

Anthropogenic Climate Change Trends and Scenarios in Denali National Park and Preserve, Alaska

Patrick Gonzalez

Natural Resource Stewardship and Science, U.S. National Park Service, Berkeley, California

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Introduction

Human-caused climate change has increased temperatures in Alaska (IPCC 2013, USGCRP 2017), causing melting of glaciers and permafrost, earlier melting of snow, a lengthening of the growing season, and other impacts (Stone et al. 2002, Hinzman et al. 2005, Markon et al. 2018). In the center of Alaska, Denali National Park and Preserve conserves unique ecosystems, biodiversity, and the tallest mountain in North America. Currently, the National Park Service (NPS) is engaged in planning of resource management and winter recreation, which depend substantially on snowpack. NPS staff have requested future scenarios relevant for planning.

Methods

Historical climate This report presents results of spatial analyses of historical climate trends (Gonzalez et al. 2018) that use climate data layers at 771 m spatial resolution produced by the University of Alaska Scenarios Network for Alaska and Arctic Planning (SNAP) (<http://ckan.snap.uaf.edu/dataset/historical-monthly-and-derived-temperature-products-771m-cru-ts>). SNAP used historical climate data layers previously published by the University of East Anglia Climate Research Unit (CRU; Harris et al. 2014) in which point measurements from weather stations from 1901 to 2009 were combined into pixels at 50 km spatial resolution. Parallel to that analysis, Oregon State University researchers used the Parameter-elevation Relationships on Independent Slopes Model (PRISM; Daly et al. 2008) to interpolate, with elevation and local topography, climate values in the spaces among weather stations from 1980 to 2010, producing climate data layers at 771 m spatial resolution. SNAP downscaled the 50 km CRU data using the 771 m PRISM data to produce time series of temperature and precipitation from 1901 to 2009 at 771 m spatial resolution.

This report summarizes results by giving trends for the area within the boundaries of the park and, separately, within the boundaries of the preserve. Although NPS manages the units

together, NPS lists them separately in the official list of 417 national parks which was used in the publication on climate change trends (Gonzalez et al. 2018) that provides the climate data used here. Linear regression of temperature and precipitation time series gives the historical climate trends, with the statistical probability of significance corrected for temporal autocorrelation. Analyses of monthly, seasonal, and annual climate were run for the periods 1901-2009 and 1950-2009.

Projected climate This report presents spatial analyses of future projections of climate (Gonzalez et al. 2018) that use output of all available general circulation models (GCMs) in the Coupled Model Intercomparison Project Phase 5 dataset developed for the most recent Intergovernmental Panel on Climate Change (IPCC) assessment report (IPCC 2013). The coarse-scale GCM output, at spatial resolutions of up to 200 km, has been downscaled to 800 m spatial resolution using the bias correction and spatial disaggregation method (Wood et al. 2004) and, as a base layer, the PRISM historical climate time series (Daly et al. 2008). Future projected changes are expressed as the change from the standard 1971-2000 historical baseline.

IPCC has coordinated numerous research groups to project possible future climates under four defined greenhouse gas emissions scenarios, called representative concentration pathways (RCPs; Moss et al. 2010). The four emissions scenarios are RCP2.6 (reduced emissions from increased energy efficiency and installation of renewable energy), RCP4.5 (low emissions), RCP6.0 (high emissions, somewhat lower than continued current practices), and RCP8.5 (highest emissions, no emissions reduction practices). Climate under each of the four scenarios was projected by up to 33 GCMs. The range of potential futures is defined first by the four emissions scenarios, then by the set of GCMs within an emissions scenario. Each scenario is characterized by the average and standard deviation of the GCM ensemble.

The report uses previously published future projections of snow, with the indicator being the fraction of days with precipitation falling as snow rather than rain (Littell et al. 2018). The projections of five GCMs were analyzed at 771 m spatial resolution for RCP4.5 and RCP8.5 for the period 2070-2090, relative to 1921-2000 (Littell et al. 2018).

Planning scenarios Scenario planning is an approach for developing a set of possible futures to enable planning in the present (Kahn and Wiener 1967). It has been applied to biodiversity

conservation (Peterson et al. 2003) and to the integration of climate change considerations into NPS planning (Star et al. 2016). NPS and SNAP collaborated in 2012 to develop planning scenarios for Denali National Park and Preserve (Winfree et al. 2014). The planning scenarios are qualitative descriptions developed from quantitative future climate projections. This report uses those scenarios as a base and updates the future climate projections with the temperature and snow data described in the previous section.

Historical Climate Trends

Temperature In the area within the boundaries of Denali National Park and Preserve, average annual temperature increased at statistically significant rates of $1.7 \pm 0.5^{\circ}\text{C}$ ($3.1 \pm 0.9^{\circ}\text{F.}$) per century (mean $\pm$ standard error) and $1.6 \pm 0.5^{\circ}\text{C}$ ($2.9 \pm 0.9^{\circ}\text{F.}$) per century, respectively, in the period 1901-2009 (Figure 1, Tables 1, 2) (Gonzalez et al. 2018). Temperature increase since the 1970s has accelerated because a cold phase of the Pacific Decadal Oscillation lowered temperatures in Alaska from the late 1940s to the mid-1970s (Bieniek et al. 2014).

Temperature increases were highest in the south-central part of the park (Figure 2). The McKinley Park weather station, however, did not show a statistically significant change from 1923 to 2018 (National Oceanic and Atmospheric Administration, <https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak5778>). Still, the spatial patterns of temperature change are consistent with previously published analyses of weather station measurements (Bieniek et al. 2014), U.S. 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).

Seasonally, temperatures from 1901 to 2009 increased at the highest rate in winter (Table 1) in the park and in spring in the preserve (Table 2). From 1901 to 2009, the period of above-freezing temperatures for the area of the park increased by approximately a week, mainly through an advance of warmth in the spring (Figure 3).

Precipitation For the area within park and preserve boundaries, annual, seasonal, and monthly precipitation showed no statistically significant trends in the time periods starting in 1901 or 1950. (Tables 3, 4, Figure 4) (Gonzalez et al. 2018). Precipitation tended to decrease across

most of the park and increase slightly across the preserve (Figure 5). The McKinley Park weather station showed a statistically significant increase in precipitation from 1923 to 2018 (National Oceanic and Atmospheric Administration, <https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak5778>). Nevertheless, previously published analyses also found a precipitation decrease in the region of the park (Harris et al. 2014, McAfee et al. 2014).

Decreases were greatest in winter and spring. From 1901 to 2009, winter precipitation decreased and peak summer precipitation advanced by approximately a week (Figure 6).

The fraction of precipitation falling as snow has decreased in the lower 48 states since the 1920s (Kunkel et al. 2009). The trend has not been determined for Alaska, however, although higher temperatures generally reduce the fraction of precipitation falling as snow (Bintanja 2018, Legates and Bogart 2009).

Extreme precipitation events are increasing. For Alaska as a whole, the amount of precipitation in 5-year 2-day events (two days with more precipitation than any other two-day-period in five years) increased from 1958 to 2016, attributable in part to anthropogenic climate change (Easterling et al. 2017).

Future Climate Projections

Temperature Under the highest emissions scenario (RCP8.5), average annual temperature for the area of the park could increase $6.4 \pm 1.4^{\circ}\text{C}$ ($11.5 \pm 2.5^{\circ}\text{F.}$) by 2100, compared to the 1971-2000 baseline (Figure 7, Table 5) (Gonzalez et al. 2018, IPCC 2013). Emissions reductions (RCP2.6) could limit the annual average temperature increase to $2.4 \pm 1^{\circ}\text{C}$ ($4.3 \pm 1.8^{\circ}\text{F.}$) by 2100. For the four emissions scenarios, the ensembles of GCMs produce a cloud of potential futures (Figure 7).

Seasonally, GCMs project the highest temperature increases in winter (December to February). The projections are nearly the same for the area of the preserve (Table 6). Projected temperature changes increase from southeast to northwest (Figure 8).

Under the reduced emissions scenario, the period of above-freezing temperatures for the area

of the park could increase by approximately a week, mainly through an advance of warmth in the spring (Figure 3). Under the highest emissions scenario, the period of above-freezing temperatures could increase by approximately six weeks, starting earlier in the spring and ending later in autumn.

Precipitation For the area within the boundaries of the park, all GCMs project increased precipitation (Figure 7). For the highest emissions scenario, total annual precipitation for the area of the park could increase $32 \pm 11\%$ from 2000 to 2100 (Table 7). For the reduced emissions scenario, the increase would be $12 \pm 7\%$. The absolute values of these changes are 200 ± 70 mm (8 ± 3 in.) for the highest emissions scenario and 76 ± 44 mm (3 ± 2 in.) for the reduced emissions scenario. The projections for the area of the preserve are nearly the same (Table 8).

