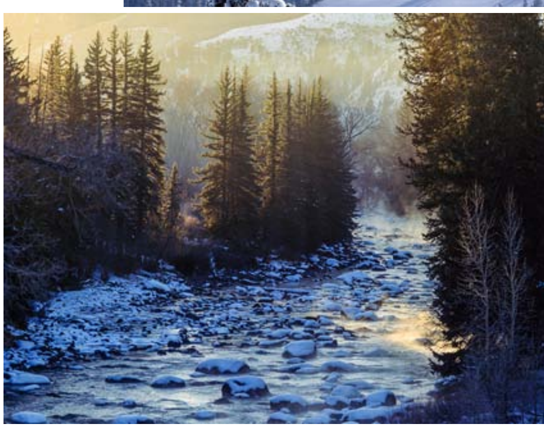
Climate Projections in Eagle County, Colorado



A report to Eagle County and
NWCCOG Water Quality/Quantity Committee

the ROCKY MOUNTAIN CLIMATE Organization

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Updated December 2021

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By
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A report by the
Rocky Mountain Climate Organization

to
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Governments Water Quality/Quantity Committee
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the ROCKY MOUNTAIN CLIMATE Organization

The Rocky Mountain Climate Organization works to reduce climate disruption and its impacts to help keep the Interior West the special place we love. We do this in part by spreading the word about what a disrupted climate can do to us here, such as through reports like this, and also about what we can do to protect our climate.

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December 2021 update

This version of this report is an updated version of the report originally released in August 2021. The material changes are the addition of two new figures (Figure 4 and Figure 7), an update with final information on summer 2021 temperatures (on page 11), and miscellaneous minor corrections.

Dedication

This report and a companion report, Climate Projections in Summit County, Colorado, are both dedicated to Adam Palmer, sustainability director for Eagle County until his untimely death in February of this year. Adam played an instrumental role in getting these reports underway and shaping them—just one example of his many efforts to preserve and protect the quality of life in Colorado's mountains.

Acknowledgements

The authors wish to thank for providing assistance on this report: first and foremost, Torie Jarvis, Northwest Colorado Council of Governments Water Quality/Quantity Committee (QQ), via Dynamic Planning + Science, for her leadership in bringing together the local governments that with QQ sponsored this project and in managing this project; Alex Krebs, also of Dynamic Planning + Science; Jessie Burley and Haley Littleton, Town of Breckenridge; former County Commissioner Jill Hunsaker Ryan, John Gitchell, Maureen Mulcahy, and Justin Patrick, Eagle County; Mayor Hunter Mortenson, Don Reimer, Gilly Plog, and Ryan Thompson, Town of Frisco; former County Commissioner Karn Stiegelmeier, Nicole Valentine, and Michael Wurzel, Summit County; Kristen Bertuglia and Suzanne Silverthorn, Town of Vail; Mike Nathan, Arapahoe Basin Ski Area; and John Fielder.

Cover photos clockwise from the top: Vail Ski Resort and Grizzly Creek fire, from istockphototo/ Adventure_Photo, and Eagle River, from and © John Fielder.

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Executive Summary

This analysis of climate change projections for Eagle County, Colorado, shows how much this area has at stake as human activities continue to change the climate, and how much difference it can make locally—how much the local climate would be protected—if heat-trapping emissions are sharply reduced.

This report, and a parallel one covering Summit County, Colorado, identify in detail what climate models project for future local temperature and precipitation. Each report analyzes 24 million individual projections of daily high and low temperatures and precipitation amounts:

- downscaled to produce local results for three specific areas in the county;
- using four different scenarios of future levels of heat-trapping pollution;
- derived from 12 to 20 global climate models per emission scenario; and
- covering four 20-year periods across the rest of this century.

Hotter summers

The most striking projections are for how much hotter Eagle County summers could become unless heat-trapping emissions are sharply reduced.

The following examples are all for the Edwards/Avon area with high emissions. The hottest days of the year in the area are projected, according to the median projections from multiple models::

- In typical mid-century (2020–2039) years, to average 90°—compared to 84° in 1970–1999.
- In the extreme year in mid-century, to be 95°—compared to 90° in 1970–1999..
- In typical late-century (2080–2099) years, to average 96°.
- In the extreme year in late century, to get all the way up to 101°.

So an *average* summer day in mid-century could be as hot as the single hottest day of the late 20th century.

Even more telling might be how much more common hot days could become. Days 85° and hotter per year in this area:

- In typical mid-century years, could average 16 days—compared to just one per year in 1970–1999.
- In the extreme year in mid-century, would occur 43 times—compared to seven in 1970–1999.
- In typical years late in the century, to average 60 days, or two months's worth.
- In the extreme year late in the century, to occur 88 times, or essentially all summer long.

In the area around the town of Eagle, at a lower elevation where the climate is warmer, and again with high emissions, the median projections are that the hottest days of the year would:

- In mid-century average 95°, and in the extreme year be 100°—compared to 89° for the average and 94° for the extreme value in 1970–1999.
- Late in the century average 100°, and in the extreme year be 106°.

Also in this area with high emissions, days 90° and hotter per year would:

- In mid-century average 11 such days in typical years, and in the extreme year occur 39 times—compared to an average of 0.6 such day and an extreme value of seven days in 1970–1999.
- Late in the century, average 52 such days in typical years, and in the extreme year occur 89 times.

The above projections are for average conditions across a grid of 18 miles by 14 miles, within which temperatures would vary with elevation. The communities of Edwards, Avon, and Eagle are all at lower elevations than the average for the grids they are in, so their actual temperatures would be higher than the grids's averages.

Sharp emission reductions halt temperature changes

There is good news, too, from this analysis—it also shows how completely the above changes can be avoided if global emissions of heat-trapping pollution are sharply reduced. The median projections for the Edwards/Avon area, but now with low future emissions, are:

The hottest days of the year are projected:

- In 2020–2039 in typical years, to average 88°, four degrees above the 1970–1999 average.
- Then to remain the same for the rest of the century—in each of the periods 2040–2059, 2060–2079, and 2080–2099, to again average 88°.

Days 85° and hotter are projected:

- In 2020–2039 in typical years, to average five such days per year, compared to one in 1970–1999.
- Then to stay essentially the same thereafter, with five such days in both 2040–2059 and 2060–2079, then actually dipping to four such days in 2080–2099.

Warmer winters and earlier spring warm-up

Temperatures were analyzed for the stretch from November 25 of one year to April 15 of the next year, chosen to approximate the core season for both snowpack accumulation and skiing and other snow-dependent sports. In the Vail Mountain area (including the Vail Ski Resort) with high emissions, the median projections are that days with high temperatures above 32°:

- In mid-century typical years, would average 55 percent of the days in that snow/ski season—compared to 40 percent in 1970–1999.
- In the hottest mid-century year, would be 71 percent of those days—compared to a high value of 58 percent in 1970–1999.
- Late in the century, in typical years would average 69 percent, and in the extreme year be 83 percent of those days.

Spring days 40° or hotter are warm enough for snowmelt and slushy skiing. For the stretch of March 16 through April 15, the last month of the core snow/skiing season, they are projected for the Vail Mountain area with high emissions:

- In mid-century typical years, to average 56 percent of the days—compared to 38 percent in 1970–1999.
- In the hottest mid-century year, to occur in 81 percent of the days—compared to a high value of 71 percent in 1970–1999.
- Late in the century in typical years, in 71 percent of the days, and in the extreme year, in 89 percent of the days.

Precipitation

Projections about precipitation are less certain than those about temperatures, and projections about summer precipitation are especially uncertain here because the models do not well represent this region's summer monsoons. But the models are consistent in suggesting two changes in precipitation changes that are particularly noteworthy.

First, the models generally project that for the cold months of the year (November through April) continued heat-trapping emissions will lead to increased precipitation. For example, in the Vail Mountain area with high emissions, the median projections are that cold season precipitation is projected:

- In mid-century typical years, to increase by seven percent, compared to 1970–1999.
- In late-century typical years, to increase by seventeen percent.

Second, the models project that days with modest precipitation (less than one-quarter inch) will become less frequent, but days with heavier precipitation amounts will become more frequent. Again using as the example the Vail Mountain grid, the median projections are that with high emissions:

- Wet days with less than a quarter-inch of precipitation are projected to average four percent less frequent in mid-century, and nine percent less frequent late in the century, compared to 1970–1999.
- Days with a quarter-inch to a half-inch of precipitation are projected to average fifteen percent more frequent in mid-century, and 23 percent more frequent late in the century.
- Days with a half-inch or more of precipitation are projected to average fifteen percent more frequent in mid-century, and 33 percent more frequent late in the century.

Consequences

Assessing the impacts of these climate changes is beyond the scope of this report, but the scientific literature documents that the changes projected here are likely to lead to the following impacts.

- Higher temperatures increase the acreage burned in wildfires and the length of the wildfire season. Projections range up to a nearly seven-fold increase in this region in area burned with only a modest increase in temperatures.
- Increases in wildfires obviously threaten people's safety and property, particularly as building expands in fire-prone areas. More wildfire smoke also increases the risk of respiratory disease and mortality, and heavy precipitation on burned areas leads to more debris flows, such as the mudslides this summer in Colorado that have repeatedly closed mountain highways.
- The season for skiing, snowboarding, and other snow-dependent sports could be shorter and the snow slushier—reducing enjoyment for skiers, profits for skiing-dependent businesses, and tax revenues for state and local governments. If ski areas do not experience long enough stretches of sub-freezing temperatures, it is conceivable they will not be able to maintain snowy slopes, regardless of whether they have snowmaking equipment or the water supply, shortening the length of the ski season.
- Increased temperatures, especially the earlier occurrence of spring warmth, have already altered the water cycle across the West, with changes that include decreases in snowpack and its water content, earlier streamflows, and shifts in precipitation from snow to rain.
- Higher temperatures decrease water availability, by increasing evaporative losses from water bodies, soils, and plants, and increase irrigation requirements for crops and other outdoor plants.
- Higher temperatures and reduced river flows clearly can reduce fishing and rafting. Other impacts to summertime recreation and tourism could include losses of visitation and visitor enjoyment, from causes ranging from temperatures too high for outdoor activities to disrupted transportation systems.
- Higher temperatures, especially if combined with drier summers, can increase tree mortality. In Colorado, tree mortality in subalpine forests has increased in recent decades, with the greatest increases occurring during hot, dry periods.
- Hotter and drier conditions can drive outbreaks of insects such as bark beetles as trees lose their resistance to infestations, allowing insect populations to grow to epidemic levels.
- The potential increases in summer heat identified in this report, especially with high emissions, are large enough to raise questions about possible impacts on public health, because extreme heat can cause increased illnesses and death. However, the models analyzed here project that even in the Eagle area with high emissions late in the century, the warmest nights of the year are not projected to get above the low 60°s in this century, which can provide an important respite to daytime extreme heat.

Especially when considered with additional scientific information on these and other possible impacts, the local climate projections analyzed in this report can help local governments, stakeholders, and the general public assess the possible future extent of these projected changes and their impacts in Eagle County, and guide local public and private decisions about taking actions both for climate protection and for climate change preparedness.

1. Introduction

This analysis of climate change projections for Eagle County, Colorado, shows how much this area has at stake as human activities continue to change the climate, and how much difference it can make locally—how much the local climate would be protected—if heat-trapping emissions are sharply reduced.

Analysis overview

This report, and a parallel one covering Summit County, Colorado,[1] identify in detail what climate models project for future local temperature and precipitation. Each report analyzes 24 million individual projections of daily high and low temperatures and precipitation amounts:

- downscaled to produce local results for three specific areas in the county;
- using four different scenarios of future levels of heat-trapping pollution;
- derived from 12 to 20 global climate models per emission scenario; and
- covering four 20-year periods across the rest of this century.

The analysis draws on the methodology developed in two parallel 2015 Rocky Mountain Climate Organization reports focused on Boulder and Larimer counties, funded by the Colorado Department of Local Affairs using federal disaster recovery funds, to help those localities and others prepare for wildfire and flooding threats as they become more extreme from continuing climate change, and expanded upon for two 2017 reports on projections for extreme heat and for precipitation in the Denver metropolitan area, funded by the City and County of Denver's Department of Environmental Health.[2] For the current reports, this methodology was adapted to focus on the climatic conditions most important in Colorado's mountains. The Denver reports and the two new reports are, as far as the authors are aware, the most detailed analyses yet done of climate model projections for any locality. This is in part because these three reports analyze not just future average conditions but also future temperatures in extreme years—in the projected hottest year in each succeeding 20-year period over the rest of this century.

The analyses for Eagle and Summit counties certainly are the most detailed analysis of the details of climate model projections for Colorado mountain locations, and should be of interest not only in those counties but also in other locations in the Southern Rocky Mountains that could experience similar changes.

The projections analyzed in this report are from global climate models that have been downscaled to produce local results and made available on an online archive created by federal agencies and others.[3] Similar downscaled projections have been used in many previous analyses, notably in this state *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation (Second Edition—August 2014)*, a report prepared by the Western Water Assessment (WWA) program at the University of Colorado Boulder for the state government's Colorado Water Conservation Board.[4] This WWA report remains the primary overall source focused on what climate change may be like in Colorado. In its report, WWA reported on many ways that climate change could be manifested in the state, including that with continued high increases in future heat-trapping emissions, statewide average temperature could increase by 2035–2064 by 2.5° to 5.5°*, compared to 1971–2000, under the emission scenario identified in this report as "medium #1" or by 3.5° to 6.5° under the "high emissions" scenario (see page 7 for details on those scenarios). These temperature ranges cover the middle 80 percent of the available projections from climate models, in the same manner illustrated by Figure 3 on page 8.

The analysis done for this report differs from and adds to the WWA report in several ways:

- First and most importantly, this report analyzes model projections for conditions that could occur on individual days—projected high and low temperatures and precipitation amounts for every individual day from January 1, 2020, through December 31, 2099 (plus retrospective projections for daily

*All temperatures presented here are in degrees Fahrenheit.

conditions in the 1970–1999 baseline). Projections for individual days have no particular reliability, but an analysis of the average and extreme daily conditions projected to occur over the 20-year periods used here identifies in detail how the models suggest that the future climate may change. Analyzing daily data in this way is rare, as it requires analyzing literally millions of more individual projections than the few thousands of projections for future decadal, annual, seasonal, and monthly averages typically analyzed by scientists (including by WWA in its report). The far more laborious process of analyzing daily projections makes it possible to identify such details as how often the models project that daily temperatures could reach certain thresholds.

- Second, this report considers projections from all four current scenarios for future levels of heat-trapping emissions (described on page 7). Considering all scenarios shows the full range of possibilities embodied in the models and shows how much difference will be made by the extent to which global emissions are reduced.
- Third, this analysis covers the full century, with results presented for four 20-year time periods—2020–2039, 2040–2059, 2060–2079, and 2080–2099. The first of those periods is a time span we have just entered, and covers the immediate planning horizon for local governments and others. Together, all four periods cover the expected lifetimes of children alive today.

For more, see the Methodology section on pages 49–50.

Geographic area

This analysis covers three separate grids in Eagle County, each one-quarter of a degree of latitude by one-quarter of a degree of longitude, or about 14 miles by 18 miles. Grids of this size are the smallest units for which the projections from the global climate models have been downscaled to yield local projections. These three grids, shown in Figure 1 on the next page, are identified in this report as:

- The **Edwards/Avon Reservoir grid**, with elevations from about 7,200 to about 11,000 feet above sea level, The grid includes the community of Edwards, with an elevation of 7,552 feet; the Town of Avon, at 7,431 feet; and nearby areas. The average high temperature in this grid in 1970–1999 was 51°, the average low temperature was 20°, and precipitation averaged 24 inches per year (see the tables at the end of the temperature and precipitation sections).
- The **Vail Mountain grid**, ranging from about 9,000 to 11,400 feet, and has the highest average elevation of these three grids. The grid includes the Vail Ski Resort. The average high temperature in this grid in 1970–1999 was 46°, the average low temperature was 17°, and the average annual precipitation was 31 inches. (The nearby town of Vail, to the north of this grid, has an elevation of 8,150 feet.)
- The **Eagle grid**, from about 6,600 to about 9,200 feet in elevation. The grid includes the town of Eagle, at 6,601 feet, and the nearby area. The average high temperature in this grid in 1970–1999 was 55°, the average low temperature was 21°, and the average annual precipitation was 17 inches.

Caveat: Temperatures vary within grid

In the database of climate projections analyzed for this report, the values for temperature and precipitation are average values across a particular grid. All of these three grids include many different elevations, and temperature varies with elevation—decreasing by an average of about 3.4° with every 1,000 feet of additional elevation.[5] This means that a grid's average temperature best represents the conditions at a grid's average elevation, and that a particular location at an elevation lower than that would be warmer than the grid's average and one at a higher elevation would be cooler.

An example from a grid analyzed for the RMCO covering Summit County, a companion report to this one (see the previous page), provides data that best illustrates this point. A weather station in the Frisco/Dillon Reservoir grid analyzed in that report is at an elevation of 9,081 feet, one of the lowest elevations within that grid. The weather station had an average summertime (June-July-August) high temperature in the baseline period of 70.9°.[6] That is nearly 3° hotter than the grid's comparable baseline value, reflecting the station's lower elevation than the grid's average elevation. With respect to this report, Edwards, Avon, and Eagle are all similarly at the low end of the elevations in their respective grids, and the actual temperatures in those communities, too, would all be higher than the average values projected for the grids.

Eagle County grids analyzed in this report

Figure 1. The three grids for which climate projections were separately analyzed for this report: (1) the Edwards/Avon grid, (2) the Vail Mountain grid, and (3) the Eagle grid.

Emissions scenarios

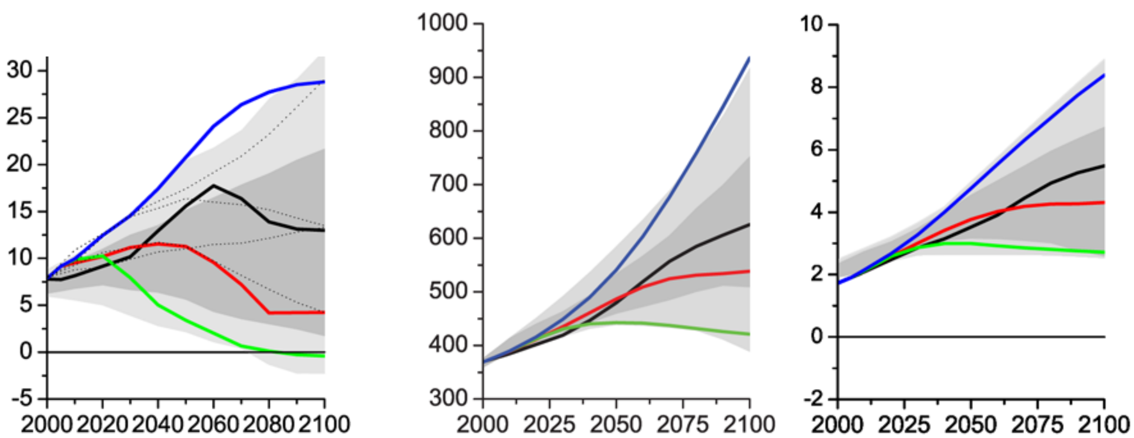
Projections of the future climate vary depending on what is assumed about future levels of heat-trapping emissions, because the magnitude of future climate change depends primarily on cumulative emissions of heat-trapping gases and how sensitive Earth's climate is in responding to those emissions.[7]

The four emission scenarios illustrating possible futures used to drive the climate projections analyzed in this report[8] are:

- What is called here the **high** scenario. Officially known as Representative Concentration Pathway or RCP 8.5, it represents an increase in energy of 8.5 watts per square meter at Earth's surface at the end of the century. To result in that level, it assumes little change in emission reduction policies; it is not a true business-as-usual scenario, but is the closest to that of the four scenarios.[9] In Figure 2 below, the high scenario is represented by the blue lines.
- A **medium #1** scenario. Officially known as RCP 6.0, again based on the net energy change at the end of the century, it initially assumes the lowest emissions levels of all scenarios but then sharp increases. From the 2060s to the end of the century, it assumes the second highest atmospheric concentrations of heat-trapping gases. It is represented by the black lines in Figure 2.
- A **medium #2** scenario, or RCP 4.5. It starts out with higher emissions than medium #1 but then has major reductions after mid-century, as shown by the red lines in Figure 2.
- A **low** scenario, RCP 2.6. It assumes emissions cuts of more than 70 percent from current levels by 2050 and an elimination of net human emissions by about 2080. This likely would keep the average global temperature increase under 3.6° (2° Celsius) compared to pre-industrial levels, but not enough to achieve the official international goal of keeping it "well below" 3.6°, preferably to 2.7° (1.5° C).[10] The low scenario is represented by the green lines in Figure 2.

