Climate Change Response Program
Natural Resource Stewardship and Science

National Park Service
U.S. Department of the Interior

Gates of the Arctic National Park & Preserve Climate Futures Summary

Prepared by the National Park Service Climate Change Response Program, 2025
U.S. Department of the Interior

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Key messages

1. The future won't look like the past. All future projections in average temperature are above the recent historical average (1980-2016).
2. There's a range of ways the future climate may evolve. In 2050, average temperature projections range from +3.2 to +9.5 °F and precipitation from +1.1 inches (+0.2%) to +6.4 inches per year (+1.3%).
3. To account for this range, consider more than one future scenario. This report contains projections for Gates of the Arctic National Park & Preserve for two plausible, divergent climate futures and summarizes potential impacts to resources.

Introduction

Rising temperatures, changing precipitation regimes, stronger storms, and other climatic changes are evident across America's national parks. Effects include more severe wildland fires and floods, changing snowpack, melting glaciers, rising sea levels, intensifying drought, and increasing erosion. These effects can impact the natural, cultural, and built resources of our parks and impact opportunities to visit and recreate in these spaces. The pervasiveness of climate change impacts on resources, assets, operations, and human well-being means that all parks stand to benefit from recognizing and addressing climate change threats. The National Park Service (NPS) has developed guidance and resources to help parks incorporate climate considerations into their planning processes (https://www.nps.gov/subjects/climatechange/planning.htm).

The NPS Planning for a Changing Climate (National Park Service 2021) guide emphasizes that climate-informed plans should:

1) Develop forward-looking goals that consider future climatic conditions according to the climate projections.

2) Consider more than one scenario of the future when developing management strategies and actions.

Successful climate change planning requires us to understand that we will need to adapt to some impacts from climate change. *Climate change adaptation* is defined as "an adjustment in natural or human systems that moderates harm or harnesses beneficial opportunities." Timely, forward-looking adaptation can help conserve cultural and natural resources, develop climate change-ready infrastructure, safeguard human well-being, and foster a positive visitor experience.[1]

This *climate futures summary* describes both recent changes in climate (broad historical trends) and plausible climate futures at Gates of the Arctic National Park & Preserve (GAAR). *Climate futures* are derived from models and explain different ways that the future might evolve at GAAR due to climate change. Climate futures help parks make short- and long-term *decisions that avoid surprises* and costly mistakes. The approach of selecting and planning around several climate futures is a practical response to the impossibility of precisely predicting greenhouse gas emissions and how our climate will respond to them. Methods for

[1] See Climate Change Glossary for full definition.

these analyses were adapted for Alaska from Runyon et al. (2024a) and Runyon et al. (2024b). Please read the Disclaimer for further information about interpreting climate future summaries.

Alaska climate trends

Alaska-wide

Alaska is warming two to three times faster than the global average (Huntington et al. 2023). Alaska has experienced significant warming since 1971, with average annual temperatures rising between 2.4°F in Southeast Alaska and 6.2°F in northern Alaska. This rate of warming is up to 2.6 times faster than the average in the contiguous United States. From 1950 to 2017, approximately 75% of the observed warming in Alaska can be attributed to greenhouse gas emissions. Heatwaves and wildfire in the Arctic are becoming more frequent, such as the summer heatwave in 2019, which brought record-breaking temperatures to southern and Interior Alaska, with daily highs exceeding normal by over 20°F (Huntington et al. 2023).

Precipitation patterns are also shifting. Annual and seasonal precipitation totals generally show an upward trend, though the magnitude and significance vary by region and dataset. The most consistent increases are observed in northern Alaska, particularly on the North Slope, where precipitation has risen by more than 2.5% per decade. Maximum one- and five-day precipitation events are becoming more frequent in most regions, with statistically significant increases since 1957 on the North Slope (over 2% per decade) and in southeastern Interior Alaska (over 1.4% per decade). Extreme rainfall and seasonal precipitation events have created challenges in various parts of the state.

Snowfall patterns are changing as well, with decreases in autumn and spring but increases in midwinter in some areas. The overall snow season in Alaska is projected to shorten.

Permafrost degradation may be worsening due to warmer winters and increased snow cover, which insulates the ground from colder air. Previous estimates of permafrost thaw rates may have underestimated the extent of this phenomenon.

These environmental changes are reshaping life in Alaska, influencing its governance, economy, demographics, cultures, and social systems in profound ways. These changes extend to Alaskan national parks and the communities who live near them. The parks have already been impacted by physical and ecological effects on park resources (Roland 2023).

In addition to changes in average conditions, Alaska is also experiencing changes in extreme conditions. For example, there has been a 21% increase in the amount of rain falling during heavy storms in the region since 1958 (Figure 1). This is because warm air can hold more water vapor, so as temperatures increase, precipitation will fall in more intense and severe events.

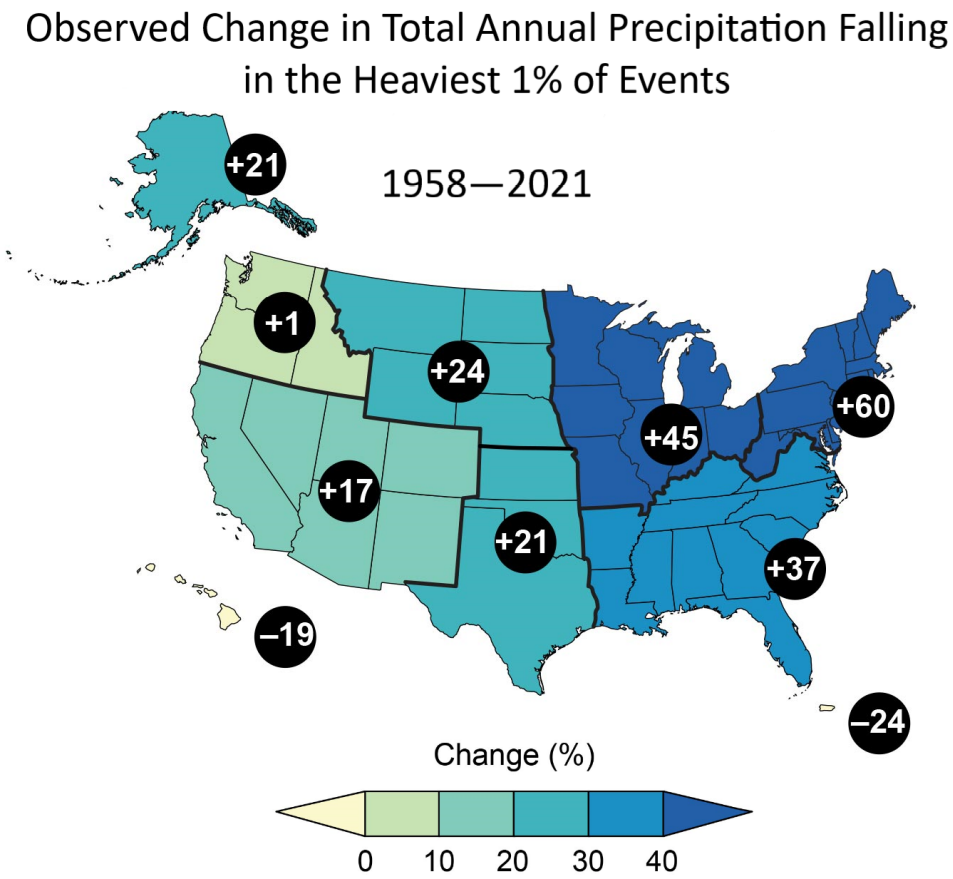

Figure 1. This map from the 5th National Climate Assessment shows regional changes in the amount of rain falling during heavy storms (heaviest 1% of events). For all regions in the contiguous US and Alaska, the percentage of rain falling during extreme precipitation events has increased since 1958.

Gates of the Arctic National Park & Preserve

Data we present here are park-wide averages, however, tools exist that allow for more specific locations. It is recommended to acquire and analyze data at decision-relevant scales.

One tool we use to present park-wide climate trends for Alaska is *Northern Climate Reports* (NCR; https://northernclimatereports.org/). NCR provides information and graphics that illustrate projected change across Alaska, at varying geographic scales and across multiple organizational units, using historical climate observations and climate projections derived from Alaska-relevant climate models. Changing climate conditions for GAAR can be found at https://northernclimatereports.org/report/area/NPS7 and will be referenced throughout this climate future summary. This report was designed to complement climate futures provide by NCR, using the same climate data and projections, so the website can be used to access additional data at finer spatial scales.

Projected climate change and related impacts

We examined 20 different climate model outputs (Mizukami et al. n.d.) to characterize the uncertainty about how climate change could affect GAAR. Relative to the 1980–2016 baseline period (see Runyon et al. 2024 for details), all climate models project significant warming by 2050 with projected increases in average annual temperature ranging from +3.2 °F to +9.5 °F. All climate models project increases in precipitation, ranging from +1.1 inches (+0.2%) to +6.4 inches (+1.3%). Given the range of these projections, it's clear that future conditions will not resemble the past, and planning for *more than one* plausible future will best position the park to manage change.

