

Climate Change, Impacts, and Vulnerabilities, Bandelier National Monument, New Mexico

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Climate Trends for the Area within Park Boundaries

- Temperature is increasing at a rate of up to 1.3° C per century, but the rate for the park as a whole is not statistically significant due to less warming in the northwest (Figures 1, 3).
- Precipitation is increasing at a statistically significant rate of 30% per century for the park as a whole, but precipitation has decreased in some areas (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).

Past Impacts

- Drought in the 1950s caused extensive mortality of ponderosa pine at Bandelier and shifted piñon-juniper woodland upslope into ponderosa pine forest (Allen and Breshears 1998).
- Drought and bark beetle infestations in the early 2000s caused extensive dieback of piñon pine at Bandelier (Breshears et al. 2005). This and numerous other cases of tree dieback around the world are consistent with climate change (Allen et al. 2010).
- Remote sensing data indicate a 38% decrease of crown area in Bandelier between 2002 and 2006, mainly in piñon-juniper woodland (Garrity et al. 2013).
- Across the western U.S., climate controlled the extent of burned area from 1916 to 2003 (Littell et al. 2009).

Future Vulnerabilities

- Under continued warming, forest drought stress could continue to cause substantial tree dieback and possible conversion of some forest to grassland (Williams et al. 2013).
- Under high emissions, fire frequencies could increase up to 25% by 2100 (Moritz et al. 2012).
- Past warming has reduced snowpack widely and rainfall in some areas, which may continue to reduce summer streamflow and water supplies (Garfin et al. 2014).
- Bandelier staff and partners are evaluating vulnerabilities of archeological resources to erosion and climate change and possible adaptation measures.

Table. Historical and projected rates of change in annual average temperature (degrees per century) and annual total precipitation (percent per century) (data Daly et al. 2008, IPCC 2013; analysis Wang et al. in preparation). The table only gives central values for the park as a whole. Figures 1, 2, 5, and 6 show spatial variation. Figures 3, 4, and 7 show the uncertainties.

	1950-2010	2000-2050	2000-2100
Historical			
Temperature	+0.3°C (0.5°F.)		
Precipitation	+30%		
Projected (compared to 1971-2000)			
Low emissions (IPCC RCP 4.5)			
Temperature		+2.2°C (4°F.)	+2.8°C (5°F.)
Precipitation		~0	+1%
High emissions (IPCC RCP 6.0)			
Temperature		+1.8°C (3°F.)	+3.3°C (6°F.)
Precipitation		-2%	-2%
Highest emissions (IPCC RCP 8.5)			
Temperature		+2.8°C (5°F.)	+5.1°C (9°F.)
Precipitation		~0	-2%

Figure 1.

