

Climate Change Summary, Cabrillo National Monument, California

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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). Spring (March-May) temperature increased at the highest rate, $2.5 \pm 1.1^{\circ}\text{C}$ ($4.5 \pm 2^{\circ}\text{F.}$) per century.
- Total annual precipitation (Figure 2) increased in the period 1950-2010, but the trend was not statistically significant.
- 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 20-25 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 6-10 years (Walsh et al. 2014).

Historical Impacts

- Analyses of tidal gauge measurements around the world have detected a statistically significant rise in global sea level of 19 ± 2 cm (7 ± 1 in.) from 1901 to 2010 with analyses of potential causal factors attributing the rise to human climate change (Church and White 2011, IPCC 2013). For more sea level information for the park, see NPS report from Maria Caffrey.
- Measurements of sea surface temperatures in southern California and around the world have found warming of the top 75 m of ocean water at a rate of $1.1 \pm 0.2^{\circ}\text{C}$ ($2 \pm 0.4^{\circ}\text{F.}$) per century from 1971 to 2010 (IPCC 2013).
- Increased atmospheric carbon dioxide (CO_2) concentrations from human activities have increased the acidity of ocean water around the world by 0.1 pH units since ~1750 (IPCC 2013). This occurs when CO_2 dissolves in water and forms carbonic acid. High acidity can dissolve the shells of many marine species.
- Analyses of Audubon Christmas Bird Count data across the United States, including counts in southern California, 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).

Vulnerabilities in the Region

- If the world does not reduce emissions from power plants, cars, and deforestation, climate change could continue to raise sea level globally 26-55 cm (10-22 inches) by 2100 for the lowest emissions scenario (RCP2.6) and 52-98 cm (20-39 inches) for the highest scenario (RCP8.5) (IPCC 2013). Storm surge would occur over and above the projected sea level rise, with models projecting more frequent and intense coastal flooding. For more sea level information for the park, see NPS report from Maria Caffrey.
- Gray whales (*Eschrichtius robustus*), which migrate along the coast off the park, may spend more time in Arctic waters due to longer and earlier ice-free conditions, changing the timing and duration of their passage through California waters (Moore and Huntington 2008).
- Off-site rearing of the intertidal aquatic crustacean *Tigriopus californicus* taken from the Monument and other sites along the Pacific Coast indicates that they show little adaptive increase in heat tolerance (Kelly et al. 2012).
- Intertidal pool invertebrates such as mollusks and snails in Monterey Bay in Central California, but similar to those found in the Monument, showed signs of a northern range shift with increasing water temperatures from 1931 to 1996 (Barry et al. 1995, Sagarin et al. 1999).
- While urban development, climate change, and altered fire regimes may substantially reduce coastal sage scrub habitat in much of the San Diego area, the area of the Monument could serve as a refugium for coastal sage scrub plant species (Lawson et al. 2010, Riordan et al. 2014).
- A rainfall manipulation experiment at the University of California, Irvine, indicates that coastal sage shrub species, found in the Monument, can outcompete invasive grasses under lower rainfall, but that invasive grasses are more competitive under higher rainfall (Goldstein and Suding 2014).
- Climate change may also substantially affect water supplies and human health in the San Diego region (Messner et al. 2011).

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	+1.8°C/century (+3.2°F./century)		
precipitation	+31%/century		
Projected (compared to 1971-2000)			
Low emissions (IPCC RCP 4.5)			
temperature		+1.6°C (+2.9°F.)	+2.2°C (+4°F.)
precipitation		+2%	+2%
High emissions (IPCC RCP 6.0)			
temperature		+1.5°C (+2.7°F.)	+2.5°C (+4.5°F.)
precipitation		+2%	-3%
Highest emissions (IPCC RCP 8.5)			
temperature		+2.1°C (+3.8°F.)	+3.8°C (+6.8°F.)
precipitation		+1%	~0

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).