Thus, we present two plausible, divergent climate futures to capture relevant variation across climate models and greenhouse gas emissions scenarios[2]. These are the same two used for temperature and precipitation metrics in NCR (Climate Future 1 = NCAR-CCSM4 RCP 8.5, Climate Future 2 = MRI-CGCM3 RCP 4.5) and represent Alaskan climate features well (Walsh et al. 2018). While they do not characterize the full range of uncertainty (which is never fully known), they represent different ways the climate might develop at GAAR through 2050 and are both plausible. Neither of these projections should be considered "predictions"—we cannot know how the future will unfold. Considering both climate futures will help the park prepare for uncertain future conditions by using scenario-based approaches to stress-test management goals and decisions (see Adaptation Planning section, below).

Climate futures are derived from an average of grid cells throughout the park because this information can provide valuable insights about changing trends and help to broadly understand how climate change might impact park resources. This method allows for characterization of extreme events and illustration of timeseries for visualizing interannual variability. While this information is still useful for topographically complex parks, the spatial extent of GAAR warrants additional maps to compliment the spatial averages to display variation of the climate futures across the park. See Appendix 2 for climate futures maps.

Annual average temperature and precipitation projections

Average annual temperatures are projected to increase under both the climate futures relative to the historical baseline period (1980-2016). Increases by 2050 under Climate Future 2 are considerable (+3.6 °F) and increases under Climate Future 1 are greater (+6.7 °F) (Figure 2, Figure A1, Table A1).

To put this in context, most historically hot years recorded at GAAR would be "average" temperature years in Climate Future 2. Average temperatures under Climate Future 1 would generally exceed anything experienced at GAAR in recent history. These projections are consistent with temperature increases already observed due to climate change at GAAR.

Increases in average temperatures can result in a range of impacts on both human life and ecosystems. Rising temperatures can stress plants and animals not accustomed to living in warmer temperatures. Temperature increases can lead to intense heat waves that threaten human health, especially for vulnerable populations. Finally, rising temperatures often lead to worsening drought conditions and increased wildfire risk.

[2] For specifics on how climate futures are typically created and used by NPS, see (Lawrence et al. 2021) and Runyon et al. (2024a).

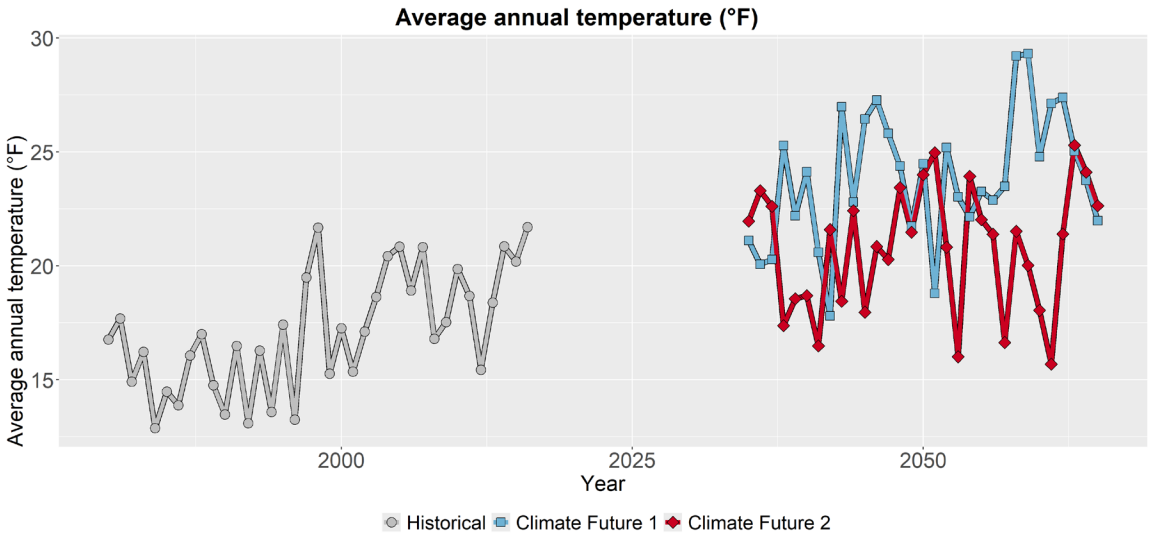

Figure 2. This graph compares observed average annual temperature at GAAR (°F) (1980-2016) with projected average annual temperature for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

Average annual precipitation is projected to be variable but have a generally upward trend. Projections under both climate futures indicate wetter years than experienced historically. These projections are consistent with the scientific understanding that climate change will result in increased extremes in precipitation (USGCRP 2023). Overall, our analysis projects +5.5 (+34.9%) inches in annual precipitation under Climate Future 1 and +2 (+12.5%) inches under Climate Future 2 relative to 1980-2016 (Figure 3, Figure A2, Table A1).

Although average annual precipitation is projected to increase for both climate futures, any changes in seasonal precipitation patterns could impact hydrologic systems, seasonal biology, and extreme events (see Appendices 1 and 2). Very dry intervals and warming can lead to drought conditions, affecting river levels, water availability, and ecosystem health. Very wet years and overall increases in annual precipitation can lead to flooding that may impact water quality, infrastructure, transportation routes, and more.

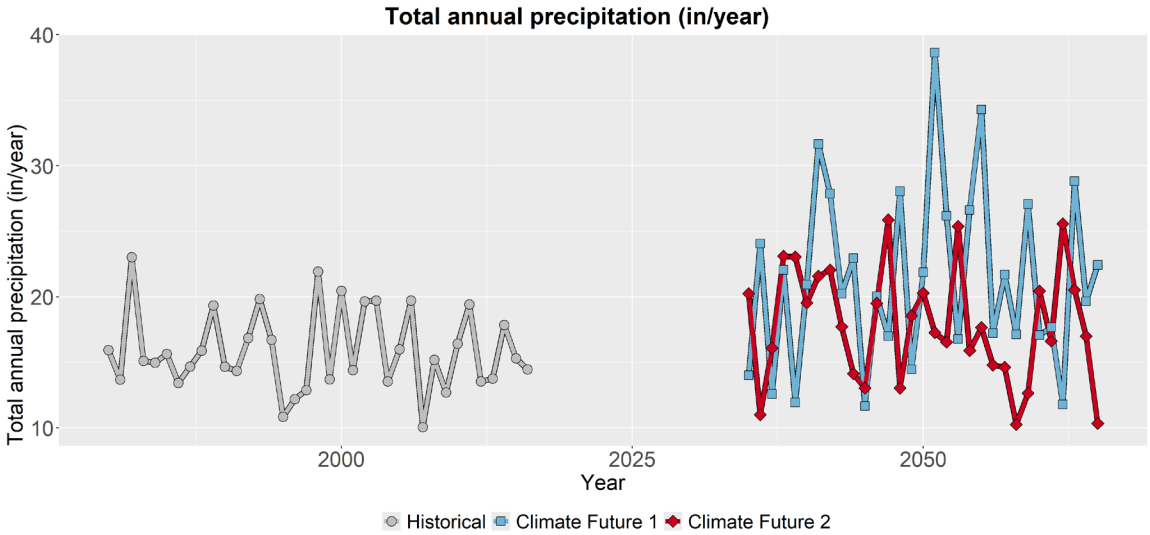

Figure 3. This line graph compares observed average annual precipitation (in/year) at GAAR (inches/year) (1980-2016) with projected average annual precipitation for the two climate futures over the period 2035-2065. The

historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

Other climate-related projections

Note: Appendix 2 contains additional figures illustrating some climate-related projections not discussed in the text below.

Changing seasonality & phenology

Changing seasonality and phenology (the timing of seasonal biological events) in northwest Alaska are profoundly reshaping ecosystems and livelihoods. Warmer temperatures and shifting precipitation patterns are increasing across most seasons (Figures 4 and 5, Table A1) and causing earlier snowmelt, delayed freeze-up, and shifts in the timing of plant growth and animal migrations. Earlier spring onset and longer growing seasons, which can be driven by changes in temperature cues or water availability, alter the phenological patterns of vegetation. For example, plants are blooming earlier, causing some migratory species, like birds, to experience population declines because of delayed departures from winter grounds and late arrivals at breeding sites after food resources have already peaked. Caribou calving seasons are also falling out of sync with the phenology of the plants they forage on, leading to declines in calf production and forage quality. Roughly three-quarters of parks (76%) are experiencing earlier spring onset than historical conditions, and this change is projected to reach all regions containing parks by mid-century (Monahan et al. 2016). Additionally, spring timing can impact the timing of park operations, events, and visitor uses (e.g., road openings, flower festivals, and backcountry recreation).

For subsistence-dependent communities, shifts in seasonality make traditional hunting, fishing, and gathering more unpredictable, as access to resources like fish runs or game becomes misaligned with historical patterns and regulatory harvest windows.

