Fort Monroe National Monument Climate Futures Summary

Prepared by the National Park Service Climate Change Response Program, 2024
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Key messages

1. The climate has already changed in Fort Monroe National Monument. Since 1970, the park warmed at a rapid rate of 5.4 °F per century.
2. The future won't look like the past. All future projections in average annual temperature are above the recent historical average (1979-2012).
3. There's a range of ways the future climate may evolve. In 2050, average temperature projections range from +1.1 to +5.4 °F and precipitation from -0.3 inches (-0.7%) to +6.8 inches per year (+14.5%).
4. To account for this range, consider more than one future scenario. This report contains projections for Fort Monroe National Monument for "Warm Dry" and "Hot Wet" 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, declining 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 (historical trends) and plausible climate futures at Fort Monroe National Monument (FOMR). *Climate futures* are derived from models and explain different ways that the future might evolve at FOMR due to climate change. Climate futures help parks make short- and long-term *decisions that avoid surprises* and costly mistakes. The approach of

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[1] See Climate Change Glossary for full definition.

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. Runyon et al. (2024) includes an in-depth description of methods used for these analyses. Please read the Disclaimer for further information about interpreting climate future summaries.

Historical climate change

Temperatures at FOMR have already increased considerably (Figure 1). Average annual temperature increased at the rate of 1.4 °F per century from 1895-2022, and since the acceleration of anthropogenic climate changes around 1970, temperatures have increased at the rate of 5.4 °F per century. The hottest two years before 2000 were 1990 and 1991, and these anomalies were exceeded in 8 years since 2000 (36.4% of years). Since 1970, daily minimum (night-time) temperatures have increased more rapidly than daily maximum (daytime) temperatures, meaning nights are warmer and the range between daytime and nighttime temperatures has diminished.

Overall precipitation has increased since 1970 but remains highly variable. In addition to changes in average conditions, FOMR is also experiencing changes in extreme conditions. For example, there has been a 37% increase in the amount of rain falling during heavy storms in the region since 1958 (Figure 2). This is because warm air can hold more water vapor, so as temperatures increase, precipitation will fall in more intense and severe events.

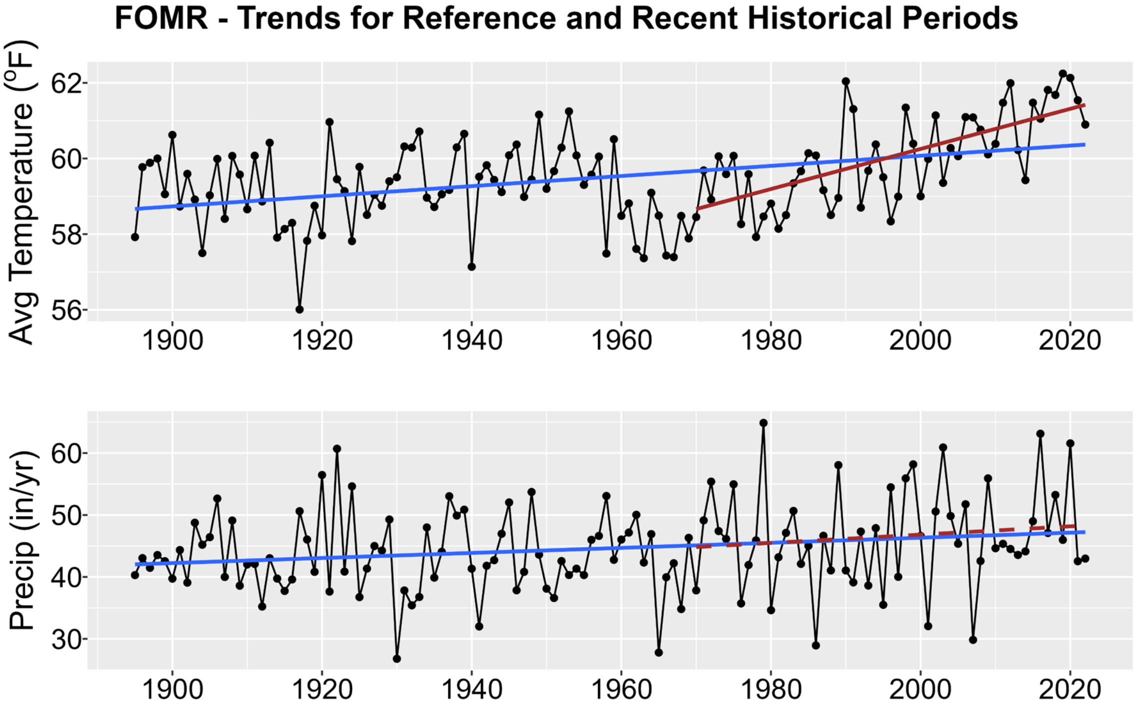

Figure 1. Historical trends in annual average temperature (upper plot) and annual total precipitation (lower plot) for FOMR from 1895-2022. Black points show yearly values while blue lines are linear regressions for the entire period record and red lines for 1970-2022 trends. Solid lines are significant trends (i.e., p<0.05); dashed lines are not statistically significant.

