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Disproportionate magnitude of climate change in United States national parks

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Abstract

Anthropogenic climate change is altering ecological and human systems globally, including in United States (US) national parks, which conserve unique biodiversity and resources. Yet, the magnitude and spatial patterns of climate change across all the parks have been unknown. Here, in the first spatial analysis of historical and projected temperature and precipitation across all 417 US national parks, we show that climate change exposes the national park area more than the US as a whole. This occurs because extensive parts of the national park area are in the Arctic, at high elevations, or in the arid southwestern US. Between 1895 and 2010, mean annual temperature of the national park area increased 1.0 °C $\pm$ 0.2 °C century^{-1} (mean $\pm$ standard error), double the US rate. Temperature has increased most in Alaska and its extensive national parks. Annual precipitation of the national park area declined significantly on 12% of national park area, compared to 3% of the US. Higher temperatures due to climate change have coincided with low precipitation in the southwestern US, intensifying droughts in the region. Physical and ecological changes have been detected and attributed mainly to anthropogenic climate change in areas of significant temperature increases in US national parks. From 2000 to 2100, under the highest emissions scenario (representative concentration pathway [RCP] 8.5), park temperatures would increase 3 °C–9 °C, with climate velocities outpacing dispersal capabilities of many plant and animal species. Even under the scenario of reduced emissions (RCP2.6), temperature increases could exceed 2 °C for 58% of national park area, compared to 22% of the US. Nevertheless, greenhouse gas emissions reductions could reduce projected temperature increases in national parks by one-half to two-thirds.

Introduction

Anthropogenic emissions of greenhouse gases have increased global temperature 0.85° $\pm$ 0.2 °C century^{-1} from 1880 to 2012 (IPCC 2013), causing glacial melt (Vaughan *et al* 2013), wildfire increases (Abtazoglou and Williams 2016), biome shifts (Gonzalez *et al* 2010), plant and animal range shifts (Chen *et al* 2011), and other historical impacts around the world (IPCC 2014). Continued climate change increases future vulnerabilities of ecosystems to plant and animal extinctions (Urban 2015), range losses (Warren *et al* 2018), invasive species (Early *et al* 2016), and other disruptions (Settele *et al* 2014). Conservation of intact ecosystems and protection of endangered species rely considerably on national parks around the world because they form the core of the global protected areas network (UNEP-WCMC and IUCN 2016). The shifts of biomes and species ranges that are occurring due to climate change increase the importance of national parks, which can offer habitat refugia for climate-sensitive species (Johnston *et al* 2012, Jones *et al* 2016).

Furthermore, national parks provide ecosystem services, including protection of watersheds that provide drinking water for people (Null 2016) and conservation of forests that store carbon, mitigating climate change (Melillo *et al* 2016).

National parks in the US protect unique ecosystems, biodiversity, and cultural sites in a network of 417 protected areas that cover 4% of the US, including Yellowstone National Park, the first national park in the world. Field research in US national parks has contributed to the detection of 20th century changes to glaciers, wildlife, and vegetation and attribution of the causes of those changes mainly to anthropogenic climate change (Moritz *et al* 2008, van Mantgem *et al* 2009, Marzeion *et al* 2014, Gonzalez 2017). Under continued climate change, analyses project future vulnerabilities of ecosystems in US national parks to glacial melt (Hall and Fagre 2003), increased wildfire (Westerling *et al* 2011), vegetation shifts (Cole *et al* 2011, Eigenbrod *et al* 2015), and wildlife extirpations (Stewart *et al* 2015, Wu *et al* 2018).

Effective resource management under climate change will require spatial data of exposure to climate change to analyze future vulnerabilities of species, ecosystems, and resources, since vulnerability is mainly a function of exposure, sensitivity, and adaptive capacity (IPCC 2007, Dawson *et al* 2011). Spatial analyses that identify vulnerable areas and potential refugia can guide prioritization of locations for habitat conservation, fire management, invasive species control, and other actions under climate change. So, achieving the mission of the US National Park Service to conserve resources unimpaired for future generations benefits from spatial data on climate change trends. Past studies examined climate exposure of 57 (Hansen *et al* 2014) and 289 large parks (Monahan and Fisichelli 2014), but no research has previously conducted a comprehensive analysis across all US national parks. Consequently, the magnitude of climate change in many parks and in the national park area relative to the entire US have been unknown.

Here, we address these knowledge gaps in the first spatial analysis of historical and projected temperature and precipitation changes across all US national parks. The objectives of this research are to: (1) determine the magnitude and spatial patterns of climate change across all US national parks, (2) characterize the magnitude of climate change in the national park area relative to the entire US, and (3) identify the individual parks most exposed to climate change.

Methods

Research area

The research covered the land area of the 50 US states, the District of Columbia, and four US territories, with analyses of the US as a whole, each of six geographic domains (contiguous 48 states, Alaska, Hawaii, Puerto Rico and Virgin Islands, Guam, American Samoa), the area of all 417 US national parks together (national park area), and each individual park. Analyses use the national boundary vector file from the US Geological Survey (https://nationalmap.gov, April 2014) and the national park boundaries vector file from the US National Park Service (http://irma.nps.gov, October 2017). Corrections of the national park boundaries file to conform with the official National Park Service list of 417 national parks (http://nps.gov/aboutus, January 2017) included removal of areas that were not national parks, corrections to some individual park boundaries, and tracing and addition of boundaries of new national parks not yet in the file, from publicly available information related to park establishment.

Historical climate data and analyses

For historical climate, we analyzed previously published spatial climate data of monthly temperature and precipitation, gridded and interpolated from weather station observations (table S1 is available online at stacks.iop.org/ERL/13/104001/mmedia). Historical trends mainly span the years 1895 to 2010, the period with spatial climate data available for the entire US, with analyses of the period 1895–2016 for the contiguous states. For the contiguous states, the 800 m spatial resolution Parameter-elevation Relationships on Independent Slopes Model (PRISM) time series (Daly *et al* 2008) was used. For Alaska, Hawaii, Guam, and American Samoa, PRISM-derived 30-year climatologies (Alaska, 771 m; Hawaii, 500 m; Guam, American Samoa, 100 m) were used to downscale by bilinear interpolation the 0.5° (~50 km) spatial resolution University of East Anglia Climatic Research Unit (CRU) time series (Harris *et al* 2014). Time series for Alaska were previously downscaled by the University of Alaska, Fairbanks (https://snap.uaf.edu). Differences between an individual month in the coarse-resolution time series and the finer resolution baseline climatology were added to (for temperature) or multiplied by (for precipitation) the baseline value to produce a finer resolution version of each month in the time series. For Puerto Rico and the Virgin Islands, the 0.5° CRU data were not downscaled, but were divided into 18.5 km spatial resolution pixels.

Most original data files were unprojected rasters in the geographic reference system, where the surface area of pixels varied with latitude. We projected all files to equal area projections (Lambert Azimuthal Equal Area, contiguous 48 states; Albers Equal Area Conic, other areas) to produce pixels of the same surface area for the accurate calculation of spatial statistics. Area-weighted averaging of results from the six domains gave results for the national park area and the US as a whole, except for the linear regression trends (described below), which were directly calculated for the US as a whole. Results extracted for each of the 417 national parks cover all pixels that completely contain an individual national park.

We calculated historical trends by linear regression, corrected for temporal autocorrelation, following Intergovernmental Panel on Climate Change (IPCC) methods (IPCC 2013). Linear least squares regression of mean annual temperature and annual precipitation versus time for the US, national park area, each domain, and each national park gave the historical trends, standard errors, and statistical probabilities. Because simple linear least squares regression may overestimate probabilities of temporal trends by omitting temporal (serial) autocorrelation, we used restricted maximum likelihood estimation (Patterson and Thompson 1971, Cooper and Thompson 1977) which, through calculation of the autocorrelation coefficient (Box and Jenkins 1976) and effective sample size (Thiébaux and Zwiers 1984, Zwiers and von Storch 1995), provides more robust estimates of probability. Climate velocity, the speed at which an area of constant temperature moves horizontally under climate change, was calculated using a previously published method (Loarie *et al* 2009).

Projected climate data and downscaling

For future projections, we conducted bias-corrected statistical downscaling of the coarse-resolution output of all general circulation models (GCMs) available for the most recent IPCC assessment report (IPCC 2013). We downloaded Coupled Model Intercomparison Project Phase 5 (https://esgf-node.llnl.gov/search/cmip5) monthly output for all four IPCC emissions scenarios, the representative concentration pathways (RCPs) (Moss *et al* 2010), for all GCMs available in October 2012 (table S2).

Using the historical climate spatial datasets as baselines, we used the bias correction and spatial disaggregation (BCSD) method (Wood *et al* 2004) to statistically downscale the coarse-resolution GCM output for the periods 1971–2000, 2036–2065, and 2071–2100. For each GCM grid cell, a bias correction function was generated by matching the empirical cumulative density function (CDF) of a GCM-modeled 1971–2000 period with the CDF of the actual historical 1971–2000 data for each month for temperature and precipitation. The bias of the modeled historical run (1971–2000) of each GCM was corrected by quantile-quantile mapping, which involved identifying the probability of the uncorrected variable value from the model CDF, then finding the corresponding variable value for that probability on the historical CDF. When correcting the bias of the projected temperature runs of each GCM, the modeled mean temperature change was first subtracted from the uncorrected projected value to get the projected values in the same range as the historical values, then the probability of the residual projected value was identified, the corresponding variable value on the historical CDF was found, and the modeled mean temperature change was added back to the bias-corrected projected temperature value. Residual projected temperature values greater than the maximum historical value were corrected using the correction value of the maximum historical value. For projected precipitation, subtracting the modeled change was not needed before the bias correction (Wood *et al* 2004).

Differences (for temperature) or ratios (for precipitation) of coarse-resolution GCM values and the fine-resolution historical baseline were calculated and bilinear interpolation was used to downscale the coarse grid cells to the finer historical resolution. After BCSD downscaling, the mean, standard deviation, and, for precipitation, the fraction of models agreeing on the direction of change were calculated for each ensemble. Area-weighted averaging of results from the six domains gave results for the national park area and the US as a whole.

Results

Historical climate changes

Between 1895 and 2010, mean annual temperature of the national park area increased at double the rate of the US as a whole (table 1, S3; figure 1) with significant increases in all six geographic domains. For the contiguous 48 states, the rates of temperature increase from 1895 to 2016 were 0.7 °C ± 0.1 °C century^{-1} (national park area, $P = 0.006$) and 0.4 °C ± 0.1 °C century^{-1} (US, $P < 0.0001$), greater than for the period 1895–2010. A greater fraction of national park area (63%) experienced significant temperature increases than the US as a whole (42%) (table S3). The highest mean annual temperature increases were in Alaska (figure 2), consistent with analyses of weather station measurements (Bieniek *et al* 2014), US National Climate Assessment spatial analyses (USGCRP 2017), and IPCC (2013) spatial analyses of the principal global temperature time series (Hansen *et al* 2010, Morice *et al* 2012, Vose *et al* 2012). Historical trends show high spatial variation (figure S1). Seasonally, winter, spring, and summer showed similar rates of increase for the national park area, while the greatest temperature increase for the US occurred in winter (table S4). Climate velocity is generally lower in mountain areas than in flat terrain (Loarie *et al* 2009, Dobrowski *et al* 2013), so average climate velocity between 1895 and 2010 was lower in the national park area, which is more mountainous than the US as a whole (table S3, figure S2).

The mean annual temperature difference between the periods 1901–1960 and 1986–2016 (table S3), the measure of change used in the US National Climate Assessment (USGCRP 2017), was the same as the 1895–2010 temperature difference derived here from the linear regression trend for the national park area and nearly the same for the US. The 1901–2016 result

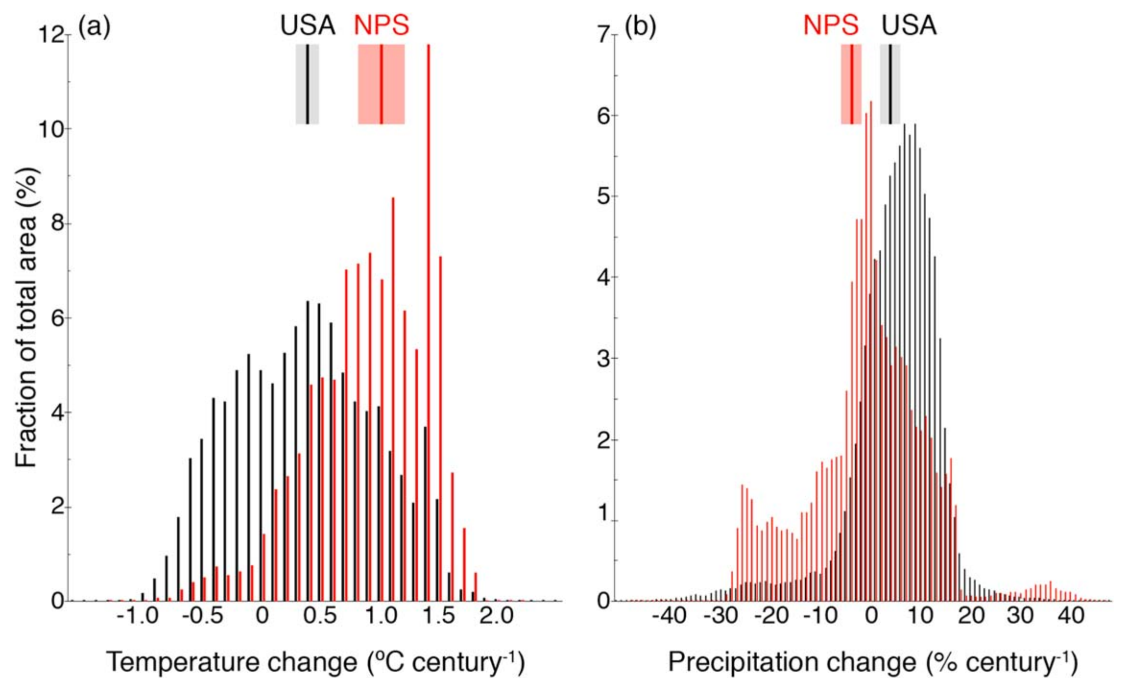

Figure 1. Historical climate change, 1895–2010. Fractions (%) of the US national park area (NPS) and the US (USA) experiencing changes in (a) mean annual temperature (°C century^{-1}) and (b) annual precipitation (% century^{-1}) (relative to 1895–2010 average precipitation). Mean (dark bar) and standard error (shaded rectangle) are indicated for each area as a whole.

Table 1. Climate changes across the US and US national park area. Historical trends and standard errors from linear regression, after correction for temporal autocorrelation. Historical period for areas outside the contiguous states is 1901–2009, the period of available spatial data. Historical precipitation trends relative to average of entire period. Projected changes and standard deviations for the difference between the periods 1971–2000 and 2071–2100, from ensembles of all general circulation model output available for IPCC (2013).

		1895–2010		2000–2100			
				Temperature		Precipitation	
	Area	Temperature	Precipitation	RCP2.6	RCP8.5	RCP2.6	RCP8.5
	km^2	°C century^{-1}	% century^{-1}	°C century^{-1}		% century^{-1}	
United States							
Contiguous 48 states	7.8×10^6	0.3 ± 0.2	$7 \pm 2^{**}$	1.7 ± 0.8	5 ± 1.1	5 ± 8	7 ± 24
Alaska	1.5×10^6	$1.2 \pm 0.3^{***}$	$-7 \pm 3^{*}$	2.5 ± 1.1	6.9 ± 1.6	11 ± 7	31 ± 11
Hawaii	1.7×10^4	$1.6 \pm 0.1^{***}$	$-14 \pm 6^{*}$	1.1 ± 0.4	3.2 ± 0.8	1 ± 200	10 ± 56
Puerto Rico, Virgin Is.	9.3×10^3	$1.3 \pm 0.1^{***}$	-8 ± 5	1 ± 0.4	3 ± 0.6	0.1 ± 11	-23 ± 26
Guam	5.6×10^2	$0.2 \pm 0.05^{***}$	-1 ± 5	1 ± 0.3	3 ± 0.6	6 ± 15	19 ± 32
American Samoa	1.6×10^2	$1.4 \pm 0.1^{***}$	5 ± 5	0.9 ± 0.3	2.7 ± 0.6	-1 ± 17	3 ± 25
Total	9.3×10^6	$0.4 \pm 0.1^{**}$	$4 \pm 2^{*}$	1.8 ± 0.8	5.3 ± 1.2	6 ± 8	11 ± 22
National Park System							
Contiguous 48 states	1.3×10^5	$0.6 \pm 0.1^{***}$	4 ± 2	1.6 ± 0.7	4.9 ± 1	6 ± 8	7 ± 17
Alaska	2.2×10^5	$1.2 \pm 0.3^{***}$	$-7 \pm 3^{*}$	2.5 ± 1.1	6.6 ± 1.5	11 ± 7	30 ± 11
Hawaii	1.8×10^3	$1.3 \pm 0.1^{***}$	-7 ± 6	1.1 ± 0.4	3.2 ± 0.8	1 ± 260	12 ± 51
Puerto Rico, Virgin Is.	39	$1.4 \pm 0.1^{***}$	-8 ± 5	1 ± 0.4	2.9 ± 0.6	-0.1 ± 10	-22 ± 25
Guam	5	$0.2 \pm 0.05^{***}$	-1 ± 5	1 ± 0.3	3 ± 0.6	6 ± 15	19 ± 32
American Samoa	13	$1.4 \pm 0.1^{***}$	5 ± 5	0.9 ± 0.3	2.7 ± 0.6	-1 ± 17	3 ± 24
Total	3.6×10^5	$1.0 \pm 0.2^{***}$	-4 ± 2	2.2 ± 0.9	5.9 ± 1.3	9 ± 9	21 ± 14

Significance: $^{*}P \leqslant 0.05$, $^{**}P \leqslant 0.01$, $^{***}P \leqslant 0.001$.

here for the contiguous states was lower than the result in the US National Climate Assessment but the 1901–2009 results for Alaska were the same.

