

Climate Change Trends and Impacts for Planning at Rocky Mountain National Park

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Historical Trends

During the 20th century, temperature has increased across North America (Figure 1) and shown a statistically significant increase in the 50 km x 50 km area that includes Rocky Mountain National Park (NP) (Figure 2, Table 1). Precipitation has increased across the southwestern U.S. (Figure 3), but shown no statistically significant change in the area including the park (Figure 4).

Future Projections

The Intergovernmental Panel on Climate Change (IPCC) has coordinated research groups in projecting possible future climate under defined greenhouse gas emissions scenarios (IPCC 2007). Current global emissions are at or above IPCC emissions scenario A2. For the three main IPCC emissions scenarios, temperature could increase three to five times the warming already observed (Table 1). Precipitation could decrease in the 50 km x 50 km area that includes the park, but projections downscaled to 4 km x 4 km indicate that, for the area of the park, 11 out of 18 General Circulation Models (GCMs) project decreases in precipitation for IPCC emissions scenario A2, while the remaining 8 GCMs project increases (Figure 5; data from Conservation International using method of Tabor and Williams (2010)).

Physical and Ecological Impacts

Data from weather stations and snow courses in 53 national parks in the western United States, including Rocky Mountain NP, have contributed to detection of physical changes in the last half of the 20th century and attribution of these to climate change, including increased winter temperatures (Barnett et al. 2008; Bonfils et al. 2008), decreased snowpack (Barnett et al. 2008; Pierce et al. 2008), decreased ratio of snow to rain (Pierce et al. 2008), earlier spring warmth (Ault et al. 2011), and earlier spring streamflow (Barnett et al. 2008).

Field measurements from numerous national parks, including Rocky Mountain NP, have contributed to detection of 20th-century ecological changes attributed to climate change. These include a northward shift of the winter ranges of numerous bird species by an average of 0.5 ±

2.4 km y⁻¹ from 1975 to 2004 across the U.S. (La Sorte and Thompson 2007) and an increase of conifer tree background mortality across the western U.S. (van Mantgem et al. 2009). Other studies in Rocky Mountain NP have observed or detected physical and ecological changes consistent with, but not definitively attributed to climate change (Baron et al. 2009, Hessler and Baker 1997, Hoffman et al. 2007, Janke 2005, Knowles et al. 2006, Sibold and Veblen 2006, Wang et al. 2002a, 2002b, 2002c). In addition, regional analyses have detected and attributed increases in wildfire (Littell et al. 2009) and mountain pine beetles (Raffa et al. 2008).

References

- Ault, T.R., A.K. Macalady, G.T. Pederson, J.L. Betancourt, and M.D. Schwartz. 2011. Northern Hemisphere modes of variability and the timing of spring in western North America. *Journal of Climate* 24: 4003-4014.
- Barnett, T.P., D.W. Pierce, H.G. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan, and M.D. Dettinger. 2008. Human-induced changes in the hydrology of the western United States. *Science* 319: 1080-1083.
- Baron, J.S., T.M. Schmidt, and M.D. Hartman. 2009. Climate-induced changes in high elevation stream nitrate dynamics. *Global Change Biology* 15: 1777-1789.
- Bonfils, C., B.D. Santer, D.W. Pierce, H.G. Hidalgo, G. Bala, T. Das, T.P. Barnett, D.R. Cayan, C. Doutriaux, A.W. Wood, A. Mirin, and T. Nozawa. 2008. Detection and attribution of temperature changes in the mountainous western United States. *Journal of Climate* 21: 6404-6424.
- 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.
- Hessler, A.E. and W.L. Baker. 1997. Spruce and fir regeneration and climate in the forest-tundra ecotone of Rocky Mountain National Park, Colorado USA. *Arctic and Alpine Research* 29: 173-183.
- Hoffman, M.J., A.G. Fountain, and J.M. Achuff. 2007. 20th-century variations in area of cirque glaciers and glacierets, Rocky Mountain National Park, Rocky Mountains, Colorado, USA. *Annals of Glaciology* 46: 349-354.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis*. Cambridge University Press, Cambridge, UK.
- Janke, J.R. 2005. Modeling past and future alpine permafrost distribution in the Colorado Front

