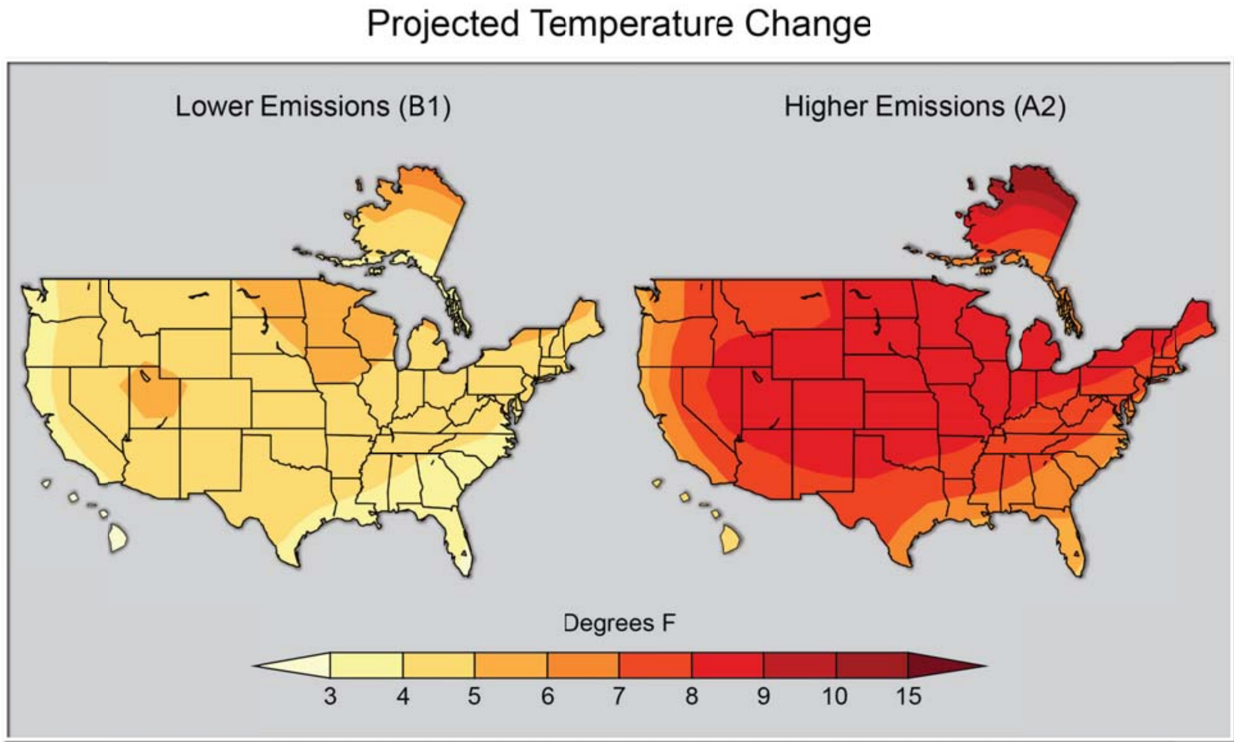


Figure 2. Projected Temperature Change. Maps show projected change in average surface air temperature in the later part of this century (2070-2099) relative to the later part of the last century (1971-1999) under a scenario that assumes substantial reductions in heat trapping gases (B1, left) and a higher emissions scenario that assumes continued increases in global emissions (A2, right). Projected changes are averages from 15 CMIP3 models for the A2 scenario and 14 models for the B1 scenario. (Figure source: adapted from (Kunkel et al. 2012).)

Projected 21st Century Precipitation Changes

Continuing increases in the emissions of greenhouse gases is projected to alter precipitation patterns across much of North America (Figure 3). “More winter and spring precipitation is projected for the northern U.S., and less for the Southwest, over this century. The projected changes in the northern U.S. are a consequence of both a warmer atmosphere and associated large-scale circulation changes. Warmer air can hold more moisture than colder air, leading to more intense rainfall. The projected reduction in Southwest precipitation is a result of large-scale circulation changes caused by increased heating of the global atmosphere.”

