

Climate Change Trends, Impacts, and Vulnerabilities, Capitol Reef National Park, Utah

Patrick Gonzalez

Natural Resource Stewardship and Science, U.S. National Park Service, Washington, DC

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Climate Trends for the Area within Park Boundaries

- Average annual temperature increased at a statistically significant rate in the period 1950-2010 (Figure 1). The highest warming was in spring (March-May), with a rate of $2.9 \pm 0.8^{\circ}\text{C}$ per century ($5.2 \pm 1.4^{\circ}\text{F}$. per century).
- Temperature increases have been higher in the southern reaches of the Waterpocket Fold (Figure 2).
- Total annual precipitation increased in the period 1950-2010, but the rate was not statistically significant (Figure 3).
- Precipitation increases have been higher in the Fruita Historic District and areas to the east (Figure 4).
- If the world does not reduce emissions from power plants, cars, and deforestation by 40-70%, models project substantial warming and changes in precipitation (Table 1, Figure 5).
- For projected average annual precipitation, the climate models do not agree, with over half projecting increases, but many projecting decreases (Figure 5).
- If precipitation increases, temperature increases may be great enough to overcome any cooling effects of increased precipitation, so evapotranspiration and overall aridity may increase.
- Projections under the highest emissions scenario project 10-25 more days per year with a maximum temperature $>35^{\circ}\text{C}$ (95°F .) and an increase in 20-year storms (a storm with more precipitation than any other storm in 20 years) to once every 5-10 years (Walsh et al. 2014).

Historical Impacts in the Region

- Multivariate analysis of wildfire across the western U.S., including southern Utah, from 1916 to 2003 indicates that climate was the dominant factor controlling burned area, even during periods of active fire suppression (Littell et al. 2009).
- Analyses of Audubon Christmas Bird Count data across the United States, including counts in southern Utah, detected a northward shift of winter ranges of a set of 254 bird species at an average rate of 0.5 ± 0.3 km per year from 1975 to 2004, attributable to human climate change and not other factors (La Sorte and Thompson 2007).

- Climate change has caused bark beetle outbreaks, including in Utah forests and woodlands, leading to the most extensive tree mortality across western North America in the last 125 years (Raffa et al. 2008).

Future Vulnerabilities in the Region

- Under high emissions, fire frequencies could increase up to 25% by 2100 (Moritz et al. 2012).
- Under all emissions scenarios, reduced snowfall and rainfall and increased temperature could reduce the flow of springs, streams, and rivers (Garfin et al. 2014).
- Lower elevation desert and mid-elevation woodland ecosystems are vulnerable to future upslope shifts due to climate change (Gonzalez et al. 2010), exacerbated by habitat fragmentation (Eigenbrod et al. 2014).
- Dieback of piñon pines (*Pinus edulis*) and other tree species due to drought and beetle infestations may continue in areas experiencing drought in the future (Breshears et al. 2005).
- In Arches and Canyonlands National Parks, on the Colorado Plateau east of Capitol Reef National Park, grassland and shrubland vegetation died back and wind erosion increased from 1989 to 2009 (Munson et al. 2011a). Modeling indicates potential reduction of Indian Ricegrass (*Achnatherum hymenoides*) and other grasses and expansion of blackbrush (*Coleogyne ramosissima*) and Utah juniper (*Juniperus osteosperma*) if climate change increases aridity (Munson et al. 2011b, Munson 2013).
- Under medium emissions, many plant species endemic to the Colorado Plateau may decrease in range because low dispersal capabilities may prevent shifts at a rate adequate to match latitudinal and elevational shifts in climate (Krause et al. 2015).
- Under high emissions, the area would continue to provide suitable habitat for invasive tamarisk trees (*Tamarix spp.*) and the range of the invasive yellow starthistle (*Centaurea solstitialis*) could expand into the region (Bradley et al. 2009).
- Research on a spotted owl (*Strix occidentalis*) population in Arizona, south of the park, indicate vulnerability to population declines under climate change, since hotter temperatures may reduce adult fecundity (Peery et al. 2012)
- Fruit orchards in the park may be vulnerable to reduced production under climate change due to reduced winter chill (Luedeling and Brown 2011), phenology mismatch of tree flowering and pollinating activity of bees (Bartomeus et al. 2013), bee decline due to pesticides and pests (Goulson et al. 2015), and range shifts of bumblebees (Kerr et al. 2015).