Because the configuration of the US weather station network stabilized only in the 1950s (Vose *et al* 2014) and because time series for small areas such as parks can change when local stations change, we also analyzed historical trends in individual parks for the period 1950–2010 (table S5). For that period, nine of the ten national parks with the highest

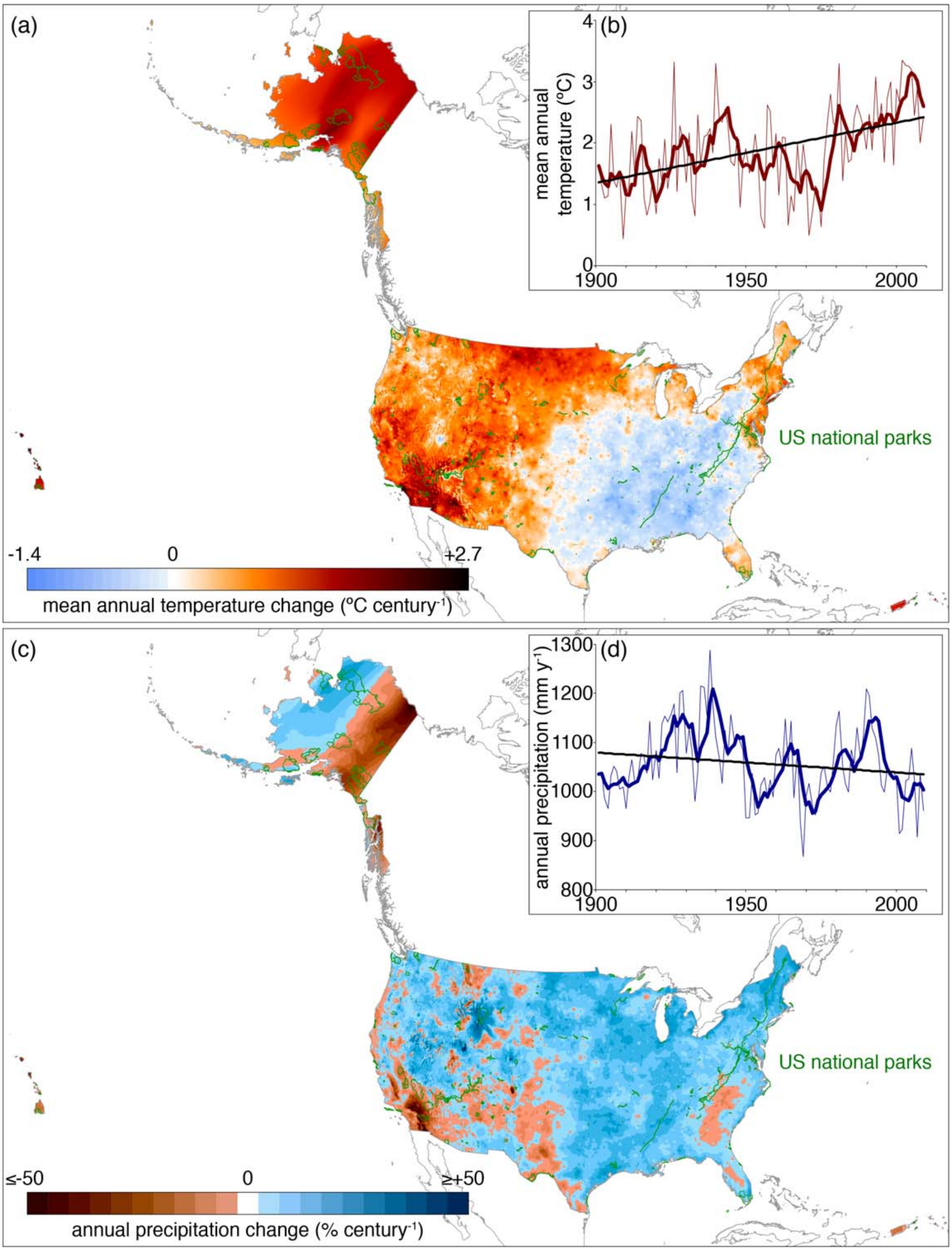

Figure 2. Historical climate change, 1895–2010. (a) Mean annual temperature change (°C century^{-1}) across the US and US national parks (green polygons). (b) Mean annual temperature (°C) of the national park area, annual values (thin line), five-year running average (thick line), and trend from linear regression (straight line, $P < 0.0001$) corrected for temporal autocorrelation. (c) Annual precipitation changes (% century^{-1}), relative to the 1895–2010 average. (d) Average annual precipitation (mm yr^{-1}) of the national park area (trend $P = 0.21$).

temperature increase were in Alaska, with the highest rate of 4.3 °C ± 1.1 °C century^{-1} in Denali National Preserve. A cold phase of the Pacific Decadal Oscillation lowered temperatures in Alaska from the late 1940s to the mid-1970s (Bieniek *et al* 2014), resulting in higher calculated rates of temperature increase for the period starting in 1950 than the period starting in 1901.

Between 1895 and 2010, precipitation declined significantly for 12% of national park area, compared to 3% of the US (table S6). Annual precipitation increased significantly in the US as a whole while annual precipitation of the national park area decreased, although the change was not statistically significant (table 1, figure 1). For the contiguous 48 states, rates of precipitation increase from 1895 to 2016 (7% ± 2% century^{-1} [US, $P = 0.0007$], 4% ± 2% century^{-1} [national park area, $P = 0.08$]) were nearly the same as rates from 1895 to 2010. For the US, precipitation differences between the periods 1901–1960 and 1986–2016 here (table S6) and in the US National Climate Assessment (USGCRP 2017) were equal to the difference calculated here from linear regression. Precipitation decreased considerably in the southwestern US, Alaska, and Hawaii (figure 2). Patterns were similar to US National Climate Assessment results, except for eastern Alaska, although the decrease there was also found in previous analyses (Harris *et al* 2014, McAfee *et al* 2014). For the period 1950–2010, seven of the ten national parks with the most severe precipitation decreases were in Hawaii (table S5), consistent with previous analyses (Frazier and Giambelluca 2017, USGCRP 2017). The largest decline, −85% ± 27% century^{-1}, occurred at Honouliuli National Monument.

Projected climate changes

With continued greenhouse gas emissions, projected rates of 21st century temperature increase under the highest emissions scenario (RCP8.5) would be six times greater than 20th century rates for the national park area and the US (table 1, S7; figure 3). Compared to RCP8.5, reduced emissions would lower the rate of temperature increase by one-half (RCP4.5) to two-thirds (RCP2.6). Under RCP8.5, 100% of national park area would experience a mean annual temperature increase >2 °C from 2000 to 2100. Under the other emissions scenarios, this would decrease to 99% (RCP6.0), 97% (RCP4.5), and 58% (RCP2.6). For the entire US, the fractions are: 100% (RCP8.5), ~100% (RCP6.0), 99% (RCP4.5), and 22% (RCP2.6). Climate velocities from 2000 to 2100 could increase in the national park area to three to nine times historical velocities (tables S3, S7, figure S2). Under RCP8.5, the fraction of the area with rapid climate velocity (>200 km century^{-1}) could increase three to seven times, to 7% of national park area (table S7). The highest projected temperature increases in the national parks are in Alaska, with rates up to 9 °C century^{-1} (table S5, figure 3).

With continued greenhouse gas emissions, GCMs project increased precipitation for the national park area and the US (table 1, S8; figure 3). The ranges (mean ± standard deviation) of almost all the projections of annual precipitation overlap the range of annual precipitation in the historical period, suggesting no significant projections of change at a large scale, with the exception of the national park area under RCP8.5. The large standard deviations indicate low agreement of GCMs on the direction of precipitation change (figure S3). Across the mid-latitudes, GCM ensembles are divided, with some GCMs projecting annual precipitation increases and others decreases, such as in Yosemite National Park (figure S4). The largest projected precipitation decreases in the national parks are in the Virgin Islands, with rates of −28% century^{-1} (table S5).

Discussion

The magnitude of the historical temperature increase and fraction of the area with significant increases were greater for the national park area than the US as a whole. This disproportionate temperature increase occurs because a large fraction of national park area is in the Arctic or at high elevations, where warming occurs more quickly due to a thinner atmosphere, melting of reflective snow cover, which uncovers darker heat-absorbing surfaces, and other factors (ACIA 2005, Vaughan *et al* 2013). Sixty-three percent (63%) of national park area is in Alaska, compared to 16% of the US, and 19% of national park area is north of the Arctic Circle, compared to 3% of the US. Much of the national park area is in mountain ranges, including the highest points in North America (Denali, Denali National Park) and the contiguous states (Mt. Whitney, Sequoia National Park). The average elevation of the national park area is ~980 m above sea level, compared to ~730 m for the US, and 5% of the national park area is above 2500 m elevation, compared to 2% of the US, from spatial analysis at 1 km spatial resolution of US Geological Survey GTOPO30 data (https://lta.cr.usgs.gov/GTOPO30). In addition, the globally anomalous area of no significant temperature change in the southeastern US (Portmann *et al* 2009, Mascioli *et al* 2017) lowered the trend for the US as a whole but affected the park trend less because of the low fraction of the national park area in that region.

Only under a scenario of substantial emissions reductions (RCP2.6) would much of the national park area be located in areas of <2 °C increase by 2100, the upper limit of the Paris Agreement goal (UNFCCC 2016). Under RCP2.6, the fraction of the national park area located in areas of >2 °C increase would be double the fraction for the US as a whole, indicating a disproportionate exposure of national park area. A majority of the national park area and most individual national parks would be located in areas of >2 °C increase under all four emissions scenarios (figure 4).

These projections of temperature increases under all scenarios indicate a need for adaptation of resource management in national parks (Baron *et al* 2009). One adaptation measure under implementation is conservation of potential climate refugia in desert ecosystems in Joshua Tree National Park, identified through a spatial analysis of vulnerability (Barrows and Murphy-Mariscal 2012). Other adaptation measures under consideration for parks include conservation of climate refugia in mountain ecosystems (Johnston *et al* 2012, Morelli *et al* 2016), conservation

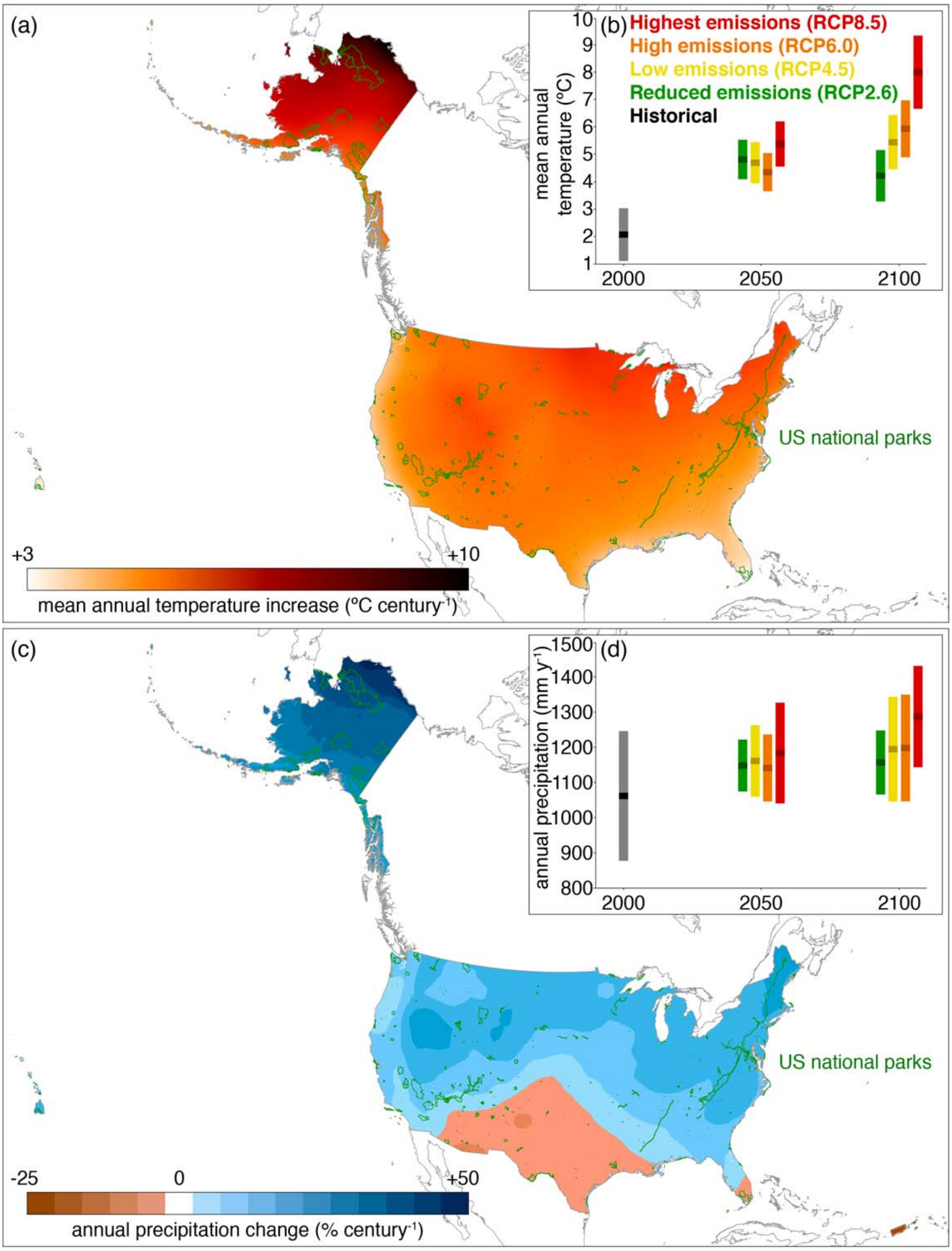

Figure 3. Projected climate change, 1971–2000 to 2071–2100. (a) Projected increase in mean annual temperature (°C century^{-1}) for the highest emissions scenario (RCP8.5). (b) Mean annual temperature (°C) of the national park area for the historical period and two projected periods, dark band = mean, bars = standard deviations of annual values (historical) or GCM ensembles (projections). (c) Projected change in annual precipitation (% century^{-1}), relative to the 1971–2000 average, for RCP8.5. (d) Annual precipitation (mm yr^{-1}) with elements as in (b).

of thermal refugia for cold water fish (Briggs *et al* 2018), protection of corridors for species migrations (Baron *et al* 2009), and prescribed burning in conifer forests to remove excessive understory vegetation and increase survival of older trees in drought (van Mantgem *et al* 2016).

The lower climate velocities in the national park area seem to show lower exposure relative to the US. This is a result of calculation of climate velocity as horizontal displacement (Loarie *et al* 2009) and the extensive area of national parks in mountainous terrain, where topographic relief creates high thermal gradients over short horizontal distances. Climate velocity can underestimate exposure in mountainous terrain, where upslope distances for species to track suitable climate are greater than horizontal distances

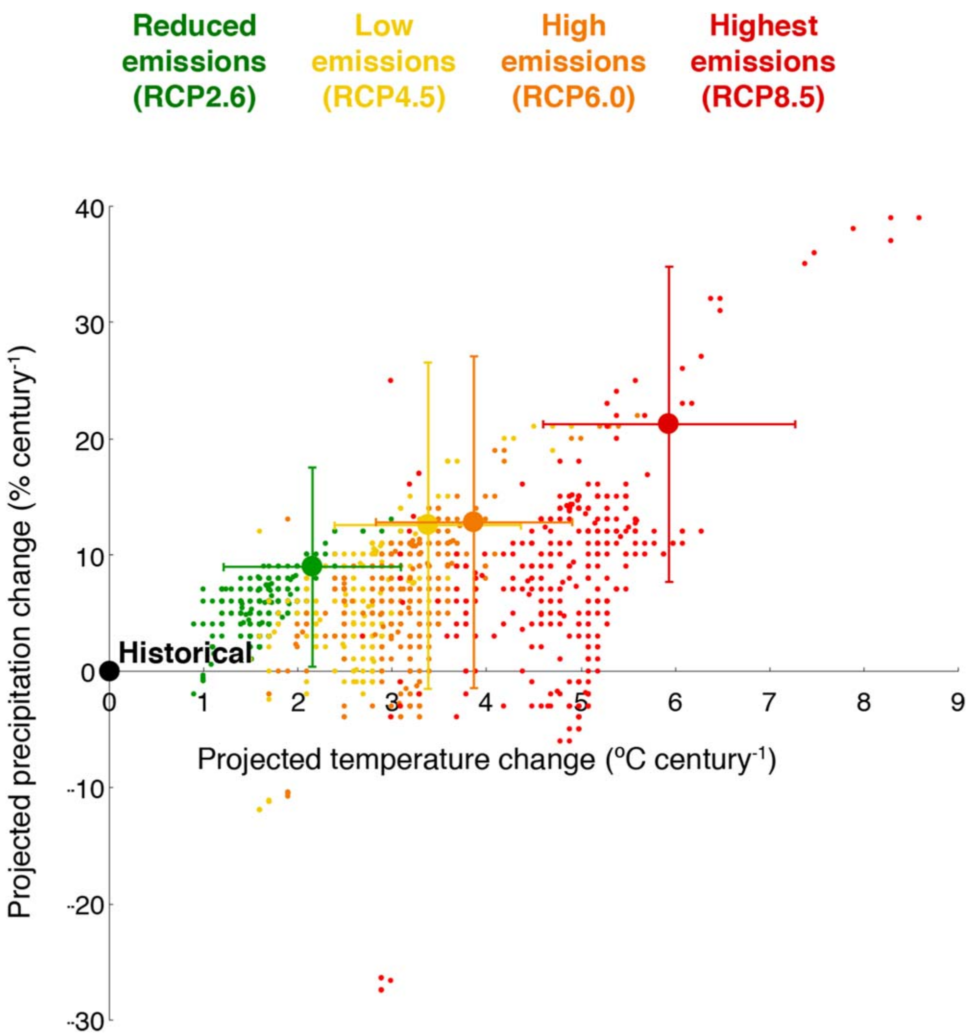

Figure 4. Projected future scenarios, 1971–2000 to 2071–2100, US national park area. Projected changes in mean annual temperature (°C century^{-1}) and annual precipitation (% century^{-1}) for the four IPCC (2013) emissions scenarios, relative to the historical (1971–2000) average, for the US national park area as a whole (large dot = mean, bars = standard deviations of GCM ensembles, all area-weighted) and each of the 417 national parks (small dots, surface areas from 80 m^2 (Thaddeus Kosciuszko National Memorial) to 34 000 km^2 (Wrangell-St. Elias National Park)).

