

Anthropogenic Climate Change in Minute Man National Historical Park, Massachusetts

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Historical Climate Change Trends

- **Historical temperature** Greenhouse gas emissions from human activities have caused increases in temperatures and altered precipitation patterns globally (IPCC 2013), including across the United States (USGCRP 2017). In the area within the boundaries of Minute Man National Historical Park, average annual temperature increased at a statistically significant rate of $1 \pm 0.2^{\circ}\text{C}$ per century in the period 1895-2016 (Figure 1) (Daly et al. 2008, Gonzalez et al. in review). The trend in annual average temperature was not significant, however, in the period 1950-2010, although March and August average temperatures in that period increased at statistically significant rates (Table 1).

Seasonally, temperatures increased at the highest rates in winter and summer in the period 1895–2010 (Table 1). In the park, temperature increases were highest around North Bridge and the Wayside and lowest around Fiske Hill (Figure 2). For the northeastern U.S. as a whole, the frost-free season lengthened 10 days from 1901 to 2012 (Walsh et al. 2014).

Concerning the historical time periods in the tables and figures, time periods starting in 1895 provide the longest available weather station-based trends for the area of the park, but the configuration of the U.S. weather station network stabilized only in the 1950s (Vose et al. 2014), so the period starting in 1950 gives a trend based on a more consistent set of weather stations. Analyses of monthly, seasonal, and annual climate were originally run for the periods 1895-2010 (Table 1) and 1950-2010 (Table 1), the data available at the time of the original research. Analyses of annual trends were later run for the period 1895–2016 when that data became available. In addition, climatologists use 1971–2000 (Table 1) as the standard baseline for comparing future projections with historical observations.

- **Historical precipitation** In the area within park boundaries, total annual precipitation increased at statistically significant rates of $18 \pm 4\%$ per century (1895-2016) and $27 \pm 12\%$ per century (1950-2010) (Table 2, Figure 3) (Daly et al. 2008, Gonzalez et al. in review). Since 1895, the greatest increases have occurred in spring and autumn. The rates of annual precipitation increase show low spatial variation across the park (Figure 4).

- **Snow** The increase in winter temperatures would normally reduce winter snowfall, but analyses of long-term snowfall trends in the northeastern U.S. have been limited by changing measurement methods over time and years with missing measurements. A quality assessment of U.S. weather station snowfall records identified the most reliable stations, including the station at Boston Logan International Airport (Kunkel et al. 2009), but the trend in total winter snowfall in the period 1931–2007 was not statistically significant. An analysis of 18 weather stations in Maine, Massachusetts, New Hampshire, and Rhode Island found a decrease of maximum winter snow depth from 1961 to 2015, but the trend was not statistically significant (Kunkel et al. 2016). For the Northern Hemisphere as a whole, snow cover extent in March and April decreased at the statistically significant rate of $8 \pm 3\%$ per century from 1922 to 2012 (Vaughan et al. 2013), attributable in large part to anthropogenic (human-caused) climate change (Rupp et al. 2013).
- **Extreme precipitation** For the northeastern U.S. as a whole, the amount of precipitation in 20-year storms (a day with more precipitation than any other day in 20 years) increased in all four seasons from 1948 to 2015 (Easterling et al. 2017). In addition, the number of five-year storms (a two-day period with more precipitation than any other two-day period in five years) increased 74% from 1901 to 2016. These trends are attributable in part to anthropogenic climate change (Easterling et al. 2017).
- **Hurricanes** The maximum intensity of during the course of individual North Atlantic hurricanes has shown a statistically significant increase from 1982 to 2009 (Kossin et al. 2013), but the number of North Atlantic hurricanes and the frequency of the strongest hurricanes (Categories 4 and 5) did not change significantly from 1970 to 2014 (Klotzbach and Landsea 2015). The surface tracking speed of North Atlantic hurricanes over land showed a statistically significant 20% decrease from 1949 to 2016, suggesting that slower hurricanes contributed to the increased precipitation in the eastern U.S. (Kossin 2018). While anthropogenic climate change contributes to increased hurricane intensity, the relative contributions of anthropogenic climate change and natural variability in causing any hurricane trend remain unresolved due to changing historical methods of tracking hurricanes, incomplete understanding of physical mechanisms, and natural variability of tropical cyclone activity (IPCC 2013, USGCRP 2017).
- **Tornadoes** Although tornadoes are much more common in the midwestern U.S. than the northeast US (Agee et al. 2016), central Massachusetts recorded the highest number of tornadoes in the northeast US in the period 1950-1986, with one or two per year (Leathers

1993). The tornado that passed right by the Wayside on August 22, 2016, damaging the grounds, but not the house, indicates that the park is vulnerable to tornadoes. Analyses of historical records of U.S. tornadoes from 1954 to 2013 indicate that the total number of tornadoes for year has shown no statistically significant trend (Brooks et al. 2014). The numbers of days with over 30 tornadoes, however, has increased (Brooks et al. 2014, Elsner et al. 2015) and the number of tornadoes per tornado outbreak has increased (Moore 2017, Tippet and Cohen 2016). Changes in methods for recording tornadoes prevent attribution of the causes of tornado trends, so they cannot be definitively attributed to climate change (Brooks et al. 2014).

Historical Impact Attributed in Part to Anthropogenic Climate Change

- **Bird range shifts** Analyses of Audubon Christmas Bird Count data across the U.S., including the count circle in and around Concord, Massachusetts, detected a northward shift of winter ranges of a set of 254 bird species at an average rate of 0.5 ± 0.3 km per year from 1975 to 2004, attributable in part to anthropogenic climate change (La Sorte and Thompson 2007). Further analyses found northward shifts in winter distributions of six raptor species across the US from 1975 to 2011 (Paprocki et al. 2014), including the American Kestrel (*Falco sparverius*), which has decreased substantially in the Concord count, and the Red-tailed Hawk (*Buteo jamaicensis*), which has increased substantially in the Concord count. The National Park Service Northeast Temperate Inventory and Monitoring Network has been monitoring birds in the park since 2006, starting a time series that in the future will make possible an analysis of any continued bird range shifts.

