

Climate Change Summary, Pictured Rocks National Lakeshore, Michigan

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July 17, 2015

Climate Trends for the Area within Park Boundaries

- Average annual temperature increased at a statistically significant rate in the period 1950-2010 (Figure 1). Spring (March-May) temperature increased at the highest rate, $2.7 \pm 1.3^{\circ}\text{C}$ ($4.9 \pm 2.3^{\circ}\text{F.}$) per century.
- Total annual precipitation (Figure 2) has increased since 1950, but the rate has not been statistically significant.
- If the world does not reduce emissions from power plants, cars, and deforestation by 40-70%, models project substantial warming and increases in precipitation (Table 1, Figure 3).
- The greatest temperature increases could occur in winter (December-February). The greatest precipitation increases could occur in spring (March-May).
- Although climate change is projected to reduce total winter snowfall, a mid-century increase of lake-effect snow in February and March is possible in the area of the park (Notaro et al. 2015).
- Projections under the highest emissions scenario project up to five 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 5-6 years (Walsh et al. 2014).

Historical Changes in the Region

- Analyses of Audubon Christmas Bird Count data across the United States, including counts in Michigan, 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).
- Lake Superior water level has varied substantially over the period of instrumental measurements, with the level generally increasing from 1860 to 1980 and decreasing 30 cm from 1980 to 2007 (Lamon and Stow 2010). The decreasing trend is consistent with, but not formally attributed, to climate change. For more lake level information for the park, see NPS report from Maria Caffrey.
- Lake Superior ice cover decreased at a statistically significant rate of 2% per from 1973 to 2010 (Wang et al. 2012), a trend consistent with climate change.

Future Vulnerabilities in the Region

- Under low emissions, the number of ice-free winters on Lake Superior could increase from none in the period (1951-1995) to 7-43% of winters without ice by 2090 AD (Lofgren et al. 2002).
- Under high emissions, models of Lake Superior water level project a slight decrease on average, but the range of projections also includes slight increases, so future projected lake level is uncertain (Angel and Kunkel 2010). For more lake level information for the park, see NPS report from Maria Caffrey.
- Increased temperature and changes in wind and ice cover may affect the success of recruitment of lake whitefish (*Coregonus clupeaformis*) off the coast of the park (Lynch et al. 2015).
- Upper Peninsula ecosystems are vulnerable to shifts of mixed broadleaf-conifer forest into conifer forest due to climate change (Gonzalez et al. 2010), exacerbated by habitat fragmentation (Eigenbrod et al. 2014).

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	+1.7°C/century (3.1°F./century)		
precipitation	+1%/century		
Projected (compared to 1971-2000)			
Low emissions (IPCC RCP 4.5)			
temperature		+2.8°C (+5°F.)	+3.6°C (+6.5°F.)
precipitation		+7%	+8%
High emissions (IPCC RCP 6.0)			
temperature		+2.3°C (+4.1°F.)	+4.1°C (+7.4°F.)
precipitation		+6%	+10%
Highest emissions (IPCC RCP 8.5)			
temperature		+3.5°C (+6.3°F.)	+6.3°C (+11.3°F.)
precipitation		+8%	+12%

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).

