Snow

Chapter 3—Snowfall Impact Study for Spokane, Washington

"In mountain towns across the United States that rely on winter tourism, snow is currency. For snow lovers and the winter sports industry, predictions of a future with warmer winters, reduced snowfall, and shorter snow seasons is inspiring them to innovate, increase their own efforts to address emissions, and speak publicly on the urgent need for action."

—Elizabeth Burakowski, "The Economic Contributions of Winter Sports in a Changing Climate"

Chapter Summary: Examines historical trends in snowfall for the Spokane region, future climate projections and mountain snow forecasts, and determines what these data suggests about the future of winter recreation at Spokane's five-area ski resorts (Mt. Spokane Ski & Snowboard Park, 49 Degrees North Mountain Resort, Silver Mountain Resort, Schweitzer Mountain Resort, and Lookout Pass Ski Area).

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Key Findings:

1. All five Spokane-area ski resorts (Mt. Spokane Ski & Snowboard Park, 49 Degrees North Mountain Resort, Silver Mountain Resort, Schweitzer Mountain Resort, and Lookout Pass Ski Area) are likely to be impacted by rising temperatures.
2. Projected climate changes at Spokane's five ski resorts by the middle of this century include:
    a. An increase in mean temperatures
    b. An overall decline in snow on the ground (as measured as snow water equivalent)
    c. A decrease in the total number of winter days below 32 degrees Fahrenheit, potentially hindering opportunities to make snow
3. Taken together, these projected climate changes pose a continuing threat to the vitality of winter sports recreation in the Spokane region.
4. Reducing greenhouse gas emissions—moving from our current path on the high emissions scenario (RCP 8.5) to the lower emissions scenario (RCP 4.5)—could mean the difference between a degraded but viable ski industry (RCP 4.5) and a nonviable ski industry (RCP 8.5) for five Spokane-area ski resorts, according to our analysis.

Recommended Resilience Actions:

- **Reduce Emissions**—The primary action for lessening the impacts to Spokane's winter sports industry associated with projected higher temperatures is to reduce greenhouse gas emissions, specifically to move away from the high emissions scenario (RCP 8.5) to the lower emissions scenario (RCP 4.5).

- **Prepare for Shorter Seasons**—As temperatures in the Spokane region continue to rise, Spokane's regional snow-dependent recreation industries—including skiing, snowboarding, snowshoeing, and snowmobiling—need to prepare for snow seasons that start later, are shorter, have less snow, and potentially provide fewer days cold enough to make snow.

- **Diversify**—Winter recreation industries in the Spokane region should consider diversifying their business models, including emphasizing warmer weather recreation activities.

Climate Data Story—Projected Future Snow at Mt. Spokane Ski & Snowboard Park

Over the course of this century, projected temperature increases and the increasing likelihood that precipitation will fall as rain rather than snow during the cold months of the year will likely shrink the length of the ski season and lead to adverse economic impacts for all five Spokane-area ski resorts: Mt. Spokane Ski & Snowboard Park, 49 Degrees North Mountain Resort, Silver Mountain Resort, Schweitzer Mountain Resort, and Lookout Pass Ski Area.

For the purposes of this summary climate data story, the authors of this chapter focused on future climate impacts at one of these five resorts: Mt. Spokane Ski & Snowboard Park (Mt. Spokane).

By the middle of this century (2040–2069) during the prime ski season (December–February), the average mean temperature at Mt. Spokane is expected to rise from a historical (1971–2000) mean of 25.9 degrees Fahrenheit to 30.6°F under the lower emissions scenario (RCP 4.5) or 31.8°F under high emissions scenario (RCP 8.5).

The rise in mean temperatures at Mt. Spokane is expected to correspond to a decline in snow at the ski park. Simply put, as temperatures rise, it becomes far more likely that precipitation will fall as rain rather than as snow. To determine how much snow Mt. Spokane might have by mid-century, our team used the variable *snow water equivalent* (SWE), which is a measure of how much liquid water is available in a given amount of snow on the ground. By mid-century, our analysis found, SWE accumulated on Mt. Spokane by the date January 1st—a key date for the local ski industry—is expected to decline from a historical mean of 10.7″ to 8.8″ under RCP 4.5 and to 7.5″ under RCP 8.5 (***Figures 8*** and ***9***). Moreover, if we examine precipitation projections, we can make the reasonable inference that this loss of snow is due to rising temperatures and not declines in precipitation. By mid-century, winter (December to February) precipitation at Mt. Spokane is projected to move from a historical mean of 14.6″ to 15.8″ under RCP 4.5 and to 16.0″ under RCP 8.5 (***Figures 7*** and ***8***). (See ***Analysis: Inferences & Limitations*** below for details on our analysis.)

During this same mid-century period, the annual number of days below freezing (32 °F) at Mt. Spokane is projected to drop from a historical average of 169 days to 127 days under RCP 4.5 and to 111 days under RCP 8.5 (***Table 6***). In other words, there is expected to be 42–58 fewer freezing days per year at Mt. Spokane by mid-century compared to what was observed during the last three decades of the 20th century. If we consider this trend of fewer freezing days, we can make the reasonable interference that by mid-century Mt. Spokane will see fewer days cold enough for snow to form in the atmosphere and remain frozen on the ground. Fewer days below freezing also means fewer days cold enough to make snow with equipment, which generally requires temperatures below freezing (specifically 30 °F or lower).

Larger Context—Climate Change and Snow-based Recreation in the Pacific Northwest

"Climate change could decrease snow-based recreation revenue by more than 70% annually in the Northwest under a higher scenario (RCP8.5)."

—Fourth National Climate Assessment

The projected rise in temperatures throughout this century is expected to lead to more rain and less snow across much of the American Mountain West (**Lute et al., 2015; Klos et al., 2014**). Such changes in mountain snowpack resulting from a warming climate are already evident. From 1955 to 2016, declines in snow were found at over 90% of snow monitoring sites (**Mote et al., 2018**) in the American West. The economic effects of this loss of snow on the United States ski industry have already being felt. From November 1999 to April 2010, the U.S. downhill ski industry lost $1.07 billion in revenue due to low snow years (**Burakowski and Magnusson 2012**). Economic losses are expected to continue as mountain snow levels decline under projected climate changes. According to an analysis published in the *Fourth National Climate Assessment* released in 2018, snow-based recreation in the U.S. Pacific Northwest could decrease by as much as 70% annually under the high emissions scenario (RCP 8.5) (**NCA 4, "Chapter 24 Northwest" 2018**).

Local Context—Climate Change and Spokane's Snow-Based Recreation

"Spokane has all the hallmarks of a great ski town: killer shops dedicated to supporting and growing the local ski community (shout out to Brian at the Alpine House), easy access to a wide variety of skiing ranging from mom-and-pop areas to regional destination resorts – all with amazing terrain, and reliably good snow. … Plus, it's a place where whole families can ski religiously and live affordably while mom and dad maintain steady jobs. In my mind that almost makes it better than many of the more glamorous ski towns out there."

—Kevin Luby, former Skiing Magazine senior editor and Spokane native

During the winter season of 2015–2016, snowboarders and skiers added an estimated $20.3 billion to the U.S. economy, spending money at resorts and hotels, as well as restaurants, bars, and grocery stores. In total, more than 20 million people downhill-skied, snowboarded, and snowmobiled during this period (**Hagenstad et al., 2018**). For decades, Spokane-area residents have enjoyed easy access to winter snow sports. Winter recreation, including skiing and snowboarding, are an important part of Spokane's identity and a significant source of winter revenue for our region. Spokane has five ski resorts within a two-and-a-half-hour drive from the city: Mt. Spokane Ski & Snowboard Park (Mt. Spokane), 49 Degrees North Mountain Resort (49 Degrees North), Silver Mountain Resort (Silver Mountain), Schweitzer Mountain Resort (Schweitzer Mountain), and Lookout Pass Ski Area (Lookout Pass). In a 2018 story, the *Spokesman-Review* reported that Mt. Spokane alone attracts about 100,000 visitors annually, creating almost $5 million in revenue for the local economy (**Kramer 2018**) or $50 in revenue per visitor.

It is important to note that much of the economic value of snow-based sports is indirect. For instance, nationally during the 2015–2016 snow season, direct spending at ski resorts, local restaurants, and the like, accounted for 41% of winter sports revenues nation-wide, or roughly $4.7 billion. The other 59% of revenues ($6.7 billion) came from indirect spending, including retail purchases and spending by resort employees (**Hagenstad et al., 2018**).