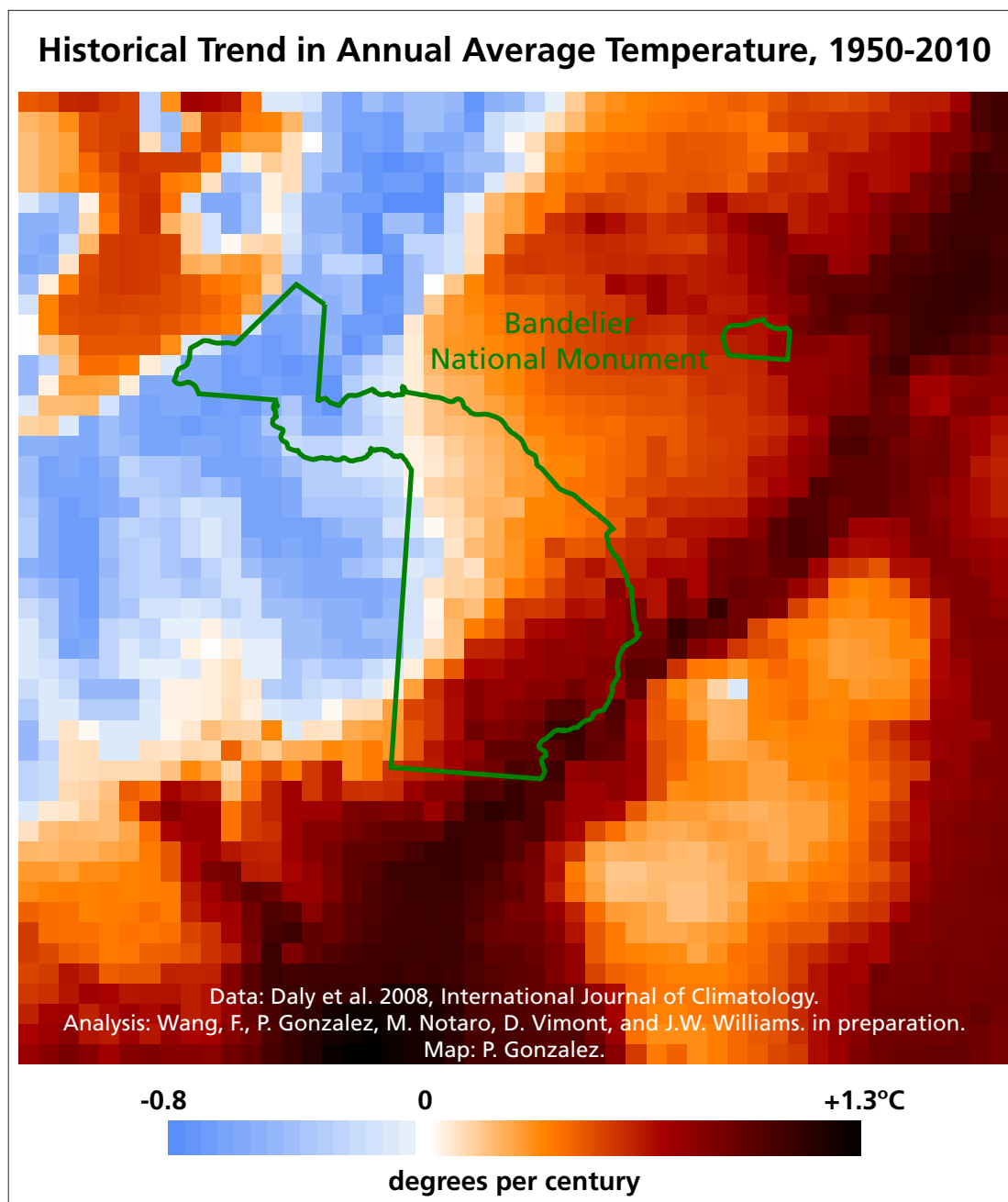


Figure 2.