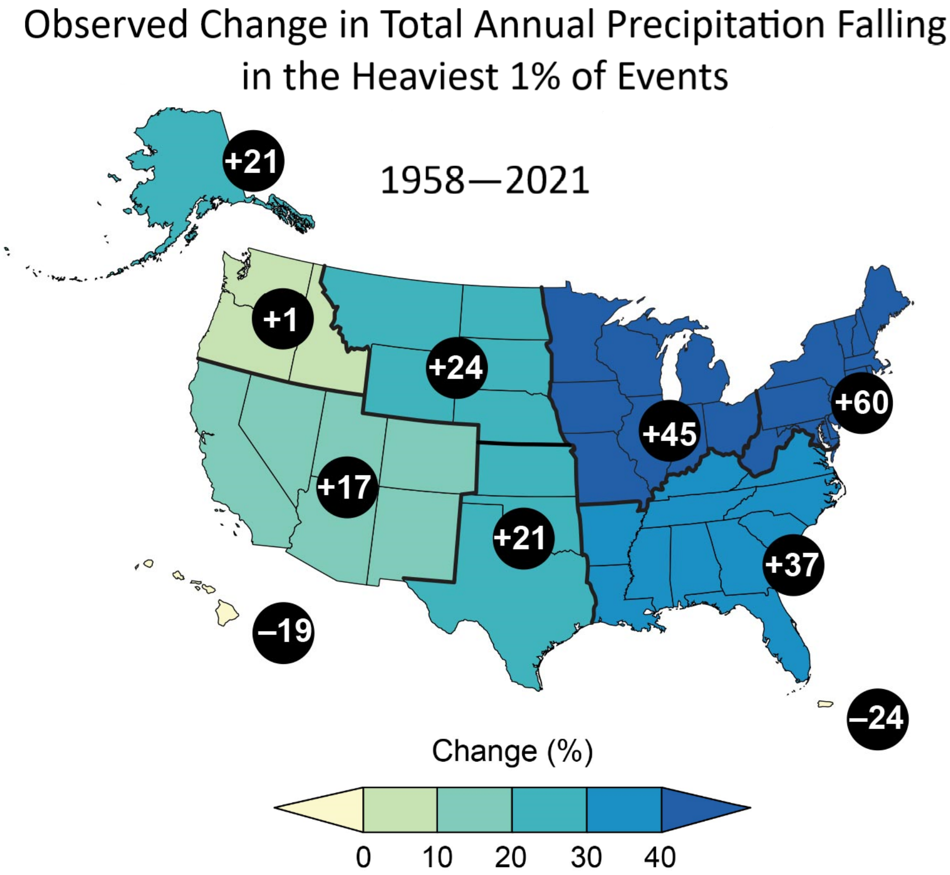

Figure 2. This map from the 5th National Climate Assessment (https://www.globalchange.gov/our-work/fifth-national-climate-assessment) shows regional changes in the amount of rain falling during heavy storms (heaviest 1% of events). For all regions in the contiguous US and Alaska, the percentage of rain falling during extreme precipitation events has increased since 1958.

Projected climate change and related impacts

We examined 40 different climate model outputs to characterize the uncertainty about how climate change could affect FOMR. Relative to the 1979–2012 baseline period[2] (see Runyon et al. 2024 for details), all climate models project significant warming by 2050 with projected increases in average annual temperature ranging from +1.1 °F to +5.4 °F. Projected changes in precipitation are less clear, with some models projecting a decrease in average annual precipitation by -0.3 inches (-0.7%) and others projecting an increase of +6.8 inches (+14.5%). 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 identified two plausible, divergent climate futures ("Warm Dry" and "Hot Wet") to capture relevant variation across climate models and greenhouse gas emissions scenarios (for more specifics on the process, see Lawrence et al. 2021; Runyon et al. 2024). These two climate futures represent different ways

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[2] The historical baseline used to compare with climate futures is from 1979-2012, the period of record for the observational dataset in the downscaling process. Historical comparisons for climate futures use this baseline period, instead of 1895-2022 range reported above to avoid statistical errors. See Runyon et al. (2024) for details.

the climate might develop at FOMR through 2050 and are both plausible. Neither of these projections should be considered as “predictions”—we cannot know how the future will unfold. Considering both climate futures will best help the park prepare for future conditions despite climate uncertainty.

It is important to note the naming of these futures is relative to one another, not the past. In other words, the Warm Dry climate future might be wetter than what the park experienced historically but the name denotes that it projects drier conditions than the Hot Wet climate future.

Annual average temperature and precipitation projections

Average annual temperatures are projected to increase under both the Warm Dry and Hot Wet climate futures relative to the historical baseline period (1979-2012). Increases by 2050 under the Warm Dry climate future are considerable (+2.4 °F) and increases under the Hot Wet climate future are extreme (+4.7 °F) (Figure 3. See Appendix 1 for “Projected changes in climate metrics”).

To put this in context, historically hot years recorded at FOMR would be “average” temperature years for most of this century in the Warm Dry climate future. Average temperatures under the Hot Wet climate future would generally exceed anything experienced at FOMR in recent history. These projections are consistent with temperature increases already observed due to climate change at FOMR.

Increases in average temperatures can result in a range of impacts to 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.