The economic value of winter snow sports for Spokane's five-area ski resorts is directly related to the number of visitors to the resorts. A 2006 economic analysis conducted by SE Group on behalf of Washington State Parks provides the visitor averages for the years 1996–2006 and is displayed in ***Table 1*** (**SE Group 2007**).

Table 1: Number of average annual visitors to Spokane's five ski resorts (Mt. Spokane, 49 Degrees North, Silver Mountain, Schweitzer Mountain, and Lookout Pass) for the ten-year period 1996–2006. Source: SE Group 2007 (http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.550.1332&rep=rep1&type=pdf).

Resort	Average Annual Visitors over the years 1996–2006
Mt. Spokane	67,747
49 Degrees North	59,866
Silver Mountain	88,246
Schweitzer Mountain	180,285
Lookout Pass	31,677

At all five Spokane-area ski resorts, winter temperatures are projected to increase over the course of this century under both the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5), according to our analysis using the Climate Toolbox. Projected rising temperatures are expected to lead to a decline in total snow levels and fewer days below freezing (potentially hindering opportunities to make snow) at all five Spokane-area ski resorts.

Taken together, less snow and less opportunities to make snow will likely lead to fewer visitors at all five Spokane-area ski resorts. If the five resorts see fewer visitors, we can expect that this will lead to adverse economic impacts to Spokane's five ski resorts as well as local businesses in Spokane and the surrounding region that rely on indirect spending connected to snow-based recreation.

Analysis—Geography, Data Tools, Inferences & Limitations, Emissions Scenarios, Timeframes, Multi-model Means, Variables, and Climate Data Story

Geography:
To investigate the effects of climate change on Spokane's snow recreation, we chose to look at the five large ski resorts within a 2.5-hour drive from Spokane: Mt. Spokane Ski & Snowboard Park (Mt. Spokane), 49 Degrees North Mountain Resort (49 Degrees North), Silver Mountain Resort (Silver Mountain), Schweitzer Mountain Resort (Schweitzer Mountain), and Lookout Pass Ski Area (Lookout Pass).

Data Tools:
Our team started by examining snow depth measurements recorded at Spokane's five resorts and data available from the website On the Snow (www.onthesnow.com) for the years 2009–2017. We then proceeded to examine simulated historical snow data as well as projected future snow data for the five resorts by using the following tools in CIRC's Climate Toolbox:

- Historical Climate Tracker
- The Future Boxplots Tool
- The Climate Mapper Tool

Inferences & Limitations:
The mapping software available as part of each Toolbox tool was used to locate each resort by putting in the name of the resort as the location, as opposed to entering precise latitude and longitude coordinates for the base and summit of the five ski resorts. The reason this was done has to do with the *resolution* of the data available. Toolbox data for snow has been downscaled to a grid cell resolution of 2.5 square miles. This 2.5-square mile resolution limited the degree of detail our team could obtain. The grid cell resolution allowed us to determine only general trends across the grid cells containing the resorts' locations rather than pinpoint precise impacts at the bases and summits of the five resorts. A more precise effort to pinpoint the exact elevations of the resorts' bases and summits would have been instructive. However, such an effort would have been unlikely to have changed the overall trends revealed in each of the tools. In other words, a more precise determination of the climate impacts to our region's ski resorts would have required an additional analysis beyond what was available using the Toolbox. Historical snow data available for Spokane's five ski resorts was also limited in scope and difficult to draw conclusions from. Data from the resorts was only available from 2009–2017 and was averaged for a full year. Our analysis also examined the projected first calendar date with freezing conditions in the fall and the projected last calendar date with freezing conditions in the spring. This was done to determine the broadest possible period of time with freezing temperatures on Mt. Spokane. However, this analysis did not give us a clear picture of the projected length of the snow season or the projected length of the ski season, which would have required a larger analysis beyond the scope performed here. Because the total length of the ski season is critical for the future viability of snow-based recreation at all five Spokane-area ski resorts, it is our hope that this analysis will be carried out at a later date (see ***Discussion*** below).

Our team made a number of inferences throughout our analysis. For instance, because climate scientists have determined that the high temperature/low snow winter of 2014–2015 resembles the high temperature/low snow conditions projected for Washington state for the middle of this century (2040–2069) (**Marlier et al., 2017**), we inferred that how Spokane's five ski resorts fared during the 2014–2015 winter could tell us something about how they might fare under similar conditions projected for the middle of this century. Our team also used multiple proxies throughout our analysis in order to make reasonable inferences (see ***Variables*** below).

Emissions Scenarios:
For this analysis, we utilized both the *lower emissions scenario (RCP 4.5)* and the *high emissions scenario (RCP 8.5)* from phase 5 of the Coupled Model Intercomparison Project (**Climate Toolbox 2019***)*. The RCP 8.5 scenario simulates in a computer what is likely to happen if greenhouse gases continue to be released into the atmosphere at their current rate, and, as result, warming is allowed to continue at its current upward trajectory throughout this century and beyond. The RCP 4.5 scenario simulates a dramatic reduction in greenhouse gas emissions, so that while warming continues throughout this century, warming starts to level off after 2100. In general, the two scenarios start to diverge around mid-century (2040–2069). At mid-century, warming under RCP 4.5 slows while warming under RCP 8.5 continues at its current rate (**CIRC "Human Choice, Warming, & Emissions" 2019**). The two scenarios were used side by side in this analysis to evaluate whether the climate impacts under RCP 4.5 and

RCP 8.5 are meaningfully different in their impact on snow recreation in the Spokane region. We found that they were.

(Note: RCP 4.5 isn't the *lowest* emissions scenario used by climate researchers. RCP 2.6 is the lowest emission scenario considered in climate models. However, because the collective global emission pathway has very likely veered off course from that modeled under RCP 2.6, RCP 2.6 is no longer used as the low emission scenario pathway. Since RCP 4.5 is lower than RCP 8.5, this report has adopted the standard used by many in the climate research community: *lower* to describe RCP 4.5 and *high* to describe RCP 8.5, rather than *lower* and *higher* to describe the two scenarios.)

Time Frames:
For our analysis, we examined projected future climate for the middle (2040–2069) and late (2070–2099) decades of this century. We chose to focus our analysis on *mid-century* (2040–2069) because this time horizon seemed soon enough to be meaningful to current policymakers and winter sports enthusiasts. When comparing impacts between the RCP scenarios, we chose to look at *late century* (2070–2099) because the differences between RCP 4.5 and RCP 8.5 become more extreme by late century.

Multi-model Means:
Many of the data and figures that make up this analysis employ the mean resulting from multiple climate models. In general, the Toolbox uses 18–20 global climate models (GCMs) to visualize its climate projections (temperature, precipitation, etc.) and 10 GCMs to visualize its hydrology projections (snow water equivalent, streamflow, etc.). Using a multi-model mean, as opposed to the results of a single model, is accepted as best practice by the climate science community. However, the multi-model mean does not show the full spread of results from all the GCMs used to create a future projection. Instead, the multi-model mean shows average of that multi-model spread. In other words, actual future climate conditions—when we get to them in the decades ahead—might lie either above or below the multi-model mean of our current projections.

Variables:
Our analysis began by examining snow measurements taken in the field at each of the five Spokane-area ski resorts for the years 2009–2017 and recorded by the website On the Snow. The data for each resort was available at two elevations: at each resort's base and summit. This historical record provided us with the following variables:

- *Average Total Annual Snowfall* in inches (**On The Snow**)
- *Average Annual Snowfall Days* (**On The Snow**)
- *Average Snow Depth* in inches at the base and summit for each resort (**On The Snow**)

Using the Toolbox, we employed simulated historical and projected future data for *snow water equivalent* (SWE)—a common metric used to determine the amount of water contained in snow present on the ground—as a proxy for the amount of snow on the ground. We compiled SWE data for January 1st. This date was chosen because many resorts make as much as a third of their annual revenue before January 1st (**Russell 2015**). We gathered data for the following variables:

- *Total January 1st SWE* (in inches) (Future Boxplots Tool)
- *Percent Change in January 1st SWE* (Climate Mapper Tool)

The Toolbox also gave us the ability to evaluate indirectly other aspects of snow by utilizing additional climate and hydrology information. This included assessing a ski resorts projected potential to make snow using the following variables:

- *Total Winter Precipitation* (Future Boxplots Tool)
- *Mean Winter Temperature* (Future Boxplots Tool)
- *Annual Number of Days Above Freezing* (Future Boxplots Tool)

Climate Data Story:
While our analysis examined all five Spokane-area ski resorts, our team focused on impacts at Mt. Spokane alone for our climate data story (see ***Climate Data Story—Mt. Spokane Ski & Snowboard Park*** above). A *climate data story* is defined by CIRC as "a narrative outlining climate facts and impacts specific to your community" (**Mooney et al., 2019**).

