

Climate Change Trends for the State of the Park Report, Horseshoe Bend National Military Park, Alabama

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March 26, 2014

Climate Change and National Parks

Climate change, in conjunction with other stressors, impacts 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 historical range of variability. Climate change will manifest itself not only as shifts in mean conditions (e.g., increasing mean annual temperature and sea level) but also as changes in climate variability (e.g., more intense storms and flooding). These changes may alter the vegetation composition and structure of cultural landscapes and accelerate weathering, deterioration, and loss of other cultural resources. Land managers are dealing with both rapid directional change and tremendous uncertainty (Heller and Zavaleta 2009). 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 climate trends

Climate trends for Horseshoe Bend National Military Park show complex patterns that vary across time periods and with specific climate measures. Historical annual climate trends (1895-2010) for the park are based on gridded climate data acquired from the PRISM Climate Group (<http://www.prism.oregonstate.edu>). Across the entire 116 year record, mean annual temperature showed a significant decreasing linear trend (-0.17°F [-0.09°C] per decade, $p < 0.0001$); however, since 1960 annual temperature has shown a significant increasing trend ($+0.2^{\circ}\text{F}$ [$+0.11^{\circ}\text{C}$] per decade, $p=0.01$; Figure 1). Annual precipitation showed strong interannual variability and no significant linear trend across the entire record (Figure 1).

A separate analysis, using climate data from Harris et al. (2013), found mean temperature for the driest quarter (3 months of the year) over the past 10-30 years to be warmer than 95% of all other periods of equal length since 1901, and for precipitation during the wettest month over the past 10-30 years to be greater than 95% of all previous periods since 1901 (Monahan and Fisichelli *In revision*). These patterns suggest more intense recent intra-annual variability for Horseshoe Bend, namely hotter conditions during the driest time of year and wetter conditions during the already wettest month of the year.

Future climate projections

Although recent climate change trends have been relatively weak in the Southeast compared with other regions of the country, such as the Northeast and Alaska, considerable future changes are projected across the Southeast. Future climate projections for the area including Horseshoe Bend are from multi-model averaged data (Kunkel et al. 2013). Mean annual temperature, compared with the 1971-1999 average, is projected to increase 3-4 $^{\circ}\text{F}$ by mid-century and 4-7 $^{\circ}\text{F}$ by the end of the century, depending on the greenhouse gas emissions scenario (Figure 1). Past greenhouse gas emissions, long residence times of these gases in the atmosphere, and our current emissions trajectory suggest that climate change will be substantial (Wigley 2005, Peters et al. 2012). Warming by mid-century is projected for all seasons, with the

greatest increases likely in summer (Figure 2). There is broad agreement among climate models in the direction and general magnitude of warming over the coming decades. Total annual precipitation may increase slightly by mid-century (Figure 1, 3); however, precipitation variability is likely to remain large over the coming decades, and there is greater uncertainty in precipitation than temperature projections (Kunkel et al. 2013).

In addition to warmer mean temperatures and changes in annual and seasonal precipitation, climate change will exhibit itself in many other ways within the region including Horseshoe Bend. These include more frequent heat waves, droughts, floods, and an extended frost-free season. The annual number of days with maximum temperatures $> 95^{\circ}\text{F}$ is projected to increase 25-30 days by mid-century while the number of days with minimum temperatures below freezing is projected to decrease by 15-20 days (high [A2] emissions scenario 2041-2070 compared with 1980-2000; Kunkel et al. 2013). Small changes in total precipitation may mask large shifts in the precipitation regime and associated impacts to ecosystems. The annual number of days with heavy rainfall (> 1 inch) is projected to increase by 10-15 %, while the maximum number of days between rain events may increase by a few days (high [A2] emissions scenario, 2041-2070 compared with 1980-2000; Kunkel et al. 2013). Significantly warmer temperatures and a more variable precipitation regime may lead to both more frequent droughts and more severe flooding and erosion. See the draft National Climate Assessment for more in-depth information on climate change projections and impacts (NCADAC 2013; <http://ncadac.globalchange.gov/>).