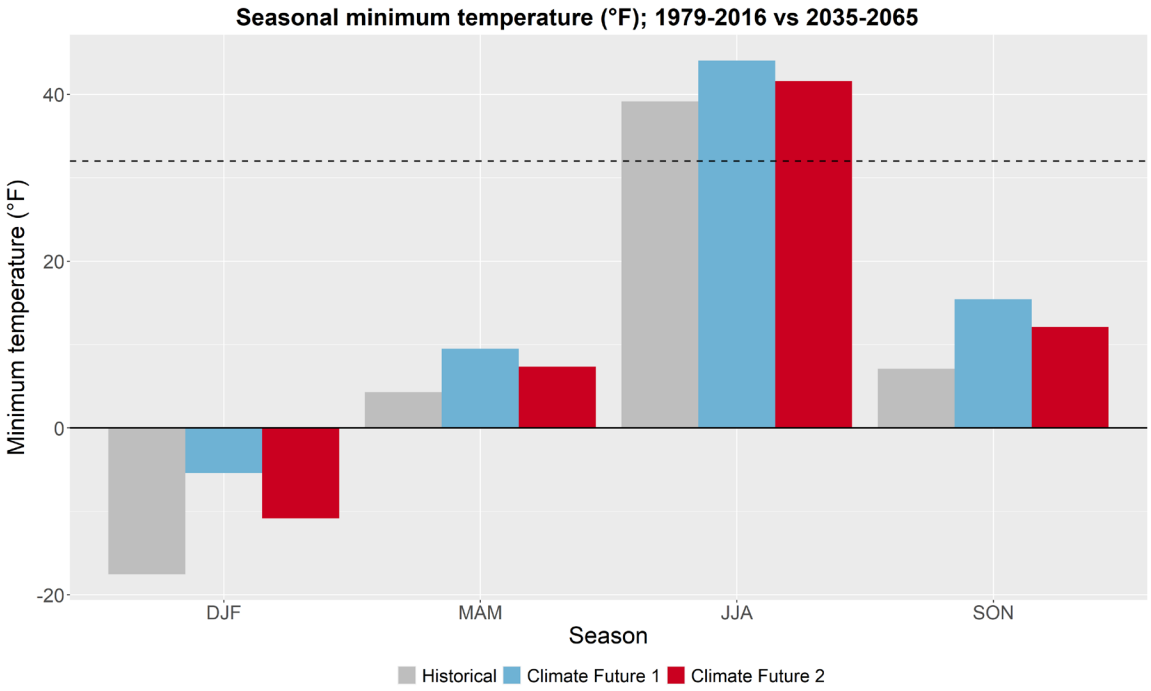

Figure 4. This bar chart shows projected seasonal minimum temperatures (°F) at GAAR for the historical period and the two climate futures (2035-2065). The dotted horizontal line represents 32°F, the temperature at which ice

melts. The solid horizontal line delineates 0°F. DJF = December, January, February; MAM = March, April, May; JJA = June, July, August; SON = September, October, November.

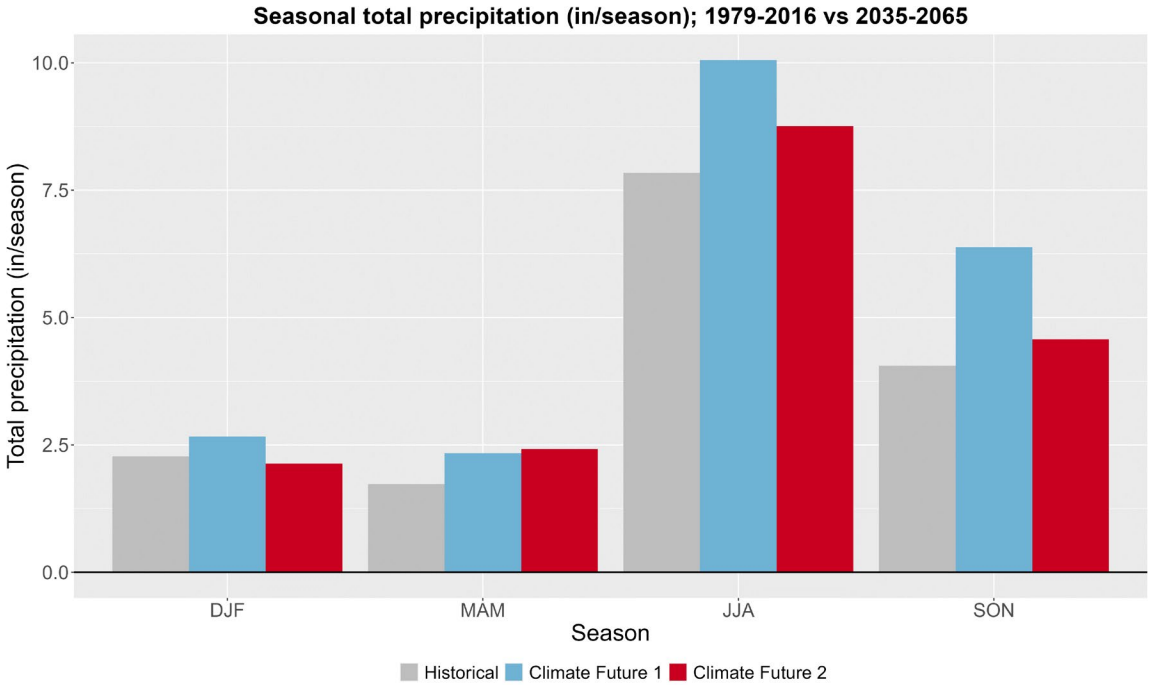

Figure 5. This bar chart shows projected seasonal change in total precipitation (in) at GAAR from historical (1980-2016) between the two climate futures (2035-2065). The solid horizontal line represents no change, with increasing seasonal precipitation above zero and decreasing precipitation below zero. DJF = December, January, February; MAM = March, April, May; JJA = June, July, August; SON = September, October, November.

Snow

Snow conditions are undergoing significant changes due to rising temperatures and shifting precipitation patterns. Snow water equivalent[3] (SWE) represents the depth of water that would result if the snow were completely melted. Figure 6 illustrates how the average maximum SWE is projected to increase by 2.5 in/year for CF1 and 1.1 in/year for CF2, resulting in greater snow depth even in a hotter climate. Seasonal and annual SWE variability will increase under both climate futures, meaning that there may be seasons or years when the snow depth is notably higher or lower than what the park has seen historically (see also Figures A3-6). Additionally, more variable and extreme snowmelt events are evident in both climate futures, especially in Climate Future 1, where earlier and more rapid melting occurs. These changes have significant implications for water availability, runoff patterns, and seasonal streamflow timing. Reduced snow cover duration and earlier snowmelt are altering the timing and availability of freshwater, impacting ecosystems, subsistence activities, and infrastructure. Thinner and less stable snowpacks affect wildlife like caribou, which rely on snow conditions for migration and foraging.

[3] Maximum SWE is used as a proxy for average snow depth. SWE is derived from Alaska VIC Hydrological Model Output (1950-2099), create by Mizukami et al. 2022.

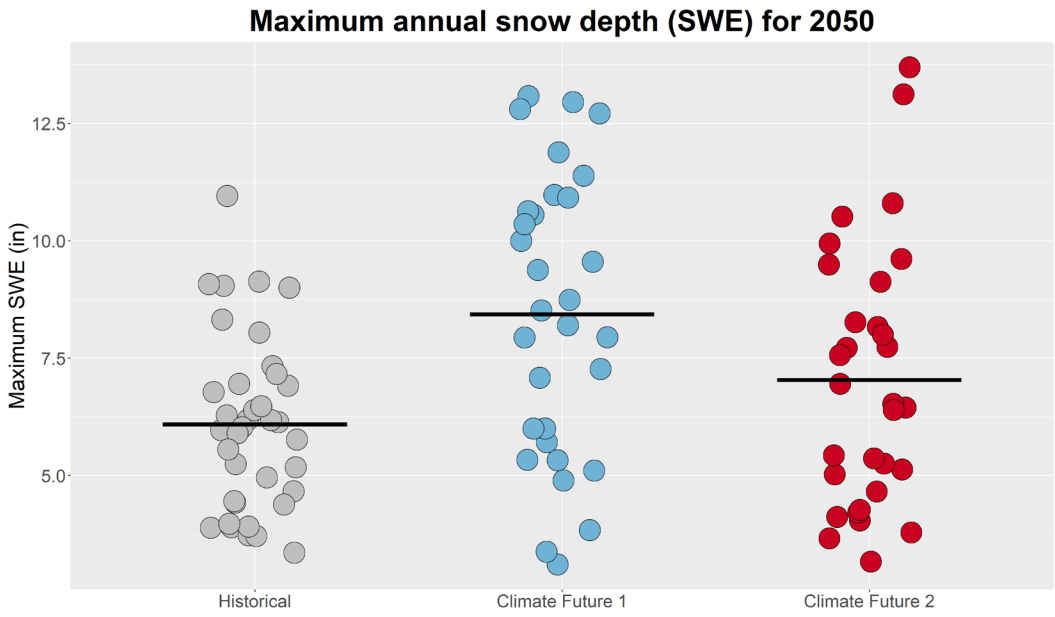

Figure 6. This figure compares annual maximum snow depth (max snow water equivalent [SWE; inches]) at GAAR in the historical period (1980-2016) and each climate future (2035-2065). Each dot represents that maximum snow depth in a given year, helping visualize changes in variability. The black horizontal lines show the average snow depth for each climate future.