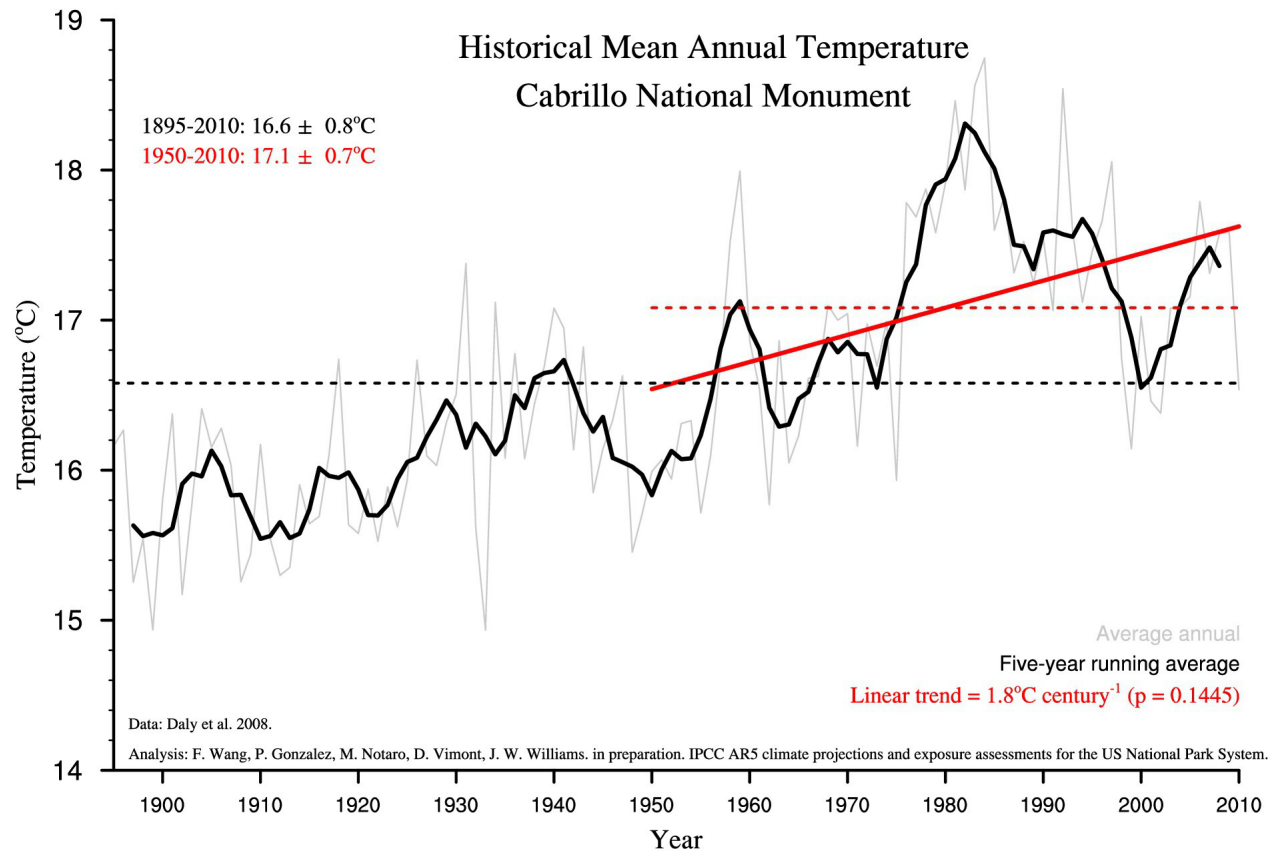


Figure 2. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1895. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al.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