No scenario is believed to be more likely than the others—instead, they were chosen to illustrate the range of plausible futures. Actual global emission levels in recent years have been lower than the high scenario's pathway, but closer to it than to any other scenario.[11] (For more on the scenarios, see pages 49–50.)

Scenarios of Future Heat-Trapping Emissions



A. Annual Emissions of Carbon Dioxide

B. Atmospheric Concentrations of Carbon Dioxide

C. Radiative Forcing

Figure 2. Key values for the four emissions scenarios used in this analysis: A, annual global emissions of carbon dioxide, the principal heat-trapping pollutant, in gigatons of carbon; B, atmospheric concentrations of carbon dioxide, in parts per million; and C, radiative forcing, or the average warming at Earth's surface resulting from heat-trapping pollution, in watts per square meter. In all three parts of the figure, the blue lines represent the scenario identified as "high" in this report; the black lines, "medium #1"; the red lines, "medium #2"; and the green lines, "low." Figures provided by Detlef van Vuuren.[12]

Climate models

The climate projections used in this analysis were obtained by RMCO from an online archive created by the U.S. Bureau of Reclamation and other institutions.[13] The projections are from the generation of climate models, known as CMIP5 models, that are the latest models have been downscaled to produce local projections. (For details, see pages 49–50.)

The climate projections obtained and analyzed for this report are of daily maximum and minimum temperatures and precipitation amounts for every day from 2020 through 2099, compared to actual observations for a baseline period of 1970–1999 (see page 47). One projection was obtained from each of the available models using the different emission scenarios—20 climate models for the high scenario, 12 for medium #1, 19 for medium #2, and 16 for the low scenario.

In all, for this report more than 24 million individual projections of future weather were analyzed, covering the three weather values, 110 years, 67 pairings of climate models and emission scenarios, and the three separate grids.

In presenting results from each pairing of climate models and emission scenario, we report both the median of all relevant projections as well as the range from the 10th percentile to the 90th percentile of the projections—setting aside the lowest and highest values, as illustrated by Figure 3 below for the subsequent figures used in this report. In the text, the values shown by the sample column in Figure 3 below would be written as "20 (15–25)," with 20 being the median projection, 15 the 10th percentile, and 25 the 90th percentile.

How this report's figures represent the projections

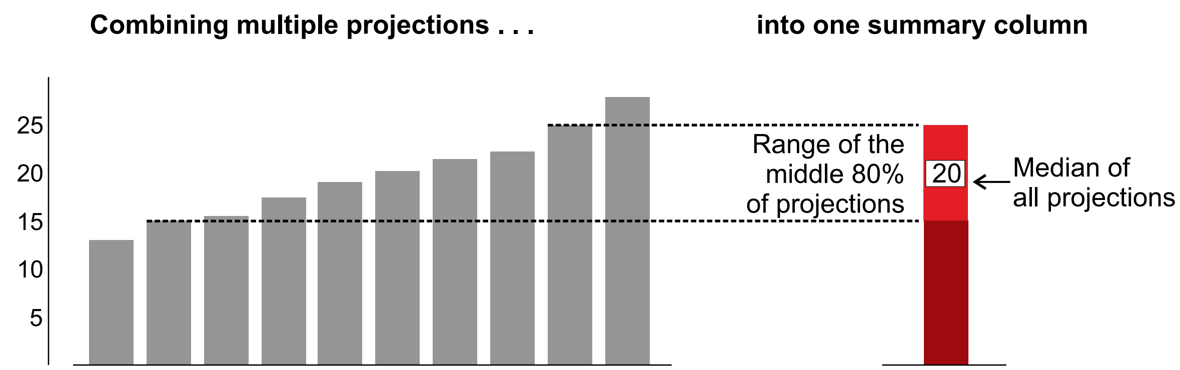


Figure 3. Illustration of how individual projections are represented in the figures on temperature projections on the following pages. On the left, of all projections (hypothetically here from 10 models), the middle 80 percent are combined into a single column (on the right), with that range shown by the lighter color of the upper portion of the column. Another way to express this is that the lighter portion of the column shows the range from the 10th percentile to the 90th percentile of all projections. The numeral in the column shows the median of all projections.

Ninety percent of the models project at least as much change as is represented by the dividing line between the brighter and the darker colors in a column. That line shows the 10th percentile of the projections—meaning that ten percent of the projections are below there, so ninety percent are above there.

2. Future Temperatures

The model projections obtained for this report were analyzed to consider 74 different measures of how local temperatures may change, including 39 measures of high temperatures and 35 of lows. This report focuses just on the most telling of those projections, and for simplicity the text uses examples from only the high and low emission scenarios and primarily from the mid-century (2020–2039) and late century (2080–2099) time periods. The figures and tables throughout the report, though, cover all four emission levels and all four time periods. Spreadsheets with the results from the analysis of all 74 temperature values (as well as of all precipitation values) are available online at www.rockymountainclimte.org/extremes/summit.

The tables at the end of this section document the statements made here, unless another source is indicated.

Baseline temperature values (and baseline precipitation values in section 3) used as comparisons to the model projections are gridded observed values for 1970–1999. These are derived from records from weather stations that have been converted into averages for each grid (see page 50).

Average temperatures

To begin with, the **average annual high temperature** in, for example, the **Edwards/Avon** grid is projected with **high emissions** to increase by mid-century by 5° (4–7°)* and by late in the century by 9° (8–12°), compared to 1970–1999 (see the online data). Somewhat larger temperature increases are forecast for hotter months than for colder ones, by a margin of about 1–2° in mid-century, depending on the grid. For example, in the **Edwards/Avon** grid in mid-century, **temperatures in the hot months** (May through October) are projected to average 6° (5–8°) hotter than in the baseline years, and the **temperatures in the cold months** (November–April) are projected to be 4° (3–6°) warmer. In this case, that is about a two-degree difference. (Throughout this report when one grid is used as an example in text or figures, the other grids show similar patterns, as shown by the data in the appropriate tables.)

But what, exactly, does an increase of a few degrees in average temperature mean across a year or six months? To understand how daily life could be different for people living in and visiting Eagle County, it helps to look at daily data. Analyzing millions of projections of hot and cold temperatures on individual days makes it possible to extract more vivid pictures of the possible futures before us.

Hotter summers

The most striking projections are for how much hotter Eagle County summers could become unless heat-trapping emissions are sharply reduced.

The following examples are all for **the Edwards/Avon grid with high emissions**. The **hottest days of the year** in the grid are projected:

- In typical mid-century years, to average 90° (89–92°)—compared to 84° in 1970–1999.
- In the extreme year in mid-century, to be 95° (93–98°)—compared to 90° in 1970–1999..
- In typical late-century years, to average 96° (94–99°).
- In the extreme year in late century, to get all the way up to 101° (98–106°).

In the Edwards/Avon grid, an *average* summer day in mid-century could be as hot as the single hottest day of the late 20th century.

*Here, 5° is the median projection, 4° is the 10th percentile, and 7° is the 90th percentile (see the previous page).

Even more telling might be how much more common hot days could become. Also in the **Edwards/Avon grid** with **high emissions**, **days 85° and hotter** per year are projected:

- In typical mid-century years, to average sixteen (8–29) days, compared to just one per year in the baseline period.
- In the extreme year in mid-century, to be 43 (29–61) days, compared to seven in the hottest baseline year. That median projection is for a month and a half's worth of 85°-plus days.
- In typical years late in the century, to average sixty (42–89) such days. That median projection is two months's worth.
- In the extreme year late in the century, to occur 88 (77–118) times—essentially all summer long.

These are the corresponding projections for the **Eagle grid** (at a lower elevation, and so with a hotter climate), also with **high emissions**.

The **hottest days of the year** are projected:

- In typical mid-century years, to average 95° (93–97°), compared to 89° in 1970–1999..
- In the extreme year in mid-century, to be 100° (97–103°), compared to 94°in 1970–1999.
- In typical late-century years, to average 100° (98–104°).
- In the extreme year in late century, to get up to an astonishing 106° (104–110°).

Days 90° and hotter per year are projected:

- In typical mid-century years, to average eleven (5–22) days, compared to 0.6 day per year in the baseline period.
- In the extreme mid-century year, to number 39 (22–54) days, compared to seven in the hottest baseline year.
- In typical years late in the century, to average 52 (33–85) such days.
- In the extreme year late in the century, to occur 89 (71–112) times.

As pointed out earlier (see pages 5–6), the actual communities of Edwards, Avon, and Eagle are all at elevations lower than the average elevations of the grids named after them, and so the actual temperatures in the communities would be higher than those projected for the overall grids, as those projections represent average conditions across the entire grids.

With high emissions, the Eagle grid in typical years could average eleven days 90° or hotter in mid-century, and 52 such days late in the century.

The hottest year in mid-century could have 39 days that hot, and the hottest year late in the century could have 89 days that hot.

These projected high temperatures, especially for the Eagle grid, raise questions about effects on public health, because it is well established that extreme heat leads to increases in illness and mortality (see page 46). But both daytime high temperatures and nighttime low temperatures are important, because nights, if cool enough, can provide an important respite from daytime heat (see page 48).

This analysis shows that the temperature increases of the warmest nights are not projected to be as large as the temperature increases of the hottest days. In the **Eagle grid** with **high emissions**, the low temperatures of the **warmest nights of the year** are projected:

- In typical mid-century years, to average 55° (54–57°), compared to 51° in 1970–1999.
- In the hottest year in mid-century, to be 58°, compared to a highest low temperature of 54° in 1970–1999.
- In typical late-century years, to average 59° (57–63°).
- In the extreme year in late century, to be 63°.

Those median projections for increases in the warmest nights are all less than the median projections for increases in the hottest days. For mid-century typical and extreme years, nights would go up 4°, days up 6°. For late-century typical years, nights would go up 8°, days up 11°. For late century extreme years, nights would go up 9°, days up 13°. That the warmest nights of the year are not projected to get hotter than this can be considered other good news from this analysis.

Caveat: Projected high temperatures could be underestimated

It is worth pointing out that the climate models appear not to actually capture how hot the future extremes could be, as the federal government's climate science program says in the following quote. So the values stated here for future hot days and extreme years could well be underestimates.

> "Climate models are more likely to underestimate than to overestimate the amount of long-term future change; this is likely to be especially true for trends in extreme events."
>
> *U.S. Global Change Research Program*[14]

Comparison to summer 2021

The summer of 2021 has been hot enough to prompt the question, how does this summer compare to the projections for typical years and the extreme year for the period 2020–2039, which has just begun? The best answer comes from the weather station located in the Frisco/Dillon Reservoir grid analyzed in RMCO's Summit County report that is a companion to this one. As stated on page 5 of this report, that weather station in the 1970–1999 baseline period had an average summertime high temperature nearly 3° hotter than the comparable value for that overall grid. Allowing for that 3° difference, the station's records for summer (June–August) 2021[15] are very close to the median projections with high emissions for conditions averaged across the grid for a typical year in 2020–2039. Key comparisons are:

- The average high temperature at the weather station in summer 2021 was 74°, which would correspond to a 71° average across the grid—one degree shy of the 72° projected for a typical year's average high temperature across the grid in 2020–2039.
- The station's hottest temperature for the year was 85°, arguably corresponding to a grid-average high of 82°—or one degree below the 83° projected for a typical year's hottest day across the grid in 2020–2039.
- The station's daily high reached 83° or hotter six times in 2021, corresponding to that many days 80° or hotter across the grid—or two more than the four 80°-plus days projected for a typical 2020–2039 year.

Compared instead to the *extreme* year projected with high emissions in the 2020–2039 period, the summer of 2021 fell short:

- The 85° temperature of the hottest day of 2021 at the weather station would correspond to an 82° hottest day across the grid—four degrees short of the 86° projected for the extreme year in that period.
- The six 83°-plus days at the weather station in 2021 would correspond to that number of 80°-plus days—nine fewer than the fifteen such days projected for the extreme year.

This suggests that the summer of 2021 in this grid resembles a typical 2020–2039 year—but is not close to the hottest year projected to occur in that period.

Sharp emission reductions halt temperature changes

There is good news, too, from this analysis. The most important is that it shows how completely the above changes can be avoided if global emissions of heat-trapping pollution are sharply reduced.

The examples on the next page are also for the **Edwards/Avon grid**, but now **with low future emissions**.

The **hottest days of the year** are projected:

- In 2020–2039 in typical years, to average 88° (87–89°)—about four degrees higher than in the baseline.
- Then to remain about the same for the rest of the century—in the next three 20-year periods, 88° (86–84°), then 88° (87–89°), and finally 88° (87–90°).

Days 85° and hotter are projected:

- In 2020–2039 in typical years, to average five (3–6) such days per year.
- To remain essentially the same for the remaining periods of the century: five (2–9) such days, then five (2–8), and finally four (3–8) such days.

These examples show, as do all other data in the figures and tables in this section, that with the low emission scenario the period 2020–2039 will have higher temperatures than the recent past, but then essentially no further temperature increases are projected for later in the century.

Figure 4 on the next page shows projections for the hottest days of the year in the Edwards/Avon grid in typical years. Following that, Figure 5 shows projections for 85°-plus days in the Edwards/Avon grid in typical years, and Figure 6 shows projections for the extreme (hottest) year in each 20-year period.

As all the following figures show, if global emissions are reduced sharply as in the low emission scenario, essentially no further temperature increases are projected after 2020–2039.

Hottest day of the year in the Edwards/Avon grid
Typical years: Averages for each 20-year period

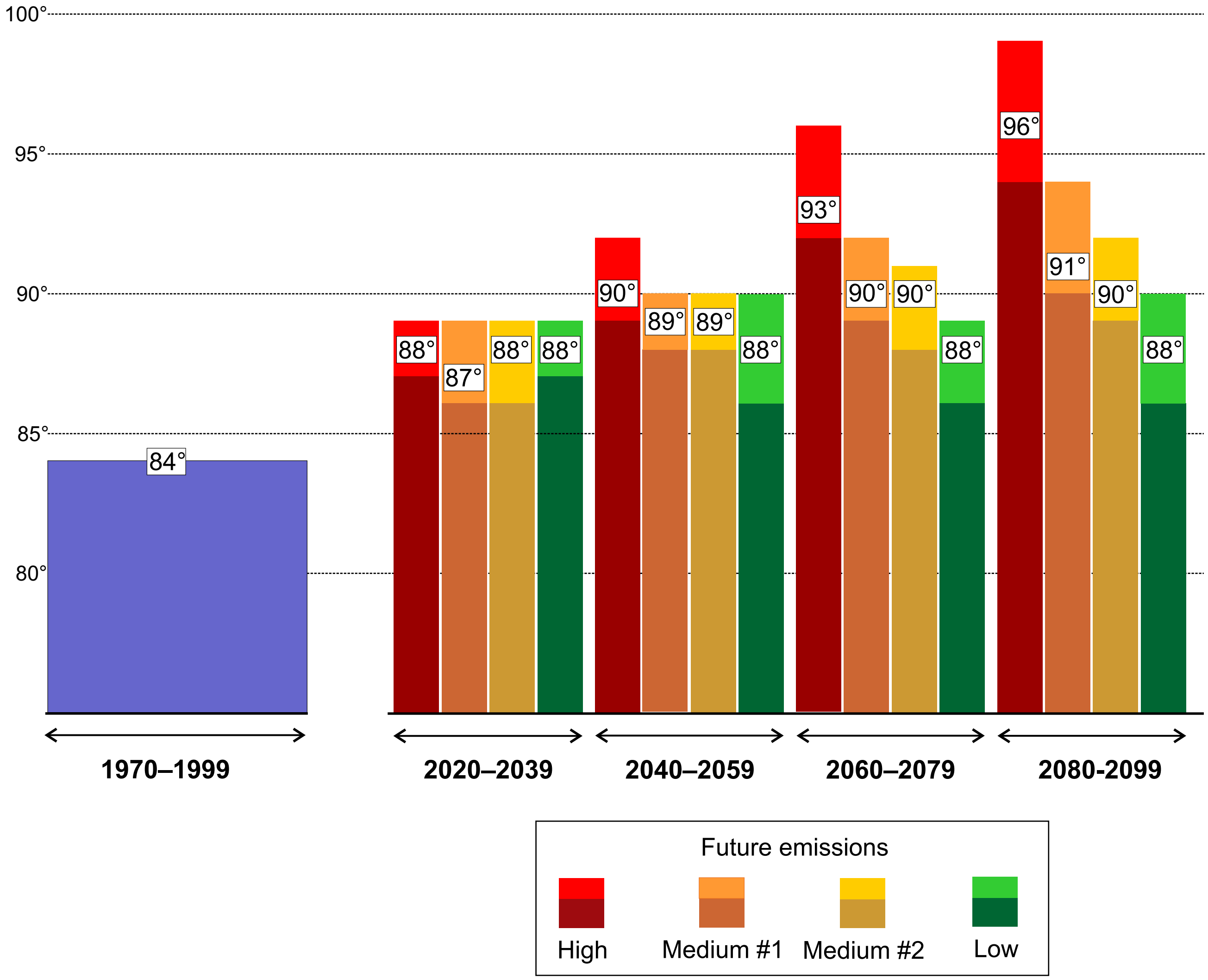


Figure 4. Observations and projections for the highest daily high temperature of the year, averaged across the Edwards/Avon grid for the indicated time periods. Observations for the 1970–1999 baseline period are from observed/gridded data (see page 50). For each future period, the four columns represent different projections based on the emission scenarios identified on page 7. For each such column, the brighter color on the top of the column shows the range of the middle 80 percent of the projections (from the 10th percentile to the 90th percentile); the numerals are the medians, as illustrated in Figure 3 on page 8. For the data illustrated here, see tables 1 and 2 on pages 23 and 24.

In the Edwards/Avon grid, an *average* summer day in mid-century could be as hot as the single hottest day of the late 20th century in that grid, which was 90° (see Table 1 on page 23).