“Drier conditions in the summer are projected in most areas of the contiguous U.S, but outside of the Northwest and south-central region, there is generally not high confidence that the changes will be large compared to natural variability. In all models and scenarios, a transition zone between drier (to the south) and wetter (to the north) shifts northward from the southern U.S. in winter to southern Canada in summer. Wetter conditions are projected for Alaska and northern Canada in all seasons.”

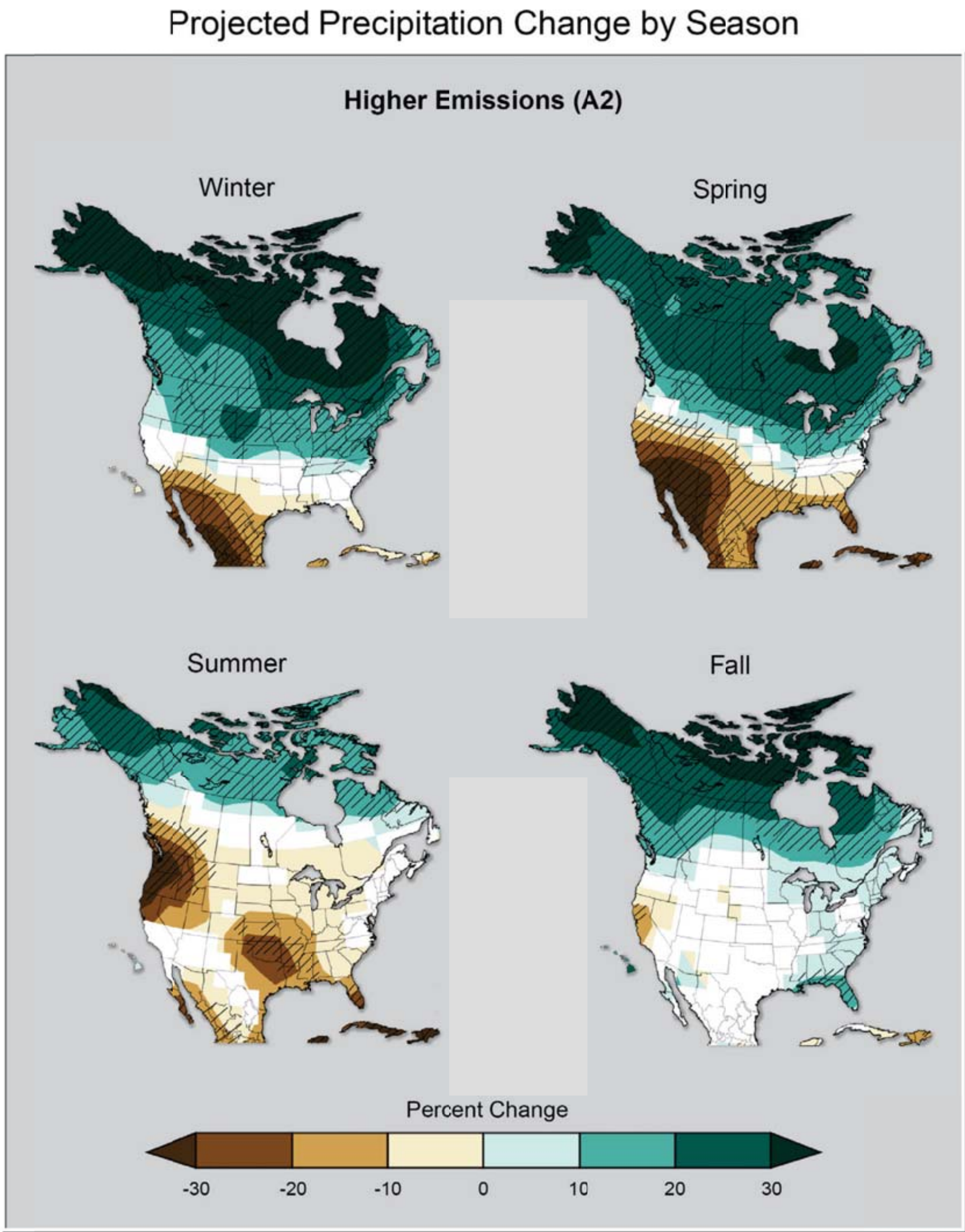


Figure 3. Projected percent change in seasonal precipitation for 2070-2099 (compared to the period 1901-1960) under an emissions scenario that assumes continued increases in emissions (A2). Teal indicates precipitation increases, and brown, decreases. Hatched areas indicate

