

Climate Change and Ecological Vulnerabilities at Zion National Park, Utah

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Historical Climate

From 1901 to 2002, mean annual temperature increased across the western United States (Figure 1; Gonzalez et al. 2010). Temperature has also increased in the area that includes Zion National Park (NP) (Figure 2), although the trend is not statistically significant.

Nevertheless, from 1928 to 2007, temperature at the Zion NP weather station showed a statistically significant increase (Figure 3, Table 1). From 1901 to 2002, precipitation increased across most of North America (Figure 4; Gonzalez et al. 2010), although it showed no statistically significant trend in the Zion NP area or in the 1928-2011 time series at the Zion NP weather station (Figure 5, Table 1).

Analyses of causal factors attribute 20th century warming and precipitation changes to greenhouse gas emissions from vehicles, power plants, deforestation, and other human activities (Intergovernmental Panel on Climate Change (IPCC) 2007, Bonfils et al. 2008).

Analyses of data from weather stations and snow courses across the western United States, including Zion NP, have detected statistically significant physical changes in the 20th century and attributed these to human climate change. The changes include 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), and earlier spring streamflow (Barnett et al. 2008) from 1950 to 1999. In the Zion region, climate change has shifted spring warmth 10 days earlier in the year from 1950 to 2005 (Ault et al. 2011).

Projected Climate

The Intergovernmental Panel on Climate Change (IPCC) has coordinated research groups to project possible future climates under defined greenhouse gas emissions scenarios (IPCC 2007). The three main IPCC greenhouse gas emissions scenarios are B1 (lower emissions), A1B (medium emissions), and A2 (higher emissions). Actual global emissions are on a path above IPCC emissions scenario A2 (Le Quéré et al. 2012, Raupach et al. 2007).

For the three main IPCC emissions scenarios, projected 21st century temperature in the Zion area could increase four to six times the amount of historical 20th century warming at the Zion NP weather station (Table 1, Mitchell and Jones 2005, Gonzalez et al. 2010). Precipitation projections from the three scenarios do not agree for the Zion area, with a projected decrease for the ensemble of general circulation models (GCMs) under emissions scenario A2, an increase under emissions scenario A1B, and nearly no change under emissions scenario B1 (Table 1). For emissions scenario A2, 12 out of 18 GCMs project decreases in precipitation (Figure 6; historical average from Mitchell and Jones 2005, Hijmans et al. 2005; projections from IPCC 2007, Tabor and Williams 2010, Conservation International; analysis by P. Gonzalez).

Projections indicate potential changes in the frequency of extreme temperature and precipitation events. Modeling under emissions scenario A2 projects 15 to 20 more days with a maximum temperature > 35°C, 30-35 fewer days with a minimum temperature < 0°C, and 10-15 more consecutive days with precipitation < 3 cm between the periods 1980-2000 and 2041-2070 (Kunkel et al. 2013).

Projected Ecological Vulnerabilities

Peer-reviewed published journal research of climate and modeling of species responses indicate potential vulnerabilities in Zion NP and the surrounding region to climate change. Analyses of the potential distributions of 213 mammal species under a temperature increase of 3.8°C by 2011 (equivalent to emissions scenario A1B) project a possible loss of 1 species and influx of 41 species into Zion NP (Burns et al. 2003). The potentially vulnerable species is the red squirrel (*Tamiasciurus hudsonicus*), while 19 of the potential new species are rodents. Records of the occurrence of the American pika (*Ochotona princeps*) throughout the Great Basin from 1898 to 2008 reveal a mean upslope shift of 360 m elevation and extirpation at 10 out of 25 research sites (Beever et al. 2011). Vegetation monitoring at Arches NP, Canyonlands NP, and Natural Bridges National Monument indicate potential loss of herbaceous cover and expansion of blackbrush (*Coleogyne ramosissima*) and Utah juniper (*Juniperus osteosperma*) under warmer, drier conditions (Munson et al. 2011b). The reduction of herbaceous cover could subsequently lead to an increase in wind erosion (Munson et al. 2011a).