Days 85° or hotter in the Edwards/Avon grid
Typical years: Averages for each 20-year period

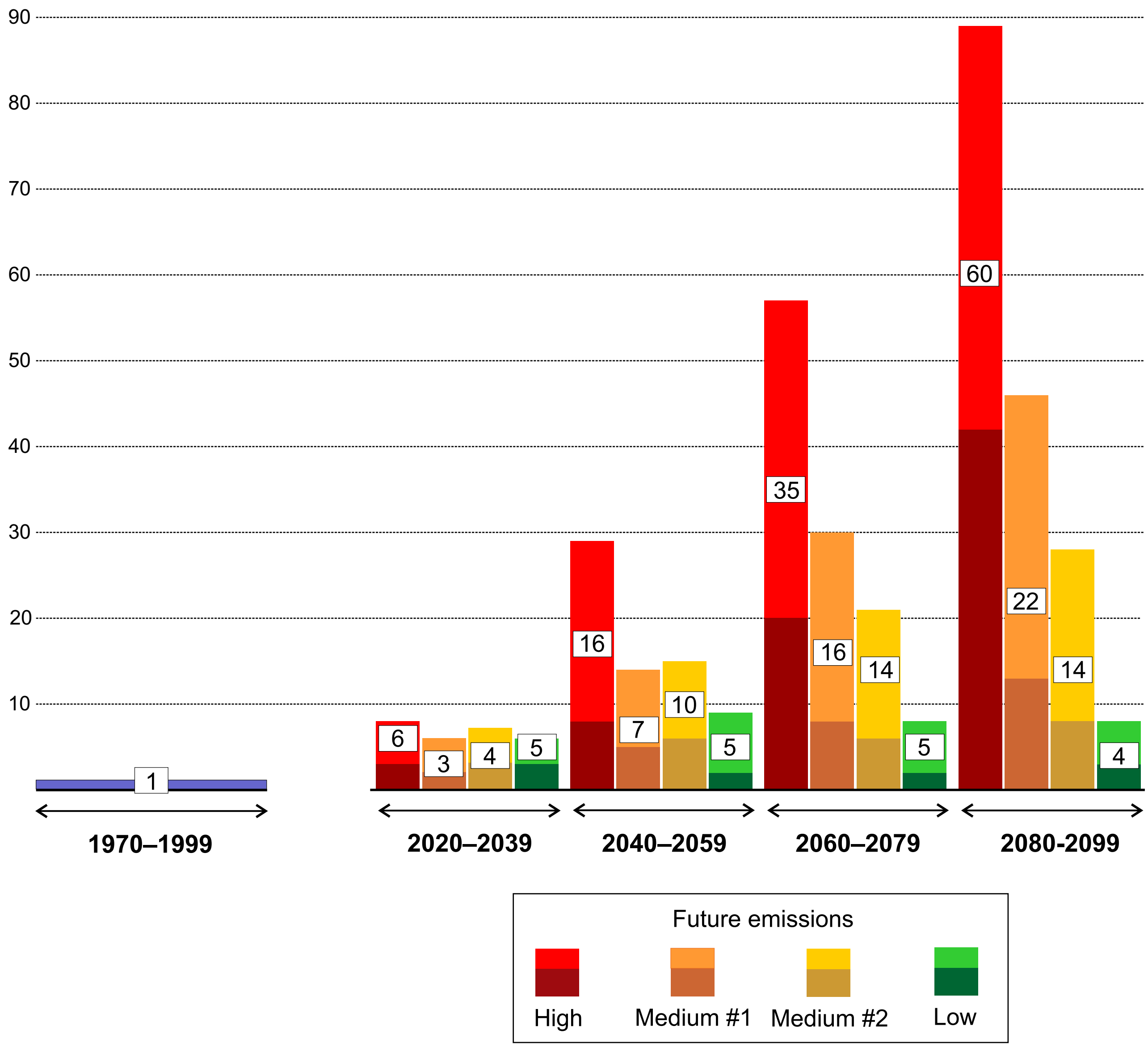


Figure 5. As Figure 4 on the previous page, but now for the observed (in 1970–1999) and projected number of days per year in which daily high temperatures (averaged across the grid) are 85° or hotter.

The four emission scenarios illustrate possible futures. Which one turns out closest to reality depends on future public and private actions.

In a future with continued high emissions, the Edwards/Avon area in mid-century could average sixteen 85°-plus days a year, compared to one a year in the recent past. Late in the century, the average could be 60 days that hot.

Days 85° or hotter in the Edwards/Avon grid
Extremes: The hottest year in each 20-year period

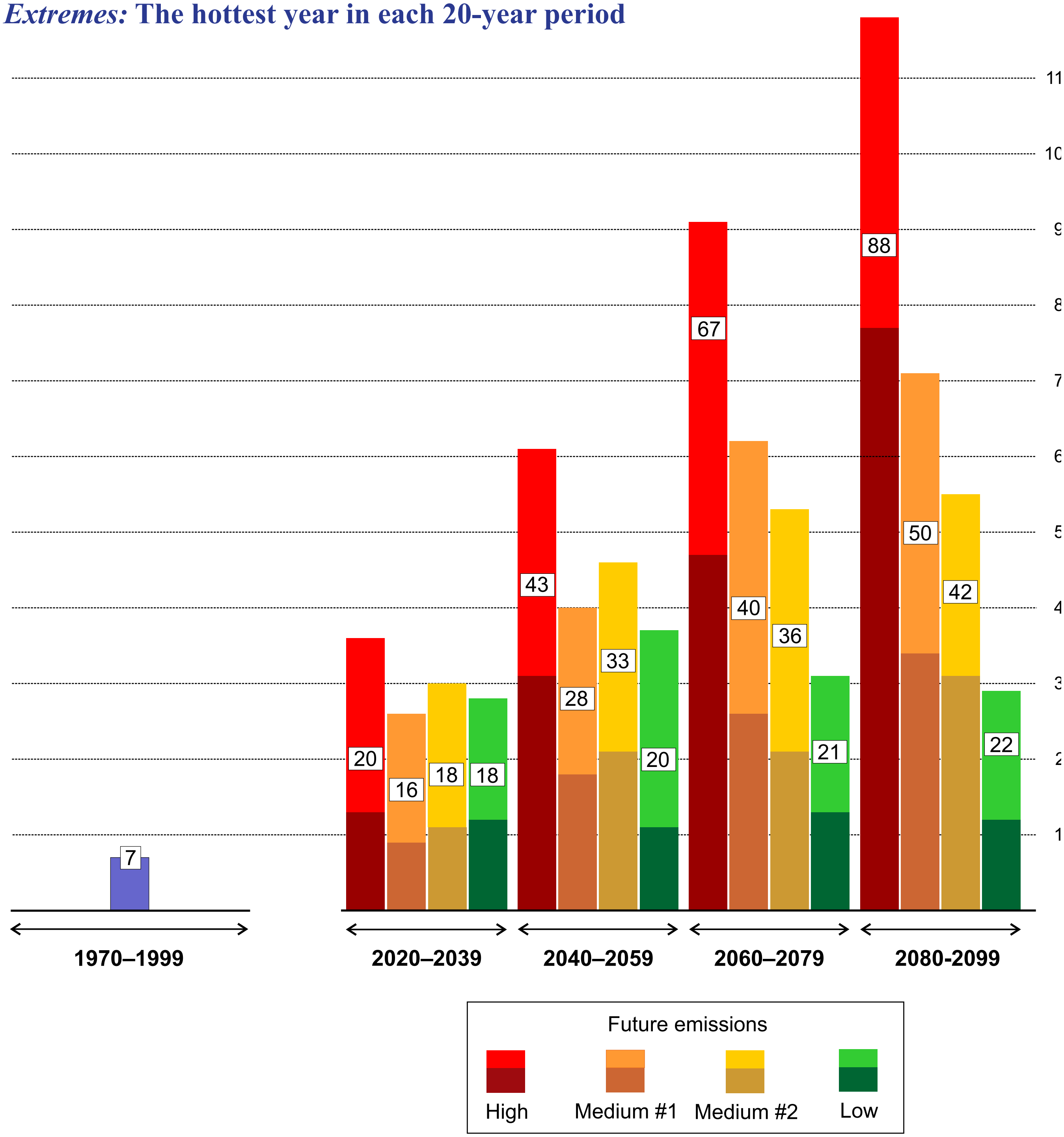


Figure 6. As Figure 5 on the previous page, but for the hottest individual year in each period—on the left, the most 80°-plus days in any single year in 1970–1999, and on the right the largest projected number of such days in any single year in each of the 20-year periods. For the data illustrated here, see tables 1 and 2 on pages 23 and 24.

With high emissions, the hottest mid-century year could have a month and a half's worth of days 85° or hotter. In late century, a whole summer could be that hot.

With low emissions, the number would remain nearly steady all century.

The Eagle grid, at a lower elevation, would have even hotter summers. The figures below and on the next page illustrate the hottest days of the year and the number of days 90° and hotter, rather than the 85°-plus days in the Edwards/Avon grid in the two previous figures.

Hottest day of the year in the Eagle grid
Typical years: Averages for each 20-year period

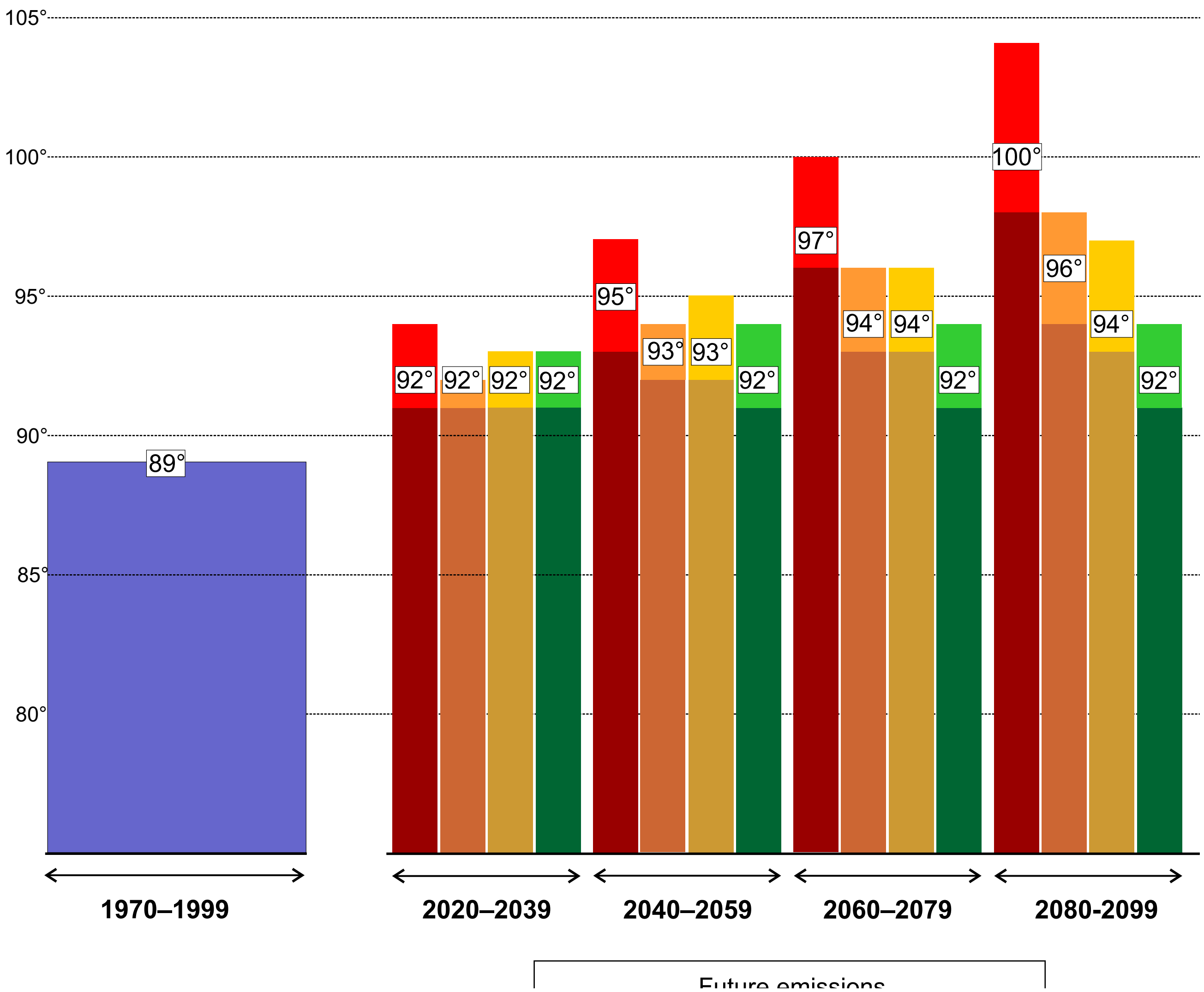


Figure 7. As figure 4 on page 13, but for the Eagle grid. For the data illustrated here, see tables 5 and 6 on pages 27 and 28.

Days 90° or hotter in the Eagle grid
Typical years: Averages for each 20-year period

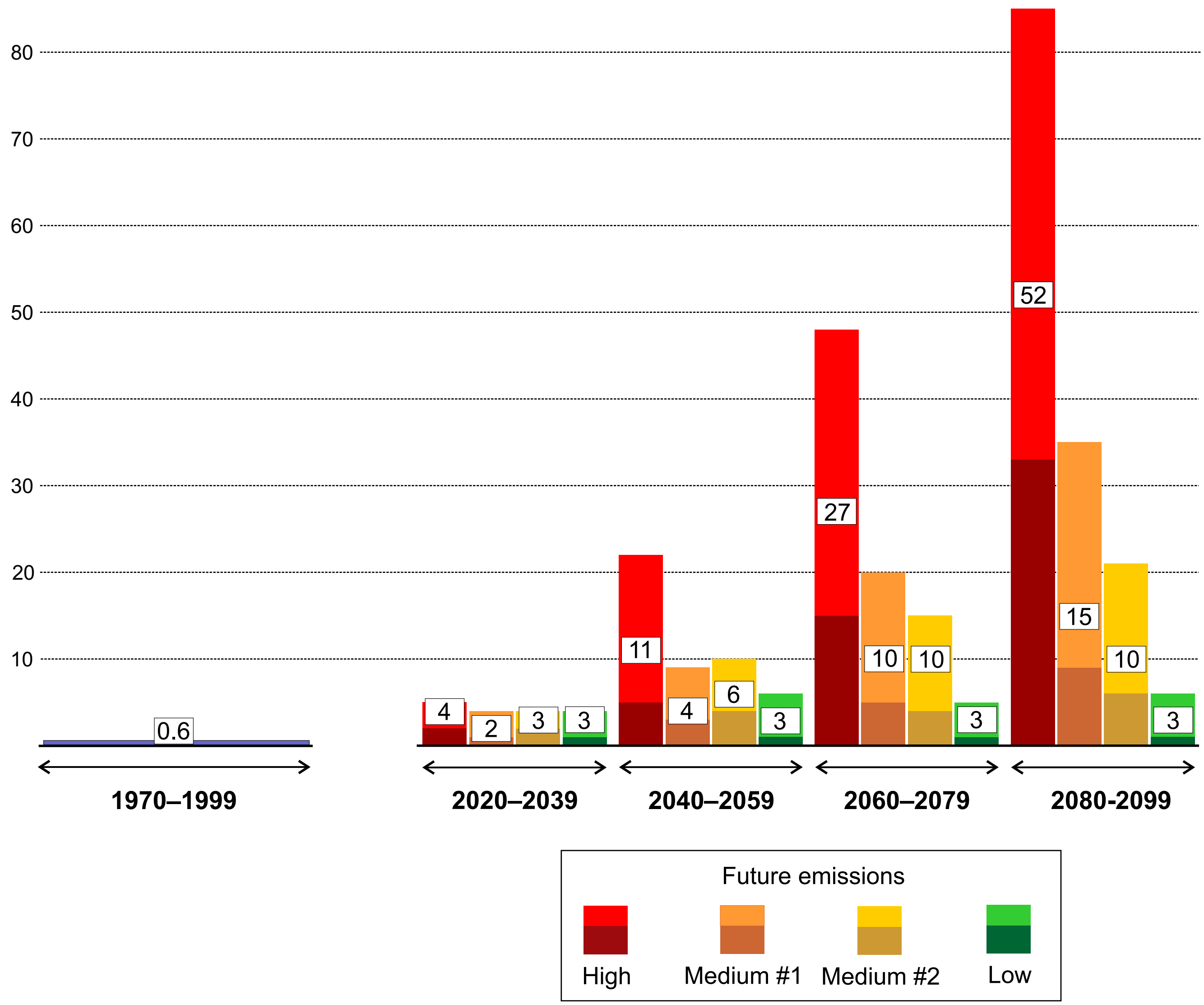


Figure 8. As figure 5 on page 14, but for the Eagle grid. For the data illustrated here, see tables 5 and 6 on pages 27 and 28.

With high emissions, a typical year in the Eagle grid in mid-century could have eighteen times as many 90°-plus days as in the baseline period.

But with low emissions the number would stay steady over the century, with perhaps two per year in each 20-year period.

Days 90° or hotter in the Eagle grid
Extremes: The hottest year in each 20-year period

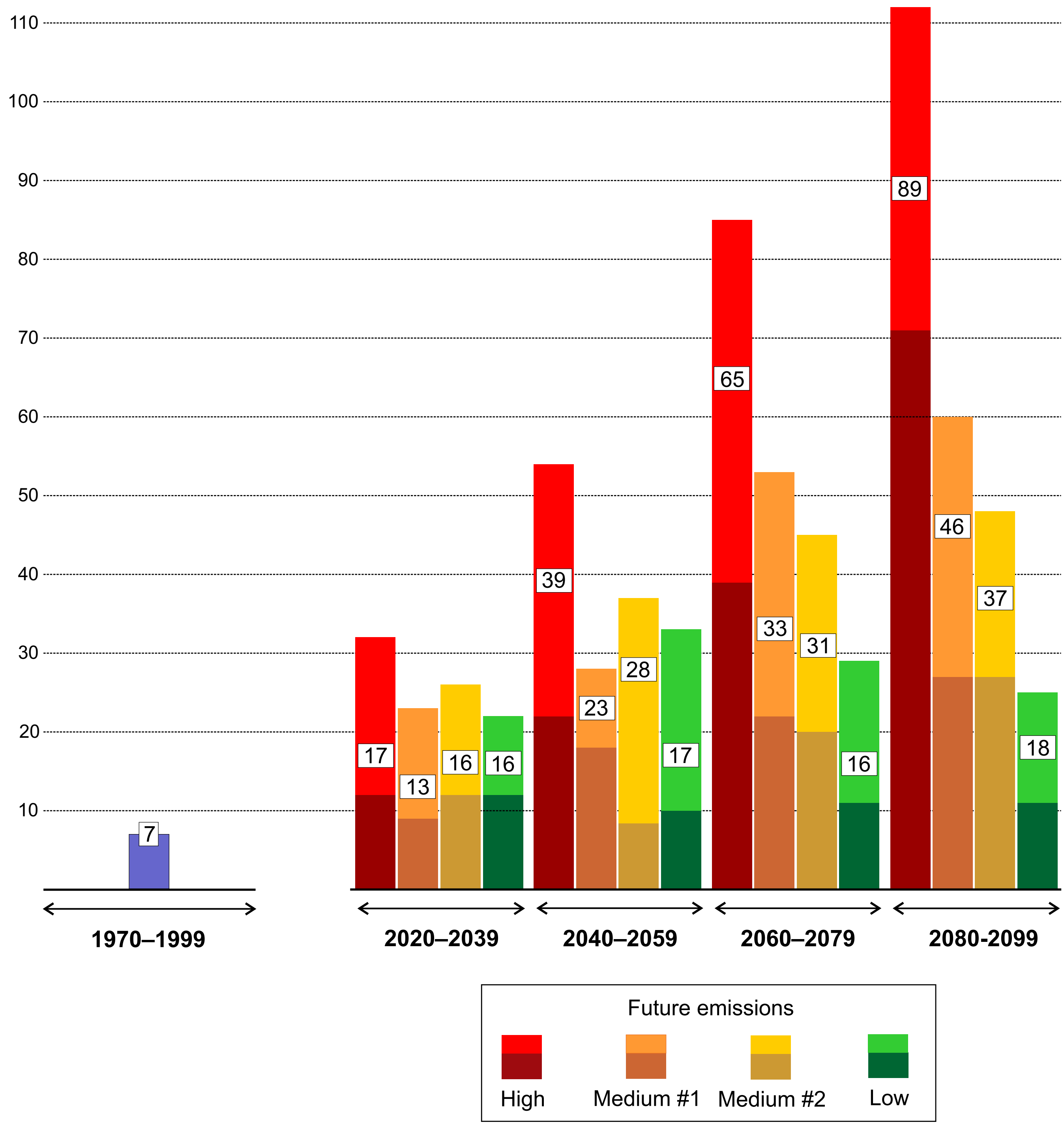


Figure 9. As figure 6 on page 15, but for days 75° and hotter in the Eagle grid. For the data illustrated here, see tables 5 and 6 on pages 27 and 28.