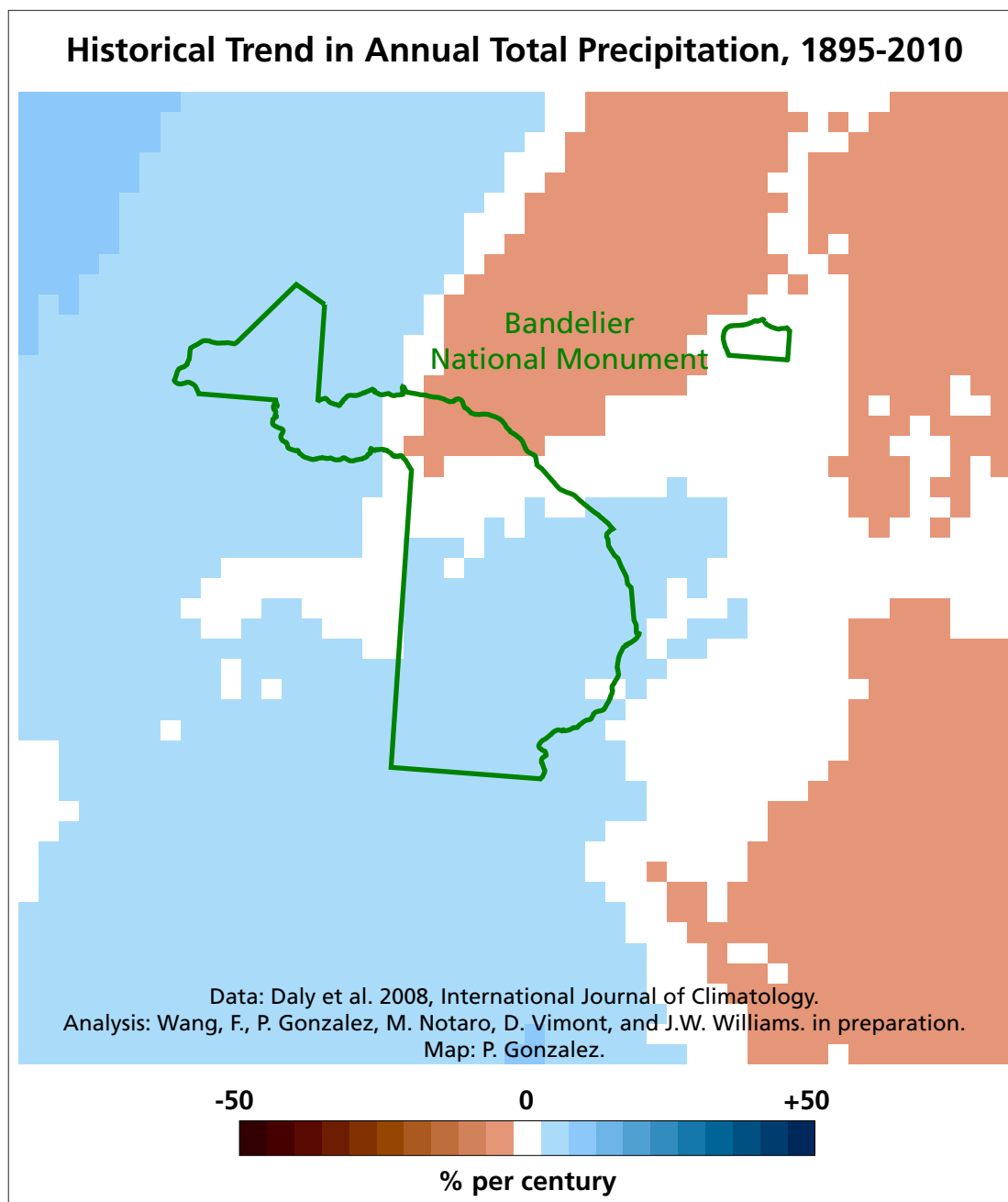


Figure 3. Temperature.

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).