Table 1. Historical rates of change per century and projected future changes in annual average temperature and annual total precipitation (data Daly et al. 2008, IPCC 2013; analysis Wang et al. in preparation). The table gives the historical rate of change per century calculated from data for the period 1950-2010. Because a rate of change per century is given, the absolute change for the 1950-2010 period will be approximately 60% of that rate. For the projections, note that under RCP6.0, temperature ramps up more slowly than under RCP4.5, but eventually overtakes the low scenario after mid-century. This is a property of how the emissions scenarios are written, with population and energy hitting their peak earlier, but at an eventually more sustainable level in RCP4.5. The table gives central values for the park as a whole. Figures 1-5 show the uncertainties.

	1950-2010	2000-2050	2000-2100
Historical			
temperature	+1.8°C/century (3.2°F./century)		
precipitation	+32%/century		
Projected (compared to 1971-2000)			
Reduced emissions (IPCC RCP2.6)			
temperature		+1.9°C (+3.4°F.)	+1.8°C (+3.2°F.)
precipitation		+4%	+6%
Low emissions (IPCC RCP4.5)			
temperature		+2.4°C (+4.3°F.)	+3.1°C (+5.6°F.)
precipitation		+3%	+5%
High emissions (IPCC RCP6.0)			
temperature		+2.1°C (+3.8°F.)	+3.6°C (+6.5°F.)
precipitation		+3	+5%
Highest emissions (IPCC RCP8.5)			
temperature		+3°C (+5.4°F.)	+5.4°C (+9.7°F.)
precipitation		+4%	+7%

Figure 1. Historical annual average temperature for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).