Research presented in a National Park Service technical report (Shovic and Thoma 2011) indicates that projected summer temperature increases could nearly eliminate potential habitat in

Zion NP for American pika (*Ochotona princeps*), desert tortoise (*Gopherus agassizii*), and Shivwits Milk-vetch (*Astragalus ampullarioides*, a perennial herb listed as endangered under the U.S. Endangered Species Act). The report (Shovic and Thoma 2011) provides detailed information on historical and projected spatial distributions of the species. In a separate research effort, a Master's Thesis (Booth 2011) on Palmer's penstemon (*Penstemon palmeri*, a perennial flower) in Zion NP indicates that the plant is more productive and flowers earlier under warmer temperatures.

Table 1. Historical and projected climate trends for the area that includes Zion NP (Mitchell and Jones 2005, IPCC 2007, Gonzalez et al. 2010) and at the Zion NP weather station (data National Oceanic and Atmospheric Administration). Historical climate and projections for IPCC emissions scenarios B1 and A1B are calculated for the 50 x 50 km pixels that include the park (Gonzalez et al. 2010). Climate under emissions scenario A2 is calculated for the 4 x 4 km pixels that include the park (data from Conservation International, using the method of Tabor and Williams (2010)).

	mean	SD	units
Historical			
temperature annual average, Zion NP area (1901-2002)	8.3	0.7	°C
temperature linear trend, Zion NP area (1901-2002)	0.4	2.3	°C century ⁻¹
temperature annual average, Zion NP station (1928-2007)	16.3	0.7	°C
temperature linear trend, Zion NP station (1928-2007)	0.8	3.3	°C century ⁻¹
precipitation annual average, Zion NP area (1901-2002)	320	76	mm y ⁻¹
precipitation linear trend, Zion NP area (1901-2002)	-12	79	% century ⁻¹
precipitation annual average, Zion NP station (1928-2011)	383	112	mm y ⁻¹
precipitation linear trend, Zion NP station (1928-2011)	26	135	% century ⁻¹
Projected (1990-2100)			
IPCC B1 scenario (lower emissions)			
temperature change in annual average	3.0	1.1	°C century ⁻¹
precipitation change in annual average	0	8	% century ⁻¹
IPCC A1B scenario (medium emissions)			
temperature change in annual average	3.9	1.1	°C century ⁻¹
precipitation change in annual average	5	8	% century ⁻¹
IPCC A2 scenario (higher emissions)			
temperature change in annual average	4.7	1.1	°C century ⁻¹
precipitation change in annual average	-5	8	% century ⁻¹

Figure 1.