(Dobrowski and Parks 2016). Moreover, climate velocity does not account for potential disappearance of suitable climate from mountain tops or other isolated high elevation points (Hamann *et al* 2015). Therefore, calculated climate velocities may underestimate exposure in mountainous areas of the national parks.

The fraction of national park area experiencing significant historical precipitation decreases was much greater than the fraction of the US as a whole, indicating a disproportionate exposure of the national park area to increased aridity. While annual precipitation increased in the US as a whole, it did not increase for the national park area because of the extensive area of national parks in the arid southwestern US, which has experienced the sharpest declines in precipitation in the contiguous 48 states (figure 2) and severe droughts that have been intensified by anthropogenic climate change, in California (Williams *et al* 2015, Berg and Hall 2017) and the upper Colorado River basin (Crouch *et al* 2017, Udall and Overpeck 2017). In these areas of high inter-annual variability of precipitation, higher temperatures have coincided with low precipitation years.

Projected temperature increases overlap with projected precipitation decreases across much of the southwestern US (figure 3), indicating increased probabilities of drought (Cook *et al* 2015) and aridification (Jones and Gutzler 2016). Even in areas of increased precipitation, projected higher temperatures would reduce the fraction falling as snow (Lute *et al* 2015) and potentially increase aridity through increased evapotranspiration (Hostetler and Alder 2016). The fraction of national park and US area with projected declines in precipitation increases with greenhouse gas emissions (table S8). The low agreement of GCMs on the direction of projected precipitation changes in the mid-latitudes (figures S3, S4) suggests a scenario planning approach when applying the projections to conservation planning (Peterson *et al* 2003).

PRISM data for the contiguous 48 states are derived from measurements at over 10 000 weather stations (Daly *et al* 2008), but a limitation of our methods is that PRISM does not completely control for weather station changes (Oyler *et al* 2015, Walton and Hall 2018) and it may be less accurate in mountainous terrain (Strachan and Daly 2017), overestimating warming at higher elevations in the western US (Oyler *et al* 2015). The TopoWx dataset (Oyler *et al* 2015), which covers the contiguous 48 states starting in 1948, has corrected for station changes over time, but it was not available at the time of this research. PRISM has demonstrated accuracy in comparisons with weather station measurements (Bishop and Beier 2013, Behnke *et al* 2016, Walton and Hall 2018). Comparison of maximum temperatures from PRISM and 3855 Global Historical Climatology Network weather stations across the US found a high correlation ($r > 0.95$) (Behnke *et al* 2016). Comparison of temperature trends from PRISM and 51 weather stations in the northeastern US found an average error for maximum temperature of 0.1 °C century^{-1} (Bishop and Beier 2013), within the standard error of historical temperature trends in our results. PRISM has also shown accuracy compared with ground-truth measurements in a watershed where PRISM came within 5% of rain gauge totals (Daly *et al* 2017).

In addition, analyses that used PRISM in parallel with other gridded climate datasets for California (Williams *et al* 2015) and the northwestern US (Abatzoglou *et al* 2014) found that the PRISM time series closely tracked the key gridded climate datasets for the world (University of East Anglia Climate Research Unit (CRU) 50 km spatial resolution dataset (Harris *et al* 2014), used in IPCC 2013) and the US (National Oceanic and Atmospheric Administration 5 km spatial resolution dataset (Vose *et al* 2014) used in the US National Climate Assessment (USGCRP 2017)). Intercomparisons of up to eight gridded climate datasets for the contiguous states found that PRISM was in the middle of the range of the datasets (Guentchev *et al* 2010, Behnke *et al* 2016, Walton and Hall 2018). Furthermore, numerous research efforts have used PRISM time series data to analyze multi-decadal trends, including trends in climate (Abatzoglou *et al* 2014, Williams *et al* 2015), hydrology (Small *et al* 2006, Pederson *et al* 2013, Velpuri and Senay 2013, Hostetler and Alder 2016), and ecology (Diaz and Eischeid 2007, van Mantgem *et al* 2009, Williams *et al* 2010, Bartomeus *et al* 2011, Crimmins *et al* 2011, Breed *et al* 2013, Dennison *et al* 2014, Hansen *et al* 2014).

It is only for the contiguous states that we use the PRISM climate time series. For Alaska, Hawaii, Guam, and American Samoa, we used historical datasets (table S1) based on the CRU climate time series (Harris *et al* 2014), which was designed for long-term trend analysis, while a PRISM-derived climate average was used only to downscale those time series by bilinear interpolation.

Another possible limitation is that the BCSD method (Wood *et al* 2004) may not completely capture changes in the shape of climate probability distributions between the historical and projected periods. The method may underestimate extreme variable changes if tails of the variable distributions expand beyond historical bounds. Extreme tail values might not be represented in the existing observational record.

This research has not sought to analyze climate extremes. We focused on mean temperature and total precipitation, to which extreme event frequencies, global patterns of biomes, and many species ranges are highly related.

Numerous physical and ecological changes detected in national parks and attributed in previous research mainly to anthropogenic climate change have occurred in areas of significant temperature increases reported here. In Glacier Bay National Park, Muir Glacier has melted and thinned 640 m in its lower reaches from 1948 to 2000 (Larsen *et al* 2007, IPCC 2013) in an area where temperature increased 2.8 °C century^{-1} (1950–2009, this research). In Yosemite National Park, subalpine forest shifted upslope into subalpine meadow from 1880 to 2002 (Millar *et al* 2004) and the ranges of small mammals moved upslope from 1914 to 2006 (Moritz *et al* 2008) in areas where temperature increased as much as 0.9 °C century^{-1} (1895–2016, this research; figure S1). In Noatak National Preserve, boreal conifer forest shifted northward 80–100 m onto tundra from the late 1700s to the late 1900s (Suarez *et al* 1999) in an area where temperature increased 1.2 °C century^{-1} (1901–2009, this research). In Yellowstone National Park and the surrounding ecosystem, bark beetle outbreaks due to climate change have caused mortality of half of the area of whitebark pine (*Pinus albicaulis*) (Macfarlane *et al* 2013, Raffa *et al* 2013) in areas where temperature increased as much as 1.9 °C century^{-1} (1950–2010, this research).

Numerous future vulnerabilities in national parks are also located in areas of projected high exposure found here. In Yellowstone National Park (5.3 °C century^{-1}, RCP8.5, this research), climate change could increase area burned by wildfire three to ten times from 1990 to 2100 (Westerling *et al* 2011), far above natural levels. In Joshua Tree National Park (4.6 °C century^{-1}, RCP8.5, this research), climate change could cause extensive mortality of Joshua trees (*Yucca brevifolia*) by 2100 (Cole *et al* 2011) and loss of up to 90% of areas with suitable climate (Barrows and Murphy-Mariscal 2012). In Lassen Volcanic National Park (4.6 °C century^{-1}, RCP8.5, this research), American pika (*Ochotona princeps*), a small alpine mammal, is vulnerable to extirpation (Stewart *et al* 2015).

Projected climate velocities could exceed maximum natural dispersal capabilities of many trees (~180 km century^{-1}), small mammals (~230 km century^{-1}), and herbaceous plants (~240 km century^{-1}) (Settele *et al* 2014), challenging the abilities of species such as Joshua tree and American pika to remain in suitable climate in national parks (Cole *et al* 2011, Stewart *et al* 2015). The possibility of future climate states in North America with no current analog, particularly in the Arctic and the southeastern and southwestern US (Mahony *et al* 2017), exacerbates the vulnerability of restricted-range endemic species to extinction.

Conclusion

Through spatial analyses of historical and projected temperature and precipitation, we have revealed a previously unreported disproportionate magnitude of climate change in the US national parks, including hotter and drier historical trends and a greater fraction of the area with projected temperature increases >2 °C, the upper limit of the Paris Agreement goal. National parks in Alaska are most exposed to temperature increases while Hawaii, the Virgin Islands, and the southwestern US are most exposed to precipitation decreases.

US national parks protect some of the most irreplaceable ecosystems and cultural sites in the world. The climate spatial data presented here can enable national parks and other US protected areas to analyze vulnerabilities of numerous endangered species and resources whose vulnerability is currently unknown. Projected changes suggest considerable future vulnerabilities and the need for adaptation under all scenarios. Nevertheless, greenhouse gas emissions reductions could substantially reduce the magnitude of anthropogenic climate change, offering hope for the future of the US national parks and the resources they protect for future generations.

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Disproportionate magnitude of climate change in United States national parks

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Supplementary Information

Figure S1. Temperature change, Yosemite National Park, California

Figure S2. Climate velocity

Figure S3. Fractional agreement of precipitation projections

Figure S4. Projected future scenarios, Yosemite National Park, California

Table S1. Historical spatial climate data sources

Table S2. General circulation models

Table S3. Historical mean annual temperature changes

Table S4. Historical seasonal changes

Table S5. Historical and projected climate changes for each of the 417 US national parks

Table S6. Historical annual precipitation changes

Table S7. Projected mean annual temperature and velocity changes

Table S8. Projected annual precipitation changes

Figure S1. Temperature change (ºC century^{-1}), 1895-2016, Yosemite National Park, California.

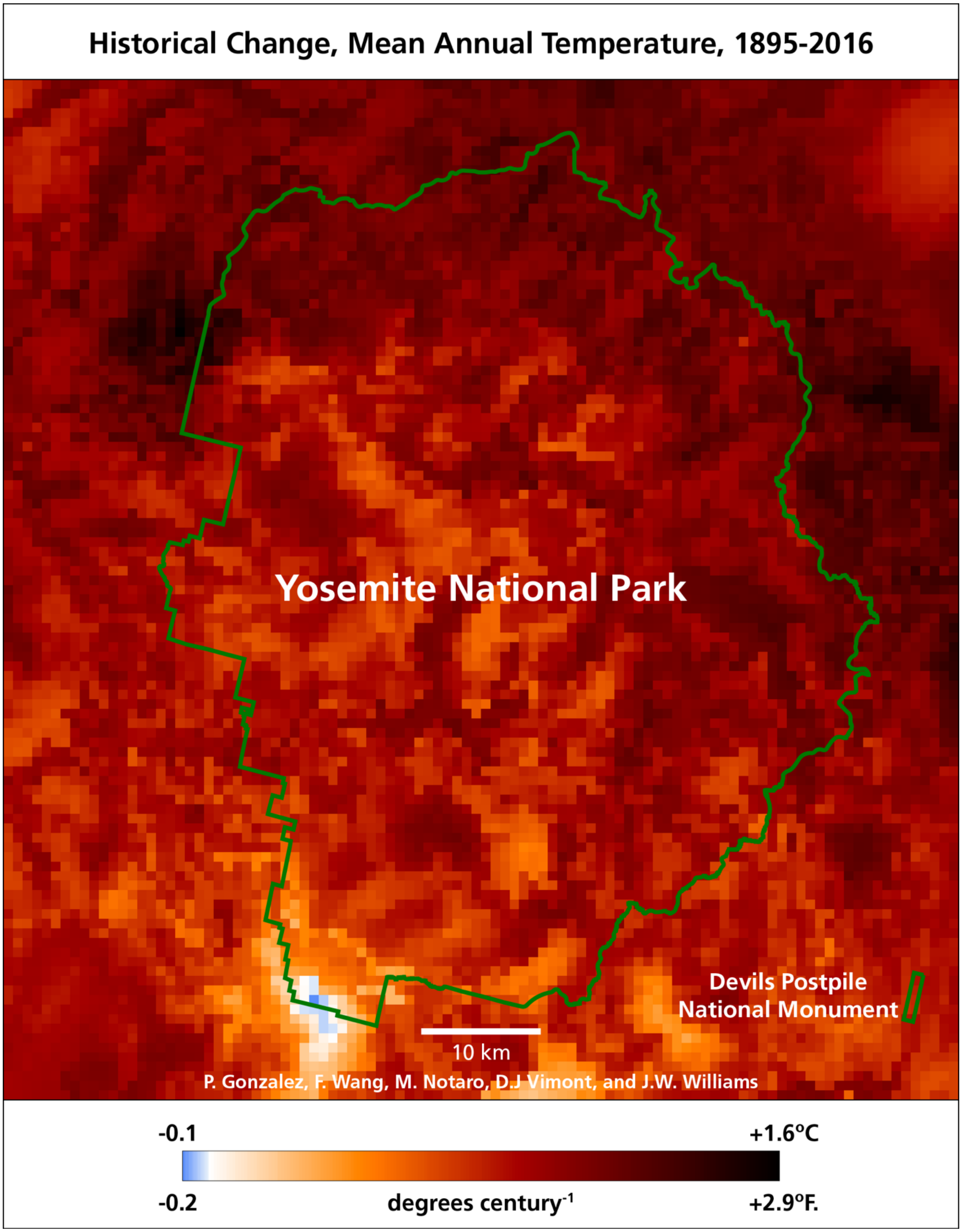

Figure S2. Climate velocity. (*a*) Historical climate velocity (km century^{-1}), based on mean annual temperature, 1895-2010. (*b*) Projected change from 1971-2000 to 2071-2100 as a multiple of the climate velocity for the period 1895-2010, for the highest emissions scenario (RCP8.5).

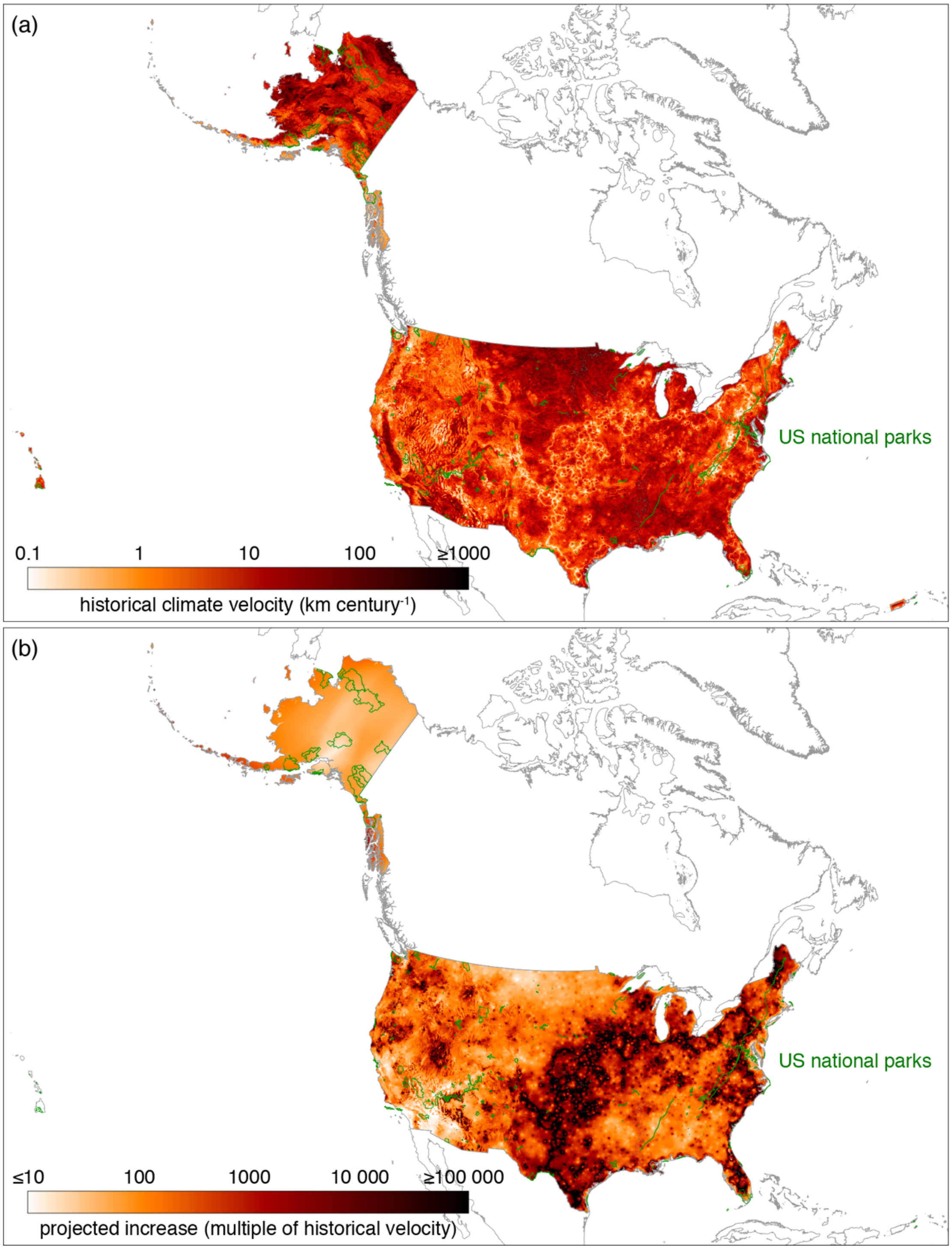

Figure S3. Fractional agreement of precipitation projections. Fraction (%) of general circulation models that project the same direction of annual precipitation change between 1971-2000 and 2071-2100 for the highest emissions scenario (RCP8.5).