Projected precipitation changes increase from south to north (Figure 9). Under the reduced emissions scenario, precipitation could increase throughout the year. Under the highest emissions scenario, the increases would be relatively high from July to December (Figure 9).

Projected higher temperatures would reduce the fraction of precipitation falling as snow (Littell et al. 2018). For the area within park boundaries, the fraction of days from October to March in which precipitation would fall as snow (rather than rain) would decrease from $92 \pm 8\%$ (1970-1999) to $77 \pm 13\%$ under the low emissions scenario (RCP4.5, 2070-2090) or $67 \pm 15\%$ under the highest emissions scenario (RCP8.5, 2070-2090) (Table 9) (Littell et al. 2018). For the area within preserve boundaries, the fraction of snow days is slightly lower (Table 9).

The relative projected decrease in snow days from 1999 to 2090 for the area of the park is $28 \pm 11\%$ for the highest emissions scenario and $17 \pm 8\%$ for the low emissions scenario, showing the benefit of emissions reductions (Table 9) (Littell et al. 2018). The projected decreases for the area of the preserve are greater. The projected decrease in snow days varies by elevation and position relative to the crest of the Alaska Range. Models project greater snow decreases at lower elevations and on the seaward side of the Alaska Range (Figure 10). In addition, the near northward slopes of the Alaska Range are areas of high projected decreases in snow.

Scenarios for Planning

The NPS and SNAP collaboration in 2012 developed planning scenarios for Denali National Park and Preserve as a function of projected time of temperatures above freezing and projected total precipitation (Winfrey et al. 2014) (Figure 11).

The updated climate projections and recently published snow projections and the spatial analyses for the area of the park, summarized in this report, provide data to update the quantitative ranges of the planning scenarios (Figure 12). The qualitative descriptions for the scenarios remain unchanged.

The high end of the projected time of temperatures above freezing increases by approximately a week over the previous estimate. The range of total precipitation slight narrows from the previous estimate. For each, the uncertainty inherent in projecting the future indicates the need to portray the future projections as approximate in order to avoid giving a false sense of precision. Consequently, the values are given in terms of weeks for the time above freezing and fractions for the precipitation projections.

Snow is a climate phenomenon that integrates the two axes selected in the original scenario planning exercise. So, the revised scenarios provide the range of snow projections in the extreme quadrants (upper right, lower left). Finally, the wide spatial variation of all of the climate variables indicates the need for planners to consider the maps in this report so that planning accounts for potential differences across the landscape.

Figure 1. Average annual temperature, 1901-2009, for the area within the boundaries of Denali National Park and Preserve. The trends, calculated by linear regression, corrected for temporal autocorrelation, show statistically significant long-term increases.

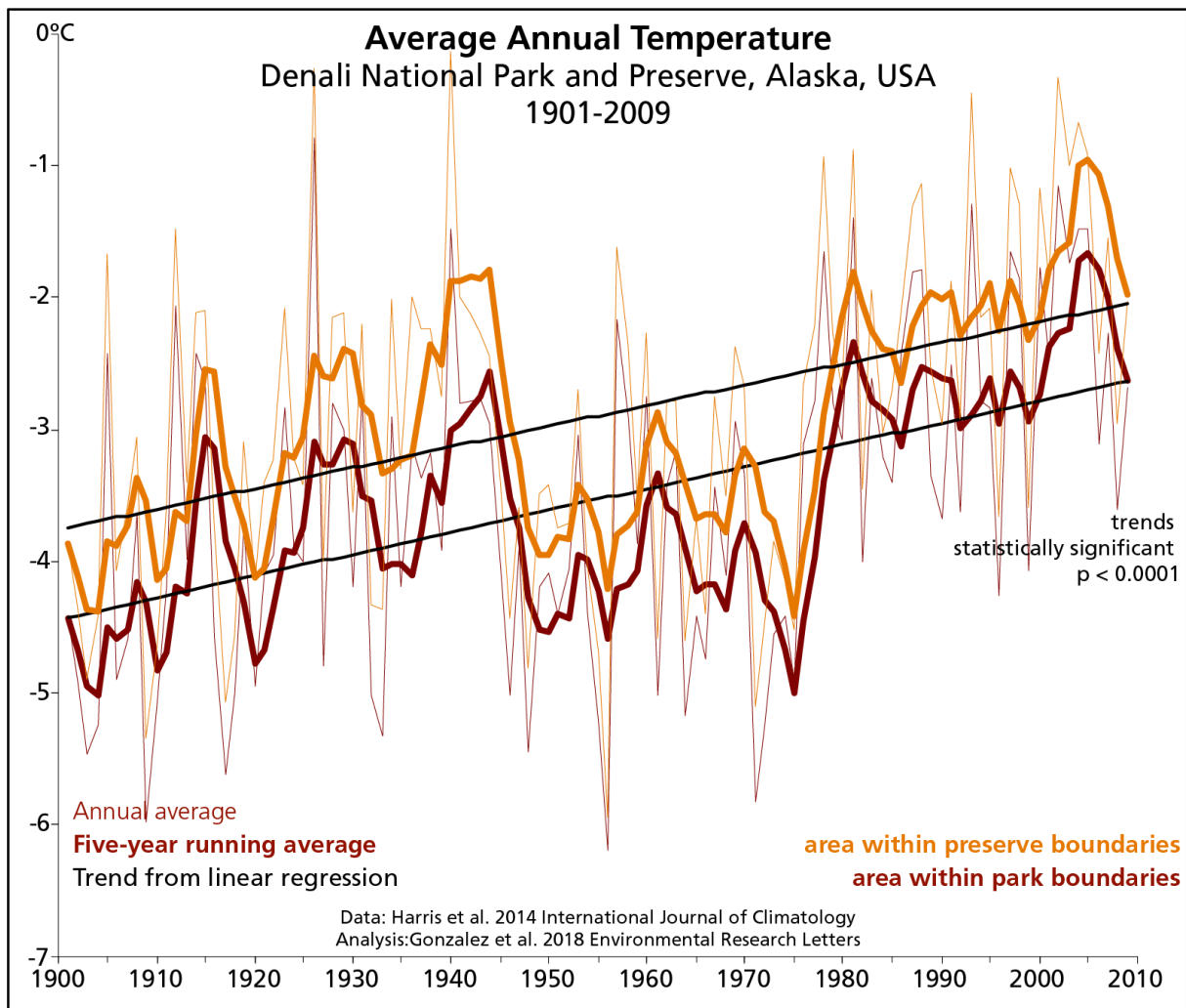


Figure 2. Trend in annual average temperature, 1901-2009, at 800 m spatial resolution, from linear regression, corrected for temporal autocorrelation.

