

Climate Change Trends and Vulnerability of the Colorado River and Lake Mead National Recreation Area

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Historical Climate

From 1901 to 2002, mean annual temperature increased across North America (Figure 1; Gonzalez et al. 2010) and showed a statistically significant increase in the area that includes Lake Mead National Recreation Area (NRA) (Figure 2, Table 1). From 1901 to 2002, precipitation increased across most of North America (Figure 3; Gonzalez et al. 2010), although it showed no statistically significant trend in the Lake Mead area (Figure 4, 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).

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 (Friedlingstein et al. 2010).

For the three main IPCC emissions scenarios, projected 21st century temperature in the Lake Mead area could increase five to nine times the amount of historical 20th century warming (Table 1, Mitchell and Jones 2005, Gonzalez et al. 2010). General circulation models (GCMs) of the atmosphere do not agree on projections of future precipitation in the Lake Mead area, with 10 out of 18 GCMs projecting decreases under emissions scenario A2 and the remaining 8 projecting increases (Figure 5; 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).

GCMs project changes in the frequency of extreme temperature and precipitation events.

Modeling under emissions scenario A2 projects 25 to 30 more days with a maximum temperature $> 35^{\circ}\text{C}$, 20-30 fewer days with a minimum temperature $< 0^{\circ}\text{C}$, and 15-25 more consecutive days with precipitation < 3 cm between the periods 1980-2000 and 2041-2070 (Kunkel et al. 2013).

Colorado River

Human water withdrawals have reduced the level of Lake Mead to 34 m below the crest of Hoover Dam, the third lowest period of water levels since formation of the lake in 1936 (Figure 6, Bureau of Reclamation <http://www.usbr.gov/lc/region/g4000/lakemead_line.pdf>).

Reconstruction of what natural flow of the Colorado River would be upstream at Lees Ferry, Arizona, indicates that river flow in 2004 was approximately at the 1906-2004 average, but that the river has experienced much lower flows for decades at a time in the period 800-2000 AD (Meko et al. 2007).

Modeling under emissions scenarios B1 and A2 projects runoff decreases in the Colorado River Basin of 10 to 30% by the end of the 21st century (Barnett and Pierce 2009b). Modeling under emissions scenarios B1, A1B, and A2 projects a 9% decrease in mean natural flow at Lees Ferry by 2060 (Bureau of Reclamation 2012). One modeling effort projects that the combination of this potential future climate change and continued human water withdrawals would generate a 50% chance that Lakes Mead and Powell would go dry by 2021 (Barnett and Pierce 2008, 2009a). Another modeling effort that uses the mean of climate change projections under emissions scenarios B1, A1B, and A2 projects a water level 32 m above dead storage in 2035 (Dawadi and Ahmad 2012). Water conservation and efficiency could compensate for water reductions from climate change (Rajagopalan et al. 2009, Overpeck and Udall 2010).

Table 1. Historical and projected climate (mean $\pm$ standard deviation (SD)) trends for the area that includes Lake Mead NRA (Mitchell and Jones 2005, IPCC 2007, Gonzalez et al. 2010). Historical climate and climate 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 method of Tabor and Williams (2010)).

	mean	SD	units
Historical (1901-2002)			
temperature annual average	17.7	0.6	°C
temperature linear trend	0.5	1.9	°C century ⁻¹
precipitation annual average	160	60	mm y ⁻¹
precipitation linear trend	7	124	% century ⁻¹
Projected (1990-2100)			
IPCC B1 scenario (lower emissions)			
temperature change in annual average	2.8	0.9	°C century ⁻¹
precipitation change in annual average	-4	19	% century ⁻¹
IPCC A1B scenario (medium emissions)			
temperature change in annual average	3.7	0.9	°C century ⁻¹
precipitation change in annual average	~0	19	% century ⁻¹
IPCC A2 scenario (higher emissions)			
temperature change in annual average	4.6	0.9	°C century ⁻¹
precipitation change in annual average	-1	19	% century ⁻¹

Figure 1.