confidence that the projected changes are large and are consistently wetter or drier. White areas indicate confidence that the changes are small. Wet regions tend to become wetter while dry regions become drier. In general, the northern part of the U.S. is projected to see more winter and spring precipitation, while the Southwest is projected to experience less precipitation in the spring. (Figure source: NOAA NCDC / CICS-NC. Data 11 from CMIP3; analyzed by Michael Wehner, LBNL)

See the National Climate Assessment for more in-depth information (http://ncadac.globalchange.gov/)

Historical and Projected Climate Trends for the Region Including Sand Creek Massacre National Historic Site

Historical climate trends (1895-2011)

Historical climate trends for Sand Creek Massacre National Historic Site are based on historic climate data from a nearby long-term weather station (Eads, CO, station 052446, approximately 12 miles west of the park) acquired from the United States Historical Climatology Network (cdiac.ornl.gov). Over the 117 year instrumental record (1895-2011) mean annual temperature showed an increasing linear trend (+0.18 °F (+0.1 °C) per decade, $p<0.0001$) (Figure 5). Seasonal temperature changes were strongest in winter (+0.34 °F (+0.19 °C) per decade, $p<0.0001$) and spring (+0.23 °F (+0.13 °C) per decade, $p<0.0001$) (Figure 6). Annual and seasonal precipitation did not exhibit significant linear trends over the instrumental record period (Figures 5, 7).

Future climate projections

Future climate projections for the area including Sand Creek Massacre NHS are from multi-model averaged data (Kunkel et al. 2012b). Mean annual temperature, compared with the 1971-1999 average, is projected to increase 4-5 °F by mid-century and 5-8 °F by the end of the century, depending on the greenhouse gas emissions scenario (Table 1). Current greenhouse gas emissions are on a trajectory above the high (A2) scenario (IPCC 2007, Friedlingstein et al. 2010). Warming by mid-century is projected for all seasons, with the greatest increase likely in summer (Figure 8). There is wide agreement among individual climate models in the direction and magnitude of warming over the coming decades.

Precipitation projections indicate very small to moderate decreases in the annual total, depending on the emissions scenario (Table 1), and divergent patterns among seasons (Figure 9). Annual precipitation by mid-century may decrease (-3 to -6%), with the greatest decrease coming in summer (-10 to -15%) and a projected increase in winter (+10 to +15%), compared with 1971-1999 values (Kunkel et al. 2013). Annual and seasonal precipitation variability is likely to remain large over the coming decades, and there is greater uncertainty in precipitation than temperature projections.

In addition to warmer mean temperatures and changes in total precipitation, climate change will manifest itself in many other ways. This includes more frequent heat waves, droughts, floods, and an extended frost-free season. Small changes in total annual precipitation may mask large shifts in the precipitation regime and associated impacts to ecosystems. For example, fewer but larger rain events will lead to both more frequent droughts and more severe flooding and erosion.

