Climate Change Summary, Tonto National Monument, Arizona

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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).
- Total annual precipitation increased in the period 1950-2010, but the rate was not statistically significant (Figure 2).
- 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 3).
- For projected average annual precipitation, the climate models do not agree, with over half projecting decreases, but many projecting increases (Figure 3).
- Projections under the highest emissions scenario project 25-35 more days per year with a maximum temperature >35ºC (95ºF.) and an increase in 20-year storms (a storm with more precipitation than any other storm in 20 years) to once every 6-10 years (Walsh et al. 2014).

Historical Impacts in the Region

- Multivariate analysis of wildfire across the western U.S., including southern Arizona, 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 Arizona, 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 Arizona 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).

- Analyses of saguaro cactus (*Carnegiea gigantea*) across the northern Sonoran Desert from 1959 to 2005 did not reveal direct relationships of growth, recruitment, or mortality to climate change, although moister conditions can increase regeneration (Pierson et al. 2013).
- Research in Saguaro National Park indicates that, under climate change, less frequent freeze events could allow the range of the saguaro cactus (*Carnegiea gigantea*) to shift upslope, but that increased wildfire related to invasive grasses could inhibit range expansion (Springer et al. 2015).
- Field research in Saguaro National Park and Organ Pipe Cactus National Monument indicates that climate change increases the vulnerability of Sonoran tree and shrub species such as foothills palo verde (*Parkinsonia microphylla*), ocotillo (*Fouquieria splendens*), and creosotebush (*Larrea tridentata*) to mortality due to higher aridity (Munson et al. 2012).
- Recent drought and beetle infestations have killed piñon pines (*Pinus edulis*) and other tree species, which may continue in areas experiencing drought in the future (Breshears et al. 2005).
- 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).
- Under high emissions, the area would provide suitable habitat for invasive tamarisk trees (*Tamarix spp.*) (Bradley et al. 2009).

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 1-3 show the uncertainties.

	1950-2010	**2000-2050**	**2000-2100**
Historical			
temperature	+1.5ºC/century (2.7ºF./century)		
precipitation	+20%/century		
Projected (compared to 1971-2000)			
Reduced emissions (IPCC RCP2.6)			
temperature		+1.7ºC (+3.1ºF.)	+1.6ºC (+2.9ºF.)
precipitation		+2%	+2%
Low emissions (IPCC RCP4.5)			
temperature		+2.1ºC (+3.8ºF.)	+2.8ºC (+5ºF.)
precipitation		-1%	~0
High emissions (IPCC RCP6.0)			
temperature		+1.9ºC (+3.4ºF.)	+3.2ºC (+5.8ºF.)
precipitation		-1%	-3%
Highest emissions (IPCC RCP8.5)			
temperature		+2.8ºC (+5ºF.)	+5ºC (+9ºF.)
precipitation		-1%	-3%

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).