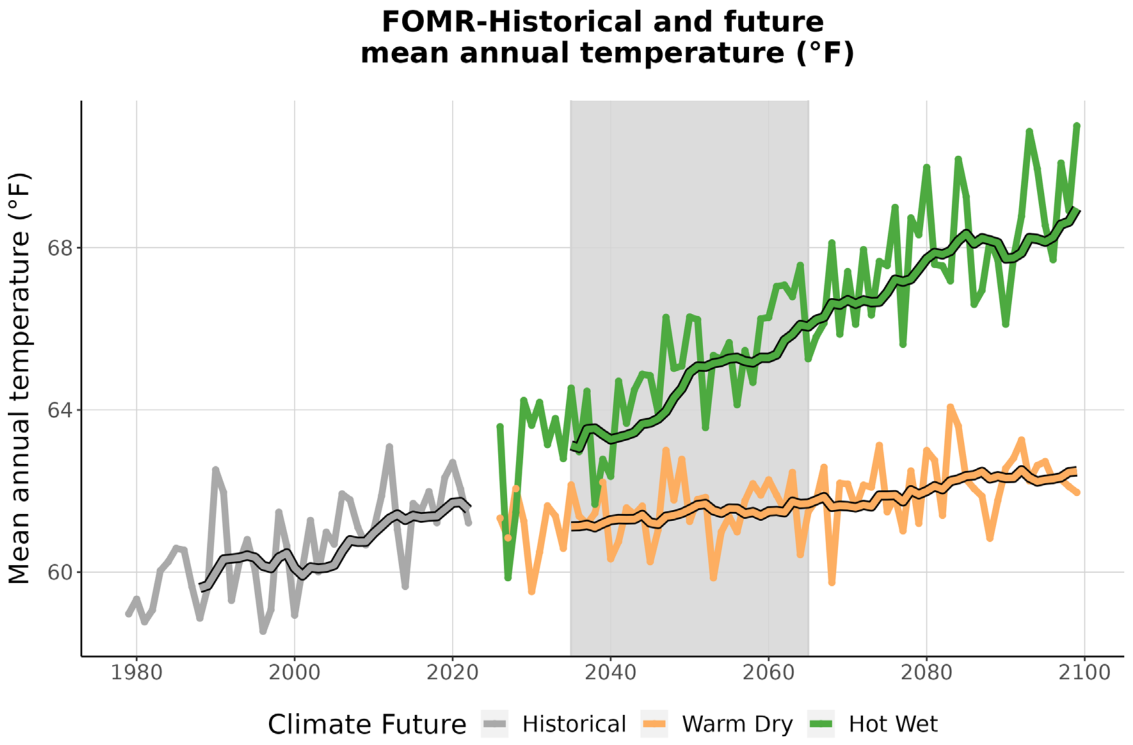

Figure 3. This graph compares observed average annual temperature at FOMR (°F) (1979-2022) with projected average annual temperature for the two climate futures over the period 2023-2099. The historically observed data

is shown in gray, the Warm Dry climate future in orange, and the Hot Wet climate future in green. The smooth line running through each projection is the 10-year running average for historical observations and future projections. Gray-shaded area represents the time period that was averaged (2035-2065) to summarize future projections for the year 2050 (Appendix 1).

Average annual precipitation is projected to be highly variable. Projections under both climate futures indicate considerably drier and also 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). This means that even very dry years could still occur under both climate futures, despite a positive trend in precipitation. Overall, our analysis projects +1 inches in annual precipitation under the Warm Dry climate future and +4.7 inches under the Hot Wet climate future relative to 1979-2012.

Although average annual precipitation is projected to increase, any changes in seasonal precipitation patterns could impact hydrologic systems, seasonal biology, and extreme events (see Appendix 1). 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.

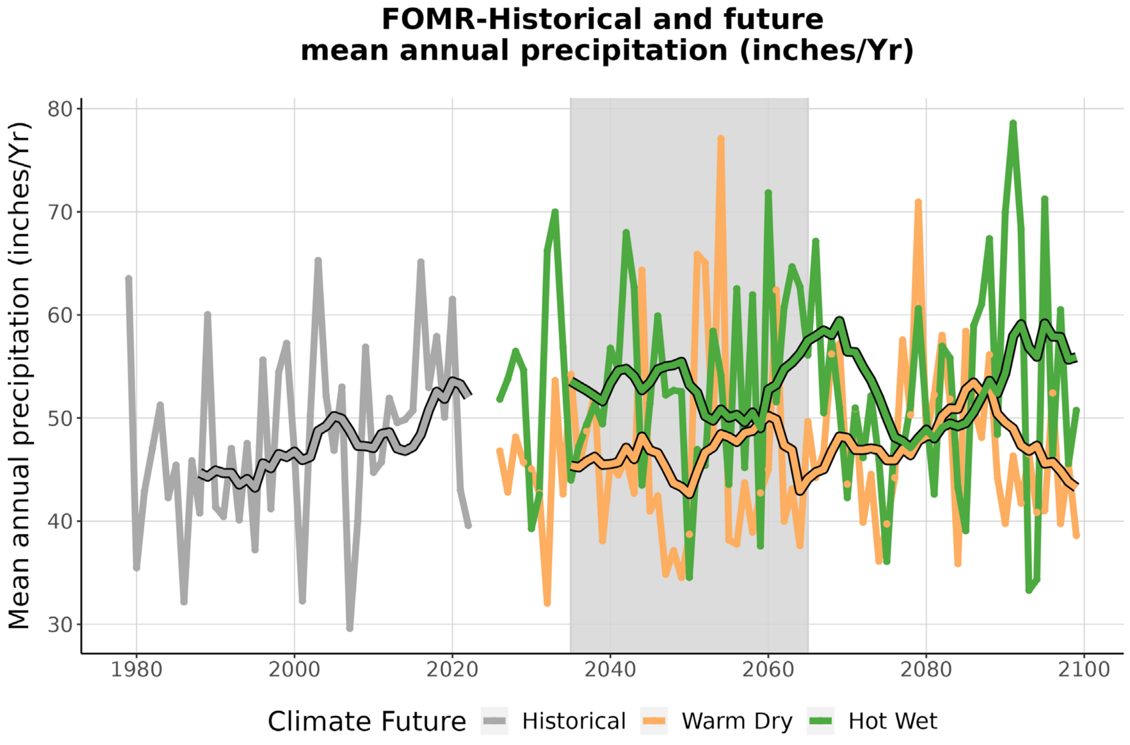

Figure 4. This graph compares observed average annual precipitation at FOMR (inches/year) (1979-2022) with projected average annual precipitation for the two climate futures over the period 2023-2099. The historically observed data is shown in gray, the Warm Dry climate future in orange, and the Hot Wet climate future in green. The smooth line running through each projection is the 10-year running average for historical observations and future projections. The gray-shaded area represents the time period that was averaged (2035-2065) to summarize future projections for the year 2050 (Appendix 1).

