# Recent Climate Change Exposure of Monocacy National Battlefield

Climate change is occurring at especially rapid rates in some areas of the U.S. In national parks, climate change challenges the ability of park managers to preserve natural and cultural resources. To understand the "climate change exposure" of national parks—that is, the magnitude and direction of ongoing changes in climate—we investigated how recent climates compare to historical conditions. This recently published research (Monahan & Fisichelli 2014) updates the basic climate inventories for 289 national park units. Here, we summarize results for Monocacy National Battlefield, including areas within 30-km (18.6-mi) of the park's boundary.

We evaluated climate-change exposure by asking which of 25 biologically relevant climate variables recently (past 10–30 years) experienced "extreme" values relative to the 1901–2012 historical range of variability. We define "extreme" conditions (e.g., extreme warm, extreme wet) as exceeding 95% of the historical range of conditions.

## Methods

To evaluate recent climate values within the context of historical conditions, we used the following methods (also illustrated in Figure 1):

- **For each temperature and precipitation variable, we analyzed data within three progressive time intervals, or "moving windows," of 10, 20, and 30 years to calculate a series of averages over the entire period of analysis (1901–2012).** For example, in progressive 10-year intervals, we calculated averages of temperature and precipitation for 103 blocks of time (1901–1910, 1902–1911 . . . 2003–2012), and repeated this approach for the 20 and 30-year "windows." This type of analysis helps to smooth year-to-year fluctuations in order to identify longer-term trends that characterize the park's historical range of variability (HRV). The three windows encompass both near- and long-term management and planning horizons, as well as important climatic periods and cycles.
- **We compared the average temperature and precipitation values for each of the *most recent* 10, 20, and 30 year intervals (2003–2012; 1993–2012; and 1983–2012) to those of all corresponding intervals across the entire period of 1901–2012. These results (expressed as percentiles) describe "recent" conditions relative to historical conditions.** For example, a 90$^{th}$ percentile for annual average temperature over the most recent 10-year interval (2003–2012) means that the annual average temperature during this time exceeded 90% of annual average temperatures for all 10-year periods from 1901 to 2012.
- **We then averaged the percentiles of the most recent 10, 20, and 30-year time periods and computed the maximum difference in recent percentile.** For each park and climate variable, this resulted in both an overall measure of recent climate change exposure with respect to HRV (dots in Figure 2), and an estimate of sensitivity to moving-window size (length of bars in Figure 2).

See Monahan & Fisichelli (2014) for a detailed explanation of methods, and Figure 1 for an example analysis applied to annual mean temperature.

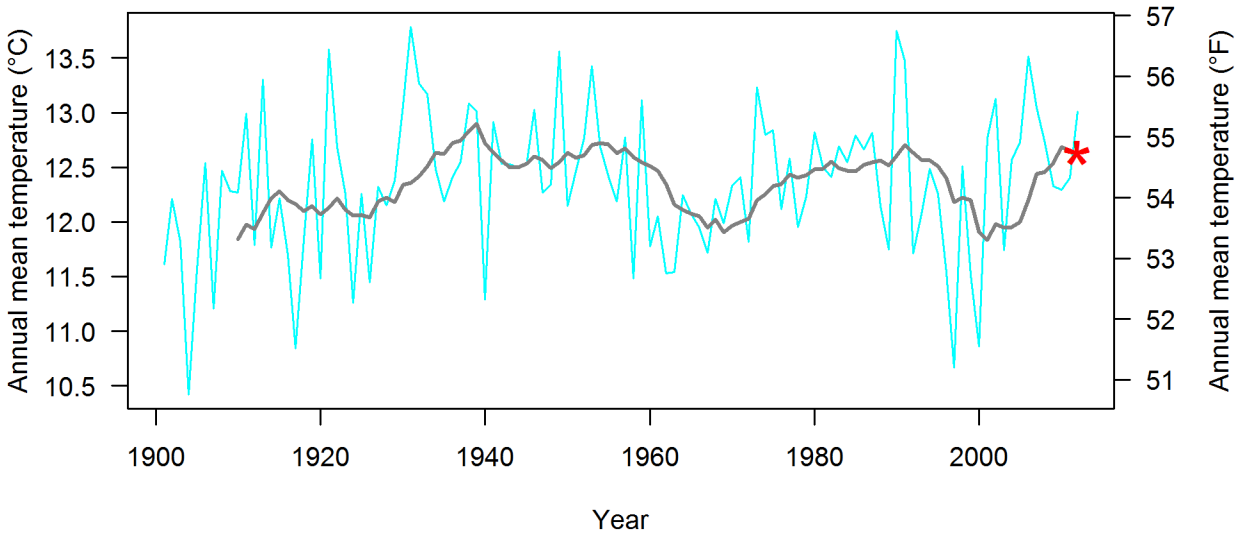


**Figure 1.** Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Monocacy National Battlefield (including areas within 30-km [18.6-mi] of the park's boundary). The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals (10-year moving windows), and the red asterisk shows the average temperature of the most recent 10-year moving window (2003–2012). The most recent percentile is calculated as the percentage of values on the gray line that fall below the red asterisk (see results of most recent percentiles for all temperature and precipitation variables in Figure 2).