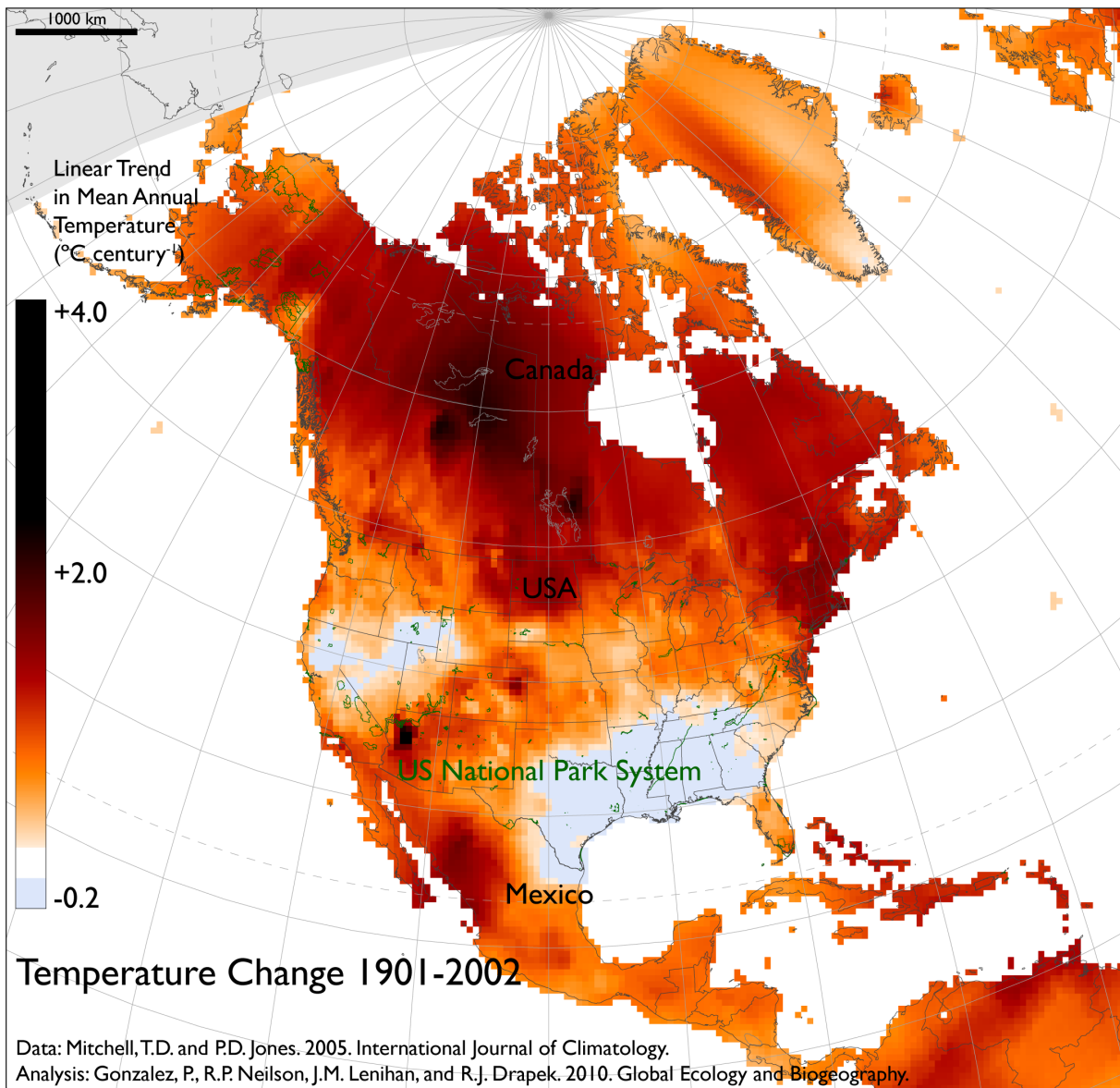


Figure 2.