Extreme Events

Average temperature and precipitation changes, particularly annual measures, can demonstrate direction and relative magnitude of change for each climate future, but on their own can be difficult to translate into resource impacts. Averages do not adequately capture variability and resulting changes in extremes or compound events that are often highly consequential for resources. Therefore, we summarize metrics of climate extremes below.[3]

Extreme temperature

Extreme temperatures are expected to increase at FOMR under both climate futures (Figure 5), with an additional +8.1 days each year exceeding the historical 99th percentile (96.7 °F) threshold under the Warm Dry climate future and a more pronounced increase of +18.6 days each year under the Hot Wet future.

Dangerously hot days can pose health risks to park employees and visitors, particularly affecting vulnerable groups such as children, the elderly, and individuals with preexisting health conditions. The Occupational Safety and Health Administration (OSHA) has established guidelines associated with heat index classifications and protective measures that should be taken for ranges of heat index values (OSHA n.d.). Dangerous heat index days are days that exceed a heat index (a combination of heat and humidity) of 105 °F. In 2004, the NPS Risk Management Office issued guidance that general heat stress controls should be applied when the heat index exceeds 105 °F, which is within the "dangerous" heat index range (NPS 2004). At FOMR, the average days per year exceeding the dangerous heat index threshold is expected to increase in both the Warm Dry and Hot Wet climate futures (+17.7 days and +29.5 days, respectively).

Extreme temperatures can also lead to infrastructure issues, such as accelerating the weathering of structures, stressing power grids and air conditioning systems, buckling and cracking roadways, and other secondary effects. Parks should consider adaptation principles in design, construction, and maintenance of infrastructure–for example, installing additional shade structures to reduce visitor exposure to extreme heat.

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[3] The caveat for these climate extremes is that the analyses necessarily evaluate events that occur rarely and, as such, are less frequently observed and are difficult to characterize. There is, therefore, a broader range in these projections than for temperature or precipitation averages.

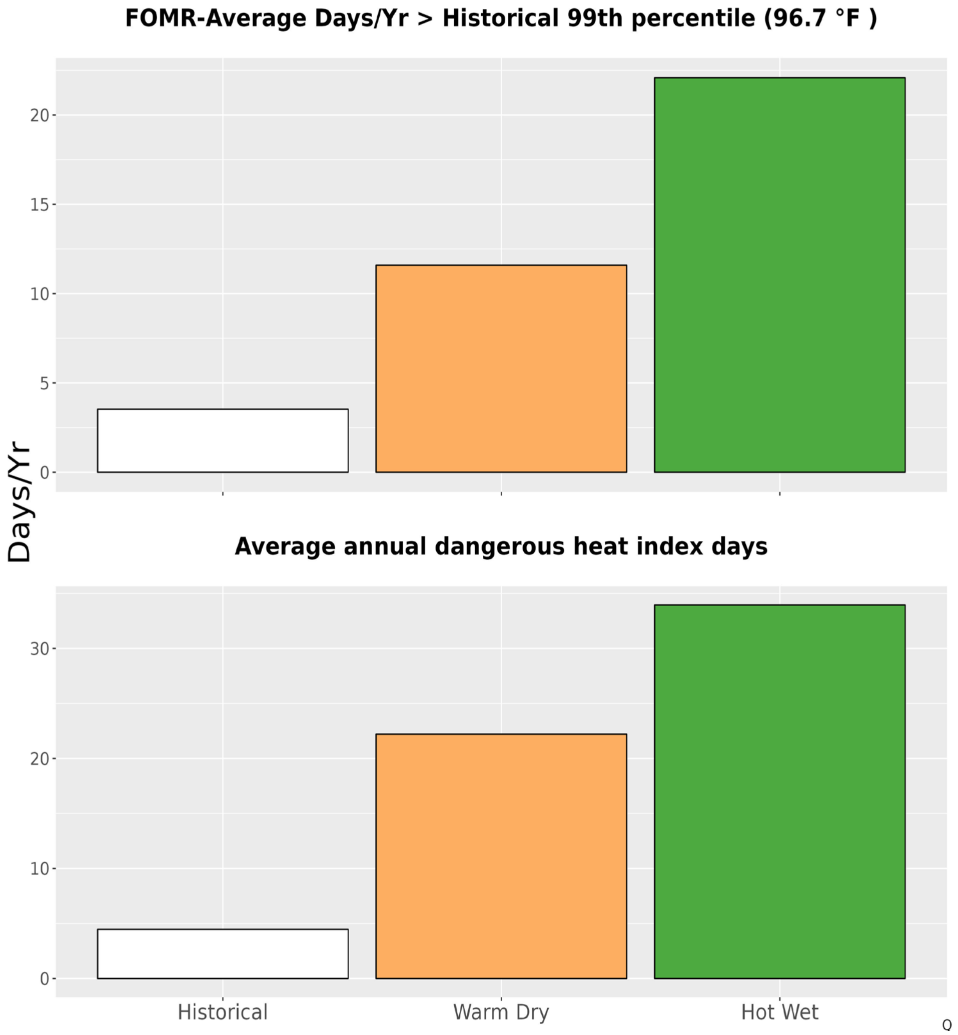

Figure 5. The upper bar graph represents the average number of days annually with temperatures greater than the historical 99th percentile (96.7 °F) historically (1979-2012) and for the two climate futures (2050). The bottom bar graph represents the average annual number of dangerous heat index days historically and for the two climate futures. Dangerous heat index days are days that exceed 105 °F.