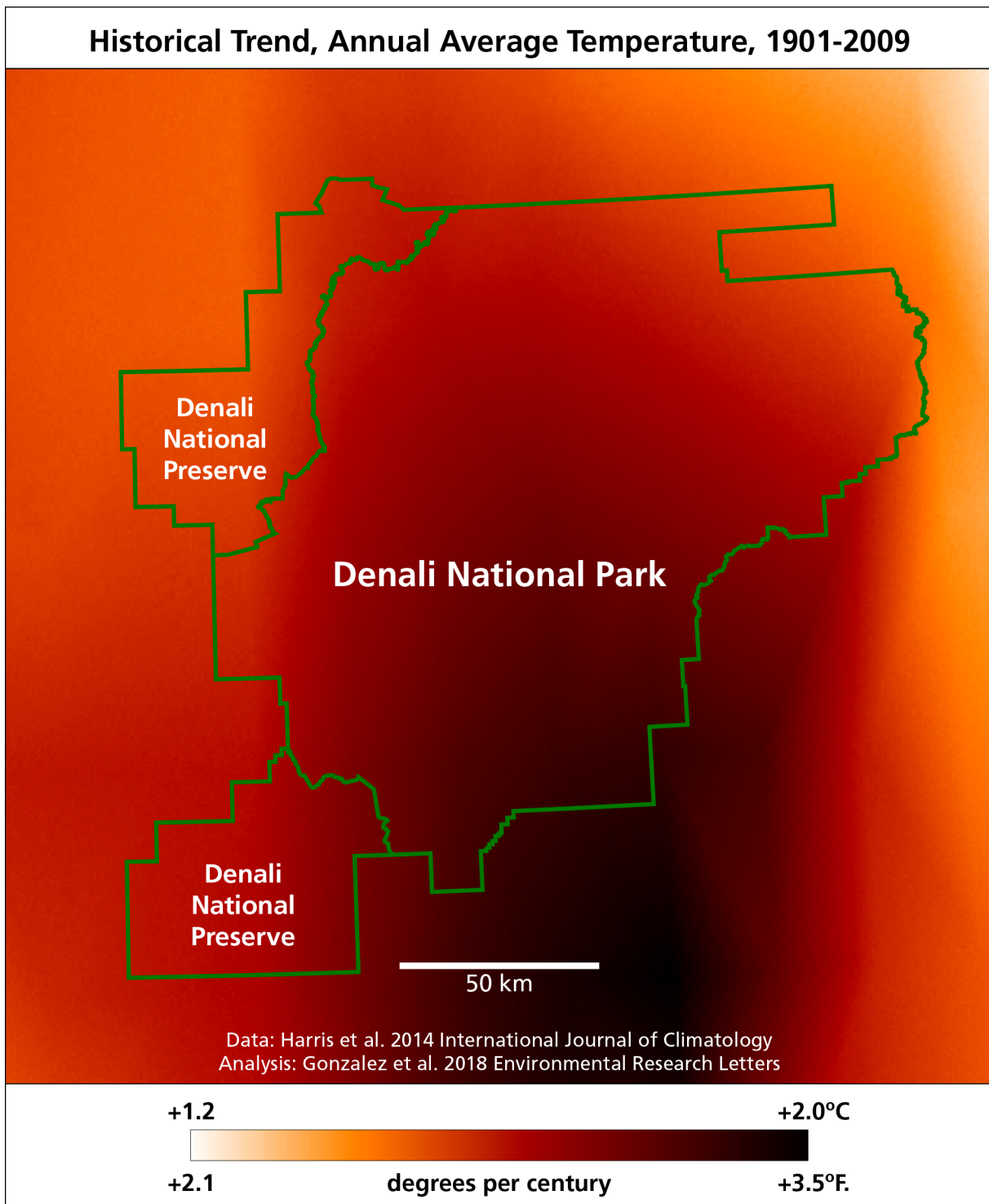


Figure 3. Monthly average temperatures, historical and projected, for the area within the boundaries of Denali National Park. From 1901 to 2009, temperature increased throughout the year. Under the reduced emissions scenario, the period of above-freezing temperatures could increase by approximately a week, mainly through an advance of warmth in the spring. Under the highest emissions scenario, the period of above-freezing temperatures could increase by approximately six weeks, starting earlier in the spring and ending later in autumn.

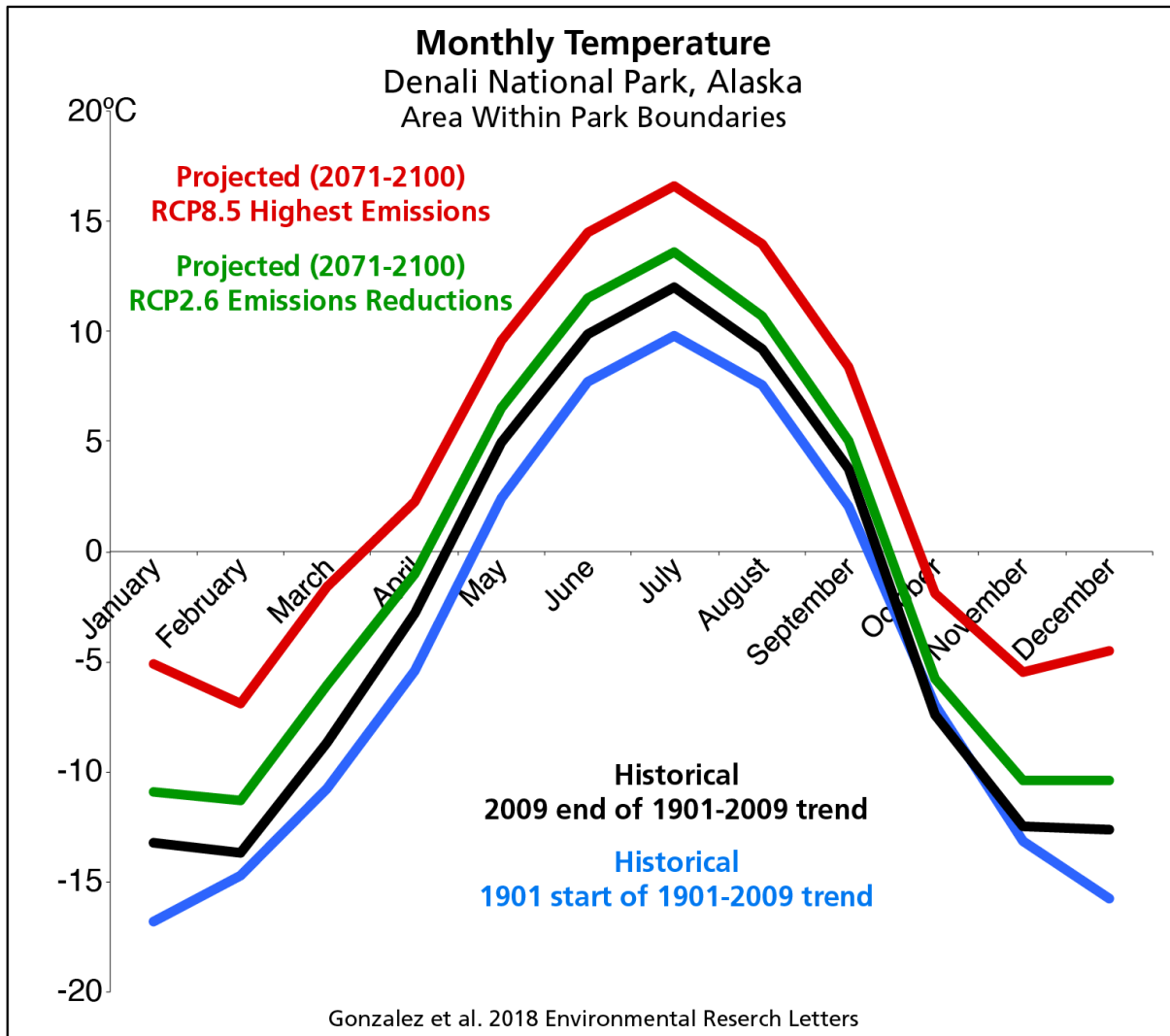


Figure 4. Total annual precipitation, 1901-2009, for the area within the boundaries of Denali National Park and Preserve. The trends, calculated by linear regression corrected for temporal autocorrelation, show no statistically significant long-term change.