Permafrost change

Permafrost in GAAR is undergoing significant changes, driven by rising temperatures and altered snow cover patterns. Warmer winters, warmer soil temperatures[4] (Figures 7 and 8) and changing snowfall—which insulates the ground from colder air—are accelerating permafrost thaw. Thawing permafrost can destabilize the ground, posing challenges for parks' infrastructure and cultural resources. Additionally, it disrupts ecosystems by altering hydrology and vegetation patterns, threatening habitats for wildlife. Based on increasing soil temperatures in both climate futures, permafrost is projected to decrease in GAAR.

[4] Average soil temperature is the temperature of the top two meters of soil. It is derived from Alaska VIC Hydrological Model Output (1950-2099), create by Mizukami et al. 2022.

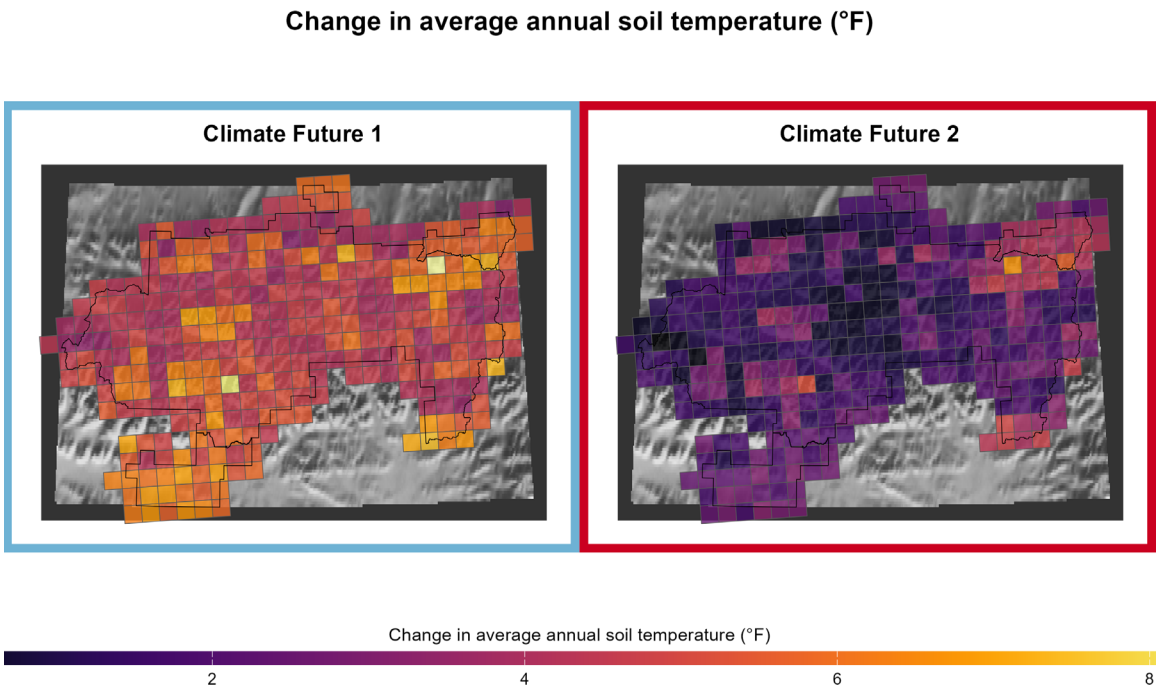

Figure 7. These maps show projected change in average annual soil temperature (°F) of the top two meters at GAAR (2035-2065) compared to historical (1980-2016) for the two climate futures. The warmer the soil the more permafrost melts. Climate Future 1 is shown with a blue box (left), and Climate Future 2 is shown with a red box (right).

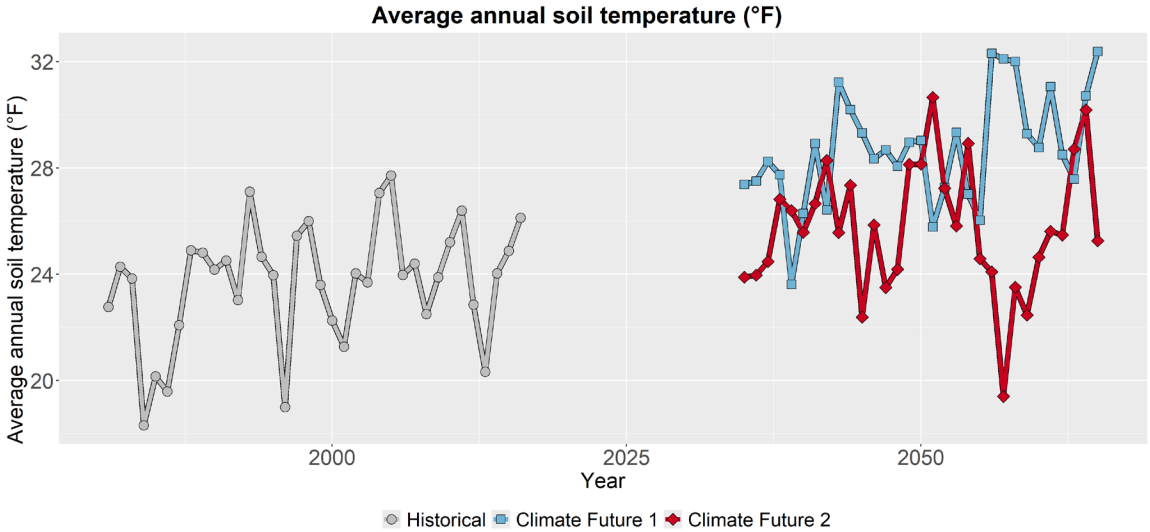

Figure 8. This line graph compares the observed average annual soil temperature (°F) at GAAR (1980-2016) with the projected average annual soil temperature for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

Fire

A warming climate, earlier snowmelt with later snowpack development, and extreme precipitation regimes intensify wildfire seasons in Alaska. More frequent and intense fires alter vegetation patterns, potentially transitioning forest types—such as boreal forests to deciduous forests of birch and aspen—which may impact

important subsistence species that rely on these habitats. Wildfires may begin expanding into areas that have not historically been at risk, while areas prone to wildfire will experience more frequent, larger events that survive over winter or reburn the same location after just a few years.

Figures from the Northern Climate Reports page for GAAR shows increasing flammability under diverse emissions scenarios (RCP 4.5 and 8.5) compared to historical conditions. Landscapes that are projected to have moderate to very high flammability experience fire frequently enough in some areas to define vegetation patterns, while low to very low flammability indicate that fire is rare and unlikely to determine vegetation patterns in that location. These projections of overall increasing flammability are aligned with research showing that, by 2050, climate change may lead to a 24-169% increase in burned area for Alaskan boreal forests, and the tundra could experience four times more frequent fires with twice the burn area by 2100 (USDA Climate Hubs, n.d.).

More frequent, high-intensity fires pose a risk to both human and ecosystem health. Managers may want to prepare for potential impacts by considering adaptation strategies such as forest thinning and prescribed burns, shaded fuel breaks, and post-fire restoration efforts to plan for intensifying wildfire regimes.

Other Possible Climate-related Impacts

Other potential climate-related impacts that may occur at GAAR but cannot be represented by basic climate exposure metrics are described below. While these impacts are based on general literature review for the region and are not specific to GAAR, park staff should be aware of their potential threat and further study may be warranted.

Invasive species and pests

Climate change can accelerate the introduction and spread of invasive species, and invasive species can amplify the effects of climate change (Beaury et al. 2020). Extreme weather events may stress native species, create opportunities for invasive species movement, and alter conditions that affect species' life cycles and their ability to spread into new areas. Invasive species of concern in Alaska such as the northern pike, Atlantic salmon, and zebra mussels could benefit from the climate change stressors that impact native species. Climate change can also affect the timing and efficacy of current invasive management treatments. Terrestrial and aquatic invasive species have the potential to cause direct damage to power, water, transportation, and building facilities (Vissichelli 2018) and impact natural and cultural resources. Indirect climate change impacts may also affect facilities through forest insect pest invasions or fluctuating groundwater levels leading to increased vegetation stress, mortality, and treefall. The potential for increased invasive species is prevented or mitigated through early detection and rapid response procedures. The National Invasive Species Council recently released EDRR tools and lessons learned and have additional resources for monitoring and managing invasive species and climate change. The NPS Integrated Pest Management Program also has resources available to help parks detect and prevent pests.