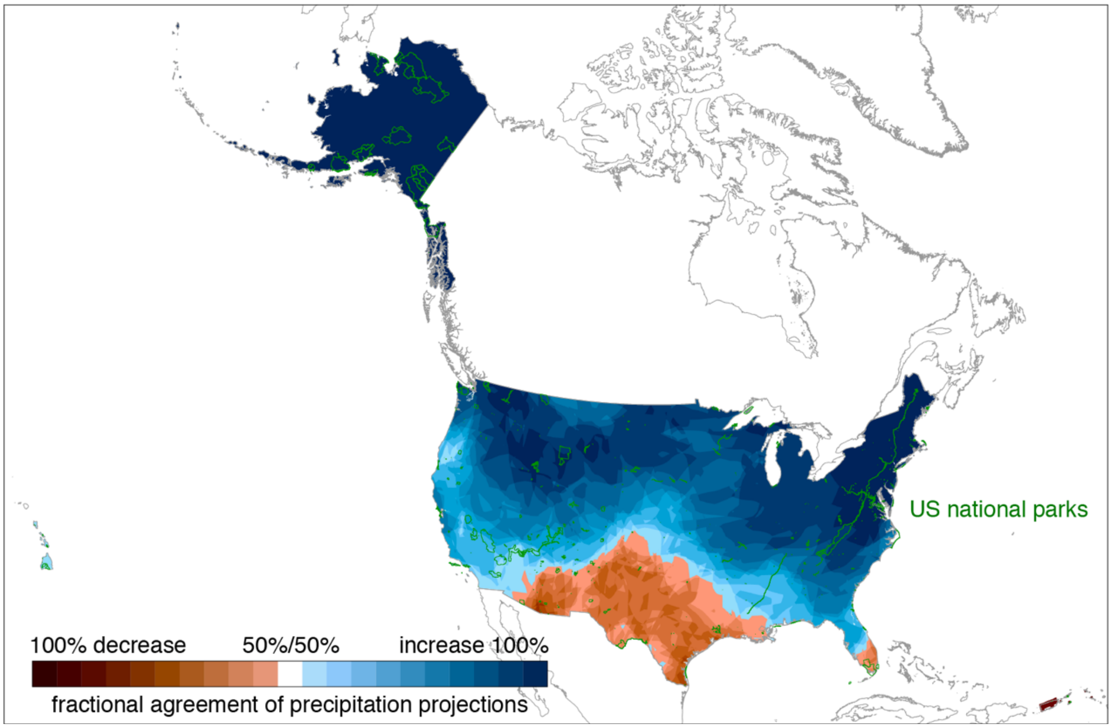

Figure S4. Projected future scenarios, 1971-2000 to 2071-2100, Yosemite National Park. Projected changes in mean annual temperature (ºC century^{-1}) and annual precipitation (% century^{-1}) for the emissions scenarios of the IPCC (2013), relative to the historical (1971-2000) average, for the area of Yosemite National Park as a whole, shown for individual GCMs (small dots), ensemble means (large dots), and standard deviations (bars).

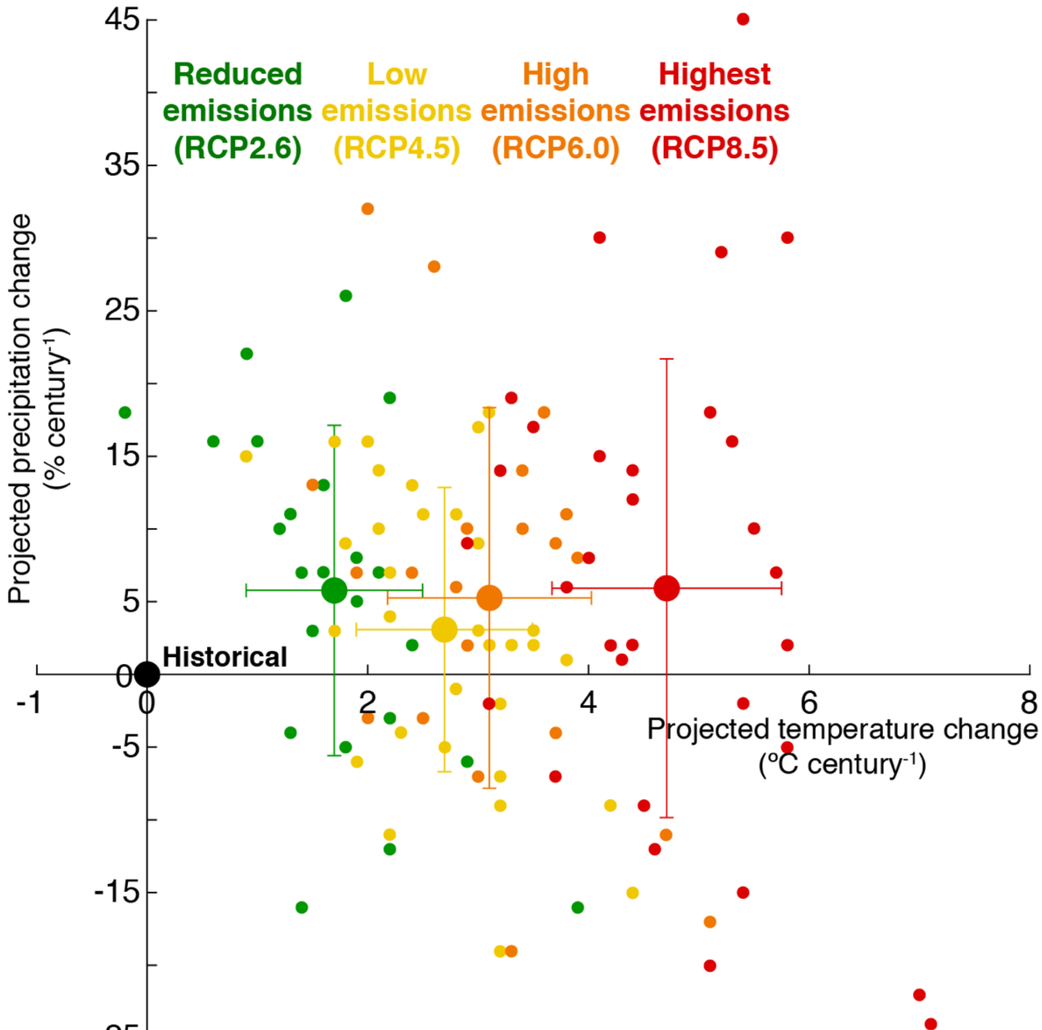

Table S1. Historical spatial climate data sources.

Geographic domain	Climatology	Time series	Spatial resolution	Time period	Applications
Contiguous 48 states	PRISM LT7.1	PRISM LT7.1	30" (800 m)	1895-2010	Linear regression of 340 national parks, climatology 1971-2000
Contiguous 48 states	PRISM LT8.1	PRISM LT8.1	30" (800 m)	1895-2016	Linear regression of US, national park area, and 29 national parks, 1901-2016 comparison, climate velocity
Alaska	PRISM SNAP	CRU3.10	771 m	1901-2009	Linear regression of US, national park area, and 23 national parks, 1901-2009 comparison, climate velocity, climatology 1971-2000
Hawaii	PRISM	CRU3.10	15" (500 m)	1901-2009	Linear regression of US, national park area, and 8 national parks, 1901-2009 comparison, climate velocity, climatology 1971-2000
Guam	PRISM	CRU3.10	3" (100 m)	1901-2009	Linear regression of US and 1 national park, 1901-2009 comparison, climate velocity, climatology 1971-2000
American Samoa	PRISM	CRU3.10	3" (100 m)	1901-2009	Linear regression of US and 1 national park, 1901-2009 comparison, climate velocity, climatology 1971-2000, only covered Tutuila, the main island
Puerto Rico, Virgin Islands	CRU3.10	CRU3.10	0.5º (50 km, re-sized to 18.5 km)	1901-2009	Linear regression of US, national park area, and 6 national parks, 1901-2009 comparison, climate velocity, climatology 1971-2000

CRU = University of East Anglia Climatic Research Unit (Harris et al. 2014)
PRISM = Parameter-elevation Relationships on Independent Slopes Model (Daly et al. 2008)
SNAP = Scenarios Network for Alaska and Arctic Planning, University of Alaska, Fairbanks (https://www.snap.uaf.edu)

Table S2. General circulation models (GCMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5). The research here used all output available in October 2012. The Lawrence Livermore National Laboratory currently hosts the data (https://esgf-node.llnl.gov/search/cmip5). RCP = Representative Concentration Pathway (Moss et al. 2010).

Modeling center (or group)	Institute	GCM	Spatial resolution (longitude x latitude)	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Commonwealth Scientific and Industrial Research Organization (CSIRO) and Bureau of Meteorology (BOM), Australia	CSIRO-BOM	ACCESS1.0	1.875°×1.25°		X		X
		ACCESS1.3	1.875°×1.25°		X		X
Beijing Climate Center, China Meteorological Administration	BCC	BCC-CSM1.1	2.8125°×2.8125°	X	X	X	X
		BCC-CSM1.1(m)	1.125°×1.125°	X	X	X	X
Canadian Centre for Climate Modelling and Analysis	CCCMA	CanESM2	2.8125°×2.8125°	X	X		X
National Center for Atmospheric Research	NCAR	CCSM4	1.25°×0.9°	X	X	X	X
Community Earth System Model Contributors	NSF-DOE-NCAR	CESM1(BGC)	1.25°×0.9°		X		X
		CESM1(CAM5)	1.25°×0.9°	X	X	X	X
Centro Euro-Mediterraneo per I Cambiamenti Climatici	CMCC	CMCC-CM	0.75°×0.75°		X		X
		CMCC-CMS	1.875°×1.875°		X		X
Centre National de Recherches Météorologiques/ Centre Européen de Recherche et Formation Avancée en Calcul Scientifique	CNRM-CERFACS	CNRM-CM5	1.4°×1.4°	X	X		X
Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence	CSIRO-QCCCE	CSIRO-Mk3.6.0	1.875°×1.875°	X	X	X	X
The First Institute of Oceanography, China	FIO	FIO-ESM	2.8125°×2.8125°	X	X	X	X
National Oceanic and Atmospheric Administration, Geophysical Fluid Dynamics Laboratory	NOAA GFDL	GFDL-CM3	2.5°×2°	X	X	X	X
		GFDL-ESM2G	2.5°×2°	X	X	X	X
		GFDL-ESM2M	2.5°×2°	X	X	X	X
National Aeronautics and Space Administration, Goddard Institute for Space Studies	NASA GISS	GISS-E2-H	2.5°×2°	X	X	X	X
		GISS-E2-R	2.5°×2°	X	X	X	X
National Institute of Meteorological Research/Korea Meteorological Administration	NIMR/KMA	HadGEM2-AO	1.875°×1.25°	X	X	X	X
Met Office Hadley Centre	MOHC	HadGEM2-CC	1.875°×1.25°		X		X

Modeling center (or group)	Institute	GCM	Spatial resolution (longitude x latitude)	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Met Office Hadley Centre (additional realizations Instituto Nacional de Pesquisas Espaciais)	MOHC/INPE	HadGEM2-ES	1.875°×1.25°	X	X	X	X
Institute for Numerical Mathematics	INM	INM-CM4	2°×1.5°		X		X
Institut Pierre-Simon Laplace	IPSL	IPSL-CM5A-LR	3.75°×1.895°	X	X	X	X
		IPSL-CM5A-MR	2.5°×1.268°	X	X	X	X
		IPSL-CM5B-LR	3.75°×1.895°		X		X
Japan Agency for Marine-Earth Science and Technology; Atmosphere and Ocean Research Institute, University of Tokyo; and National Institute for Environmental Studies	MIROC	MIROC-ESM	2.8125°×2.8125°	X	X	X	X
		MIROC-ESM-CHEM	2.8125°×2.8125°	X	X	X	X
Atmosphere and Ocean Research Institute, University of Tokyo; National Institute for Environmental Studies; and Japan Agency for Marine-Earth Science and Technology	MIROC	MIROC5	1.4°×1.4°	X	X	X	X
Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology)	MPI-M	MPI-ESM-LR	1.875°×1.875°	X	X		X
		MPI-ESM-MR	1.875°×1.875°	X	X		X
Meteorological Research Institute	MRI	MRI-CGCM3	1.125°×1.125°	X	X		X
Norwegian Climate Centre	NCC	NorESM1-M	2.5°×1.895°	X	X	X	X
		NorESM1-ME	2.5°×1.895°	X	X	X	X
Totals				**25**	**33**	**20**	**33**

Table S3. Historical mean annual temperature changes. Trends and standard errors (SE) from linear regression, corrected for temporal autocorrelation. For the contiguous states, the historical period is 1895-2010. Outside the contiguous states, the historical period is 1901-2009, the period of available spatial data. The 1901-2016 difference is the difference between 1901-60 and 1986-2016. Significance: * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

	Area	1895-2010 Mean	1895-2010 Trend mean ± SE	1901-2016 Difference	1895-2010 Significant change	Increase	Significant increase	Velocity	Velocity >200 km century^{-1}
	km^2	ºC	ºC century^{-1}	ºC	% of area			km century^{-1}	% of area
United States									
Contiguous 48 states	7.8 x 10^6	11.4	0.3 ± 0.2	0.3	43	65	33	430	1
Alaska	1.5 x 10^6	-3.5	1.2 ± 0.3 ***	1.0	83	100	83	47	4
Hawaii	1.7 x 10^4	19.5	1.6 ± 0.1 ***	1.1	100	100	100	7	0.2
Puerto Rico, Virgin Is.	9.3 x 10^3	24.2	1.3 ± 0.1 ***	0.9	100	100	100	9	<0.1
Guam	560	27.1	0.2 ± 0.05 ***	0.2	87	100	87	2	<0.1
American Samoa	160	26.4	1.4 ± 0.1 ***	1.1	100	100	100	49	2
Total	9.3 x 10^6	9.0	0.4 ± 0.1 **	0.4	50	71	42	370	1
National Park System									
Contiguous 48 states	1.3 x 10^5	11.8	0.6 ± 0.1 ***	0.7	48	89	45	660	0.2
Alaska	2.2 x 10^5	-4.1	1.2 ± 0.3 ***	1.0	74	100	74	17	0.1
Hawaii	1.8 x 10^3	16.2	1.3 ± 0.1 ***	0.9	100	100	100	4	<0.1
Puerto Rico, Virgin Is.	39	25.5	1.4 ± 0.1 ***	1.0	100	100	100	1	0
Guam	5	27.3	0.2 ± 0.05 ***	0.2	100	100	100	1	0
American Samoa	13	26.1	1.4 ± 0.1 ***	1.1	100	100	100	5	1
Total	3.6 x 10^5	1.9	1.0 ± 0.2 ***	0.9	64	96	63	260	1

Table S4. Historical seasonal changes in temperature and precipitation. Trends and standard errors (SE) from linear regression, corrected for temporal autocorrelation. For the contiguous states, the historical period is 1895-2010. Outside the contiguous states, the historical period is 1901-2009, the period of available spatial data. Significance: * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

