

Historical and Projected Climate Trends and Implications for Ozark National Scenic Riverways

Prepared by Nicholas Fisichelli, NPS Climate Change Response Program

March 1, 2013

Historical climate trends (1895-2011)

Climate trends across the Midwest region are highly variably, both seasonally and annually. Temperature trends for the region include a warming trend during the first decades of the 20th century, up to a peak in the 1930s, then cooling during the 1960s and 1970s, and again increasing temperatures over the past 40 years. Mean annual temperature has largely been well above the 1901-1960 average since the late 1990s and the decade of the 2000s is the warmest on record (Kunkel et al. 2013). Overnight low temperatures and winter seasonal averages have increased most strongly, concomitant with the projected effects of increased atmospheric greenhouse gas concentrations (NCADAC 2013). Regional precipitation shows high interannual variability, though similar to temperature, annual totals over the past 40 years have generally been above the 1901-1960 average (Kunkel et al. 2013). Important extreme climate events in the Midwest include flooding, severe thunderstorms, summer drought, and summer heat waves; in particular, extreme rainfall events and flooding have increased during the 20th century (Kunkel et al. 2013)..

Local climate trends for the Ozark National Scenic Riverways area were similar to regional patterns. Historical climate data from the nearest long-term weather station to the NPS Riverways (Doniphan, MO, station 232289, 40 miles southwest of the confluence of the Jack Forks and Current River) were acquired from the United States Historical Climatology Network (cdiac.ornl.gov) (Table 1). Over the 117 year instrumental record (1895-2011), mean annual temperature and precipitation exhibited typical variability for the region (Figure 1). Annual temperature did not show a significant linear trend ($p=0.86$) across the full record (mean = 56.6 °F (13.7 °C)); however, over the past 40 years (1972-2011), temperature warmed at a rate of 0.6 °F (0.33 °C) per decade ($p < 0.0001$). Warming during this recent period occurred in all seasons, with the strongest patterns in winter (0.9 °F (0.5 °C)/decade, $p=0.03$) and summer (0.7 °F (0.4 °C)/decade, $p=0.002$) (Figure 2). Annual precipitation showed a non-significant increasing trend ($p=0.18$) over the 117 years (mean = 48.15 inches (1223 mm)). Seasonally, precipitation decreased in summer and increased in spring and fall (Figure 3).

Future climate projections

Future climate projections for the area including Ozark National Scenic Riverways are from multi-model averaged data (Kunkel et al. 2013). Projected conditions for mid-century (2041-2070) were based on the A2 higher CO₂ emissions scenario (IPCC 2007). This was deemed the most likely trajectory of atmospheric CO₂ concentrations over the next half century, as global emissions are currently on a trajectory similar to the higher emissions scenarios (Friedlingstein et al. 2010). By mid-century, mean annual temperatures around OZAR will rise roughly 4.7 °F (2.6 °C) compared with the 1971-2000 average (Table 1). Additionally, the frost-free season will extend by three weeks and there will be 25 more days above 95 °F in summer and 21 fewer days below 32 °F in winter. There is wide agreement among individual climate models in the direction and magnitude of warming.

There is greater uncertainty in precipitation than temperature projections for mid-century (Table 1). Strong interannual and seasonal variability are likely to be the dominant trends over

the coming decades. Annual precipitation may increase slightly (+2 to +4%), with the greatest increase coming in winter (+10 to +15%) and a projected decrease in summer (-5 to -10%), compared with 1971-2000 values (Kunkel et al. 2013). Greater variability in the precipitation regime is also projected, including a 20% increase in the annual number of > 1 inch rain events and a slight increase in the number of consecutive dry days (Kunkel et al. 2013).

Potential Impacts to Natural and Cultural Resources

Climate change, land-use change and invasive nonnative species are threats to the ecological integrity of systems in the Midwest (Rahel and Olden 2008; Dale et al. 2011). As temperatures continue to warm, species are predicted to shift their range limits north. Species with limited dispersal ability and specific habitat requirements are most vulnerable to a rapidly changing climate (Parmesan 2006). For the NPS Riverways, this may include aquatic species with restricted ranges and limited thermal tolerances (Poff et al. 2002). Changes in air temperature, water temperature, and precipitation patterns will influence growth rates and health of terrestrial and aquatic species, such as trees and fish (Guyette & Rabeni 1995, Rypel 2009).