Adaptation planning: Address climate change impacts and implications

Concepts from Planning for a Changing Climate (National Park Service 2021) can help address potential climate impacts in planning for GAAR and develop a robust climate change response, which will better protect park resources and assets today and for future generations. Potential climate impacts can be

considered during goal setting, reviewing existing management activities, or identifying new climate change adaptation strategies. Below are some of the key principles from Planning for a Changing Climate, intended to inform a park's climate change response.

Develop forward-looking goals that consider future climatic conditions

Adaptation planning looks to the future, which is likely to differ from the past, using climate projections to adopt forward-looking goals. The term 'goals' should be interpreted broadly, recognizing that different planning processes use different terms and approaches. For example, a General Management Plan or a Visitor Use Management Plan may focus on developing desired conditions, whereas a Resource Stewardship Strategy seeks to identify long- and short-term goals. Regardless of the specific terminology, adaptation planning offers an important opportunity to establish or adjust climate-informed goals which look to the future and seek to strike a balance between traditional aspirations and emerging realities. Furthermore, the information provided above can be used to identify climate implications for management strategies and actions that may flow from broader climate-informed goals.

Putting it into action: This summary provides information about past, present, and potential future climate conditions for GAAR. The intent of this work is to enable managers to use climate information to develop new goals (e.g., desired conditions or trajectories) or reconsider existing management goals.

The worksheet below (Table 1) is an example that can help to assess whether desired conditions, and/or management strategies and actions are feasible under different climate scenarios. Use this worksheet in conjunction with the climate information provided above to identify potential climate implications for desired conditions, goals, strategies, and/or actions and revise these as needed.

- Adaptation planning offers an important opportunity to establish or adjust *desired conditions* for the future and formulate *climate-informed goals* that strike a balance between traditional aspirations and emerging realities.

- If it is apparent that goals cannot be met under projected future conditions, goals will need to be updated or refined. Goals should increasingly acknowledge continuous change and the potential for unavoidable losses or transformations.

Consider more than one scenario of the future

Adaptation planning considers *multiple scenarios* of the future to account for uncertainty in the anticipated scope, magnitude, and effects of climate change. This structured approach allows planners and managers to (1) explore a variety of *plausible future conditions*; (2) evaluate the implications of those conditions; and (3) identify a portfolio of possible management strategies. A table or exercise similar to Table 1 can be used to test existing (or develop new) management goals, strategies, or other plan elements. See Schuurman et al. 2019 for examples.

Putting it into action: This summary provides two climate scenarios ("Climate Future 1" and "Climate Future 2") that represent plausible future conditions for GAAR. Under each future, managers can identify what strategies and actions can reduce risk and enable the park to meet its goals. You might also consider what strategies and actions can take advantage of possible opportunities under each scenario.

1. Start by brainstorming an array of strategies that could address important climate risks. Consult existing sources of climate-informed management strategies and actions, which might be found in other planning documents like a Resource Stewardship Strategy, Natural Resource Condition

Assessment, Cultural Resource Stewardship Assessment, climate-friendly park plan, or vulnerability assessments.

2. Next, decide how you will compare and evaluate strategies to decide which to select and include in the plan. Strategies and actions could be evaluated based on their effectiveness across multiple scenarios, effectiveness in extreme scenarios, how they align with park management goals, and/or their feasibility.

Table 1. Example worksheet that can be used to assess if desired conditions/goals are feasible under different climate futures.

Resource/ Asset/ Value	Draft Desired Condition	How will climate change affect this desired condition under Climate Future 1?	Is the Desired Condition achievable under Climate Future 1?	How will climate change affect this desired condition under Climate Future 2?	Is the Desired Condition achievable under Climate Future 2?	Revise Desired Condition? Remove Desired Condition?
Wetlands	No net loss of wet meadows and fens	Warmer conditions could lead to smaller or fully-dried and transformed wetlands. Under wetter conditions, some wetlands could remain stable or potentially expand.	No net loss is probably not feasible, but minimal loss might be possible.	No practical way to keep water in all meadows. Marginal wetlands will convert to uplands. All wetlands could periodically dry out under extreme drought conditions.	No. No net loss is not attainable.	Revision: Minimize loss of high value wetlands.

This climate futures summary includes a concise summary of key climate trends, projections, impacts, and planning concepts to empower parks in managing climate change and adapting to an uncertain future. Browse the NPS Climate Change Response Program website to find additional information about climate assessments, climate adaptation by parks, and more.

Disclaimer

This series of park-specific climate future summaries were developed to provide information that can serve as cursory identification of vulnerabilities or "red flag checks" for areas that may require further scoping. Information provided by the climate future summaries is widely used by the NPS and partners in many routine planning processes. For example, an assessment of historical and future climate exposure is foundational for climate change vulnerability assessments, scenario-based climate change adaptation, and basic evaluations of proposed infrastructure projects and other climate-sensitive planning. However, climate futures should be interpreted as representations of future uncertainty, rather than predictive forecasts.

The climate future summaries described here are, in general, most appropriately used as a coarse filter or initial climate assessment that can identify concerns that warrant a more detailed assessment. These summaries use a standardized approach that is not tailored to site-specific issues or climate sensitivities. A more detailed and site-specific climate assessment is required for evaluations of, e.g., requirements of major infrastructure or resource projects that may be highly consequential.

Technical Assistance Request Process

While the high-level climate change information provided in this report is a useful first step to understanding potential climate risks, many decisions may require more in-depth analysis. For further assistance, please either submit a technical assistance request through the NPS System for Technical Assistance Requests, email the Climate Change Response Program (Climate_Change@nps.gov) or reach out to the USGS Alaska Climate Adaptation Science Center.

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Appendix 1. Climate futures table

Table A1. Projected changes in annual and seasonal temperature and precipitation presented in this report. Change values are the difference between the climate metric's future-period (2035-2065) average and the historical-period (1980-2016) average. Historical are absolute values.

Climate metric	**Average temperature**					**Average Precipitation**				
Season	Annual	DJF	MAM	JJA	SON	Annual	DJF	MAM	JJA	SON
Historical	17.1	-9.3	14.9	48.6	14.3	15.9	2.3	1.7	7.8	4.1
Climate Future 1	+6.7	+10.4	+3.9	+5.4	+7.1	+5.5	+0.4	+0.6	+2.2	+2.3
Climate Future 2	+3.6	+6.2	+2.4	+2.3	+3.7	+2	-0.1	+0.7	+0.9	+0.5

Table A2. Projected changes in annual and seasonal maximum and minimum temperature. Change values are the difference between the climate metric's future-period (2035-2065) average and the historical-period (1980-2016) average. Historical are absolute values.

Climate metric	**Minimum temperature**				**Maximum Temperature**			
Season	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Historical	-17.5	4.3	39.2	7.1	-1.1	25.6	58	21.5
Climate Future 1	+12.1	+5.2	+4.9	+8.3	+8.7	+2.5	+5.9	+5.9
Climate Future 2	+6.7	+3	+2.4	+5	+5.8	+1.7	+2.1	+2.4

Table A3. Projected changes in selected threshold climate metrics presented in this report. Historical values are absolute and the climate futures represent change values (the difference between the climate metric's future-period (2035-2065) average and the historical-period (1980-2016) average). Timeseries figures showing change in these metrics are available in Appendix 2. Dozens of additional threshold metrics are available on the Northern Climate Reports page for GAAR.

Climate Metric	Historical	Climate Future 1	Climate Future 2
Maximum annual snow depth (in)	6	+2.5	+1.1
Annual freeze-thaw cycles, calculated as days when the maximum temperature is >34°F and the minimum temperature is <28°F	36.8	+4.1	+7.6
Days per year when the minimum temperature is below 32°F	274.4	-28.2	-14.1
Days per year when the maximum temperature is above 68°F	14.6	+21	+8
DJF days per year when the minimum temperature is below 32°F	90.3	-1	-0.4
Annual days per year when precipitation is greater than 0.5 inches	6.1	+8.1	+4
Average temperature of the top two meters of soil (°F)	23.7	+5.1	+2.1

