

Climate Change Trends and Vulnerabilities, Haleakalā National Park, Hawai'i

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June 2, 2014

Climate Trends for the Area within Park Boundaries

- Temperature is increasing at a rate of 1.6° C (2.9° F.) per century for the park as a whole (Figures 1, 3), but the trend is not statistically significant
- Precipitation is decreasing at a rate of 17% per century for the park as a whole, but the trend is not statistically significant (Figures 2, 4).
- Analyses of atmospheric measurements and other data show that emissions from cars, power plants, and other human activities are causing climate change (IPCC 2013).
- If we do not reduce our emissions, models project substantial future warming and slight decreases in precipitation (Figures 5-7).

Ecological Vulnerabilities

- Mortality of the Haleakalā silversword (*Argyroxiphium sandwicense macrocephalum*), a plant species found only on Haleakalā, increases with hotter temperatures and lower rainfall, making the species more vulnerable under climate change (Krushelnycky et al. 2013).
- The tropical montane cloud forests of Haleakalā are vulnerable to increased mortality under arid conditions of continued climate change (Loope and Giambelluca 1998).
- Changes in spatial climate patterns could favor certain established invasive plant species, such as Monterey pine (*Pinus radiata*) (Daehler 2005).
- Elevation differentiates the vegetation of Haleakalā into distinct zones that could be vulnerable to upslope shifting under continued temperature increases (Gonzalez et al. 2010).
- Hawaiian honeycreepers (numerous species of endemic birds, subfamily *Drepanidinae*) are vulnerable to extinction from a combination of agricultural replacement of native forest, non-native mosquitoes bearing avian malaria, and elevational shifts of climate and native vegetation (Benning et al. 2002, Atkinson and LaPointe 2009).
- Climate change may increase the spread of the invasive Argentine ant (*Linepithema humile*) (Hartley et al. 2010).

Table. 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 tables give the historical rate of change per century calculated from data for the period 1950-2009. We use the 1950-2009 rate of change because the weather station network was more stable for that period than for 1900-2009. Because a rate of change per century is given, the absolute change for the 1950-2009 period will be approximately 60% of that rate. The table gives central values for the park as a whole. Figures 1, 2, 5, and 6 show the spatial variation. Figures 3, 4, and 7 show the uncertainties.

	1950-2009	2000-2050	2000-2100
Historical			
Temperature	+1.6°C (2.9°F.)/century		
Precipitation	-17%/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		-3%	-3%
High emissions (IPCC RCP 6.0)			
Temperature		+1.2°C (2.2°F.)	+2.0°C (3.6°F.)
Precipitation		-1%	-1%
Highest emissions (IPCC RCP 8.5)			
Temperature		+1.7°C (3.1°F.)	+3.2°C (5.8°F.)
Precipitation		-1%	-1%