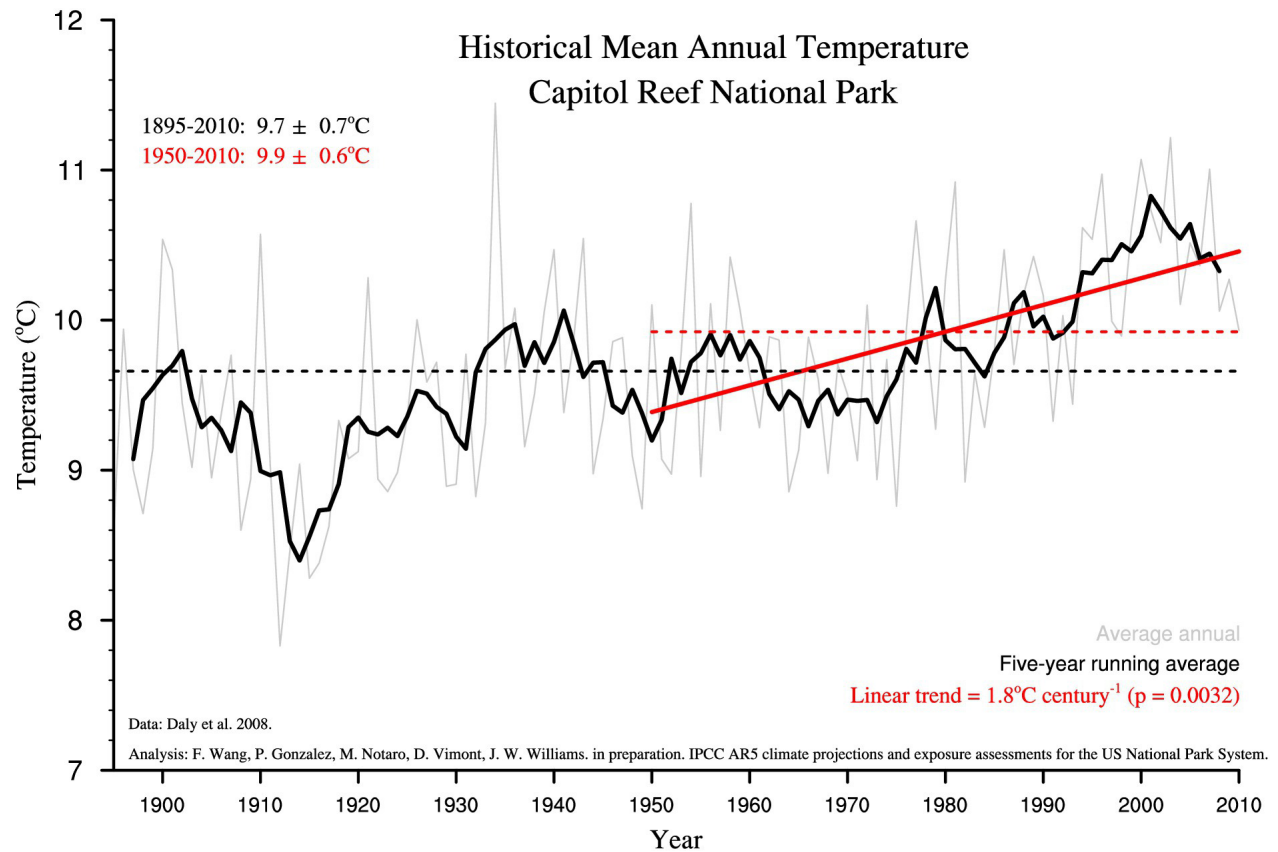


Figure 2.