Appendix 2. Additional climate futures figures

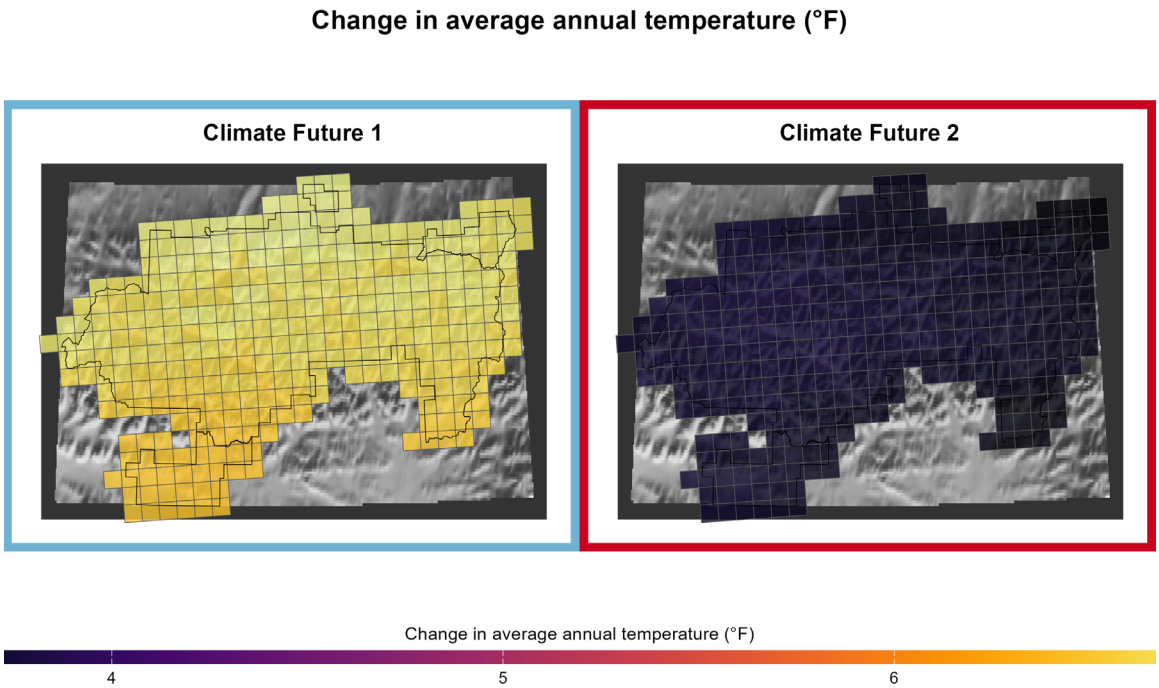

Figure A1. These maps show projected change in the average annual temperature (°F) at GAAR (2035-2065) compared to historical (1980-2016) for the two climate futures. Climate Future 1 is shown with a blue box (left), and Climate Future 2 is shown with a red box (right).

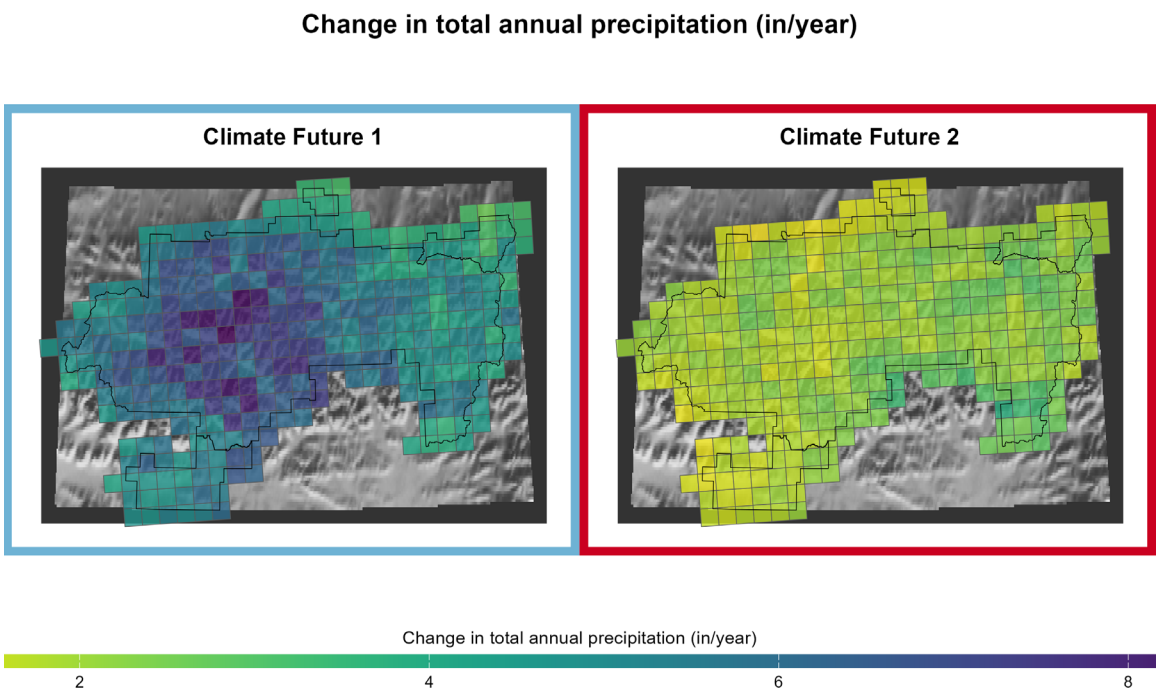

Figure A2. These maps show projected change in total annual precipitation (in/year) at GAAR (2035-2065) compared to historical (1980-2016) for the two climate futures. Climate Future 1 is shown with a blue box (left), and Climate Future 2 is shown with a red box (right).

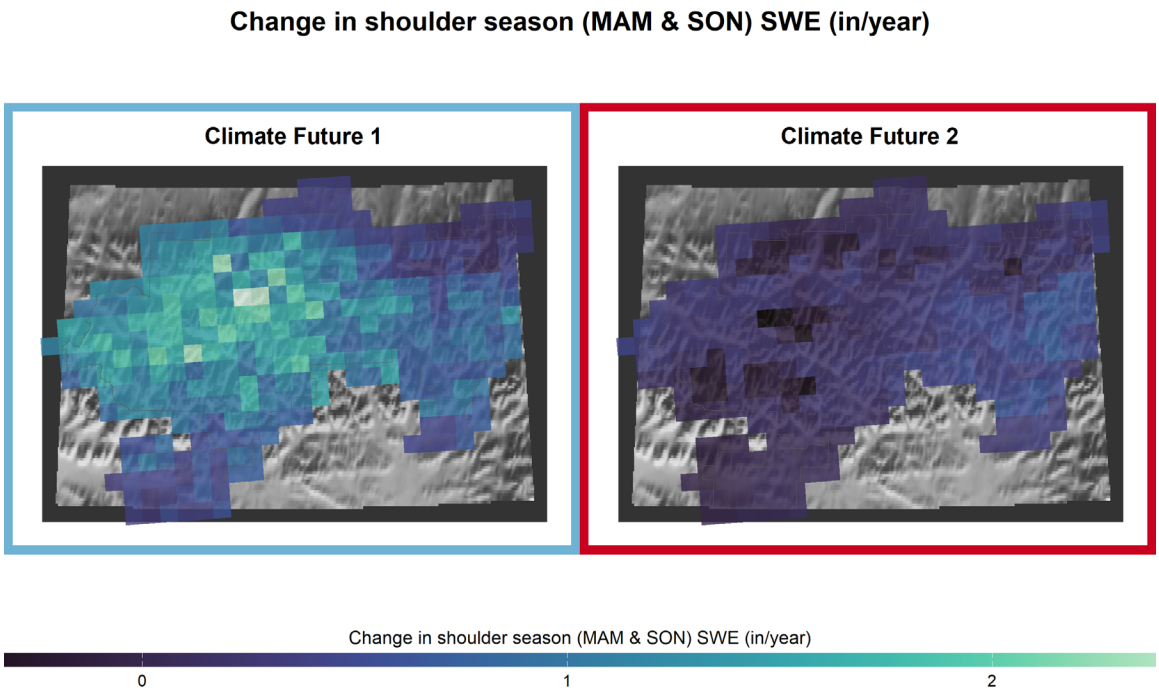

Figure A3. These maps show projected seasonal change in shoulder season snow water equivalent (SWE; in/year) at GAAR (2035-2065) compared to historical (1980-2016) for the two climate futures. SWE represents the depth of water that would result if the snow were completely melted. Climate Future 1 is shown with a blue box (left), and Climate Future 2 is shown with a red box (right). MAM = March, April, May; SON = September, October, November.