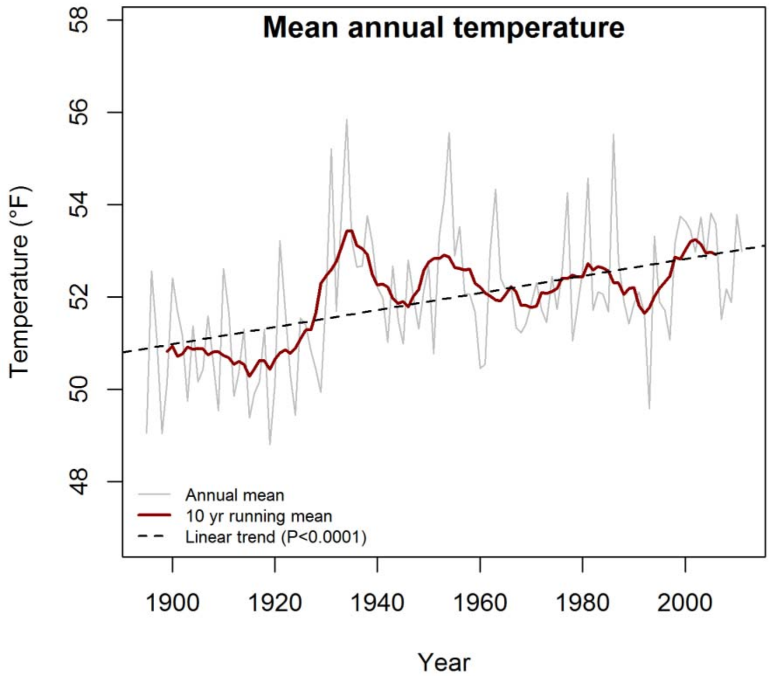
Table 1. Projected annual temperature and precipitation changes for three future time periods compared with the 1971-1999 average. Two greenhouse gas emissions scenarios are presented, the low (B1) and high (A2) scenarios (IPCC 2007). Projected changes are based on multi-model means from 14-15 CMIP3 climate models. (Data from Kunkel et al. 2012b, see Figures 14, 25).

Temperature Difference from 1971-1999

Years	Greenhouse Gas Emissions Scenario		Confidence in Projection
	Low (B1)	High A2	
2021-2050	+3 °F	+3 °F	High
2041-2070	+4 °F	+5 °F	High
2070-2099	+5 °F	+8 °F	High

Precipitation Difference (%) from 1971-1999

Years	Greenhouse Gas Emissions Scenario		Confidence in Projection
	Low (B1)	High A2	
2021-2050	0% to -3%	0% to -3%	Low
2041-2070	0% to -3%	-3% to -6%	Medium
2070-2099	0% to -3%	-6% to -9%	Medium



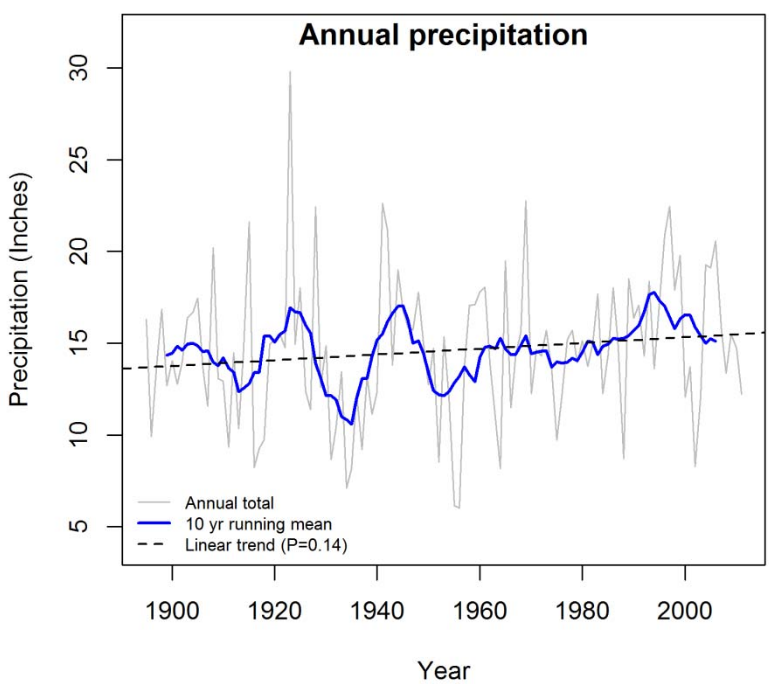


Figure 5. Mean annual temperature and annual precipitation (1895-2011) from the Eads, CO long-term weather station (cdiac.ornl.gov).

