Climate Change Trends, Impacts, and Vulnerabilities,

Pu`uhonua O Hōnaunau National Historical Park, Hawai‘i

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Climate Trends for the Area within Park Boundaries

- Average annual temperature increased at a statistically significant rate in the period 1950-2009 (Table 1, Figure 1).
- Total annual precipitation decreased at a statistically significant rate in the period 1950-2009, (Table 1, Figure 2).
- Tropical cyclone frequency in the central North Pacific Ocean did not show from 1966 to 2010 (Keener et al. 2013).
- 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).
- For projected average annual precipitation, the climate models do not agree, with the average of all models projecting a slight increase, but many individual models projecting decreases.
- Projections under the highest emissions scenario project 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).
- Modeling under medium emissions projects an increase in tropical cyclone frequency from 2003 to 2099 from 1-2 per year to 2-3 per year in the area of the island of Hawai‘i (Murakami et al. 2013).

Historical Impacts in the Region Attributed to Human Climate Change

- **Sea level rise** 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 sea level information for the park, see NPS report from Maria Caffrey.
- **Ocean acidification** When carbon dioxide (CO_2) dissolves in water it forms carbonic acid. Increased atmospheric 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).

- **Sea surface temperatures** Measurements of sea surface temperatures in the Pacific Ocean and around the world have found warming of the top 75 m of ocean water at a rate of 1.1 ± 0.2ºC (2 ± 0.4ºF.) per century from 1971 to 2010 (IPCC 2013).

Future Vulnerabilities in the Region

- **Sea level rise** 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.
- **Sea level rise** Research at the park on the effects of the non-climate change related Japanese tsunami of 2011, which caused inundation in the park up to 1.1 m, and modeling of potential future sea level rise indicates that half of the archaeological features of the park, including anchialine pools, are vulnerable to inundation at 1 m rise (Johnson et al. 2015).
- **Ocean acidification** Further carbon dioxide emissions would continue to acidify ocean waters, with general circulation models projecting acidification by 0.06 to 0.3 pH units by 2100 (IPCC 2013). This acidity can dissolve corals and the shells of many marine species.
- **Sea surface temperatures** General circulation models project increases of ocean temperatures at the latitude of Hawai‘i of 0.7-3ºC in the upper 200 m of the ocean by 2100 (IPCC 2013). These temperatures could substantially increase the vulnerability of coral reefs to bleaching (IPCC 2014). Warm waters caused coral bleaching off Oahu and some other part of Hawai‘i in 1996 and 2002 (Jokiel et al. 2004).
- **Green turtle** Research on the green turtle (*Chelonia mydas*) on Oahu, listed as threatened under the Endangered Species Act, indicates that, with projected heating under climate change, terrestrial basking would cease globally by 2100 (Van Houtan et al. 2015). Warmer sand temperatures could decrease green turtle hatchling survival (Cavallo et al. 2015).
- **Monk seals** Analyses of population counts of Hawaiian monk seals (*Monachus schauinslandi*) in the Northwest Hawaiian Islands since the 1930s indicates a correlation between the Pacific Decadal Oscillation (PDO), a medium-term climate cycle, and monk seal populations (Baker et al. 2012). Projected impacts of climate change on the PDO are not clearly resolved (IPCC 2013).

- **Freshwater** Reduced precipitation and increased evapotranspiration could reduce already scarce freshwater supplies (Leong et al. 2014).

Table 1. Historical rates of change per century and projected future changes in annual average temperature and annual total precipitation for the park as a whole (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 1950-2009. The U.S. weather station network was more stable for the period starting 1950 than for the period starting 1901. 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 with standard errors (historical) and standard deviations (projected).