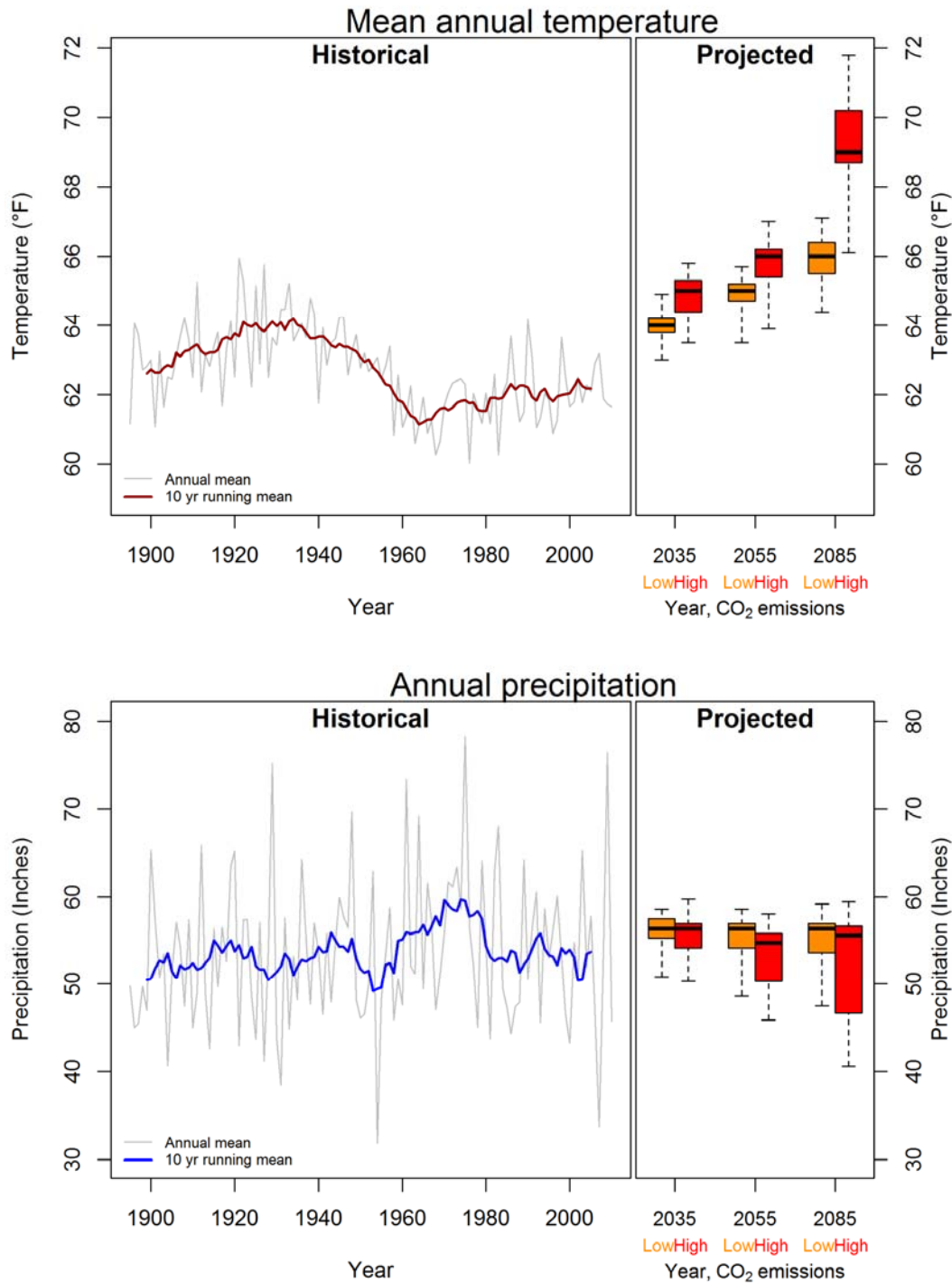


Figure 1. Historical and projected mean annual temperature and annual precipitation for Horseshoe Bend National Military Park. Historical data (1895-2010) for the park are averaged from PRISM gridded climate data (<http://www.prism.oregonstate.edu>). Projected climate change (30 year means) for the region including the park (data from Kunkel et al. 2013, see Tables 4, 6 and Figures 26, 37) are for three future time periods centered on 2035 (2021-2050), 2055 (2041-2070), and 2085 (2070-2099). Two greenhouse gas emissions scenarios are presented, the **low** (B1) and **high** (A2) scenarios (IPCC 2007). Projected climate boxplots indicate the variability in future projections among 14-15 CMIP3 climate models. Values for the area including the park are based on the mean model output for that location and the range of climate model projections for the region: the bold horizontal black line represents the mean among all models, the upper and lower bounds of the boxes indicate the 25th and 75th percentile model output values and the whiskers show the minimum and maximum values.