The dominant forest type in the region is projected to remain oak-hickory; however, individual species may expand or decline as the climate changes (Prasad et al. 2007). Northern oak species such as white oak (*Quercus alba*) and black oak (*Quercus velutina*) are modeled to decline while southern species, such as post oak (*Quercus stellata*), loblolly pine (*Pinus taeda*), and shortleaf pine (*Pinus echinata*) are expected to increase in abundance (Prasad et al. 2007). There are also numerous significant relict species and populations within the long-unglaciated lands of the park, which may be sensitive to changing conditions. Changes in terrestrial vegetation can also have cascading impacts on stream ecosystems (Mulholland et al. 2009).

Shifts to the hydrologic flow-regime due to changes in precipitation patterns in conjunction with warming air temperatures may have cascading effects on aquatic and terrestrial ecosystems and cultural resources within the park. A more variable precipitation regime will lead to both increased risk of flooding and drought, causing more frequent erosional disturbance to aquatic and streambank natural communities and potential damage to cultural resources (Poff et al. 2002). Nine out of the ten lowest water level records have occurred since 2000 (<http://water.weather.gov>) and this trend is likely to continue. Under a changed climate, the rivers in the park may also exhibit changes in the seasonal timing of peak flows and duration of low flows (Gibson et al. 2005). River stretches with consistent flow and cool temperatures, such as near source springs may become refugia for sensitive species as air and water temperatures rise and periods of low water flow become more common. Thus, the abundant springs within the NPS Riverways may become vital habitat to an increasing number of species as conditions change in the coming decades. In addition to the above changes to natural and cultural resources, visitor use spatial and temporal patterns and intensity may also shift in response to climate change, further stressing resources and park infrastructure in ways not seen in the past.

Table 1. Historical climate (1971-2000) and projected changes (2041-2070) for Ozark National Scenic Riverways. Climate modeling (Kunkel et al. 2013) was based on the A2 CO2 emissions scenario (IPCC 2007). Historical data are from the Doniphan, MO, weather station (cdiac.ornl.gov).

Temperature	Mean (1971-2000)	Projected change for 2041-2070 compared with 1971-2000 period
Mean annual temperature	56.2 °F (13.5 °C)	+4.7 °F (4.1-5.3 °F: 25th-75th percentiles)
Frost-free season	150 days	+21 (standard deviation = 5 days)
days with max temp > 95 F	25 days	+25 (standard deviation = 6 days)
days with min temp < 32 F	80 days	-21 (standard deviation = 4 days)
Precipitation		
Annual precipitation	49.6 in. (1261 mm)	+3 % (-2 to +6 %: 25th-75th percentiles) +12 % (+9 to +15 %: 25th-75th percentiles)
Winter precipitation	11.2 in. (285 mm)	
Spring precipitation	15.1 in. (384 mm)	+5 % (-1 to +8 %: 25th-75th percentiles)
Summer precipitation	10.7 in. (271 mm)	-7 % (-25 to +3 %: 25th-75th percentiles)
Fall precipitation	12.6 in. (320 mm)	0 % (-10 to +7 %: 25th-75th percentiles)

Figure 1. Mean annual temperature and annual precipitation (1895-2011) from the Doniphan, MO long-term weather station (cdiac.ornl.gov).