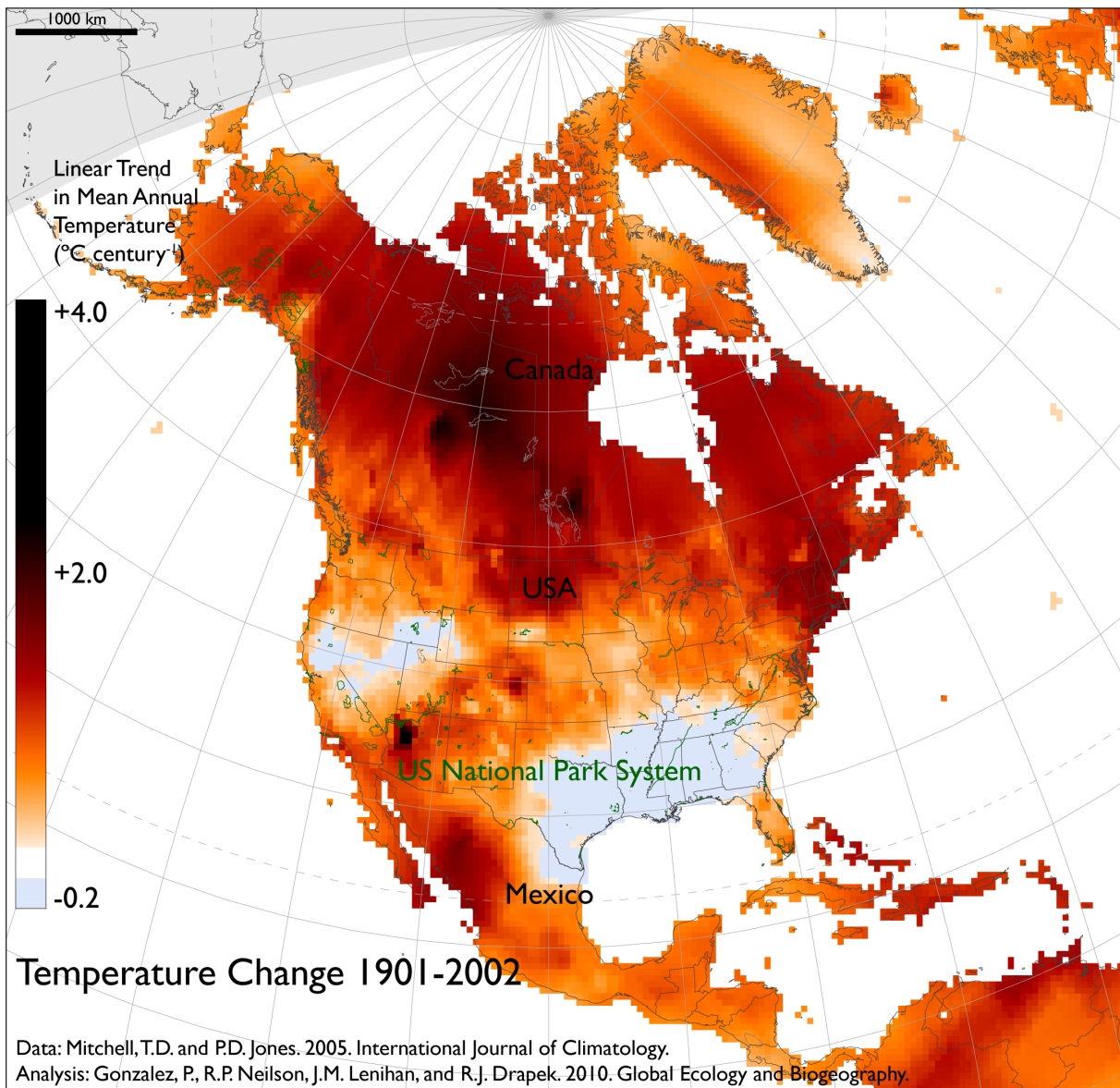


Figure 2.