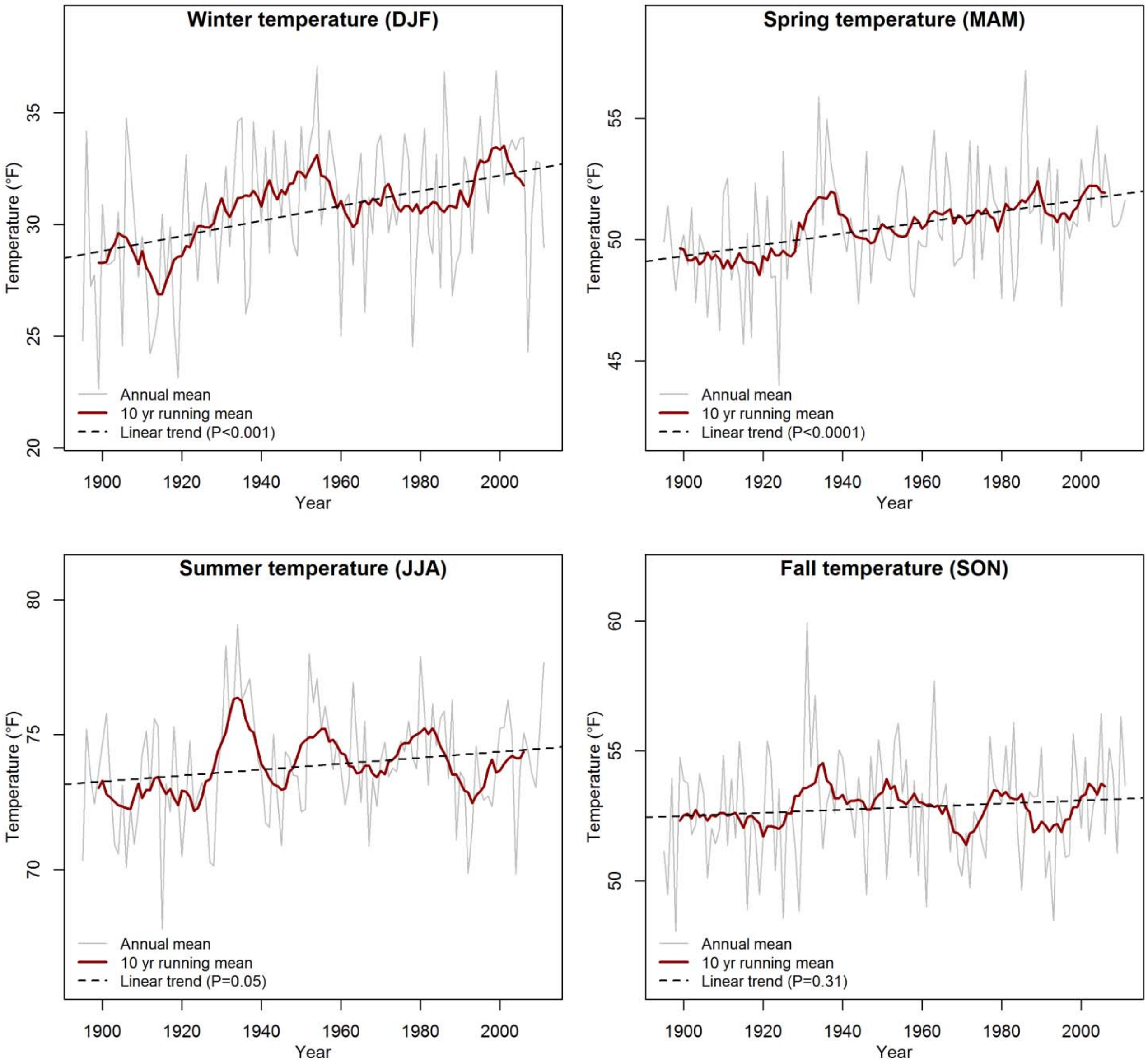


Figure 6. Seasonal temperature trends (1895-2011) from the Eads, CO long-term weather station (cdiac.ornl.gov).