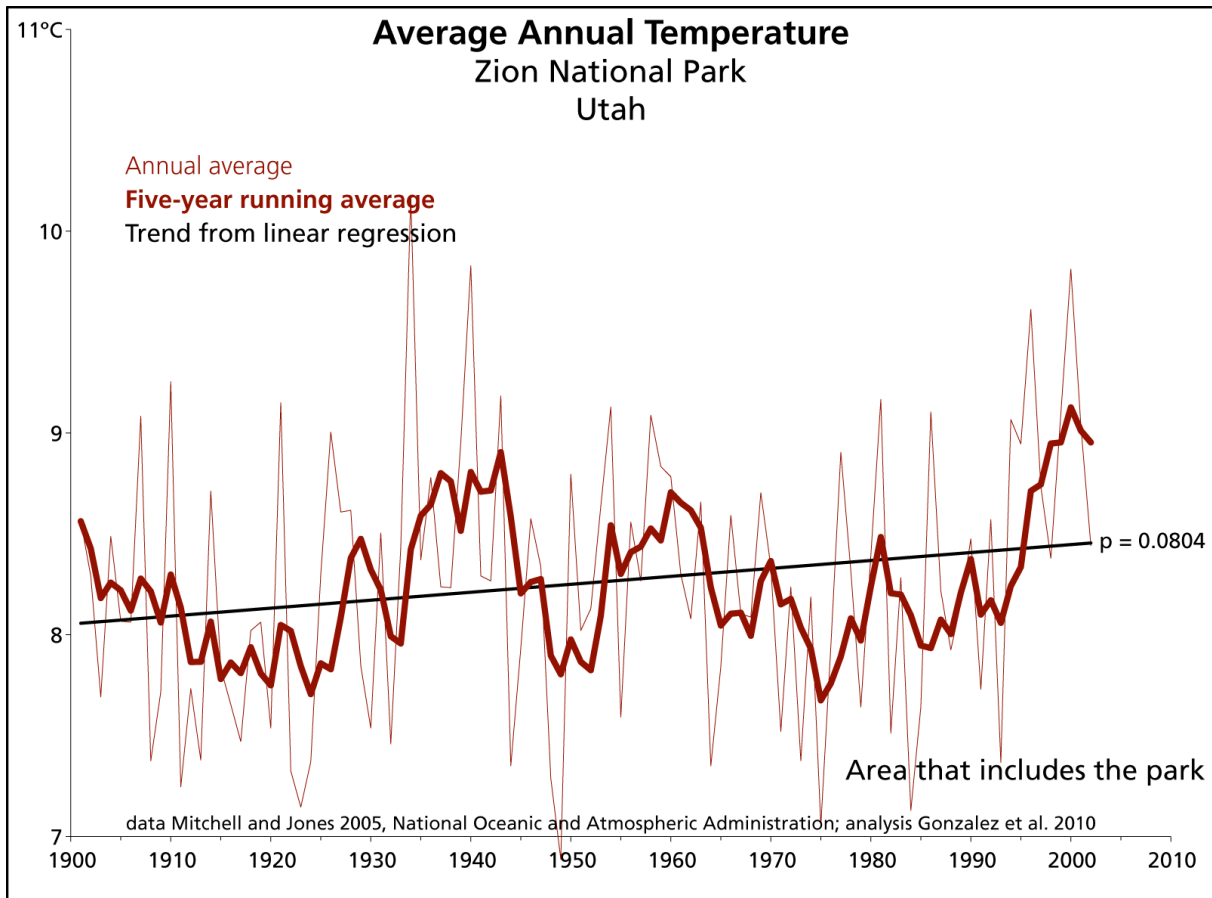


Figure 3.