Historical Change Consistent with, but not Formally Attributed to Climate Change

- **Earlier plant flowering** At Walden Pond, just 2 km south of the park, comparison of observations recorded by Henry David Thoreau in the 1850s with field observations in the early 2000s showed that the flowering of 43 plant species has advanced on average by a week (Miller-Rushing and Primack 2008). These shifts in phenology are highly correlated to the 2.4°C temperature increase over that time at Blue Hill Meteorological Observatory, Milton, Massachusetts, so they are consistent with climate change, although the research did not analyze the relative contributions of climate and non-climate factors. The flowering of Highbush blueberry (*Vaccinium corymbosum*) and yellow wood sorrel (*Oxalis europaea*) advanced 21 and 32 days, respectively, more than most others (Miller-Rushing and Primack

2008). They are both listed (NPS 2018) as found in the park. For the area in the park and a 30 km wide area around the park, indices of spring warmth related to leafing and blooming (Ault et al. 2015) advanced up to 5% earlier in the period 1982–2012, in the earliest 5% of dates in the period 1901–2012 (Monahan et al. 2016). That research did not analyze the relative contributions of climate and non-climate factors.

Projected Climate Change Trends

- **Projected temperature** Without reductions of greenhouse gas emissions from power plants, cars, and other human sources by 40 to 70%, the set of general circulation models (GCMs) in IPCC (2013) (up to 33 GCMs) project additional heating of the area within park boundaries of $5.1 \pm 1.1^{\circ}\text{C}$ (9.2°F.) by 2100 under the highest emissions scenario (RCP8.5), but $1.8 \pm 0.8^{\circ}\text{C}$ (3.2°F.) under a scenario of emissions reductions (RCP2.6) (Tables 3, 4, Figures 5, 6) (IPCC 2013, Gonzalez et al. in review). GCMs project the highest temperature increases in winter.
- **Projected precipitation** With continued greenhouse gas emissions, the set of GCMs in IPCC (2013) (up to 33 GCMs) project future increases in total annual precipitation in the park $16 \pm 7\%$ per century by 2100 under the highest emissions scenario (RCP8.5), but $7 \pm 6\%$ under a scenario of emissions reductions (RCP2.6) (Tables 5, 6, Figures 5, 7) (IPCC 2013, Gonzalez et al. in review). From 1895 to 2010, precipitation had shifted from a relatively even distribution to an annual cycle with pronounced peaks in March and November, a trend that GCMs project to continue (Figure 7).
- **Projected snow** Almost all GCMs project increases in total precipitation for the park (Figure 5), but temperature increases would reduce the fraction of winter precipitation falling as snow and increase the fraction falling as rain. In eastern Massachusetts, the fraction of precipitation falling as snow in February could decrease from $\sim 70\%$ (1981–2000) to $\sim 30\%$ (2081–2100) under the low emissions scenario (RCP4.5) and to $\sim 10\%$ under the highest emissions scenario (RCP8.5) (Ning and Bradley 2015). In eastern Massachusetts, the number of days with snowfall >1 cm could decrease from 2000 to 2100 by two-thirds under a high emissions scenario (Notaro et al. 2014).
- **Extreme temperatures** For eastern Massachusetts, under the highest emissions scenario (RCP8.5), models project an increase of 20 to 30 more days per year with a maximum temperature $>32^{\circ}\text{C}$ (90°F.), an increase of $2\text{--}3^{\circ}\text{C}$ ($4\text{--}6^{\circ}\text{F.}$) in the hottest temperature of the year, and a decrease of 20 to 40 fewer days per year below freezing (0°C , 32°F.), from 1990

to 2050 (Vose et al. 2017).

- **Extreme storms** For the northeastern U.S. as a whole, models project an increase in five-year storms (a two-day period with more precipitation than any other two-day period in five years) to once every two years (low emissions scenario, RCP4.5) or every year (highest emissions scenario, RCP8.5) (Easterling et al. 2017). In addition, models project a 22% increase in the amount of precipitation in 20-year storms (a storm with more precipitation than any other storm in 20 years) under the highest emissions scenario (RCP8.5) (Easterling et al. 2017).
- **Hurricanes** Models project an increase in North Atlantic hurricane intensity and rainfall rates under continued climate change, although projections of the total number of North Atlantic hurricanes under climate change do not agree (IPCC 2013, USGCRP 2017). Under low emissions (RCP4.5), the maximum intensity of during the course of individual North Atlantic hurricanes could increase 4% and rainfall rates increase 15% to 20% by 2100 (Knutson et al. 2015).
- **Tornadoes** With continued climate change, the potential for severe thunderstorms that provide conditions for tornadoes may increase substantially (Diffenbaugh et al. 2013, Gensini and Mote 2015). Under the highest emissions scenario, models project a 40% increase from 2000 to 2100 of the number of days in spring in the eastern U.S. with severe thunderstorms that could produce tornadoes (Diffenbaugh et al. 2013).

Future Projected Vulnerabilities

- **Stream flooding** In eastern Massachusetts, river runoff could increase 5 to 15% in autumn and winter by 2050 (Naz et al. 2016), with the increase in winter due to earlier snow melt under climate change (Demaria et al. 2016, Dudley et al. 2017). In New England, flood frequency had showed a statistically significant increase from 1940 to 2013 (Archfield et al. 2016), although climate is just one factor leading to flooding (Peterson et al. 2013), with urbanization and other land cover changes exerting a strong influence (Yang et al. 2015).
- **Tree range shifts** For one GCM under very high emissions, models project potential losses of paper birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*) and potential increases of southern red oak (*Quercus falcata*) and other southern species by 2100 from the 16 000 km² area that includes the park (Fisichelli et al. 2014). In Massachusetts as a whole, climate change could by 2100 reduce red maple (*Acer rubrum*) and white pine (*Pinus strobus*) trees as hickories (*Carya spp.*) and other broadleaf tree species shift from the south (Iverson et al. 2008). The net effect of these species changes in eastern Massachusetts

would be a shift of potential vegetation at the level of the biome (major vegetation formation), with the temperate mixed forest biome shifting north and the temperate broadleaf forest and temperate shrubland biomes shifting from the south by 2100 (Gonzalez et al. 2010).