Historical Trend in Annual Average Temperature, 1950-2010

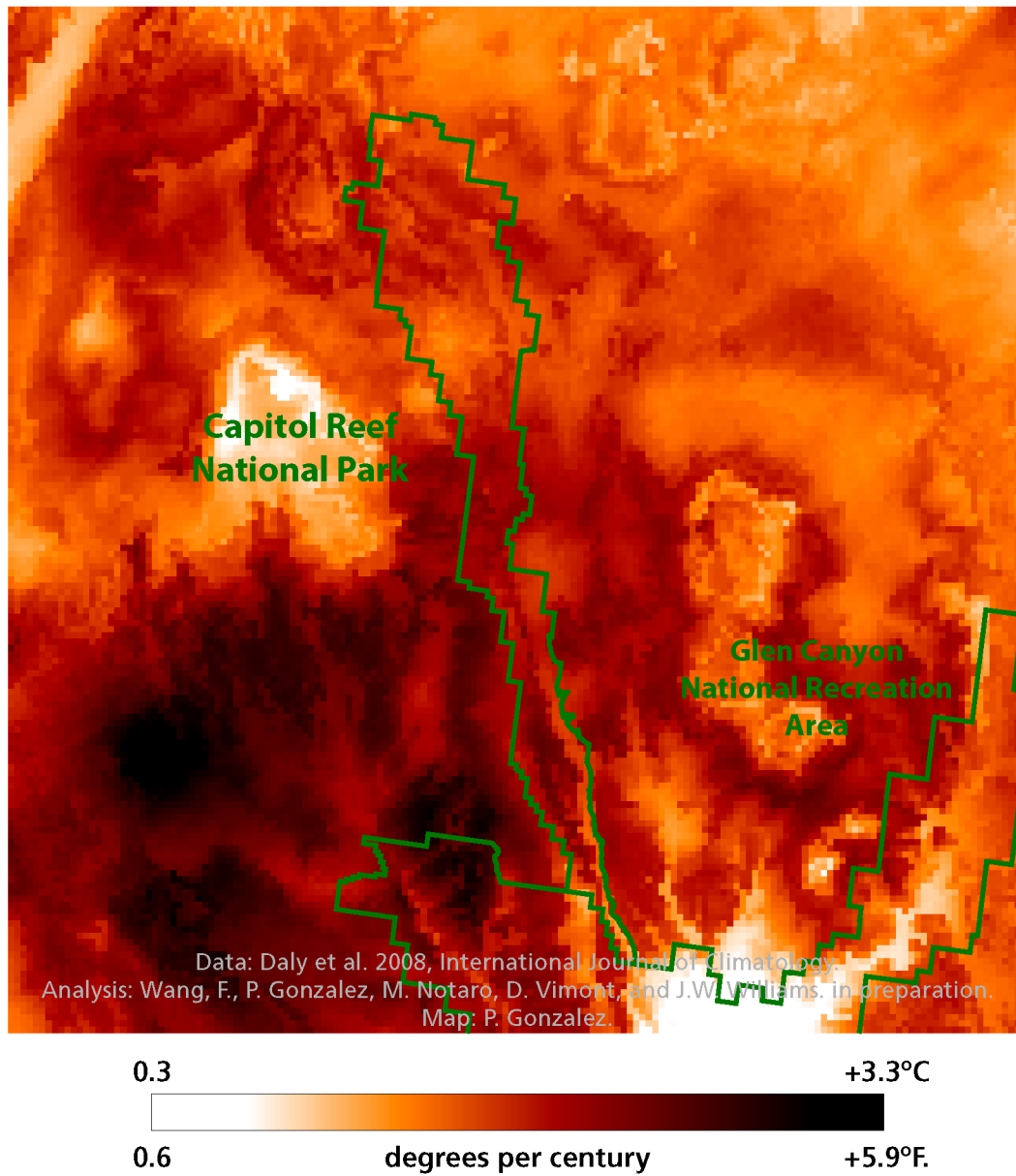


Figure 3. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).

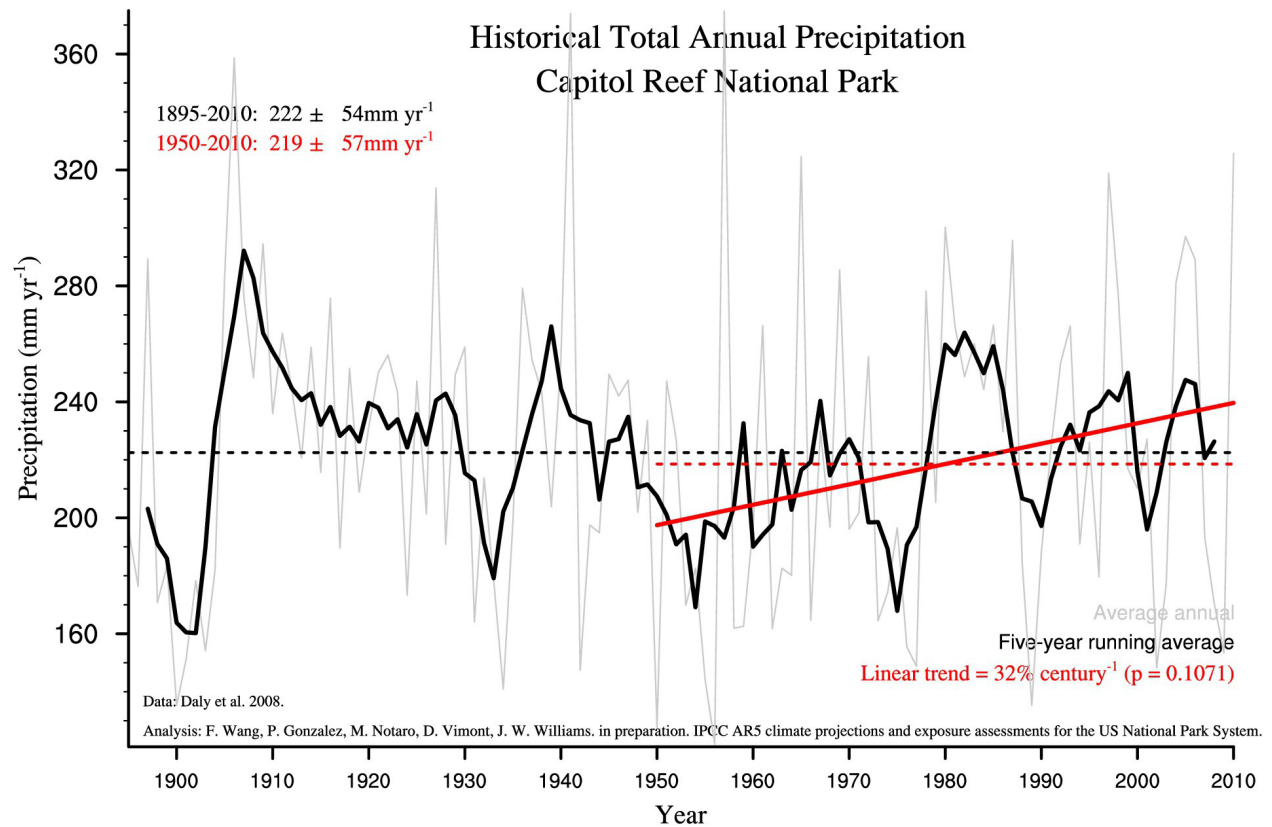


Figure 4.