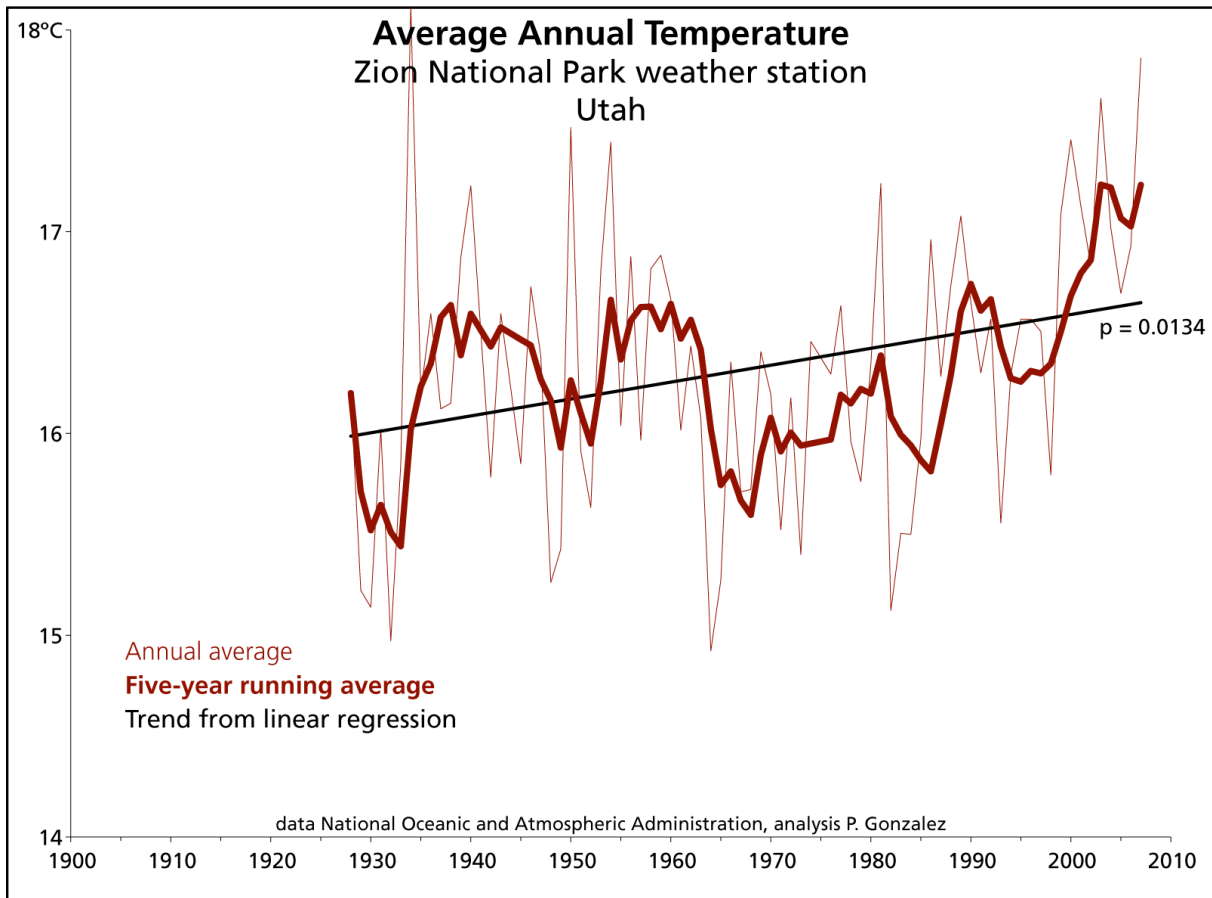


Figure 4.