- **Invasive plants** Climate change tends to favor invasive alien plants in temperate zones for three main reasons: (1) Invasive alien plants generally exploit atmospheric carbon dioxide more efficiently than native species (Davidson et al. 2011, Liu et al. 2017), (2) Increasing warmth, particularly in winter, and moisture due to climate change increase the suitability of temperate zone ecosystems to plants from sub-tropical and tropical zones (Hellmann et al. 2008, Theoharides and Dukes 2007), and (3) Invasive alien plants often proliferate in disturbed sites (Hellmann et al. 2008, Theoharides and Dukes 2007) and climate change can increase disturbances, particularly biome shifts and wildfire changes (Early et al. 2016). Under low emissions, warmer summers and wetter spring seasons would continue to provide suitable habitat in eastern Massachusetts for the invasive Japanese barberry (*Berberis thunbergii*) (Merow et al. 2017), currently present in the park. Under high emissions, hotter and moister conditions would make eastern Massachusetts more favorable to the invasive plants kudzu (*Pueraria lobata*) and privet (*Ligustrum sinense*) by 2100 (Bradley et al. 2010), currently not present in the park.
- **Insect pests** U.S. Department of Agriculture monitoring has found over 50 forest pests and pathogens in the general region of the park (Fisichelli et al. 2014). The emerald ash borer, an exotic and invasive insect that has killed ash trees (*Fraxinus spp.*) across the eastern US, has been found as close to the park as Waltham, Massachusetts, but not yet in the park <<https://www.mass.gov/guides/emerald-ash-borer-in-massachusetts>>. Moving infected firewood and other material remains the main cause of the spread of the insect. The Concord area is in the currently suitable climate of emerald ash borer and could remain in its potential range under a range of climate change emissions scenarios (Liang and Fei 2014). Because warm and moist conditions favor many termite species, eastern Massachusetts is vulnerable to the expansion from the south of up to four more termite species under a low emission scenario (RCP4.5) by 2050 (Buczowski and Bertelsmeier 2017).
- **Bird range changes** Climate change could continue to shift the ranges of bird species northward across the US (Langham et al. 2015). Modeling of suitable climate for bird species in 2050 indicates that, under the highest emissions scenario (RCP8.5), the park and a 10 km wide area around the park may gain suitable climate for 18 bird species not currently present in winter and 17 species not currently present in summer but lose suitable climate for six

species in winter and 37 species in summer (Wu et al. 2018). Potential colonizers include the black vulture (*Coragyps atratus*) and the Carolina chickadee (*Poecile carolinensis*). Species vulnerable to extirpation include the American bittern (*Botaurus lentiginosus*), listed as endangered under the Massachusetts Endangered Species Act, and the black-capped chickadee (*Poecile atricapillus*). The full list of species changes is at <https://s3.amazonaws.com/audubon-filehost/MinuteManNationalHistoricalPark.pdf>.

- **Surface ozone** The formation of ground-level ozone, a pollutant hazardous to people, increases as temperature increases. Under high emissions (RCP6.0), ground-level ozone concentrations in eastern Massachusetts could increase 10-15 parts per billion (10%) by 2050 (Meehl et al. 2018). Under low emissions (RCP4.5), the number of episodes in the Boston area with ground-level ozone >75 parts per billion could increase four to six days by 2050 (Shen et al. 2016).

Acknowledgements

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Table 1. Historical average temperatures and temperature trends of the area within the boundaries of Minute Man National Historical Park. Historical average and standard deviation (SD) given for a standard historical period (1971-2000). Historical trends, standard errors (SE), and statistical significance (sig.) given for longer periods. Statistical significance gives the probability (P) that a trend is random. The lower the probability, the more significant the trend. * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$. (Data: Daly et al. 2008; Analyses: Gonzalez et al. in review)

	1971-2000		1895-2010			1950-2010		
	mean	SD	trend	SE	sig.	trend	SE	sig.
	°C		°C century ⁻¹			°C century ⁻¹		
Annual	9.4	0.6	1	0.3	***	0.6	0.6	
December-February	-2.2	1.4	1.3	0.5	**	0.7	1.4	
March-May	8.4	0.9	0.8	0.3	**	0.9	0.6	
June-August	20.9	0.8	1.3	0.3	***	0.8	0.5	
September-November	10.6	0.9	0.5	0.3		-0.2	0.6	
January	-3.7	2.5	0.2	0.7		-0.3	2	
February	-2.2	2.2	2.2	0.7	**	0.9	2.2	
March	2.6	1.5	0.9	0.5		1.7	0.8	*
April	8.4	1.2	1.1	0.3	**	0.8	0.9	
May	14.4	1.1	0.5	0.4		0.3	0.8	
June	19.2	1.2	1.2	0.4	**	0.2	0.7	
July	22.2	1.1	1	0.3	**	0.4	0.8	
August	21.3	1	1.7	0.4	***	1.6	0.8	*
September	16.5	0.9	0.4	0.4		1	0.8	
October	10.3	1.4	-0.1	0.4		-1.6	1	
November	5.1	1.6	1.3	0.4	**	-0.1	0.9	
December	-0.8	2.4	1.3	0.5	*	1.7	1.4	

Table 2. Historical average precipitation totals and precipitation trends of the area within the boundaries of Minute Man National Historical Park. Historical average and standard deviation (SD) given for a standard historical period (1971-2000). Historical trends, standard errors (SE), and statistical significance (sig.) given for longer periods. Statistical significance gives the probability (P) that a trend is random. The lower the probability, the more significant the trend.

* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$. (Data: Daly et al. 2008; Analyses: Gonzalez et al. in review)

	1971-2000		1895-2010			1950-2010		
	mean	SD	trend	SE		trend	SE	
	mm y ⁻¹		% century ⁻¹			% century ⁻¹		
Annual	1187	168	19	5	***	27	12	*
December-February	293	87	16	7	*	4	18	
March-May	302	90	24	9	**	42	24	
June-August	278	85	11	8		49	21	*
September-November	313	83	25	9	**	16	18	
January	106	64	15	15		-4	45	
February	84	39	1	10		-9	24	
March	106	47	25	13		52	34	
April	101	50	15	11		24	28	
May	96	44	32	15	*	48	43	
June	91	73	16	15		81	41	
July	97	38	11	13		81	34	*
August	90	48	7	16		-13	48	
September	97	58	5	16		22	35	
October	105	53	43	17	*	67	42	
November	111	50	26	12	*	-34	24	
December	102	54	27	13	*	13	34	

Table 3. Projected temperature increases (°C), 2000 to 2050, for the area within the boundaries of Minute Man National Historical Park, from the average of all available general circulation model projections (up to 33) in IPCC (2013) for the four emissions scenarios (RCPs = representative concentration pathway). The lower the standard deviation (SD), the closer together the model projections within and emissions scenario. (Data: IPCC 2013; Analyses: Gonzalez et al. in review)