Historical Climate—The 2015 Snow Drought

Variables: *Average Total Annual Snowfall*; *Average Annual Snowfall Days*; *Average Snow Depth at Base*; *Average Snow Depth at Summit*; *Total January–March Precipitation; Mean Maximum January–March Temperature*

Finding: All five Spokane-area ski resorts show responses to the larger climate trends that occurred across the Western United States and the state of Washington in recent years. Specifically, all five resorts appear to have been impacted by the snow drought that occurred during the winter of 2014–2015.

Justification: The historical climate data reported in the figures and tables below only capture a short period of time (2009–2017). They therefore should not be used to draw far-reaching conclusions about larger trends regarding impacts from climate change over longer and projected future periods of time. However, the metrics noted in ***Figures 1–4*** show what appears to be a clear snow drought signal during the winter of 2014–2015. During the 2014––2015 winter (*2014* in the figures), all five Spokane-area resorts saw declines in *Average Total Annual Snowfall* (***Figure 1***), *Average Annual Snowfall Days* (***Figure 2***), and *Average Snow Depth* recorded at the resorts' bases and summits (***Figures 3, 4***) (***Table 2***).

During the period October 1st, 2014 to September 30th, 2015 (the 2015 water year), record low snow levels were recorded at 80% of mountain recording sites across the Western United States. In spring 2015, snow levels in the state of Washington (as measured as snow water equivalent recorded on April 1st) tied for lowest on record (**Mote et al., 2016**).

A snow drought occurs when a region receives a less-than-adequate amount of snow. Snow droughts can result from insufficient precipitation leading to declines in snow or warm temperatures and near normal levels of precipitation leading to declines in snow **(Harpold et al., 2017**). According to meteorological data collected at the time, the 2015 snow drought in Washington (**Marlier et al., 2017**) and the Western US as a whole (**Mote et al., 2016**) was the result of warm temperatures rather than a lack of precipitation. Precipitation levels during the 2014–2015 winter were at near normal levels for Washington and the Western US generally. However, temperatures during this period were above average (**Mote et al., 2016**; **Marlier et al., 2017; Harpold et al., 2017**). In Washington, the 2014–2015 winter was 3.8 degrees Fahrenheit warmer on average than winters over the period 1950–2015 (**Marlier et al., 2017**). If we examine Mt. Spokane, we can see how the 2014–2015 snow drought played out at the local scale.

From January to March 2015, Mt. Spokane saw 12.3 inches of precipitation. This is near the average of 13.0″ for the period 1979–2019 (***Figure 5***). However, temperatures during this period were above normal. For instance, mean maximum daily temperatures at Mt. Spokane during January–March 2015 was 41.3 °F compared to an average of 36.0 °F over the same three-month period for the years 1979–2019 (***Figure 6***).

The abnormally warm temperatures during the winter of 2014–2015 can be seen reflected in the record low snow numbers recorded at all five Spokane-area ski resorts during the same period (***Figures***, ***1, 3***, ***4***; ***Table 2***). For instance, average annual snow accumulated and recorded at Mt. Spokane from 2009 to 2017 was 144″, but during the snow drought of 2014–2015, average accumulated snow fall recorded on the mountain was just 67″ (***Table 2***). Similarly snow depth at Mt. Spokane's base averaged 43.2″ from 2009 to 2017, but measured only 17″ during the 2014–2015 winter (***Table 2***). This strongly suggests that the high January-to-March temperatures caused precipitation to fall as rain rather than as snow. The data also suggest that warm temperatures likely led to snow melting on the ground, leading to the observed reduction in average snow depths.

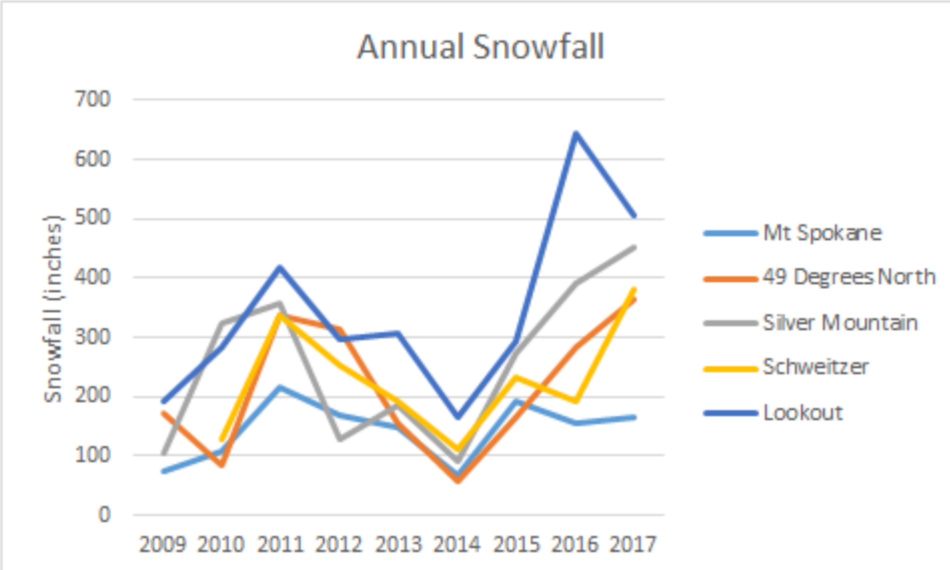

Figure 1:Annual Snowfall, 2009–2017. Average Annual Snowfall (in accumulated inches) recorded at the five resorts (Mt. Spokane; 49 Degrees North; Silver Mountain; Schweitzer; and Lookout) for the years 2009–2017. Snowfall in inches are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). Due to the calendar change that occurs over the winter months, the year designation includes both that year and the year that follows it. For instance, 2014 represents the winter that occurred over the calendar years 2014–2015. Note: Schweitzer Mountain is missing data for 2009. Source: On the Snow (www.onthesnow.com).

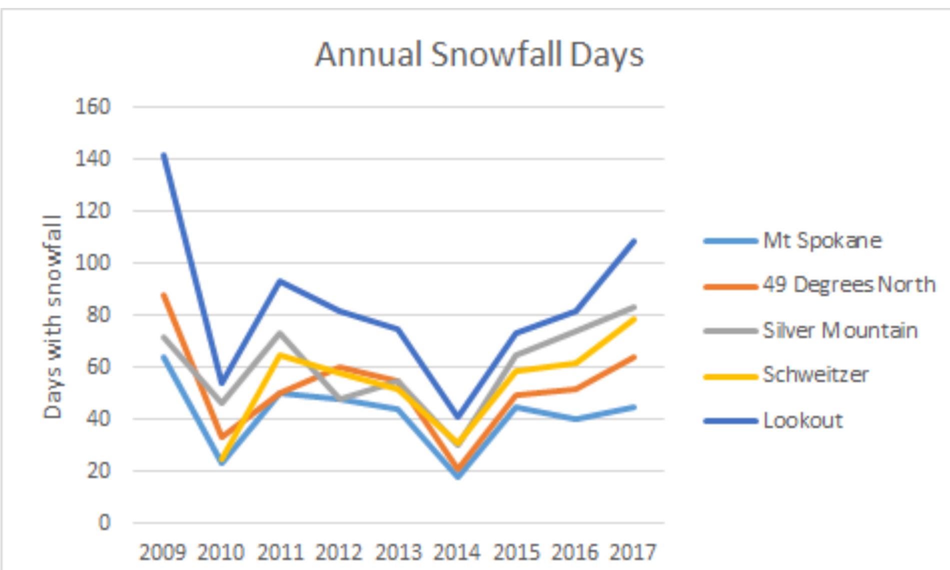

Figure 2: Average Annual Snowfall Days, 2009–2017. Snowfall days recorded at the five resorts for the years 2009–2017. "Snowfall days" are defined as days where snowfall is greater than 1 inch. Days with snowfall are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). Note: Schweitzer Mountain is missing data for the winter of 2009. Source: On the Snow (www.onthesnow.com).