	Area	Temperature				Precipitation			
		Winter Dec.-Feb.	Spring March-May	Summer June-August	Autumn Sept.-Oct.	Winter Dec.-Feb.	Spring March-May	Summer June-August	Autumn Sept.-Oct.
	km^2	ºC century^{-1}				% century^{-1}			
United States									
Contiguous 48 states	7.8 x 10^6	0.4 ± 0.3	0.3 ± 0.2	0.3 ± 0.1	0 ± 0.2	3.5 ± 3.5	6.4 ± 3.4	3.2 ± 2.6	16.5 ± 4.3 ***
Alaska	1.5 x 10^6	1.7 ± 0.7	1.4 ± 0.5 **	1.1 ± 0.2 ***	0.5 ± 0.4	-8.1 ± 4.6	-12.4 ± 4.4 *	-1.8 ± 4	-9.2 ± 4.8
Hawaii	1.7 x 10^4	1.3 ± 0.1 ***	1.6 ± 0.1 ***	1.8 ± 0.1 ***	1.7 ± 0.1 ***	-7.6 ± 11.8	-17.9 ± 10	-19 ± 8.6	-11.5 ± 8.5
Puerto Rico, Virgin Is.	9.3 x 10^3	0.9 ± 0.1 ***	1.5 ± 0.1 ***	1.7 ± 0.1 ***	1.2 ± 0.1 ***	-5.7 ± 8.7	-6.4 ± 9.3	-12.7 ± 7	-4.5 ± 7
Guam	560	0.3 ± 0.1 **	0.2 ± 0.1 **	0.2 ± 0.1 ***	0.2 ± 0.1 ***	21.6 ± 10.9	7.4 ± 15.5	-4.7 ± 8	-8.6 ± 5.6
American Samoa	160	1.6 ± 0.2***	1.5 ± 0.1 ***	1.2 ± 0.1 ***	1.2 ± 0.1 ***	-6 ± 7.9	-1.3 ± 8	16 ± 11.3	19 ± 9.3
Total	9.3 x 10^6	0.6 ± 0.3 *	0.5 ± 0.2 *	0.4 ± 0.1 **	0 ± 0.2	1 ± 2.9	3.7 ± 3.3	2 ± 2.4	11 ± 3.6 **
National Park System									
Contiguous 48 states	1.3 x 10^5	0.6 ± 0.2 *	0.6 ± 0.2 **	0.7 ± 0.1 ***	0.4 ± 0.2 *	5.5 ± 4.4	6.5 ± 3.4	1.5 ± 2.5	12 ± 4.1 **
Alaska	2.2 x 10^5	1.8 ± 0.7 *	1.4 ± 0.5 **	1.1 ± 0.2 ***	0.4 ± 0.4	-9.4 ± 5.8	-10.7 ± 5.4	0.3 ± 4.5	-8 ± 5.5
Hawaii	1.8 x 10^3	1.1 ± 0.1 ***	1.3 ± 0.1 ***	1.5 ± 0.1 ***	1.4 ± 0.1 ***	-1.2 ± 13.2	-9.9 ± 10.4	-14.4 ± 9.3	-5.6 ± 9.8
Puerto Rico, Virgin Is.	39	1.0 ± 0.1 ***	1.6 ± 0.1 ***	1.7 ± 0.1 ***	1.2 ± 0.1 ***	-4.2 ± 8.6	-0.7 ± 10	-13.4 ± 8.4	-8.7 ± 7.6
Guam	5	0.3 ± 0.1 **	0.2 ± 0.1 **	0.2 ± 0.1 ***	0.2 ± 0.1 ***	21.5 ± 10.9	7.5 ± 15.6	-4.7 ± 8	-8.6 ± 5.6
American Samoa	14	1.6 ± 0.2 ***	1.5 ± 0.1 ***	1.2 ± 0.1 ***	1.2 ± 0.1 ***	-5.9 ± 7.9	-1.4 ± 8	16.7 ± 11.4	18.9 ± 9.3
Total	3.6 x 10^5	0.8 ± 0.2 ***	0.8 ± 0.2 ***	0.8 ± 0.1 ***	0.4 ± 0.2	2.5 ± 3.6	3.3 ± 3	0.6 ± 2.3	6.7 ± 2.7

Table S5. Historical and projected climate changes for each of the 417 US national parks. Trends for the area of each park as a whole. The US National Park Service manages some adjacent parks as single units, *e.g.* Denali National Park and Preserve. Historical trends and standard errors (SE) from linear regression, corrected for temporal autocorrelation. Historical period for areas outside the contiguous states is 1950-2009, the period of available spatial data. Projected changes and standard deviations (SD) are for the difference between the periods 1971-2000 and 2071-2100, from ensembles of all general circulation model output available for IPCC (2013), for the emissions reductions scenario (RCP2.6) and the highest emissions scenario (RCP8.5).

Significance: * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

		1950-2010						2000-2100							
		Temperature Trend ± SE			Precipitation Trend ± SE			RCP2.6 Temperature Increase ± SD		RCP8.5 Temperature Increase ± SD		RCP2.6 Precipitation Change ± SD		RCP8.5 Precipitation Change ± SD	
National park	State	ºC $century^{-1}$			% $century^{-1}$			ºC $century^{-1}$		ºC $century^{-1}$		% $century^{-1}$		% $century^{-1}$	
Abraham Lincoln Birthplace National Historical Park	KY	0.6	0.6		7	12		1.6	0.7	4.9	1.0	6	6	11	9
Acadia National Park	ME	0.1	0.5		21	11		1.8	0.9	5.1	1.2	6	6	14	7
Adams National Historical Park	MA	0.9	0.5		26	11	*	1.7	0.8	4.9	1.1	6	6	15	7
African Burial Ground National Monument	NY	1.6	0.5	**	21	14		1.7	0.7	4.9	0.9	7	6	14	8
Agate Fossil Beds National Monument	NE	0.6	0.5		4	13		1.7	0.8	5.1	1.2	6	7	9	9
Alagnak Wild River	AK	3.5	1.2	**	12	12		2.4	1.0	6.2	1.5	9	4	23	6
Alibates Flint Quarries National Monument	TX	-0.5	0.5		19	15		1.6	0.7	5.1	1.1	4	8	-3	10
Allegheny Portage Railroad National Historic Site	PA	0.3	0.6		4	10		1.8	0.7	5.2	1.0	6	4	12	6
Amistad National Recreation Area	TX	0.3	0.6		44	23		1.5	0.7	4.7	1.0	4	8	-2	13
Andersonville National Historic Site	GA	-0.9	0.5		4	12		1.4	0.5	4.3	0.9	6	6	8	10
Andrew Johnson National Historic Site	TN	-0.8	0.6		2	11		1.5	0.6	4.6	0.9	5	5	10	8
Aniakchak National Monument	AK	2.4	1.0	*	18	9	*	2.2	0.9	5.4	1.4	8	4	20	5
Aniakchak National Preserve	AK	2.3	1.1	*	13	9		2.1	0.9	5.3	1.3	9	4	21	6
Antietam National Battlefield	MD	0.1	0.5		16	13		1.7	0.7	5.0	1.0	7	5	14	7
Apostle Islands National Lakeshore	WI	0.9	0.7		1	10		2.0	0.9	6.0	1.4	6	4	11	7

		1950-2010						2000-2100							
National park	State	Temperature Trend ± SE °C century^{-1}			Precipitation Trend ± SE % century^{-1}			RCP2.6 Temperature Increase ± SD °C century^{-1}		RCP8.5 Temperature Increase ± SD °C century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Appalachian National Scenic Trail	14 states	0.4	0.4		16	8		1.7	0.7	5.1	1.0	7	5	14	8
Appomattox Court House National Historical Park	VA	0.1	0.6		20	13		1.6	0.6	4.8	0.9	8	6	14	9
Arches National Park	UT	1.2	0.5	*	32	18		1.9	0.9	5.5	1.2	6	9	7	12
Arkansas Post National Memorial	AR	0.3	0.5		7	14		1.5	0.7	4.7	1.0	3	7	4	11
Arlington House, the Robert E. Lee Memorial	VA	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Assateague Island National Seashore	MD, VA	1.1	0.5	*	15	11		1.5	0.6	4.2	0.8	6	5	10	7
Aztec Ruins National Monument	NM	1.2	0.7		25	19		1.7	0.8	5.2	1.1	5	8	3	13
Badlands National Park	SD	0.7	0.8		32	17		1.8	0.8	5.2	1.3	6	7	10	9
Bandelier National Monument	NM	0.3	0.7		30	15		1.6	0.8	5.1	1.0	4	8	-2	11
Belmont-Paul Women's Equality National Monument	DC	0.7	0.4		13	12		1.7	0.7	4.9	1.0	7	6	14	8
Bent's Old Fort National Historic Site	CO	-0.2	0.5		41	16	*	1.6	0.7	5.0	1.1	5	8	-1	11
Bering Land Bridge National Preserve	AK	2.7	1.1	*	35	18		3.0	1.5	8.3	2.2	11	9	37	15
Big Bend National Park	TX	-0.4	0.6		43	24		1.4	0.7	4.8	1.0	4	8	-2	14
Big Cypress National Preserve	FL	0.8	0.4	*	9	13		1.1	0.4	3.3	0.6	4	5	-2	9
Big Hole National Battlefield	MT	1.2	0.5	*	18	11		1.8	0.8	5.2	1.2	6	4	9	6
Big South Fork National River and Recreation Area	KY, TN	-0.2	0.5		4	11		1.5	0.6	4.7	1.0	5	6	10	9
Big Thicket National Preserve	TX	0.4	0.6		29	12	*	1.4	0.6	4.2	0.8	1	5	-3	11
Bighorn Canyon National Recreation Area	MT, WY	0.8	0.6		2	15		1.8	0.8	5.2	1.4	8	6	15	9
Birmingham Civil Rights National Monument	AL	0.4	0.5		5	12		1.4	0.6	4.5	0.9	5	7	7	11
Biscayne National Park	FL	1.6	0.5	**	13	17		0.9	0.4	3.0	0.7	4	6	-4	10
Black Canyon of the Gunnison National Park	CO	0.3	0.5		42	17	*	1.7	0.9	5.3	1.1	6	7	6	11

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
		Temperature Trend ± SE			Precipitation Trend ± SE			Temperature Increase ± SD		Temperature Increase ± SD		Precipitation Change ± SD		Precipitation Change ± SD	
National park	State	ºC century^{-1}			% century^{-1}			ºC century^{-1}		ºC century^{-1}		% century^{-1}		% century^{-1}	
Blackstone River Valley National Historical Park	MA, RI	0.9	0.4		24	11		1.7	0.8	4.9	1.0	6	6	15	8
Blue Ridge Parkway	NC, VA	0.2	0.5		8	10		1.5	0.6	4.7	0.9	7	5	12	8
Bluestone National Scenic River	WV	0.6	0.5		12	11		1.6	0.7	4.8	1.0	6	5	11	7
Booker T. Washington National Monument	VA	-0.1	0.5		15	11		1.6	0.6	4.7	0.9	7	6	13	8
Boston African American National Historic Site	MA	0.6	0.4		18	12		1.8	0.8	5.0	1.1	6	6	15	7
Boston Harbor Islands National Recreation Area	MA	1.0	0.4	*	20	11		1.7	0.8	4.9	1.1	6	6	15	7
Boston National Historical Park	MA	0.7	0.4		16	12		1.8	0.8	5.0	1.1	6	6	15	7
Brices Cross Roads National Battlefield Site	MS	-0.4	0.6		19	14		1.5	0.6	4.7	1.0	5	7	6	11
Brown v. Board of Education National Historic Site	KS	0.4	0.8		24	14		1.7	0.8	5.2	1.2	4	5	6	8
Bryce Canyon National Park	UT	1.7	0.5	**	27	18		1.8	0.9	5.3	1.2	6	7	6	12
Buck Island Reef National Monument	VI	1.5	0.6	*	-1	14		1	0.4	2.9	0.6	-1	12	-28	20
Buffalo National River	AR	-0.5	0.6		16	13		1.6	0.7	5.0	1.1	3	5	5	9
Cabrillo National Monument	CA	1.8	1.0		31	31		1.4	0.6	3.8	0.9	4	12	0	19
Canaveral National Seashore	FL	0.3	0.4		1	11		1.1	0.5	3.6	0.8	6	6	3	11
Cane River Creole National Historical Park	LA	0	0.6		19	12		1.5	0.6	4.5	0.9	2	6	-1	11
Canyon de Chelly National Monument	AZ	1.2	0.6	*	15	17		1.7	0.8	5.2	1.1	5	8	2	13
Canyonlands National Park	UT	1.2	0.5	*	28	17		1.8	0.9	5.4	1.2	6	8	7	12
Cape Cod National Seashore	MA	0.3	0.5		25	10	*	1.6	0.8	4.6	1.0	6	6	13	7
Cape Hatteras National Seashore	NC	0.9	0.6		11	7		1.2	0.5	3.7	0.7	5	4	6	9
Cape Krusenstern National Monument	AK	2.8	1.1	*	41	18	*	3.1	1.6	8.6	2.2	12	10	39	16
Cape Lookout National Seashore	NC	0.4	0.6		12	8		1.2	0.5	3.7	0.7	5	5	7	9
Capitol Reef National Park	UT	1.8	0.5	**	32	18		1.8	0.9	5.4	1.2	6	8	7	11

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
National park	State	Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			Temperature Increase ± SD ºC century^{-1}		Temperature Increase ± SD ºC century^{-1}		Precipitation Change ± SD % century^{-1}		Precipitation Change ± SD % century^{-1}	
Capulin Volcano National Monument	NM	0.7	0.4		26	13		1.6	0.7	5.0	1.0	5	8	-3	11
Carl Sandburg Home National Historic Site	NC	0.7	0.5		-3	13		1.5	0.6	4.5	0.9	7	6	11	9
Carlsbad Caverns National Park	NM	-0.4	0.8		51	24	*	1.6	0.7	5.0	1.0	3	9	-3	15
Carter G. Woodson Home National Historic Site	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Casa Grande Ruins National Monument	AZ	2.1	0.6	**	5	28		1.6	0.7	4.9	1.0	2	8	-3	14
Castillo de San Marcos National Monument	FL	0.5	0.4		-8	11		1.2	0.5	3.7	0.8	6	6	4	10
Castle Clinton National Monument	NY	1.7	0.5	**	22	14		1.7	0.7	4.9	0.9	7	6	14	8
Castle Mountains National Monument	CA	1.4	0.4	**	41	30		1.6	0.7	4.8	0.9	8	11	5	18
Catoctin Mountain Park	MD	0.9	0.6		16	14		1.7	0.7	5.1	1.0	7	5	14	7
Cedar Breaks National Monument	UT	2.0	0.8	*	29	19		1.8	0.8	5.2	1.2	7	7	7	12
Cedar Creek and Belle Grove National Historical Park	VA	-0.1	0.4		18	12		1.7	0.7	5.0	1.0	7	5	14	7
César E. Chávez National Monument	CA	0.9	0.3	*	23	28		1.5	0.6	4.4	0.8	5	14	4	19
Chaco Culture National Historical Park	NM	1.0	0.5		37	18	*	1.7	0.8	5.2	1.0	5	8	0	12
Chamizal National Memorial	TX	1.6	0.7	*	53	25	*	1.6	0.7	5.0	1.0	3	10	-3	14
Channel Islands National Park	CA	1.4	0.6	*	38	28		1.3	0.5	3.5	0.8	7	13	6	20
Charles Pinckney National Historic Site	SC	0.8	0.6		2	11		1.2	0.5	3.8	0.7	7	6	9	9
Charles Young Buffalo Soldiers National Monument	OH	0.2	0.5		20	10		1.7	0.7	5.2	1.1	6	5	13	9
Chattahoochee River National Recreation Area	GA	0.3	0.8		6	13		1.4	0.6	4.5	0.9	6	6	9	9
Chesapeake and Ohio Canal National Historical Park	DC, MD, WV	0.4	0.4		14	12		1.7	0.7	5.0	1.0	7	5	14	7
Chickamauga and Chattanooga National Military Park	GA	0	0.6		-11	13		1.5	0.6	4.6	0.9	5	6	9	10
Chickasaw National Recreation Area	OK	-1.4	0.5	*	30	15		1.6	0.7	4.9	1.0	2	5	-1	8

National park	State	1950-2010 Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			2000-2100 RCP2.6 Temperature Increase ± SD ºC century^{-1}		RCP8.5 Temperature Increase ± SD ºC century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Chiricahua National Monument	AZ	1.0	0.6		27	21		1.6	0.7	5.0	1.0	2	8	-5	13
Christiansted National Historic Site	VI	1.5	0.6	*	-1	14		1.0	0.4	2.9	0.6	-1	12	-28	20
City of Rocks National Reserve	ID	0.7	0.6		23	21		2.0	1.0	5.5	1.3	9	7	14	10
Clara Barton National Historic Site	MD	0.8	0.5		14	12		1.7	0.7	4.9	1.0	7	6	14	8
Colonial National Historical Park	VA	1.2	0.6	*	19	11		1.5	0.6	4.5	0.8	6	5	11	9
Colorado National Monument	CO	1.6	0.7	*	26	18		1.8	0.9	5.4	1.2	6	8	7	11
Congaree National Park	SC	-0.1	0.5		0	12		1.4	0.5	4.3	0.8	8	6	11	9
Constitution Gardens	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Coronado National Memorial	AZ	0	0.4		25	20		1.5	0.7	4.9	1.0	2	8	-6	14
Cowpens National Battlefield	SC	-0.4	0.5		-8	13		1.5	0.6	4.5	0.9	7	6	11	9
Crater Lake National Park	OR	1.0	0.6		-18	14		1.6	0.7	4.5	0.9	4	6	4	10
Craters of the Moon National Monument	ID	1.7	0.5	**	1	17		1.9	1.0	5.6	1.3	8	6	13	9
Craters of the Moon National Preserve	ID	0.8	0.6		8	17		2.0	1.0	5.6	1.3	8	6	13	9
Cumberland Gap National Historical Park	KY	-0.3	0.7		-3	12		1.5	0.6	4.7	0.9	5	5	10	8
Cumberland Island National Seashore	GA	0	0.5		-9	10		1.2	0.5	3.9	0.7	6	6	6	9
Curecanti National Recreation Area	CO	0.9	0.6		23	14		1.7	0.8	5.2	1.1	6	7	6	10
Cuyahoga Valley National Park	OH	0.3	0.6		22	11	*	1.8	0.8	5.3	1.1	6	4	12	7
Dayton Aviation Heritage National Historical Park	OH	0.2	0.6		20	11		1.7	0.7	5.2	1.1	6	5	13	9
De Soto National Memorial	FL	1.0	0.4	*	-7	15		1.2	0.5	3.8	0.8	6	5	4	10
Death Valley National Park	CA	1.3	0.5	*	38	27		1.7	0.7	4.9	1.0	9	12	8	19
Delaware Water Gap National Recreation Area	PA	1.1	0.5	*	17	14		1.8	0.7	5.2	1.0	8	6	15	8
Denali National Park	AK	3.9	1.1	**	-11	15		2.4	1.0	6.4	1.4	12	7	32	11
Denali National Preserve	AK	4.3	1.1	***	5	14		2.4	1.0	6.5	1.4	12	7	32	11
Devils Postpile National Monument	CA	1.9	0.7	*	35	29		1.7	0.8	4.8	1.0	6	11	7	16
Devils Tower National Monument	WY	0.4	0.7		31	15	*	1.8	0.8	5.3	1.4	6	7	13	9
Dinosaur National Monument	CO, UT	1.9	0.7	**	25	16		1.8	1.0	5.6	1.2	9	8	10	11