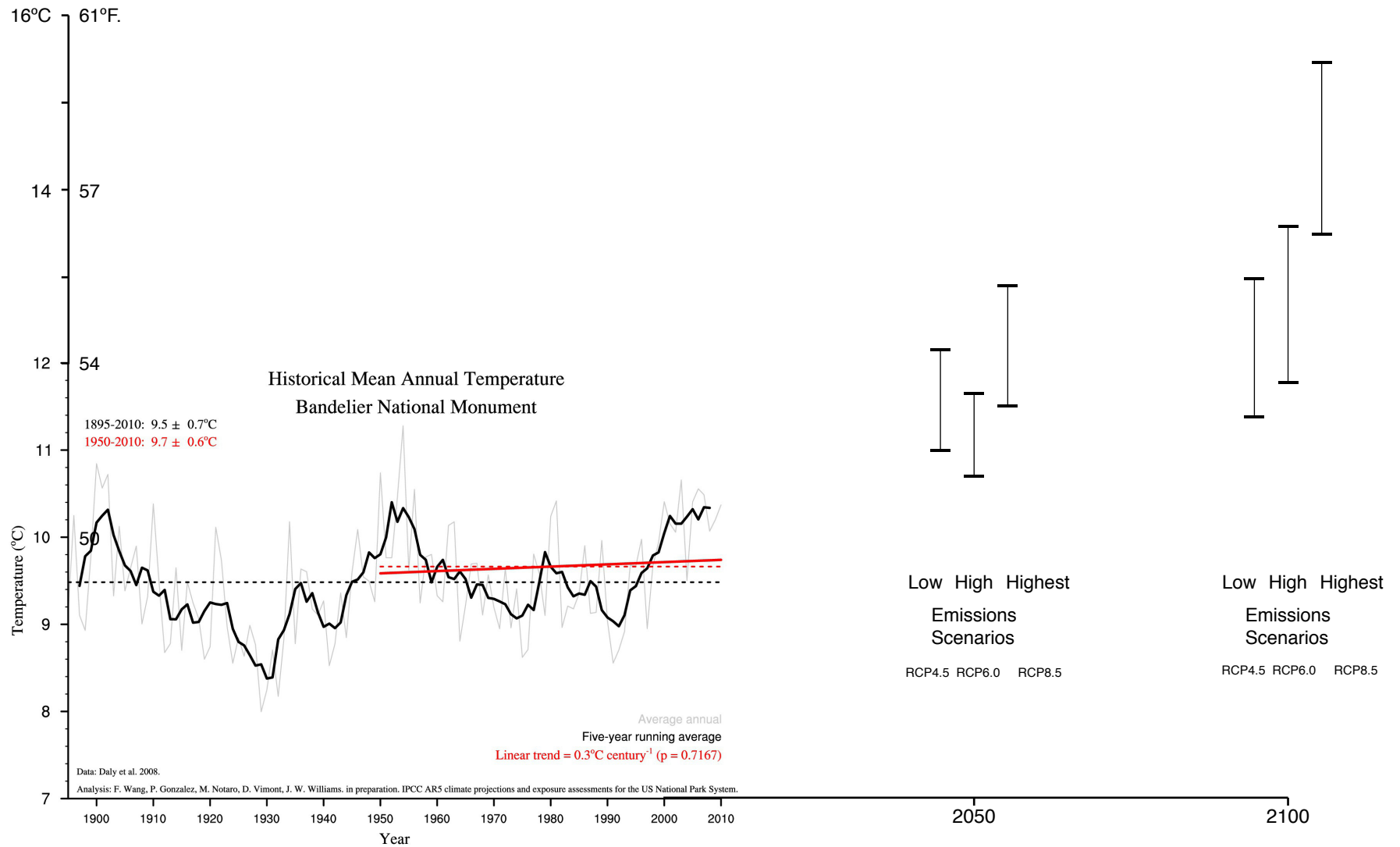


Figure 4. Precipitation.

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).

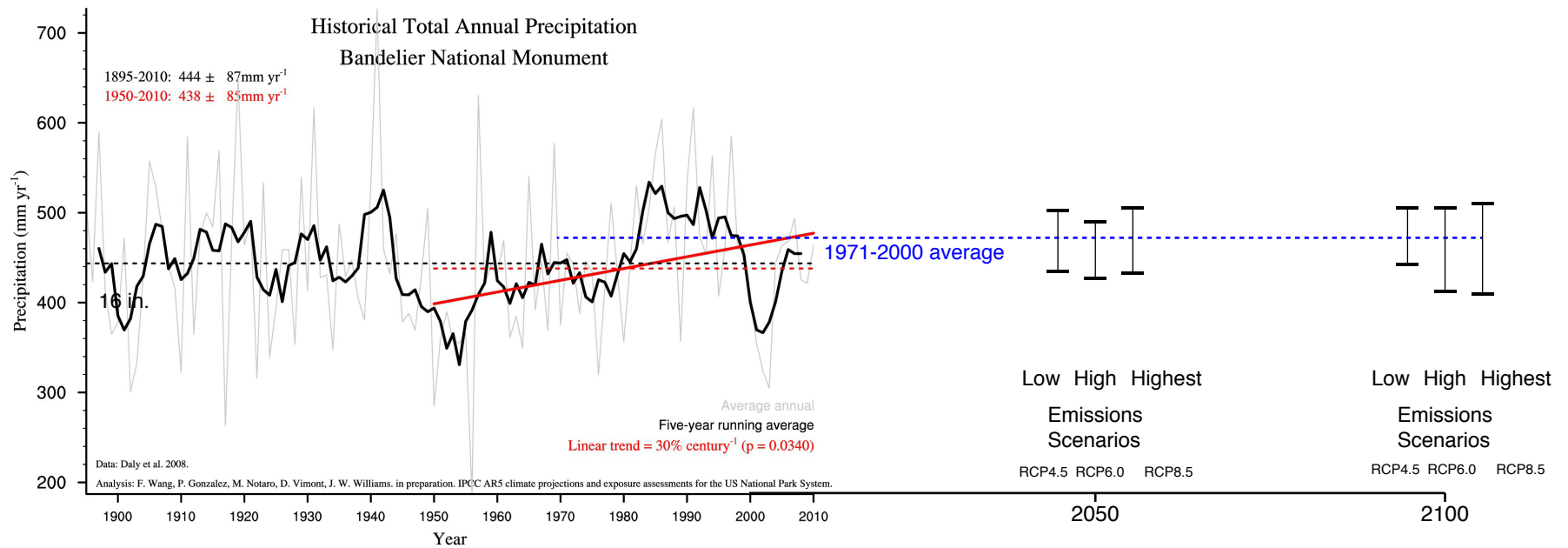


Figure 5.