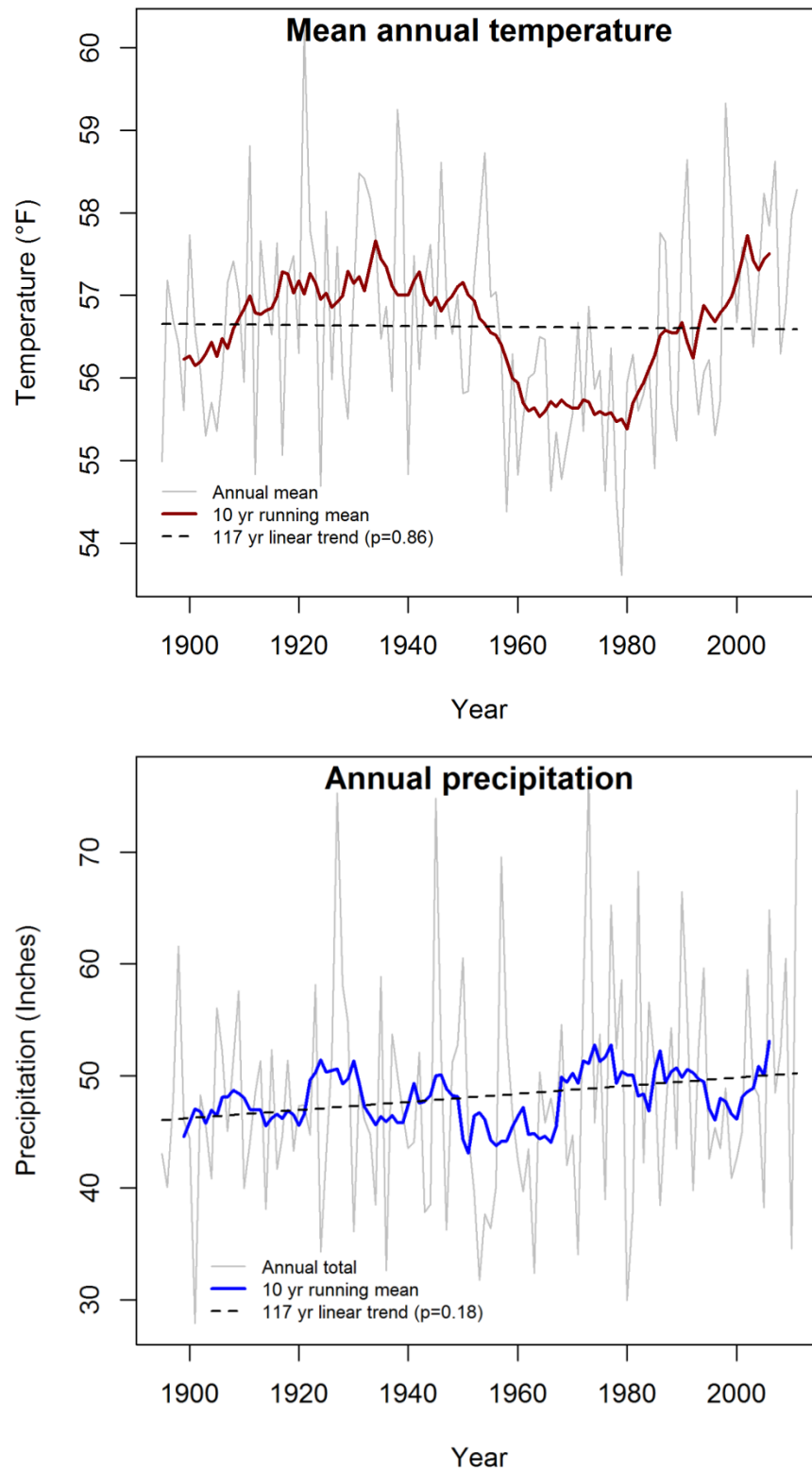


Figure 2. Seasonal temperature trends (1895-2011) from the Doniphan, MO long-term weather station (cdiac.ornl.gov).