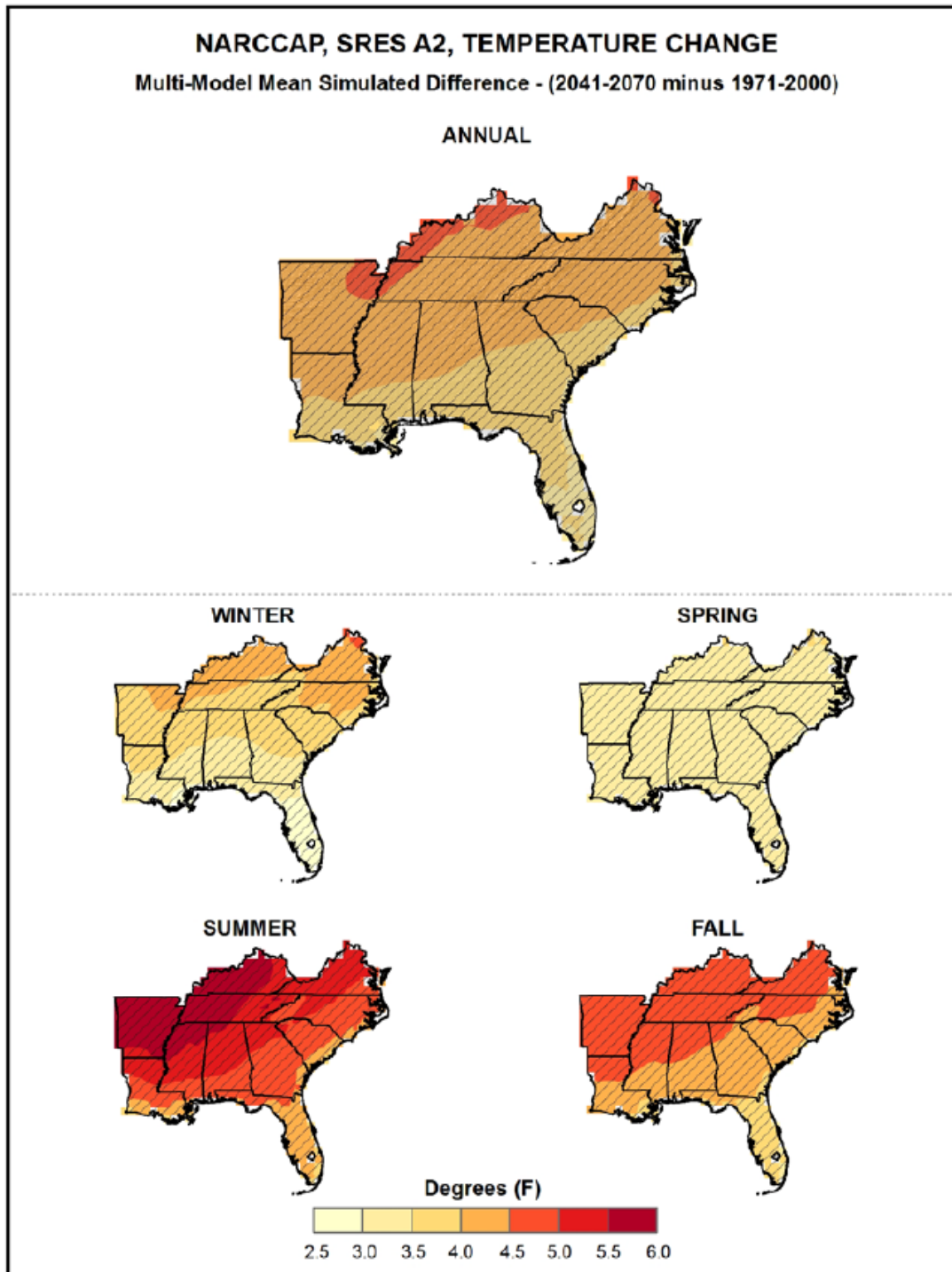


Figure 2. Projected annual and seasonal temperature change. Maps show projected change in average surface air temperature in mid-century (2041-2070) relative to the later part of the last century (1971-2000). Projected changes are averages from 11 NARCCAP regional climate simulations for the high (A2) CO₂ emissions scenario. Color with hatching indicates that more than 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change. Figure and legend from Kunkel et al. (2013).