Warmer winters

This analysis considered temperatures from November 25 of one year to April 15 of the next, chosen to approximate the core season for both snowpack accumulation and skiing and other snow-dependent sports. The examples on this page are for the **Vail Mountain grid** (including the Vail Ski Resort) with **high emissions**.

High temperatures above freezing.—The number of days with highs above 32° in the November 25 through April 15 stretch (which is 142 days long, or 143 in leap years) are projected:

- In typical years in mid-century, to average 55 (49–64) percent of those days (or a count of 78 (70–91) days). That compares to an average of 40 percent in 1970–1999.
- In the extreme year in mid-century, to be 71 (62–82) percent of those days—compared to a high of 58 percent in 1970–1999.
- In typical years late in the century, to average 69 (60–79) percent of those days.
- In the extreme year late in the century, to be 83 (72–90) percent of the days.

Figure 10 on the following page illustrates these projections.

On the other hand, some good news: Over the same snow/skiing season, no nights are projected to have low temperatures above freezing, even in extreme years late in the century.

With high emissions, temperatures above freezing could occur in 55 percent of the days in the snow/ski season in typical mid-century years, up from 40 percent. In the extreme year in mid-century, about seven out of ten days in the snow/season could be that warm.

Earlier spring warm-up

As winter turns to spring, days appreciably above freezing start melting snowpacks and turning ski slopes slushy. This analysis identified the number of days 40° or hotter, warm enough to cause snowmelt and slushy skiing, for the stretch of March 16 through April 15, chosen to represent the last month of the core snow/skiing season. In the **Vail Mountain grid** with **high emissions**, the percentage of **40°-plus days** in that 31-day stretch is projected:

- In mid-century in typical years, to average 56 (48–73) percent of those days—compared to 38 percent in 1970–1999.
- In mid-century in the extreme year, to be 81 (71–90) percent of those days—compared to 71 percent, the high number in 1970–1999.
- Late in the century in typical years, to average 71 (60–87) percent.
- Late in the century in the extreme year, to be 89 (80–100) percent of those days.

The first month of the core snow/skiing season, by contrast, does not have as many 40°-plus days to begin with, nor a similar projected growth in such days. For instance, 40°-plus days in the Vail Mountain grid in November 25 through December 24 with high emissions are projected to average five (3–7) such days in typical mid-century years, compared to two such days in the baseline period (see the online data). This and related data posted online suggests that temperature changes may be more likely to have an effect at the end of the snow/skiing season than at the beginning.

Percent of Nov 25-Apr 15 days with highs above 32° in the Vail Mountain grid
Typical years: The average year in each 20-year period

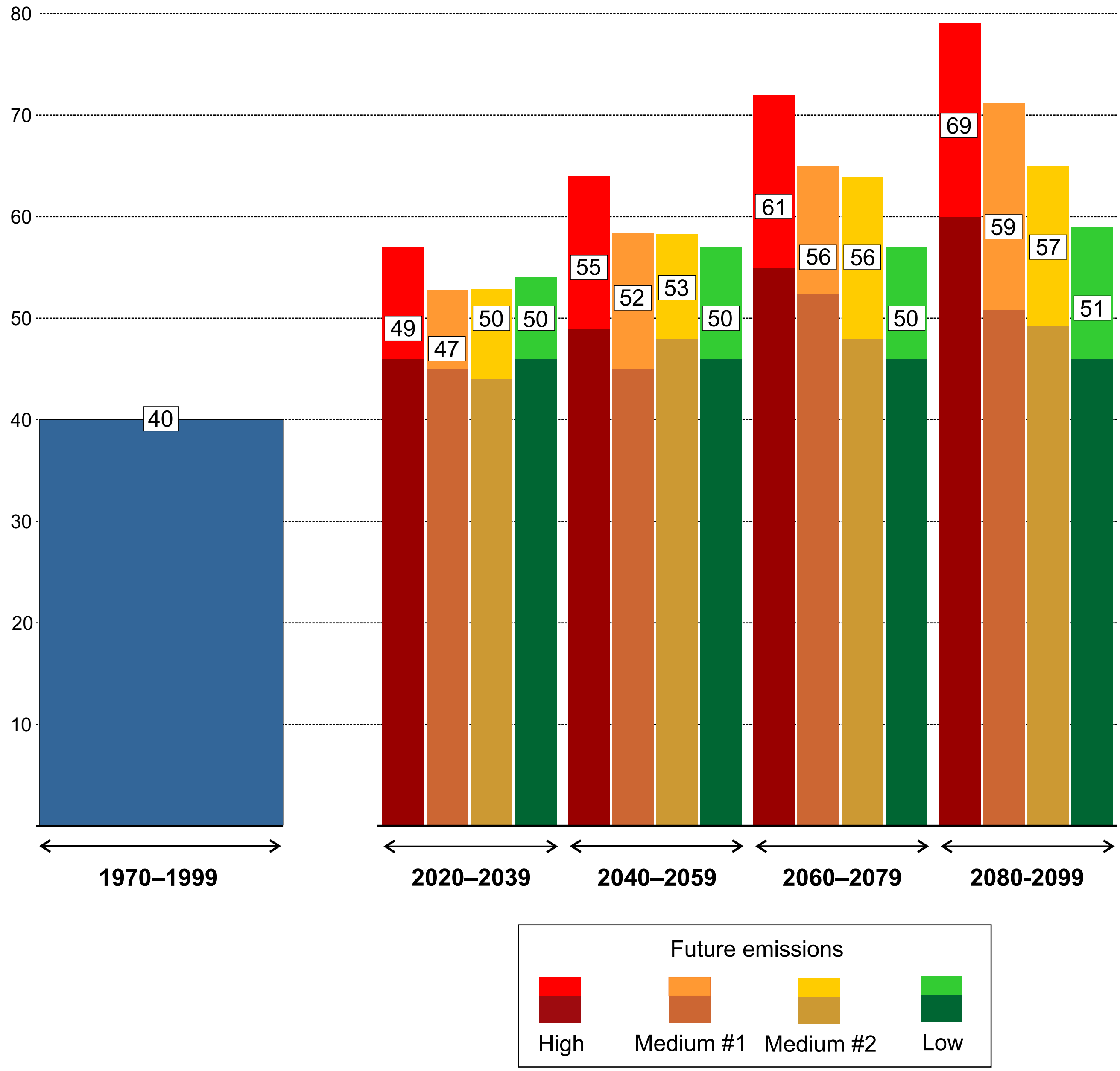


Figure 10. As figure 4 on page 13, but for days 32° and hotter from November 25 of one year through April 15 of the following year in the Vail Mountain grid. The number of days in that stretch is 143 (144 in leap years), and the average number of days in 1970–1999 is 57. For the data illustrated here, see tables 3 and 4 on pages 25 and 26. (In those tables, the data shown above are presented as the *number* of such days in the stretch of November 25 through April 15; the figure above instead shows the data as the *percentage* of such days in that stretch.)

With high emissions, the percentage of days in the core snow/skiing season that get above freezing in the Vail Mountain grid could reach 55 percent by mid-century and 69 percent by late in the century. But with low emissions, the percentage could stay at about 50 percent over the full century.

Percent of Nov 25-Apr 15 days with highs above 32° in the Vail Mountain grid
***Extremes:* The hottest year in each 20-year period**

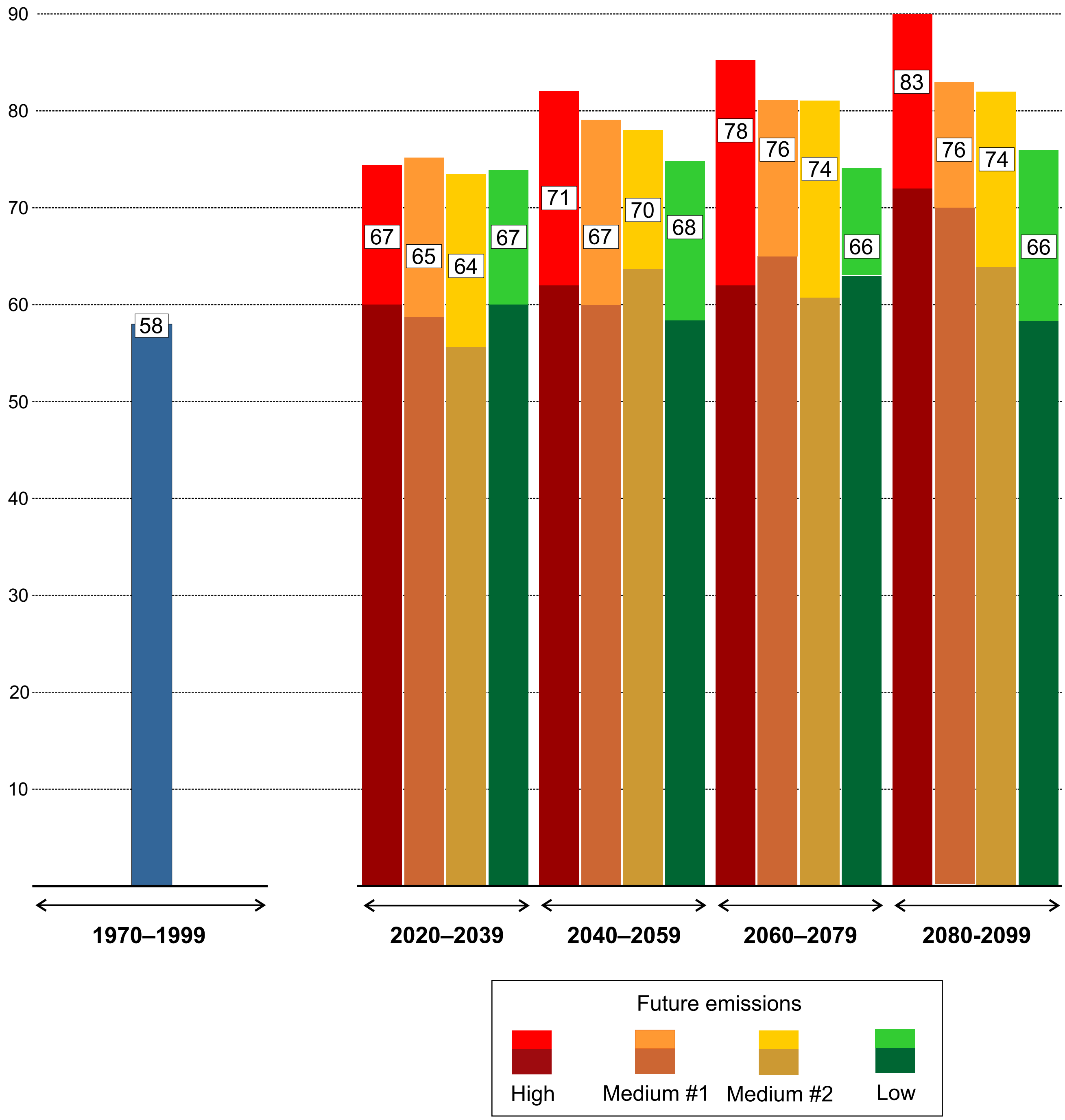


Figure 11. As Figure 10 on the previous page, but for the hottest individual year in each period. On the left, the highest percentage of days above 32° of any single year in 1970–1999, and on the right the highest projected percentage for any single year in each 20-year period. For the data illustrated here, see tables 3 and 4 on pages 25 and 26.

Tables of High Temperature Projections

Tables 1 through 6 that follow (through page 28) present key results of the analysis of the climate models's projections of future high temperatures. After those, tables 7 through 12 (on pages 29–34) do the same for low temperatures. Both sets of tables are in pairs, with the first of each pair showing projections for the first two 20-year periods (2020–2039 and 2040–2059) for a particular grid and the next table showing projections for the two subsequent periods.

Full results from the analysis of all 74 temperature values considered in this project can be found at www.rockymountainclimate.org/extremes/summit.

High temperatures in Edwards/Avon grid, 2020–2059

	1970-99 Actual	2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg high (Nov thru Apr), change	35°	+3° (+1/+4°)	+2° (+1/+3°)	+3° (+2/+4°)	+3° (+2/+4°)	+4° (+3/+7°)	+3° (+2/+5°)	+4° (+2/+5°)	+3° (+2/+5°)
Hot months avg high (May thru Oct), change	57°	+4° (+2/+5°)	+3° (+2/+4°)	+4° (+2/+4°)	+3° (+2/+4°)	+6° (+5/+8°)	+4° (+4/+5°)	+5° (+3/+6°)	+4° (+2/+5°)
Average high in Jun-Jul-Aug	74°	77° (76–78°)	76° (76–77°)	77° (75–78°)	77° (76–78°)	79° (78–81°)	78° (77–79°)	78° (76–80°)	77° (76–78°)
Days per year 80° or hotter	12	38 (30–47)	31 (25–35)	36 (25–44)	36 (27–45)	59 (47–75)	43 (36–55)	50 (33–61)	37 (25–49)
Days per year 85° or hotter	1	6 (3–8)	3 (2–6)	4 (3–7)	5 (3–6)	16 (8–29)	7 (5–14)	10 (6–15)	5 (2–9)
High temp of year's hottest day	84°	88° (87–89°)	87° (86–88)°	88° (87–89°)	88° (87–89°)	90° (89–92°)	89° (88–90°)	89° (88–90°)	88° (86–90°)
Nov 25–Apr 15 days 32° or hotter	75	88 (81–98)	86 (82–92)	88 (81–96)	90 (83–95)	97 (90–108)	93 (87–99)	95 (87–100)	90 (84–98)
Mar 16–Apr 15 days 40° or hotter	19	22 (20–24)	22 (19–25)	21 (20–24)	21 (20–25)	23 (21–26)	22 (20–26)	22 (20–26)	22 (20–25)
Extreme years									
Average high in Jun-Jul-Aug	76°	80° (78–82°)	79° (77–80°)	80° (78–81°)	80° (78–81°)	82° 80–84°	80° (79–82°)	80° (79–83°)	79° (77–82°)
Days per year 80° or hotter	28	61 (42–74)	52 (34–67)	59 (44–70)	59 (39–71)	81 (66–94)	67 (46–76)	74 (50–86)	63 (41–73)
Days per year 85° or hotter	7	20 13–36	16 (9–26)	18 (12–30)	18 (12–28)	43 (29–61)	28 (18–40)	33 (21–46)	20 (11–37)
High temp of year's hottest day	90°	93° (91–95°)	92° (91–94°)	92° (91–95°)	92° (90–94°)	95° (93–98°)	94° (92–96°)	95° (92–96°)	93° (91–96°)
Nov 25–Apr 15 days 32° or hotter	103	114 (102–122)	112 (99–125)	111 (98–122)	112 (104–122)	122 (111–129)	112 (104–124)	120 (108–124)	116 (104–126)
Mar 16–Apr 15 days 40° or hotter	29	30 (29–31)	30 (29–31)	30 (29–31)	30 (29–31)	30 (29–31)	30 (28–31)	30 (29–31)	31 (29–31)

Projections with Different Emission Levels (columns 2020–2039 and 2040–2059).

Table 1. For 1970–1999, the actual values for the grid are from observed/gridded data (see page 50); the first two rows show changes from these values, and the other rows show projected future absolute values. The projections are for the four emission scenarios identified on page 7. Values for typical years are annual averages for the 20 years in each time period. Values for extreme years are the highest projected values in each period. For the projections, the top row shows the median of the projections from all climate models for that emissions scenario, and the next row shows in parentheses the 10th percentile of the projections and the 90th percentile—in other words, the range of the middle 80 percent of those projections (see page 8).

High temperatures in Edwards/Avon grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg high (Nov thru Apr), change	35°	+6° (+5/+10°)	+5° (+3/+7°)	+4° (+2/+7°)	+2° (+2/+5°)	+9° (+6/+11°)	+6° (+4/+8°)	+5° (+3/+7°)	+3° (+2/+5°)
Hot months avg high (May thru Oct), change	57°	+8° (+7/+11°)	+6° (+4/+7°)	+6° (+4/+7°)	+4° (+2/+5°)	+11° (+9/+15°)	+7° (+6/+9°)	+6° (+4/+8°)	+4° (+2/+5°)
Average daily high in Jun-Jul-Aug	74°	82° (80–85°)	79° (77–81°)	79° (77–81°)	77° (75–79°)	84° (83–89°)	80° (79–83°)	79° (78–82°)	77° (76–79°)
Days per year 80° or hotter	12	81 (69–97)	58 (44–78)	57 (40–73)	35 (23–53)	100 (89–119)	69 (57–91)	57 (46–80)	34 (25–53)
Days per year 85° or hotter	1	35 (20–57)	16 (8–30)	14 (6–21)	3 (1–7)	60 (42–89)	22 (13–46)	14 (8–28)	3 (2–7)
High temp of year's hottest day	84°	93° (92–96°)	90° (89–92°)	90° (88–91°)	88° (87–89°)	96° (94–99°)	91° (90–94°)	90° (89–92°)	88° (87–90°)
Nov 25–Apr 15 days 32° or hotter	75	106 (97–117)	99 (93–107)	99 (87–110)	91 (84–99)	114 (104–123)	103 (95–114)	98 (88–108)	90 (84–101)
Mar 16–Apr 15 days 40° or hotter	19	25 (23–28)	23 (22–28)	22 (20–26)	22 (20–25)	26 (24–28)	25 (24–27)	22 (21–26)	22 (21–26)
Extreme years									
Average high in Jun-Jul-Aug	76°	84° (82–88°)	82° (81–84°)	81° (79–84°)	80° (78–81°)	87° (84–92°)	83° (81–86°)	82° (80–84°)	80° (79–82°)
Days per year 80° or hotter	28	100 (83–121)	77 (66–101)	73 (59–91)	61 (41–78)	121 (95–141)	90 (72–102)	79 (61–102)	58 (44–76)
Days per year 85° or hotter	7	67 (47–91)	40 (26–62)	36 (21–53)	21 (13–31)	88 (77–118)	50 (34–71)	42 (31–55)	22 (12–29)
High temp of year's hottest day	90°	98° (95–103°)	95° (94–98°)	95° (93–98°)	93° (91–95°)	101° (98–106°)	97° (94–101°)	95° (93–98°)	93° (91–95°)
Nov 25–Apr 15 days 32° or hotter	103	129 (117–133)	122 (109–129)	121 (108–128)	112 (107–120)	133 (120–137)	124 (113–130)	124 (110–127)	114 (106–123)
Mar 16–Apr 15 days 40° or hotter	29	30 (29–31)	31 (29–31)	30 (28–31)	30 (29–31)	30 (29–31)	30 (29–31)	30 (29–31)	31 (29–31)

Table 2. As Table 1 on the previous page, but for the two later 20-year periods.

Late in the century with high emissions, the hottest day of the year could be 96° in a typical year and 101° in the extreme year.

But with low emissions, the hottest days would not keep climbing after the initial 2020–2021 period. Instead they would stay at an average of 88° across the entire century.