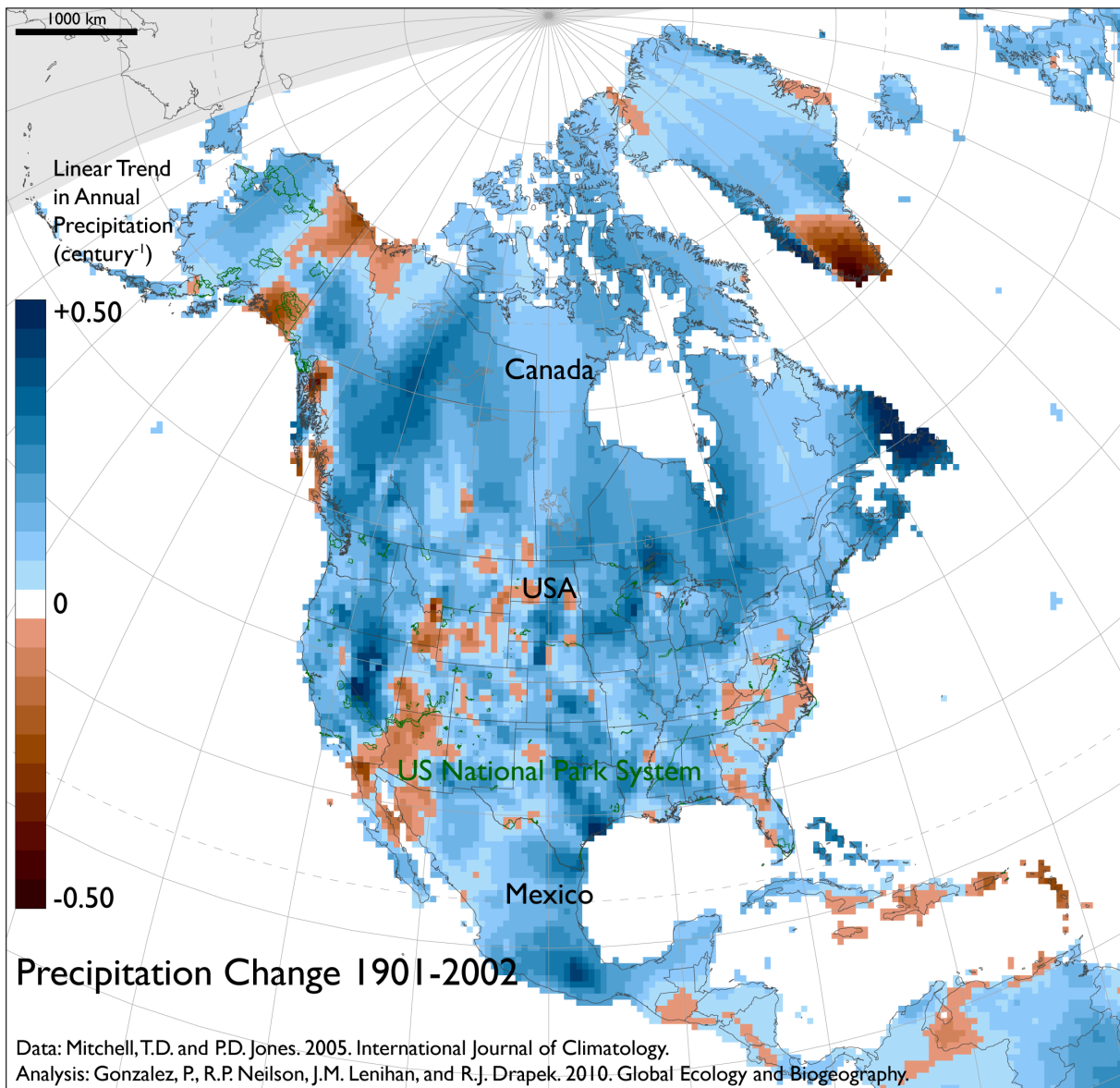


Figure 5.