	1950-2009	**2000-2100**
Historical		
temperature	+1.5 ± 0.3ºC per century (3 ± 0.5ºF. per century)	
precipitation	-17 ± 16% per century	
Projected (compared to 1971-2000)		
Reduced emissions (IPCC RCP2.6)		
temperature		+1.1 ± 0.4ºC (+2 ± 0.7ºF.)
precipitation		+2 ± 27%
Low emissions (IPCC RCP4.5)		
temperature		+1.8 ± 0.5ºC (+3 ± 0.9ºF.)
precipitation		+4 ± 33%
High emissions (IPCC RCP6.0)		
temperature		+2.1 ± 0.7ºC (+4 ± 1.3ºF.)
precipitation		+3 ± 40%
Highest emissions (IPCC RCP8.5)		
temperature		+3.3 ± 0.7ºC (+6 ± 1.3ºF.)
precipitation		+15 ± 56%

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 1901. (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).

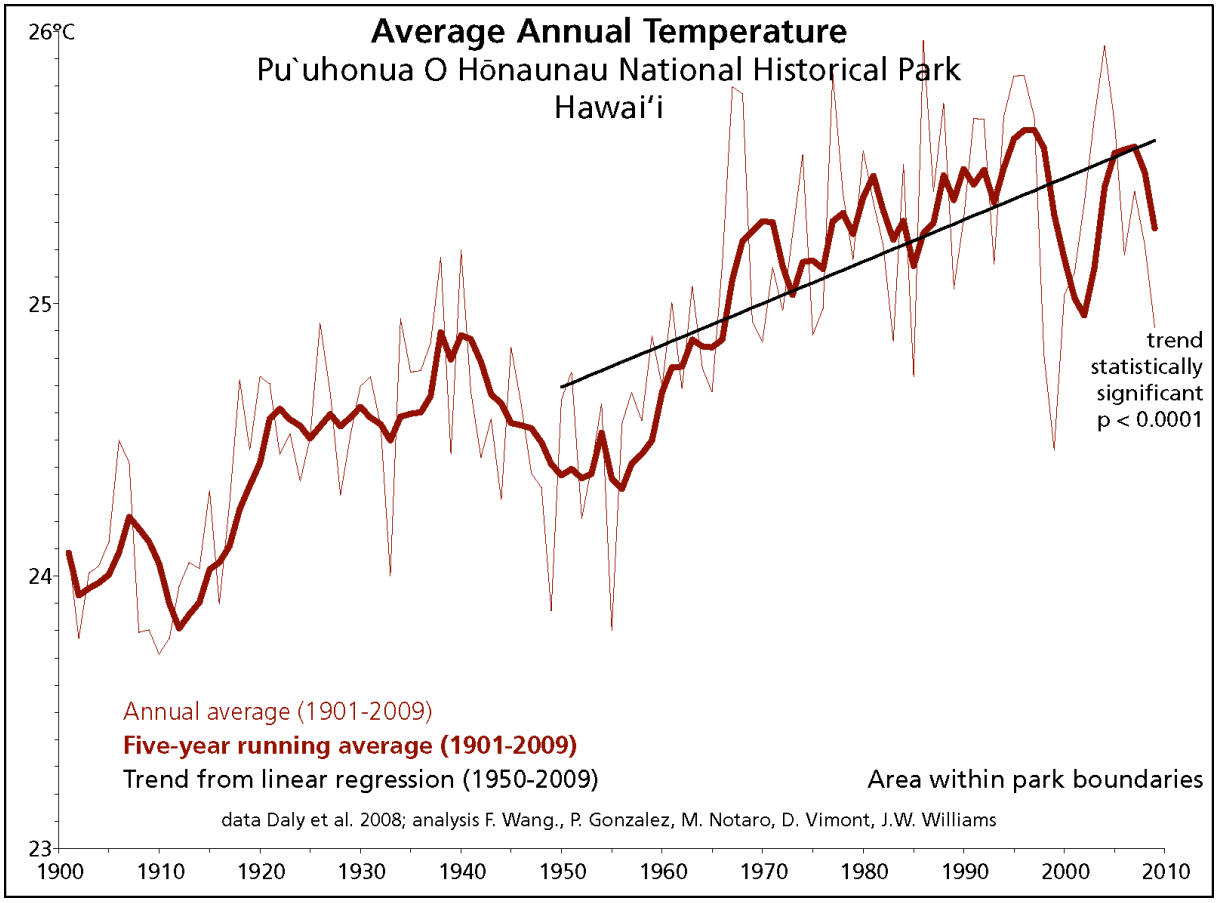
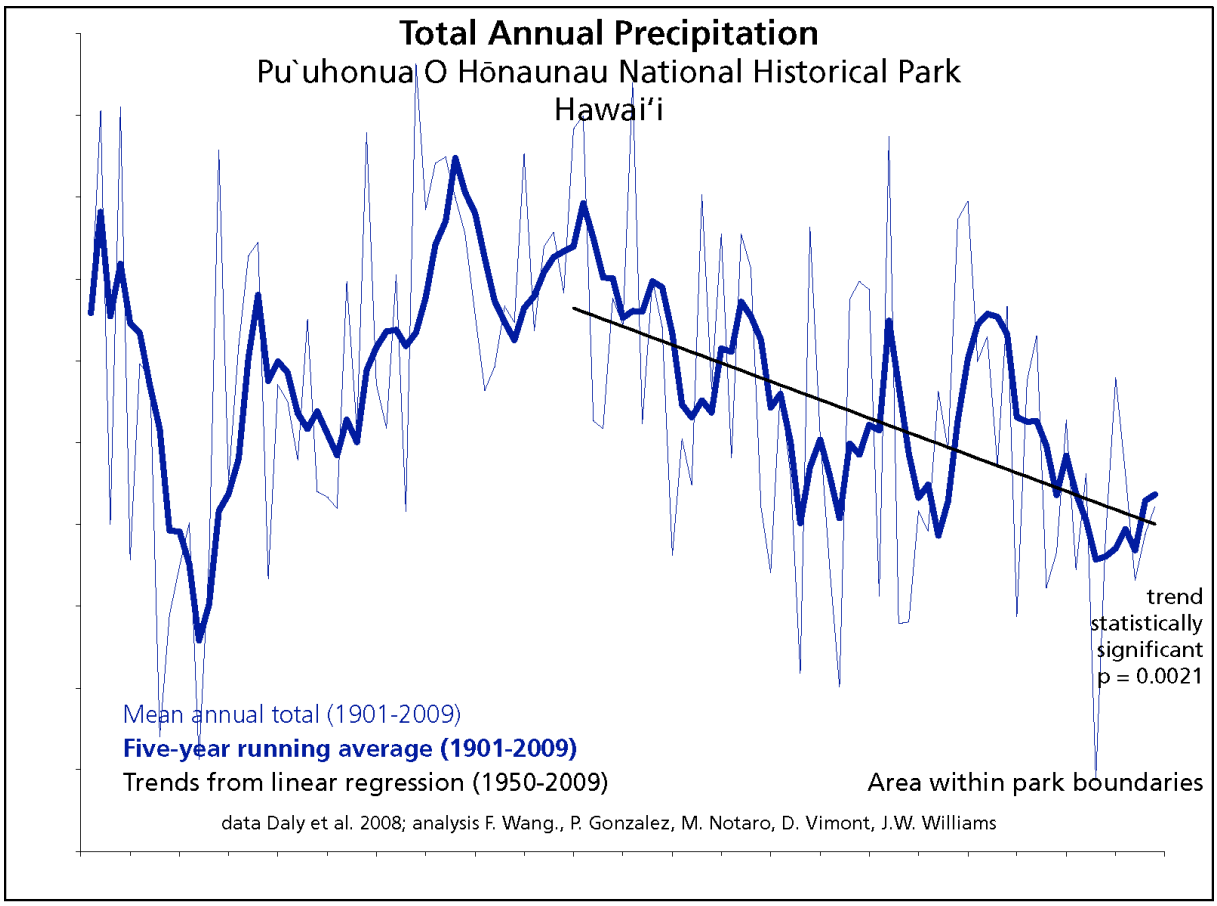


Figure 2. Historical annual total precipitation for the area within park boundaries. Note that the U.S. weather station network was more stable for the period starting 1950 than for the period starting 1901. (Data: National Oceanic and Atmospheric Administration, Daly et al. 2008. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).



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