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
		Temperature Trend ± SE			Precipitation Trend ± SE			Temperature Increase ± SD		Temperature Increase ± SD		Precipitation Change ± SD		Precipitation Change ± SD	
National park	State	ºC century^{-1}			% century^{-1}			ºC century^{-1}		ºC century^{-1}		% century^{-1}		% century^{-1}	
Dry Tortugas National Park	FL	0.2	0.4		31	19		1.0	0.4	3.1	0.6	6	6	-1	12
Ebey's Landing National Historical Reserve	WA	1.8	0.6	**	13	12		1.7	0.7	4.5	1.1	4	4	7	5
Edgar Allan Poe National Historic Site	PA	2.1	0.7	**	23	10	*	1.7	0.7	4.9	0.9	7	6	14	8
Effigy Mounds National Monument	IA	0.4	0.7		29	15		2.0	0.9	5.7	1.3	5	6	10	9
Eisenhower National Historic Site	PA	0.3	0.5		15	13		1.7	0.7	5.1	1.0	7	5	14	7
El Malpais National Monument	NM	1.1	0.5	*	46	18	*	1.7	0.7	5.1	1.0	4	8	-2	11
El Morro National Monument	NM	0.7	0.4		42	17	*	1.7	0.8	5.1	1.0	4	8	-2	11
Eleanor Roosevelt National Historic Site	NY	0.3	0.5		29	15		1.8	0.8	5.2	1.0	7	6	15	7
Eugene O'Neill National Historic Site	CA	1.7	0.5	**	11	26		1.5	0.6	3.9	0.9	5	12	8	16
Everglades National Park	FL	1.2	0.4	**	9	15		1.0	0.4	3.1	0.6	4	5	-3	9
Federal Hall National Memorial	NY	1.7	0.5	**	22	14		1.7	0.7	4.9	0.9	7	6	14	8
Fire Island National Seashore	NY	1.9	0.6	**	14	12		1.6	0.7	4.6	0.9	7	7	13	9
First Ladies National Historic Site	OH	-0.4	0.6		25	11	*	1.8	0.8	5.2	1.1	6	4	12	7
First State National Historical Park	DE, PA	1.3	0.4	**	26	12		1.7	0.7	4.9	0.9	7	6	14	8
Flight 93 National Memorial	PA	0.1	0.7		7	10		1.8	0.7	5.1	1.0	6	4	12	6
Florissant Fossil Beds National Monument	CO	-0.7	0.5		23	13		1.6	0.8	5.1	1.1	7	8	4	11
Ford's Theatre National Historic Site	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Fort Bowie National Historic Site	AZ	0.7	0.5		23	23		1.6	0.7	5.0	1.0	2	8	-5	12
Fort Caroline National Memorial	FL	0.4	0.5		-7	11		1.2	0.5	3.8	0.8	6	6	5	9
Fort Davis National Historic Site	TX	1.0	0.6		47	21	*	1.5	0.7	4.9	1.0	3	8	-3	14
Fort Donelson National Battlefield	TN	0.4	0.8		6	13		1.6	0.7	4.9	1.1	5	7	9	10
Fort Frederica National Monument	GA	0.6	0.4		-18	10		1.2	0.5	3.9	0.7	7	6	7	9
Fort Laramie National Historic Site	WY	-0.2	0.5		18	12		1.7	0.8	5.1	1.2	8	7	10	9
Fort Larned National Historic Site	KS	-0.4	0.6		24	15		1.7	0.8	5.2	1.2	4	6	1	10
Fort Matanzas National Monument	FL	0.1	0.4		-3	10		1.2	0.5	3.7	0.8	6	6	3	10
Fort McHenry National Monument and Historic Shrine	MD	1.7	0.5	**	11	13		1.7	0.7	4.9	0.9	7	6	14	8

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
National park	State	Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			Temperature Increase ± SD ºC century^{-1}		Temperature Increase ± SD ºC century^{-1}		Precipitation Change ± SD % century^{-1}		Precipitation Change ± SD % century^{-1}	
Fort Monroe National Monument	VA	1.1	0.7		23	11	*	1.4	0.6	4.3	0.8	6	5	10	8
Fort Necessity National Battlefield	PA	0.2	0.6		12	9		1.7	0.7	5.1	1.1	6	4	12	6
Fort Point National Historic Site	CA	1.6	0.6	*	19	27		1.4	0.6	3.8	0.8	5	12	9	16
Fort Pulaski National Monument	GA	0.7	0.6		-1	15		1.2	0.5	3.9	0.7	7	6	8	9
Fort Raleigh National Historic Site	NC	1.1	0.5	*	4	9		1.3	0.6	3.9	0.7	5	4	7	9
Fort Scott National Historic Site	KS	-1.9	0.9	*	38	17	*	1.7	0.8	5.1	1.1	4	5	6	8
Fort Smith National Historic Site	AR, OK	0	0.6		29	16		1.6	0.7	5.0	1.1	2	5	3	8
Fort Stanwix National Monument	NY	1.0	0.5		22	13		1.9	0.8	5.6	1.2	6	4	12	5
Fort Sumter National Monument	SC	1.0	0.6		2	12		1.2	0.5	3.8	0.7	7	6	9	9
Fort Union National Monument	NM	0.7	0.5		37	16	*	1.6	0.7	5.0	1.0	4	8	-4	11
Fort Union Trading Post National Historic Site	ND	2.6	1.1	*	9	15		2.0	0.9	5.6	1.5	6	8	13	10
Fort Vancouver National Historic Site	WA	1.1	0.5	*	-8	16		1.6	0.7	4.2	1.0	3	5	4	6
Fort Washington Park	MD	1.2	0.6		15	12		1.7	0.7	4.9	0.9	7	6	14	8
Fossil Butte National Monument	WY	1.3	0.6	*	16	18		1.9	1.0	5.6	1.3	9	7	11	10
Franklin Delano Roosevelt Memorial	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Frederick Douglass National Historic Site	DC	0.8	0.5		13	12		1.7	0.7	4.9	1.0	7	6	14	8
Frederick Law Olmsted National Historic Site	MA	-0.3	0.6		24	12	*	1.8	0.8	5.0	1.1	6	6	15	7
Fredericksburg and Spotsylvania National Military Park	VA	0.7	0.6		17	13		1.6	0.7	4.9	0.9	8	5	14	8
Freedom Riders National Monument	AL	0.4	0.4		4	12		1.4	0.6	4.5	0.9	6	7	8	10
Friendship Hill National Historic Site	PA	-0.4	0.7		16	10		1.7	0.7	5.1	1.1	6	4	11	6
Gates of the Arctic National Park	AK	4.2	1.0	***	-10	13		2.7	1.3	7.5	1.8	12	8	36	14
Gates of the Arctic National Preserve	AK	4.1	1.1	***	-13	12		2.7	1.2	7.4	1.7	12	8	35	13
Gateway Arch National Park	MO	-0.3	0.8		37	15	*	1.8	0.8	5.2	1.2	5	5	11	8
Gateway National Recreation Area	NY, NJ	1.7	0.5	**	15	12		1.7	0.7	4.8	0.9	7	6	14	8
Gauley River National Recreation Area	WV	0.1	0.5		12	10		1.6	0.7	4.9	1.0	6	5	11	7

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
National park	State	Temperature Trend ± SE °C century^{-1}			Precipitation Trend ± SE % century^{-1}			Temperature Increase ± SD °C century^{-1}		Temperature Increase ± SD °C century^{-1}		Precipitation Change ± SD % century^{-1}		Precipitation Change ± SD % century^{-1}	
General Grant National Memorial	NY	1.6	0.5	**	22	15		1.7	0.7	4.9	0.9	7	6	14	8
George Rogers Clark National Historical Park	IN	0.9	0.7		27	12	*	1.7	0.8	5.1	1.1	5	5	12	9
George Washington Birthplace National Monument	VA	1.3	0.5	*	18	12		1.6	0.6	4.8	0.9	7	5	13	8
George Washington Carver National Monument	MO	-0.9	0.6		35	16	*	1.7	0.7	5.1	1.1	3	5	5	8
George Washington Memorial Parkway	DC	0.8	0.5		15	12		1.7	0.7	4.9	1.0	7	6	14	8
Gettysburg National Military Park	PA	0.2	0.5		15	13		1.7	0.7	5.1	1.0	7	5	14	7
Gila Cliff Dwellings National Monument	NM	0.5	0.3		39	19	*	1.6	0.7	5.0	1.0	3	9	-4	12
Glacier Bay National Park	AK	2.8	1.1	*	22	15		1.9	0.7	5.0	1.1	8	5	18	7
Glacier Bay National Preserve	AK	2.6	1.2	*	24	19		1.9	0.7	4.8	1.1	7	5	18	7
Glacier National Park	MT	2.1	0.8	**	-13	11		1.9	0.9	5.2	1.2	5	6	10	9
Glen Canyon National Recreation Area	AZ, UT	1.4	0.5	*	32	19		1.8	0.9	5.3	1.2	6	8	6	12
Golden Gate National Recreation Area	CA	1.4	0.5	*	7	25		1.4	0.6	3.7	0.8	5	12	9	16
Golden Spike National Historic Site	UT	1.0	0.7		30	25		2.0	1.0	5.6	1.3	9	6	12	10
Governors Island National Monument	NY	1.7	0.5	**	22	14		1.7	0.7	4.9	0.9	7	6	14	8
Grand Canyon National Park	AZ	1.1	0.6		20	20		1.7	0.8	5.1	1.1	5	7	3	12
Grand Portage National Monument	MN	0.9	0.7		4	10		2.0	0.9	6.1	1.4	6	4	12	8
Grand Teton National Park	WY	1.9	0.6	**	7	14		1.7	0.9	5.4	1.2	6	6	13	9
Grant-Kohrs Ranch National Historic Site	MT	0.3	0.5		13	13		1.8	0.8	5.2	1.2	6	5	10	7
Great Basin National Park	NV	0.6	0.5		36	18		1.8	0.9	5.3	1.1	9	8	10	13
Great Egg Harbor Scenic and Recreational River	NJ	1.0	0.5	*	9	10		1.6	0.7	4.6	0.9	7	6	13	8
Great Sand Dunes National Park	CO	0.7	0.6		40	17	*	1.6	0.8	5.1	1.1	5	8	2	11
Great Sand Dunes National Preserve	CO	1.0	0.7		54	19	**	1.6	0.8	5.1	1.1	5	8	2	11
Great Smoky Mountains National Park	TN, NC	0.1	0.5		4	11		1.5	0.6	4.6	0.9	6	6	10	9

National park	State	1950-2010 Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			2000-2100 RCP2.6 Temperature Increase ± SD ºC century^{-1}		RCP8.5 Temperature Increase ± SD ºC century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Greenbelt Park	MD	1.5	0.5	**	11	12		1.7	0.7	4.9	1.0	7	6	14	8
Guadalupe Mountains National Park	TX	0.1	0.5		43	23		1.5	0.7	5.0	1.0	2	9	-3	15
Guilford Courthouse National Military Park	NC	0.7	0.5		7	11		1.5	0.6	4.6	0.9	8	6	13	9
Gulf Islands National Seashore	FL, MS	0	0.4		28	13	*	1.3	0.5	3.9	0.7	6	6	3	10
Hagerman Fossil Beds National Monument	ID	0.2	0.6		2	23		2.0	1.0	5.5	1.3	9	7	16	10
Haleakala National Park	HI	2.0	0.6	**	-18	20		1.1	0.4	3.2	0.8	2	15	12	32
Hamilton Grange National Memorial	NY	1.6	0.5	**	21	15		1.7	0.7	4.9	0.9	7	6	14	9
Hampton National Historic Site	MD	1.2	0.5	*	17	14		1.7	0.7	5.0	1.0	7	6	14	8
Harpers Ferry National Historical Park	WV	-0.2	0.4		19	13		1.7	0.7	5.0	1.0	7	5	14	7
Harriet Tubman National Historical Park	NY	0.7	0.5		47	10	***	1.9	0.8	5.5	1.2	7	4	12	5
Harriet Tubman Underground Railroad National Monument	MD	1.5	0.4	***	14	11		1.6	0.6	4.6	0.8	7	5	12	8
Harry S Truman National Historic Site	MO	-0.1	0.7		31	14	*	1.7	0.8	5.2	1.2	4	5	7	8
Hawai‘i Volcanoes National Park	HI	1.4	0.6	*	-38	17	*	1.1	0.4	3.3	0.8	2	15	17	36
Herbert Hoover National Historic Site	IA	0.6	0.7		29	16		1.9	0.8	5.5	1.3	5	5	10	9
Hohokam Pima National Monument	AZ	2.9	0.8	**	14	29		1.6	0.7	4.9	1.0	2	8	-3	15
Home of Franklin D. Roosevelt National Historic Site	NY	0.4	0.5		29	15		1.8	0.8	5.2	1.0	7	5	15	7
Homestead National Monument of America	NE	-0.3	0.7		3	15		1.8	0.8	5.3	1.2	5	6	6	8
Honouliuli National Monument	HI	2.3	0.3	***	-85	27	**	1.1	0.4	3.1	0.7	1	25	6	38
Hopewell Culture National Historical Park	OH	-0.4	0.7		11	11		1.7	0.7	5.1	1.1	6	5	12	8
Hopewell Furnace National Historic Site	PA	1.0	0.5		24	13		1.7	0.7	5.0	1.0	7	6	14	8
Horseshoe Bend National Military Park	AL	0	0.4		1	12		1.4	0.5	4.4	0.9	6	7	7	10
Hot Springs National Park	AR	-1.3	0.7		12	14		1.6	0.7	4.9	1.0	2	6	3	10
Hovenweep National Monument	UT	1.1	0.5	*	16	18		1.8	0.9	5.3	1.2	6	8	5	13

		1950-2010						2000-2100							
National park	State	Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			RCP2.6 Temperature Increase ± SD ºC century^{-1}		RCP8.5 Temperature Increase ± SD ºC century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Hubbell Trading Post National Historic Site	AZ	2.2	0.6	***	8	21		1.7	0.8	5.1	1.1	4	8	1	12
Independence National Historical Park	PA	1.9	0.6	**	23	10	*	1.7	0.7	4.9	0.9	7	6	14	8
Indiana Dunes National Lakeshore	IN	0.3	0.7		18	10		1.9	0.9	5.4	1.3	6	5	11	8
Isle Royale National Park	MI	1.5	0.8		1	8		2.1	0.9	6.1	1.4	6	4	12	8
James A Garfield National Historic Site	OH	1.1	0.6		22	10	*	1.9	0.8	5.4	1.2	6	4	12	7
Jean Lafitte National Historical Park and Preserve	LA	0.8	0.5		16	11		1.2	0.5	3.8	0.7	4	6	0	10
Jewel Cave National Monument	SD	1.5	0.7	*	35	16	*	1.8	0.8	5.2	1.3	6	7	11	9
Jimmy Carter National Historic Site	GA	-1.0	0.6		7	12		1.4	0.5	4.3	0.9	6	6	7	10
John D. Rockefeller, Jr. Memorial Parkway	WY	1.5	0.6	*	11	14		1.7	0.9	5.3	1.2	6	6	13	9
John Day Fossil Beds National Monument	OR	1.4	0.5	**	1	17		1.7	0.8	4.7	1.1	8	7	11	10
John Fitzgerald Kennedy National Historic Site	MA	-0.1	0.5		23	12		1.8	0.8	5.0	1.1	6	6	15	7
John Muir National Historic Site	CA	1.6	0.6	*	17	26		1.4	0.6	3.9	0.8	5	12	8	16
Johnstown Flood National Memorial	PA	0.4	0.6		7	9		1.8	0.7	5.2	1.0	6	4	12	6
Joshua Tree National Park	CA	1.5	0.5	**	48	45		1.5	0.6	4.6	0.9	7	11	4	19
Kalaupapa National Historical Park	HI	2.2	0.8	*	-57	26	*	1.1	0.4	3.1	0.8	2	15	10	30
Kaloko-Honokohau National Historical Park	HI	1.6	0.3	***	-63	17	**	1.1	0.4	3.2	0.8	2	27	13	52
Katahdin Woods and Waters National Monument	ME	0.4	0.5		16	12		2.0	0.9	5.7	1.2	8	5	17	5
Katmai National Park	AK	2.9	1.1	*	20	11		2.3	0.9	5.7	1.3	9	4	22	6
Katmai National Preserve	AK	3.1	1.1	**	10	11		2.4	1.0	6.1	1.4	9	4	23	6
Kenai Fjords National Park	AK	1.3	1.0		20	20		2.1	0.9	5.4	1.3	10	5	24	8
Kennesaw Mountain National Battlefield Park	GA	0.2	0.7		5	13		1.4	0.6	4.5	0.9	6	6	9	9