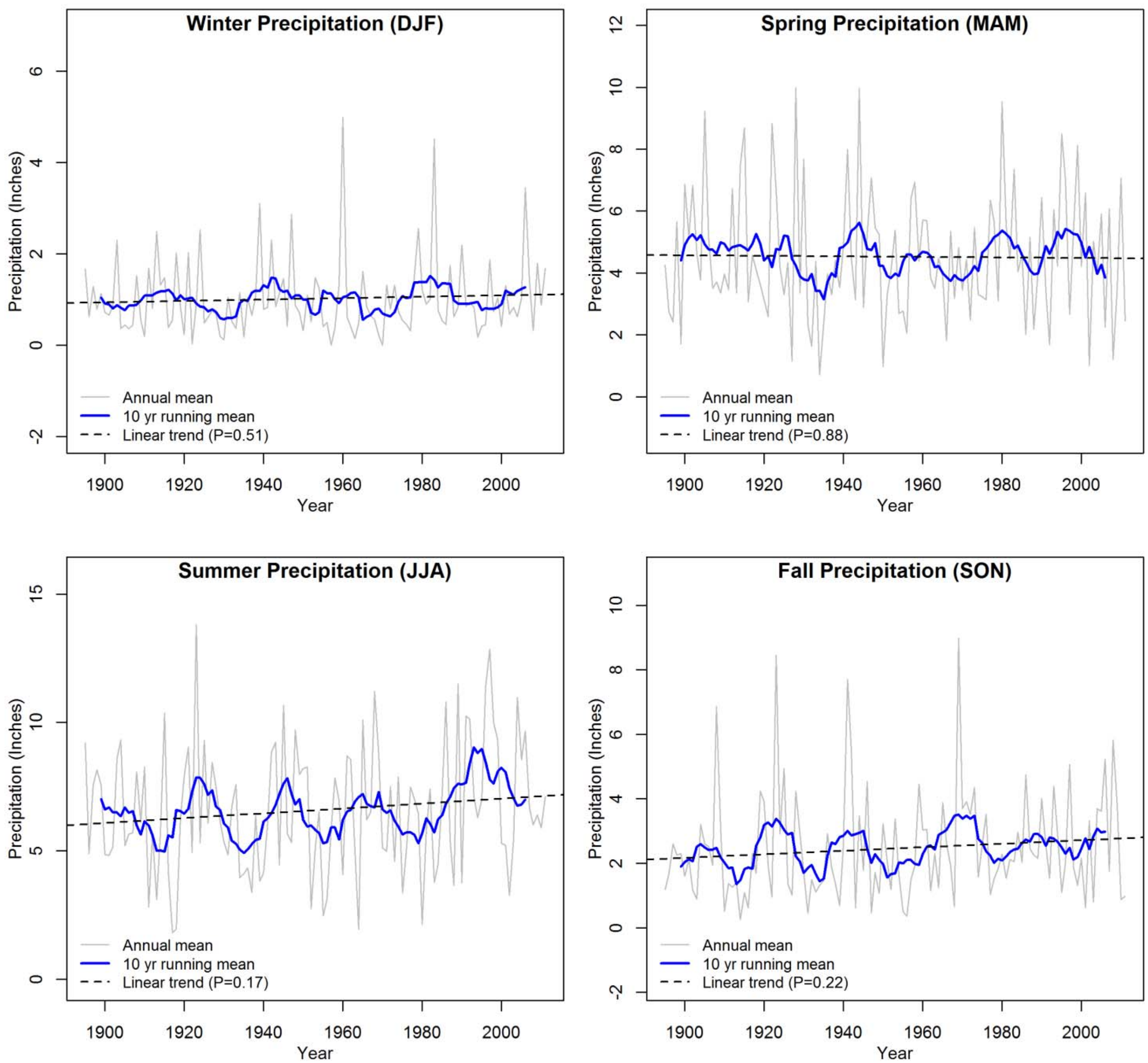


Figure 7. Seasonal precipitation trends (1895-2011) from the Eads, CO long-term weather station (cdiac.ornl.gov).