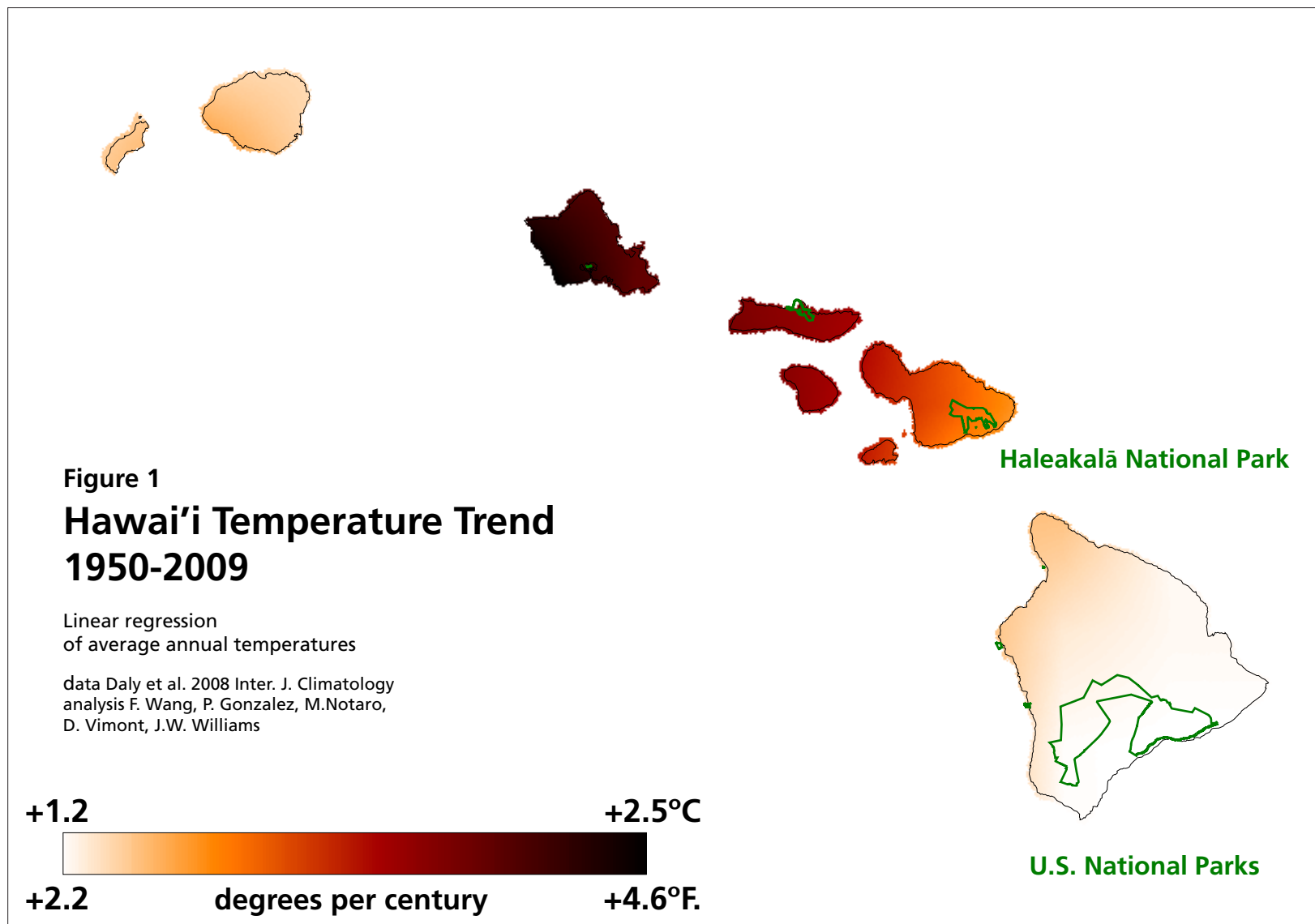


Figure 2
**Hawai'i Precipitation Trend
1950-2009**

Linear regression
of total annual precipitation

data Daly et al. 2008 Inter. J. Climatology
analysis F. Wang, P. Gonzalez, M. Notaro,
D. Vimont, J.W. Williams