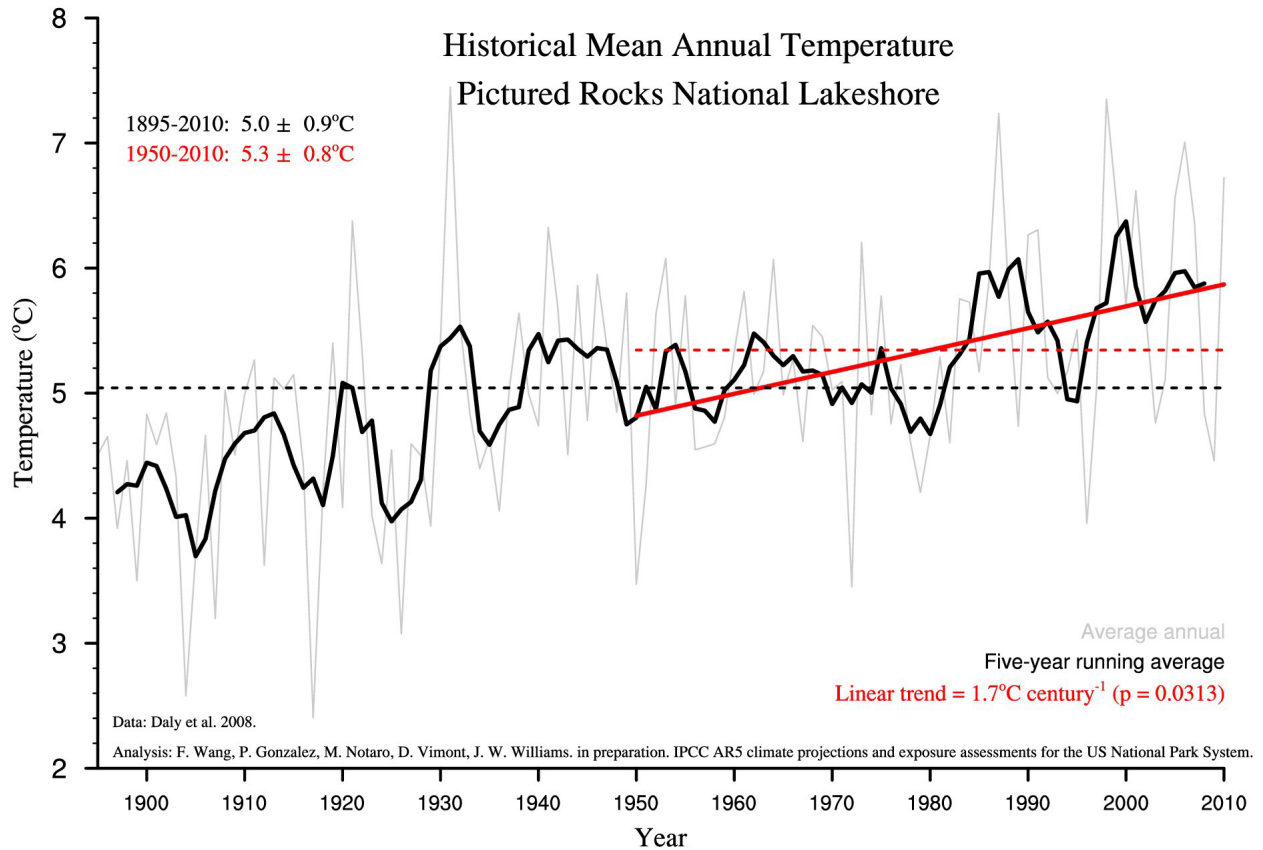


Figure 2. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al.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