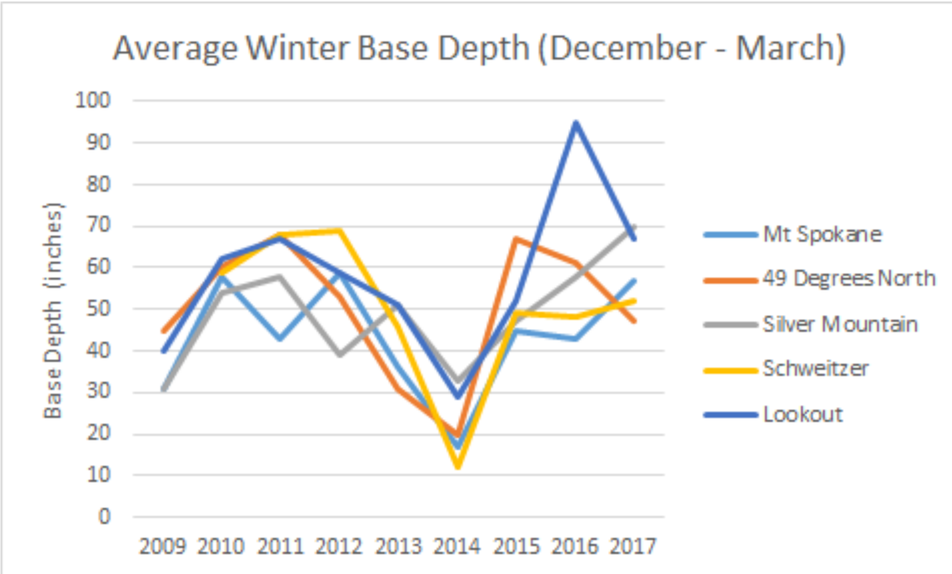

Figure 3: Winter Base Snow Depth, 2009–2017. Average snow depth (in inches) recorded at the five resorts' bases from December to March for the years 2009–2017. Note: Schweitzer Mountain is missing data for the winter of 2009. Source: On the Snow (www.onthesnow.com).

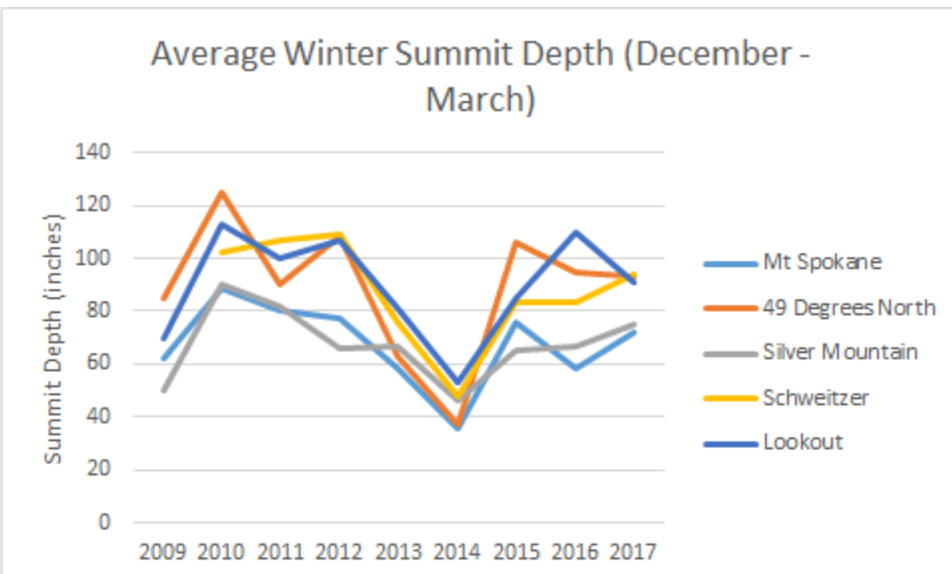

Figure 4: Winter Summit Snow Depth, 2009–2017. Average snow depth (in inches) recorded at the five resorts' summits from December to March for the years 2009–2017. Note: Schweitzer Mountain is missing data for the winter of 2009. Source: On the Snow (www.onthesnow.com).

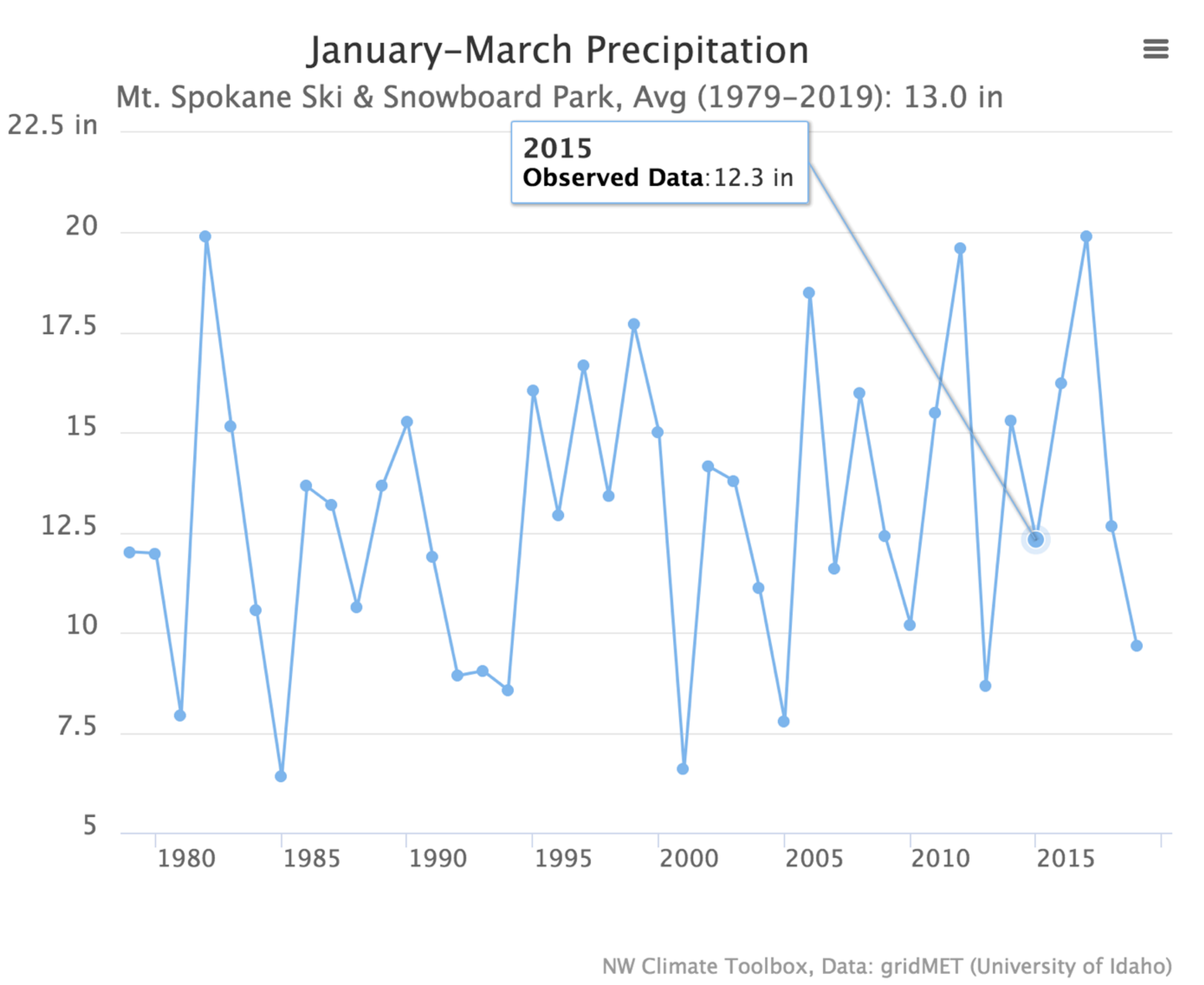

Figure 5: Total precipitation (in inches) at Mt. Spokane for January–March 2015 (simulated historical) and January–March 1979–2019 (simulated historical). Inches of precipitation are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). Source: Historical Climate Tracker (https://climatetoolbox.org/tool/Historical-Climate-Tracker), The Climate Toolbox.