Extreme precipitation

Changes in extreme precipitation are characterized by two factors: frequency (how often extreme precipitation events occur) and intensity (amount of rainfall during an event). Although both intensity and frequency often change in the same direction, impactful consequences—like ground saturation or rapid runoff—can result from changes in either intensity or frequency alone.

Figure 6 shows the number of days per year in which precipitation at FOMR is greater than or equal to 2.1 inches in 24 hours, which is the historical (1979-2012) 99th-percentile event. This measure of extreme precipitation frequency shows that the number of days with extreme precipitation greater than the historical 99th percentile is projected to slightly increase under both climate futures. The 24-hour period with the most precipitation observed historically (1979-2012) was 7.4 inches. The largest rainfall event projected in the future 30-year period (2035-2065) is 10.4 inches for the Warm Dry climate future and 11.2 inches for the Hot Wet climate future. Note that the maximum 24-hour precipitation events for the 30-year period are higher not only in the Warm Dry scenario but also in the Hot Wet scenario. This reflects the fact that climate change is projected to lead to more intense extremes in precipitation (USGCRP 2023). Managers should consider potential impacts to infrastructure from flooding, disruptions to transportation routes, water quality impacts from stormwater runoff into freshwater systems, and the potential for landslides or mudslides.

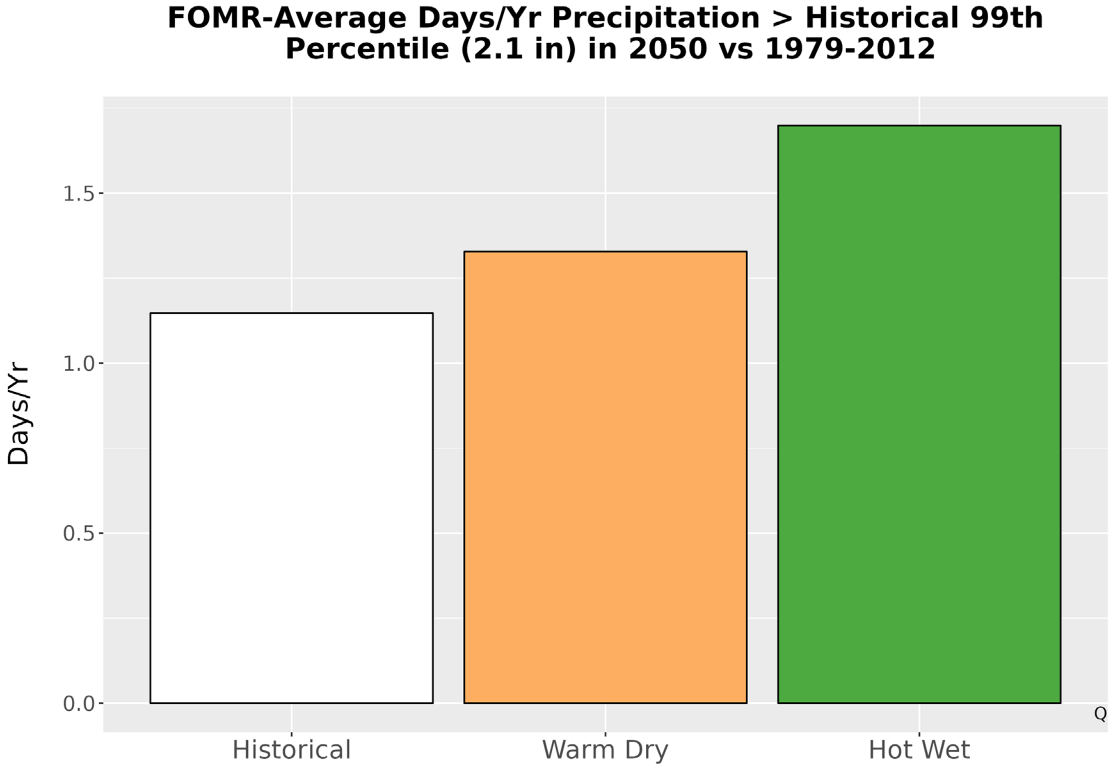

Figure 6. Average number of days annually with precipitation exceeding the 99th percentile (2.1 in.) of precipitation from the historical period 1979-2012 and for each climate future.

Drought

Exacerbated by more extreme precipitation regimes, hotter temperatures in both climate futures can rapidly evaporate surface water and increase drought risk. Figure 7 uses the Standardized Precipitation Evaporation Index (SPEI) to assess changing drought conditions at FOMR (Runyon et al. 2024). SPEI factors in both precipitation and evapotranspiration, providing a measure of how much water is available in an area compared to what occurred historically. Positive SPEI values indicate wetter-than-average conditions, while negative values indicate drier-than-average conditions. The further the bars are from zero (positive or negative), the more extreme the conditions are.