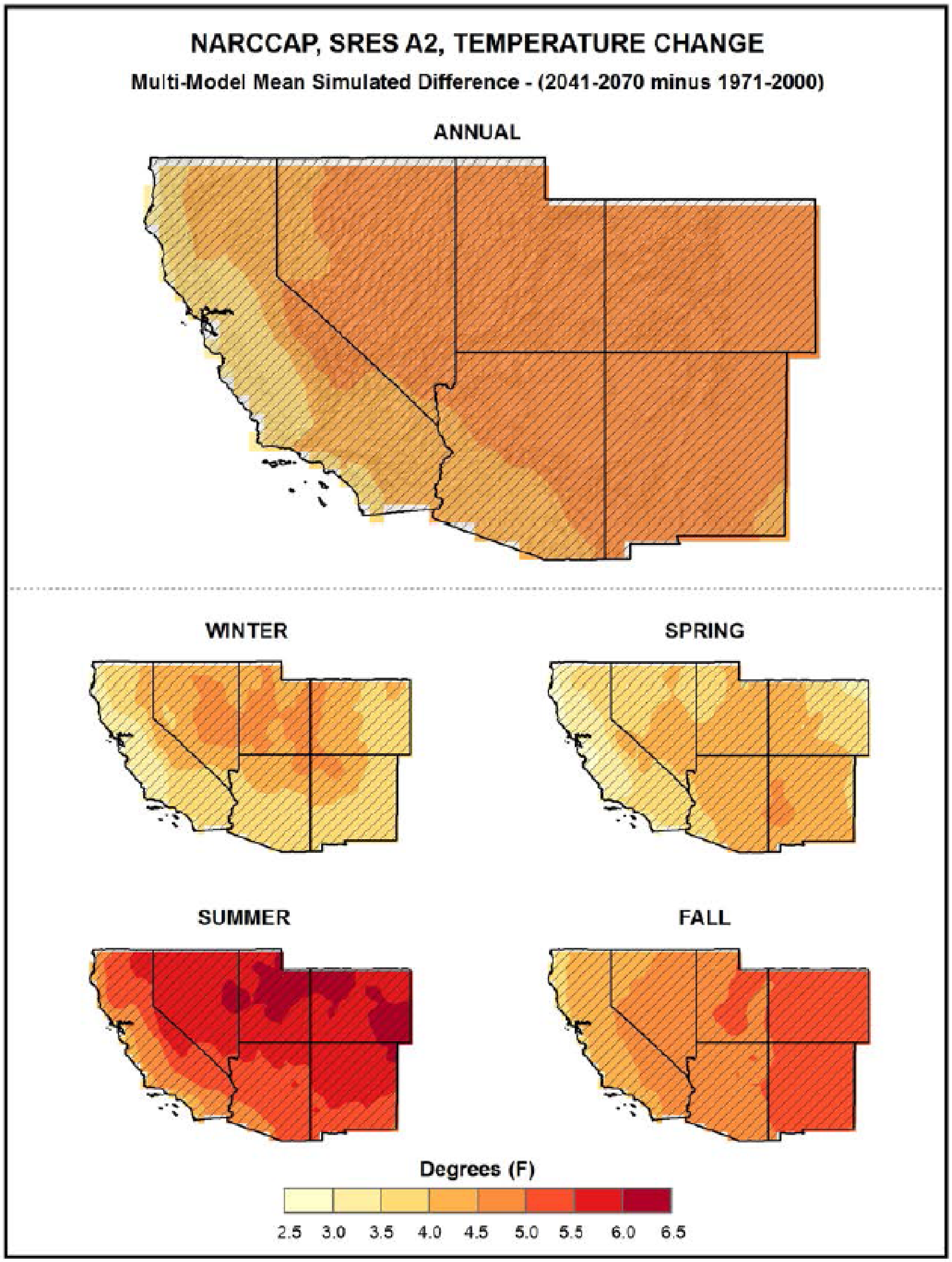


Figure 8. Projected annual and seasonal temperature change. Maps show projected change in average surface air temperature in mid-century (2040-2070) relative to the later part of the last century (1971-1999). Projected changes are averages from 11 NARCCAP regional climate simulations for the high (A2) emissions scenario. Color with hatching indicates that more that 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change. Figure from Kunkel et al. (2012b).