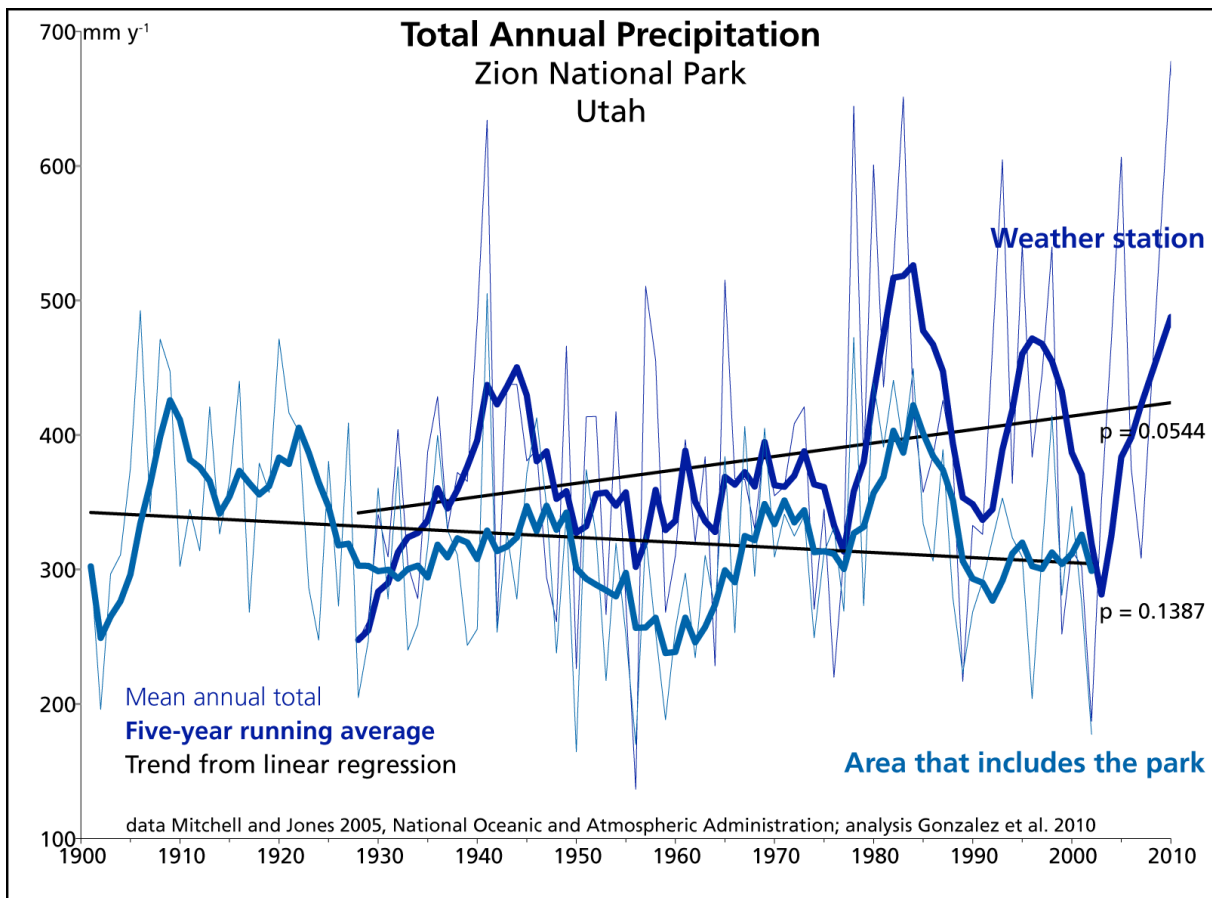
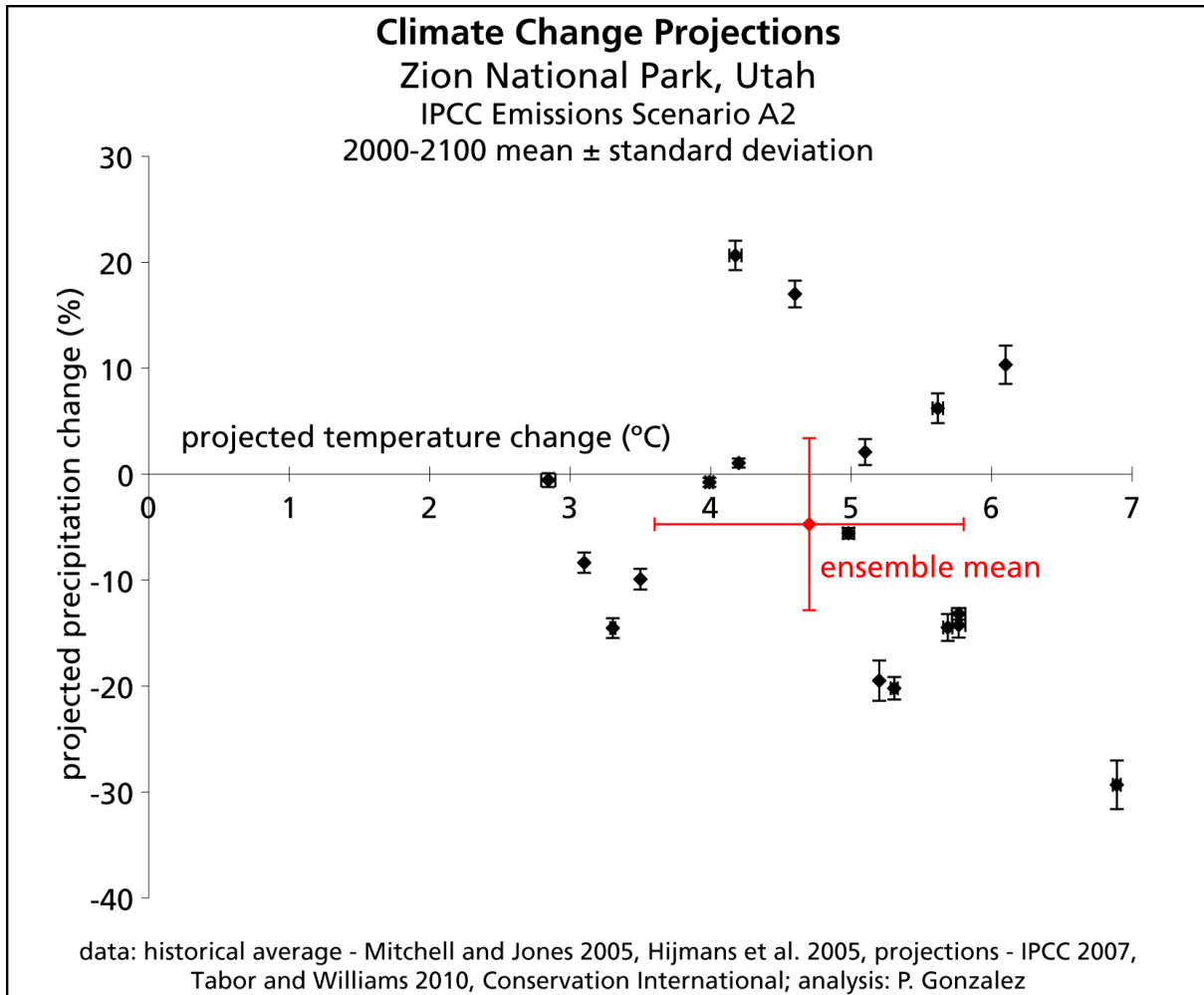


Figure 6.



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