High temperatures in Vail Mountain grid, 2020-2059

	1970-99 Actual	Projections with Different Emission Levels: 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg high (Nov thru Apr): *change*	31°	2° (+1/+4°)	2° (+1/+3°)	3° (+1/+4°)	2° (+1/+4°)	4° (+3/+6°)	3° (+2/+4°)	3° (+2/+5°)	3° (+2/+4°)
Hot months avg high (May thru Oct): *change*	51°	4° (+2/+5°)	3° (+2/+4°)	4° (+2/+4°)	3° (+2/+4°)	6° (+5/+8°)	4° (+4/+5°)	5° (+3/+6°)	4° (+2/+5°)
Average high in Jun-Jul-Aug	66°	70° (69–71°)	69° (68–70°)	70° (68–71°)	70° (69–71°)	72° (71–74°)	71° (70–71°)	71° (69–72°)	70° (69–71°)
Days per year 70° or hotter	28	62 (52–72)	55 (47–62)	60 (47–69)	61 (49–68)	83 (69–94)	67 (57–77)	74 (55–83)	61 (48–74)
Days per year 75° or hotter	4	16 (11–21)	10 (9–16)	14 (9–18)	14 (10–19)	32 (22–49)	18 (16–29)	24 (16–34)	15 (9–22)
High temp of year's hottest day	77°	81° (80–82°)	80° (80–81°)	81° (80–82°)	81° (80–82°)	84° (82–85°)	82° (81–83°)	82° (81–84°)	81° (80–83°)
Nov 25–Apr 15 days 32° or hotter	57	69 (64–81)	66 (63–75)	71 (63–76)	71 (65–77)	78 (70–91)	74 (65–82)	75 (68–83)	71 (66–80)
Mar 16–Apr 15 days 40° or hotter	12	16 (14–20)	16 (13–18)	15 (14–20)	15 (14–21)	17 (15–23)	16 (15–22)	17 (15–22)	17 (14–21)
Extreme years									
Average high temp in June-July-August	69°	73° (70–75°)	71° (70–73°)	72° (71–74°)	72° (70–73°)	75° (73–77°)	73° (71–75°)	73° (72–76°)	72° (70–75°)
Days per year 75° or hotter	14	39 (28–57)	35 (19–45)	39 (27–45)	36 (28–47)	67 (45–78)	46 (38–63)	54 (36–72)	38 (28–55)
Days per year 80° or hotter	4	7 (5–19)	5 (4–9)	7 (4–10)	6 (5–10)	19 (10–36)	9 (7–16)	9 (7–17)	7 (4–17)
High temp of year's hottest day	83°	87° (84–89°)	86° (83–88°)	86° (84–89°)	86° (84–87°)	89° (87–91°)	88° (87–90°)	88° (84–90°)	87° (84–89°)
Nov 25–Apr 15 days 32° or hotter	82	95 (86–105)	93 (84–106)	91 (79–105)	95 (86–106)	102 (89–117)	96 (86–113)	100 (91–111)	97 (83–106)
Mar 16–Apr 15 days 40° or hotter	22	25 (20–28)	24 (20–27)	24 (21–28)	26 (22–29)	25 (22–28)	23 (20–26)	26 (21–28)	25 (23–28)

Table 3. As Table 1 on page 23, but instead for the Vail Mountain grid.

With high emissions, the number of 75°-plus days in the Vail Mountain grid could go from four per year in the baseline period to a month's worth per year in mid-century—an eight-fold increase.

High temperatures in Vail Mountain grid, 2060–2099

	1970-99 Actual	2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
		Projections with Different Emission Levels							
Typical years									
Cold months avg high (Nov thru Apr): *change*	31°	+6° (+4/+9°)	+4° (+3/+7°)	+4° (+2/+6°)	+2° (+2/+4°)	8° (+6+11°)	+5° (+4/+7°)	+5° (+2/+7°)	+2° (+2/+5°)
Hot months avg high (May thru Oct): *change*	51°	+8° (+7/+11°)	+6° (+4/+7°)	+6° (+4/+7°)	+4° (+2/+5°)	+11° (+9/+14°)	+7° (+6/+9°)	+6° (+4/+8°)	+3° (+2/+5°)
Average high in Jun-Jul-Aug	66°	74° (73–77°)	72° (70–74°)	72° (70–74°)	70° (68–71°)	77° (76–82°)	73° (72–76°)	72° (71–74°)	70° (68–71°)
Days per year 70° or hotter	28	100 (90–115)	83 (66–96)	80 (64–94)	59 (46–78)	116 (107–136)	91 (83–110)	80 (69–98)	58 (47–78)
Days per year 75° or hotter	4	58 (42–77)	33 (19–48)	30 (17–43)	13 (9–22)	80 (66–102)	45 (31–67)	31 (21–51)	14 (9–23)
High temp of year's hottest day	77°	86° (85–89°)	84° (82–85°)	83° (82–85°)	81° (80–83°)	88° (87–92°)	84° (83–87°)	83° (82–86°)	81° (80–83°)
Nov 25–Apr 15 days 32° or hotter	57	87 (79-103)	80 (74-92)	80 (69-91)	71 (65-82)	99 (85-112)	84 (73-101)	82 (69-92)	72 (65-83)
Mar 16–Apr 15 days 40° or hotter	12	21 (17–25)	18 (15–26)	17 (14–24)	16 (13–22)	22 (19–27)	21 (17–27)	18 (15–23)	17 (14–23)
Extreme years									
Average high temp in June-July-August	69°	77° (75–81°)	75° (73–77°)	74° (72–77°)	73° (70–74°)	80° (77–84°)	76° (74–78°)	75° (73–77°)	72° (71–75°)
Days per year 75° or hotter	14	88 (76–107)	65 (50–76)	56 (41–75)	37 (28–50)	111 (93–134)	78 (59–90)	62 (48–78)	38 (29–49)
Days per year 80° or hotter	4	38 (20–64)	13 (9–35)	15 (8–29)	6 (4–16)	67 (48–94)	26 (12–41)	18 (9–27)	7 (6–13)
High temp of year's hottest day	83°	91° (89–96°)	88° (87–91°)	88° (86–91°)	86° (84–89°)	95° (92–98°)	90° (88–94°)	88° (87–92°)	86° (85–89°)
Nov 25–Apr 15 days 32° or hotter	82	111 (96–120)	108 (92–115)	105 (86–116)	94 (89–105)	119 (102–128)	108 (99–119)	105 (91–116)	94 (85–109)
Mar 16–Apr 15 days 40° or hotter	22	27 (22–30)	25 (21–28)	27 (23–29)	24 (21–28)	28 (25–31)	26 (22–30)	26 (20–28)	25 (21–29)

Table 4. As Table 3 on the previous page, but with projections for the last two 20-year periods of the century.

This table again shows that low emissions keep temperatures from continuing to climb. For the Vail Mountain grid, the average hottest day of the year would not go above 77° or 78°.

High temperatures in Eagle grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels: 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg high (Nov thru Apr): *change*	39°	+3° (+2/+4°)	+2° (+1/+4°)	+3° (+2/+4°)	+3° (+2/+4°)	+5° (+3/+8°)	+4° (+3/+5°)	+4° (+2/+6°)	+3° (+2/+5°)
Hot months avg high (May thru Oct): *change*	60°	+4° (+3/+5°)	+3° (+2/+4°)	+4° (+2/+5°)	+4° (+3/+5°)	+6° (+5/+8°)	+5° (+4/+5°)	+5° (+3/+6°)	+4° (+2/+5°)
Average high in Jun-Jul-Aug	78°	81° (80–83°)	81° (80–81°)	81° (79–82°)	81° (80–82°)	84° (82–86°)	82° (81–83°)	82° (81–84°)	81° (80–83°)
Days per year 85° or hotter	9	31 (23–41)	24 (20–28)	29 (19–37)	28 (21–36)	52 (40–68)	36 (29–48)	42 (27–52)	31 (19–42)
Days per year 90° or hotter	0.6	4 (2–5)	2 (1–4)	3 (2–4)	3 (1–4)	11 (5–22)	4 (3–9)	6 (4–10)	3 (1–6)
High temp of year's hottest day	89°	92° (91–94°)	92° (91–92°)	92° (91–93°)	92° (91–93°)	95° (93–97°)	93° (92–94°)	93° (92–95°)	92° (91–94°)
Nov 25–Apr 15 days 32° or hotter	94	107 (99–114)	102 (101–109)	106 (98–112)	107 (101–112)	115 (108–123)	111 (104–116)	112 (106–117)	108 (102–115)
Extreme years									
Average high in Jun-Jul-Aug	80°	84° (81–86°)	83° (82–84°)	84° (82–85°)	84° (81–85°)	86° (84–88°)	84° (82–86°)	84° (83–87°)	83° (81–86°)
Days per year 85° or hotter	19	53 (34–69)	45 (29–59)	48 (36–63)	50 (35–60)	74 (59–85)	58 (37–71)	59 (46–80)	48 (31–65)
Days per year 90° or hotter	7	17 (12–32)	13 (9–23)	16 (12–26)	16 (12–22)	39 (22–54)	23 (18–28)	28 (16–37)	17 (10–33)
Days per year 95° or hotter	0.0	0 (0–3)	0 (0–1)	0 (0–1)	0 (0–2)	4 (1–13)	1 (0–4)	1 (1–4)	1 (0–3)
High temp of year's hottest day	94°	98° (96–100°)	96° (95–98°)	98° (96–99°)	97° (95–99°)	100° (97–103°)	99° (96–100°)	99° (98–101°)	98° (96–100°)
Nov 25–Apr 15 days 32° or hotter	119	127 (122–135)	125 (118–135)	125 (114–130)	126 (119–137)	134 (123–141)	129 (120–140)	130 (124–136)	128 (123–138)

Table 5. As Table 1 on page 23, but instead for the Eagle grid.

With high emissions, a typical year in the Eagle grid in mid-century could have eleven days 90° or hotter—eighteen times as many as in the baseline period.

High temperatures in Eagle grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg high (Nov thru Apr), change	39°	+7° (+5/+10°)	+5° (+4/+7°)	+5° (+3/+7°)	+3° (+2/+5°)	+9° (+7/+12°)	+7° (+4/+9°)	+5° (+3/+8°)	+3° (+2/+6°)
Hot months avg high (May thru Oct), change	60°	+9° (+7/+11°)	+6° (+5/+8°)	+6° (+4/+8°)	+4° (+2/+6°)	+11° (+10/+15°)	+8° (+6/+10°)	+6° (+4/+8°)	+4° (+2/+6°)
Average high in Jun-Jul-Aug	78°	86° (85–89°)	83° (82–86°)	84° (81–85°)	81° (79–83°)	89° (87–93°)	84° (84–88°)	83° (82–86°)	81° (80–83°)
Days per year 85° or hotter	9	75 (61–94)	51 (38–72)	50 (32–67)	27 (18–46)	96 (82–116)	60 (51–86)	49 (40–73)	27 (20–46)
Days per year 90° or hotter	0.6	27 (15–48)	10 (5–20)	10 (4–15)	3 (1–5)	52 (33–85)	15 (9–35)	10 (6–21)	3 (1–6)
High temp of year's hottest day	89°	97° (96–100°)	94° (93–96°)	94° (93–96°)	92° (91–94°)	100° (98–104°)	96° (94–98°)	94° (93–97°)	92° (91–94°)
Nov 25–Apr 15 days 32° or hotter	94	122 (113–131)	116 (110–121)	116 (105–122)	109 (103–116)	127 (120–134)	118 (112–127)	115 (104–124)	108 (104–118)
Extreme years									
Average high in Jun-Jul-Aug	80°	89° (86–92°)	86° (84–88°)	86° (83–88°)	84° (82–85°)	92° (88–96°)	87° (85–90°)	86° (84–88°)	84° (83–86°)
Days per year 85° or hotter	19	93 (80–116)	73 (61–91)	69 (45–84)	49 (33–66)	112 (88–143)	85 (66–100)	77 (52–91)	52 (42–68)
Days per year 90° or hotter	7	65 (39–85)	33 (22–53)	31 (20–45)	16 (11–29)	89 (71–112)	46 (27–60)	37 (27–48)	18 (11–25)
Days per year 95° or hotter	0.0	17 (5–37)	1 (0–14)	3 (1–10)	0 (0–4)	39 (21-70)	6 (1–18)	4 (1–9)	0 (0–3)
High temp of year's hottest day	94°	104° (100°-107°)	99° (98°-102°)	100° (99°-102°)	97° (96–100°)	106° (104°-110°)	102° (98°-105°)	101° (98°-103°)	97° (95°-100°)
Nov 25–Apr 15 days 32° or hotter	119	138 (131–142)	136 (123–139)	133 (124–138)	126 (120–133)	140 (132–146)	137 (127–143)	133 (125–141)	129 (121–137)

Table 6. As Table 5 on the previous page, but with projections for the last two 20-year periods of the century.

With high emissions, by late in the century every summer day in the Eagle grid could be 90° or hotter.

But with low emissions, 90°-plus days would stay steady from 2020–2039 on, averaging about three per year in each 20-year period.

Tables of Low Temperature Projections

The table below and those that follow on the five pages following present key results from the analysis of projected future low temperatures.

Edwards/Avon grid low temperatures, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels: 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	8°	+3° (+2/+4°)	+2° (+1/+3°)	+2° (+1/+3°)	+3° (+1/+4°)	+4° (+3/+5°)	+3° (+2/+5°)	+4° (+2/+5°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	27°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+1/+3°)	+3° (+2/+3°)	+4° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+5°)	+3° (+2/+4°)
Average low in Dec-Jan-Feb	1°	4° (3–5°)	3° (2–4°)	4° (2–5°)	4° (3–5°)	6° (4–7°)	5° (3–6°)	5° (3–6°)	4° (3–5°)
Low temp of year's coldest night	-25°	-22° (-23/-19°)	-23° (-25/-21°)	-23° (-25/-19°)	-22° (-24/-20°)	-19° (-22/-15°)	-22° (-24/-18°)	-21° (-23/-16°)	-22° (-24/-18°)
Low temp of year's warmest night	46°	49° (48–50°)	48° (48–50°)	49° (48–50°)	49° (48–50°)	51° (50–53°)	50° (48–51°)	50° (49–52°)	49° (48–51°)
Nights per year with lows above 32°	93	117 (108–121)	110 (105–118)	113 (107–119)	114 (108–121)	130 (120–139)	118 (108–125)	119 (108–133)	116 (108–127)
Nights Nov 25–Apr 15 with lows above 32°	0.1	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	1 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)
Nights per year with lows below 0°	48	33 (30–40)	39 (36–41)	35 (30–40)	36 (31–41)	27 (20–33)	31 (25–38)	30 (25–37)	34 (26–38)
May nights per year with lows above 32°	5	11 (9–12)	9 (8–11)	10 (8–13)	9 (8–12)	15 (12–18)	11 (9–14)	12 (9–16)	11 (9–14)
Days in frost-free growing season*	51	75 (65–82)	66 (61–75)	71 (64–77)	74 (64–83)	85 (72–97)	74 (66–85)	79 (65–90)	73 (62–85)
Extreme years									
Low temp of year's coldest night	-12°	-9° (-13°/-3°)	-11° (-14°/-8°)	-9° (-17°/-6°)	-10° (-15°/-6°)	-6° (-12°/-3°)	-9° (-15°/-5°)	-7° (-13°/-3°)	-9° (-13°/-7°)
Low temp of year's warmest night	50°	53° (51–54°)	52° (51–53°)	52° (51–54°)	53° (50–54°)	55° (51–54°)	53° (52–55°)	53° (52–56°)	53° (51–54°)
May nights per year w/ lows 32° or warmer	15	22 (16–29)	19 (14–23)	21 (18–26)	21 (14–27)	28 (21–31)	21 (18–26)	22 (17–28)	23 (16–28)

Table 7. As Table 1 on page 23, but with respect to daily low temperatures (typically occurring in the nighttime). The first two rows show changes compared to 1970–1999 actual values.

*The frost-free growing season is the maximum number of consecutive days in a year with low temperatures above 32°.

Edwards/Avon grid low temperatures, 2060–2099

	1970-99 Actual	2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	8°	+6° (+5–8°)	+5° (+3–6°)	+4° (+3–5°)	+3° (+2–4°)	+8° (+6–10°)	+6° (+4–8°)	+4° (+3–6°)	+3° (+2–4°)
Hot months avg low (May thru Oct): *change*	27°	+7° (+5–8°)	+4° (+2–6°)	+4° (+2–6°)	+3° (+1–4°)	+9° (+6–11°)	+6° (+4–7°)	+4° (+3–6°)	+3° (+1–4°)
Average low in Dec-Jan-Feb	1°	7° (6–10°)	6° (4–7°)	6° (4–7°)	4° (3–6°)	10° (7–12°)	7° (5–9°)	6° (4–7°)	4° (3–6°)
Low temp of year's coldest night	-25°	-16° (-20–12°)	-19° (-22–14°)	-19° (-22–16°)	-21° (-25–19°)	-14° (-17–8°)	-18° (-21–10°)	-20° (-21–15°)	-21° (-24–18°)
Low temp of year's warmest night	46°	53° (51–55°)	51° (49–53°)	51° (49–53°)	49° (48–51°)	55° (53–58°)	52° (50–54°)	51° (49–53°)	49° (48–51°)
Nights per year with lows above 32°	93	146 (131–159)	130 (125–142)	125 (116–142)	115 (106–125)	163 (146–177)	140 (126–155)	129 (115–144)	115 (105–127)
Nights Nov 25–Apr 15 with lows above 32°	0.1	1 (0–2)	1 (0–1)	0 (0–1)	0 (0–0)	2 (1–4)	1 (0–2)	1 (0–1)	0 (0–0)
Nights per year with lows below 0°	48	21 (13–26)	26 (19–33)	28 (21–33)	33 (27–39)	16 (9–21)	22 (13–29)	27 (19–34)	34 (25–39)
May nights per year with lows above 32°	5	19 (15–24)	15 (11–19)	15 (11–20)	10 (8–14)	24 (28–36)	17 (14–25)	14 (11–21)	10 (9–14)
Days in frost-free growing season	51	101 (80–115)	88 (68–102)	81 (71–97)	73 (57–86)	116 (91–141)	95 (76–116)	84 (69–99)	78 (56–84)
Extreme years									
Low temp of year's coldest night	-12°	-2° (-9/+2°)	-7° (-12/+-4°)	-7° (-11/-4°)	-8° (-12/-6°)	-1° (-6/+2°)	-4° (-10/0°)	-6° (-10/-3°)	-10° (-13/-5°)
Low temp of year's warmest night	50°	56° (53–60°)	55° (52–57°)	53° (52–55°)	52° (51–55°)	59° (57–60°)	55° (54–57°)	55° (53–56°)	52° (50–55°)
May nights per year w/ lows 32° or warmer	15	31 (26–31)	25 (20–31)	26 (22–31)	22 (17–26)	31 (28–31)	27 (21–31)	26 (21–31)	22 (17–27)

Projections with Different Emission Levels

Table 8. As Table 7 on the previous page, but with projections for the last two 20-year periods of the century.

With continued high emissions, late in the century there could be about 80 more nights a year above freezing in the Edwards/Avon grid than in the baseline period.

Vail Mountain grid low temperatures, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	Med. #1	Med. #2	Low	2040–2059 High	Med. #1	Med. #2	Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	5°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+1/+3°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+4°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	25°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+2/+3°)	+3° (+2/+3°)	+5° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+5°)	+3° (+2/+4°)
Average low in Dec-Jan-Feb	0°	3° (2–3°)	2° (1–2°)	3° (1–3°)	3° (1–3°)	4° (3–5°)	3° (1–4°)	3° (2–5°)	3° (2–4°)
Low temp of year's coldest night	-24°	-21° (-23 -19°)	-22° (-25, -21°)	-22° (-24, -19°)	-22° (-24, -20°)	-19° (-22, -15°)	-21° (-23, -18°)	-21° (-23, -17°)	-21° (-24, -19°)
Low temp of year's warmest night	42°	45° (44–46°)	45° (44–46°)	45° (44–46°)	45° (44–46°)	47° (46–48°)	45° (44–46°)	45° (44–46°)	45° (44–46°)
Nights per year with lows above 32°	69	97 (85–101)	89 (83–96)	93 (85–96)	92 (85–99)	109 (100–119)	96 (86–104)	100 (87–112)	94 (85–104)
Nights Nov 15–Apr 15 with lows above 32°	0	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	56	42 (35–48)	47 (41–48)	42 (35–48)	42 (36–49)	34 (25–40)	37 (32–46)	37 (32–44)	41 (33–46)
May nights per year w/ lows 32° or warmer	1	3 (2–4)	1 (1–2)	3 (2–4)	3 (2–4)	6 (5–9)	3 (3–5)	5 (3–7)	4 (2–6)
Days in frost-free growing season	31	58 (47–67)	53 (42–62)	56 (45–63)	60 (47–67)	73 (58–85)	63 (50–71)	66 (49–78)	58 (46–71)
Extreme years									
Low temp of year's coldest night	-14°	-12° (-14, -6°)	-12° (-16, -8°)	-11° (-16, -9°)	-11° (-14, -8°)	-8° (-13, -4°)	-8° (-16, -7°)	-11° (-13, -8°)	-12° (-15, -9°)
Low temp of year's warmest night	46°	49° (47–50°)	48° (46–49°)	48° (47–49°)	49° (47–50°)	50° (48–52°)	49° (48–5-°)	49° (48–51°)	48° (47–50°)
May nights per year w/ lows 32° or warmer	5	10 (8–15)	10 (10–11)	12 (7–16)	10 (7–15)	16 (12–24)	11 (6–15)	12 (8–19)	12 (8–17)

Table 9. As Table 7 on page 29, but instead for the Vail Mountain grid.