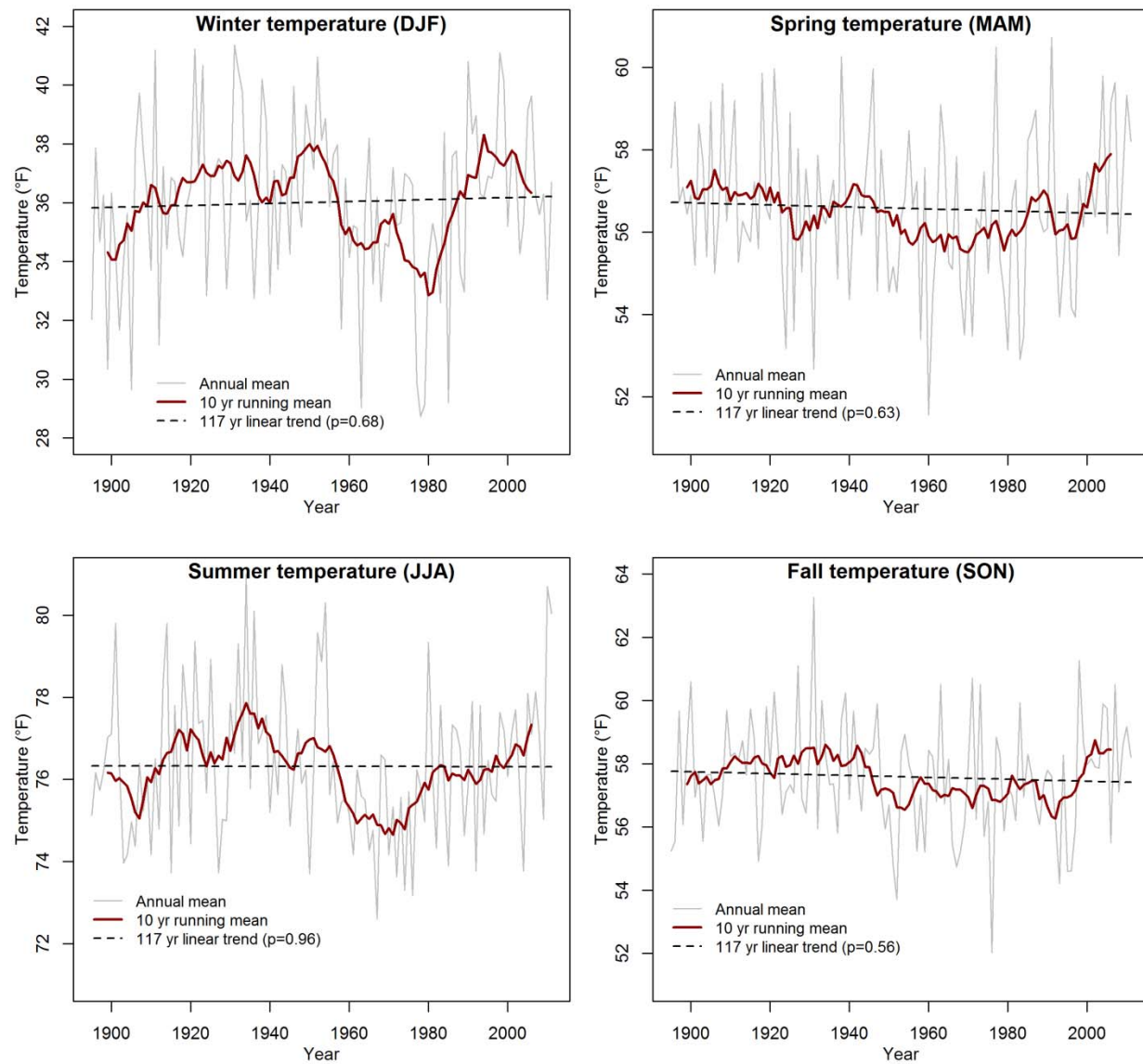
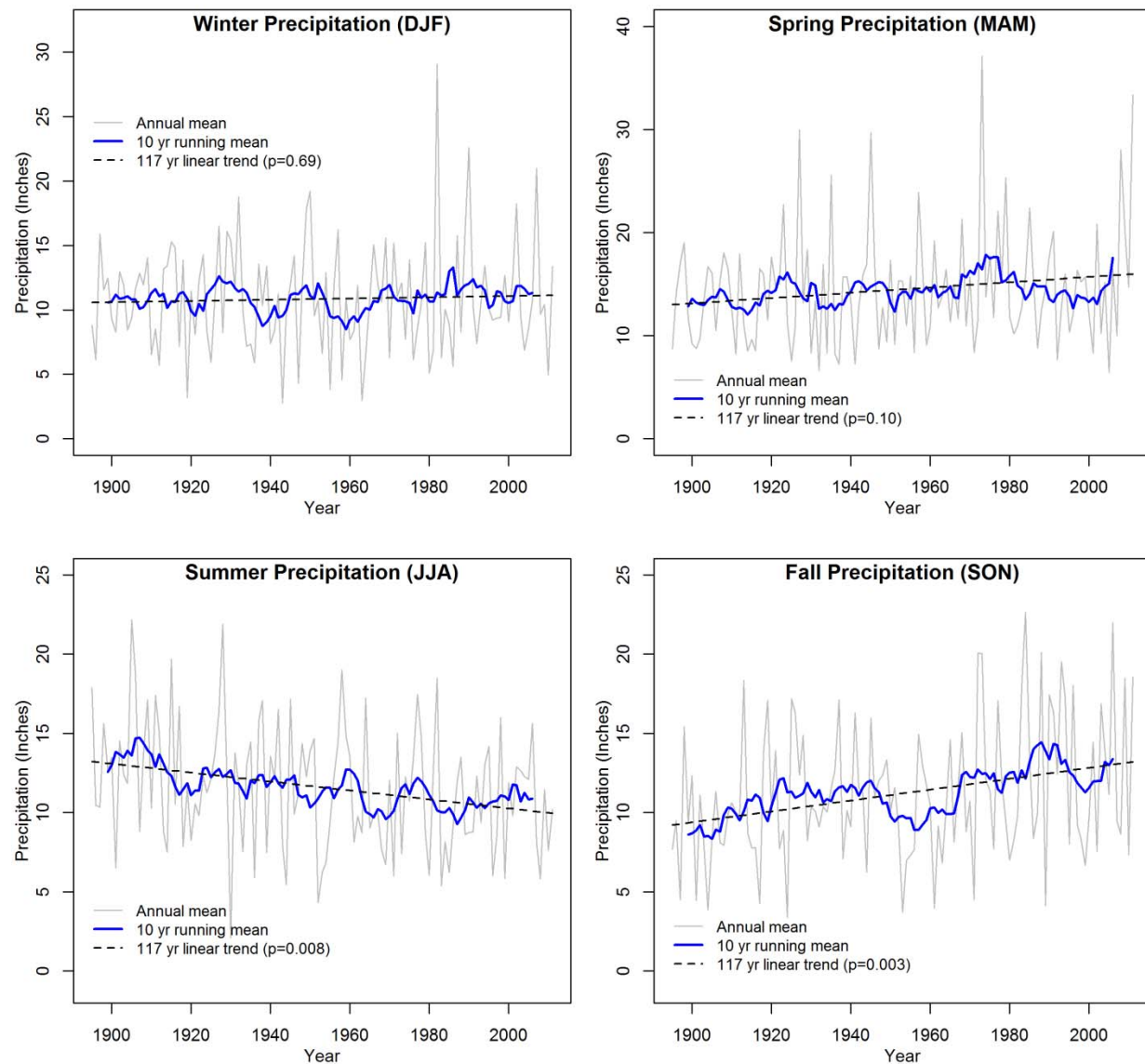