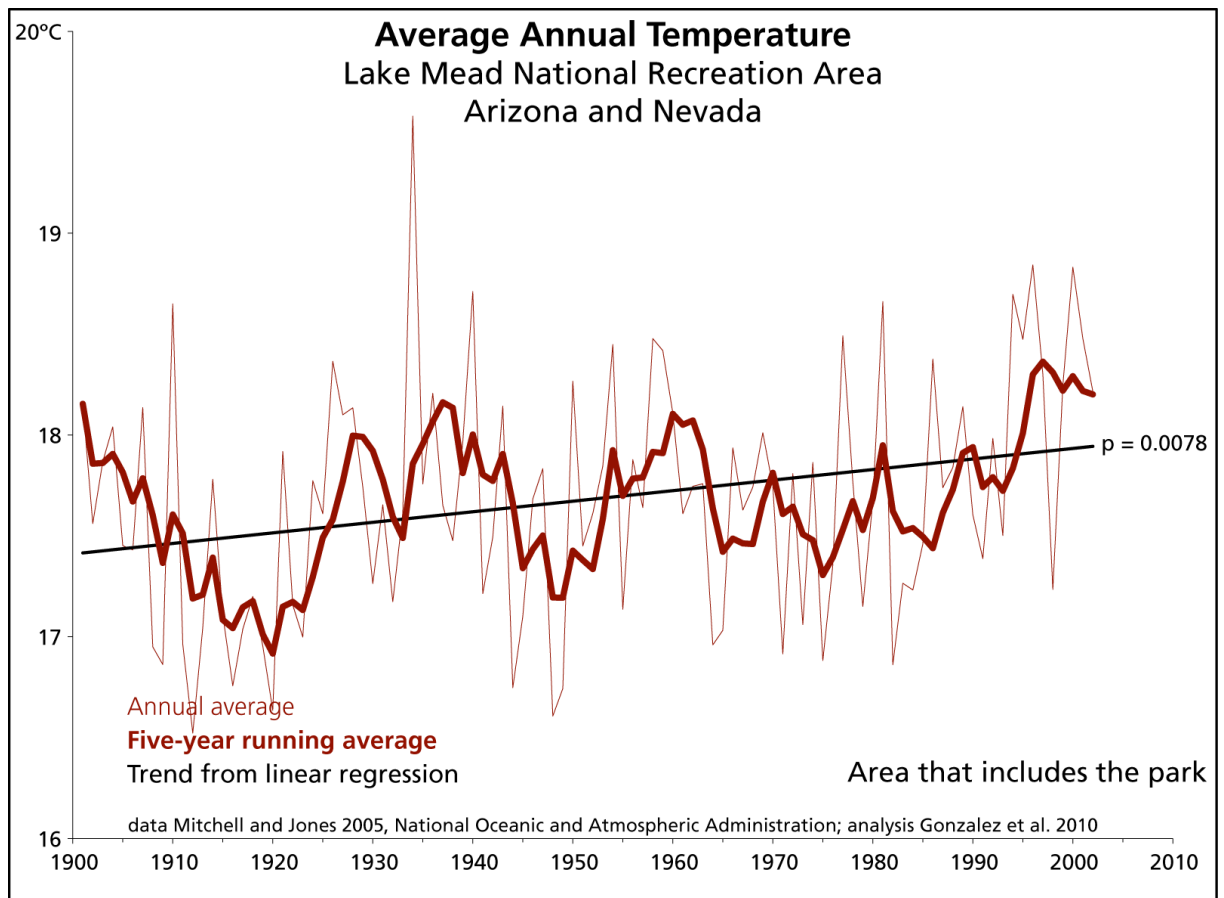


Figure 3.