Vail Mountain grid low temperatures, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	5°	+6° (+4/+8°)	+4° (+3/+6°)	+4° (+2/+5°)	+2° (+2/+4°)	+8° (+6/+10°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	25°	+7° (+5/+9°)	+4° (+3/+6°)	+4° (+2/+6°)	+3° (+1/+4°)	+9° (+6/+12°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+1/+4°)
Average low in Dec-Jan-Feb	0°	6° (4–8°)	5° (3–6°)	4° (2–5°)	3° (2–4°)	8° (6–10°)	6° (4–8°)	5° (3–6°)	3° (2–4°)
Low temp of year's coldest night	-24°	-17° (-19/-13°)	-20° (-21/-15°)	-19° (-21/-17°)	-20° (-23/-19°)	-15° (-17/-9°)	-18° (-21/-10°)	-20° (-21/-15°)	-21° (-23/-17°
Low temp of year's warmest night	42°	49° (48–51°)	47° (45–48°)	46° (45–48°)	45° (44–46°)	51° (49–54°)	48° (46–50°)	47° (45–48°)	45° (43–46°
Nights per year with lows above 32°	69	127 (113–141)	109 (95–124)	104 (92–120)	93 (83–105)	146 (130–161)	120 (106–136)	109 (96–125)	92 (83–106
Nights Nov 15–Apr 15 with lows above 32°	0.0	0 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)	1 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	56	28 (16–33)	32 (24–39)	33 (26–41)	40 (32–47)	20 (11–27)	27 (15–36)	34 (24–43)	42 (30–47)
May nights per year w/ lows 32° or warmer	1	11 (7–15)	7 (4–8)	6 (4–9)	4 (2–5)	16 (11–21)	9 (7–14)	6 (4–11)	3 (2–5)
Days in frost-free growing season	31	87 (68–100)	72 (53–91)	70 (52–84)	57 (42–71)	103 (82–126)	77 (63–99)	69 (61–87)	58 (39–71)
Extreme years									
Low temp of year's coldest night	-14°	-6° (-11, -4°)	-12° (-14, -5°)	-10° (-12, -7°)	-12° (-14, -6°)	-4° (-8, -1°)	-7° (-11, -3°)	-9° (-11, -3°)	-11° (-14, -6°
Low temp of year's warmest night	46°	53° (51–54°)	50° (49–53°)	50° (48–51°)	49° (47–51°)	55° (53–58°)	51° (49–53°)	50° (49–52°)	48° (47–50°
May nights per year w/ lows 32° or warmer	5	22 (16–26)	16 (9–23)	15 (11–22)	9 (7–14)	26 (22–31)	19 (11–26)	17 (11–23)	11 (7–16)

Table 10. As Table 9 on the previous page, but with projections for the last two 20-year periods of the century.

With high emissions, in the extreme year in mid-century in the Vail Mountain grid, half the nights in May could stay above freezing.

Eagle grid low temperatures, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	10°	+3° (+2/+4°)	+2° (+1/+3°)	+3° (+1/+4°)	+3° (+2/+4°)	+5° (+3/+6°)	+3° (+2/+5°)	+4° (+2/+5°)	+3° (+2/4°)
Hot months avg low (May thru Oct): *change*	29°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+1/+3°)	+3° (+2/+3°)	+5° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+5°)	+3° (+2/4°)
Average low in Dec-Jan-Feb	3°	7° (6-8°)	6° (5-6°)	7° (5-7°)	6° (5-7°)	9° (7-10°)	7° (5-9°)	8° (6-9°)	7° (6-8°)
Low temp of year's coldest night	-15°	-11° (-13/-9°)	-13° (-16/-10°)	-12° (-15/-8°)	-12° (-14/-9°)	-8° (-12/-4°)	-10° (-14/-6°)	-10° (-12/-5°)	-11° (-14/-7°)
Low temp of year's warmest night	51°	53° (53–55°)	53° (52–54°)	53° (52–54°)	53° (52–54°)	55° (54–57°)	54° (53–55°)	54° (53–56°)	54° (52–55°)
Nights per year with lows above 32°	115	135 (128–140)	130 (126–138)	131 (127–140)	134 (128–140)	148 (137–155)	137 (128–144)	139 (128–149)	135 (127–145)
Nights Nov 25–Apr 15 with lows above 32°	0.4	1 (1–2)	1 (0–1)	1 (0–1)	1 (1–2)	2 (1–2)	1 (1–1)	1 (1–2)	1 (1–2)
Nights per year with lows below 0°	37	24 (21–29)	28 (25–31)	26 (22–30)	26 (22–30)	18 (13–22)	22 (16–29)	22 (17–27)	25 (18–28)
May nights per year with lows above 32°	10	16 (15–18)	15 (14–18)	15 (13–19)	16 (14–19)	20 (16–25)	17 (14–21)	18 (15–21)	17 (14–21)
Days in frost-free growing season	69	89 (83–99)	83 (77–93)	85 (78–95)	89 (82–97)	99 (89–113)	89 (82–102)	94 (82–106)	87 (79–102)
Extreme years									
Low temp of year's coldest night	-8°	-5° (-7/-1°)	-6° (-11/0°)	-4° (-9/-2°)	-4° (-9/-1°)	-1° (-7/3°)	-3° (-7/1°)	-3° (-7/1°)	-5° (-8/-1°)
Low temp of year's warmest night	54°	56° (55–58°)	56° (54–58°)	56° (55–60°)	56° (53–57°)	58° (56–61°)	57° (56–59°)	58° (55–60°)	57° (54–58°)
May nights per year with lows above 32°	17	22 (17–28)	20 (14–26)	23 (18–26)	20 (17–29)	25 (22–29)	22 (18–28)	23 (20–27)	23 (17–27)

Table 11. As Table 7 on page 29, but with respect to the Eagle grid.

Eagle grid low temperatures, 2060–2099

	1970-99 Actual	2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	10°	+6° (+5/+8°)	+5° (+3/+6°)	+4° (+3/+6°)	+3° (+2/+4°)	+8° (+7/+10°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+2/+5°)
Hot months avg low (May thru Oct): *change*	29°	+7° (+5/+8°)	+4° (+2/+6°)	+4° (+2/+6°)	+3° (+1/+4°)	+9° (+6/+12°)	+6° (+4/+7°)	+4° (+3/+6°)	+3° (+1/+4°)
Average low in Dec-Jan-Feb	3°	10° (9–13°)	9° (7–10°)	8° (7–10°)	7° (5–8°)	12° (10–15°)	10° (8–12°)	9° (6–10°)	7° (6–8°)
Low temp of year's coldest night	-15°	-5° (-8/-1°)	-8° (-11/-3°)	-8° (-12/-5°)	-11° (-14/-7°)	-2° (-6/4°)	-7° (-11/2°)	-9° (-11/-4°)	-10° (-14/-6°)
Low temp of year's warmest night	51°	58° (56–60°)	55° (53–57°)	55° (53–57°)	53° (52–55°)	59° (57–63°)	57 (54–58°)	55° (53–57°)	53° (52–55°)
Nights per year with lows above 32°	115	163 (149–174)	149 (135–158)	144 (135–158)	136 (126–145)	180 (164–193)	159 (143–172)	146 (133–159)	134 (127–147)
Nights Nov 25–Apr 15 with lows above 32°	0.4	3 (2–4)	2 (1–3)	1 (1–2)	1 (1–1)	5 (3–8)	3 (1–5)	2 (1–3)	1 (1–1)
Nights per year with lows below 0°	37	14 (6–17)	17 (13–24)	19 (14–24)	23 (18–28)	8 (4–13)	14 (7–20)	18 (12–25)	25 (17–28)
May nights per year with lows above 32°	10	24 (20–29)	20 (17–24)	19 (16–25)	16 (13–21)	27 (24–31)	21 (19–30)	20 (17–26)	16 (14–21)
Days in frost-free growing season	69	114 (98–129)	103 (86–116)	96 (83–113)	86 (72–100)	130 (106–150)	110 (92–129)	98 (82–114)	90 (73–103)
Extreme years									
Low temp of year's coldest night	-8°	2° (-2/6°)	-1° (-6/4°)	-3° (-7/2°)	-3° (-6/1°)	4° (-1/7°)	1° (-5/4°)	0° (-7/3°)	-4° (-8/0°)
Low temp of year's warmest night	54°	61° (58–64°)	58° (55–61°)	57° (54–60°)	56° (54–59°)	63° (60–67°)	60° (57–63°)	59° (56–60°)	56° (54–58°)
May nights per year with lows above 32°	17	29 (25–31)	24 (21–31)	24 (21–29)	21 (18–27)	30 (25–31)	26 (22–31)	26 (23–29)	22 (18–28)

Projections with Different Emission Levels

Table 12. As Table 11 on the previous page, but with projections for the last two 20-year periods of the century.

4. Future Precipitation

For this report, 60 different precipitation values were analyzed, with key results summarized in this section and full results available online at www.rockymountainclimate.org/extremes/summit. Again in this section, statements in text are based on the tables at the end of the section unless indicated otherwise.

Projecting future precipitation is complex and challenging.[16] The precipitation projections presented here should be considered more uncertain than the temperature projections in the preceding section, for the following reasons.

First, modeling precipitation is more uncertain for a region, such as Colorado located between areas where increases are clearly projected (to our north) and those where decreases are clearly projected (to our south).[17]

Second, model variations are larger for small areas, such as the grids analyzed here, than for larger ones.[18]

Third, climate models do a better job in projecting overall precipitation amounts than extreme precipitation events.[19]

Fourth, today's climate models do not do a good job of simulating the North American monsoon and thunderstorms that drive much of Colorado's summer precipitation, making summer projections here more uncertain.[20] As a result, those projections in particular may understate the amount of precipitation in that season. And the projections for summer precipitation in particular often show broad disagreement among the models, with projections ranging from significant decreases to significant increases, as the tables at the end of this section show.

Finally, as a careful examination of the projections presented here shows, for precipitation (unlike for temperature) there often is not a clear relationship between more heat-trapping emissions and larger climate changes.

Still, there are some important precipitation values for which the models are in general agreement and for which the extent of the projected changes appears linked to the amount of future emissions, and we focus on them in this section.

> "Due to the greater level of complexity associated with modeling precipitation, scientific uncertainty tends to dominate in precipitation projections throughout the entire century, affecting both the magnitude and sometimes (depending on location) the sign [direction] of the projected change in precipitation."
>
> *U.S. Global Change Research Program*[21]

Precipitation probably to increase, mostly in cold months

Total annual precipitation amounts are generally projected to increase somewhat. For all three Eagle County grids, all four emission scenarios, and all four future time periods, the median projections are for increases in precipitation amounts over the baseline period. Of those 48 combinations of grids, scenarios, and periods, one of the median projections is for an increase of 10 percent, and the rest are for single-digit percentage increases.

Note, however, that even with such general agreement among the models, some of the models do project decreases, as shown by the values for the 10th percentiles of the projections—the first value in the parentheses following the median projection.

The following examples are for the **Vail Mountain grid with high emissions**.

Total precipitation is projected:

- In mid-century, to increase by an average of three percent (-5 to +12 percent), compared to the baseline period.
- Late in the century, to increase by eight percent (-1 to +15 percent).

Precipitation in cold months, November through April, is projected:

- In typical years in mid-century, to increase by seven percent (3–16 percent).
- Late in the century, to increase by seventeen percent (3–25 percent).

Within the cold months, **winter precipitation** (in December-January-February) is projected:

- In mid-century, to increase by an average of nine percent (2–17 percent).
- Late in the century, to increase by an average of twenty percent (4–32 percent).

Precipitation in hot months, May through October, is suggested by the median projections to have little or no change—but several individual models project sizeable increases and several others show sizeable decreases, as shown by the wide range from the 10th to the 90th percentiles of the projections:

- In mid-century, an average increase of one percent (-17 to +8 percent).
- Late in the century, an average decrease of three percent (-18 to +8 percent).

Within the hot months, **summer precipitation** (in June-July-August) is projected:

- In mid-century, to increase by an average of one percent (-15 to +14 percent).
- Late in the century, to increase by an average of one percent (-22 to +14 percent).

It is worth re-emphasizing the caveats from the previous page: Since the models appear not to well represent summer monsoons or thunderstorms, the projections for the hot months could be low. And the projections for the hot months and for summer show a wide spread, spanning from double-digit percentage decreases to double-digit percentage increases, further suggesting that these projections are uncertain. Even with these uncertainties, it would be reassuring if the models clearly project enough of an increase in hot season precipitation, especially summer (June-July-August) precipitation, to offset the inherent drying effect of the significantly higher temperatures projected for then. But that is not the case.

The projections for changes in precipitation amounts in cold and hot months are illustrated in Figure 12 on the next page, using the Vail Mountain grid as an example.

Precipitation amounts in Vail Mountain grid, 2020–2099

Percentage change compared to 1970–1999

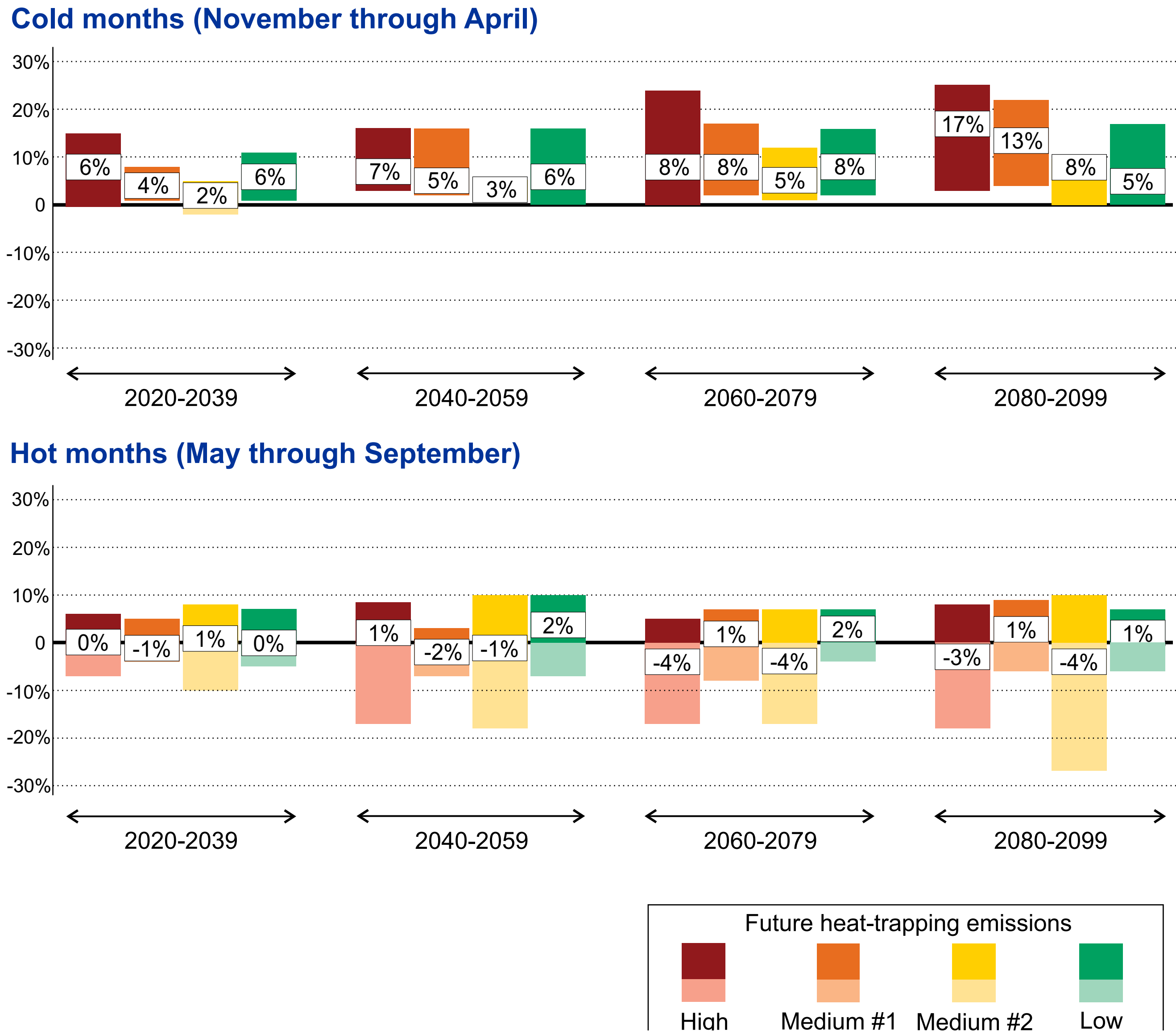


Figure 12. Projections for changes in the amounts of precipitation in the cold months of November–April and below that in the hot months of May–October, in percentage change compared to the gridded/observed amounts in the 1970–1999 baseline (see page 50). For each future period, the four columns represent separate projections based on the emission scenarios identified on page 7. The columns represent the range from the 10th percentile to the 90th percentile of the projections, and the numerals in the columns are the medians of all projections (see page 8), In a column, the darker color shows a projected increase and a lighter color a decrease. The gridded/observed 1970–1999 average precipitation amounts serving as baselines for the percentage changes illustrated here are 19 inches in the cold months and 12 inches in the hot months. For the data illustrated here, see tables 15 and 16 on pages 42 and 43.

Increases in winter precipitation are projected, especially with higher emissions. The models do not show an increase in summer precipitation.

Everyday precipitation events become less frequent, heavy storms more frequent

An even clearer, more consistent signal from the precipitation projections is that the frequency of storms of different intensity could change, with days of everyday, modest amounts of precipitation becoming less frequent and heavier storms becoming more frequent. The following examples are also from the Vail Mountain grid.

Routine wet days, those with less than a quarter-inch of precipitation in a day, are projected:

- In mid-century, to average 4 percent less frequent (-8 to 0%), compared to the baseline.
- Late in the century, to average 9 percent less frequent (-14 to -1 percent).

Storms of 1/4 inch to 1/2 inch of precipitation are projected:

- In mid-century, to average 15 percent more frequent (+4 to +29 percent).
- Late in the century, to average 23 percent more frequent (+9 to +41 percent).

Storms of 1/2 inch or more are projected:

- In mid-century to average 18 percent (+4 to +29) more frequent.
- Late in the century, to average 33 percent (+18 to +50 percent) more frequent.

The above projections are for the year-round frequency of these different wet days. The projections for increased frequency of heavy storms are even more pronounced in the cold months than in the hot months, especially with high emissions, as the tables on pages 40–45 show.

Figure 13 on the next page illustrates the changes in the projected annual frequency of different types of storms, with the Vail Mountain grid as the example.