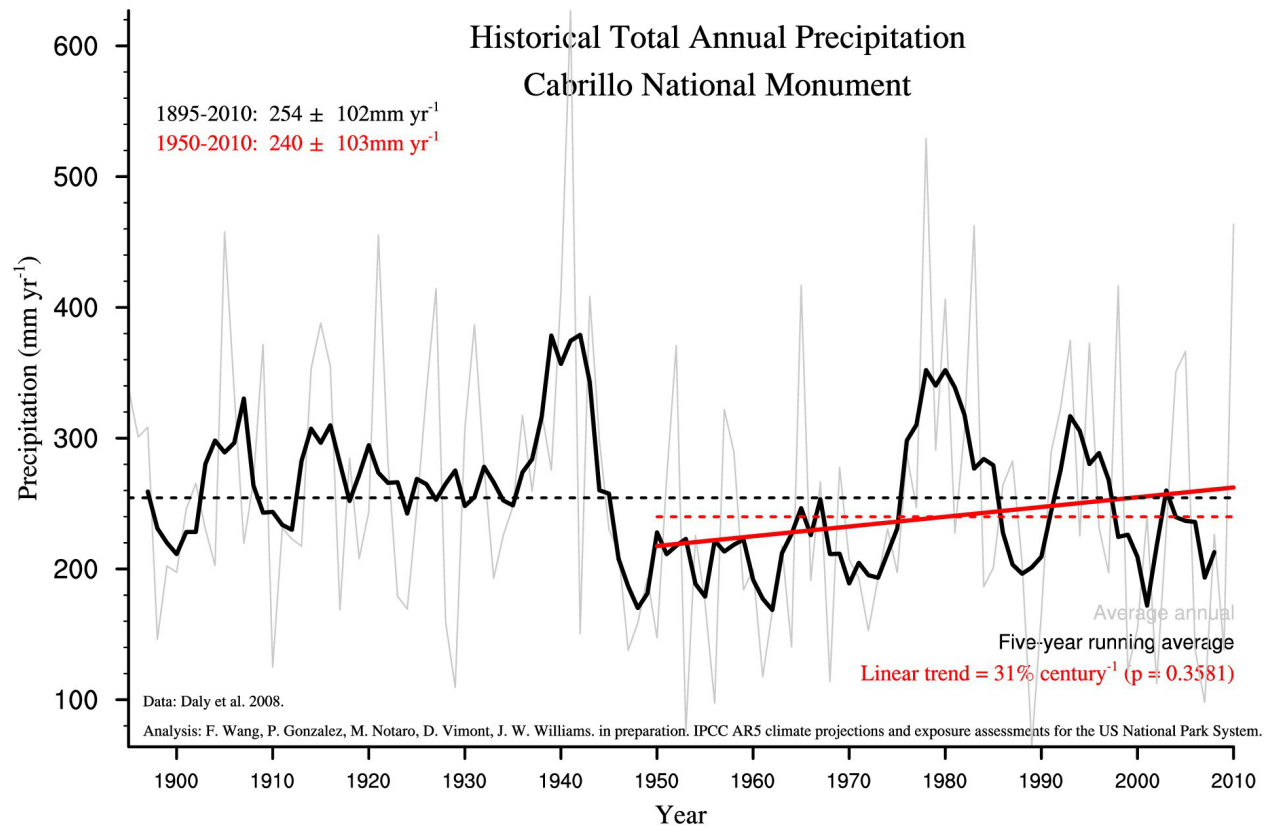
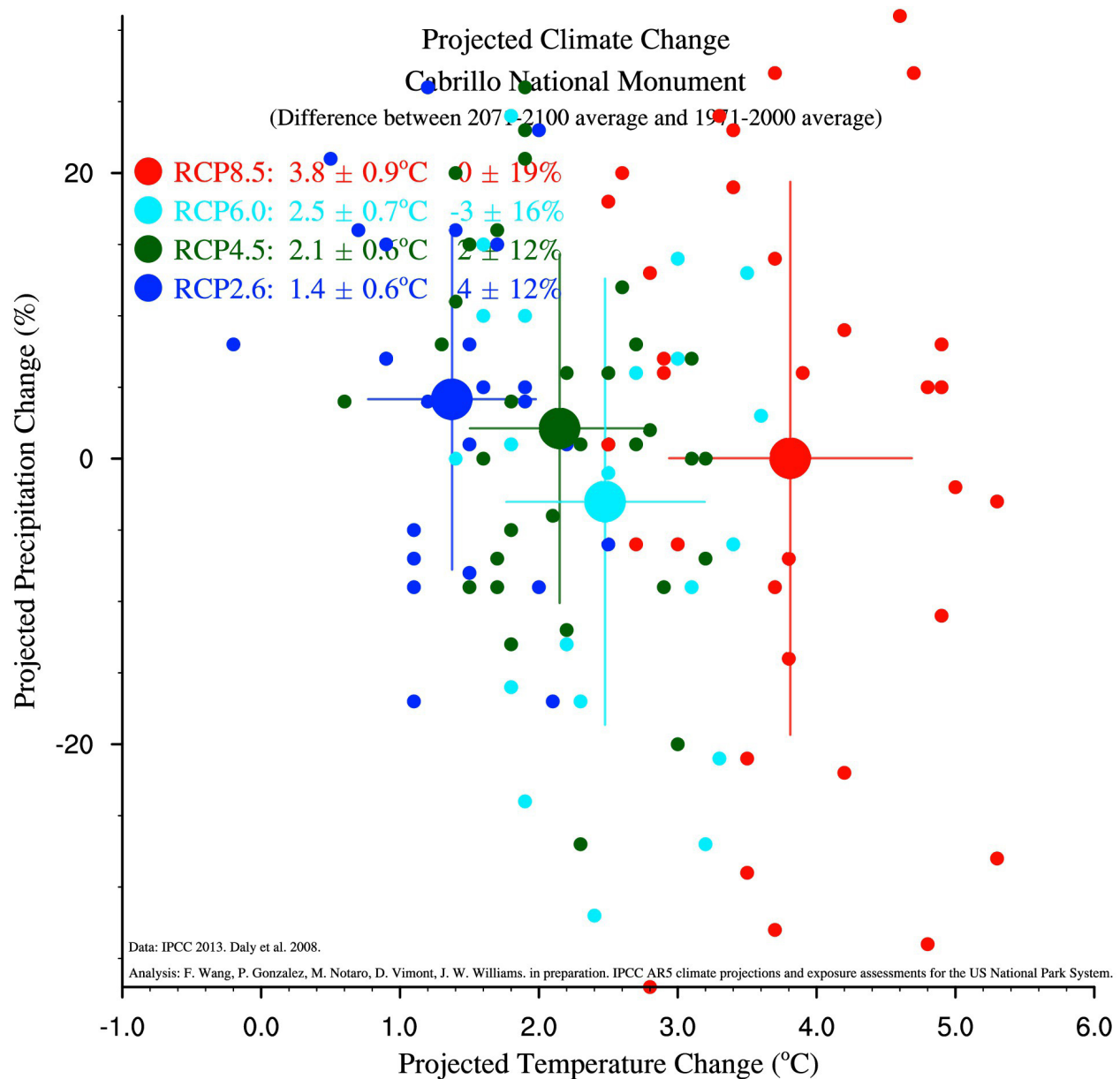


Figure 3. Projections of future climate for the area within park boundaries. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The lines are the standard deviations of each average value. (Data: IPCC 2013, Daly et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



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