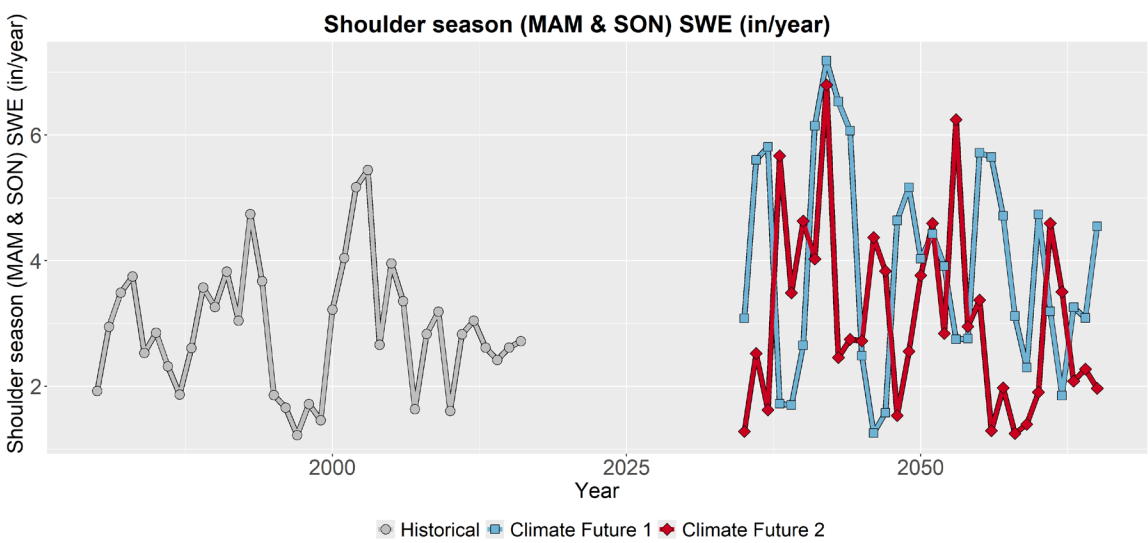

Figure A4. This line graph compares observed seasonal change in shoulder season snow water equivalent (SWE; in/year) at GAAR (1980-2016) with projected seasonal change in shoulder season SWE for the two climate futures over the period 2035-2065. SWE represents the depth of water that would result if the snow were completely melted. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

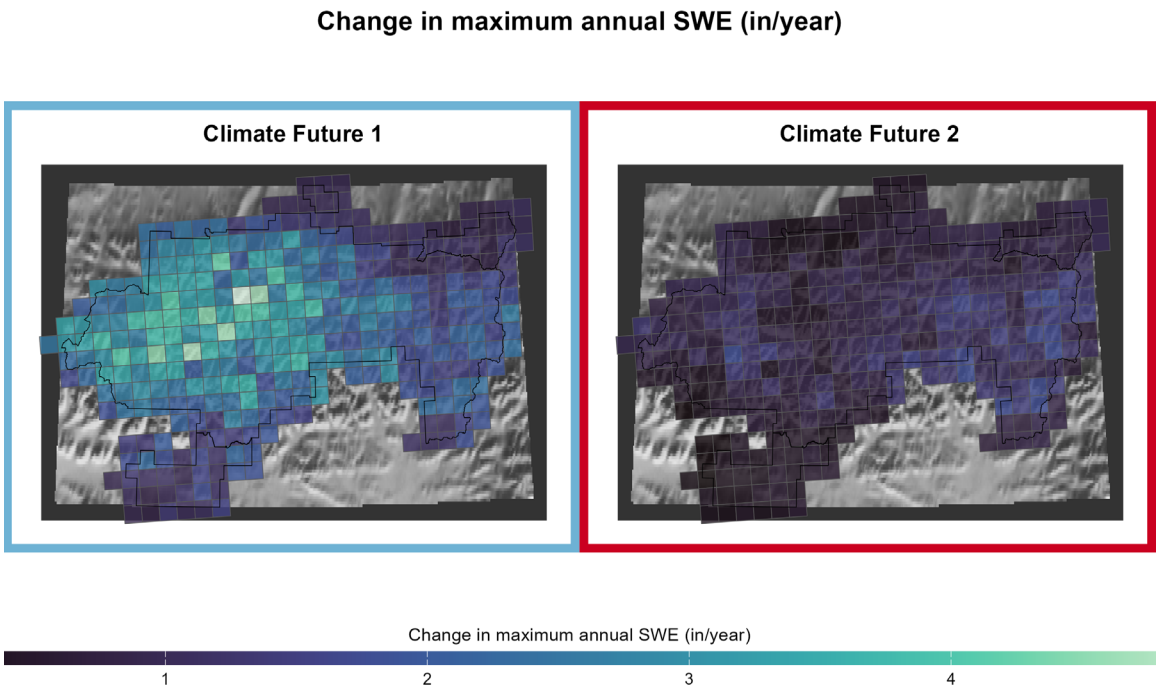

Figure A5. These maps show projected change in maximum annual snow water equivalent (SWE; in/year) at GAAR (2035-2065) compared to historical (1980-2016) for the two climate futures. SWE represents the depth of water that would result if the snow were completely melted. Climate Future 1 is shown with a blue box (left), and Climate Future 2 is shown with a red box (right).

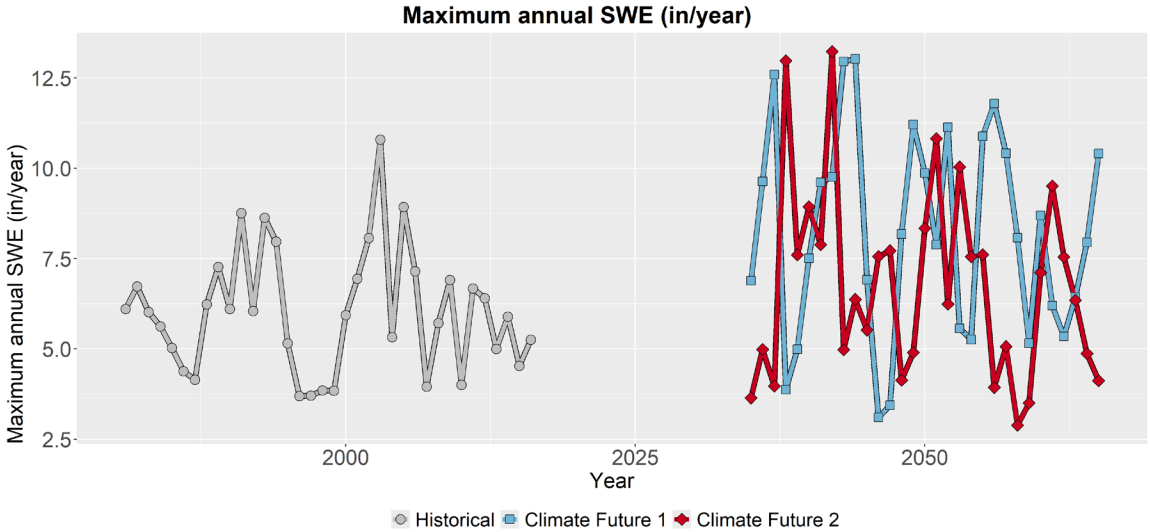

Figure A6. This line graph compares observed maximum annual snow water equivalent (SWE; in/year) at GAAR (1980-2016) with projected maximum annual SWE for the two climate futures over the period 2035-2065. SWE represents the depth of water that would result if the snow were completely melted. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

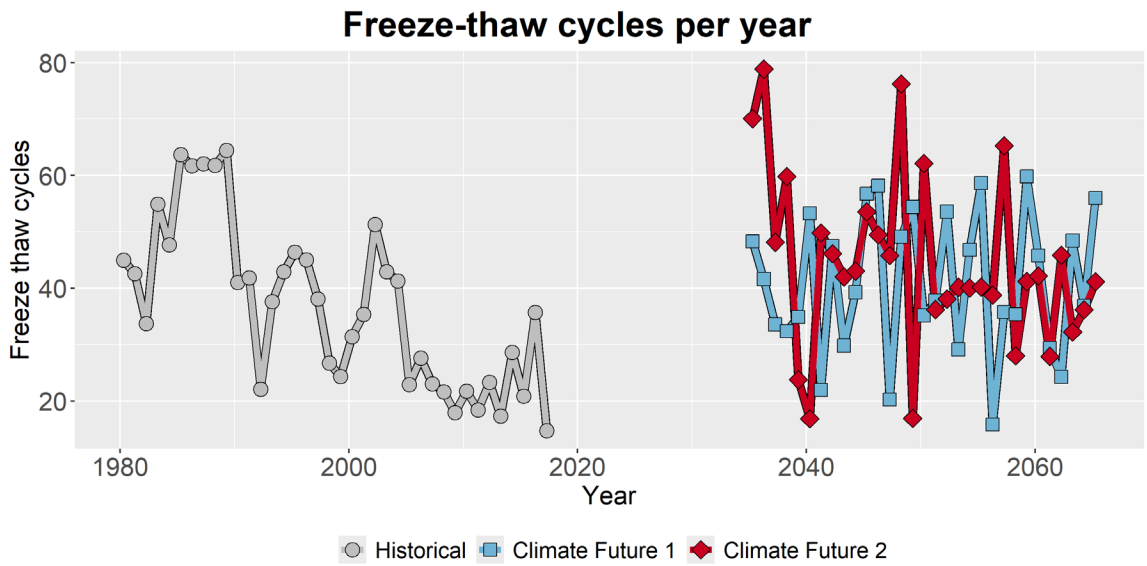

Figure A7. This line graph compares observed freeze thaw cycles at GAAR (1980-2016) with projected freeze thaw cycles for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