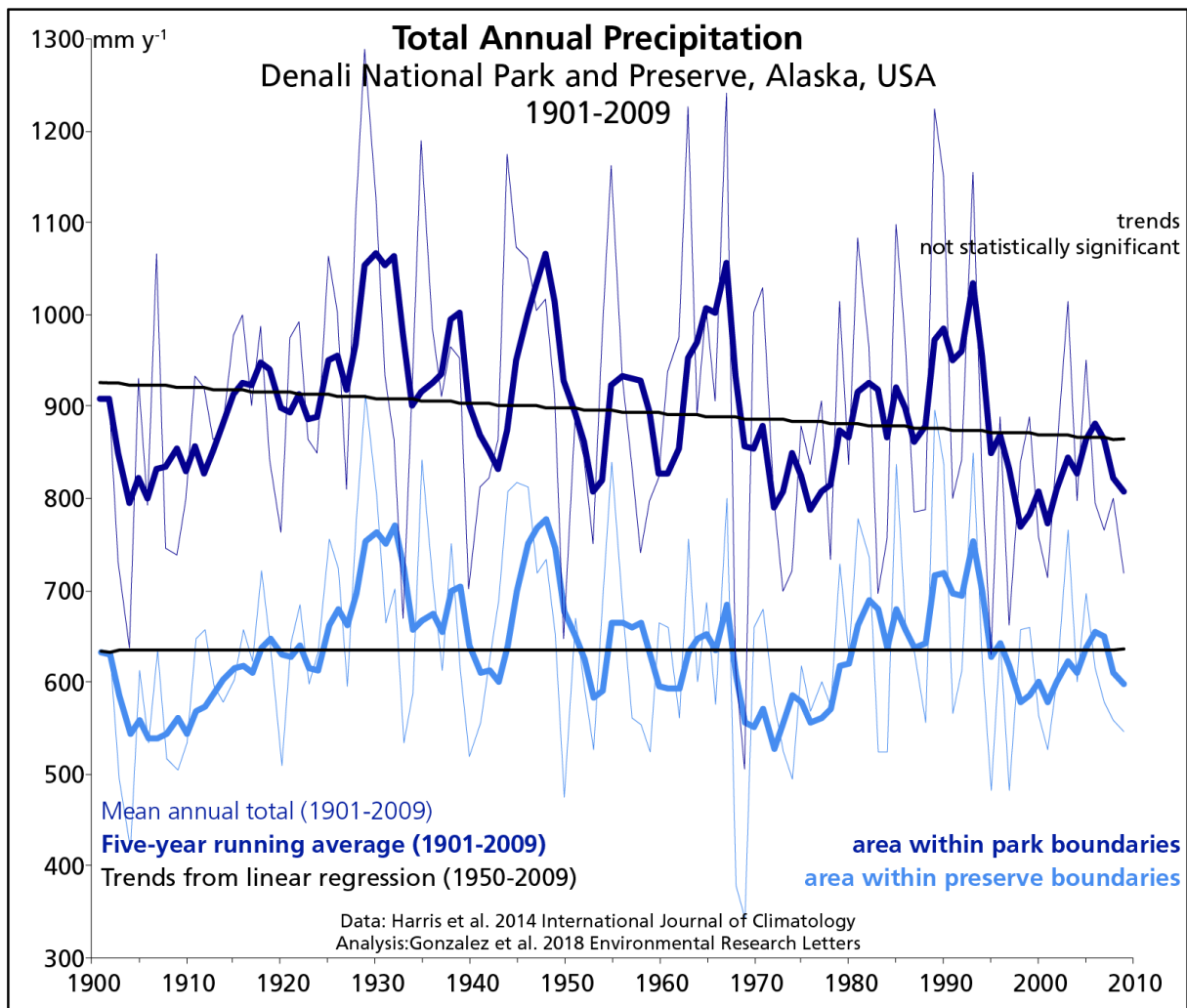


Figure 5. Trend in total annual precipitation, 1901-2009, at 800 m spatial resolution, from linear regression, corrected for temporal autocorrelation.

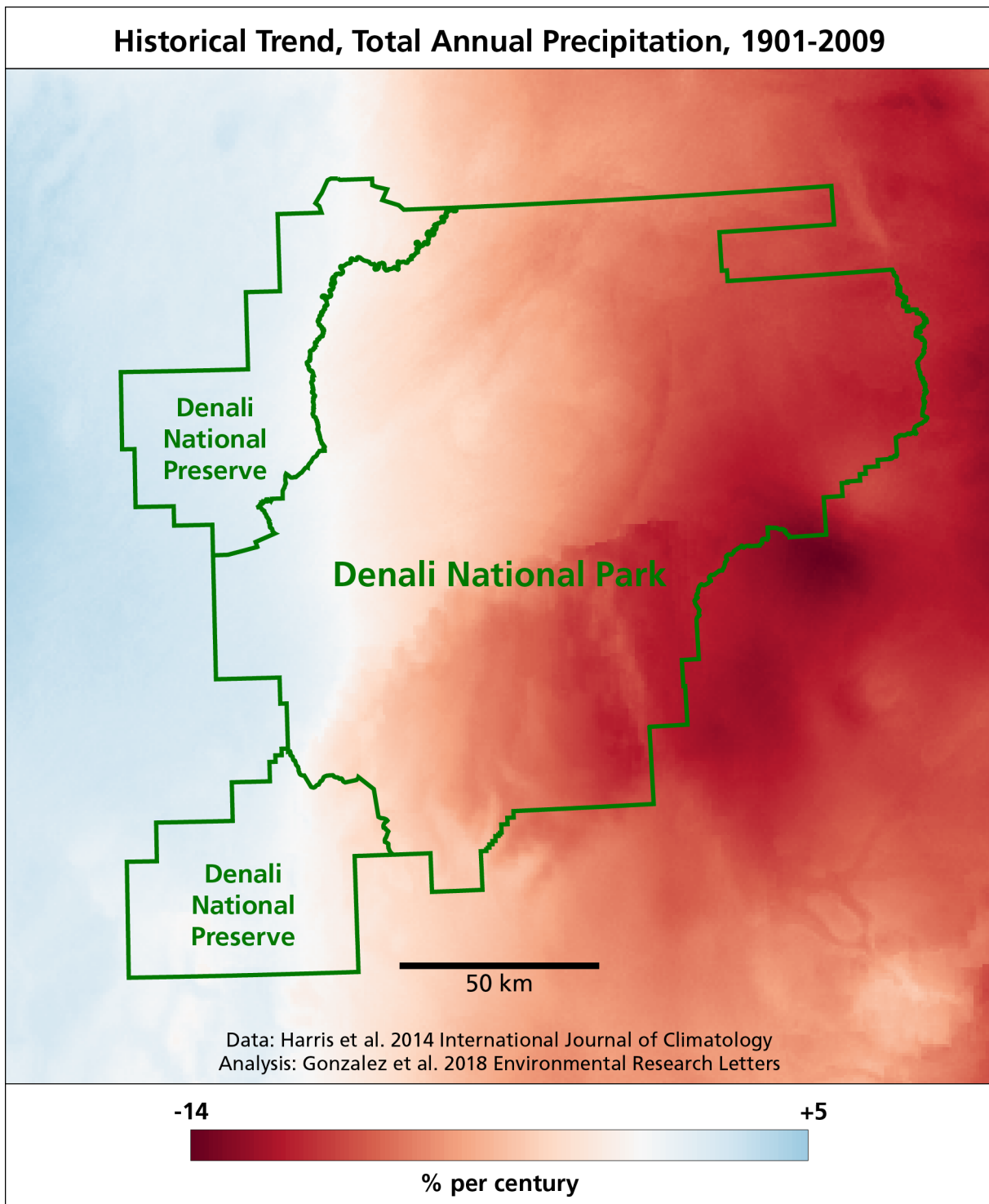


Figure 6. Historical and projected total monthly precipitation for the area within the boundaries of Denali National Park. From 1901 to 2009, winter precipitation decreased and peak summer precipitation advanced by approximately a week. Under the reduced emissions scenario, precipitation could increase throughout the year. Under the highest emissions scenario, the increases would be particularly high from July to December.