		1950-2010					2000-2100							
		Temperature Trend ± SE			Precipitation Trend ± SE		RCP2.6 Temperature Increase ± SD		RCP8.5 Temperature Increase ± SD		RCP2.6 Precipitation Change ± SD		RCP8.5 Precipitation Change ± SD	
National park	State	ºC century^{-1}			% century^{-1}		ºC century^{-1}		ºC century^{-1}		% century^{-1}		% century^{-1}	
Keweenaw National Historical Park	MI	2.5	0.8	**	-3	11	2.0	0.9	6.0	1.4	6	4	11	7
Kings Canyon National Park	CA	1.5	0.5	**	19	25	1.7	0.8	4.8	1.0	6	11	6	17
Kings Mountain National Military Park	SC	-0.3	0.6		-7	12	1.5	0.6	4.5	0.9	7	6	12	9
Klondike Gold Rush National Historical Park	AK	3.1	1.2	*	4	13	2.1	0.8	5.4	1.2	10	5	22	8
Knife River Indian Villages National Historic Site	ND	2.0	1.1		13	13	2.0	0.9	5.8	1.5	6	7	12	10
Kobuk Valley National Park	AK	3.6	1.1	**	19	15	2.9	1.3	7.9	1.8	12	9	38	16
Korean War Veterans Memorial	DC	0.8	0.5		12	12	1.7	0.7	4.9	1.0	7	6	14	8
Lake Chelan National Recreation Area	WA	3.2	0.4	***	-7	12	1.8	0.7	4.9	1.2	5	4	9	6
Lake Clark National Park	AK	2.6	1.0	*	11	15	2.3	0.9	6.1	1.3	10	5	26	8
Lake Clark National Preserve	AK	2.8	1.1	*	12	13	2.4	1.0	6.3	1.4	10	5	27	8
Lake Mead National Recreation Area	AZ, NV	1.8	0.6	**	25	24	1.6	0.7	5.0	1.0	7	9	4	15
Lake Meredith National Recreation Area	TX	-0.5	0.5		19	16	1.6	0.7	5.1	1.1	4	8	-3	10
Lake Roosevelt National Recreation Area	WA	1.3	0.6	*	-8	16	1.9	0.8	5.1	1.2	7	5	12	6
Lassen Volcanic National Park	CA	-0.2	0.5		-11	22	1.6	0.6	4.6	0.9	5	10	7	14
Lava Beds National Monument	CA	1.2	0.5	*	-14	18	1.7	0.6	4.7	0.9	5	8	7	13
Lewis and Clark National Historical Park	OR	0.6	0.4		-17	14	1.5	0.6	3.8	0.9	3	5	5	6
Lincoln Boyhood National Memorial	IN	0.6	0.7		22	12	1.7	0.7	5.0	1.1	6	6	12	9
Lincoln Home National Historic Site	IL	0	0.7		26	14	1.8	0.8	5.3	1.2	5	6	11	8
Lincoln Memorial	DC	0.8	0.5		12	12	1.7	0.7	4.9	1.0	7	6	14	8
Little Bighorn Battlefield National Monument	MT	2.0	0.8	*	10	14	1.8	0.8	5.3	1.4	8	6	15	9
Little River Canyon National Preserve	AL	-0.1	0.7		4	13	1.4	0.6	4.5	0.9	6	6	8	10
Little Rock Central High School National Historic Site	AR	0.5	0.6		4	14	1.6	0.7	4.8	1.0	2	6	4	10
Longfellow National Historic Site	MA	0.2	0.5		22	12	1.8	0.8	5.0	1.1	6	6	15	7

		1950-2010						2000-2100							
National park	State	Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			RCP2.6 Temperature Increase ± SD ºC century^{-1}		RCP8.5 Temperature Increase ± SD ºC century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Lowell National Historical Park	MA	-0.7	0.7		28	13	*	1.8	0.8	5.2	1.1	7	6	16	7
Lyndon B. Johnson National Historical Park	TX	0.3	0.6		36	18		1.5	0.7	4.6	1.0	1	7	-3	12
Lyndon Baines Johnson Memorial Grove on the Potomac	VA	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Maggie L. Walker National Historic Site	VA	1.1	0.7		13	12		1.6	0.6	4.7	0.9	7	5	13	9
Mammoth Cave National Park	KY	1.0	0.7		7	12		1.6	0.7	4.9	1.0	6	7	11	10
Manassas National Battlefield Park	VA	0.4	0.4		21	12		1.7	0.7	4.9	1.0	7	6	14	8
Manhattan Project National Historical Park	NM, TN, WA	1.0	0.3	*	9	8		1.7	0.7	4.8	1.1	6	7	8	14
Manzanar National Historic Site	CA	2.1	0.7	**	14	30		1.7	0.8	4.8	1.0	7	11	7	18
Marsh-Billings-Rockefeller National Historical Park	VT	1.1	0.6		32	13	*	1.9	0.9	5.5	1.1	7	5	15	6
Martin Luther King, Jr. Memorial	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Martin Luther King, Jr. National Historical Park	GA	0.3	0.7		7	13		1.4	0.6	4.5	0.9	6	6	9	9
Martin Van Buren National Historic Site	NY	0.5	0.6		37	16	*	1.9	0.8	5.4	1.1	7	5	15	7
Mary McLeod Bethune Council House National Historic Site	DC	0.7	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Mesa Verde National Park	CO	-0.3	0.6		22	15		1.8	0.9	5.3	1.1	6	8	4	13
Middle Delaware National Scenic River	PA	1.1	0.5	*	17	14		1.8	0.7	5.2	1.0	8	6	15	8
Minidoka National Historic Site	ID	0.4	0.5		15	19		2.0	1.0	5.5	1.3	9	7	14	9
Minute Man National Historical Park	MA	0.6	0.6		27	12	*	1.8	0.8	5.1	1.1	7	6	16	7
Minuteman Missile National Historic Site	SD	0.9	0.9		27	16		1.8	0.8	5.3	1.3	6	7	11	10
Mississippi National River and Recreation Area	MN	1.7	0.8	*	28	10	**	2.1	0.9	5.9	1.4	5	4	10	8
Missouri National Recreational River	SD	0.8	0.9		25	14		1.9	0.9	5.5	1.4	5	6	9	9
Mojave National Preserve	CA	1.3	0.5	*	44	35		1.6	0.7	4.8	0.9	8	12	5	19

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
		Temperature Trend ± SE			Precipitation Trend ± SE			Temperature Increase ± SD		Temperature Increase ± SD		Precipitation Change ± SD		Precipitation Change ± SD	
National park	State	ºC century^{-1}			% century^{-1}			ºC century^{-1}		ºC century^{-1}		% century^{-1}		% century^{-1}	
Monocacy National Battlefield	MD	1.5	0.6	*	21	14		1.7	0.7	5.0	1.0	7	5	14	8
Montezuma Castle National Monument	AZ	1.2	0.5	*	24	20		1.7	0.8	5.0	1.1	3	8	-1	14
Moores Creek National Battlefield	NC	0.5	0.5		8	9		1.3	0.5	4.0	0.7	7	5	10	10
Morristown National Historical Park	NJ	0.7	0.6		15	14		1.7	0.7	5.0	1.0	7	6	15	8
Mount Rainier National Park	WA	1.1	0.6		-11	12		1.7	0.7	4.6	1.1	4	4	6	6
Mount Rushmore National Memorial	SD	0.9	0.7		24	19		1.8	0.8	5.2	1.3	6	7	11	9
Muir Woods National Monument	CA	1.3	0.5	*	-2	21		1.4	0.6	3.8	0.8	5	12	9	16
Natchez National Historical Park	MS	-0.8	0.6		9	11		1.4	0.6	4.4	0.9	3	6	0	11
Natchez Trace National Scenic Trail	AL, MS, TN	-0.3	0.4		15	12		1.5	0.6	4.6	1.0	4	7	5	18
Natchez Trace Parkway	AL, MS, TN	-0.4	0.6		16	12		1.5	0.6	4.6	1.0	4	7	5	11
National Capital Parks	DC, MD	0.9	0.4		14	12		1.7	0.7	4.9	1.0	7	6	14	8
National Mall	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
National Park of American Samoa	AS	2.6	0.9	*	-7	14		0.9	0.3	2.7	0.6	-15	146	28	193
Natural Bridges National Monument	UT	0.5	0.4		25	18		1.8	0.9	5.3	1.2	6	8	6	13
Navajo National Monument	AZ	1.5	0.6	*	20	20		1.8	0.8	5.2	1.1	6	8	5	13
New Bedford Whaling National Historical Park	MA	-0.4	0.5		44	13	**	1.6	0.8	4.6	1.0	6	6	13	8
New Orleans Jazz National Historical Park	LA	0.8	0.5		21	12		1.2	0.5	3.9	0.7	4	6	0	10
New River Gorge National River	WV	0.4	0.5		9	9		1.6	0.7	4.8	1.0	6	5	11	7
Nez Perce National Historical Park	ID, MT, OR, WA	1.6	0.5	**	-7	11		1.9	0.8	5.1	1.2	5	4	8	6
Nicodemus National Historic Site	KS	-0.1	0.7		15	15		1.7	0.8	5.2	1.2	5	6	2	10
Ninety Six National Historic Site	SC	-0.3	0.7		-4	13		1.4	0.5	4.4	0.9	7	6	11	9
Niobrara National Scenic River	NE	0.4	0.8		27	15		1.8	0.8	5.3	1.3	5	6	8	9
Noatak National Preserve	AK	3.5	1.1	**	17	16		3.0	1.5	8.3	2.0	13	10	39	16
North Cascades National Park	WA	1.8	0.6	**	-15	12		1.8	0.7	4.9	1.2	4	4	9	5
Obed Wild and Scenic River	TN	0.2	0.6		8	13		1.5	0.6	4.7	0.9	5	6	9	9

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
		Temperature Trend ± SE			Precipitation Trend ± SE			Temperature Increase ± SD		Temperature Increase ± SD		Precipitation Change ± SD		Precipitation Change ± SD	
National park	State	ºC century^{-1}			% century^{-1}			ºC century^{-1}		ºC century^{-1}		% century^{-1}		% century^{-1}	
Ocmulgee National Monument	GA	-0.5	0.5		3	11		1.4	0.5	4.4	0.9	6	6	9	10
Olympic National Park	WA	0.7	0.4		-8	11		1.6	0.6	4.2	1.0	4	5	7	5
Oregon Caves National Monument and Preserve	OR	1.8	0.7	*	-17	20		1.5	0.6	4.1	0.9	3	8	3	9
Organ Pipe Cactus National Monument	AZ	2.1	0.7	**	4	28		1.5	0.7	4.7	0.9	3	8	-3	15
Ozark National Scenic Riverways	MO	-0.4	0.6		25	14		1.7	0.8	5.1	1.1	4	6	8	9
Padre Island National Seashore	TX	0.1	0.5		35	23		1.2	0.6	3.8	0.7	3	6	-2	12
Palo Alto Battlefield National Historical Park	TX	1.2	0.6	*	37	21		1.2	0.5	3.7	0.7	4	7	-4	12
Paterson Great Falls National Historical Park	NJ	0.6	0.4		5	11		1.7	0.7	5.0	1.0	7	6	15	8
Pea Ridge National Military Park	AR	-0.5	0.7		22	16		1.6	0.7	5.0	1.1	3	5	4	8
Pecos National Historical Park	NM	1.5	0.5	*	42	15	**	1.6	0.7	5.0	1.0	4	9	-4	11
Pennsylvania Avenue National Historic Site	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Perry's Victory and International Peace Memorial	OH	-0.4	0.6		14	9		1.9	0.8	5.4	1.2	6	4	12	8
Petersburg National Battlefield	VA	1.4	0.6	*	12	12		1.5	0.6	4.6	0.8	7	5	13	10
Petrified Forest National Park	AZ	1.8	0.6	*	15	20		1.7	0.8	5.1	1.1	3	7	-1	12
Petroglyph National Monument	NM	0.6	0.5		57	21	*	1.6	0.8	5.1	1	4	9	-3	11
Pictured Rocks National Lakeshore	MI	1.7	0.7	*	1	9		2.1	1.0	6.3	1.7	7	4	12	8
Pinnacles National Park	CA	-0.6	0.5		19	23		1.4	0.6	3.9	0.9	5	13	8	17
Pipe Spring National Monument	AZ	0.9	0.4	*	39	21		1.7	0.8	5.1	1.1	6	7	5	12
Pipestone National Monument	MN	1.2	0.9		31	13	*	2.0	0.9	5.7	1.4	6	6	11	9
Piscataway Park	MD	1.3	0.6		14	12		1.7	0.7	4.9	0.9	7	6	14	8
Point Reyes National Seashore	CA	1.3	0.5	*	3	25		1.4	0.6	3.7	0.8	5	11	10	16
Port Chicago Naval Magazine National Memorial	CA	2.6	0.4	***	29	25		1.5	0.6	4.0	0.8	5	12	8	16

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
		Temperature Trend ± SE			Precipitation Trend ± SE			Temperature Increase ± SD		Temperature Increase ± SD		Precipitation Change ± SD		Precipitation Change ± SD	
National park	State	ºC century^{-1}			% century^{-1}			ºC century^{-1}		ºC century^{-1}		% century^{-1}		% century^{-1}	
Potomac Heritage National Scenic Trail	DC, MD, PA, VA	0.7	0.5		15	11		1.7	0.7	4.9	1.0	7	5	13	7
Poverty Point National Monument	LA	0	0.6		21	15		1.5	0.7	4.6	1.0	3	7	2	11
President William Jefferson Clinton Birthplace Home National Historic Site	AR	-0.6	0.6		15	15		1.6	0.7	4.8	1.0	2	6	1	10
Prince William Forest Park	VA	0.8	0.5		16	12		1.7	0.7	4.9	0.9	7	6	14	8
Pu`uhonua O Hōnaunau National Historical Park	HI	1.5	0.5	*	-57	19	**	1.1	0.4	3.3	0.8	2	15	17	37
Pu`ukoholā Heiau National Historic Site	HI	1.6	0.6	*	-28	17		1.1	0.4	3.2	0.8	2	16	16	38
Pullman National Monument	IL	1.0	0.5		25	11		1.9	0.9	5.4	1.3	6	5	12	8
Rainbow Bridge National Monument	UT	1.7	0.6	**	31	21		1.8	0.8	5.2	1.1	6	8	6	13
Reconstruction Era National Monument	SC	1.7	0.4	***	6	12		1.2	0.5	3.9	0.7	7	6	8	9
Redwood National Park	CA	0.4	0.4		-24	17		1.4	0.6	3.8	0.9	3	9	4	10
Richmond National Battlefield Park	VA	1.5	0.6	*	14	12		1.5	0.6	4.7	0.9	7	5	13	9
Rio Grande Wild and Scenic River	TX	-0.2	0.4		27	22		1.4	0.7	4.8	1.0	4	8	-2	14
River Raisin National Battlefield	MI	0.1	0.7		19	11		1.9	0.8	5.4	1.2	6	4	12	8
Rock Creek Park	DC	0.9	0.4		15	12		1.7	0.7	4.9	1.0	7	6	14	8
Rocky Mountain National Park	CO	1.7	0.6	**	11	11		1.7	0.8	5.1	1.1	8	8	9	10
Roger Williams National Memorial	RI	1.0	0.6		23	11	*	1.7	0.8	4.8	1.0	6	6	15	8
Rosie the Riveter WWII Home Front National Historical Park	CA	1.3	0.5	*	20	28		1.4	0.6	3.8	0.8	5	12	9	16
Ross Lake National Recreation Area	WA	1.5	0.6	*	-13	11		1.8	0.7	4.9	1.2	4	4	9	5
Russell Cave National Monument	AL	-0.7	0.6		4	12		1.5	0.6	4.6	0.9	5	6	8	10
Sagamore Hill National Historic Site	NY	1.4	0.5	**	17	14		1.7	0.7	4.8	0.9	7	7	14	9
Saguaro National Park	AZ	1.2	0.4	**	13	21		1.6	0.7	4.9	1.0	2	8	-5	13
Saint Croix Island International Historic Site	ME	0.4	0.5		15	12		1.8	0.9	5.3	1.2	7	6	15	7
Saint Croix National Scenic Riverway	WI	1.8	0.8	*	8	10		2.1	1.0	5.9	1.4	5	4	10	8