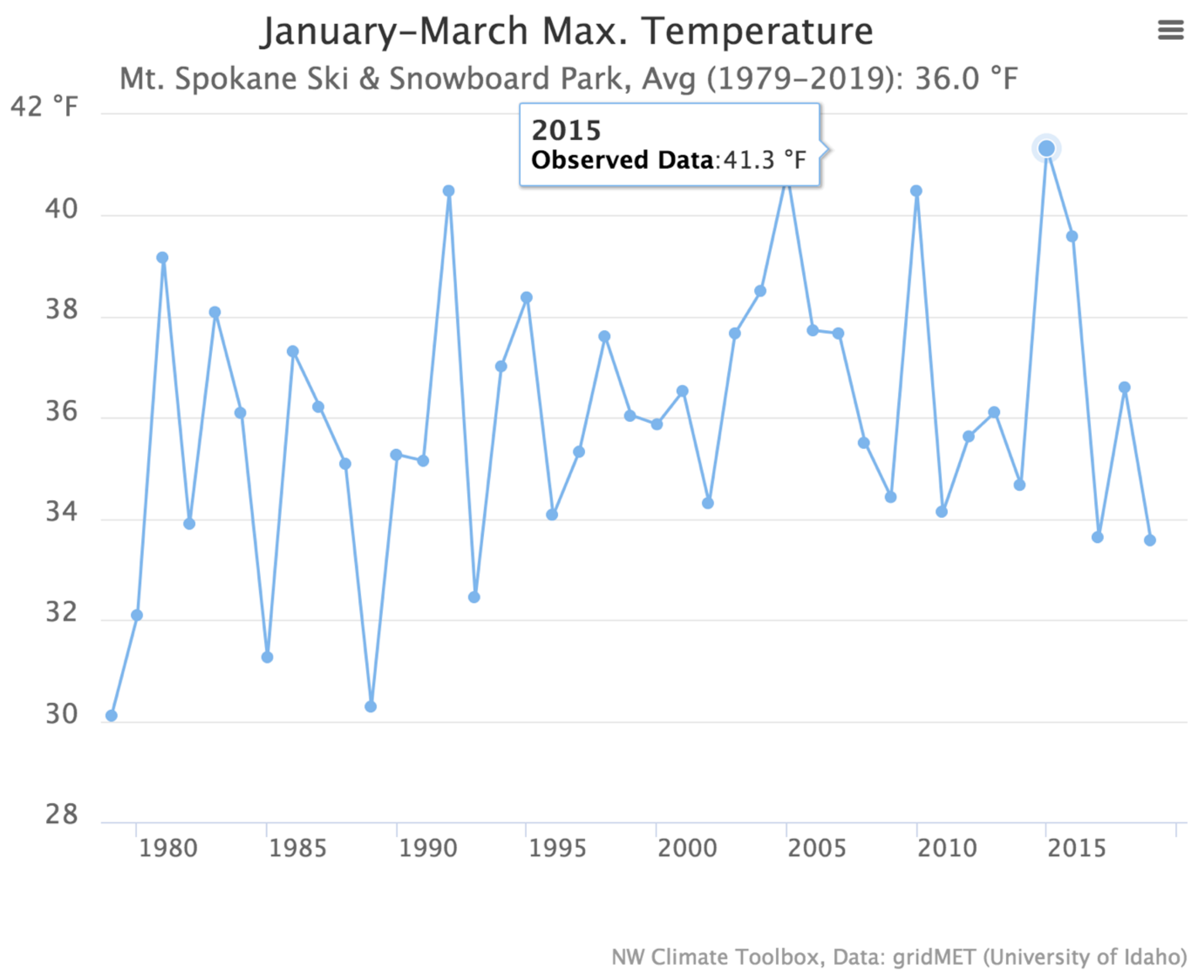

Figure 6: Average maximum temperature in degrees Fahrenheit at Mt. Spokane for January–March 2015 (simulated historical) and January–March 1979–2019 (simulated historical). Degrees Fahrenheit are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). Source: Historical Climate Tracker (https://climatetoolbox.org/tool/Historical-Climate-Tracker), The Climate Toolbox.

Table 2: Average total snowfall (in inches) observed at the five Spokane-area ski resorts, and observed average snow depth (in inches) at the five resorts' bases and summits for the years 2009–2017 and for the "snow drought" winter of 2014–2015. Source: On The Snow (www.onthesnow.com).

Resort	2009–2017 Average Total Annual Snowfall (inches)	2014–2015 (Snow Drought) Total Annual Snowfall (inches)	2009–2017 Average Snow Depth at Base (inches)	2014–2015 (Snow Drought) Average Snow Depth at Base (inches)	2009–2017 Average Snow Depth at Summit (inches)	2014–2015 (Snow Drought) Average Snow Depth at Summit (inches)
Mt. Spokane	144″	67″	43.2″	17″	67.6″	36″
49 Degrees North	215″	57″	50.2″	20″	89.1″	37″

Silver Mountain	256.8″	92″	49″	33″	67.6″	46″
Schweitzer Mountain	229″	113″	50.4″	12″	87.8″	48″
Lookout Pass	345.4″	167″	58″	29″	90″	53″

Finding: Not one of Spokane's five ski resorts is likely to be insulated from future climate changes. Some resorts are likely to fare better than others.

Justification: The available data recorded at all five Spokane-area ski resorts indicates that all five resorts have responded to the climate events of recent years and that no one resort has been insulated from the declines in snow associated with the snow drought of 2014–2015 (*2014* in the figures) (***Figures 1–4***). If we consider the available ski resort data recorded during the winter of 2014–2015 in conjunction with the finding that the climate conditions that led to the recent snow drought look similar to projections for mid-century (2040–2069) (**Marlier et al., 2017**), we can make the reasonable inference that snow conditions similar to those that occurred during the winter of 2014–2015 may occur more commonly by mid-century. What's more, by comparing the recent snow drought to the snow drought conditions projected for mid-century, we can infer that all five resorts are very likely to see less snow under a warming climate.

The resort-specific data demonstrates variability from resort-to-resort for observed annual snowfall (***Figure 1***), snowfall days (***Figure 2***), and snow depth (***Figures 3* and *4***). These variations can likely be attributed to differences in elevation and latitude at the respective resorts (***Table 3***). (*Aspect*, for instance, whether a resort faces north—away from the sun—or south—toward the sun—was not explored in this analysis.) For example, of the five resorts Lookout Pass has the highest base elevation (4,500 ft.) and consistently reported the highest snow depths, snowfall, and days with snow for each year (***Figure 1–3***).

If we consider all our findings together, we may infer three things:

1. Because all five resorts showed clear declines in snow that corresponded with the 2014–2015 winter's abnormally warm temperatures (***Figures 1–4***), all five resorts are therefore likely to see similar declines under the similarly warm temperatures projected for mid-century under RCP 4.5.

2. Likewise, because some of the five resorts clearly fared better than others during the 2014–2015 winter's snow drought, some of the five resorts will likely fare better than others during similar snow drought conditions projected for mid-century under RCP 4.5.

3. We might also reasonably infer that the reason some of the five resorts fared slightly better during 2014–2015 had to do with difference in elevation and latitude (***Table 3***) at the various resorts; because of this, latitude and elevation differences are likely to be key factors in the future success of the five resorts in a warming climate.

We should also note here that all five ski resorts in the Spokane region are at relatively low elevations. Elevation and temperature are closely related. Temperatures go down with elevation gains and go up with elevation loss. The elevation of a resort has direct implications to its sensitivity to rising temperatures projected under climate change. Being at lower elevations makes Spokane's ski resorts more sensitive to projected warming than higher (and consequently colder) resorts in the U.S. West (**Abatzoglou 2019**).

Table 3: Geography of Ski Resort Locations. Latitude/Longitudes were assessed from geo-locating the name of the resort using the Google search engine. Source: Google (www.google.com). The elevations of the base and summits for each resort were located from the website On the Snow. Source: On the Snow (www.onthesnow.com).

Resort	**Latitude (degrees N)**	**Longitude (degrees W)**	**Elevation (Base)**	**Elevation (Summit)**
Mt. Spokane	47.9214 °N	117.0964 °W	4,200 ft.	5,886 ft.
49 Degrees North	48.3011 °N	117.5629 °W	3,923 ft.	5,774 ft.
Silver Mountain	47.5407 °N	116.1332 °W	4,100 ft.	6,300 ft.
Schweitzer Mountain	48.368 °N	116.6227 °W	4,000 ft.	6,400 ft.
Lookout Pass	47.456 °N	115.6973 °W	4,500 ft.	5,650 ft.

