

Climate Change and Ecological Vulnerabilities at Mammoth Cave National Park, Kentucky

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Introduction

Greenhouse gas emissions from vehicles, power plants, deforestation, and other human activities have increased temperatures around the world and changed other aspects of climate (IPCC 2007a). Published field research shows that climate change is also altering ecosystems by shifting biomes, contributing to species extinctions, and causing numerous other changes (IPCC 2007b). To help Mammoth Cave National Park (NP) integrate climate change into its foundation document and resource management in general, this report presents results of spatial analyses of historical and projected climate and a summary of published scientific findings on ecological changes related to climate change.

Historical Climate Changes

From 1901 to 2002, average annual temperature increased across the United States (U.S.) (Figure 1) and in the 50 km x 50 km (30 mile x 30 mile) square that includes Mammoth Cave NP (Figure 2, Table 1), but the trend in the park area was not statistically significant. Although a weather station has been located in the park since 1934, the temperature record is usable for only 34 of the past 77 years because too many days are missing data. An annual average can only be calculated if no more than five days are missing from every month of a year. This highlights the importance of the quick task of writing down the temperature every day. From 1901 to 2002, precipitation increased across the U.S. (Figure 3) and showed a statistically significant increase in the area that includes Mammoth Cave NP (Figure 4).

Historical Ecological Changes

Climate change has shifted the winter ranges of a set of 254 bird species northward across the U.S. at an average rate of $0.5 \pm 2.4 \text{ km y}^{-1}$ from 1975 to 2004 (La Sorte and Thompson 2007). Data from Kentucky contributed to that research. A search of the scientific literature did not find any other published case where field measurements from Mammoth Cave NP or the surrounding area contributed to the detection of statistically significant 20th century ecological changes attributable to climate change.

Future Climate Projections

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. 2013, Raupach et al. 2007).

For the three main IPCC emissions scenarios, projected 21st century mean annual temperature in the Mammoth Cave area could increase 2.5 to 4.4°C (4.5-8°F.) between the periods 1961-1990 and 2071-2100 (Table 1). The average of ensembles of general circulation models (GCMs) of the atmosphere project increased precipitation for the Mammoth Cave NP area under all three IPCC emissions scenarios (Table 1). For emissions scenario A2, 15 out of 18 GCMs project increases in precipitation (Figure 5).

Projections indicate potential changes in the frequency of extreme temperature and precipitation events. Modeling under emissions scenario A2 projects 20 to 30 more days with a maximum temperature > 35°C (95°F.), 20 to 25 fewer days with a minimum temperature < 0°C (32°F.), and 10 to 15% more days each year with precipitation > 2.5 cm (1 inch) between the periods 1980-2000 and 2041-2070 (Kunkel et al. 2013).

Projected Ecological Vulnerabilities

A search of the scientific literature found a few published vulnerability analyses relevant to the Mammoth Cave NP area. Climate change could shift the ranges of numerous tree species northward, reducing potential densities in Kentucky of sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and white oak (*Quercus alba*) (Iverson et al. 2008). Modeling of the range of the invasive species kudzu (*Pueraria lobata*) indicates a potential increase in Kentucky (Bradley et al. 2010). Experimental increases of atmospheric carbon dioxide in a North Carolina forest (Mohan et al. 2006) indicate that climate change could increase the growth and toxicity of poison ivy (*Toxicodendron radicans*).

Table 1. Historical and projected climate trends for the area that includes Mammoth Cave NP (Mitchell and Jones 2005, IPCC 2007, Gonzalez et al. 2010). Historical climate and projections for IPCC emissions scenarios B1 and A1B calculated for the 50 x 50 km (30 mile x 30 mile) square that includes the park (Gonzalez et al. 2010). Climate under emissions scenario A2 calculated for the 4 x 4 km (2.4 mile x 2.4 mile) squares that include the park (data from Conservation International, using method of Tabor and Williams (2010)).