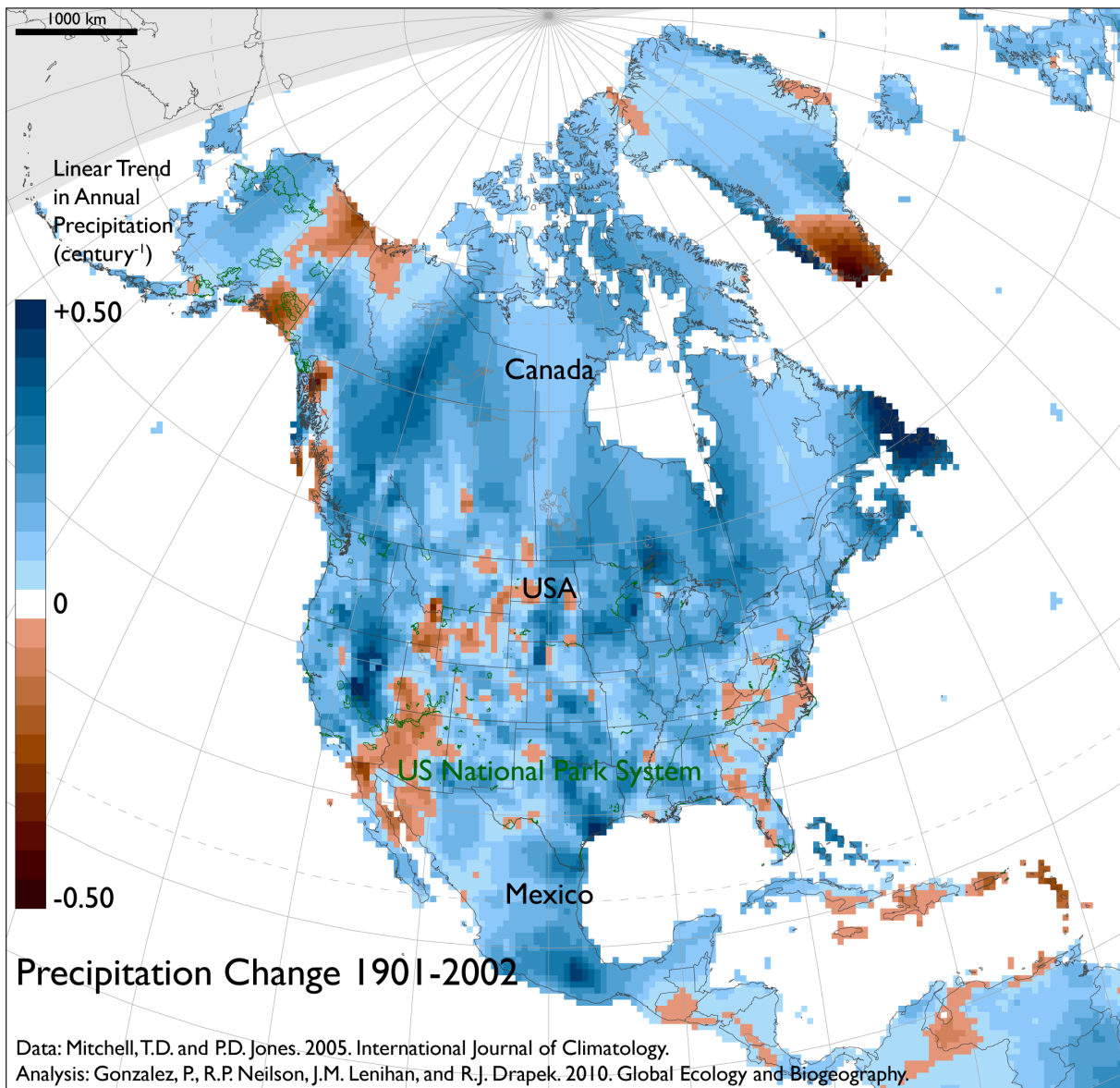


Figure 4.

