

Climate Change Trends and Vulnerabilities, Dry Tortugas National Park, Florida

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 has increased since 1950, but the rate has not been statistically significant (Table 1, Figure 1). Summer (June-August) temperature showed the greatest increase at $1 \pm 0.5^{\circ}\text{C}$ ($1.8 \pm 0.9^{\circ}\text{F.}$) per century.
- Average total precipitation has increased since 1950, but the rate has not been statistically significant (Table 1, Figure 2). Summer (June-August) precipitation increased at a statistically significant rate of $67 \pm 27\%$ per century.
- Although records suggest that climate change may have contributed to an increase in the intensity of North Atlantic hurricanes from 1970 to 2004 (Hoyos et al. 2006, Webster et al. 2006), the Intergovernmental Panel on Climate Change (IPCC 2013) has concluded that changing historical methods, incomplete understanding of physical mechanisms, and tropical cyclone variability prevent direct attribution of hurricane changes to climate change.
- 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 increases, but many projecting decreases (Figure 3).
- Under the highest emissions scenario, models project 25-30 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 6-10 years (Walsh et al. 2014).
- Projections of North Atlantic hurricanes under climate change do not agree on possible future hurricane trends (IPCC 2013).

Historical Impacts

- Climate change has raised sea level globally and along the Florida Keys. [See NPS sea level report for the park from Maria Caffrey.]
- Climate change has increased sea surface temperatures globally (IPCC 2013) and in the Florida Keys (Kuffner et al. 2015). These higher temperatures have caused coral bleaching globally (IPCC 2014) and in the Florida Keys (Eakin et al. 2010).

- Monitoring of leatherback turtles (*Dermochelys coriacea*) in the Atlantic Ocean indicate that warming sea surface temperatures have shifted the northern edge of the range north hundreds of kilometers from 1985 to 2002 (McMahon and Hays 2006).

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Future Vulnerabilities

- Under all emissions scenarios, climate change would continue to raise sea level globally and along the Florida coast (IPCC 2013). [See NPS sea level report for the park from Maria Caffrey.]
- Under all emissions scenarios, increased atmospheric carbon dioxide levels may cause substantial ocean acidification and dissolution of coral reefs (IPCC 2014). In Dry Tortugas NP, ocean acidification could especially affect early life-phases of coral (Kuffner et al. 2013).
- Projected increases of sea surface temperatures under climate change render coral reefs more vulnerable to bleaching (IPCC 2014).
- Loggerhead sea turtles (*Caretta caretta*) in Canaveral National Seashore showed a statistically significant advance of nesting of ~7 days earlier in the year from 1989 to 2003 at the same time as a 1.1°C (2°F.) increase in May sea surface temperatures (Pike et al 2006).
- The temperature sensitivity of loggerhead sea turtles (*Caretta caretta*) suggests that increases in air and sand temperatures due to climate change could skew population sex ratios to more females (Hawkes et al. 2007).
- Green turtles (*Chelonia mydas*) in Archie Carr National Wildlife Refuge on Cape Canaveral showed a statistically significant shift of nesting time to earlier in the year from 1989 to 2008 (Weishampel et al. 2010).
- Green turtles (*Chelonia mydas*) may be most vulnerable to any increase in tropical storms due to potential flooding of nests (Pike and Stiner 2007).

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, not that under RCP6.0, temperature ramps up more slowly than 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	+0.2°C/century (0.4°F./century)		
precipitation	+31%/century		
Projected (compared to 1971-2000)			
Low emissions (IPCC RCP 4.5)			
temperature		+1.3°C (+2.3°F.)	+1.7°C (+3.1°F.)
precipitation		+4%	+6%
High emissions (IPCC RCP 6.0)			
temperature		+1.1°C (+2°F.)	+2°C (+3.6°F.)
precipitation		+5%	+2%
Highest emissions (IPCC RCP 8.5)			
temperature		+1.7°C (+3.1°F.)	+3.1°C (+5.6°F.)
precipitation		+4%	-1%

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).