Historical Trend in Total Annual Precipitation, 1950-2010

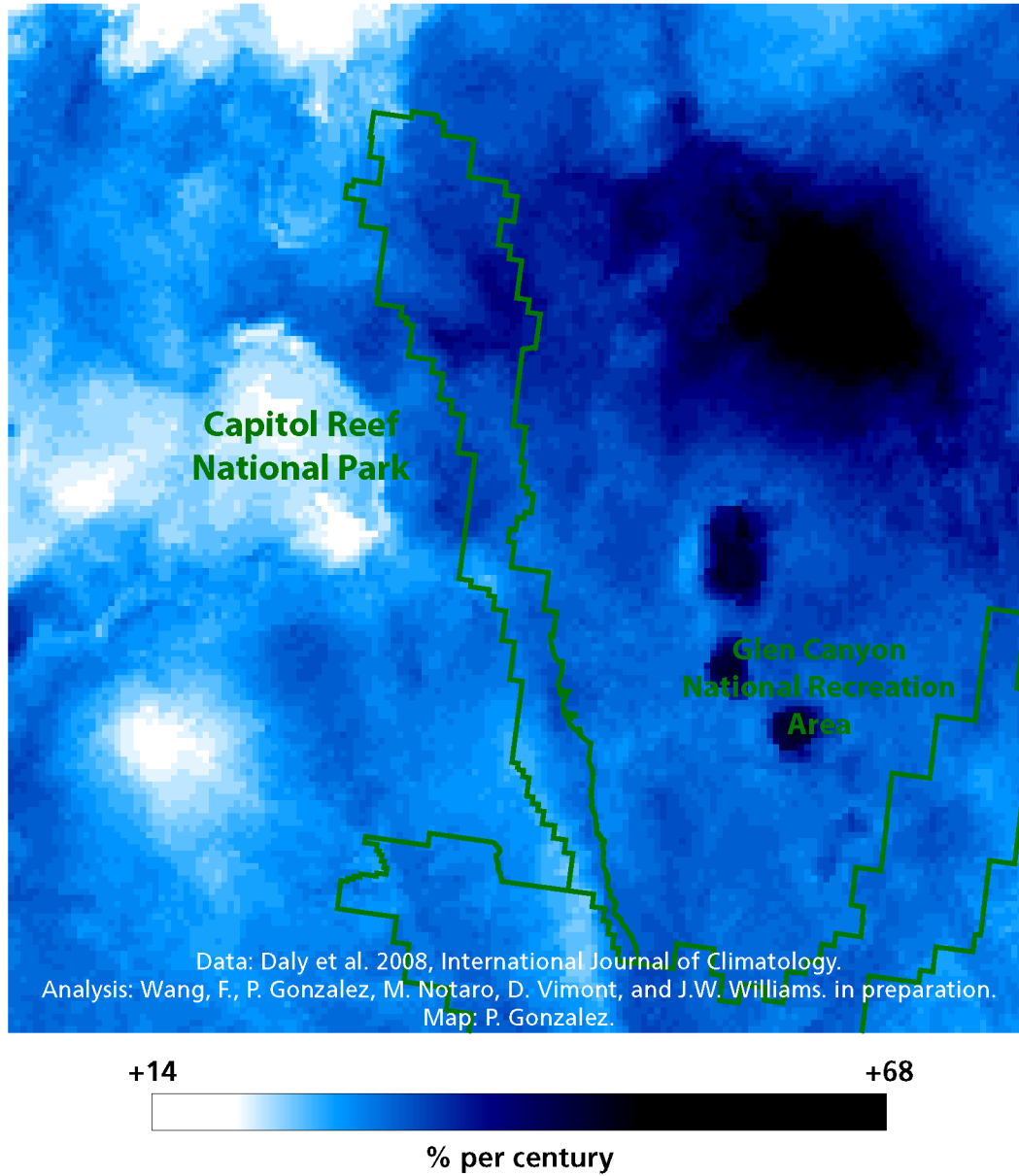
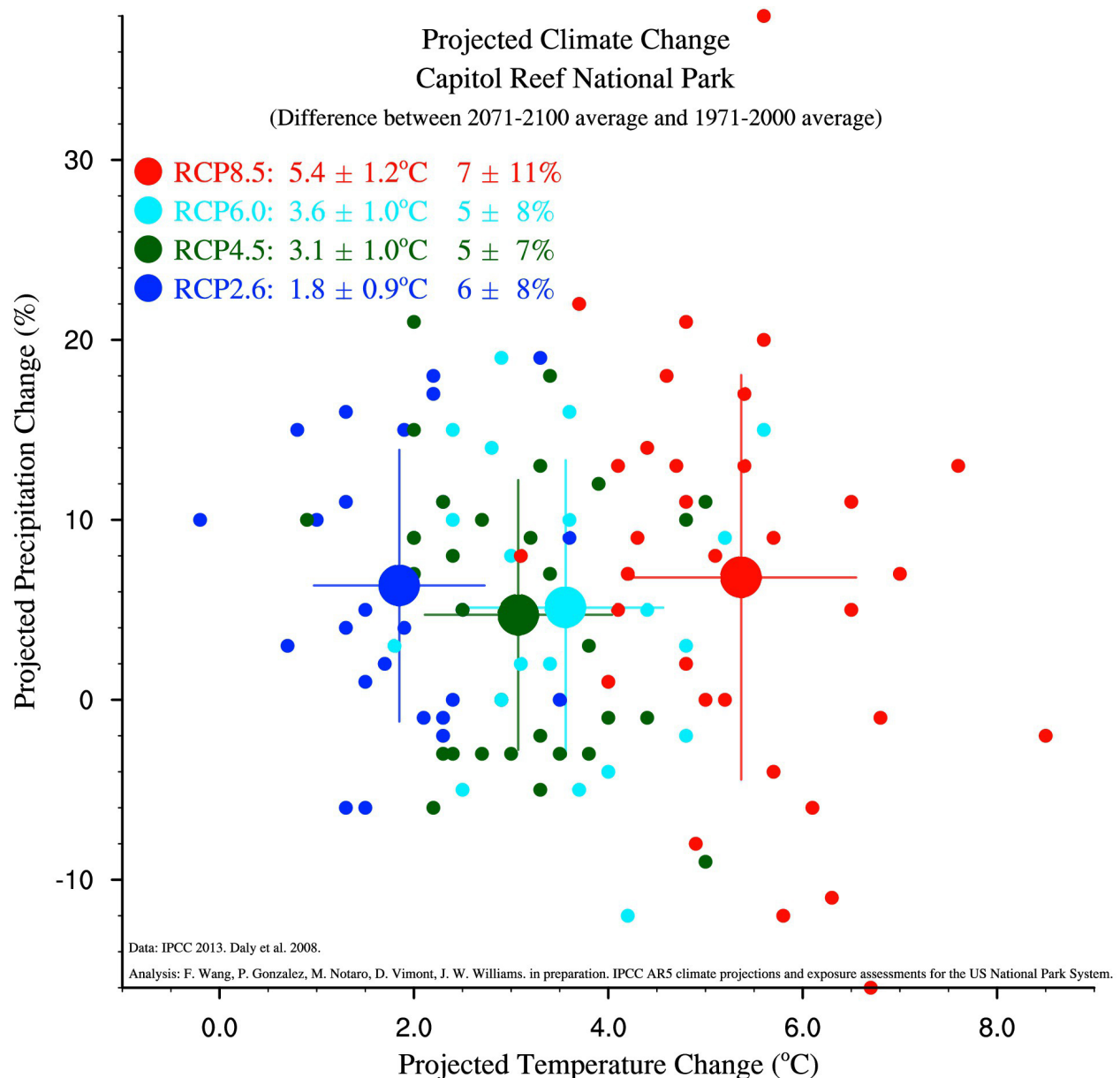


Figure 5. Projections of future climate for the area within park boundaries. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The lines are the standard deviations of each average value. (Data: IPCC 2013, Daly et al. 2008; Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).



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