	mean	SD	mean	SD
Historical (1901-2002)				
temperature annual average	13.4	0.7 °C	56	1.3 °F.
temperature linear trend	0.03	NS °C/century	0.03	NS °F./cent.
precipitation annual average	1200	200 mm/y	47	7 in./year
precipitation linear trend	12	Signif. %/century	12	Signif. %/century
Projected (1990-2100)				
IPCC B1 scenario (lower emissions)				
temperature annual average	2.5	1 °C/century	4.5	1.8 °F./cent.
precipitation annual average	2	7 %/century	2	7 %/century
IPCC A1B scenario (medium emissions)				
temperature annual average	3.8	1 °C/century	6.8	1.8 °F./cent.
precipitation annual average	3	7 %/century	3	7 %/century
IPCC A2 scenario (higher emissions)				
temperature annual average	4.4	1 °C/century	8	1.8 °F./cent.
precipitation annual average	3	7 %/century	3	7 %/century

SD = standard deviation

Signif. = statistically significant

NS = not statistically significant

Figure 1.

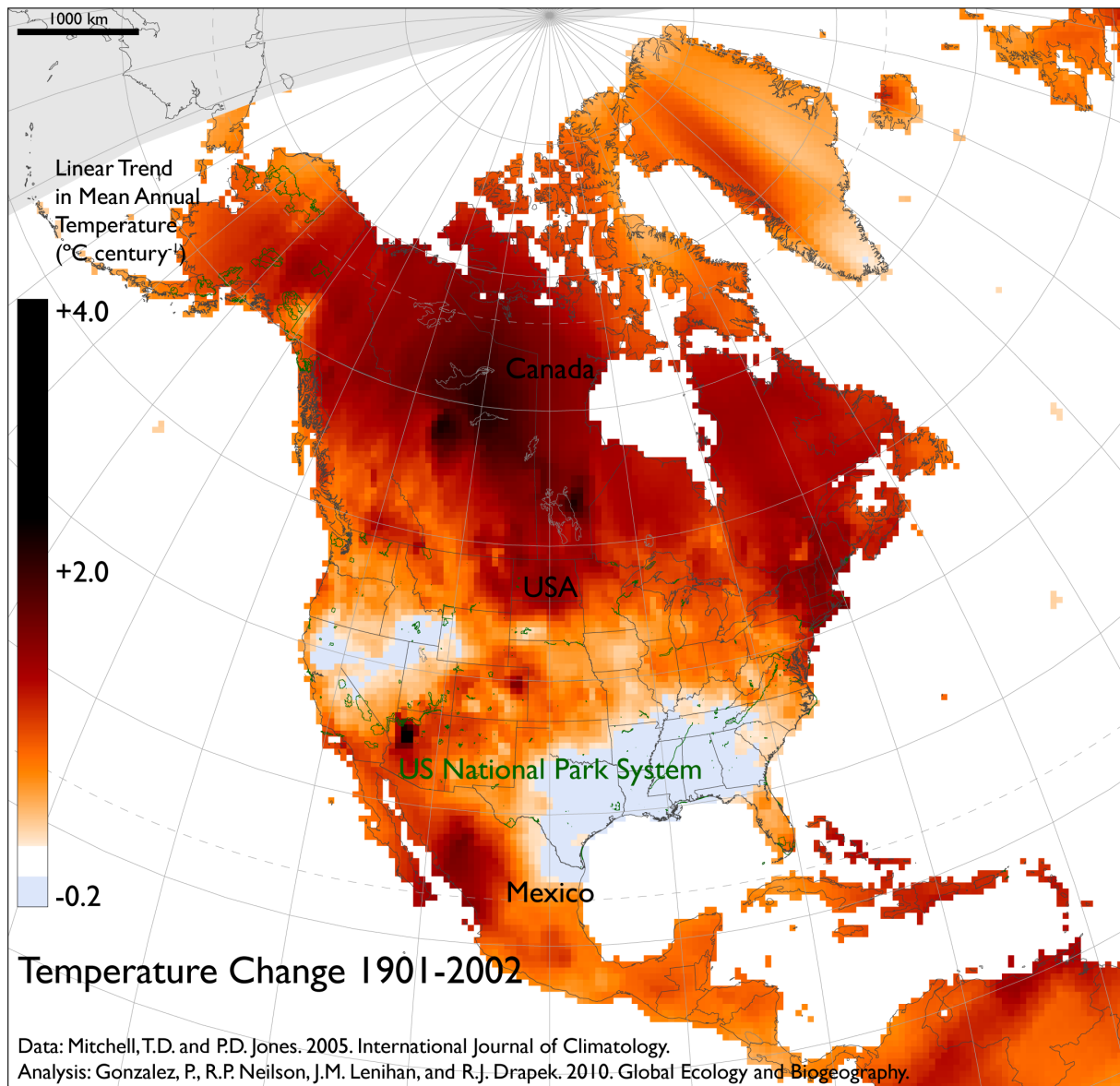


Figure 2.

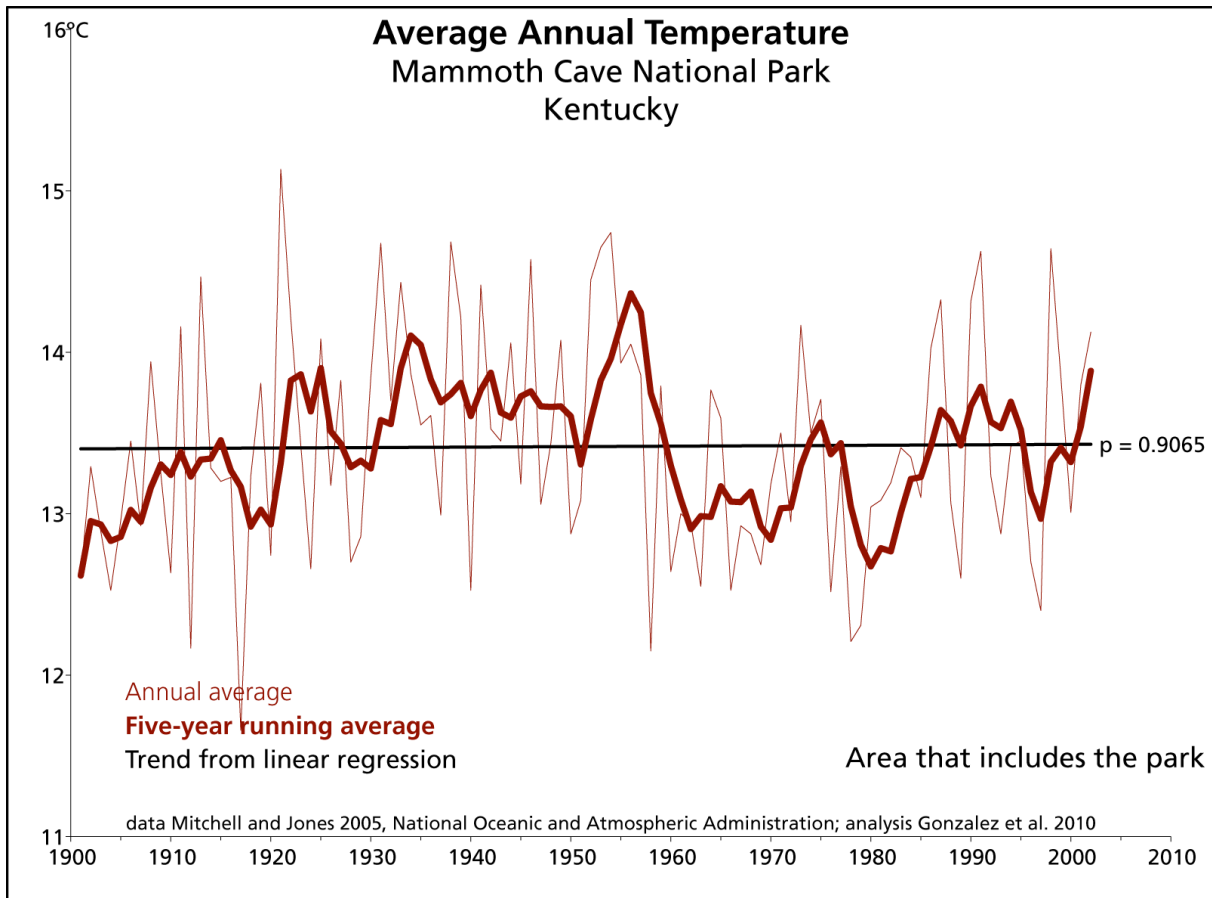


Figure 3.