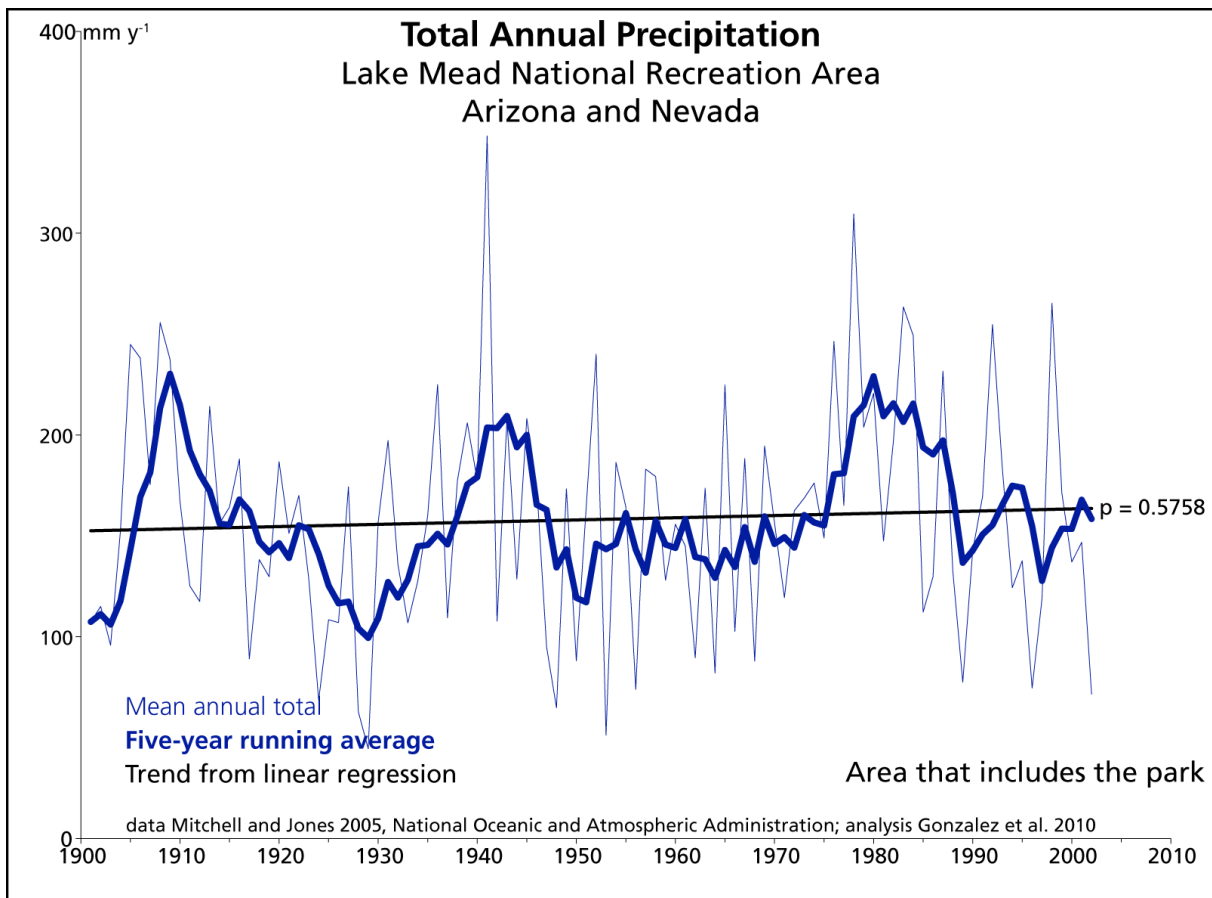


Figure 5.