		1950-2010						2000-2100									
National park	State	Temperature Trend ± SE ºC $century^{-1}$			Precipitation Trend ± SE % $century^{-1}$			RCP2.6 Temperature Increase ± SD ºC $century^{-1}$		RCP8.5 Temperature Increase ± SD ºC $century^{-1}$		RCP2.6 Precipitation Change ± SD % $century^{-1}$		RCP8.5 Precipitation Change ± SD % $century^{-1}$	
Saint Paul's Church National Historic Site	NY	1.4	0.5	**	17	14		1.7	0.7	4.9	0.9	7	7	14	9
Saint-Gaudens National Historic Site	NH	1.0	0.5	*	29	13	*	1.9	0.8	5.5	1.1	7	5	15	6
Salem Maritime National Historic Site	MA	0.9	0.5		37	12	**	1.8	0.8	5.0	1.1	6	6	15	7
Salinas Pueblo Missions National Monument	NM	1.2	0.5	*	51	21	*	1.6	0.7	5.0	1.0	3	10	-4	12
Salt River Bay National Historic Park and Ecological Preserve	VI	1.5	0.6	*	-1	14		1.0	0.4	2.9	0.6	-1	12	-28	20
San Antonio Missions National Historical Park	TX	0	0.6		33	22		1.4	0.6	4.5	0.9	1	7	-3	13
San Francisco Maritime National Historical Park	CA	1.6	0.7	*	22	27		1.4	0.6	3.8	0.8	5	12	9	16
San Juan Island National Historical Park	WA	1.2	0.6	*	-1	10		1.7	0.7	4.5	1.1	4	4	8	6
San Juan National Historic Site	PR	1.0	0.5		6	17		1.0	0.4	3.0	0.6	0	10	-27	19
Sand Creek Massacre National Historic Site	CO	-0.4	0.6		45	18	*	1.6	0.7	5.0	1.1	5	7	-1	11
Santa Monica Mountains National Recreation Area	CA	1.4	0.5	*	23	30		1.4	0.6	3.9	0.8	5	13	3	20
Saratoga National Historical Park	NY	1.0	0.6		30	15		1.9	0.8	5.5	1.1	7	4	15	6
Saugus Iron Works National Historic Site	MA	0.8	0.5		26	11	*	1.8	0.8	5.0	1.1	6	6	15	7
Scotts Bluff National Monument	NE	0.9	0.5		8	13		1.7	0.8	5.1	1.2	7	7	8	9
Sequoia National Park	CA	1.4	0.5	**	14	26		1.6	0.7	4.7	0.9	6	12	5	17
Shenandoah National Park	VA	0	0.6		23	13		1.7	0.7	4.9	1.0	8	6	14	8
Shiloh National Military Park	TN	0.2	0.7		21	15		1.5	0.6	4.7	1.0	5	7	7	11
Sitka National Historical Park	AK	3.0	1.1	*	6	11		1.8	0.7	4.4	1.0	8	5	16	6
Sleeping Bear Dunes National Lakeshore	MI	1.6	0.6	*	11	9		2	0.9	5.8	1.3	6	5	11	8

		1950-2010						2000-2100							
National park	State	Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			RCP2.6 Temperature Increase ± SD ºC century^{-1}		RCP8.5 Temperature Increase ± SD ºC century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Springfield Armory National Historic Site	MA	-0.3	0.6		15	13		1.8	0.8	5.2	1.0	7	6	15	7
Statue of Liberty National Monument	NY	1.8	0.6	**	22	14		1.7	0.7	4.9	0.9	7	6	14	8
Steamtown National Historic Site	PA	0.1	0.5		22	14		1.8	0.7	5.3	1.1	7	5	14	7
Stones River National Battlefield	TN	-1.2	0.8		6	12		1.5	0.6	4.7	1.0	5	7	9	10
Stonewall National Monument	NY	1.7	0.5	***	25	11		1.7	0.7	4.9	0.9	7	6	14	8
Sunset Crater Volcano National Monument	AZ	0.1	0.4		13	16		1.7	0.8	5.1	1.1	4	7	1	13
Tallgrass Prairie National Preserve	KS	-0.4	0.7		23	16		1.7	0.8	5.1	1.2	4	5	4	8
Thaddeus Kosciuszko National Memorial	PA	1.9	0.6	**	23	10	*	1.7	0.7	4.9	0.9	7	6	14	8
Theodore Roosevelt Birthplace National Historic Site	NY	1.5	0.5	**	22	14		1.7	0.7	4.9	0.9	7	6	14	8
Theodore Roosevelt Inaugural National Historic Site	NY	0.8	0.5		22	9	*	2.0	0.8	5.6	1.2	7	4	12	6
Theodore Roosevelt Island Park	VA	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Theodore Roosevelt National Park	ND	2.1	1.1		5	14		2.0	0.9	5.6	1.5	6	7	13	10
Thomas Edison National Historical Park	NJ	1.4	0.5	*	18	14		1.7	0.7	5.0	0.9	7	6	14	8
Thomas Jefferson Memorial	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Thomas Stone National Historic Site	MD	1.1	0.6		13	11		1.6	0.7	4.8	0.9	7	5	14	8
Timpanogos Cave National Monument	UT	1.0	0.7		13	23		1.9	1.0	5.5	1.3	8	7	10	10
Timucuan Ecological and Historic Preserve	FL	0.2	0.5		-6	11		1.2	0.5	3.8	0.8	6	6	6	9
Tonto National Monument	AZ	1.5	0.8		20	25		1.6	0.7	5.0	1.0	2	7	-3	13
Tule Springs Fossil Beds National Monument	NV	1.9	0.4	***	54	35		1.6	0.7	5.0	0.9	9	10	7	17
Tumacacori National Historical Park	AZ	0.8	0.4	*	8	23		1.5	0.7	4.8	1.0	2	8	-6	14
Tupelo National Battlefield	MS	-0.2	0.7		14	14		1.5	0.6	4.7	1.0	5	7	6	11
Tuskegee Airmen National Historic Site	AL	-1.0	0.5		6	12		1.4	0.5	4.3	0.9	6	7	7	10

National park	State	1950-2010 Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			2000-2100 RCP2.6 Temperature Increase ± SD ºC century^{-1}		RCP8.5 Temperature Increase ± SD ºC century^{-1}		RCP2.6 Precipitation Change ± SD % century^{-1}		RCP8.5 Precipitation Change ± SD % century^{-1}	
Tuskegee Institute National Historic Site	AL	-1.1	0.6		6	12		1.4	0.5	4.3	0.9	6	7	7	10
Tuzigoot National Monument	AZ	1.8	0.6	**	2	20		1.7	0.8	5.0	1.1	3	8	-1	14
Ulysses S. Grant National Historic Site	MO	-0.2	0.8		34	15	*	1.8	0.8	5.2	1.2	5	5	11	8
Upper Delaware Scenic and Recreational River	NY, PA	0.5	0.5		16	14		1.8	0.8	5.3	1.1	7	5	14	7
Valles Caldera National Preserve	NM	0.8	0.4		11	15		1.6	0.8	5.1	1.0	4	8	-2	11
Valley Forge National Historical Park	PA	0.9	0.5		18	12		1.7	0.7	5.0	0.9	7	6	14	8
Vanderbilt Mansion National Historic Site	NY	0.4	0.5		27	15		1.8	0.8	5.2	1.0	7	5	15	7
Vicksburg National Military Park	MS	0.1	0.6		29	13	*	1.5	0.6	4.5	1.0	3	7	2	11
Vietnam Veterans Memorial	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Virgin Islands Coral Reef National Monument	VI	1.4	0.6	*	6	15		1.0	0.4	2.9	0.6	-1	11	-26	19
Virgin Islands National Park	VI	1.4	0.6	*	6	15		1.0	0.4	2.9	0.6	-1	11	-26	19
Voyageurs National Park	MN	1.1	0.8		5	8		2.1	1.0	6.1	1.5	6	5	11	8
Waco Mammoth National Monument	TX	0.1	0.4		25	17		1.5	0.7	4.7	1.0	1	5	-3	10
Walnut Canyon National Monument	AZ	1.6	0.5	**	12	18		1.7	0.8	5.1	1.1	3	7	0	13
War in the Pacific National Historical Park	GU	0.4	0.3		7	13		1.0	0.3	3.0	0.6	7	8	25	26
Washington Monument	DC	0.8	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
Washita Battlefield National Historic Site	OK	-0.9	0.6		31	15	*	1.6	0.7	5.1	1.1	3	7	-2	9
Weir Farm National Historic Site	CT	1.2	0.5	*	18	14		1.7	0.8	5.0	1.0	7	6	14	8
Whiskeytown National Recreation Area	CA	1.5	0.5	**	18	23		1.5	0.6	4.3	0.8	4	10	5	12
White House	DC	0.7	0.5		12	12		1.7	0.7	4.9	1.0	7	6	14	8
White Sands National Monument	NM	0.6	0.5		64	28	*	1.6	0.7	5.0	1.0	2	10	-4	13
Whitman Mission National Historic Site	WA	0	0.5		21	13		1.8	0.7	4.8	1.2	6	5	10	7
William Howard Taft National Historic Site	OH	-0.2	0.6		15	11		1.7	0.7	5.1	1.1	6	5	12	9

		1950-2010						2000-2100							
								RCP2.6		RCP8.5		RCP2.6		RCP8.5	
National park	State	Temperature Trend ± SE ºC century^{-1}			Precipitation Trend ± SE % century^{-1}			Temperature Increase ± SD ºC century^{-1}		Temperature Increase ± SD ºC century^{-1}		Precipitation Change ± SD % century^{-1}		Precipitation Change ± SD % century^{-1}	
Wilson's Creek National Battlefield	MO	-0.5	0.7		29	15		1.7	0.7	5.1	1.1	4	5	6	8
Wind Cave National Park	SD	1.4	0.7	*	31	16		1.8	0.8	5.2	1.3	6	7	10	9
Wolf Trap National Park for the Performing Arts	VA	0	0.4		12	12		1.7	0.7	4.9	1	7	6	14	8
Women's Rights National Historical Park	NY	0.5	0.5		23	11	*	1.9	0.8	5.5	1.2	7	4	12	5
World War I Memorial	DC	0.7	0.4		14	12		1.7	0.7	4.9	1	7	6	14	8
World War II Memorial	DC	0.8	0.5		12	12		1.7	0.7	4.9	1	7	6	14	8
World War II Valor in the Pacific National Monument	HI	2.4	0.6	**	-81	29	**	1.1	0.4	3.1	0.7	3	15	8	28
Wrangell-St. Elias National Park	AK	1.9	1.1		2	18		2.1	0.8	5.3	1.2	9	5	23	8
Wrangell-St. Elias National Preserve	AK	2.2	1.1	*	-10	14		2.2	0.9	5.6	1.3	10	6	25	9
Wright Brothers National Memorial	NC	1.2	0.6		8	9		1.3	0.6	3.9	0.7	5	4	7	9
Wupatki National Monument	AZ	1.4	0.5	**	10	23		1.7	0.8	5.1	1.1	4	7	1	13
Yellowstone National Park	ID, MT, WY	1.4	0.7		7	12		1.7	0.9	5.3	1.2	6	6	12	9
Yosemite National Park	CA	1.9	0.7	**	5	28		1.7	0.8	4.7	1	6	11	6	16
Yucca House National Monument	CO	0.8	0.5		14	17		1.8	0.9	5.3	1.1	6	8	5	13
Yukon-Charley Rivers National Preserve	AK	3.2	1.0	**	-66	20	**	2.3	1.0	6.5	1.5	11	8	31	12
Zion National Park	UT	1.9	0.7	**	34	20		1.8	0.8	5.2	1.1	7	7	6	12

Table S6. Historical annual precipitation changes. Trends and standard errors (SE) from linear regression, corrected for temporal autocorrelation. Historical period for areas outside the contiguous states is 1901-2009, the period of available spatial data. The 1901-2016 difference is the difference between 1901-60 and 1986-2016. Significance: * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

		1895-2010		1901-2016	1895-2010		
	Area km^2	Mean mm y^{-1}	Trend mean ± SE % century^{-1}	Difference %	Significant change (% of area)	Decrease (% of area)	Significant decrease (% of area)
United States							
Contiguous 48 states	7.8 x 10^6	760	7 ± 2 **	6	27	11	<0.5
Alaska	1.5 x 10^6	890	-7 ± 3 *	-4	27	54	24
Hawaii	1.7 x 10^4	2200	-14 ± 6 *	-11	21	99	21
Puerto Rico, Virgin Is.	9.3 x 10^3	1900	-8 ± 5	-5	36	1	36
Guam	560	7600	-1 ± 5	2	0	78	0
American Samoa	160	3000	5 ± 5	1	0	0	0
Total	9.3 x 10^6	790	4 ± 2 *	4	27	18	4
National Park System							
Contiguous 48 states	1.3 x 10^5	770	4 ± 2	3	10	26	<0.5
Alaska	2.2 x 10^5	1200	-7 ± 3 *	-4	20	63	19
Hawaii	1.8 x 10^3	1800	-7 ± 6	-7	3	1	3
Puerto Rico, Virgin Is.	39	1500	-8 ± 5	-5	0	1	0
Guam	5	7400	-1 ± 5	2	0	1	0
American Samoa	13	3200	5 ± 5	1	0	0	0
Total	3.6 x 10^5	1100	-4 ± 2	-2	16	49	12

Table S7. **Projected mean annual temperature and velocity changes.** Projected changes and standard deviations (SD) for the difference between the periods 1971-2000 and 2071-2100, from ensembles of all general circulation models available for IPCC (2013).

		RCP2.6	RCP4.5	RCP6.0	RCP8.5	RCP2.6	RCP8.5	RCP2.6	RCP8.5
	Area	Increase mean ± SD				Velocity		Velocity >200 km century^{-1}	
	km^2	ºC century^{-1}				x historical			
United States									
Contiguous 48 states	7.8 x 10^6	1.7 ± 0.8	2.9 ± 0.9	3.3 ± 0.9	5 ± 1.1	4	11	9	40
Alaska	1.5 x 10^6	2.5 ± 1.1	3.9 ± 1.2	4.5 ± 1.2	6.9 ± 1.6	2	6	3	6
Hawaii	1.7 x 10^4	1.1 ± 0.4	1.7 ± 0.5	2 ± 0.7	3.2 ± 0.8	0.7	2	0.4	2
Puerto Rico, Virgin Is.	9.3 x 10^3	1 ± 0.4	1.7 ± 0.4	1.9 ± 0.5	3 ± 0.6	0.8	2	1	1
Guam	560	1 ± 0.3	1.6 ± 0.4	1.9 ± 0.4	3 ± 0.6	4	13	36	197
American Samoa	160	0.9 ± 0.3	1.5 ± 0.4	1.7 ± 0.5	2.7 ± 0.6	0.6	2	0.7	1
Total	9.3 x 10^6	1.8 ± 0.8	3 ± 0.9	3.5 ± 0.9	5.3 ± 1.2	4	11	6	22
National Park System									
Contiguous 48 states	1.3 x 10^5	1.6 ± 0.7	2.8 ± 0.8	3.2 ± 0.8	4.9 ± 1	6	20	2	12
Alaska	2.2 x 10^5	2.5 ± 1.1	3.8 ± 1.1	4.3 ± 1.2	6.6 ± 1.5	0.8	2	0.7	2
Hawaii	1.8 x 10^3	1.1 ± 0.4	1.8 ± 0.5	2.1 ± 0.7	3.2 ± 0.8	0.5	1	0.1	0.5
Puerto Rico, Virgin Is.	39	1 ± 0.4	1.7 ± 0.4	1.9 ± 0.5	2.9 ± 0.6	0.1	0.2	1	1
Guam	5	1 ± 0.3	1.6 ± 0.4	1.9 ± 0.4	3 ± 0.6	2	6	14	57
American Samoa	14	0.9 ± 0.3	1.5 ± 0.4	1.7 ± 0.5	2.7 ± 0.6	0.1	0.2	0.1	0.6
Total	3.6 x 10^5	2.2 ± 0.9	3.4 ± 1	3.9 ± 1	5.9 ± 1.3	3	9	2	7

Table S8. Projected annual precipitation changes. Projected changes and standard deviations (SD) for the difference between the periods 1971-2000 and 2071-2100, from ensembles of all general circulation model available for IPCC (2013).

	Area	RCP2.6	RCP4.5	RCP6.0	RCP8.5	RCP2.6	RCP4.5	RCP6.0	RCP8.5
		Change mean ± SD				Decrease			
	km^2	% $century^{-1}$				% of area			
United States									
Contiguous 48 states	7.8×10^6	5 ± 8	5 ± 25	6 ± 20	7 ± 24	0	12	16	19
Alaska	1.5×10^6	11 ± 7	17 ± 8	18 ± 9	31 ± 11	0	0	0	0
Hawaii	1.7×10^4	1 ± 196	1 ± 65	3 ± 42	10 ± 56	6	31	0	0
Puerto Rico, Virgin Is.	9.3×10^3	0.1 ± 11	-10 ± 20	-9 ± 21	-23 ± 26	44	100	100	100
Guam	560	6 ± 15	9 ± 21	10 ± 18	19 ± 32	0	0	0	0
American Samoa	160	-1 ± 17	1 ± 18	-1 ± 22	3 ± 25	100	0	100	0
Total	9.3×10^6	6 ± 8	7 ± 22	8 ± 18	11 ± 22	<1	10	13	16
National Park System									
Contiguous 48 states	1.3×10^5	6 ± 8	5 ± 24	6 ± 24	7 ± 17	0	4	8	14
Alaska	2.2×10^5	11 ± 7	17 ± 7	17 ± 9	30 ± 11	0	0	0	0
Hawaii	1.8×10^3	1 ± 256	3 ± 76	3 ± 41	12 ± 51	4	7	0	0
Puerto Rico, Virgin Is.	39	-0.1 ± 10	-10 ± 20	-8 ± 21	-22 ± 25	67	100	100	100
Guam	5	6 ± 15	9 ± 21	10 ± 18	19 ± 32	0	0	0	0
American Samoa	14	-1 ± 17	1 ± 18	-1 ± 22	3 ± 24	100	0	100	0
Total	3.6×10^5	9 ± 9	13 ± 14	13 ± 14	21 ± 14	<1	2	3	5