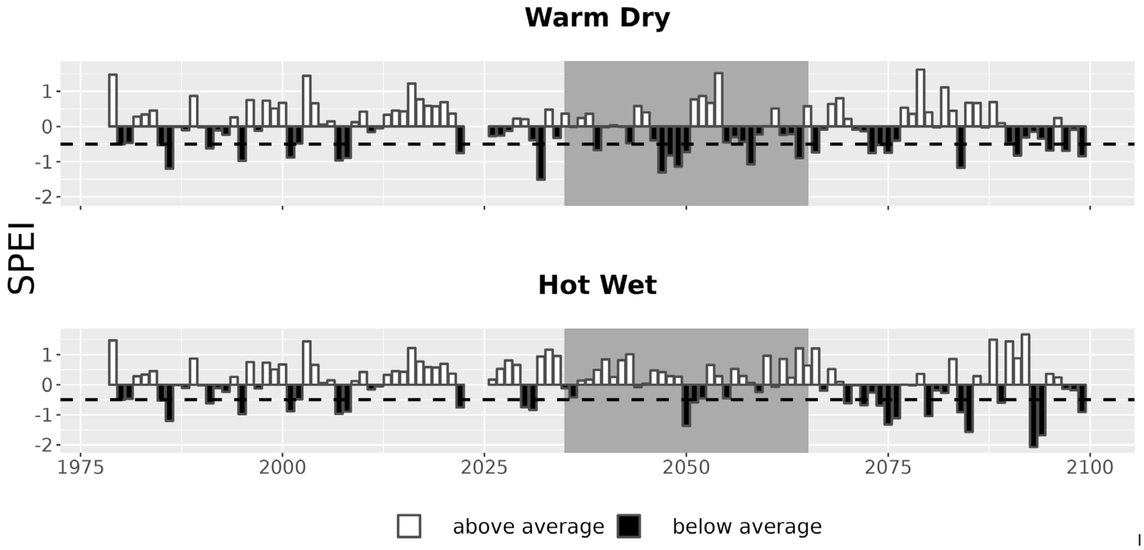

Figure 7. Drought metrics for FOMR. Drought index (SPEI; units = standard deviations from historical) timeseries for each climate future. Below-average SPEI (black bars) indicates dry conditions. The dotted line (SPEI = -0.5) indicates drought conditions.

Figure 8 complements the SPEI data by providing a more detailed view of projected drought characteristics in the region. Drought duration (left graph) refers to the length of time during which the area experiences continuous drought conditions, extending the impact on water availability in the area. The drought-free interval (middle graph, an alternative measure of drought frequency) represents periods between drought events when there is sufficient water availability. More years in a drought-free interval signify more extended periods of recovery from drought. Drought severity (right graph) reflects the intensity of drought conditions compounded by the duration of the drought period. For both the Warm Dry and Hot Wet climate futures at FOMR, average drought duration and drought-free intervals and are both projected to increase compared to recent history. Drought severity is projected to increase considerably as well, relative to the past.

For FOMR, drought under a Hot Wet climate future is projected to become increasingly severe compared to historical droughts, represented by the black bars in Figure 7. However, as we near mid-century (gray shaded area in Figure 7), drought-free intervals are also expected to increase. This means that managers should prepare for less frequent but more severe droughts than have been experienced in the past and consider adaptations for surface water and drought-intolerant plant species. For the Warm Dry climate future, droughts are projected to become longer and more severe, but FOMR is also projected to experience slightly longer drought-free intervals between drought events.

These projections are aligned with research showing that climate change may lead to droughts that are longer and more severe than what has occurred historically (USGCRP 2023). Generally, the longer that an area experiences drought conditions, the more severe the drought becomes. More severe and prolonged droughts pose a risk to water supplies and both human and ecosystem health. Areas prone to wildfires may also experience more severe and higher intensity fires, as drought can dry out vegetation and make it more likely to burn. The Northeast U.S. is a wet region that historically experiences damaging droughts, despite simultaneous increasing precipitation (Dupigny-Giroux et al. 2018). Climate models suggest that, despite projected increasing precipitation, increased temperatures and precipitation variability will likely lead to more frequent short, but intense drought conditions (Krakauer et al. 2019, Pendergrass et al. 2020). These “flash droughts” are characterized by short, intense sudden onset droughts and rapid intensification of conditions with severe impacts (Pendergrass et al. 2020). In 2016, the Northeast experienced an abnormally warm, dry summer, preceded by low winter snowfall causing a flash drought that challenged water resource managers throughout the region (Sweet et al. 2017). Managers should prepare for potential impacts to water sources, plant species, and ecosystem health in the face of severe and prolonged drought.

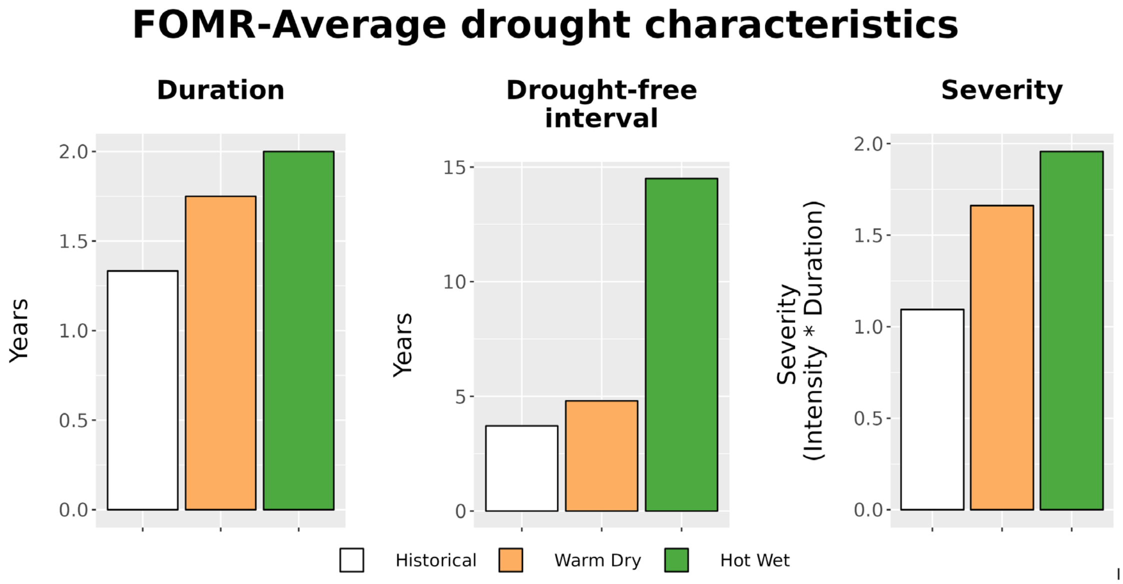

Figure 8. Drought metrics for FOMR. (Left) Average drought duration (years) historically (1979-2012) and under each climate future. (Middle) Average drought return interval (years), indicating the expected amount of time between periods of drought, historically and under each climate future. (Right) Average drought severity, a measure of drought intensity multiplied by duration, historically and under each climate future.