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	1.8	0.7	2.3	0.6	2	0.6	2.9	0.7
December-February	2	0.8	2.6	1	2.1	0.7	3.2	1
March-May	1.7	0.8	1.9	1.2	1.9	0.7	2.4	1.2
June-August	1.8	0.7	2.2	0.8	2	0.6	2.8	0.8
September-November	1.9	0.7	2.5	1.3	2	0.5	3.1	1.5
January	2.2	0.8	2.8	1.3	2	0.9	3.4	1.3
February	1.8	1.1	2.3	0.9	2	1	3	0.9
March	1.8	1	2	1.3	1.9	0.9	2.6	1.4
April	1.7	0.9	1.9	1.3	1.8	0.8	2.4	1.3
May	1.6	0.8	1.9	1.2	1.8	0.7	2.4	1.2
June	1.6	0.7	1.9	1	1.8	0.6	2.6	1
July	1.8	0.8	2.2	0.9	2	0.6	2.9	0.9
August	1.8	0.8	2.4	0.7	2.1	0.6	3	0.8
September	1.9	0.7	2.5	1.1	2.2	0.7	3.2	1.3
October	2	0.7	2.4	1.6	1.9	0.6	3.1	1.7
November	1.8	0.7	2.5	1.5	2	0.5	3	1.6
December	1.9	0.9	2.7	1.7	2.2	0.8	3.3	1.7

Table 4. Projected temperature increases (°C), 2000 to 2100, for the area within the boundaries of Minute Man National Historical Park, from the average of all available general circulation model projections (up to 33) in IPCC (2013) for the four emissions scenarios (RCPs = representative concentration pathway). The lower the standard deviation (SD), the closer together the model projections within and emissions scenario. (Data: IPCC 2013; Analyses: Gonzalez et al. in review)

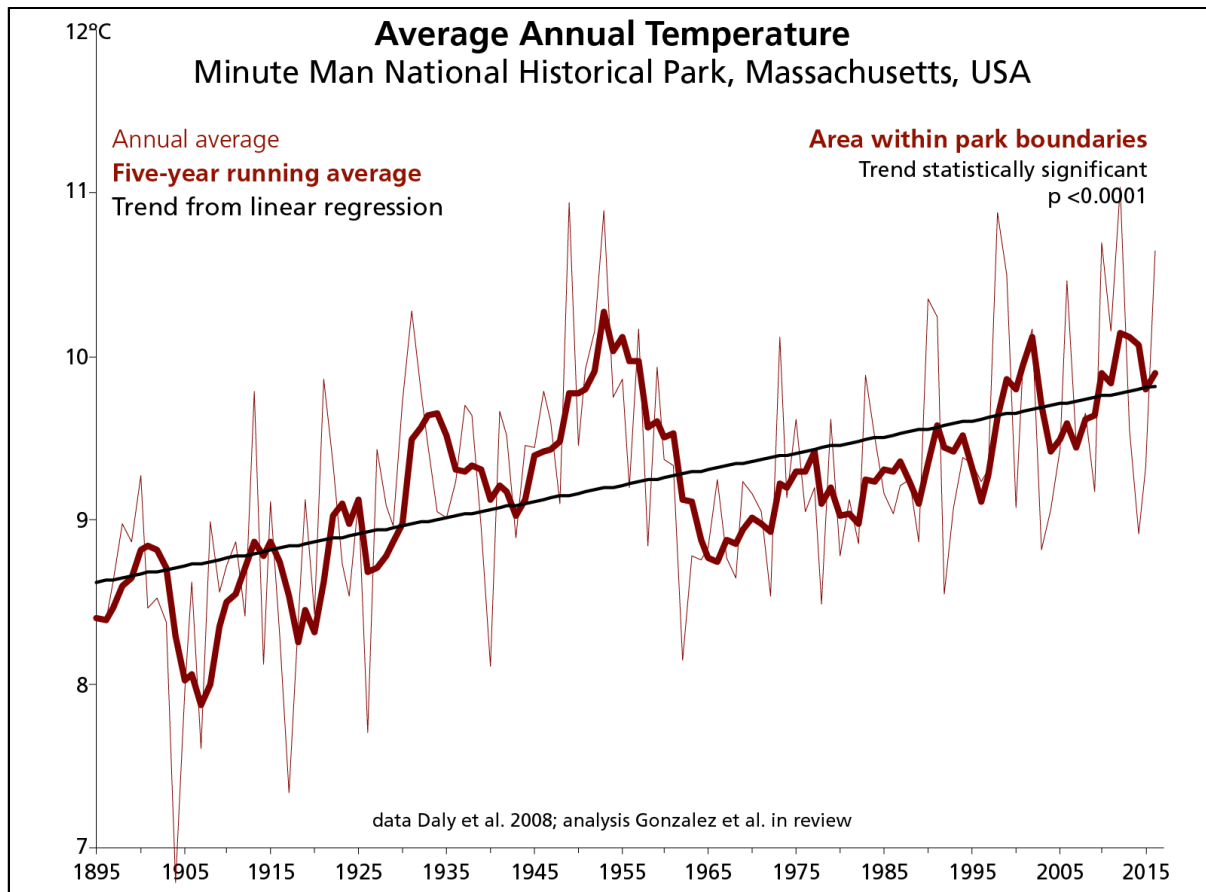
	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	1.8	0.8	2.9	0.8	3.4	0.9	5.1	1.1
December-February	2.1	1	3.3	1.2	3.6	1	5.5	1.4
March-May	1.6	0.9	2.5	1.3	3.1	1.1	4.4	1.4
June-August	1.7	0.9	2.8	1	3.3	1	5.1	1.2
September-November	1.8	0.8	3.1	1.6	3.4	1	5.4	2
January	2.1	1.2	3.5	1.4	3.7	1.1	5.7	1.6
February	1.9	1.2	3	1.1	3.6	1.3	5.2	1.2
March	1.7	1	2.5	1.5	3.1	1.2	4.5	1.6
April	1.6	1	2.6	1.4	3.1	1.2	4.4	1.5
May	1.6	0.9	2.5	1.2	3	1	4.4	1.4
June	1.6	0.9	2.5	1.2	3	1	4.6	1.3
July	1.7	0.9	2.8	1	3.4	1	5.2	1.4
August	1.8	0.9	3	1.1	3.5	1.1	5.6	1.4
September	1.8	0.9	3.2	1.4	3.6	1.1	5.7	1.9
October	1.7	0.8	3.1	1.7	3.3	1.1	5.4	2.1
November	1.8	0.8	3.1	1.8	3.4	0.9	5.1	2.1
December	2.1	1	3.4	1.8	3.7	1.1	5.5	2

Table 5. Projected precipitation changes (%), 2000 to 2050, for the area within the boundaries of Minute Man National Historical Park, from the average of all available general circulation model projections (up to 33) in IPCC (2013) for the four emissions scenarios (RCPs = representative concentration pathway). The lower the standard deviation (SD), the closer together the model projections within and emissions scenario. (Data: IPCC 2013; Analyses: Gonzalez et al. in review)