Frequency of storms by intensity, Vail Mountain grid

Percentage change compared to 1970–1999

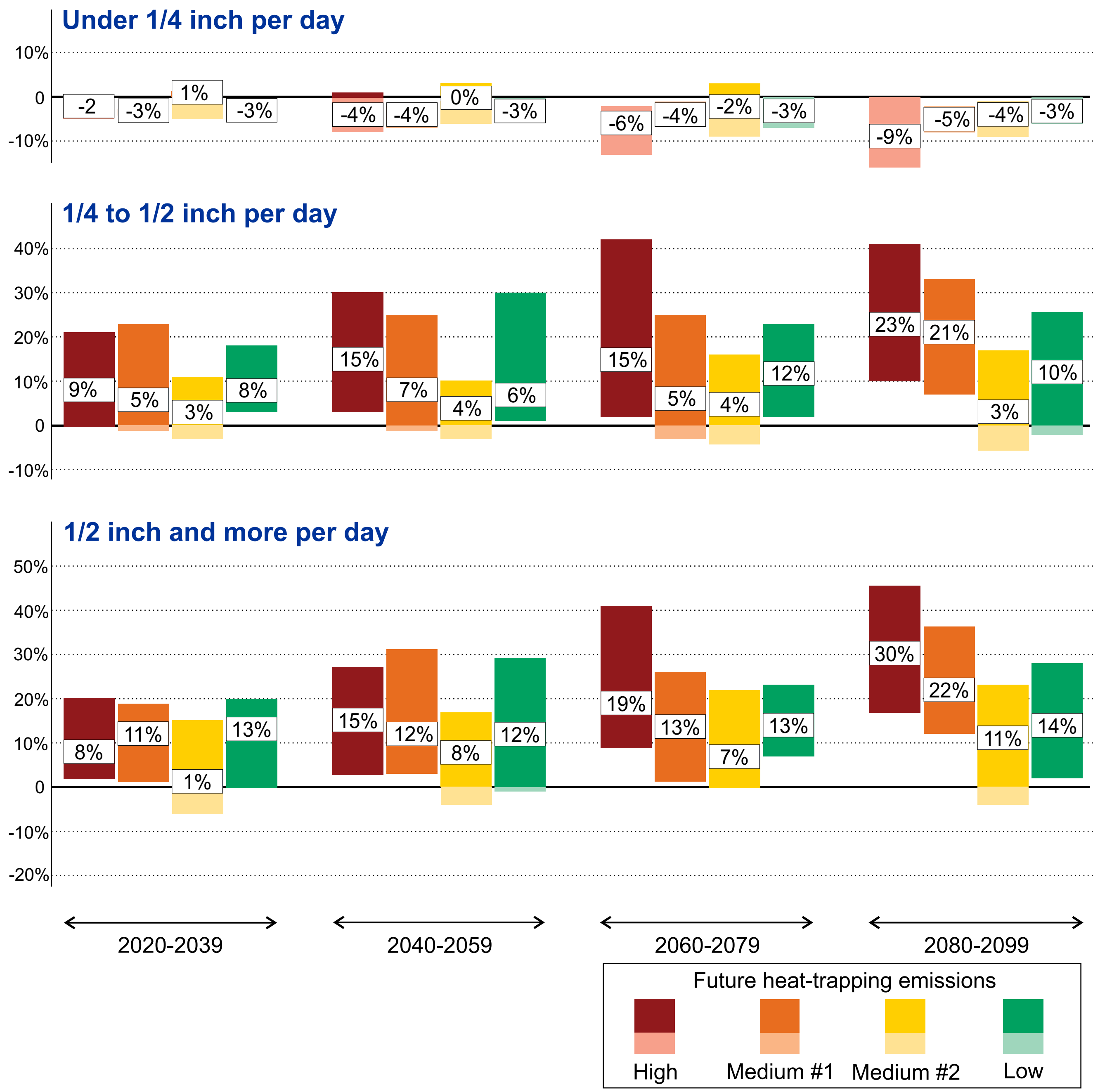


Figure 13. Projected percentage changes in the annual frequency of days of precipitation with the indicated precipitation amounts in the Vail Mountain grid, otherwise as Figure 12 on page 37. The gridded/observed 1970–1999 average frequencies serving as baselines for the percentage changes illustrated here are averages of 180 days per year for storms of under 1/4 inch of precipitation per day, 28 for 1/4 to 1/2 inch, and eight for 1/2 inch and more. For the data illustrated here, see tables 15 and 16 on pages 42 and 43.

Heavy storms are projected to occur more often. The projected increases are larger with high emissions, and with high emissions the projections continue increasing through the century. This correlates with what would be increasing atmospheric levels of heat-trapping pollution.

Tables of Precipitation Projections

The table below and those on the next fives pages show key results of the analysis of projected precipitation for each of the three grids. As with the temperature tables, these are in pairs, with the first of each pair showing projections for 2020–2059 and the next for 2060–2099.

The results from the analysis of all 60 precipitation values done for this report are available online at www.rockymountainclimate.org/extremes/eagle.

Precipitation in Edwards/Avon grid, 2020–2059

Percentage change compared to 1970–1999

		Projections with Different Emission Levels							
	1970-99	2020–2039				2040–2059			
	Actual	High	Med. #1	Med. #2	Low	High	Med. #1	Med. #2	Low
Precip amount in year	24 in.	+5% (-2/+9%)	+4% (-1/+5%)	+1% (-4/+8%)	+2% (0/+10%)	+4% (-5/+14%)	+3% (-3/+12%)	+2% (-6/+9%)	+4% (-1/+15%)
Cold months precip (Nov thru April)	14 in.	+7% (-1/+15%)	+5% (0/+11%)	+3% (-3/+6%)	+6% (+2/+13%)	+7% (+2/+18%)	+4% (+1/+17%)	+4% (+1/+8%)	+6% (+1/+18%)
Hot months precip (May thru October)	10 in.	+1% (-7/+5%)	0% (-6/+5%)	+1% (-12/+10%)	0% (-5/+7%)	+2% (-18/+9%)	-2% (-8/+4%)	-1% (-21/+12%)	+4% (-7/+12%)
Winter precip (Dec-Jan-Feb)	7.3 in.	+7% (-4/+20%)	+6% (-6/+14%)	+2% (0/+7%)	+6% (-1/+12%)	+10% (+2/+17%)	+3% (0/+18%)	+4% (0/+7%)	+7% (-3/+13%)
Spring precip (Mar-Apr-May)	7.4 in.	+2% (-3/+12%)	+3% (-3/+15%)	-2% (-9/+15%)	+3% (-3/+24%)	+4% (-3/+20%)	+5% (-6/+25%)	+4% (-4/+19%)	+4% (0/+21%)
Summer precip (Jun-Jul-Aug)	4.6 in	+1% (-8/+13%)	+2% (-6/+6%)	-1% (-9/+14%)	-2% (-11/+11%)	+2% (-18/+14%)	-3% (-5/+1%)	+1% (-22/+17%)	+4% (-5/+10%)
Fall precip (Sep-Oct-Nov)	5.6 in.	+1% (-6/+9%)	+1% (-5/+6%)	+3% (-7/+9%)	-2% (-7/+11%)	+1% (-12/+9%)	-1% (-5/+7%)	+1% (-6/+7%)	+3% (-9/+13%)
Days w/ less than 1/4 in. precip	165	-1% (-7/+2%)	-2% (-5/-1%)	+1% (-6/+3%)	-2% (-6/+2%)	-2% (-11/+2%)	-4% (-7/-1%)	0% (-7/+3%)	-1% (-5/+2%)
Days with 1/4 to 1/2 in. precip	21	+9% (0/+15%)	+8% (0/+18%)	+3% (-4/+15%)	+8% (-1/+18%)	+10% (+1/+28%)	+6% (-3/+22%)	+5% (-4/+13%)	+7% (-1/+30%)
Days w/ 1/2 in. or more precip	6	+9% (-3/+21%)	+8% (-6/+20%)	+2% (-9/+22%)	+10% (+2/+18%)	+14% (+5/+27%)	+10% (+6/+26%)	+11% (-6/+23%)	+12% (-6/+25%)
Cold-month days w/ 1/2 in. or more	3.7	+15% (-10/+33%)	+14% (-1/+31%)	+3% (-7/+14%)	+12% (-3/+27%)	+20% (+9/+38%)	+13% (+1/+44%)	+10% (-2/+18%)	+14% (-9/+29%)
Hot-month days w/ 1/2 in. or more	1.9	+1% (-12/+22%)	-4% (-16/+14%)	+4% (-22/+47%)	+8% (-5/+20%)	+7% (-4/+21%)	+8% (-9/+18%)	+12% (-28/+42%)	+4% (-4/+25%)
Precip in wettest day in year	0.9 in.	+1% (-4/+20%)	+6% (-5/+11%)	-3% (-12/+16%)	+6% (+1/+17%)	+9% (-3/+15%)	+2% (-5/+18%)	+3% (-11/+16%)	+4% (-4/+18%)

Table 13. Projections for percentage change in average amounts of precipitation in the Edwards/Avon grid, compared to the gridded/observed 1970–1990 values shown in the first column (see page 50), for the indicated time periods and the four emission scenarios identified on page 7. For the projections, the top row shows the median of the projections from all climate models for that emissions scenario, and the next row shows in parentheses the 10th percentile of the projections and the 90th percentile—in other words, the range of the middle 80 percent of those projections (see page 8).

Precipitation in Edwards/Avon grid, 2060–2099

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Precip amount in year	24 in.	+5% (-6/+17%)	+4% (+1/+12%)	+2% (-5/+12%)	+5% (+1/+11%)	+8% (-3/+18%)	+9% (+1/+18%)	+2% (-6/+11%)	+3% (-2/+13%)
Cold months precip (Nov thru April)	14 in.	+10% (-1/+26%)	+7% (-1/+18%)	+7% (+1/+15%)	+7% (+1/+17%)	+18% (+5/+25%)	+13% (+4/+25%)	+10% (0/+13%)	+3% (-1/+19%)
Hot months precip (May thru October)	10 in.	-4% (-17/+7%)	+2% (-7/+8%)	-5% (-20/+8%)	+3% (-3/+8%)	-2% (-21/+10%)	+2% (-5/+11%)	-5% (-31/+12%)	+3% (-6/+7%)
Winter precip (Dec-Jan-Feb)	7.3 in.	+7% (+1/+28%)	+5% (-2/+17%)	+5% (+2/+9%)	+5% (-1/+11%)	+21% (+7/+32%)	+9% (-1/+18%)	+7% (+2/+13%)	+2% (-6/+14%)
Spring precip (Mar-Apr-May)	7.4 in.	+4% (-3/+29%)	+4% (-2/+29%)	+4% (-9/+22%)	+9% (+3/+24%)	+7% (-4/+25%)	+13% (+1/+39%)	+4% (-6/+14%)	+8% (-2/+25%)
Summer precip (Jun-Jul-Aug)	4.6 in	-4% (-20/+8%)	0% (-8/+12%)	-8% (-29/+9%)	+6% (-9/+10%)	0% (-22/+15%)	+7% (-7/+11%)	-9% (-34/+24%)	+4% (-7/+11%)
Fall precip (Sep-Oct-Nov)	5.6 in.	+2% (-16/+10%)	-1% (-8/+7%)	+1% (-8/+6%)	+2% (-8/+11%)	+3% (-11/+12%)	+4% (-4/+10%)	+1% (-9/+9%)	+5% (-8/+10%)
Days w/ less than 1/4 in. precip	165	-5% (-16/-1%)	-2% (-8/0%)	-2% (-10/+2%)	-2% (-6/+2%)	-7% (-15/+2%)	-3% (-9/0%)	-4% (-10/+3%)	-2% (-7/+1%)
Days with 1/4 to 1/2 in. precip	21	+11% (+1/+38%)	+8% (-2/+21%)	+6% (-6/+21%)	+7% (+1/+22%)	+20% (+7/+40%)	+20% (+8/+34%)	+4% (-7/+22%)	+12% (-2/+25%)
Days w/ 1/2 in. or more precip	6	+19% (+3/+43%)	+16% (-2/+25%)	+10% (-1/+31%)	+11% (+7/+22%)	+24% (+15/+44%)	+18% (+5/+38%)	+15% (-8/+33%)	+11% (0/+28%)
Cold-month days w/ 1/2 in. or more	3.7	+27% (+6/+56%)	+23% (-2/+35%)	+10% (-5/+29%)	+16% (+5/+31%)	+34% (+22/+65%)	+25% (+11/+50%)	+19% (+3/+29%)	+12% (-6/+38%)
Hot-month days w/ 1/2 in. or more	1.9	+2% (-4/+16%)	+4% (-5/+21%)	+10% (-16/+43%)	+4% (-4/+17%)	+8% (-12/+24%)	+5% (-7/+27%)	+13% (-39/+56%)	+7% (-7/+18%)
Precip in wettest day in year	0.9 in.	+10% (-2/+21%)	+11% (-5/+16%)	+6% (-5/+16%)	+8% (-1/+13%)	+15% (+6/+23%)	+13% (-4/+21%)	+1% (-9/+24%)	+6% (0/+17%)

Table 14. As Table 13 on the previous page, but for the last two 20-year periods of the century.

The median projections across all emission scenarios are for precipitation amounts in the six cold months of the year to increase, and days with a quarter-inch or more of precipitation to become more frequent.

Precipitation in Vail Mountain grid, 2020–2059

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels: 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Precip amount in year	31 in.	+4% (-1/+9%)	+2% (+1/+5%)	+1% (-3/+6%)	+3% (0/+8%)	+3% (-5/+12%)	+3% (-1/+11%)	+2% (-4/+7%)	+3% (-1/+13%)
Cold months precip (Nov thru April)	19 in.	+6% (0/+15%)	+4% (+1/+8%)	+2% (-2/+5%)	+6% (+1/+11%)	+7% (+3/+16%)	+5% (+2/+16%)	+3% (+1/+6%)	+6% (0/+16%)
Hot months precip (May thru October)	12 in.	0% (-7/+5%)	-1% (-4/+4%)	+1% (-10/+8%)	0% (-5/+7%)	+1% (-17/+8%)	-2% (-7/+3%)	-1% (-18/+10%)	+2% (-7/+10%)
Winter precip (Dec-Jan-Feb)	9.9 in.	+7% (-1/+15%)	+5% (-7/+12%)	+2% (0/+5%)	+7% (-1/+11%)	+9% (+2/+17%)	+4% (+2/+16%)	+3% (0/+5%)	+6% (0/+11%)
Spring precip (Mar-Apr-May)	9.9 in.	+3% (-3/+11%)	+1% (-4/+11%)	-1% (-7/+11%)	+5% (-4/+19%)	+3% (-3/+17%)	+5% (-5/+21%)	+3% (-3/+14%)	+4% (-1/+20%)
Summer precip (Jun-Jul-Aug)	5.3 in	+2% (-8/+12%)	0% (-6/+5%)	-1% (-8/+12%)	+1% (-9/+10%)	+1% (-15/+14%)	0% (-7/+1%)	+1% (-19/+15%)	+4% (-5/+11%)
Fall precip (Sep-Oct-Nov)	6.8 in.	0% (-6/+7%)	+2% (-2/+6%)	+2% (-6/+7%)	-1% (-7/+6%)	-2% (-10/+8%)	+1% (-6/+7%)	+1% (-5/+6%)	+1% (-10/+10%)
Days w/ less than 1/4 in. precip	180	-2% (-5/0%)	-3% (-4/-1%)	-1% (-5/+2%)	-3% (-4/-1%)	-4% (-8/+1%)	-4% (-7/-2%)	0% (-6/+3%)	-3% (-5/0%)
Days with 1/4 to 1/2 in. precip	28	+9% (0/+21%)	+5% (-2/+13%)	+3% (-3/+11%)	+8% (+3/+18%)	+15% (+3/+30%)	+7% (-1/+25%)	+4% (-3/+10%)	+6% (+1/+30%)
Days w/ 1/2 in. or more precip	8	+8% (+2/+20%)	+11% (+1/+19%)	+1% (-6/+16%)	+13% (0/+20%)	+15% (+3/+27%)	+12% (+3/+31%)	+8% (-4/+17%)	+12% (-1/+29%)
Cold-month days w/ 1/2 in. or more	5.9	+12% (+1/+29%)	+13% (+1/+25%)	+2% (-5/+9%)	+15% (+1/+25%)	+22% (+5/+35%)	+16% (+4/+36%)	+6% (-2/+11%)	+15% (-1/+31%)
Hot-month days w/ 1/2 in. or more	2.0	0% (-7/+13%)	+4% (-11/+17%)	+3% (-20/+43%)	+8% (-9/+16%)	+4% (-13/+19%)	+9% (-4/+19%)	+11% (-26/+38%)	+3% (-4/+26%)
Precip in wettest day in year	1.0 in.	+5% (-2/+12%)	+5% (0/+12%)	-3% (-11/+15%)	+4% (-2/+10%)	+6% (0/+11%)	+2% (0/+9%)	+3% (-10/+15%)	+5% (-5/+12%)

Table 15. As Table 13 on page 40, but for the Vail Mountain grid.

Precipitation in Vail Mountain grid, 2060–2099
Percentage change compared to 1970–1999

		Projections with Different Emission Levels							
	1970-99	2060–2079				2080–2099			
	Actual	High	Med. #1	Med. #2	Low	High	Med. #1	Med. #2	Low
Precip amount in year	31 in.	+6% (-6/+17%)	+4% (0/+11%)	+2% (-4/+10%)	+6% (0/+11%)	+8% (-1/+15%)	+10% (+1/+15%)	+2% (-5/+9%)	+4% (-2/+12%)
Cold months precip (Nov thru April)	19 in.	+8% (0/+24%)	+8% (+2/+17%)	+5% (+1/+11%)	+8% (+2/+16%)	+17% (+3/+25%)	+13% (+4/+22%)	+8% (0/+9%)	+5% (0/+17%)
Hot months precip (May thru October)	12 in.	-4% (-17/+5%)	+1% (-8/+7%)	-4% (-17/+7%)	+2% (-4/+7%)	-3% (-18/+8%)	+1% (-6/+9%)	-4% (-27/+10%)	+1% (-6/+7%)
Winter precip (Dec-Jan-Feb)	9.9 in.	+8% (+2/+25%)	+9% (+1/+16%)	+4% (+2/+6%)	+7% (-1/+11%)	+20% (+4/+32%)	+9% (-1/+17%)	+5% (+2/+10%)	+5% (-4/+12%)
Spring precip (Mar-Apr-May)	9.9 in.	+4% (-4/+27%)	+4% (-7/+25%)	+3% (-7/+17%)	+8% (+2/+20%)	+7% (-5/+22%)	+11% (-1/+33%)	+3% (-5/+10%)	+9% (-2/+23%)
Summer precip (Jun-Jul-Aug)	5.3 in	-3% (-19/+9%)	+2% (-5/+10%)	-7% (-25/+8%)	+4% (-9/+12%)	+1% (-22/+14%)	+4% (-5/+12%)	-8% (-29/+21%)	+1% (-6/+10%)
Fall precip (Sep-Oct-Nov)	6.8 in.	0% (-15/+8%)	-4% (-10/+6%)	+1% (-6/+5%)	+2% (-8/+10%)	-4% (-11/+12%)	+3% (-5/+9%)	+1% (-7/+8%)	+3% (-10/+8%)
Days w/ less than 1/4 in. precip	180	-6% (-13/-2%)	-4% (-7/-1%)	-2% (-9/+2%)	-3% (-7/0%)	-9% (-15/0%)	-5% (-8/-2%)	-4% (-9/+2%)	-3% (-6/0%)
Days with 1/4 to 1/2 in. precip	28	+15% (+2/+42%)	+5% (-3/+25%)	+4% (-4/+16%)	+12% (+2/+23%)	+23% (+10/+41%)	+21% (+7/+34%)	+3% (-5/+17%)	+10% (-2/+26%)
Days w/ 1/2 in. or more precip	8	+19% (+9/+41%)	+13% (+1/+26%)	+7% (0/+22%)	+13% (+7/+23%)	+30% (+17/+46%)	+22% (+12/+36%)	+11% (-6/+23%)	+14% (+2/+28%)
Cold-month days w/ 1/2 in. or more	5.9	+24% (+13/+51%)	+18% (+4/+31%)	+6% (-3/+18%)	+17% (+8/+29%)	+43% (+20/+61%)	+26% (+16/+47%)	+12% (+2/+18%)	+17% (+1/+34%)
Hot-month days w/ 1/2 in. or more	2.0	+7% (-8/+20%)	+7% (-7/+15%)	+9% (-15/+40%)	+11% (-7/+20%)	+6% (-10/+29%)	+7% (-5/+21%)	+11% (-36/+51%)	+8% (-9/+17%)
Precip in wettest day in year	1.0 in.	+8% (+1/+14%)	+5% (-1/+15%)	+6% (-4/+14%)	+6% (+2/+10%)	+13% (+5/+16%)	+9% (+2/+14%)	+1% (-9/+22%)	+4% (-1/+10%)

Table 16. As Table 15 on the previous page, but for the last two 20-year periods of the century.