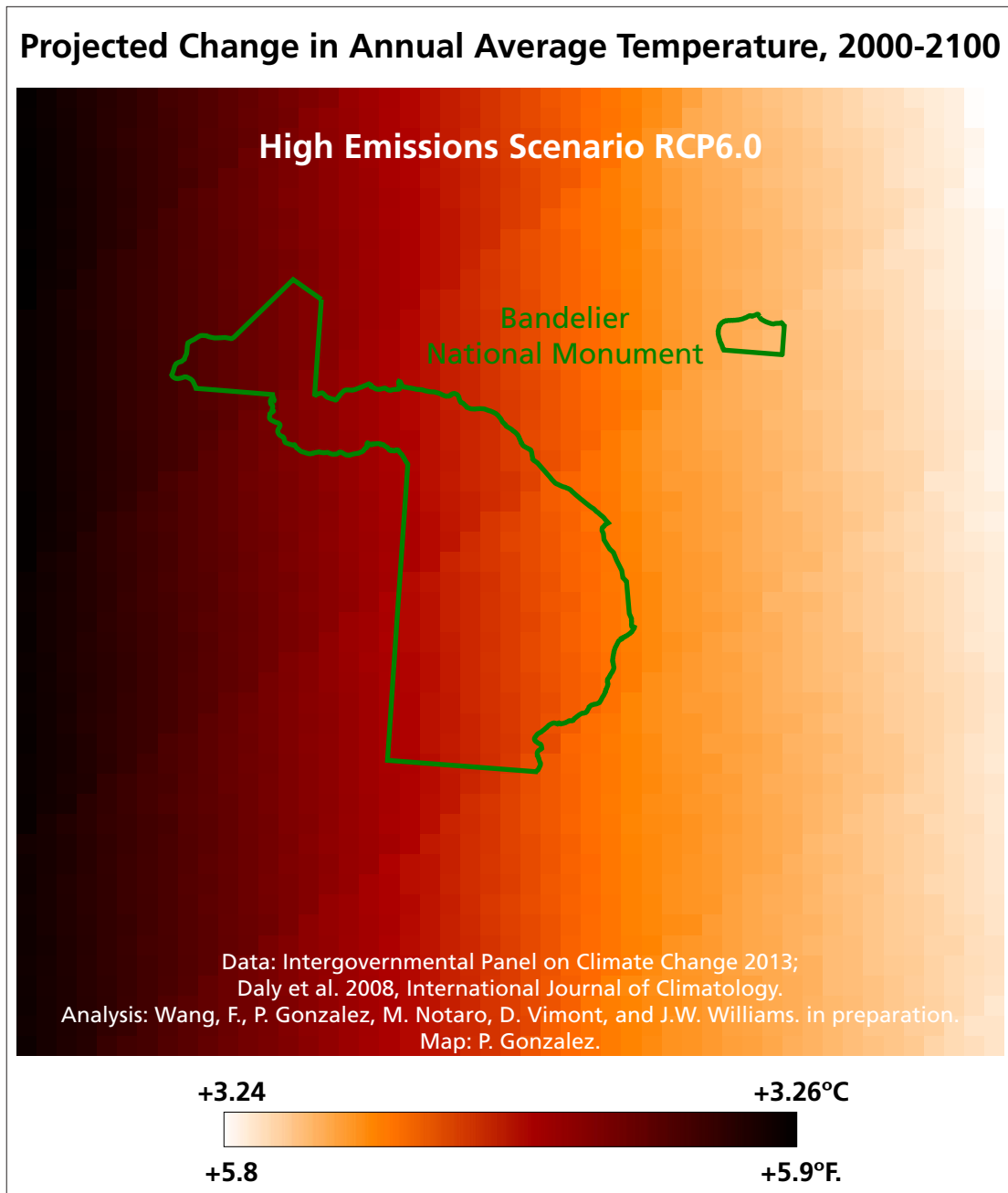


Figure 6.