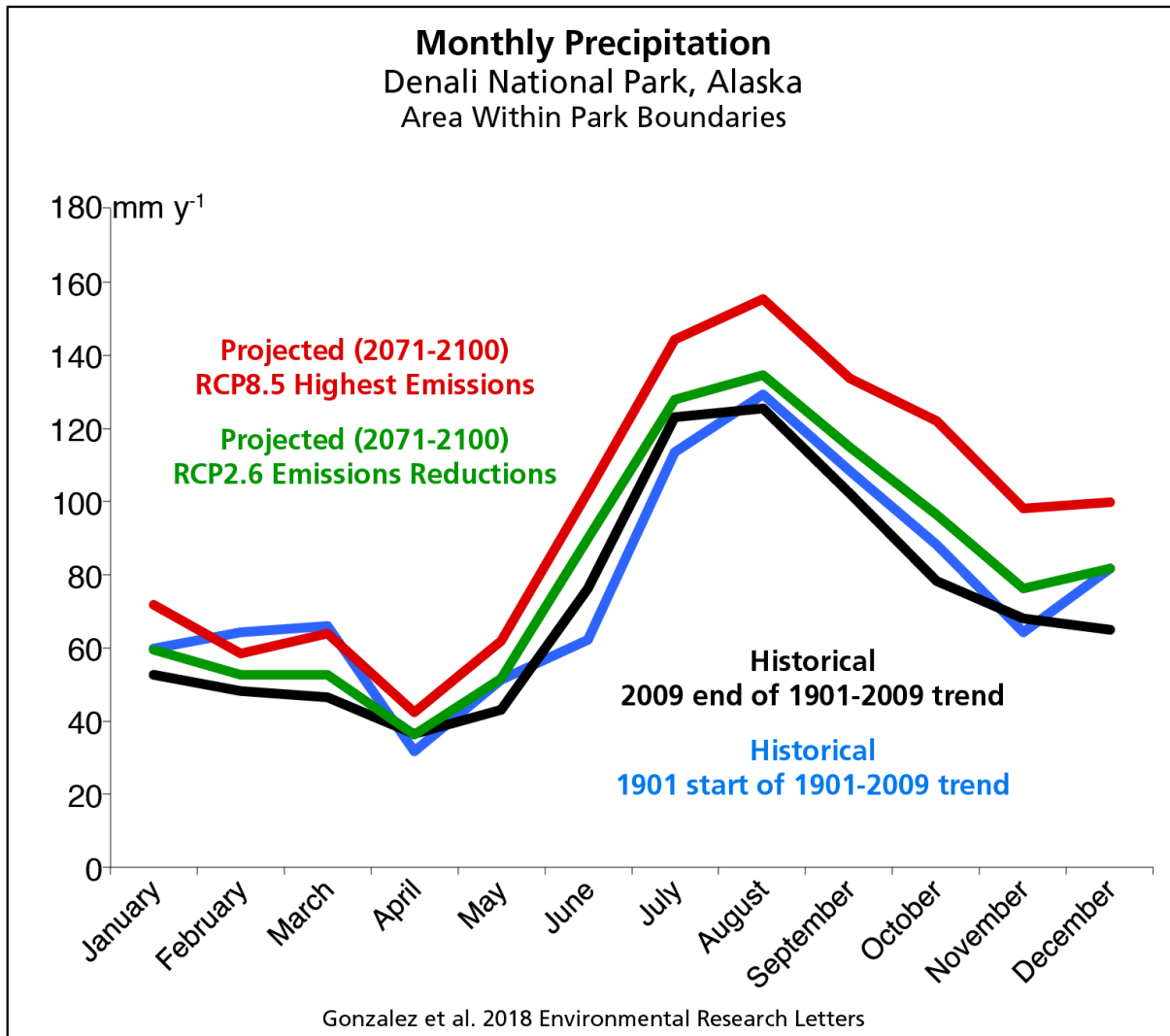
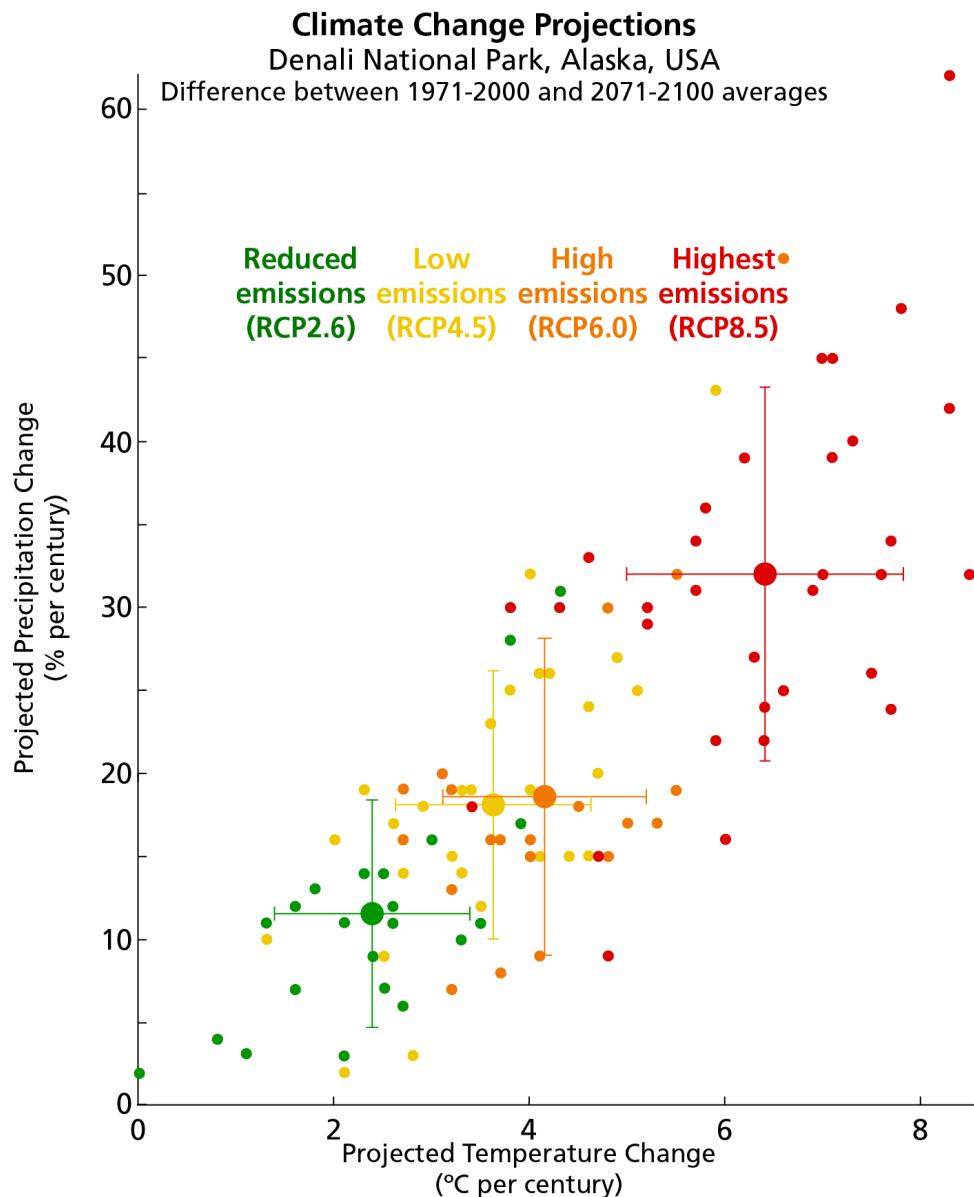


Figure 7. Projections of future climate for the area within the boundaries of Denali National Park, relative to 1971-2000 average values. Each small dot is the output of a single general circulation model. The large color dots are the average values for the four IPCC emissions scenarios. The crosses are the standard deviations of the average values. All models project increased temperature and precipitation.



Data: Intergovernmental Panel on Climate Change 2013
Analysis: Gonzalez et al. 2018 Environmental Research Letters

Figure 8. Projected change in annual average temperature, 2000-2100, at 800 m spatial resolution, for the highest emissions scenario (RCP8.5) for the average of 33 general circulation models.

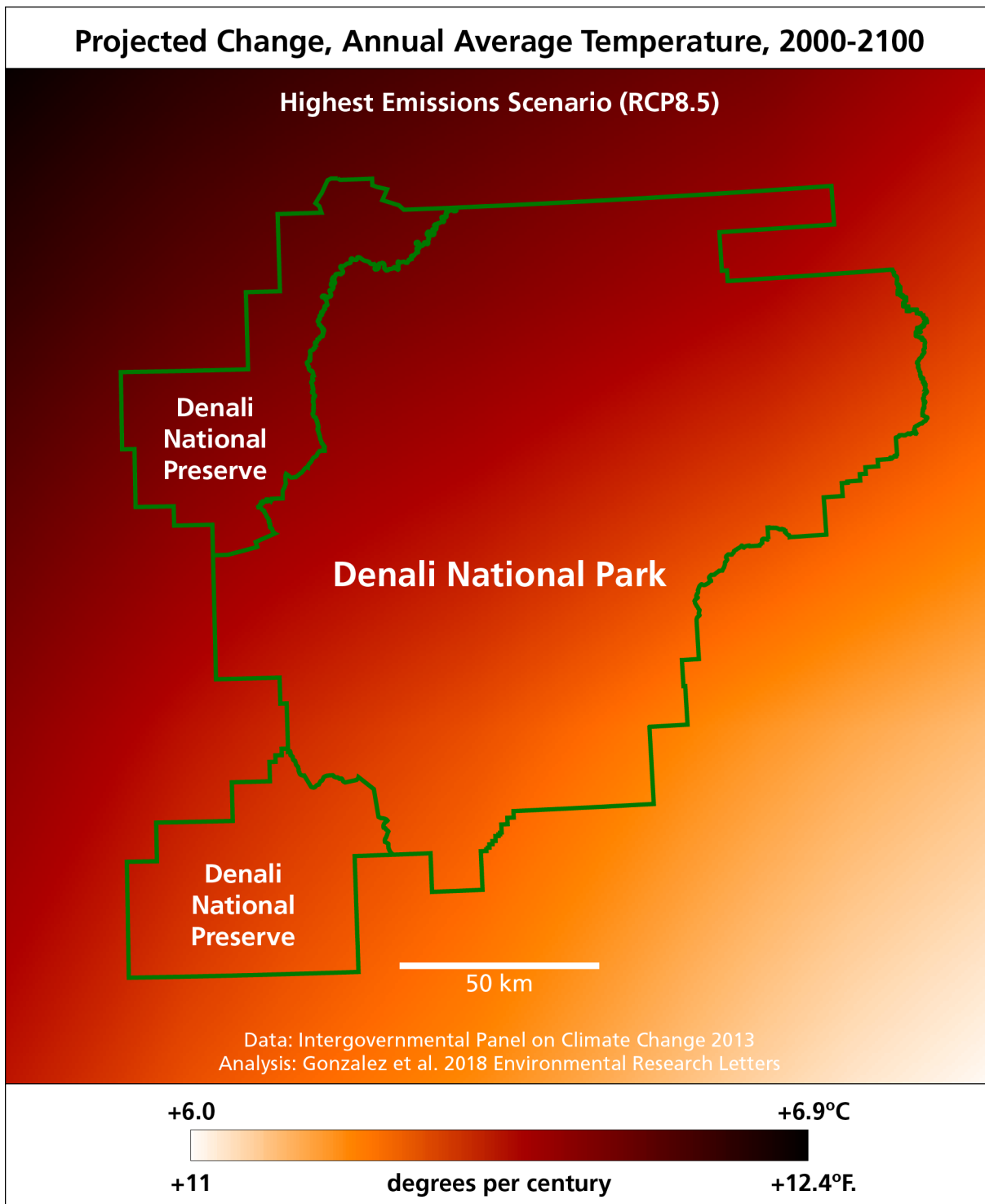


Figure 9. Projected change in total annual precipitation, 2000-2100, at 800 m spatial resolution, for the highest emissions scenario (RCP8.5) for the average of 33 general circulation models.