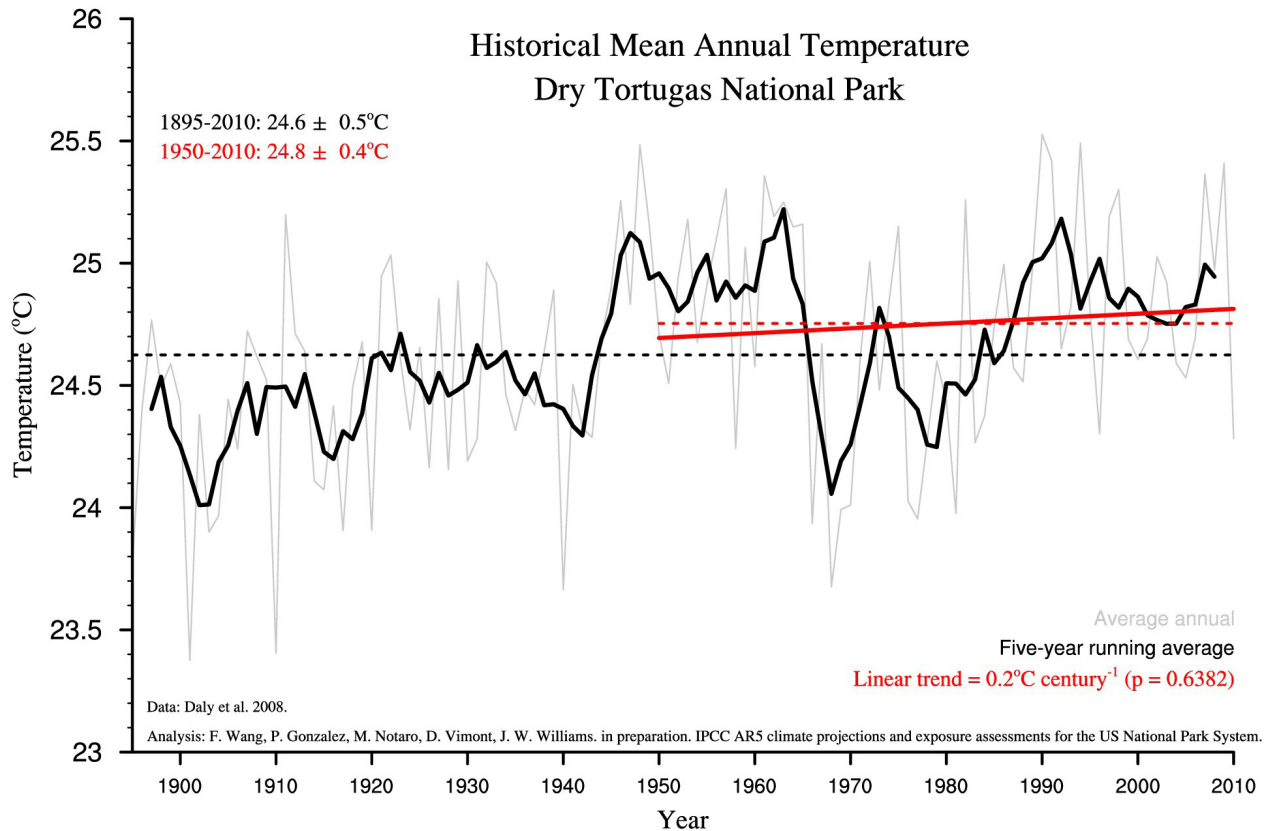


Figure 2. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al.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