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	8	6	9	6	8	5	10	6
December-February	11	12	11	8	12	10	15	11
March-May	8	8	8	10	7	6	10	8
June-August	9	11	10	12	7	12	10	13
September-November	4	7	6	8	6	8	5	8
January	17	18	14	15	19	22	22	20
February	7	12	10	14	9	11	10	12
March	8	13	13	15	12	11	16	14
April	6	15	8	13	3	9	7	13
May	9	10	4	12	6	11	7	12
June	12	18	11	21	10	17	11	18
July	6	10	7	12	4	10	6	13
August	10	15	13	21	7	19	14	24
September	2	14	5	18	4	14	5	14
October	4	13	6	16	4	19	0	14
November	6	10	7	9	10	10	10	13
December	11	14	10	11	12	10	15	12

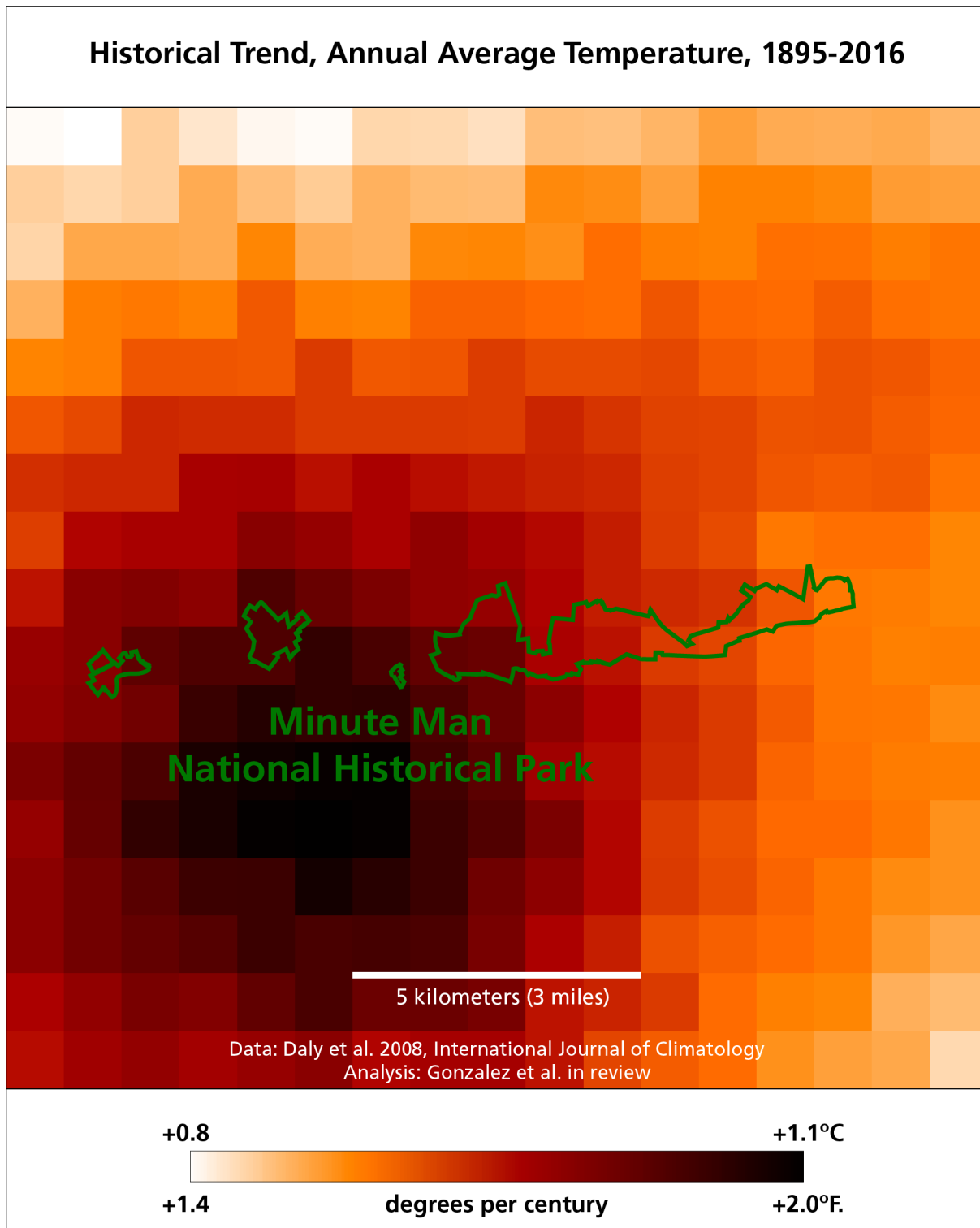
Table 6. Projected precipitation changes (%), 2000 to 2100, for the area within the boundaries of Minute Man National Historical Park, from the average of all available general circulation model projections (up to 33) in IPCC (2013) for the four emissions scenarios (RCPs = representative concentration pathway). The lower the standard deviation (SD), the closer together the model projections within and emissions scenario. (Data: IPCC 2013; Analyses: Gonzalez et al. in review)

	Emissions Scenarios							
	Reductions		Low		High		Highest	
	RCP2.6		RCP4.5		RCP6.0		RCP8.5	
	mean	SD	mean	SD	mean	SD	mean	SD
Annual	7	6	11	6	11	6	16	7
December-February	8	9	16	9	18	10	27	14
March-May	7	9	10	8	11	7	17	9
June-August	8	11	13	14	11	14	14	15
September-November	3	7	5	8	7	8	6	10
January	11	19	20	18	20	18	34	23
February	7	12	16	17	17	11	24	16
March	8	13	14	12	15	12	22	15
April	8	13	10	16	9	13	16	19
May	6	17	6	11	9	13	14	13
June	8	17	14	18	14	23	17	22
July	9	15	9	16	8	16	9	16
August	8	14	17	29	10	15	16	31
September	3	11	5	15	5	13	1	17
October	1	18	1	15	-2	14	3	21
November	5	10	9	13	16	11	14	15
December	9	13	14	10	18	16	24	16