- Range. *Earth Surface Processes and Landforms* 30: 1495-1508.
- Knowles, N., M.D. Dettinger, and D.R. Cayan. 2006. Trends in snowfall versus rainfall in the western United States. *Journal of Climate* 19: 4545-4559.
- La Sorte, F.A. and F.R. Thompson. 2007. Poleward shifts in winter ranges of North American birds. *Ecology* 88: 1803-1812.
- Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoregions, 1916–2003. *Ecological Applications* 19: 1003-1021.
- Mitchell, T.D. and P.D. Jones. 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology* 25: 693-712.
- Pierce, D.W., T.P., Barnett, H.G. Hidalgo, T. Das, C. Bonfils, B.D. Santer, G. Bala, M.D. Dettinger, D.R. Cayan, A. Mirin, A.W. Wood, and T. Nozawa. 2008. Attribution of declining western U.S. snowpack to human effects. *Journal of Climate* 21: 6425-6444.
- Raffa, K.F., B.H. Aukema, B.J. Bentz, A.L. Carroll, J.A. Hicke, M.G. Turner, and W.H. Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. *BioScience* 58: 501-517.
- Sibold, J.S. and T.T. Veblen. 2006. Relationships of subalpine forest fires in the Colorado Front Range with interannual and multidecadal-scale climatic variation. *Journal of Biogeography* 33: 833-842.
- Tabor, K. and J.W. Williams. 2010. Globally downscaled climate projections for assessing the conservation impacts of climate change. *Ecological Applications* 20: 554-565.
- van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fule, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, and T.T. Veblen. 2009. Widespread increase of tree mortality rates in the western United States. *Science* 323: 521-524.
- Wang, G.M., N.T. Hobbs, F.J. Singer, D.S. Ojima, and B.C. Lubow. 2002a. Impacts of climate changes on elk population dynamics in Rocky Mountain National Park, Colorado, USA. *Climatic Change* 54: 205-223.
- Wang, G.M., N.T. Hobbs, H. Galbraith, and K.M. Giesen. 2002b. Signatures of large-scale and local climates on the demography of white-tailed ptarmigan in Rocky Mountain National Park, Colorado, USA. *International Journal of Biometeorology* 46: 197-201.
- Wang, G.M., N.T. Hobbs, K.M. Giesen, H. Galbraith, D.S. Ojima, and C.E. Braun. 2002c. Relationships between climate and population dynamics of white-tailed ptarmigan *Lagopus leucurus* in Rocky Mountain National Park, Colorado, USA. *Climate Research* 23: 81-87.

Table 1. Rocky Mountain National Park. Historical and projected climate (mean $\pm$ standard deviation (SD)) for the 50 km x 50 km square area that includes the park (Mitchell and Jones 2005, IPCC 2007, Gonzalez et al. 2010).

	mean	SD	units
Historical			
temperature 1901-2002 annual average	1.5	0.7	°C
temperature 1901-2002 linear trend	0.8	0.2	°C/century
precipitation 1901-2002 annual average	400	75	mm/year
precipitation 1901-2002 linear trend	~0	<0.01	%/century
Projected			
IPCC B1 scenario (lower emissions)			
temperature 1990-2100	2.8	0.8	°C/century
precipitation 1990-2100	2	14	%/century
IPCC A1B scenario (medium emissions)			
temperature 1990-2100	3.8	1.0	°C/century
precipitation 1990-2100	2	14	%/century
IPCC A2 scenario (higher emissions)			
temperature 1990-2100	4.7	1.2	°C/century
precipitation 1990-2100	-1	12	%/century

Figure 1.