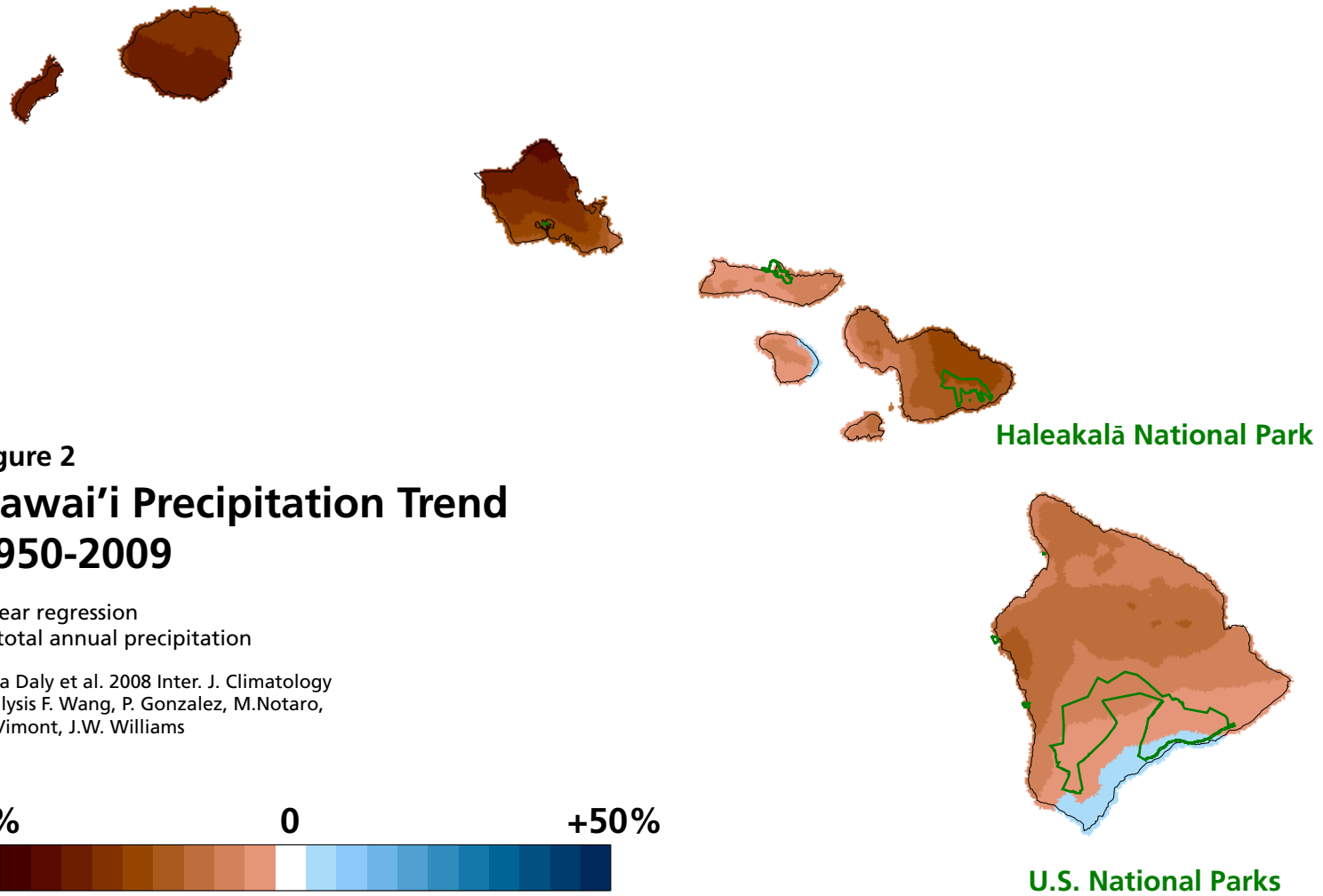
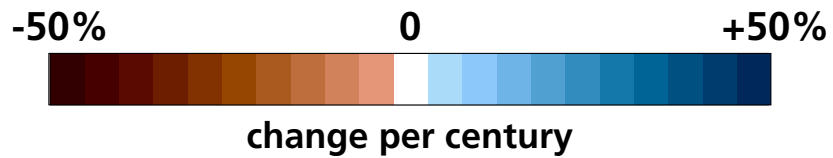


Figure 3. Temperature.

Historical and projected average annual average temperature for the area within park boundaries. For projections, each bar shows one standard deviation above and below the average of up to 33 climate models. (Data: Daly et al. 2008, IPCC 2013. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).