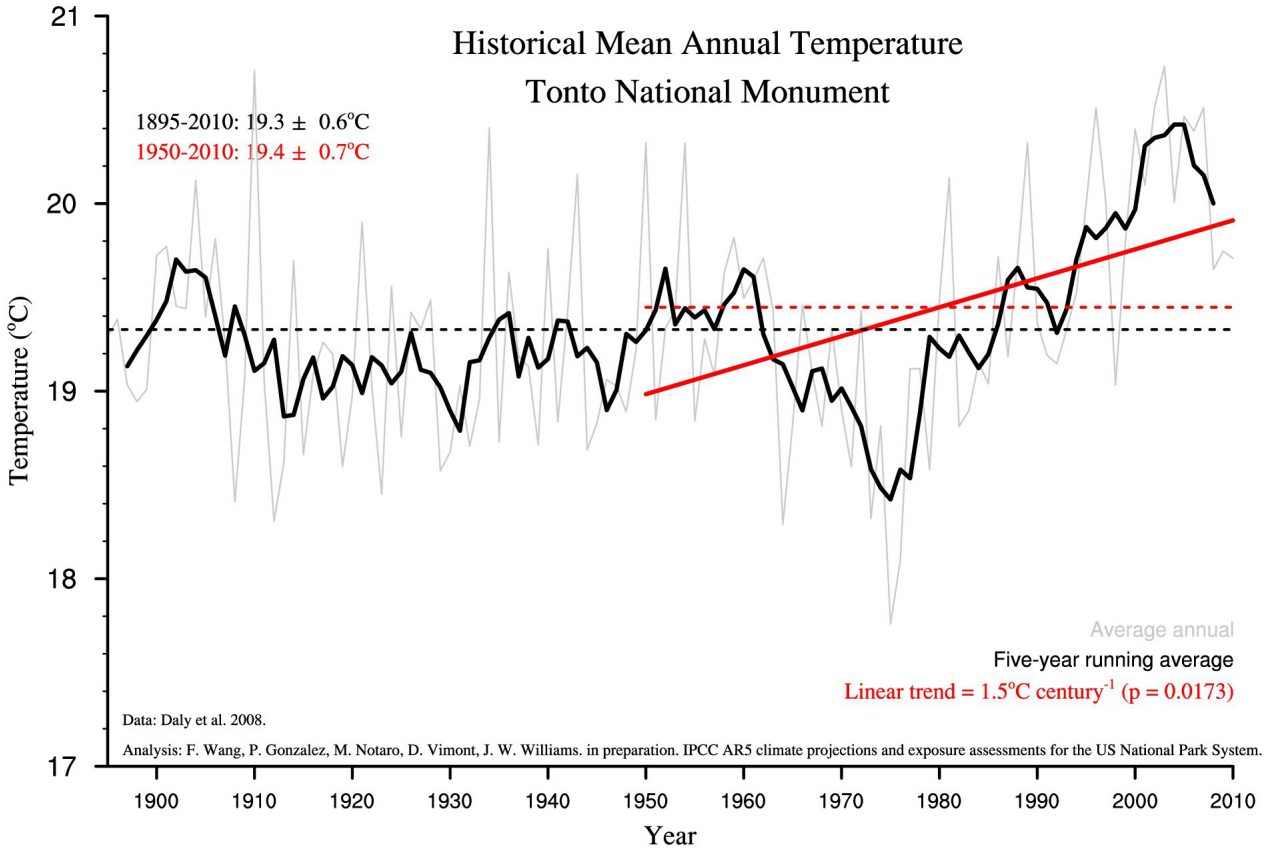


Figure 2. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).