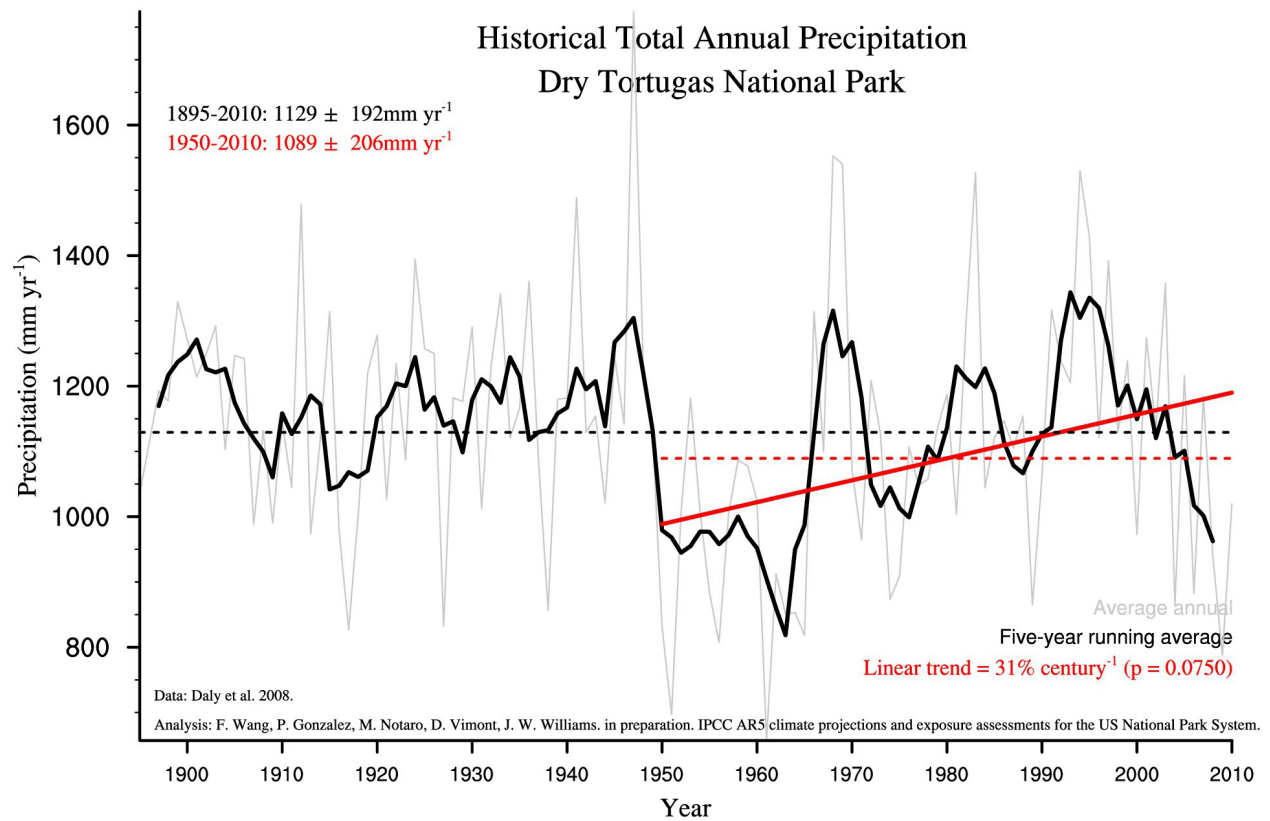
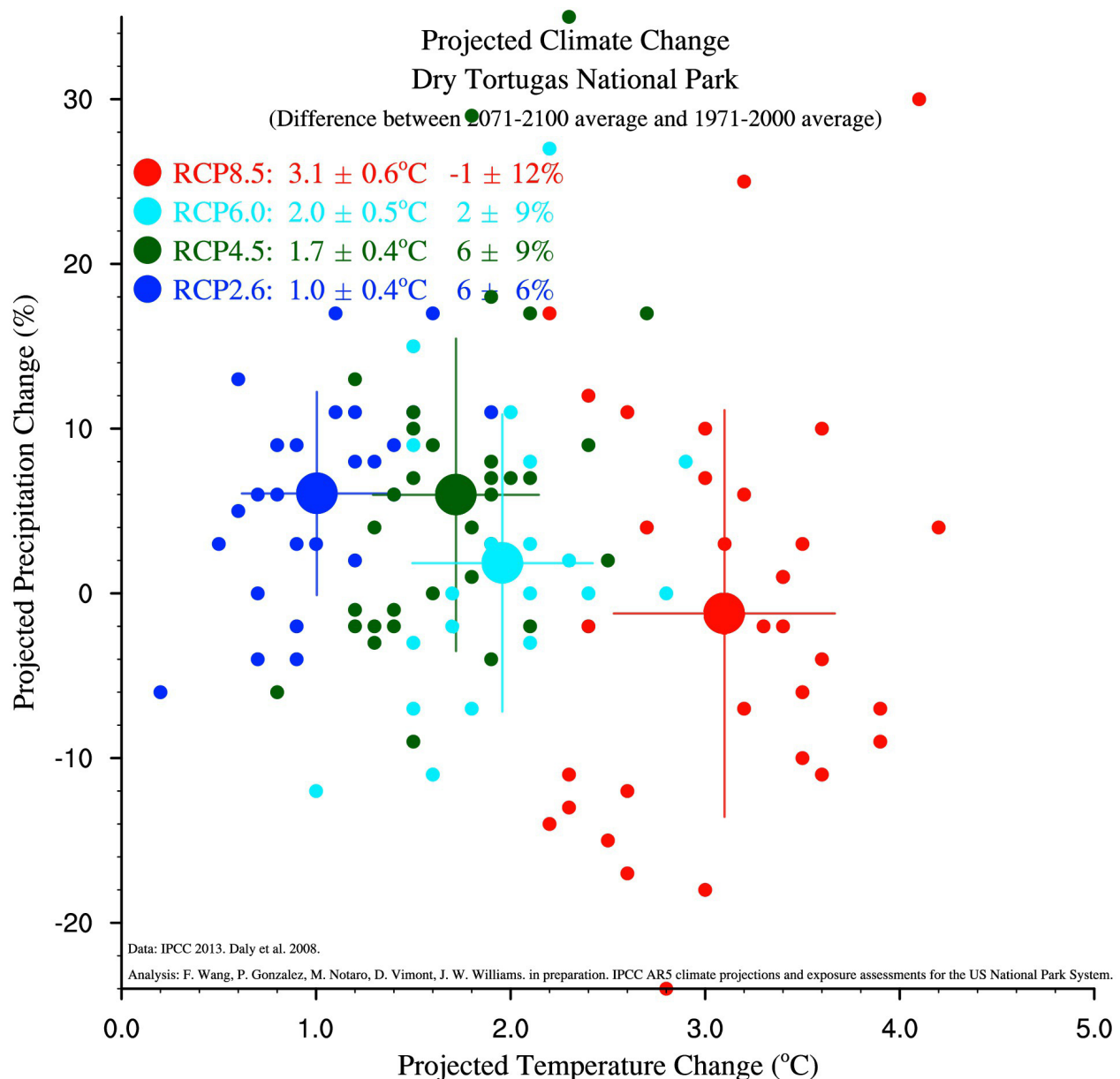


Figure 3. Projections of future climate for the area within park boundaries. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The lines are the standard deviations of each average value. (Data: IPCC 2013, Daly et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



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