Projected Future Climate—Precipitation Projected to Increase, Snow Projected to Decrease

Variables: *Mean Winter (December–February) Precipitation; Mean Winter (December–February) Temperature; January 1st Snow Water Equivalent (SWE); Change in January 1st Snow Water Equivalent (SWE)*

Finding: All five Spokane-area ski resorts see declines in snow under both the lower and high emission scenarios (RCP 4.5 and RCP 8.5).

Justification: Our investigation considered projected future changes in mean winter (December–February) precipitation and temperature for all five Spokane-area ski resorts. We also considered projected future changes in snow water equivalent (SWE)—the amount of liquid water in a given amount of snow—for all five resorts. Our analysis focused in particular on the difference between the lower emissions (RCP 4.5) and high emissions (RCP 8.5) scenarios at mid-century (2040–2069) and late century (2070–2099).

As noted in the ***Precipitation*** chapter of this report, the timing and volume of precipitation in the Spokane region is not expected to change dramatically over the course of this century. The Spokane region is projected to see a slight increase in annual precipitation, a slight decrease in precipitation during the summer months, and a slight increase in precipitation during the fall, winter, and spring months. However, despite projected future increases in annual precipitation, the primary concern for snow-based businesses and recreation is not the amount of precipitation that will fall but the form that precipitation will take. Throughout this century, temperatures are projected to rise in the Spokane region. This will lead to precipitation falling more as rain, rather than as snow.

For the purposes of our analysis, we looked at precipitation during the height of the winter ski season (December–February) at Mt. Spokane. By mid-century under RCP 4.5, mean winter precipitation at Mt. Spokane is projected to increase from a historical (1971–2000) mean of 14.6 inches to 15.8″ (***Figure 7***), according to the Toolbox's Future Boxplots Tool. By mid-century under RCP 8.5, mean winter precipitation at Mt. Spokane is projected to reach 16.0″ (***Figure 8***). By late century (2070–2099), mean winter precipitation at Mt. Spokane is projected to reach 15.9″ under RCP 4.5 (***Figure 7***) and 17.0″ under RCP 8.5 (***Figure 8***). However, more precipitation does not mean more snow. The projected rise in precipitation corresponds with a projected rise in mean temperature.

By mid-century, mean winter temperatures at Mt. Spokane are projected to rise from the historical (1971–2000) mean of 25.9 °F to 30.6 °F under RCP 4.5 and to 31.8 °F under RCP 8.5 (***Table 5***). As temperatures warm, precipitation becomes far more likely to fall as rain, rather than as snow, and snow on the ground becomes far more likely to melt earlier in the winter season, both of which result in reduced snow on the ground. By mid-century the amount of snow water equivalent (SWE) expected by January 1st is projected to decline at Mt. Spokane from a historical (1971–2000) mean of 10.7″ to 8.8″ under RCP 4.5 (***Figure 9***) and to 7.5″ under RCP 8.5 (***Figure 10***).

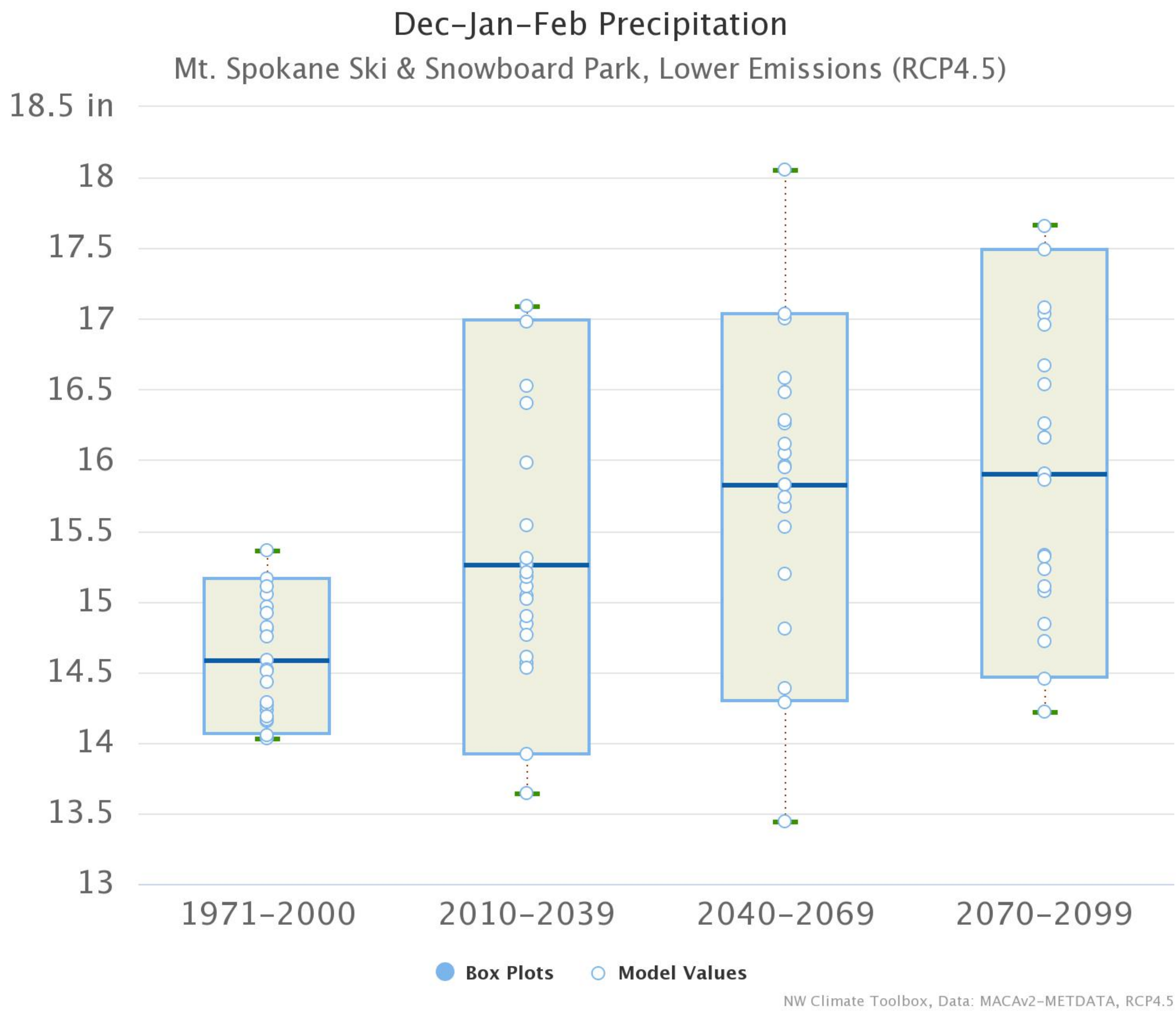

Figure 7: Mean winter (December to February) precipitation (in inches) at Mt. Spokane for the simulated historical period 1971–2000 and the projected future periods 2010–2039, 2040–2069, and 2070–2099 under the lower emissions scenario (RCP 4.5). Inches of precipitation are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). The results of each of the 20 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