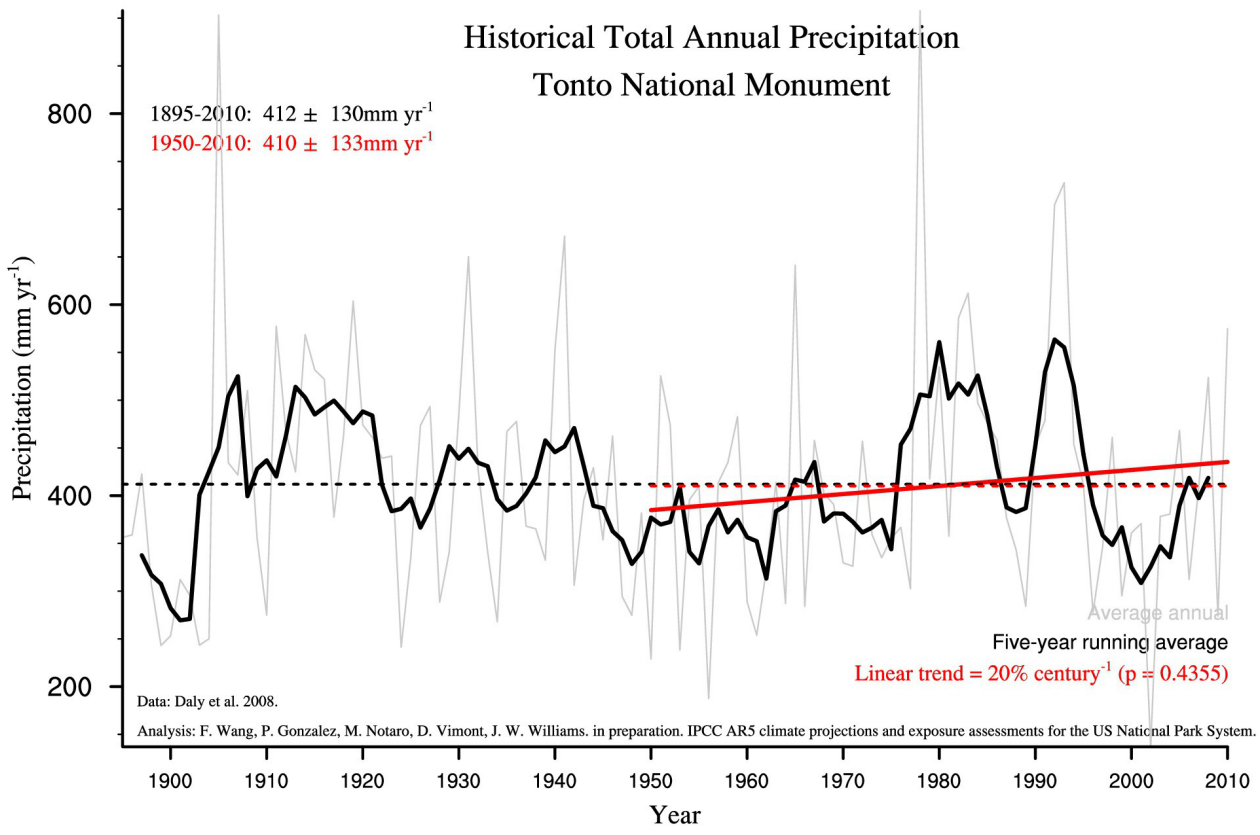
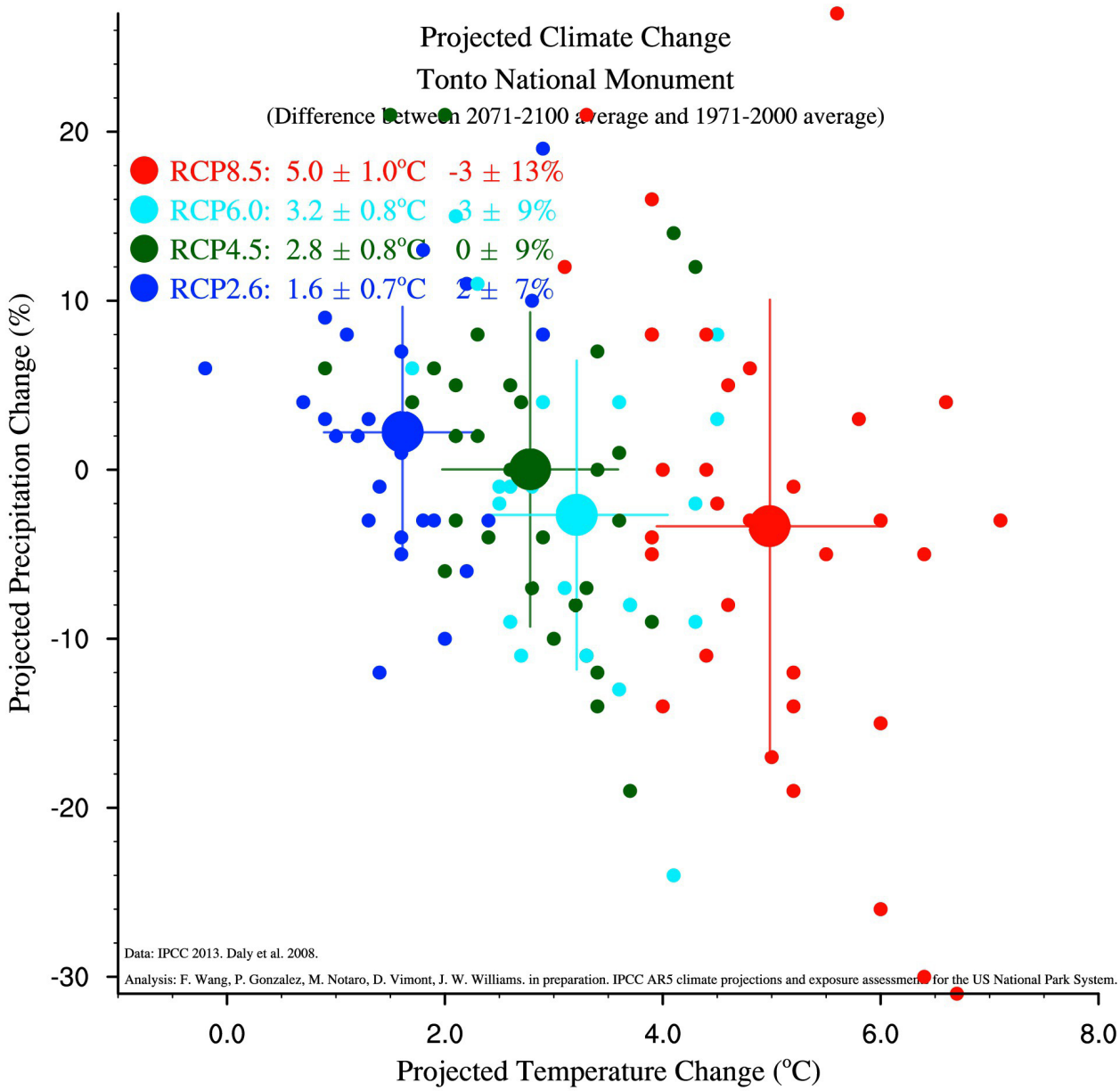


Figure 3. Projections of future climate for the area within park boundaries. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The lines are the standard deviations of each average value. (Data: IPCC 2013, Daly et al. 2008; Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).



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