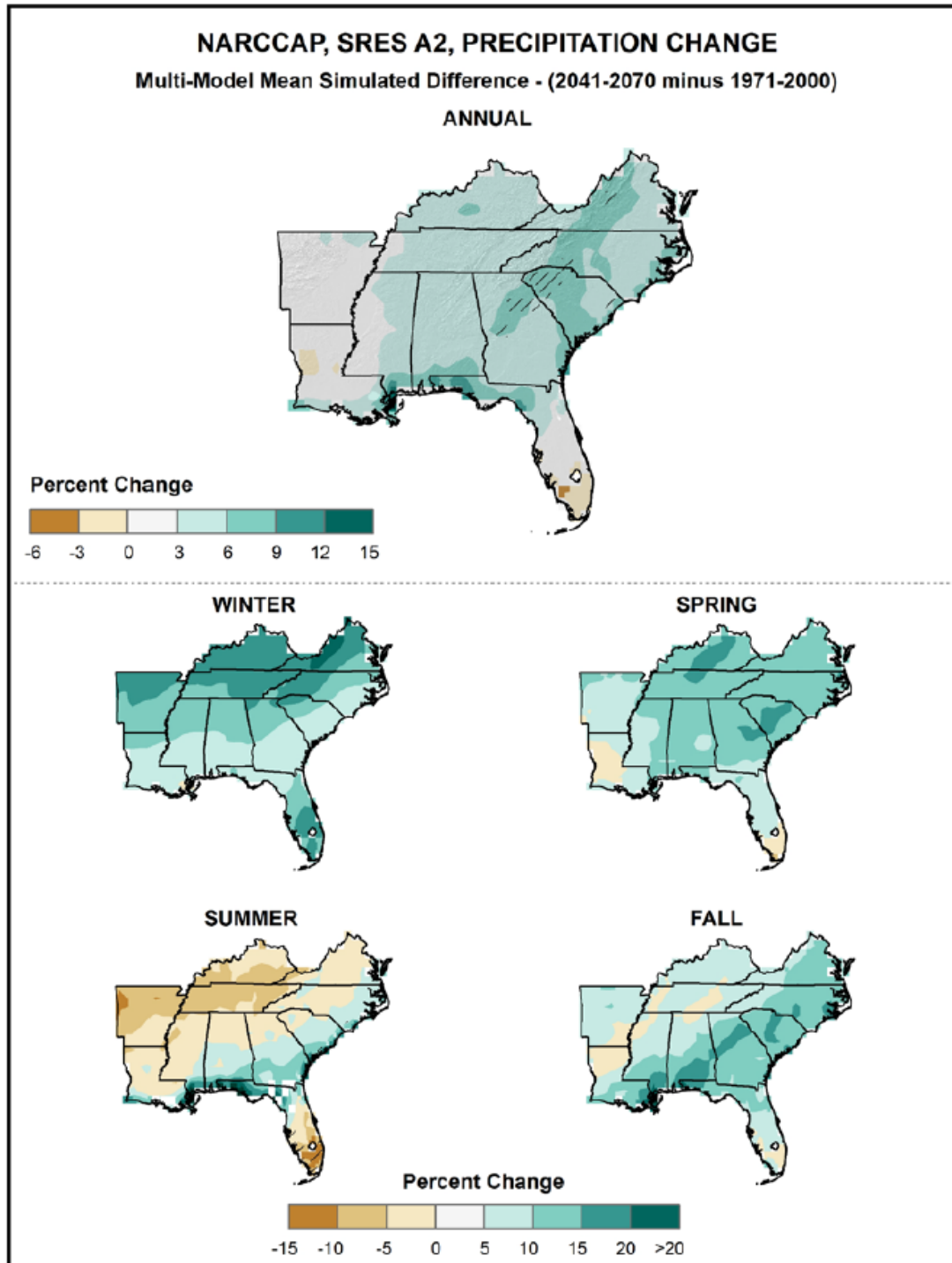


Figure 3. Projected annual and seasonal precipitation change. Maps show projected change in precipitation for mid-century (2041-2070) relative to the later part of the last century (1971-2000). Projected changes are averages from 11 NARCCAP regional climate simulations for the high (A2) CO₂ emissions scenario. Color only indicates that less than 50% of the models show a statistically significant change in precipitation. Color with hatching indicates that more than 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change. Figure and legend from Kunkel et al. (2013).

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