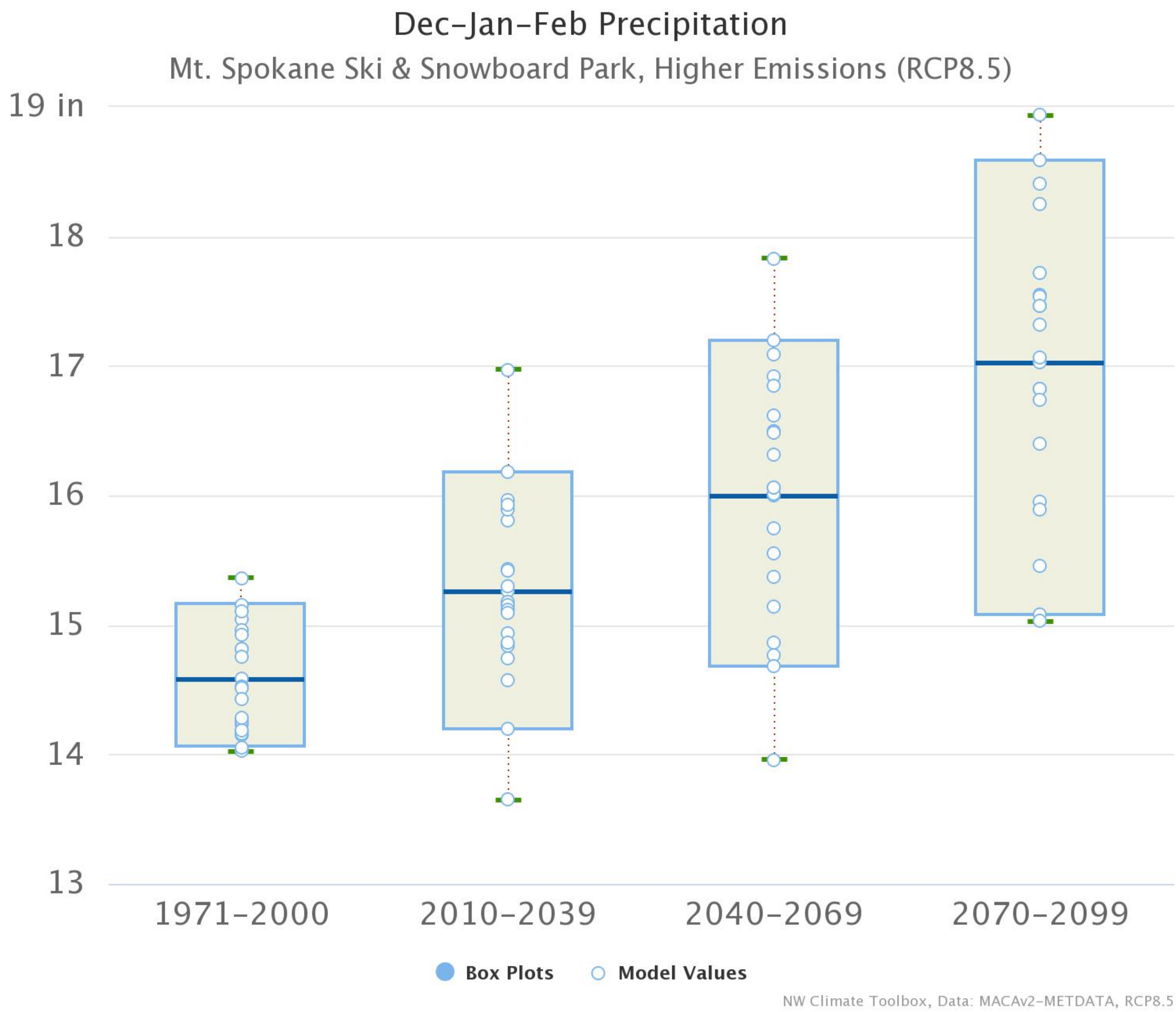

Figure 8: Mean winter (December to February) precipitation (in inches) at Mt. Spokane for the simulated historical period 1971–2000 and the projected future periods 2010–2039, 2040–2069, and 2070–2099 under the high emissions scenario (RCP 8.5). Inches of precipitation are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). The results of each of the 20 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

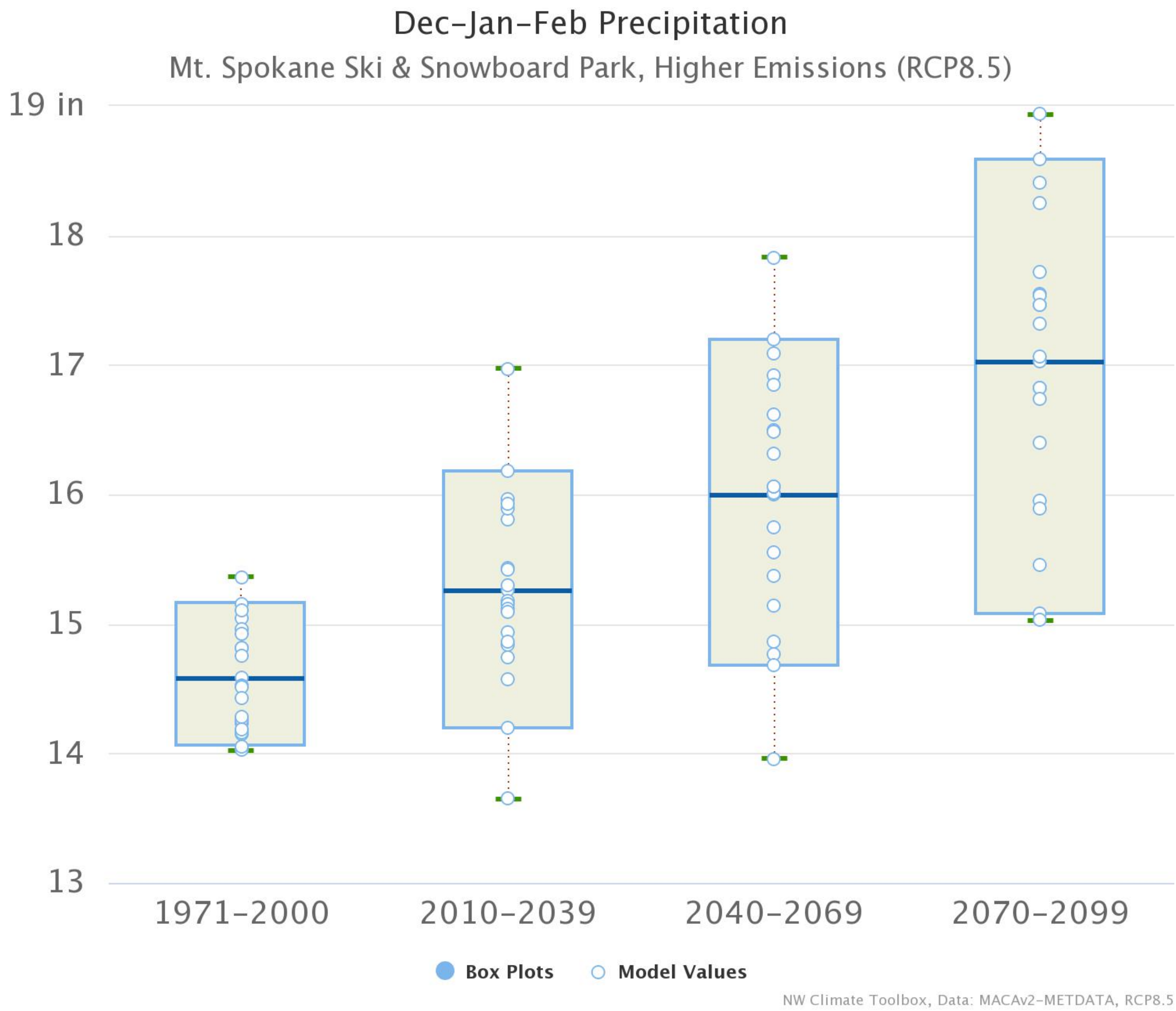

Figure 9: January 1st snow water equivalent (SWE) (in inches) at Mt. Spokane for simulated historical years 1971–2000 and projected future years 2010–2039, 2040–2069, and 2070–2099 under the lower emissions scenario (RCP 4.5). Inches of SWE are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). The results of each of the 10 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. Source Future Bloxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