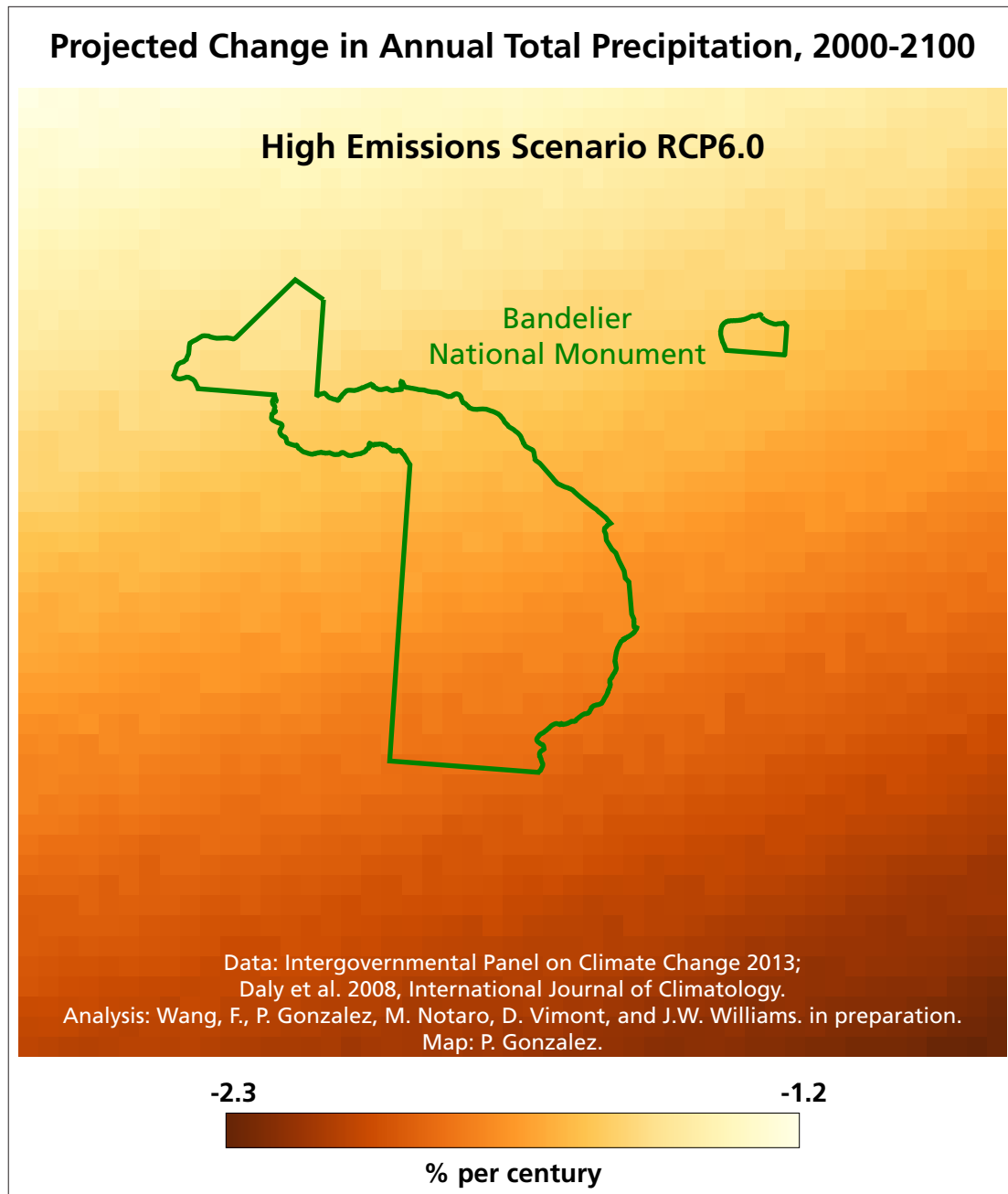
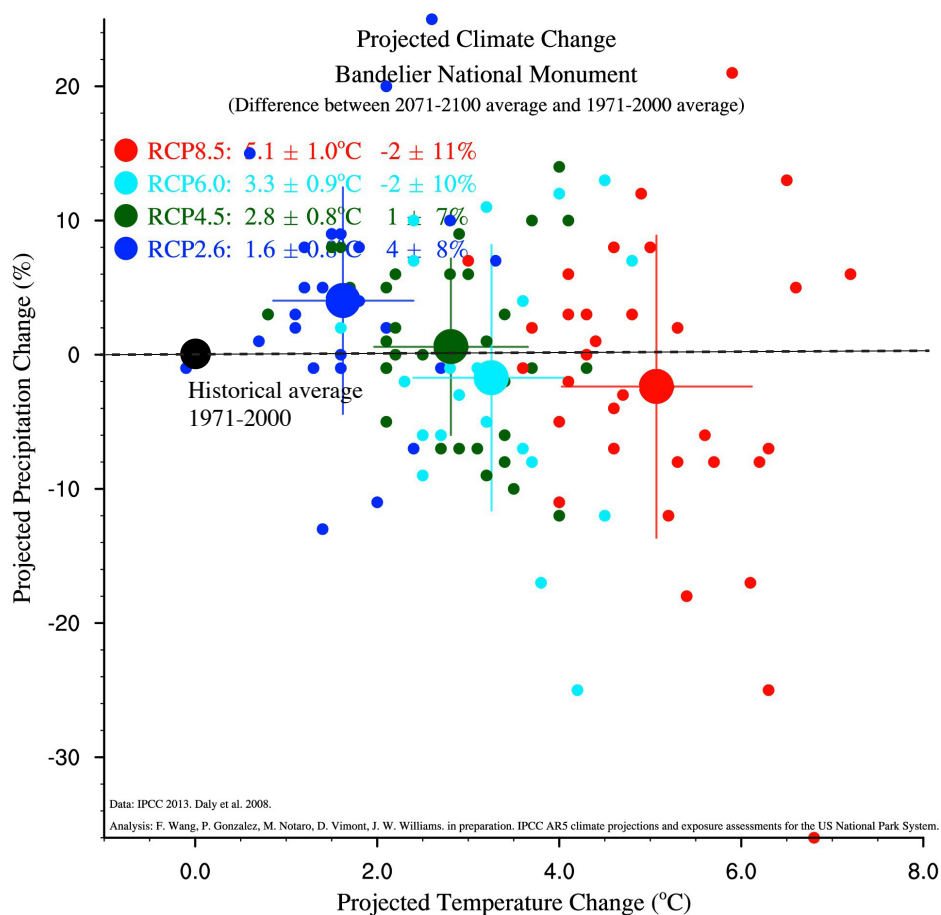