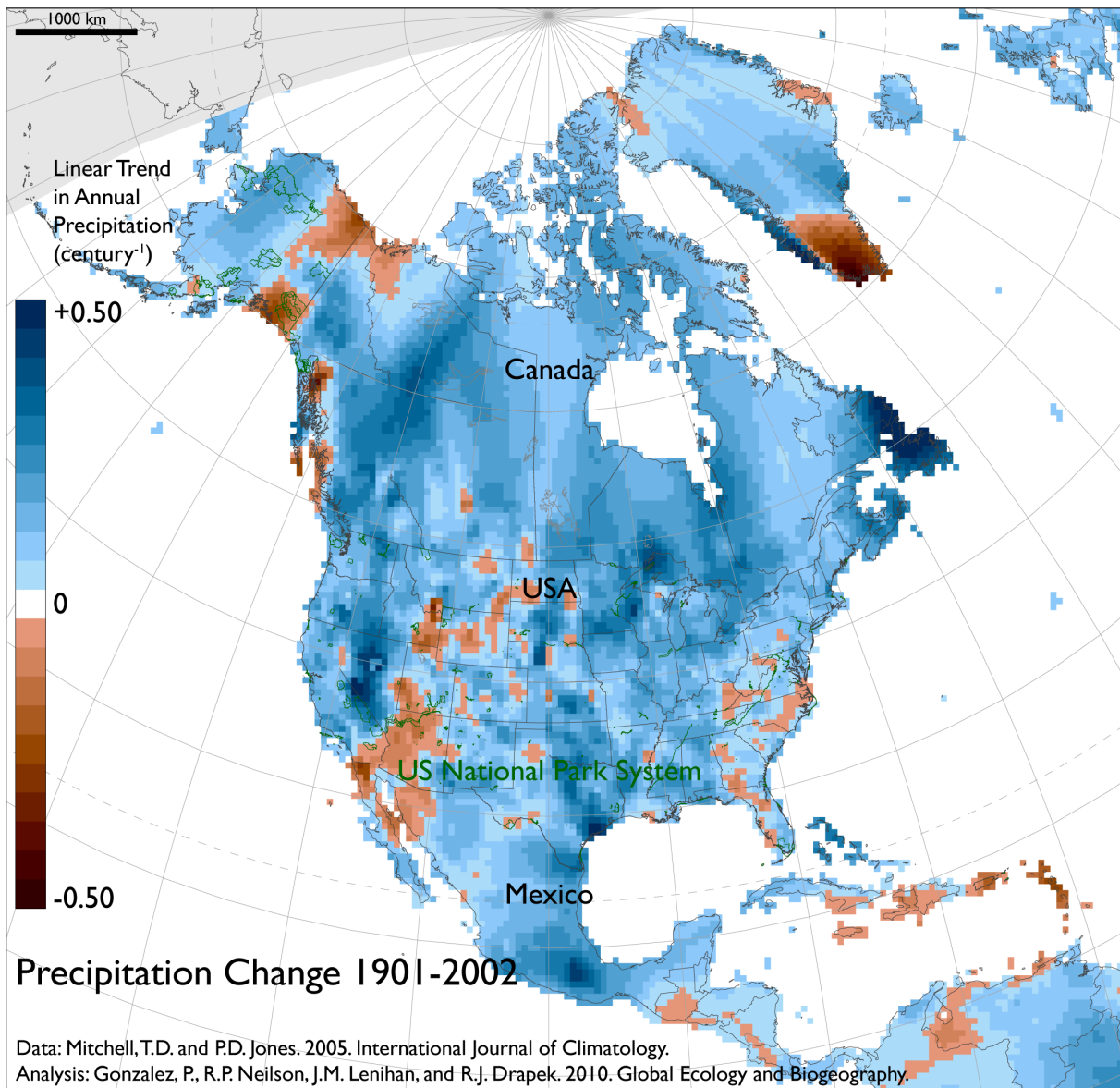


Figure 4.