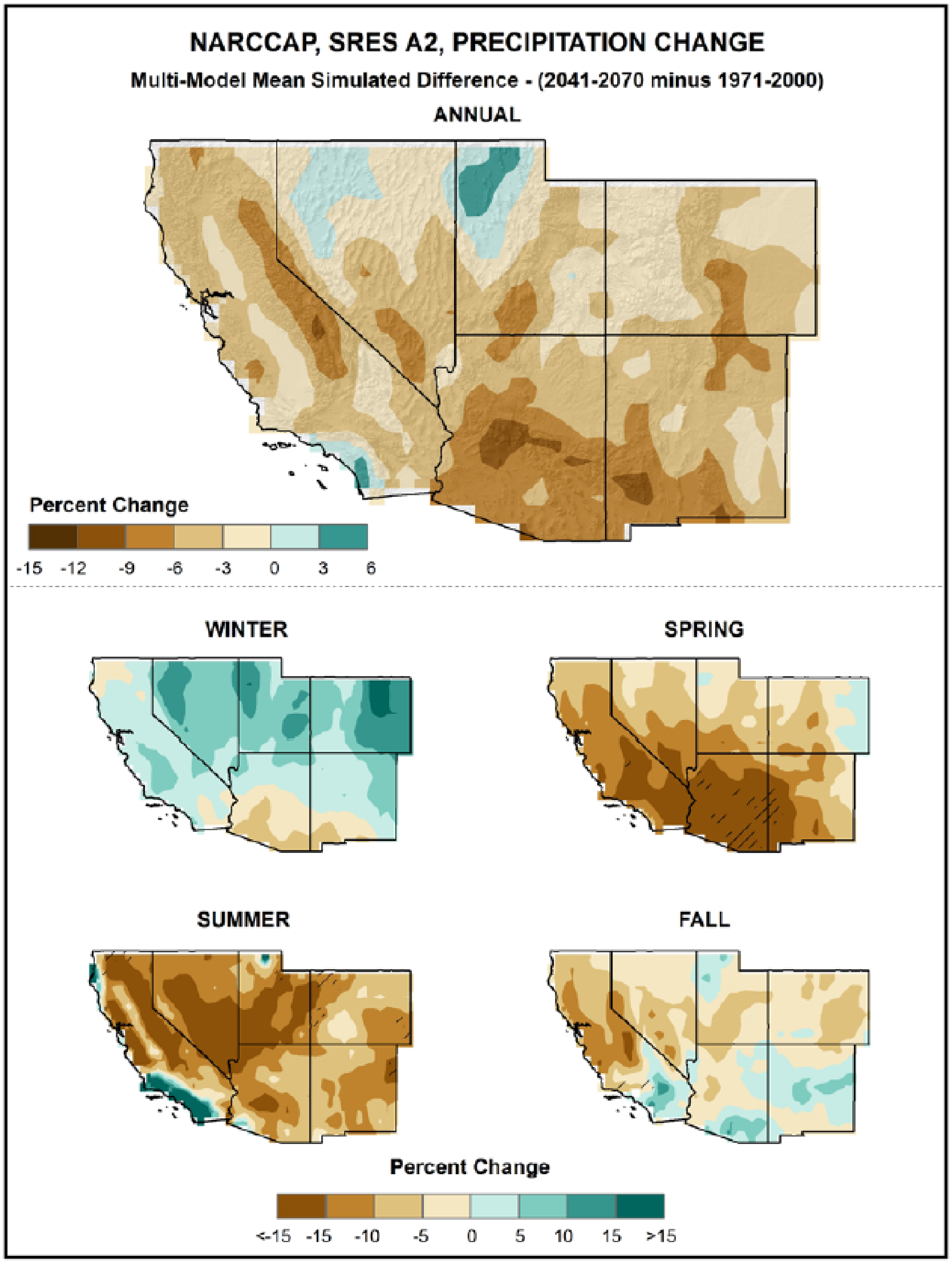


Figure 9. Projected annual and seasonal precipitation change. Maps show projected change in precipitation for mid-century (2040-2070) relative to the later part of the last century (1971-2000). Projected changes are averages from 11 NARCCAP regional climate simulations for the high (A2) emissions scenario. Color only indicates that less than 50% of the models show a statistically significant change in precipitation. Color with hatching indicates that more that 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change. Figure from Kunkel et al. (2012b).

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