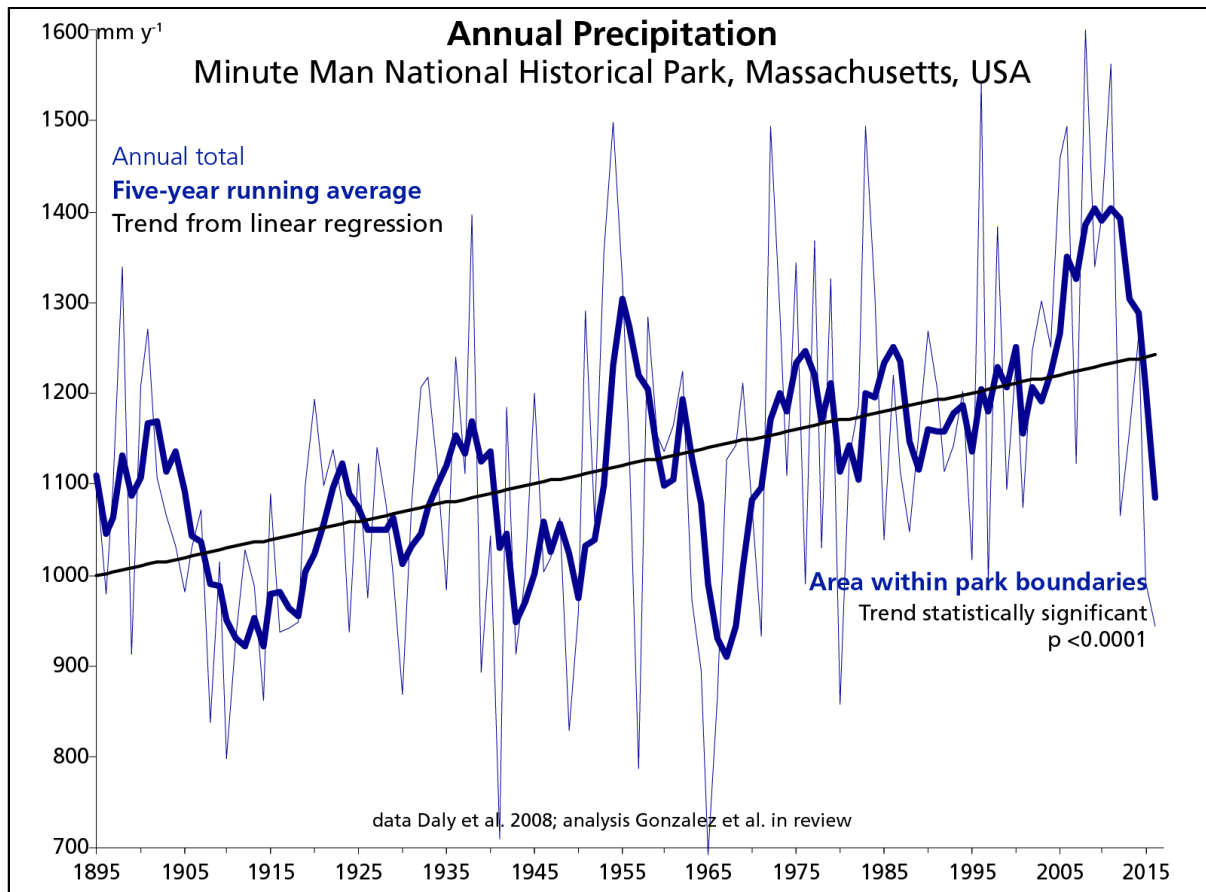
Figure 1.

Main conclusion: Temperature increased at the statistically significant rate of $1 \pm 0.2^{\circ}\text{C}$ ($1.8 \pm 0.4^{\circ}\text{F.}$) per century in the period 1895-2016.

Figure 2.

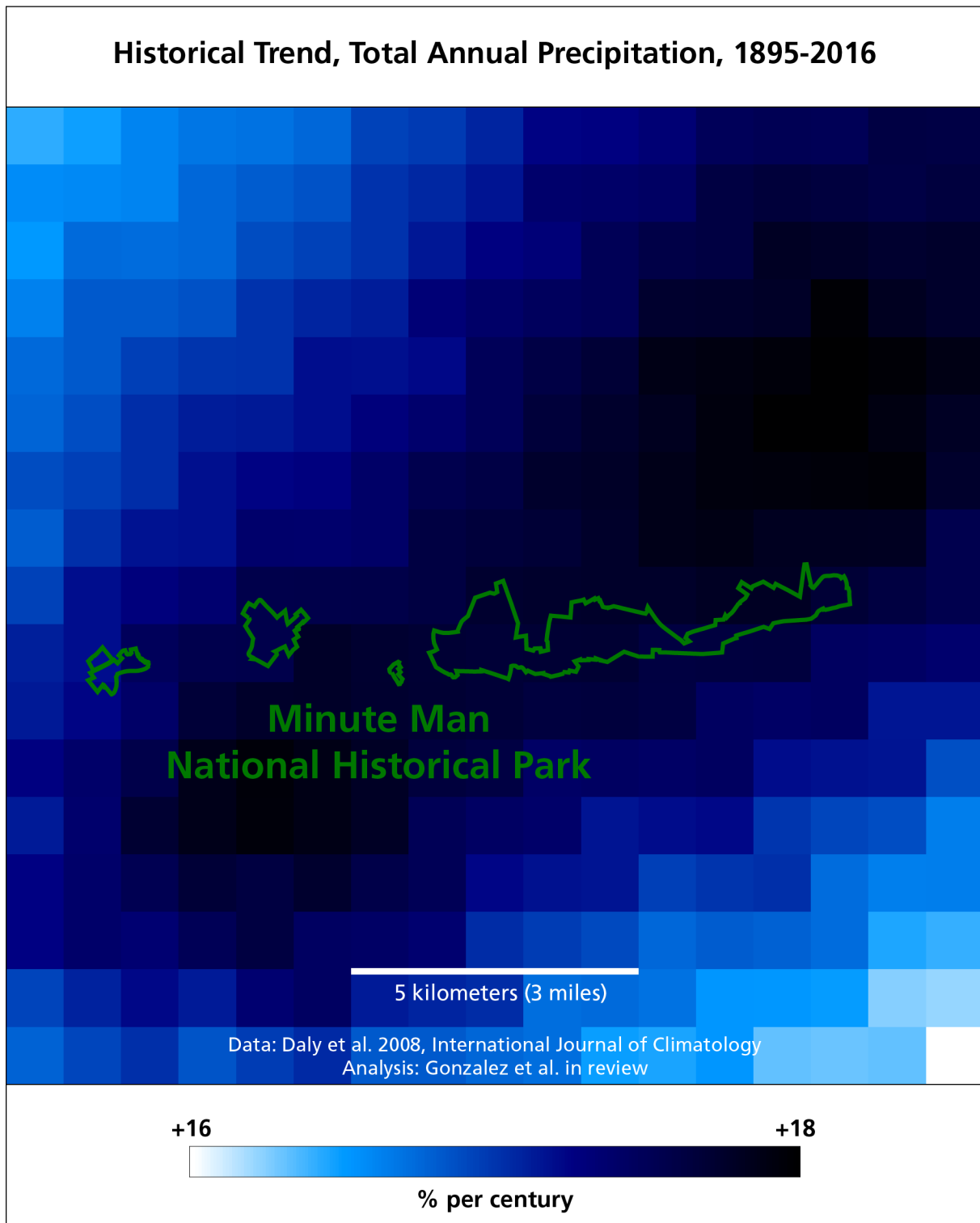


Main conclusion: Temperature increased across the park from 1895 to 2016 with the greatest increases near Concord, Massachusetts.