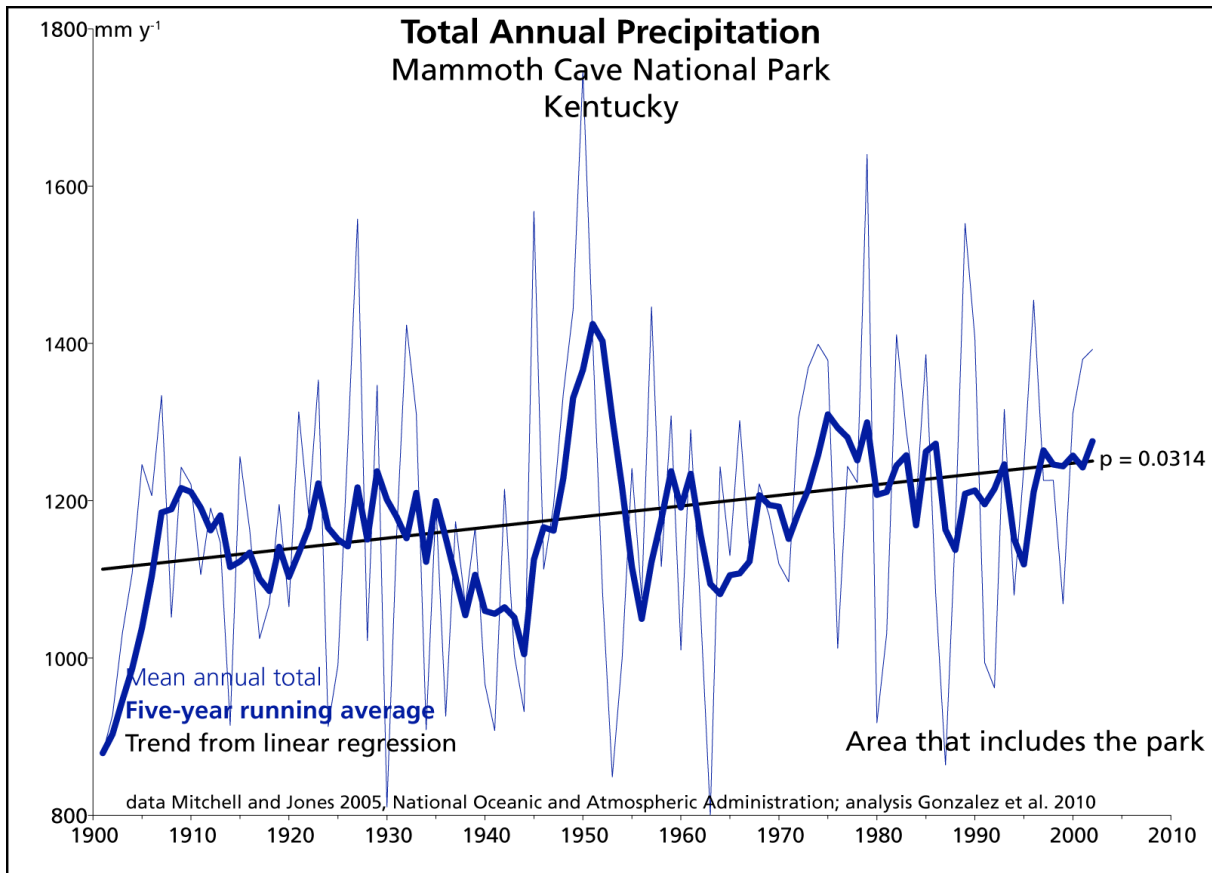
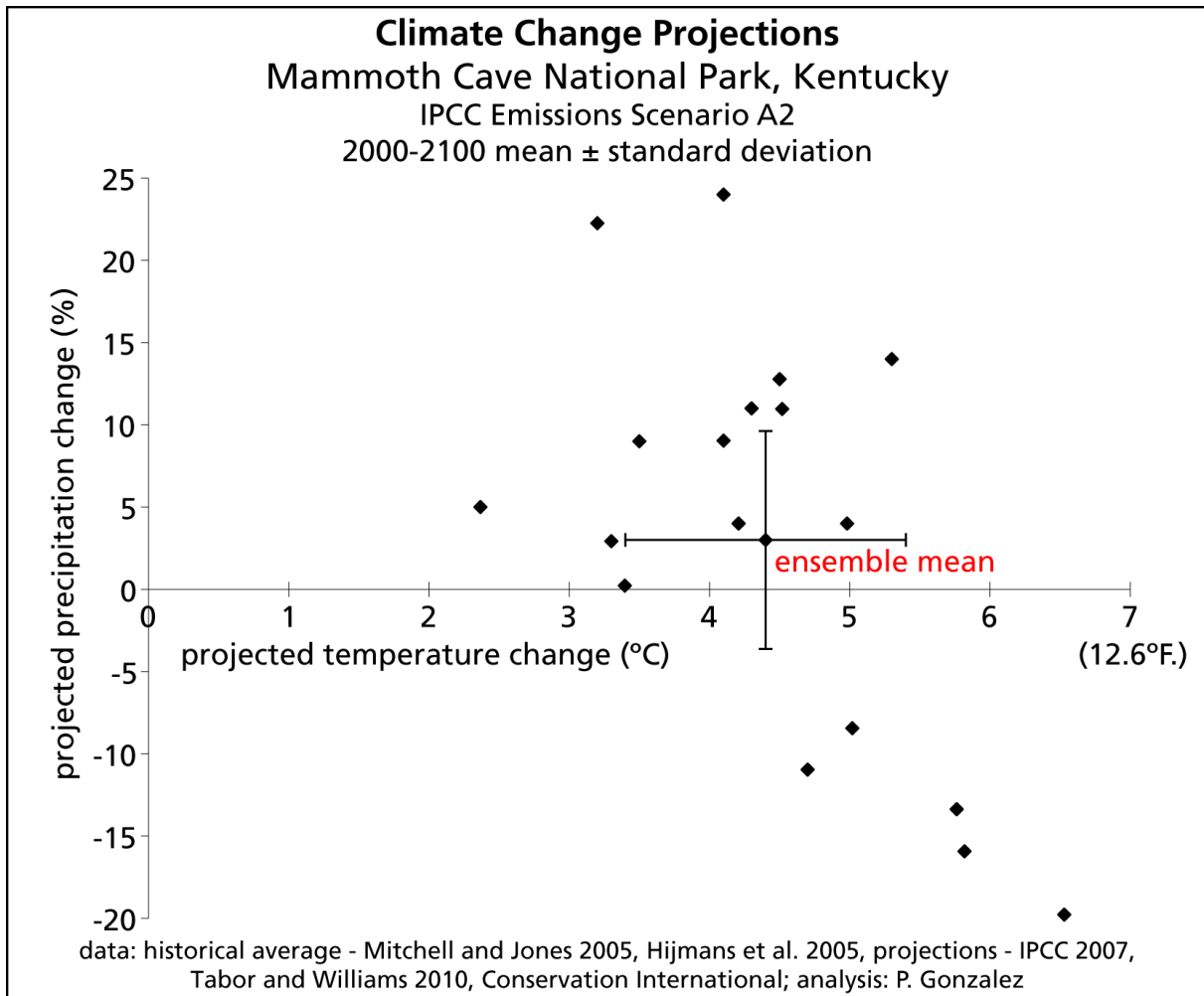


Figure 5.



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