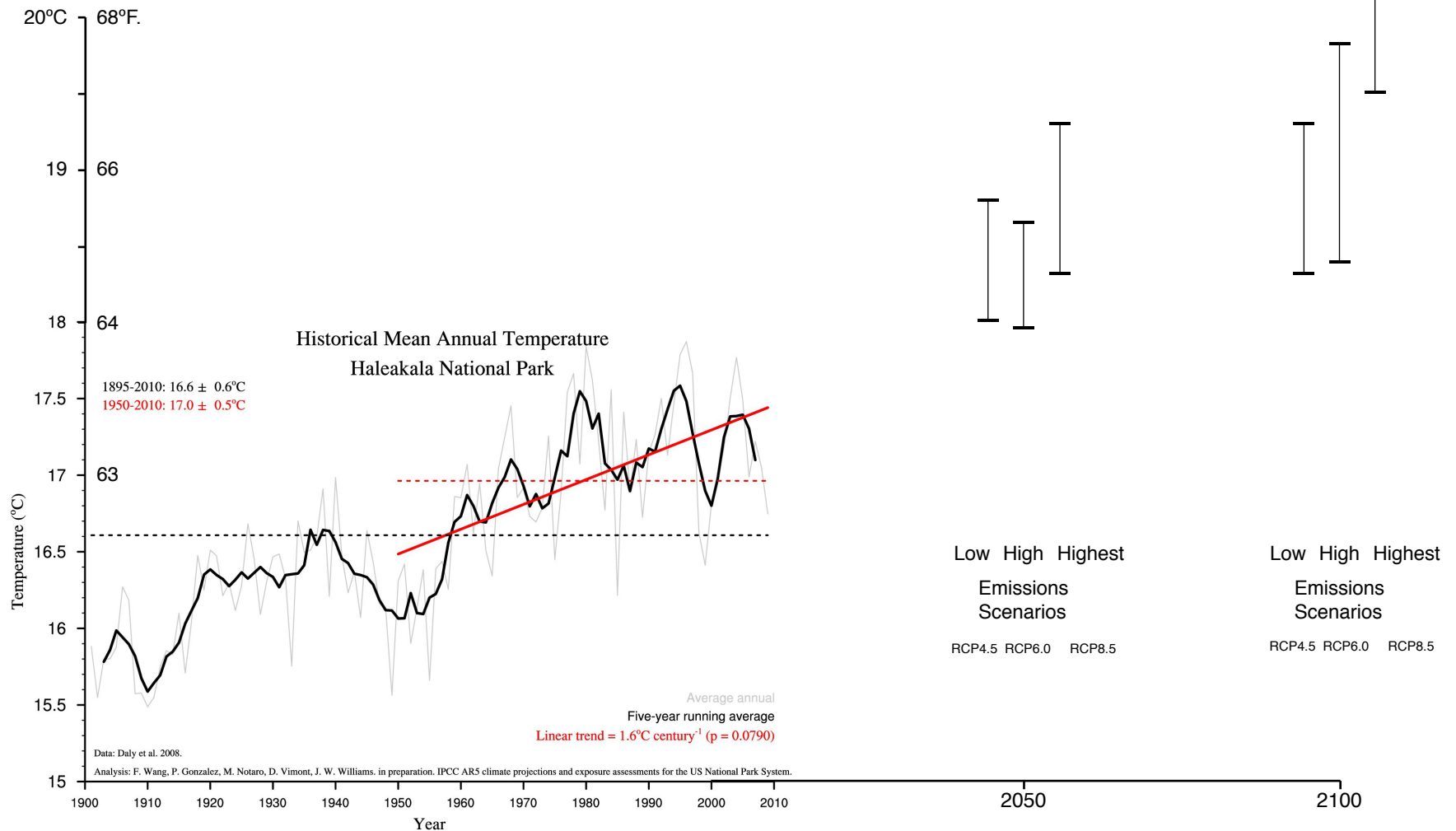
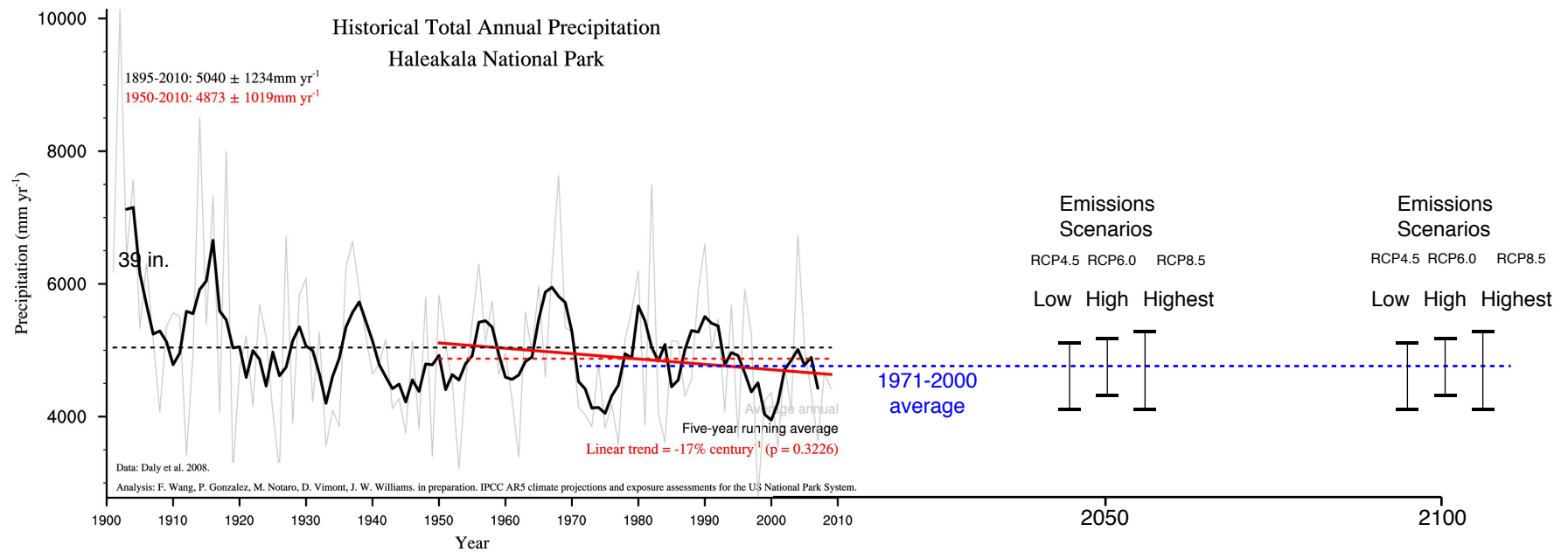