## Results

Recent percentiles for 14 temperature and precipitation variables at Monocacy National Battlefield appear in Figure 2. Results for "extreme" variables at the park were as follows:

- No temperature variables were "extreme warm."
- No temperature variables were "extreme cold."
- No precipitation variables were "extreme dry."
- No precipitation variables were "extreme wet."

Key points for interpreting these results in the context of park resources include:

- Recent climatic conditions are within the historical range of variability.
- Although recent climates are not "extreme", future changes are likely and opportunities exist to proactively incorporate possible climate change effects into park management, including natural and cultural resource protection as well as park operations and visitor experience.
- Effective planning and management must be grounded in our comprehension of past dynamics, present conditions, and projected future change.
- Climate change will manifest itself not only as changes in average conditions, as summarized here, but also as changes in particular climate events (e.g., more intense storms, floods, or drought). Extreme climate events can cause widespread and fundamental shifts in conditions of park resources.

## Climate Change Adaptation

These findings can inform climate change adaptation at Monocacy National Battlefield by helping park managers, planners, and interpreters to understand how recent climates compare to past conditions. For example, these findings may be used to:

- Characterize park exposure to recent climate change in a vulnerability assessment.
- Develop plausible and divergent futures for use in a climate-change scenario planning workshop.
- Synthesize desired future conditions (i.e., reference conditions) for use in a Resource Stewardship Strategy or other National Park Service management plan.
- Create interpretive materials for communicating with local communities and park visitors.

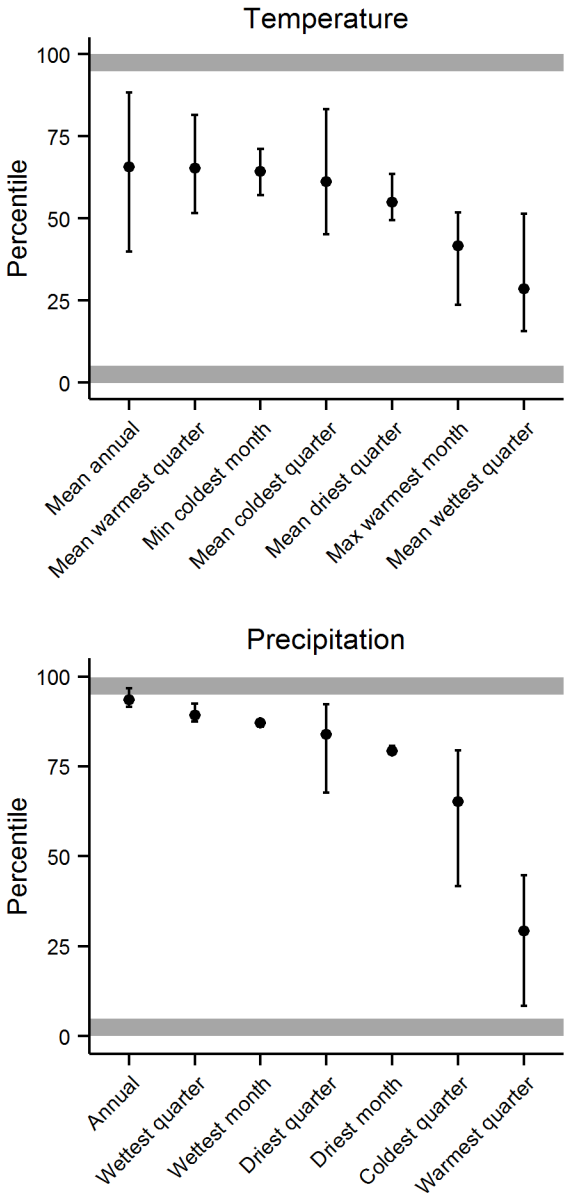


**Figure 2.** Recent temperature and precipitation percentiles at Monocacy National Battlefield (including areas within 30-km [18.6-mi] of the park's boundary). Black dots indicate average recent percentiles across the 10, 20, and 30-year intervals (moving windows). Variables are considered "extreme" if the mean percentiles are <5$^{th}$ percentile or >95$^{th}$ percentile (i.e., the gray zones, where recent climate is pushing the limits of all observed climates since the year 1901). Black bars indicate the range of recent percentiles across 10, 20, and 30-year moving windows (larger bars indicate higher sensitivity to moving window size).

## More Information

Monahan WB, and NA Fisichelli. 2014. Climate exposure of US national parks in a new era of change. PLoS ONE 9(7): e101302. doi:10.1371/journal.pone.0101302. Available from http://dx.plos.org/10.1371/journal.pone.0101302.

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