Plant-available water

Climatic water deficit—the difference between potential evapotranspiration and actual evapotranspiration—indicates the amount of additional water plants would use if it were available and it is often used to indicate landscape dryness. High climatic water deficit is also an indicator of increased fire risk and plant stress (Thoma et al. 2020). We use a water balance model to determine climatic water deficit that accounts for the interactive effects of temperature, precipitation, and local characteristics (e.g., slope, aspect, soil profile).

The average annual climatic water deficit at FOMR is projected to increase in both climate futures relative to the historical period (1979-2012) (Warm Dry: +1.2 inches/year, Hot Wet: +0.4 inches/year; Figure 9). Both climate futures project more years that are drier than in the past, some notably wet years, and fewer years that would have historically been considered ‘average.’ During years with a higher water deficit, managers can expect most years to have reduced plant growth, lower stream flow, and increased fire risk and plant stress.

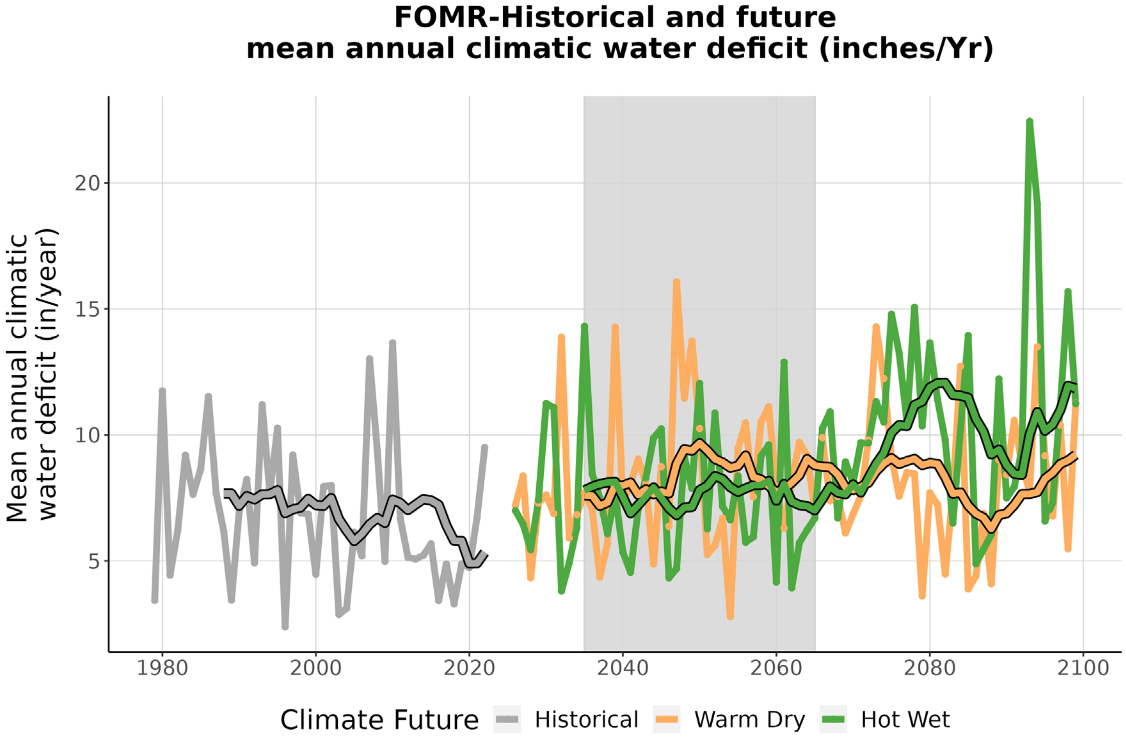

Figure 9. This line graph compares observed climatic water deficit at FOMR (inches/year) (1979-2022) with projected climatic water deficit for the two climate futures over the period 2023-2099. The historical observation data is shown in gray, the Warm Dry climate future in orange, and the Hot Wet climate future in green. The smooth line running through each projection is the 10-year running average for historical observations and future projections. Gray-shaded area represents the time period that was averaged (2035-2065) to summarize future projections for the year 2050.

Other Possible Climate-related Impacts

Other potential climate-related impacts that may occur at FOMR 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 FOMR, park staff should be aware of their potential threat and further study may be warranted.

Wildfire

Wildfire is a natural part of many forest, woodland, and grassland ecosystems. Extremely severe and intense fires, however, can transform ecosystems, endanger human life, impact air quality, and damage infrastructure. Climate change is intensifying the heat that drives wildfire (Jolly et al. 2015) and altering the distribution and density of vegetation that comprises the fuel for wildfires (Westerling 2016). The effects of climate change on wildfire vary across landscapes. For areas where projected climate change increases fire risk, buildings, cultural landscapes, and other infrastructure are vulnerable to burning and destruction. Furthermore, wildfires can endanger human life and the impacts of wildfire on air quality can have serious health impacts, especially for vulnerable populations. Finally, wildfire leaves a lasting, physical mark on ecosystems and natural landscapes which may alter park visitation, tourism, and recreation both during and after a wildfire.