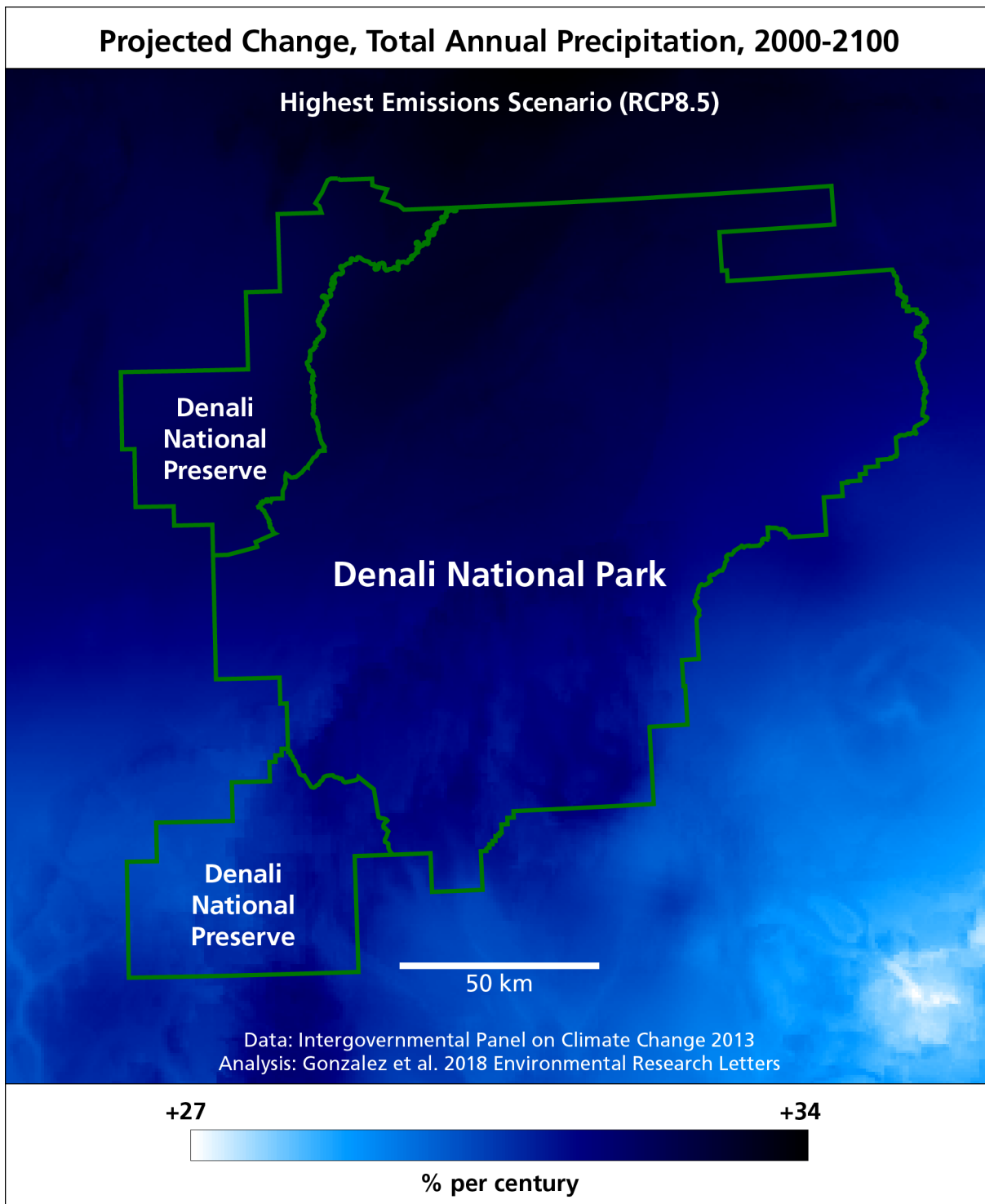


Figure 10. Projected change in the fraction of days from October to March in which precipitation would fall as snow (Littell et al. 2018).

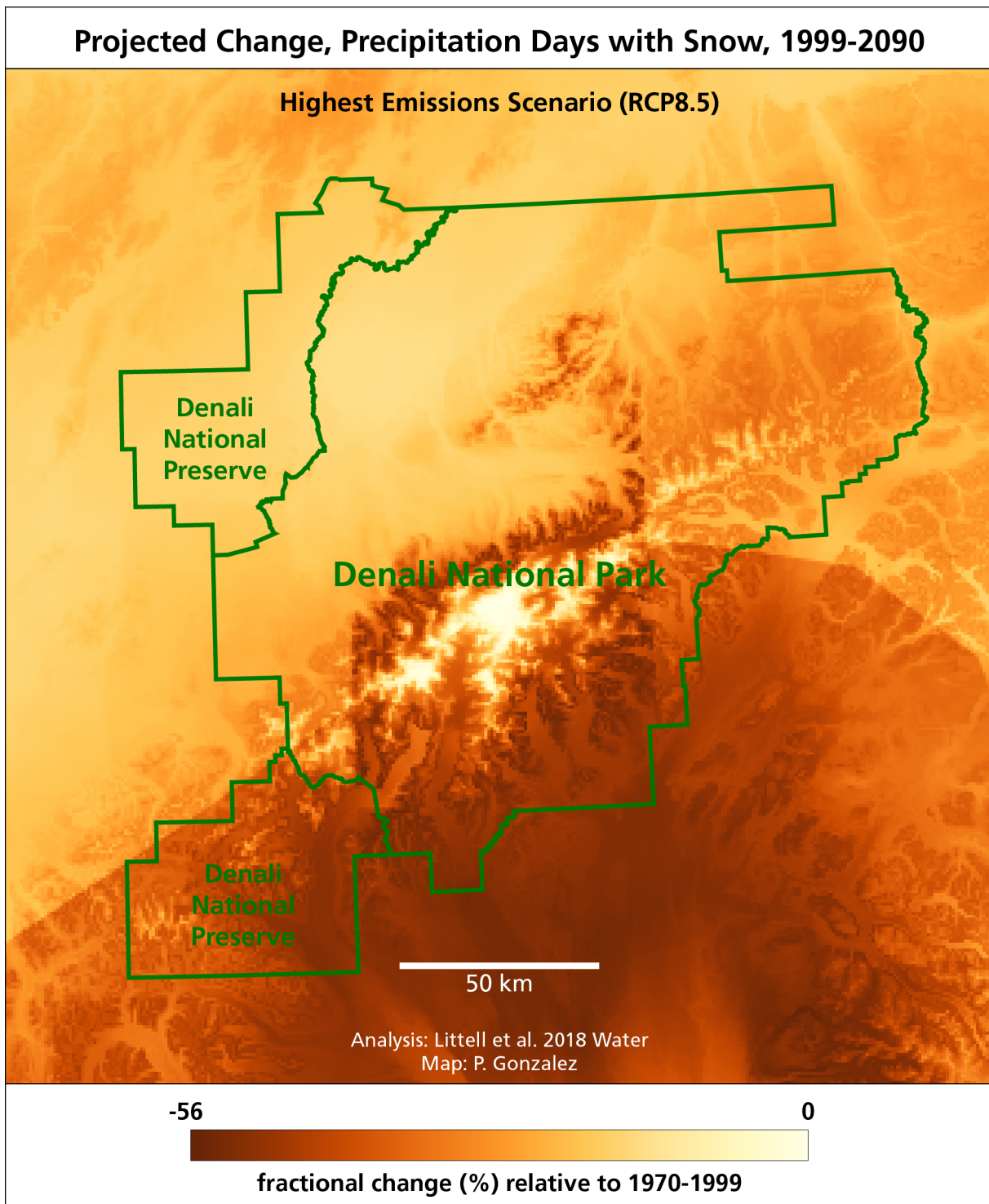


Figure 11. NPS planning scenarios from Winfree et al. (2014).