Figure 7. Projections of future climate for the area within park boundaries. The large black dot is the current combination of temperature and precipitation. Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios. The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



References

- Allen, C.D. and D.D. Breshears. 1998. Drought-induced shift of a forest–woodland ecotone: Rapid landscape response to climate variation. *Proceedings of the National Academy of Sciences of the USA* 95: 14 839-14 842.
- Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D.D. Breshears, E.H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.H. Lim, G. Allard, S.W. Running, A. Semerci, and N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259: 660-684.
- Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. *Proceedings of the National Academy of Sciences of the USA* 102: 15 144-15 148.
- Daly, C., M. Halbleib, J.I. Smith, W.P. Gibson, M.K. Doggett, G.H. Taylor, J. Curtis, and P.P. Pasteris. 2008. Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. *International Journal of Climatology* 28: 2031–2064.
- Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Southwest. In Melillo, J.M., T.C. Richmond, and G.W. Yohe (Eds.) 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, Washington, DC.
- Garrity, S.R., C.D. Allen, S.P. Brumby, C. Gangodagamage, N.G. McDowell, D.M. Cai. 2013. Quantifying tree mortality in a mixed species woodland using multitemporal high spatial resolution satellite imagery. *Remote Sensing of Environment* 129: 54-65.
- Intergovernmental Panel on Climate Change (IPCC). 2013. *Climate Change 2013: The Physical Science Basis*. Cambridge University Press, Cambridge, UK.
- Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. *Ecological Applications* 19: 1003-1021.
- Moritz, M.A., M.A. Parisien, E. Batllori, M.A. Krawchuk, J. Van Dorn, D.J. Ganz, and K. Hayhoe. 2012. Climate change and disruptions to global fire activity. *Ecosphere* 3: art49. doi:10.1890/ES11-00345.1.
- Wang, F., P. Gonzalez, M. Notaro, D. Vimont, and J.W. Williams. in preparation. IPCC AR5 climate projections and exposure assessments for the US National Park System.

Williams, A.P., C.D. Allen, A.K. Macalady, D. Griffin, C.A. Woodhouse, D.M. Meko, T.W. Swetnam, S.A. Rauscher, R. Seager, H.D. Grissino-Mayer, J.S. Dean, E.R. Cook, C. Gangodagamage, M. Cai, and N.G. McDowell. 2013. Temperature as a potent driver of regional forest drought stress and tree mortality. *Nature Climate Change* 3: 292-297.