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 mean conditions that affect species' life cycles and their ability to spread into new areas. 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. FOMR is in a region where climate change can favor invasive alien plant species in temperate zone ecosystems due to increased warmth, humidity, vegetation disturbances, and atmospheric carbon dioxide (Davidson et al. 2011, Hellmann et al. 2008, Liu et al. 2017). 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 should be 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 have resources available to help parks detect and prevent pests.

Phenology

The timing of spring onset affects the seasonal life-history stages of plants throughout the national parks. 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). Earlier spring onset and longer growing seasons influenced by climate change will alter the phenological patterns of species that flower before or after peak summer heat, follow other temperature cues, or are driven by water availability. Spring timing can impact animals reliant on the rhythms of plant life stages (e.g., mismatches in plant-pollinator interactions), the timing of park operations, events, and visitor uses (e.g., road openings, flower festivals, and backcountry recreation), cascading effects on carbon cycling and other ecosystem processes, the risk of "false springs" that create devastating hard freezes and facilitate the spread of invasive species.

Coastal

Cumulative impacts of sea level rise and storm surge on FOMR ecosystems threaten the stability of the land on which infrastructure is based and will flood many of those structures during intense storm events. Higher relative sea level causes accelerated coastal erosion, landward migration of shorelines, saltwater intrusion and changes in groundwater, and amplifies flooding caused by higher storm surges. Sea level rise poses considerable risks to infrastructure, lighthouses, forts, and other historic structures.

Since coastal terrestrial and freshwater ecosystems are highly sensitive to increases in inundation and salinity, sea level rise could result in the rapid conversion of these systems to tidal saline habitats. Historically, coastal ecosystems in the region have adjusted to sea level rise by vertical and horizontal movement across the landscape (Doyle et al. 2015). Where barriers are present (for example, levees and other coastal infrastructure), the potential for landward migration of natural systems will be reduced and certain coastal habitats will be lost. For example, mangroves or salt marshes—which stabilize sediments—might be able to keep pace with slowly rising sea levels by accumulating soil and effectively raising ground elevation. These habitats are also natural buffers for park infrastructure and help stabilize soils; restoring degraded areas and mitigating additional impacts to these "natural defenses" for park infrastructure must be a component of any park asset management plan.

Hurricanes also threaten structures via damage from wind, wind-blown rain, and debris. Their large temperature swings stress buildings through sudden thermal expansion and can crack pipes; they also can cause flooding and road wash outs. With higher sea levels and increasing saltwater intrusion, the high winds, high precipitation rates, and storm surges that accompany hurricanes will have large ecological impacts to terrestrial and freshwater ecosystems.

Tools are available to track sea level rise through the NOAA Sea Level Rise Viewer in locally mapped 1 foot increments or NASA Sea Level Change Portal of interagency SLR scenarios (Sweet et al. 2022) by decade based on the nearest NOAA tide gauge. For parks with exposure or vulnerability assessment by asset, check the Climate Vulnerability Data Viewer, and the links for climate change vulnerability assessment for infrastructure through the eTIC, or Coastal Facilities Vulnerability Assessments.

Adaptation planning: Address climate change impacts and implications

Concepts from Planning for a Changing Climate (National Park Service 2021) can help address the above-described potential climate impacts in planning for FOMR 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, testing 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 FOMR. 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. If a goal clearly cannot be met under projected future conditions, it needs updating. Goals should acknowledge continuous change and the potential for unavoidable losses or ecological transformations.

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 ("Warm Dry" and "Hot Wet") that represent plausible future conditions for FOMR. 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 the Warm Dry scenario?	Is the Desired Condition achievable under the Warm Dry scenario?	How will climate change affect this desired condition under the Hot Wet scenario?	Is the Desired Condition achievable under the Hot Wet scenario?	Revise Desired Condition? Remove Desired Condition?
Wetlands	No net loss of wet meadows and fens	Marginal wetlands may convert to uplands due to warmer conditions. Some wetlands could expand or remain stable under wetter conditions.	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 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.

See Runyon et al. (2024) for details on data, methods, further discussion on scope and limitations, and FAQ section.

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Appendix 1. Climate futures table

Table A1. Projected changes in climate metrics presented in this report. Change values are the difference between the climate metric's future-period (2035-2065) average and the historical-period (1979-2012) average.

Climate Metric	Historical	Warm Dry	Hot Wet
Change in annual average temperature (°F)	60.4	+2.4	+4.7
Change in average winter (DJF) temperature (°F)	42.3	+1.9	+4.4
Change in average spring (MAM) temperature (°F)	58.7	+2.5	+4.8
Change in average summer (JJA) temperature (°F)	78.1	+2.7	+4.9
Change in average fall (SON) temperature (°F)	62.2	+2.3	+4.7
Change in annual precipitation (in)	46.6	+1	+4.7
Change in average winter (DJF) precipitation (total in)	10	+0.7	+1.1
Change in average spring (MAM) precipitation (total in)	11.2	+0.8	+1.6
Change in average summer (JJA) precipitation (total in)	13.6	-0.2	+1.8
Change in average fall (SON) precipitation (total in)	11.9	-0.2	+0.2
Change in days / > 99th Tmax / year (number of days)	3.5	+8.1	+18.6
Change in days with 'dangerous' heat index (number of days)	4.5	+17.7	+29.5
Change in largest rainfall event (in/day)	7.4	+3	+3.8
Change in days > 99th precipitation / year (number of days)	1.1	+0.2	+0.6
Change in average drought duration (years)	1.3	+0.5	+0.7
Change in drought-free interval (years)	3.7	+1.1	+10.8
Change in drought severity	1.1	+0.6	+0.9
Change in annual average water deficit (in/yr)	7.2	+1.2	+0.4
Change in annual actual evapotranspiration (in/yr)	30.9	-0.1	+3.8