Figure 3.

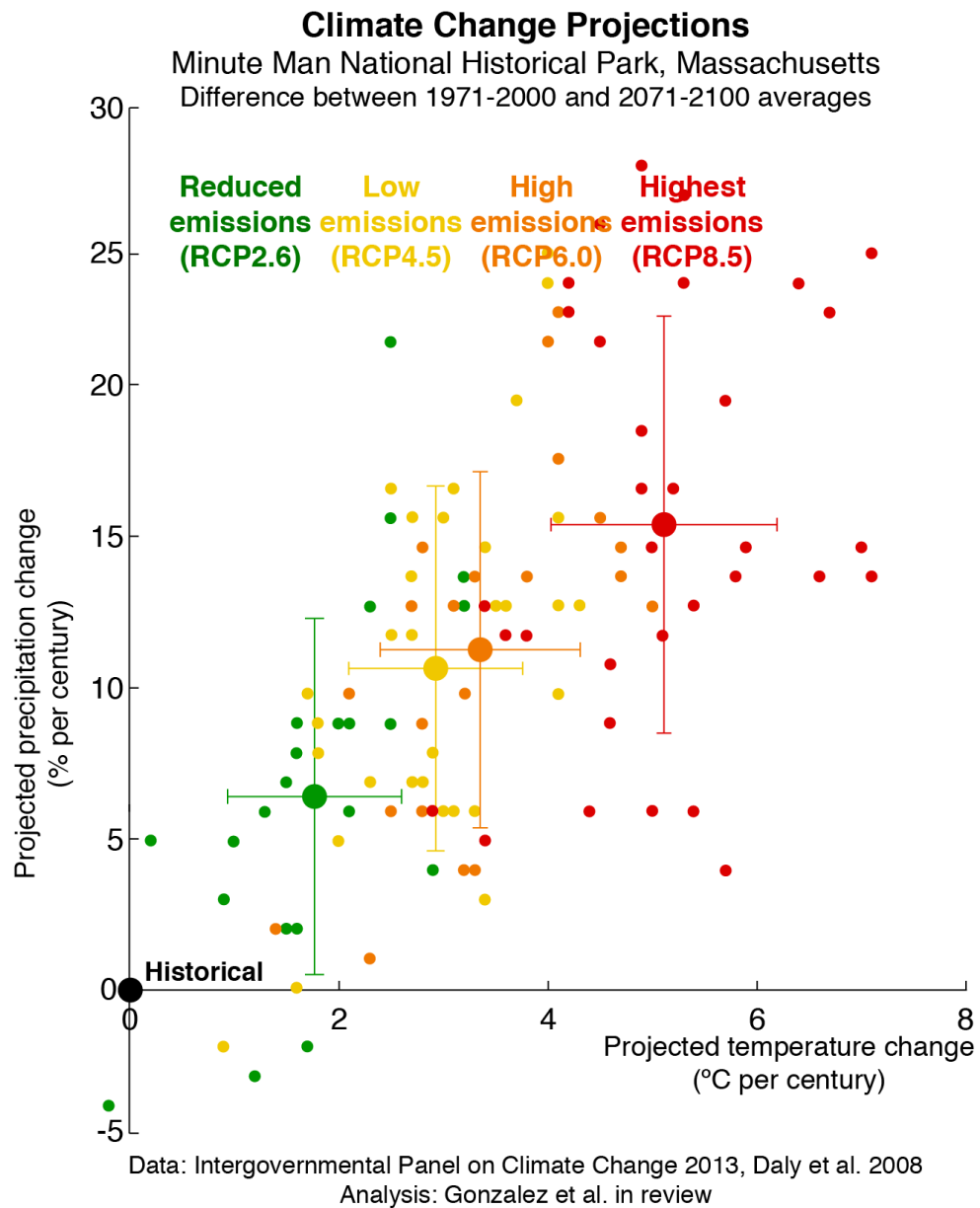
Main conclusion: Precipitation increased at the statistically significant rate of $18 \pm 4\%$ per century from 1895 to 2016, as a fraction of the 1895-2016 average.

Figure 4.



Main conclusion: Precipitation increased across the park from 1895 to 2016 with the greatest increases near Concord, Massachusetts.