Figure 3. Seasonal precipitation trends (1895-2011) from the Doniphan, MO long-term weather station (cdiac.ornl.gov).



References

- Dale V. H., R. A. Efroymsen, and K. L. Kline. 2011. The land use–climate change–energy nexus. *Landscape Ecology* 26:755-773.
- Friedlingstein P., R. Houghton, G. Marland, J. Hackler, T. A. Boden, T. Conway, J. Canadell, M. Raupach, P. Ciais, and C. Le Quéré. 2010. Update on CO₂ emissions. *Nature Geoscience* 3:811-812.
- Gibson C., J. Meyer, N. Poff, L. Hay, and A. Georgakakos. 2005. Flow regime alterations under changing climate in two river basins: implications for freshwater ecosystems. *River Research and Applications* 21:849-864.
- Gonzalez P., R. P. Neilson, J. M. Lenihan, and R. J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography* 19:755-768.
- Guyette, R. P. and Rabeni, C. F. 1995. Climate response among growth increments of fish and trees. - *Oecologia* 104: 272-279.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis*. Cambridge University Press, Cambridge, UK.
- Kunkel, KE; Stevens LE; Stevens SE; Sun L; Janssen E; Wuebbles D; Hilberg S; Timlin MS; Stoecker L; Westcott NE; Dobson JG. 2013. *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 3. Climate of the Midwest U.S.* NOAA Technical Report NESDIS 142-3.
- Mulholland P. J., B. J. Roberts, W. R. HILL, and J. G. Smith. 2009. Stream ecosystem responses to the 2007 spring freeze in the southeastern United States: unexpected effects of climate change. *Global Change Biology* 15:1767-1776.
- National Climate Assessment and Development Advisory Committee (NCADAC). 2013. U.S. National Climate Assessment v. 11 Jan 2013 DRAFT. <http://ncadac.globalchange.gov/>
- Parmesan C. 2006. Ecological and Evolutionary Responses to Recent Climate Change. *Annual Review of Ecology, Evolution and Systematics* 37:637-669.
- Poff N., M. M. Brinson, and J. Day. 2002. Aquatic ecosystems and global climate change. *Pew Center on Global Climate Change*, Arlington, VA :44.
- Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. <http://www.nrs.fs.fed.us/atlas/tree>, Northern Research Station, USDA Forest Service, Delaware, Ohio.

Rahel F. J., J. D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology* 22:521-533.

Rypel, A. L. 2009. Climate–growth relationships for largemouth bass (*Micropterus salmoides*) across three southeastern USA states. - *Ecol Freshwat Fish* 18: 620-628.