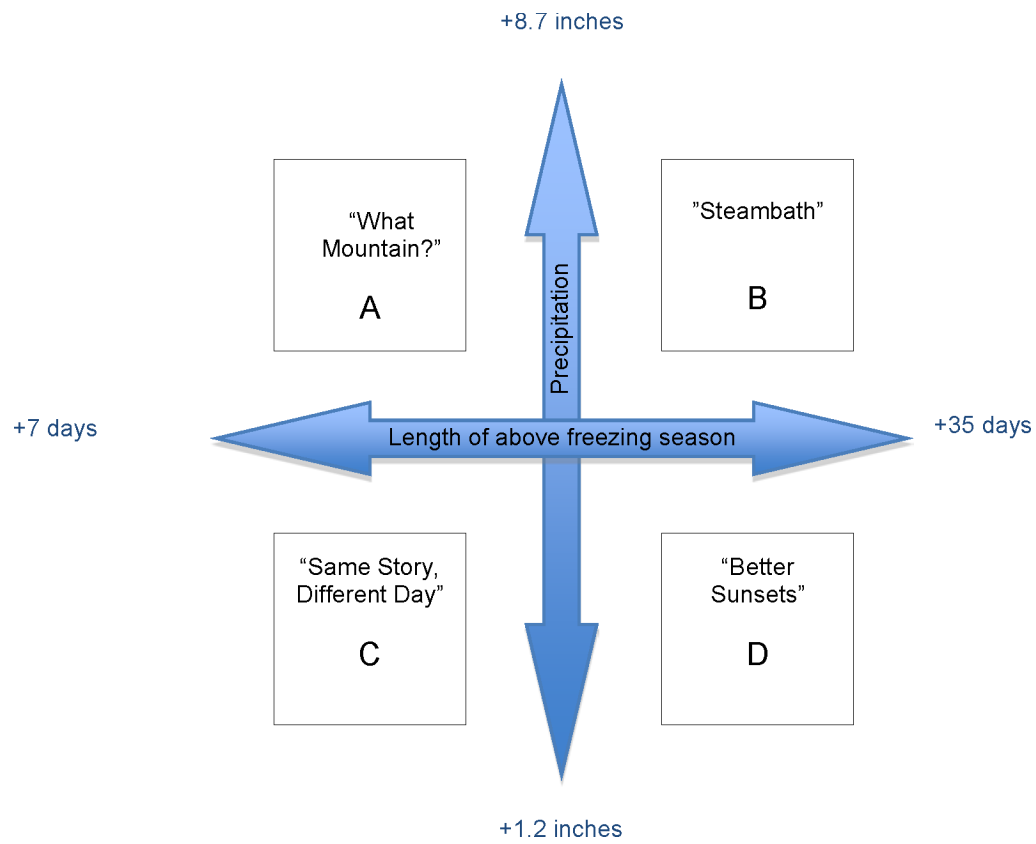


Figure 12. Updated planning scenarios, keeping the original qualitative scenarios and updating the quantitative ranges.

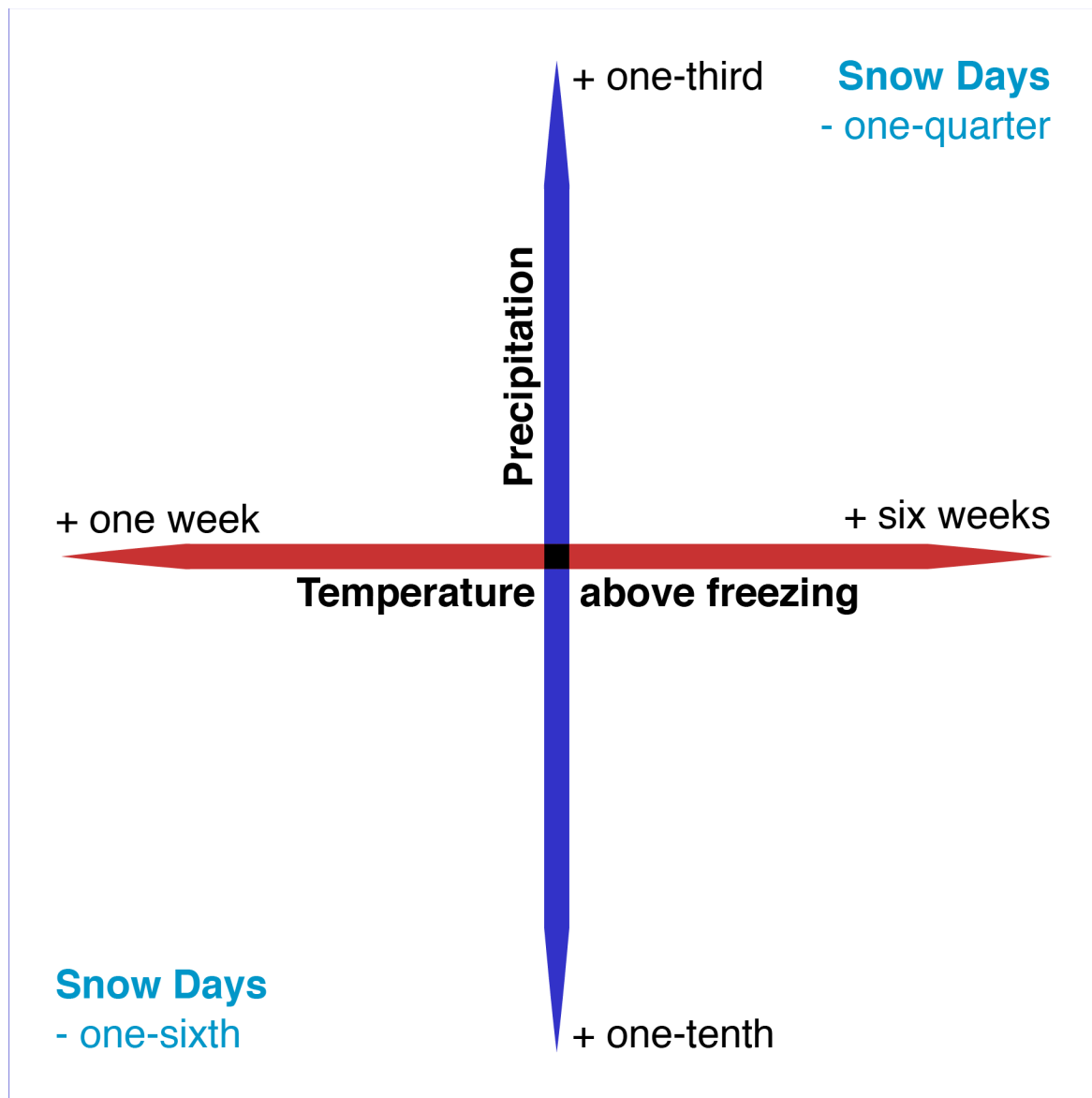


Table 1. Historical average temperatures and temperature trends of the area within the boundaries of Denali National Park. SD = standard deviation, SE = standard error, sig. = statistical significance, * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

	1971-2000		1901-2009			1950-2009		
	mean	SD	trend	SE	sig.	trend	SE	sig.
	°C		°C century ⁻¹			°C century ⁻¹		
Annual	-3.1	1.2	1.7	0.5	***	3.9	1.1	**
						1.1	0.4	*
December-February	-14	2.9	2.3	1	*	7.3	2.6	**
March-May	-2.5	1.9	2.1	0.6	**	4.3	1.5	**
June-August	10	0.7	1.7	0.4	***	2.6	0.7	**
September-November	-5.9	1.6	0.5	0.5		1.6	1.1	
January	-14.1	5.4	3.1	1.6		6.3	4.6	
February	-14.6	4.6	0.9	1.4		6.8	3.2	*
March	-8.7	3.2	1.8	0.9		4.5	2.4	
April	-3.3	2.5	2.3	0.9	*	4.6	2	*
May	4.4	1.4	2.2	0.6	***	3.8	1.5	*
June	9.4	1	1.9	0.5	***	3.1	1	**
July	11.7	0.9	1.9	0.4	***	3	0.8	***
August	9	1.2	1.4	0.4	**	1.6	1	
September	3.3	1.4	1.5	0.4	***	2.2	0.9	*
October	-8	2.1	-0.4	0.7		1.4	1.8	
November	-13	3.5	0.6	1		1.4	2.5	
December	-13.1	3.8	2.7	1.2	*	8.3	3.1	**

Table 2. Historical average temperatures and temperature trends of the area within the boundaries of Denali National Preserve. SD = standard deviation, SE = standard error, sig. = statistical significance, * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$.