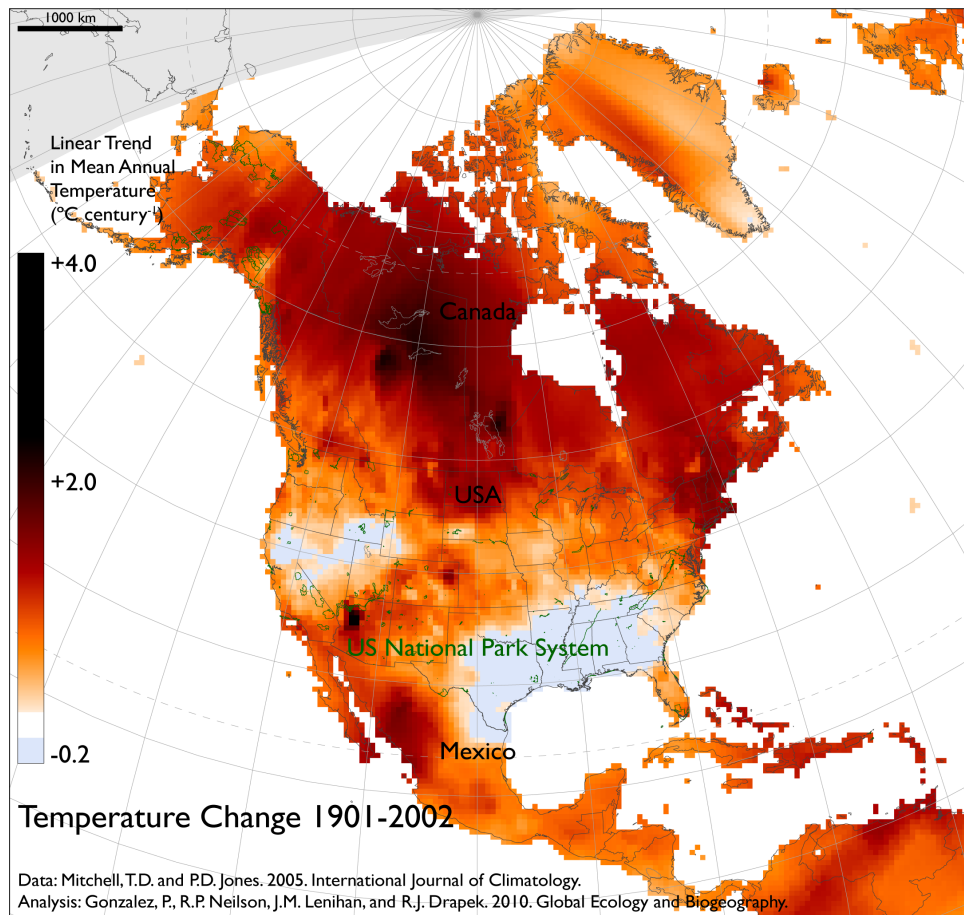


Figure 2.

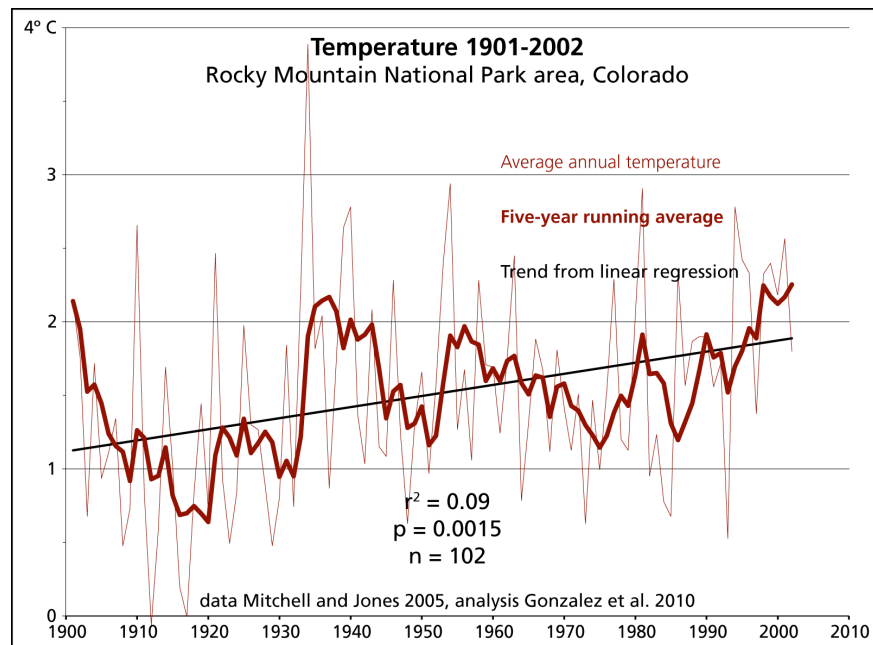


Figure 3.