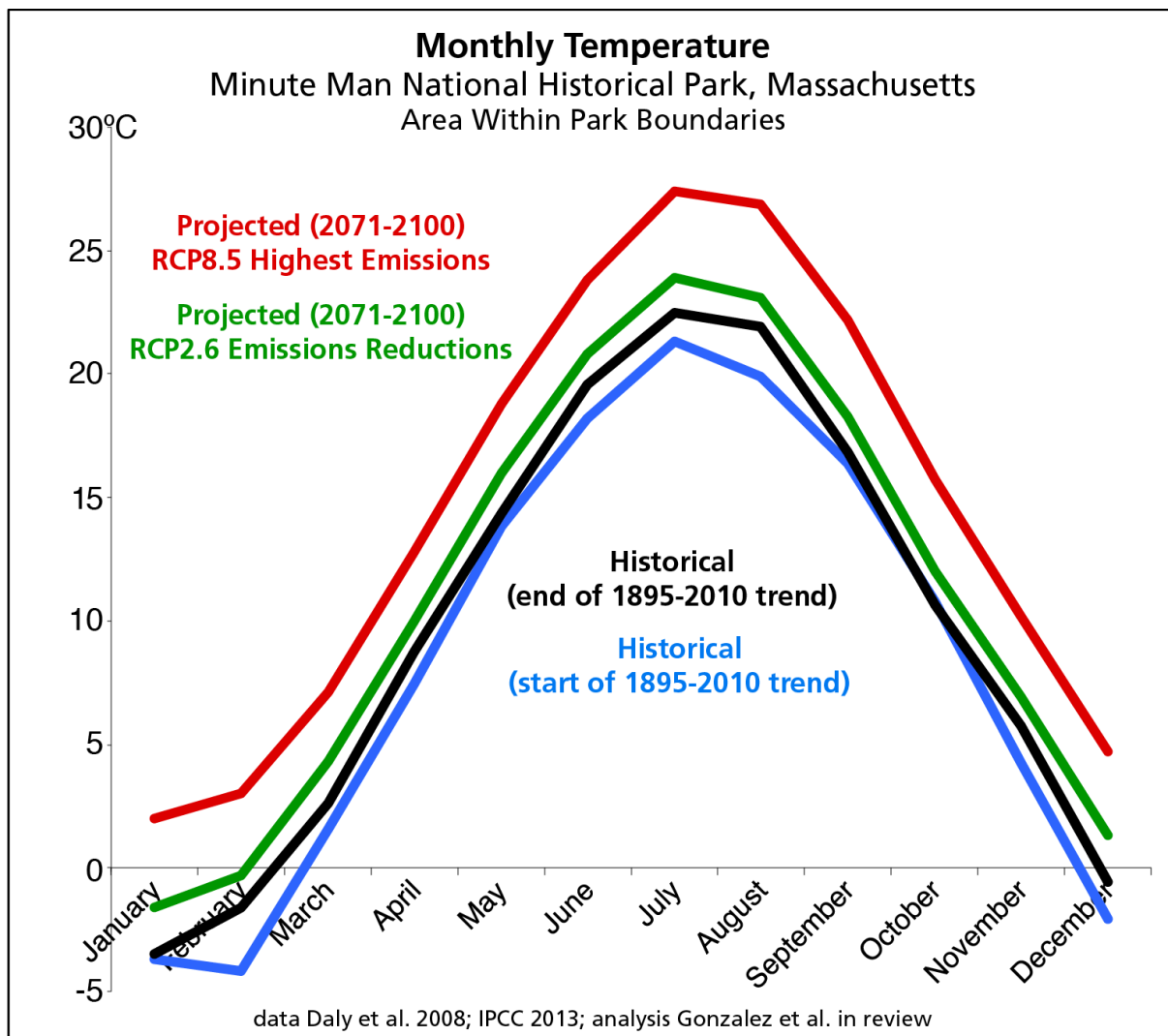
Figure 5.



Main conclusion: Models agree on projections of temperature increases and total precipitation increases in the park.

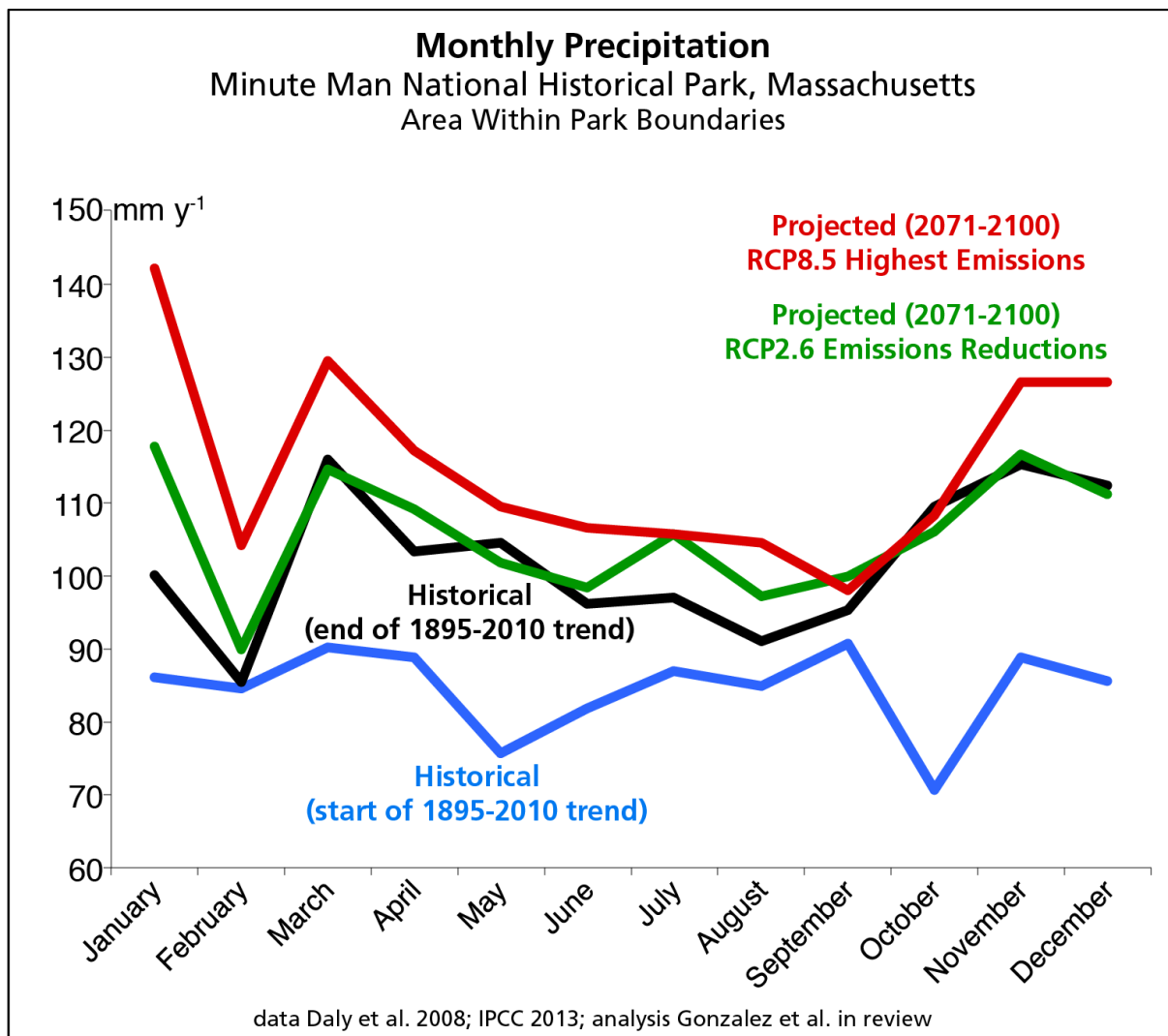
Each small dot is the output of a single climate model. The large color dots are the average values for the four IPCC emissions scenarios and the historical baseline. The lines are the standard deviations of each average value.

Figure 6.



Main conclusion: Temperature has increased throughout the year from 1895 to 2010. The reduced emissions scenario would limit warming to the historical rate. The highest emissions scenario would cause substantial heating throughout the year.

Figure 7.



Main conclusion: Historically, precipitation has shifted to peak in early spring and in late autumn. Under continued climate change, these shifts could continue.

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