	1971-2000		1901-2009			1950-2009		
	mean	SD	trend	SE	sig.	trend	SE	sig.
	°C		°C century ⁻¹			°C century ⁻¹		
Annual	-2.5	1.2	1.6	0.5	**	4.3	1.1	***
December-February	-15.6	2.9	2	1.1		7.5	2.7	**
March-May	-1.6	2	2	0.7	**	4.7	1.6	**
June-August	12.1	0.7	1.6	0.4	***	3.2	0.8	*
September-November	-5	1.5	0.7	0.5		1.9	1.1	
January	-15.8	5.4	2.7	1.7		6.3	4.5	
February	-16.1	4.8	0.8	1.4		7.5	3.3	*
March	-8.8	3.3	1.7	1		4.4	2.4	
April	-2.1	2.8	2.3	1	*	5.3	2.2	*
May	6.2	1.4	2	0.6	**	4.3	1.6	*
June	11.5	1	1.7	0.5	**	3.9	1.1	**
July	13.9	0.9	1.8	0.4	***	3.7	0.9	***
August	11	1.2	1.3	0.4	**	2	1	*
September	5	1.4	1.4	0.4	**	2.5	0.9	**
October	-6.7	2.1	-0.3	0.7		1.9	1.7	
November	-13.4	3.5	0.9	1		1.4	2.6	
December	-14.8	4	2.6	1.3	*	8.3	3.2	**

Table 3. Historical average precipitation totals and precipitation trends of the area within the boundaries of Denali National Park. No trends were statistically significant.

SD = standard deviation, SE = standard error.

	1971-2000		1901-2009		1950-2009	
	mean	SD	trend	SE	trend	SE
	mm y ⁻¹		% century ⁻¹		% century ⁻¹	
Annual	872	155	-6	6	-11	15
December-February	174	64	-20	12	-59	32
March-May	126	51	-17	13	-10	35
June-August	315	85	6	8	9	22
September-November	259	91	-5	11	-5	26
January	53	34	-13	19	-27	42
February	47	34	-29	17	-77	42
March	49	37	-35	19	-40	50
April	32	23	14	21	3	56
May	45	19	-18	15	12	36
June	78	29	20	14	-3	38
July	115	49	8	12	37	33
August	122	41	-3	13	-12	26
September	104	57	-6	13	-6	31
October	85	40	-12	15	9	30
November	69	50	6	20	-21	52
December	72	37	-23	17	-65	45

Table 4. Historical average precipitation totals and precipitation trends of the area within the boundaries of Denali National Preserve. No trends were statistically significant.

SD = standard deviation, SE = standard error.

	1971-2000		1901-2009		1950-2009	
	mean	SD	trend	SE	trend	SE
	mm y ⁻¹		% century ⁻¹		% century ⁻¹	
Annual	635	113	0	7	5	14
December-February	121	48	-4	12	-4	31
March-May	93	35	-8	11	10	28
June-August	235	62	3	8	-1	22
September-November	187	67	5	12	16	26
January	37	23	12	20	4	43
February	35	26	-18	19	-22	45
March	31	24	-17	20	-20	52
April	25	19	27	21	3	52
May	37	16	-23	16	43	29
June	58	25	21	15	-2	42
July	82	36	-1	11	25	32
August	94	31	-3	14	-23	29
September	78	43	6	15	6	33
October	59	25	-5	15	36	32
November	50	36	16	19	8	48
December	49	28	-9	17	3	43

Table 5. Projected temperature increases (°C), 2000 to 2100, for the area within Denali National Park boundaries, from the average of all available general circulation model projections used for IPCC (2013). RCP = representative concentration pathway, SD = standard deviation.

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	2.4	1	3.6	1	4.1	1	6.4	1.4
December-February	3.1	1.4	4.9	1.5	5.4	1.6	8.4	2.2
March-May	2.4	1.2	3.2	1.7	3.8	1.3	6	2
June-August	1.9	1	2.7	1.1	3.5	1.2	5	1.5
September-November	2.2	0.9	3.7	1.7	3.9	0.8	6.2	2
January	3.2	1.7	5	1.9	5.8	2	9	2.5
February	3.3	1.5	4.5	1.9	5.3	1.7	7.7	2.5
March	2.6	1.4	3.8	1.6	4.5	1.4	7.1	2.1
April	2.3	1.2	3.1	1.8	3.4	1.3	5.6	2.1
May	2.1	1.3	2.7	2	3.5	1.5	5.2	2.2
June	2.1	1.3	2.8	1.7	3.8	1.5	5.1	2.2
July	1.9	1.1	2.7	1.2	3.4	1.3	4.9	1.6
August	1.7	0.8	2.7	1	3.3	1	5	1.6
September	1.7	0.8	2.8	1.3	3.2	0.8	5.1	1.8
October	2.2	1.1	3.6	1.9	3.9	1	6.1	2.2
November	2.6	1.2	4.5	2	4.6	1.1	7.5	2.2
December	2.7	2.2	5.2	1.8	5.1	1.8	8.6	2.4

Table 6. Projected temperature increases (°C), 2000 to 2100, for the area within Denali National Preserve boundaries, from the average of all available general circulation model projections used for IPCC (2013). RCP = representative concentration pathway, SD = standard deviation.

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	2.4	1	3.6	1	4.2	1	6.5	1.4
December-February	3.1	1.5	5	1.5	5.5	1.6	8.6	2.2
March-May	2.4	1.2	3.2	1.6	3.9	1.3	6.1	1.9
June-August	1.9	1	2.7	1	3.5	1.2	5	1.5
September-November	2.2	0.9	3.7	1.7	3.9	0.8	6.2	1.9
January	3.3	1.7	5.1	1.9	5.8	2	9.1	2.5
February	3.3	1.5	4.5	1.9	5.4	1.7	7.8	2.5
March	2.7	1.4	3.8	1.6	4.6	1.4	7.2	2.1
April	2.4	1.3	3.1	1.8	3.5	1.4	5.7	2.1
May	2.1	1.3	2.7	2	3.5	1.5	5.2	2.2
June	2.1	1.2	2.8	1.7	3.8	1.5	5.1	2.1
July	1.9	1	2.7	1.1	3.3	1.2	4.9	1.5
August	1.7	0.8	2.7	1	3.3	1	5	1.5
September	1.7	0.8	2.8	1.3	3.2	0.8	5.1	1.8
October	2.2	1.1	3.6	1.9	3.9	1	6	2.1
November	2.6	1.2	4.6	2	4.6	1.1	7.6	2.2
December	2.7	2.3	5.3	1.9	5.2	1.8	8.7	2.4

Table 7. Projected precipitation changes (%), 2000 to 2100, for the area within Denali National Park boundaries, from the average of all available general circulation model projections used for IPCC (2013). RCP = representative concentration pathway, SD = standard deviation.

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	12	7	18	8	19	9	32	11
December-February	13	10	20	12	20	13	33	17
March-May	11	10	17	11	18	10	33	16
June-August	11	9	16	9	17	12	27	13
September-November	11	9	20	14	20	11	37	20
January	12	14	20	15	22	17	35	19
February	12	14	17	16	16	16	24	22
March	7	13	16	13	15	13	30	20
April	13	14	16	12	18	14	32	19
May	14	17	18	20	22	20	37	28
June	15	14	18	18	22	21	31	26
July	11	9	15	9	16	9	25	15
August	10	11	17	12	15	17	27	15
September	10	10	17	12	16	10	28	17
October	13	14	23	22	24	15	43	31
November	10	13	20	19	20	17	42	24
December	13	15	22	16	21	18	38	26

Table 8. Projected precipitation changes (%), 2000 to 2100, for the area within Denali National Preserve boundaries, from the average of all available general circulation model projections used for IPCC (2013). RCP = representative concentration pathway, SD = standard deviation.

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	12	7	18	8	18	10	32	11
December-February	13	9	20	12	20	13	34	17
March-May	12	10	18	11	20	11	35	17
June-August	11	8	16	9	16	11	27	12
September-November	11	9	19	13	19	11	36	18
January	12	13	20	13	22	16	36	18
February	12	12	17	15	17	16	25	21
March	7	13	17	12	16	12	32	21
April	13	14	18	12	18	14	34	20
May	14	16	19	18	23	18	37	27
June	15	12	18	17	22	20	31	23
July	11	9	15	10	15	9	25	13
August	10	11	16	11	14	16	26	14
September	10	10	16	12	16	9	27	16
October	12	14	22	21	24	15	42	28
November	10	14	20	19	19	17	41	24
December	13	16	22	17	21	19	39	27

Table 9. Projected changes in snow for the area within the boundaries Denali National Park and Preserve (Littell et al. 2018). The indicator is the fraction of days from October to March with precipitation falling as snow rather than rain. Historical values are derived from weather stations. Projections are the averages of the outputs five GCMs for two emissions scenarios. The relative change is the decrease from 1970-1999 to 2070-2090, as a fraction of the 1970-1999 value. RCP = representative concentration pathway, SD = standard deviation.

	Fraction of precipitation days with snow (%)						Projected change (%)			
	1970-1999			2070-2090			1999-2090			
	RCP4.5		RCP8.5		RCP4.5		RCP8.5		RCP8.5	
	average	SD	average	SD	average	SD	average	SD	average	SD
Park	92	8	77	13	67	15	-17	8	-28	11
Preserve	89	9	72	15	63	18	-20	9	-30	13

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