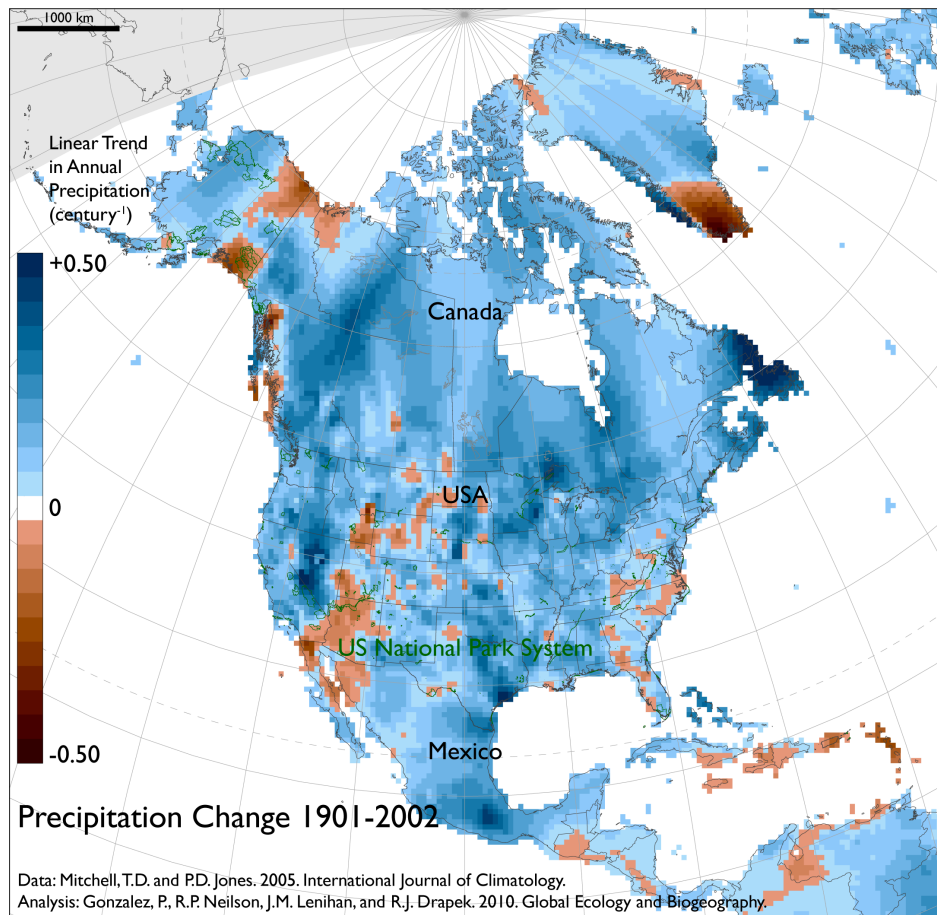


Figure 4.

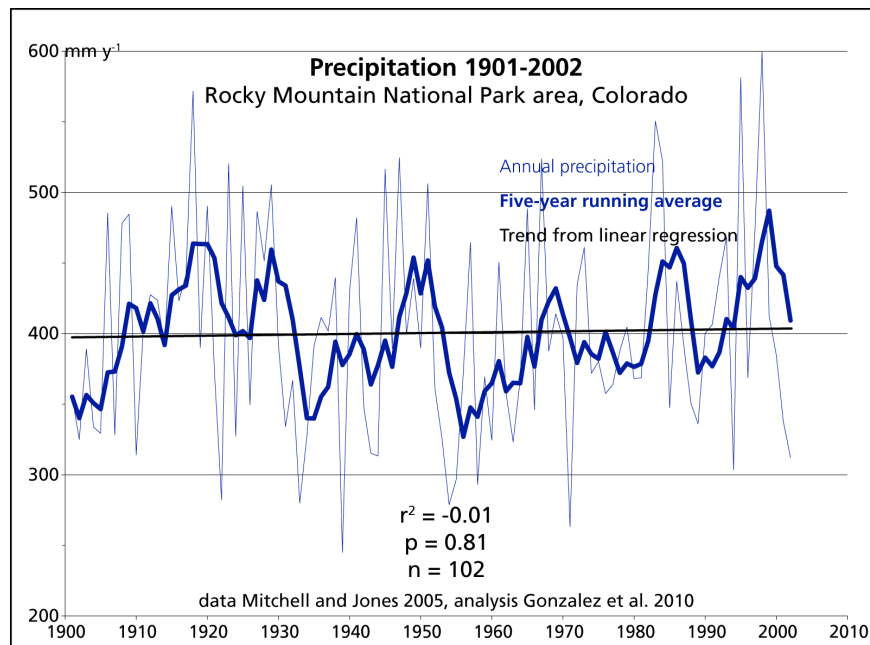


Figure 5.