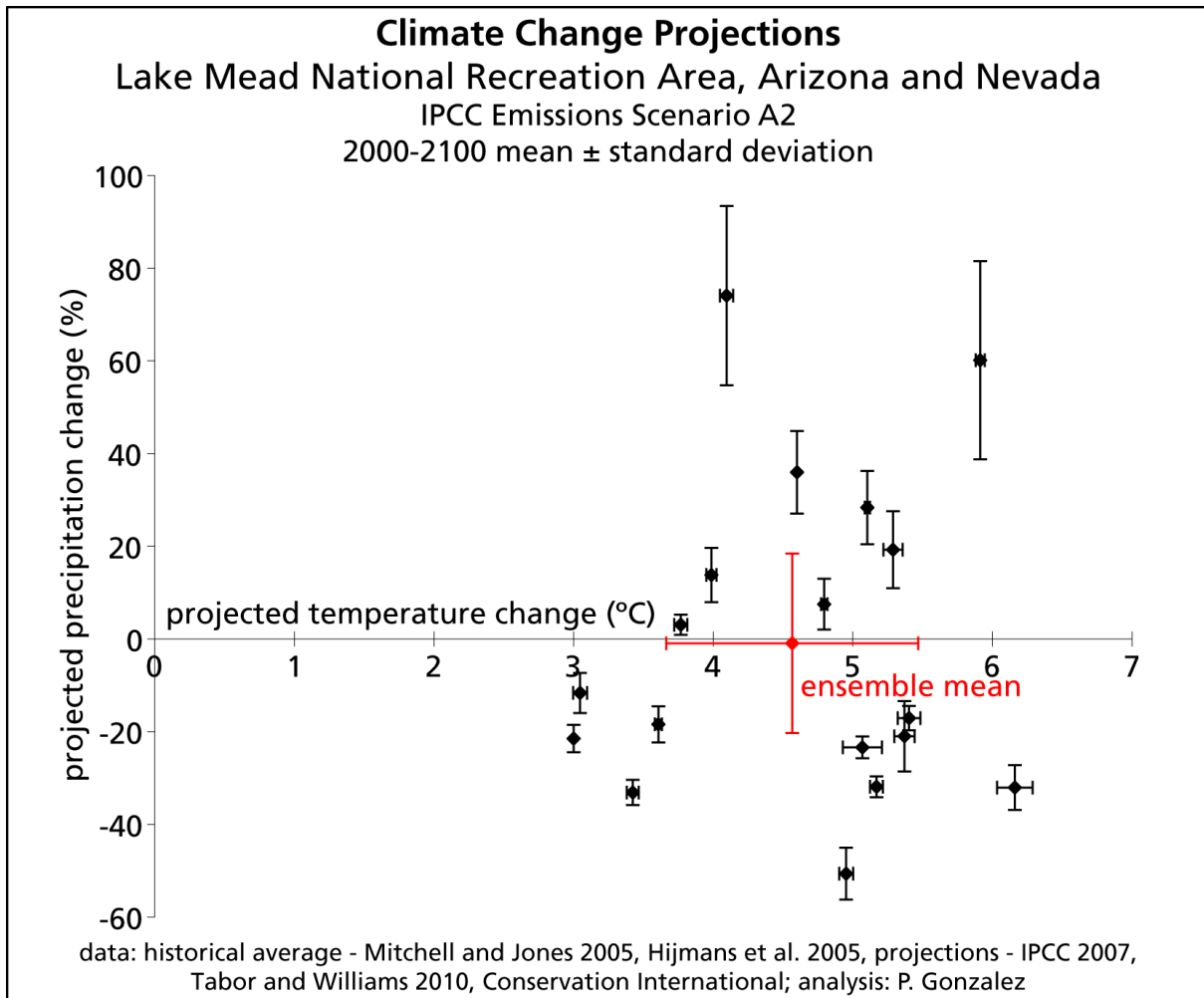
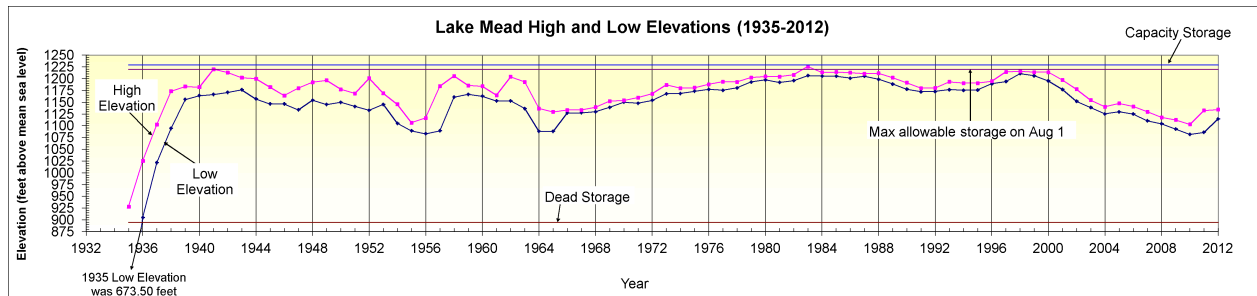


Figure 6.

Lake Mead water level

(Bureau of Reclamation <http://www.usbr.gov/lc/region/g4000/lakemead_line.pdf>).



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