Figure 4. Precipitation.

Historical and projected annual total precipitation for the area within park boundaries. For projections, each bar shows one standard deviation above and below the average of up to 33 climate models. (Data: Daly et al. 2008, IPCC 2013. Analysis: Wang et al. in preparation, University of Wisconsin and U.S. National Park Service).



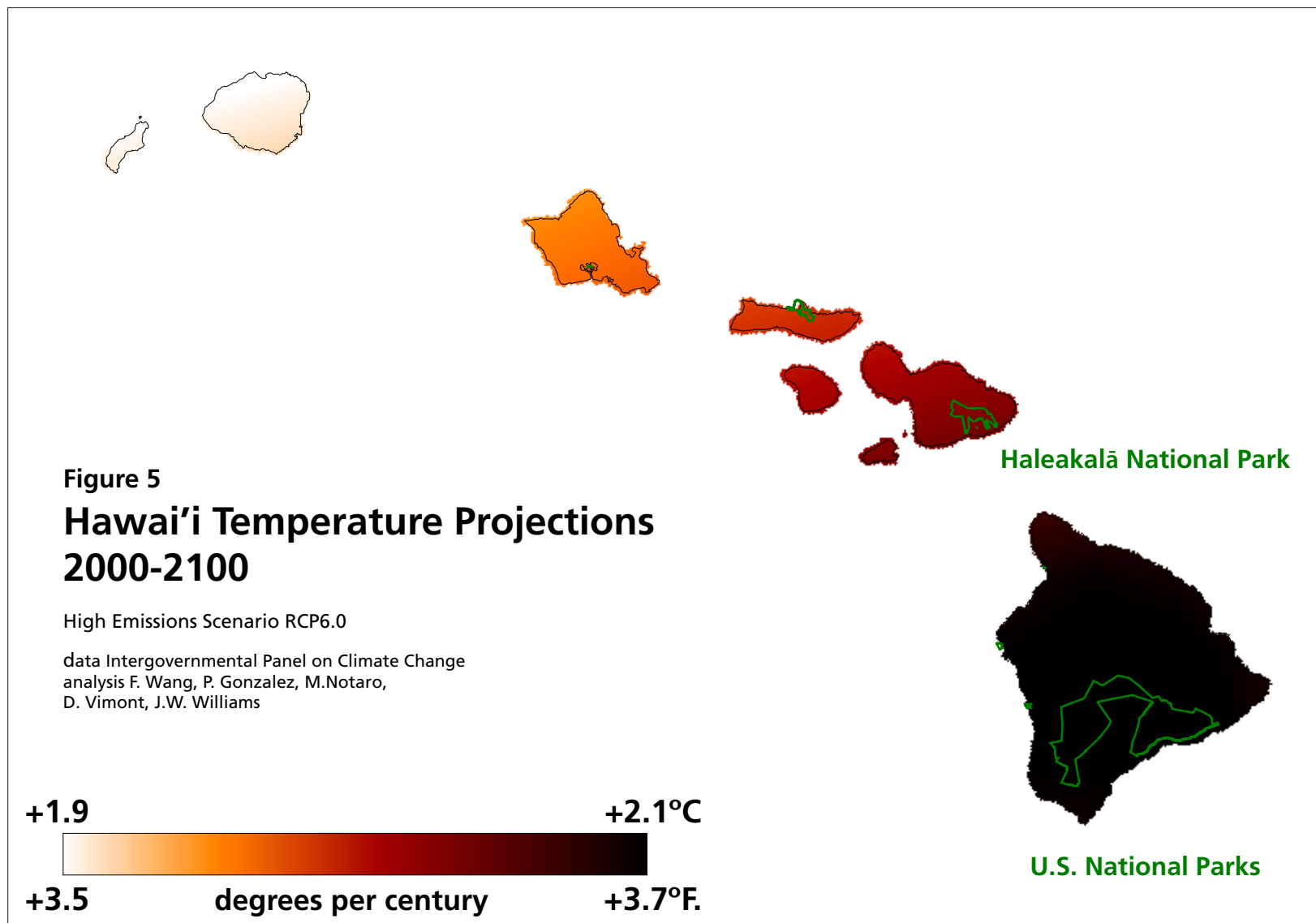


Figure 6
**Hawai'i Precipitation Projections
2000-2100**

High Emissions Scenario RCP6.0

data Intergovernmental Panel on Climate Change
analysis F. Wang, P. Gonzalez, M. Notaro,
D. Vimont, J.W. Williams