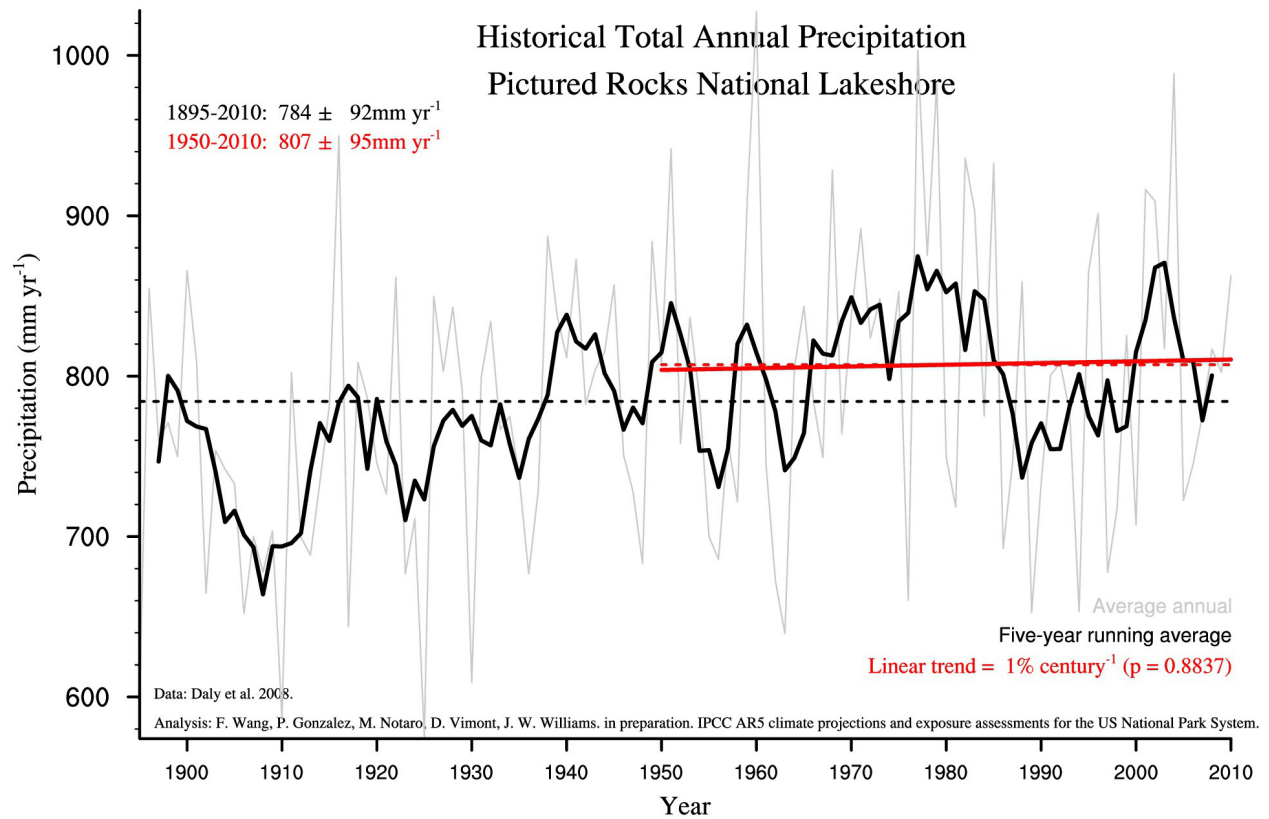
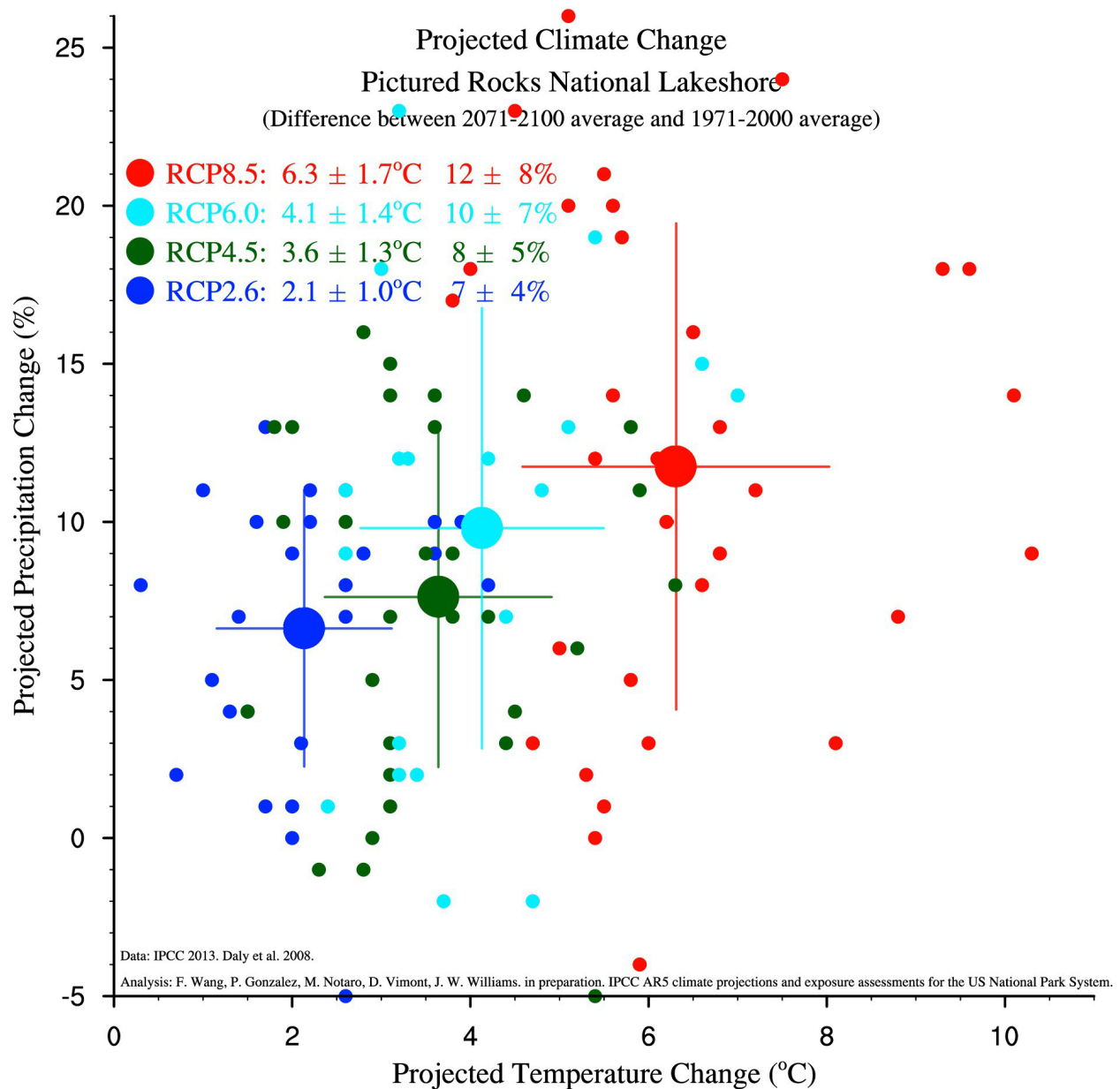


Figure 3. Projections of future climate for the area within park boundaries. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The lines are the standard deviations of each average value. (Data: IPCC 2013, Daly et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



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