By late in the century, the projected increases in precipitation with high emissions become larger.

Precipitation in Eagle grid, 2020–2059

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Precip amount in year	17 in.	+5% (-1/+9%)	+4% (-3+6%)	+2% (-5/+11%)	+4% (-2/+11%)	+6% (-7/+14%)	+2% (-4/+12%)	+3% (-8/+13%)	+5% (-2/+17%)
Cold months precip (Nov thru April)	8.5 in.	+8% (-2/+19%)	+5% (-1/+14%)	+5% (-6/+11%)	+7% (+1/+14%)	+9% (+1/+19%)	+3% (-1/+19%)	+8% (+2/+13%)	+5% (+1/+14%)
Hot months precip (May thru October)	8.5 in.	+2% (-7/+6%)	0% (-8/+7%)	+1% (-14/+12%)	+2% (-7/+11%)	+3% (-18/+10%)	+1% (-8/+6%)	-2% (-25/+14%)	+5% (-9/+12%)
Winter precip (Dec-Jan-Feb)	4.2 in.	+7% (-5/+24%)	+7% (-10/+19%)	+4% (-1/+11%)	+6% (-1/+18%)	+12% (+1/+21%)	+1% (-5/+25%)	+7% (0/+12%)	+7% (-7/+18%)
Spring precip (Mar-Apr-May)	4.6 in.	+2% (-3/+14%)	+1% (-5/+15%)	-3% (-15/+24%)	+4% (-6/+27%)	+4% (-5/+26%)	+6% (-6/+30%)	+7% (-7/+31%)	+4% (0/+25%)
Summer precip (Jun-Jul-Aug)	3.9 in.	0% (-10/+14%)	+2% (-7/+9%)	-1% (-11/+16%)	-2% (-13/+12%)	+1% (-19/+15%)	-2% (-6/+1%)	-1% (-25/+20%)	+4% (-7/+11%)
Fall precip (Sep-Oct-Nov)	4.3 in.	+2% (-7/+10%)	+2% (-7/+8%)	+4% (-9/+11%)	-3% (-6/+16%)	+4% (-15/+13%)	0% (-6/+10%)	+1% (-8/+9%)	+3% (-10/+16%)
Days w/ less than 1/4 in. precip	130	+1% (-8/+4%)	-2% (-3/+1%)	+1% (-7/+3%)	-1% (-5/+5%)	-2% (-11/+8%)	-3% (-7/+4%)	0% (-9/+4%)	0% (-5/+8%)
Days with 1/4 to 1/2 in. precip	13	+7% (-3/+21%)	+5% (-5/+21%)	+5% (-6/+24%)	+5% (-2/+17%)	+16% (-3/+35%)	+10% (-6/+22%)	+9% (-6/+21%)	+10% (-1/+30%)
Days w/ 1/2 in. or more precip	4	+6% (-7/+20%)	+7% (-9/+17%)	+3% (-12/+30%)	+8% (-1/+15%)	+11% (-4/+26%)	+4% (-4/+20%)	+15% (-9/+32%)	+10% (-4/+25%)
Cold-month days w/ 1/2 in. or more	1.6	+5% (-18/+38%)	+13% (-18/+31%)	+7% (-17/+31%)	+12% (-10/+37%)	+23% (-5/+50%)	+3% (-11/+51%)	+22% (-6/+40%)	+19% (-18/+62%)
Hot-month days w/ 1/2 in. or more	2.7	+3% (-13/+13%)	+3% (-5/+9%)	+3% (-16/+33%)	+3% (-7/+19%)	+5% (-11/+15%)	+5% (-10/+12%)	+8% (-20/+29%)	+4% (-6/+14%)
Precip in wettest day in year	0.8 in.	+4% (-4/+15%)	+2% (-3/+9%)	-3% (-13/+17%)	+7% (+1/+14%)	+8% (-3/+14%)	+2% (-6/+16%)	+4% (-12/+17%)	+8% (-3/+16%)

Table 17. As Table 13 on page 40, but for the Eagle grid.

Precipitation in Eagle grid, 2060–2099

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Precip amount in year	17 in.	+6% (-8/+18%)	+3% (-1+11%)	+3% (-7/+18%)	+5% (0/+12%)	+7% (-4/+21%)	+10% (-1/+18%)	+3% (-9/+16%)	+4% (-3/+13%)
Cold months precip (Nov thru April)	8.5 in.	+11% (0/+31%)	+8% (-5/+18%)	+11% (+2/+26%)	+9% (0/+19%)	+21% (+5/+30%)	+14% (+2/+27%)	+17% (0/+21%)	+4% (-2/+23%)
Hot months precip (May thru October)	8.5 in.	-4% (-18/+9%)	+3% (-9/+9%)	-6% (-24/+10%)	+2% (-5/+9%)	0% (-23/+12%)	+3% (-5/+13%)	-6% (-37/+15%)	+5% (-7/+8%)
Winter precip (Dec-Jan-Feb)	4.2 in.	+8% (0/+41%)	+5% (-8/+22%)	+9% (+4/+15%)	+5% (-4/+18%)	+26% (+6/+42%)	+9% (-5/+25%)	+12% (+4/+22%)	+1% (-8/+20%)
Spring precip (Mar-Apr-May)	4.6 in.	+4% (-5/+32%)	+3% (-2/+31%)	+6% (-15/+35%)	+11% (+3/+26%)	+7% (-6/+27%)	+15% (+1/+40%)	+6% (-10/+22%)	+8% (-3/+30%)
Summer precip (Jun-Jul-Aug)	3.9 in.	-4% (-20/+9%)	0% (-10/+14%)	-10% (-33/+10%)	+6% (-13/+10%)	0% (-24/+16%)	+6% (-7/+13%)	-10% (-39/+28%)	+3% (-8/+12%)
Fall precip (Sep-Oct-Nov)	4.3 in.	+3% (-14/+16%)	+1% (-10/+10%)	+2% (-10/+8%)	+2% (-9/+13%)	+5% (-15/+12%)	+6% (-5/+12%)	+2% (-12/+12%)	+6% (-8/+10%)
Days w/ less than 1/4 in. precip	130	-3% (-20/+5%)	-1% (-10/+3%)	-3% (-13/+3%)	0% (-5/+5%)	-5% (-16/+5%)	+1% (-10/+7%)	-5% (-13/+3%)	0% (-9/+7%)
Days with 1/4 to 1/2 in. precip	13	+15% (-2/+39%)	+10% (-8/+25%)	+9% (-9/+33%)	+8% (+1/+20%)	+19% (+3/+45%)	+19% (+4/+32%)	+7% (-11/+35%)	+8% (-1/+19%)
Days w/ 1/2 in. or more precip	4	+16% (-1/+33%)	+10% (-8/+20%)	+14% (-1/+42%)	+8% (+1/+21%)	+21% (+6/+41%)	+14% (+1/+30%)	+21% (-11/+45%)	+10% (-2/+21%)
Cold-month days w/ 1/2 in. or more	1.6	+30% (+5/+57%)	+23% (-21/+43%)	+22% (-10/+67%)	+16% (+4/+38%)	+47% (+21/+80%)	+26% (+2/+46%)	+44% (+6/+66%)	+15% (-4/+53%)
Hot-month days w/ 1/2 in. or more	2.7	+4% (-8/+17%)	+4% (-5/+12%)	+7% (-12/+30%)	+4% (-11/+14%)	+8% (-4/+20%)	+8% (+1/+22%)	+9% (-28/+39%)	+3% (-5/+15%)
Precip in wettest day in year	0.8 in.	+10% (-3/+18%)	+10% (-7/+19%)	+7% (-5/+17%)	+7% (+2/+17%)	+16% (+1/+24%)	+11% (-1/+28%)	+1% (-10/+25%)	+10% (0/+17%)

Table 18. As Table 17 on the previous page, but for the last two 20-year periods of the century.

5. Consequences

It is beyond the scope of this project to assess the impacts of the potential climate changes identified here, but there is an abundance of scientific information elsewhere that does that. The following summarizes a small sample of that information about just a few key impacts.

Increase in wildfires

- Higher temperatures increase the acreage burned in wildfires and the length of the wildfire season.[22] Climate change has been estimated to have doubled the area burned in the American West from 1984 through 2015.[23]
- Studies project major increases in wildfire in the Colorado mountains as climate change continues. Two examples: a report by the National Academy of Sciences projected a nearly seven-fold increase in this region in area burned with a modest 1.8° increase in global temperatures, and another study projected nearly a three-fold increase by mid-century with a medium level of future heat-trapping emissions.[24]

"The duration of the season during which wildfires occur has increased throughout the western United States as a result of increased temperatures and earlier snowmelt. . . . By the middle of this century, the annual area burned in the western United States could increase 2–6 times from the present, depending on the geographic area, ecosystem, and local climate."

U.S. Global Change Research Program[25]

Impacts of increased wildfires

- Increased wildfires obviously directly threaten people's safety and property, particularly as building expands in fire-prone areas.[26] More wildfire smoke also increases the risk of respiratory disease and mortality.[27]
- Heavy precipitation on burned areas leads to debris flows across the West, and those events are projected to increase with future increases in extreme storms and wildfires.[28] This summer in Colorado, mudslides from heavy storms over burned areas have repeatedly closed mountain highways.[29]
- Post-fire erosion from burned areas can adversely affect water quality and require expensive mitigation actions.[30] This summer, runoff from a storm over a burn scar has so polluted the Cache la Poudre River that treatment became impossible and Fort Collins had to stop using river water as a water supply.[31] After the 2002 Hayman fire, Denver Water had to spend $25 million in restoration costs to protect its water source in the area.[32]
- Wildfires and smoke can keep people from engaging in outdoor recreation activities.[33] More wildfires also can reduce summer tourism, even in areas not directly experiencing fires, and affect people's enjoyment of areas following fires.[34]

Skiing and other winter recreation and tourism

- The season for skiing, snowboarding, and other snow-dependent sports could be shorter and the snow slushier—reducing enjoyment for skiers, profits for skiing-dependent businesses, and tax revenues for state and local governments.[35]

- If ski areas do not experience long enough stretches of sub-freezing temperatures, it is conceivable they will not be able to maintain snowy slopes, regardless of whether they have snowmaking equipment or the water supply, shortening the length of the available ski season.[36]

"Resorts require a certain number of days just to break even; cutting the season short by even a few weeks, particularly if those occur during the lucrative holiday season, could easily render a resort unprofitable."

U.S. Global Change Research Program[37]

- Snowmobiling, cross-country skiing, and snowshoeing could experience the greatest declines in usage of all forms of outdoor recreation as the climate continues to change.[38]

Water availability and dryness

- Increased temperatures, especially the earlier occurrence of spring warmth, have already altered the water cycle across the West, with changes that include decreases in snowpack and its water content, earlier streamflows, and shifts in precipitation from snow to rain.[39] High temperatures due mainly to climate change have been estimated to account for 17%–50% of the record-setting reductions in the Colorado River between 2000 and 2014.[40]
- Higher temperatures inherently decrease water availability, by increasing evaporative losses from water bodies, soils, and plants, including crops.[41]
- Irrigation requirements are likely to increase for crops and other outdoor plants.[42]

Summer recreation and tourism

- Higher temperatures and reduced river flows clearly can reduce opportunities for fishing and rafting.[43]
- Other impacts to summertime recreation and tourism could include losses of visitation and visitor enjoyment, from causes ranging from temperatures too high for outdoor activities to disrupted transportation systems.[44]

Ecosystem effects

- Higher temperatures, especially if combined with drier summers, can increase tree mortality. Already, increases in background tree mortality (not including the effects of wildfires, insect infestations, or similar disruptions) have been detected in western forests, with particular increases in mortality of large trees, and changed climatic conditions have been determined to be largely responsible.[45] In Colorado, tree mortality in subalpine forests has increased in recent decades, with the greatest increases occurring during hot, dry periods.[46]
- Hotter and drier conditions can drive outbreaks of insects such as bark beetles as trees lose their resistance to infestations, allowing insect populations to grow to epidemic levels. A combination of warming temperatures in the winter allowing for greater number of mountain pine beetle larvae to overwinter and a longer growing season for the insects to produce have also contributed to the magnitude of recent West-wide bark beetle outbreaks, including in Colorado.[47] Winters with less intense cold and hotter summers have enabled bark beetles to reach outbreak levels at higher elevations than before.[48]

"Forest disturbance from epidemic bark beetle populations tracks closely with long-term precipitation levels and temperature patterns."

Colorado State Forest Service[49]

Public health

- The potential increases in summer heat identified in this report, especially with high emissions, are large enough to raise questions about possible impacts on public health, because extreme heat is conclusively linked to increased illnesses and death, particularly among older adults, pregnant women, and children.[50] Historically, Colorado has not been considered at high risk for heat-related illnesses and death, due to low humidity and cool nights. But as a Colorado climate change vulnerability report has warned, where extreme heat is less common, both public health officials and individuals may be less prepared to take protective actions, and a lack of air conditioning (certainly the case in the mountains), increases risks during heat waves.[51] As shown on Table 12 on page 34, however, the models analyzed here project that even in the Eagle grid (the lowest elevation and therefore the hottest grid) with high emissions late in the century, the warmest nights of the year are not projected to get above the low 60°s. Nighttime lows can provide an important respite to daytime extreme heat;[52] that the worst-case nighttime temperatures are projected to remain this low can be significant in offsetting daytime highs that could get into the 100°s.

Especially when considered with additional scientific information on these and other possible impacts, the local climate projections analyzed in this report can help local governments, stakeholders, and the general public assess the possible future extent of these projected changes and their impacts in Eagle County, and guide local public and private decisions about taking actions both for climate protection and for climate change preparedness.

6. Methodology

The climate projections used in this analysis were obtained from an online archive created by a consortium of partners: the U.S. Bureau of Reclamation, Climate Analytics Group, Climate Central, Lawrence Livermore National Laboratory, Santa Clara University, Scripps Institution of Oceanography, U.S. Army Corps of Engineers, U.S. Geological Survey, and National Center for Atmospheric Research and maintained on a website operated by Santa Clara University.[53] RMCO acknowledges and expresses appreciation to those collaborating organizations responsible for the online archive and also to the World Climate Research Program's Working Group on Coupled Modelling and the climate modeling groups for producing and making available their model output, and the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison and the Global Organization for Earth System Science Portals for their additional support with respect to the latest generation of models, which we used in this analysis.

The projections RMCO obtained are of daily climate values for maximum temperatures, minimum temperatures, and precipitation amounts from the latest generation of climate models, known as CMIP5 models, that have been downscaled by the consortium described above to produce results for grids 1/8 of a degree of longitude by 1/8 of a degree of latitude. The projections obtained are from the first listed ensemble from each available climate model for each emissions scenario—twenty models for the high emission scenario (officially known as Representative Concentration Pathway, or RCP, 8.5); twelve for the medium #1 scenario (RCP 6.0); nineteen for the medium #2 scenario (RCP 4.5), and sixteen for the low scenario (RCP 2.6).

The climate projections available on this archive have been widely used by many researchers with methodology like ours, including by Western Water Assessment for *Climate Change in Colorado*, its report to the Colorado Water Conservation Board (see page 4). An excellent general discussion of the climate models and their use is in that WWA report, from which the following points are taken.[54]

First, climate scientists have confidence that climate models can credibly project future climate conditions, for several reasons:

- The models are based on fundamental, well-understood scientific principles. (This is especially so for temperature, less so for precipitation.)
- The models are successful in replicating such climatic features as jet streams and ocean currents.
- Retrospective projections from the models successfully match historical climate conditions.

Second, projections from different models do differ, even with the same assumptions about future heat-trapping emissions. These differences reflect current scientific uncertainty on some key climate processes. When tested by how well the models retrospectively project the conditions of past years, combined results from all models are consistently more accurate than any single model is. But considering the range of results from the projections, not just an average value, captures the current uncertainties of the models. Accordingly, in this report, as WWA also did in *Climate Change in Colorado*, we present both the median (the mid-point) of all projections and also the 10th percentile and the 90th percentile of the projections—in other words, the range of the middle 80 percent of the projections (see page 8).

Third, despite recent improvements in climate models, they still have tendencies to over- or under-project certain climate aspects. A simple "delta method" approach, as used by WWA for *Climate Change in Colorado* and by RMCO for this report, effectively cancels out much of this bias.[55] In the case of this report, the downscaled projections from each model for a particular grid are compared to its retroactive projections for the baseline period of 1970–1999, and it is the difference that was analyzed for this report. Since a model that consistently overestimates temperatures, for example, would do so for the baseline period as well as for the future, by considering only how much the model's future projections differs from its retroactive projections compensates for any such bias. The model's projected differences from the baseline were then added to the gridded/observed values for the baseline period, described next, to produce the future values that were analyzed here.

Baseline observational data

The baseline data for 1970–1999 are average values for a grid, derived from observational data from local weather stations, that are available from the same online archive identified on the previous page. The baseline data, being derived from weather station records, are independent of the models from which the downscaled projections are produced.

Newer models and scenarios

A newer generation of global climate models ("CMIP6") and a newer generation of emission scenarios was developed for and used in the United Nations's Intergovernmental Panel on Climate Change Sixth Assessment Report, of which the first part was released in August 2021.[56] Downscaled local results from these models are not yet available, and so the projections presented here remain the latest such projections that are available.

The new generation of emission scenarios now includes five—four that roughly correspond to the four scenarios used in the models analyzed here, and a new one with very low future emissions, reflecting an understanding in the scientific community of the need for even sharper emission reductions than those assumed in the low scenario considered here.

Notes

1. S. Saunders, T. Easley, and M. Mezger, *Climate Projections for Summit County, Colorado*, report of the Rocky Mountain Climate Organization (RMCO) (Almont, CO: RMCO, 2021), www.rockymountainclimate.org/extremes/summit.

2. S. Saunders, T. Easley, and M. Mezger, *Future Climate Extremes in Boulder County* and *Future Climate Extremes in Larimer County*, reports of RMCO (Louisville, CO: RMCO, 2016), http://www.rockymountainclimate.org/extremes/boulder and http://www.rockymountainclimate.org/extremes/larimer, respectively; S. Saunders, T. Easley, and M. Mezger, "Future extreme heat in the Denver metro area," report of RMCO (Louisville, CO: RMCO, 2017), http://rockymountainclimate.org/images/DenverHeatExtremes.pdf; and S. Saunders, T. Easley, and M. Mezger, "Future precipitation in the Denver metro area," report of RMCO (Louisville, CO: RMCO, 2017), http://rockymountainclimate.org/images/DenverPrecip.pdf.

3. U.S. Bureau of Reclamation and others, "Downscaled CMIP3 and CMIP5 climate and hydrology projections," http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/#Welcome. See also L. Brekke and others, 2013, "Downscaled CMIP3 and CMIP5 climate projections: Release of downscaled CMIP5 climate projections, comparison with preceding Information, and summary of user needs," http://gdodcp.ucllnl.org/downscaled_cmip_projections/techmemo/downscaled_climate.pdf.

4. J. Lukas and others, *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation (Second Edition—August 2014)*, report by Western Water Assessment, University of Colorado, Boulder, to the Colorado Water Conservation Board (Boulder: University of Colorado, Boulder, 2014), http://wwa.colorado.edu/climate/co2014report/Climate_Change_CO_Report_2014_FINAL.pdf.

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