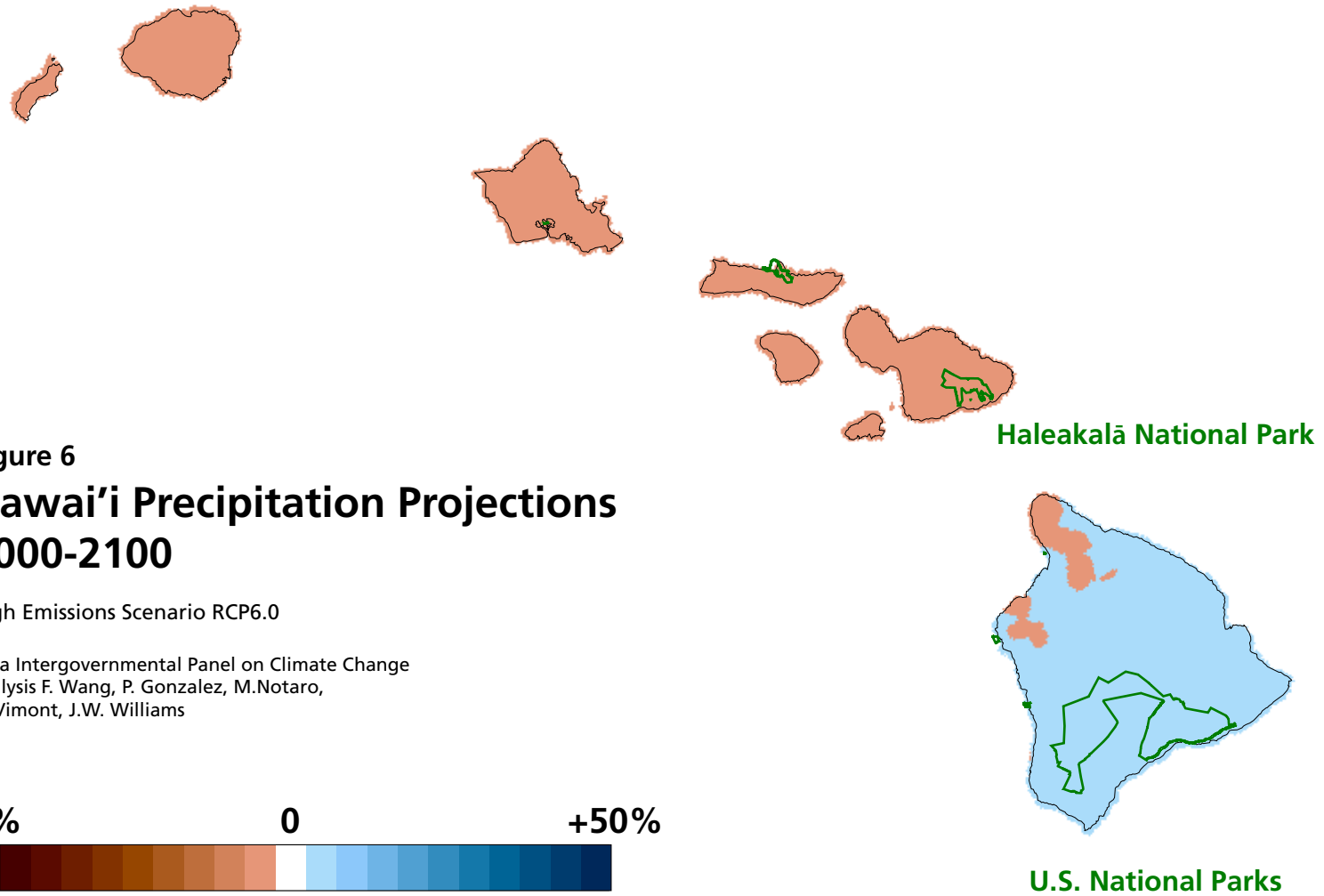
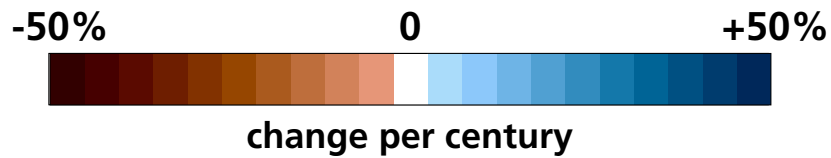
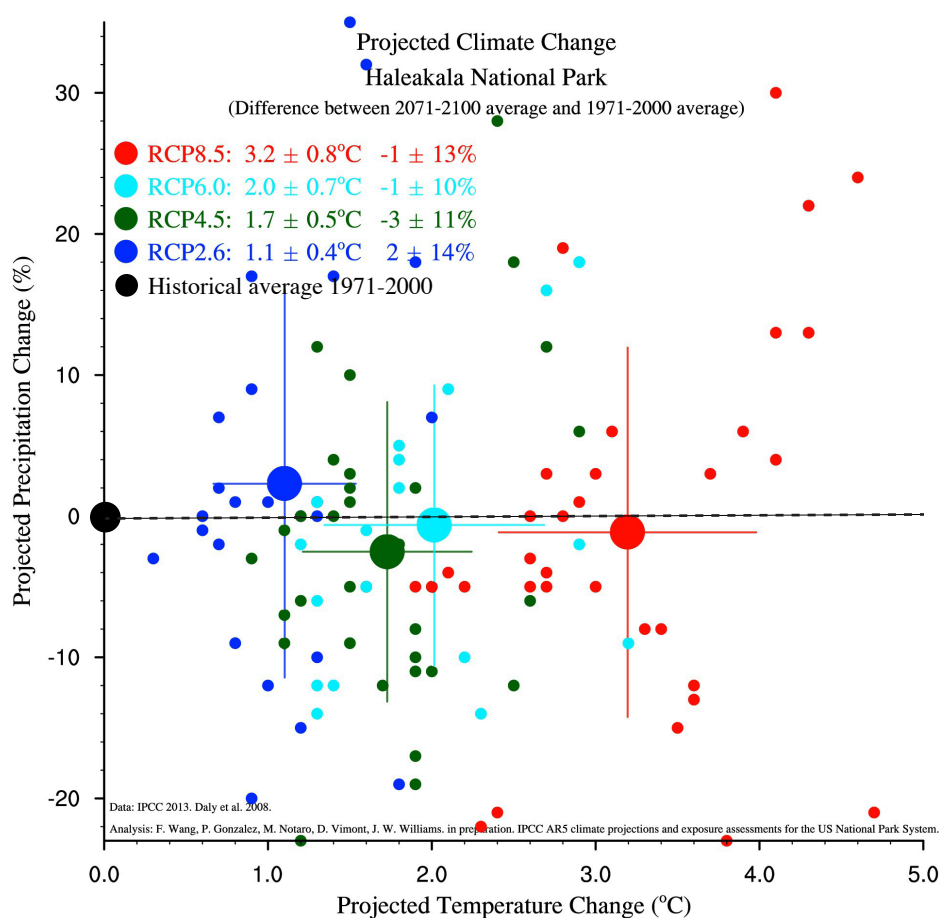


Figure 7. Projections of future climate for the area within park boundaries. The large black dot is the current combination of temperature and precipitation. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The 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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