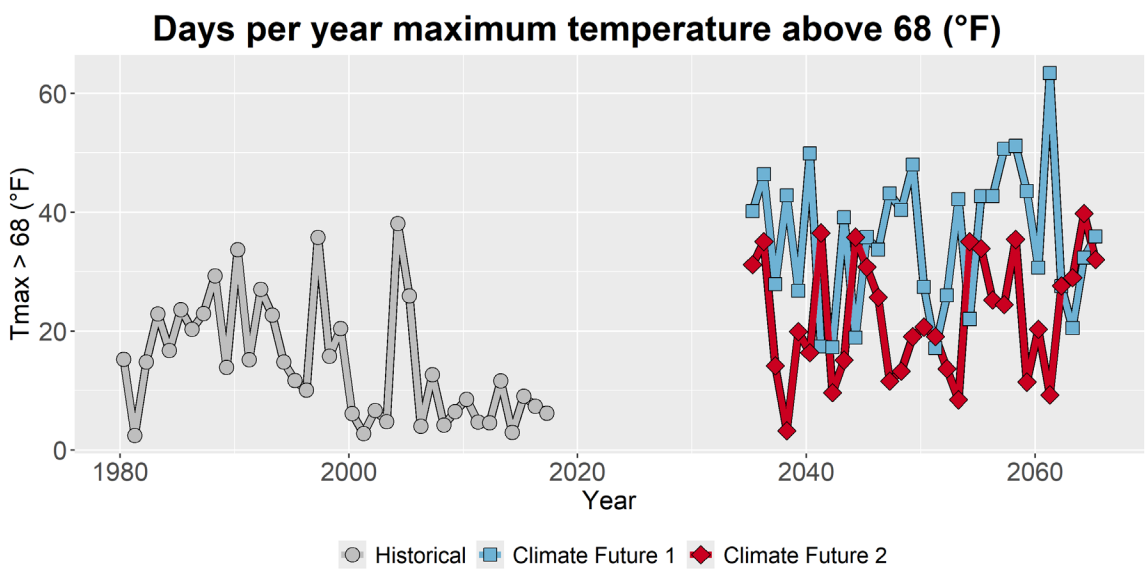

Figure A8. This line graph compares observed maximum temperatures above 68°F at GAAR (1980-2016) with projected maximum temperatures above 68°F for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

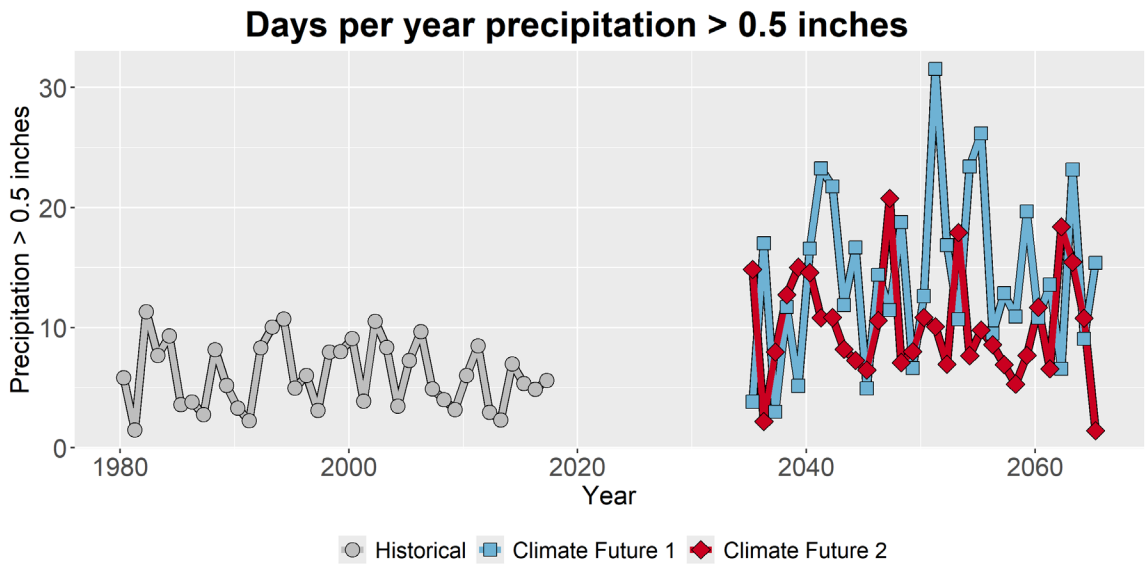

Figure A9. This line graph compares observed precipitation greater than 0.5 in at GAAR (1980-2016) with projected precipitation greater than 0.5 in for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

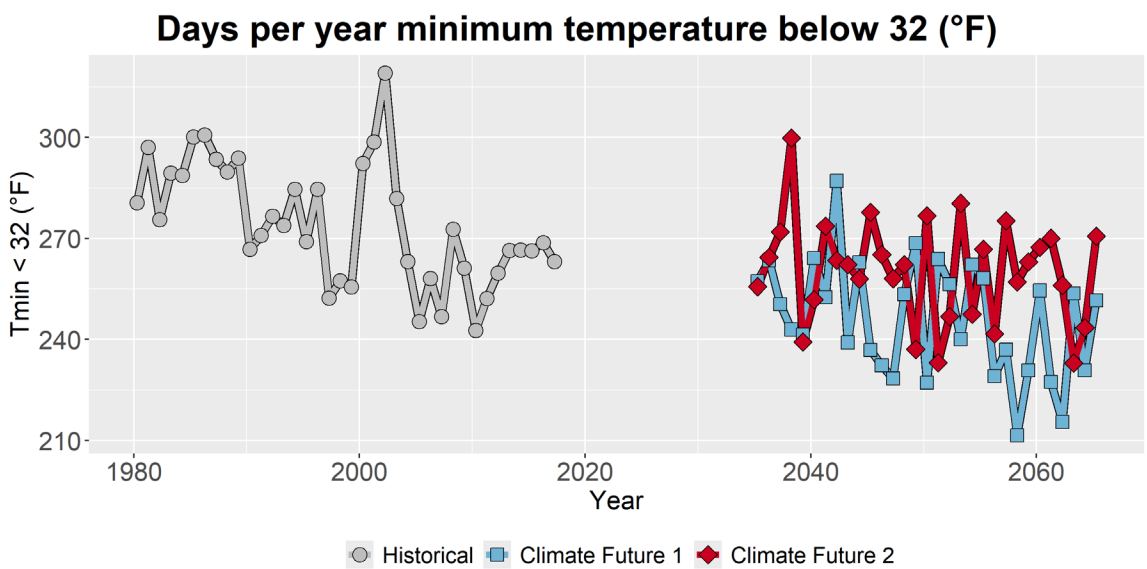

Figure A10. This line graph compares observed minimum temperatures below 32°F at GAAR (1980-2016) with projected minimum temperatures below 32°F for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.

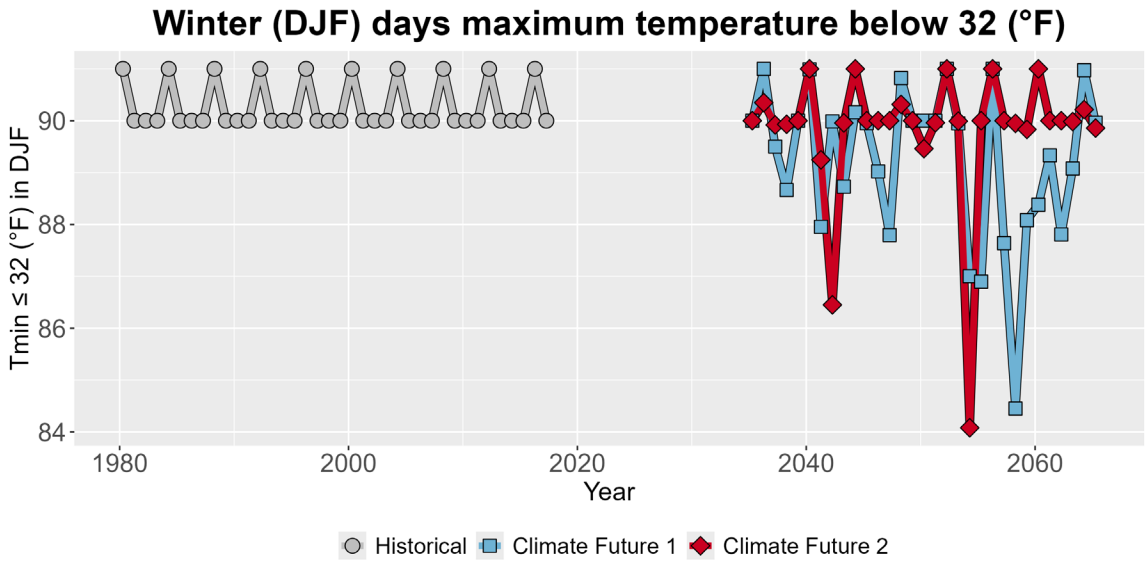

Figure A11. This line graph compares observed winter (DJF) maximum temperatures below 32°F at ALAG (1980-2016) with projected winter (DJF) maximum temperatures below 32°F for the two climate futures over the period 2035-2065. The historically observed data is shown in gray, Climate Future 1 is shown in blue, and Climate Future 2 is shown in red.