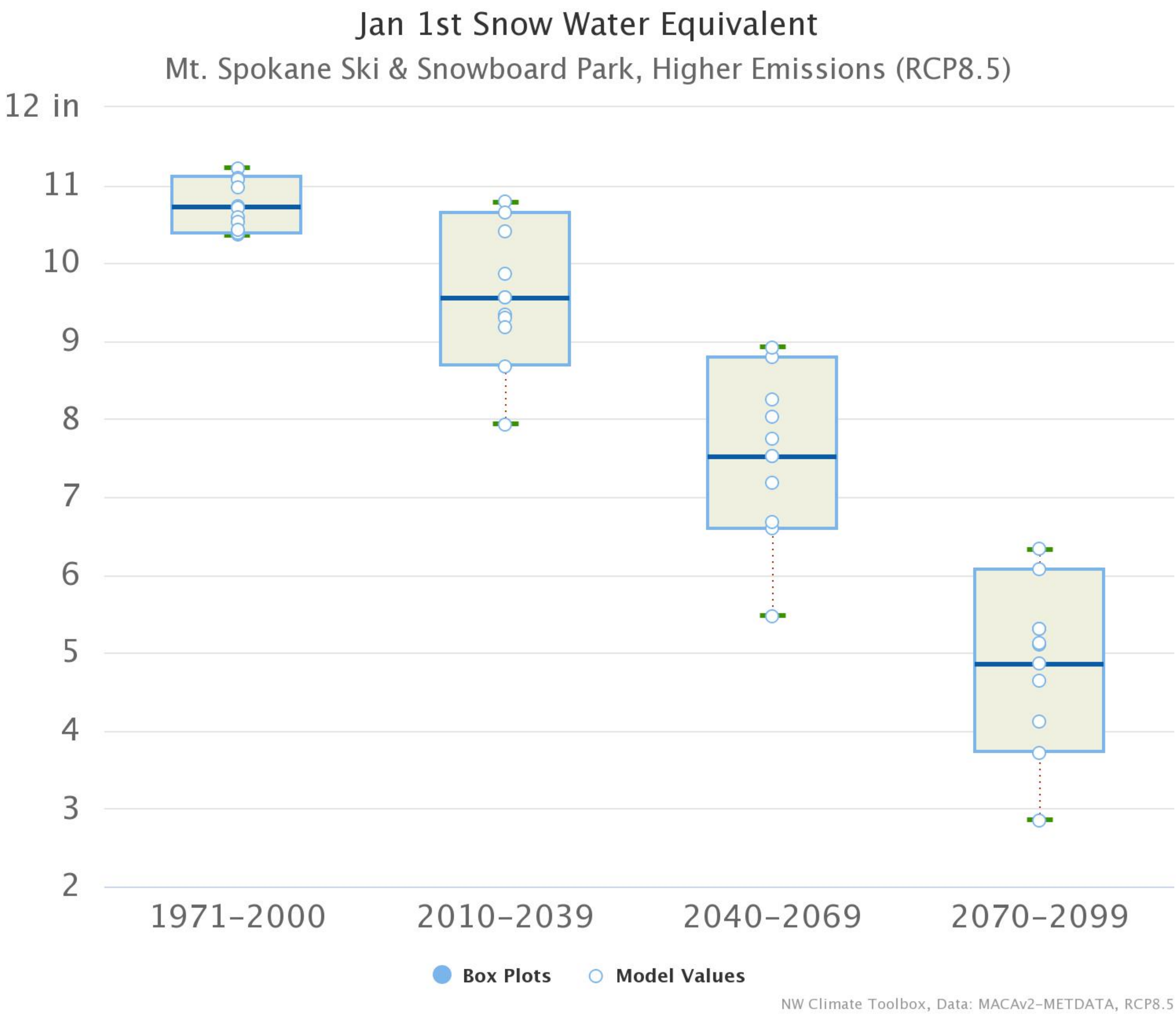

Figure 10: January 1st snow water equivalent (SWE) (in inches) at Mt. Spokane for simulated historical years 1971–2000 and projected future years 2010–2039, 2040–2069, and 2070–2099 under the high emissions scenario (RCP 8.5). Inches of SWE are displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). The results of each of the 10 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. Source Future Bloxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

Finding: The difference between the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5) could mean the difference between a degraded but viable ski industry (RCP 4.5) and a nonviable ski industry (RCP 8.5) for all five Spokane-area ski resorts.

Justification: January 1st snow water equivalent (SWE) projections for mid-century (2040–2069) at all five Spokane-area ski resorts tell a similar story. By mid-century, declines in January 1st SWE are projected to occur at all five resorts under both the lower emissions scenario (RCP 4.5) (***Figure 11***) and the high emissions scenario (RCP 8.5) (***Figure 12***). In all cases, the projected declines in SWE are notably different between RCP 4.5 and RCP 8.5 (***Table 4***). To take just one example, Mt. Spokane is projected to see a decline of 9% under RCP 4.5 and a decline of 30% under RCP 8.5. In other words, by mid-century the difference between the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5) could mean the difference between a degraded but viable ski season (RCP 4.5) and a nonviable ski industry (RCP 8.5) for all five resorts.

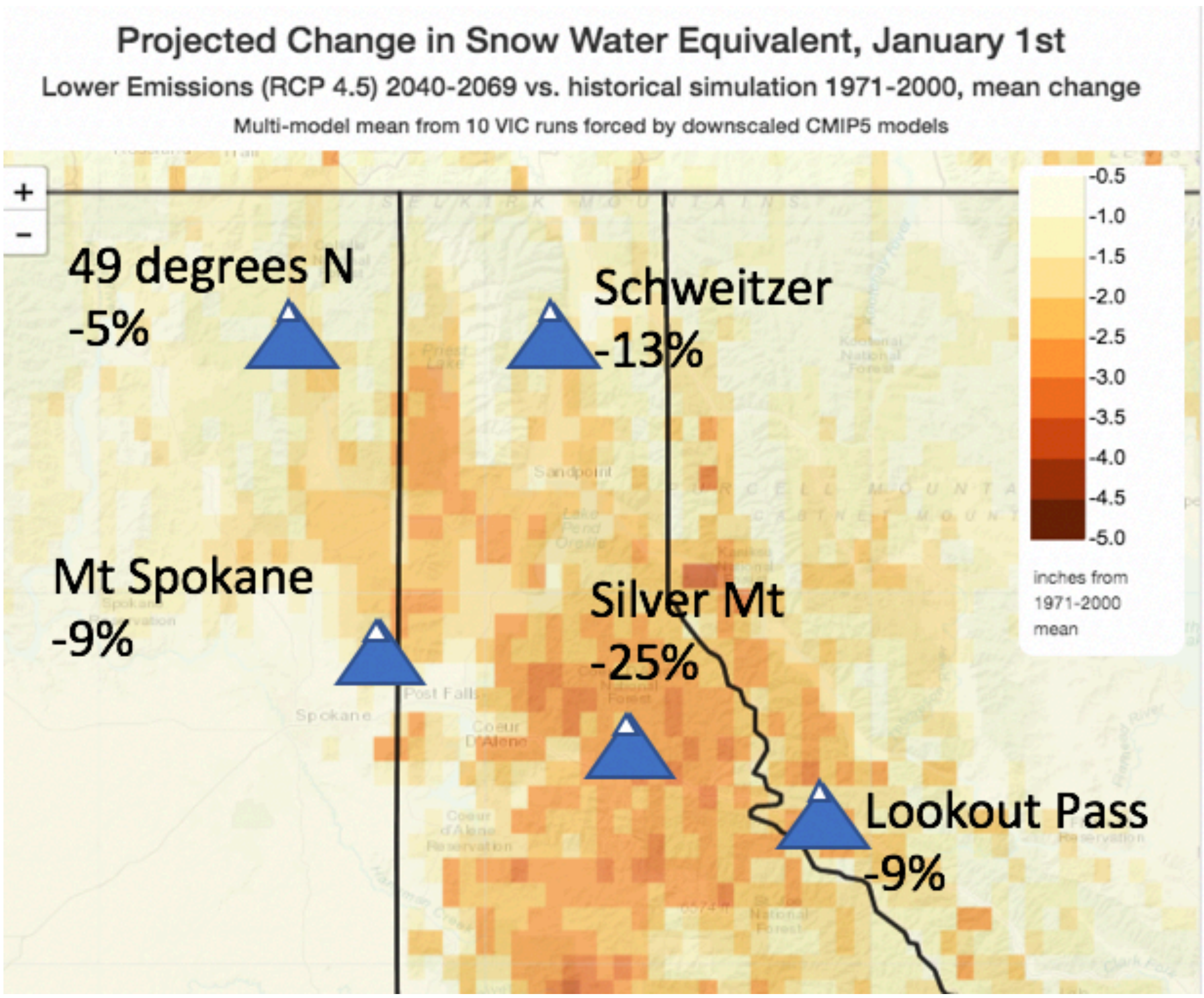

Figure 11: Projected future January 1st snow water equivalent (SWE) (in inches and as percent change from simulated historical period 1971–2000) for all five Spokane-area ski resorts for the middle of this century (2040–2069) under the lower emissions scenario (RCP 4.5). The percent changes shown here represent the multi-model mean resulting from 10 climate models. Source: The Climate Mapper Tool (https://climatetoolbox.org/tool/Climate-Mapper), The Climate Toolbox.

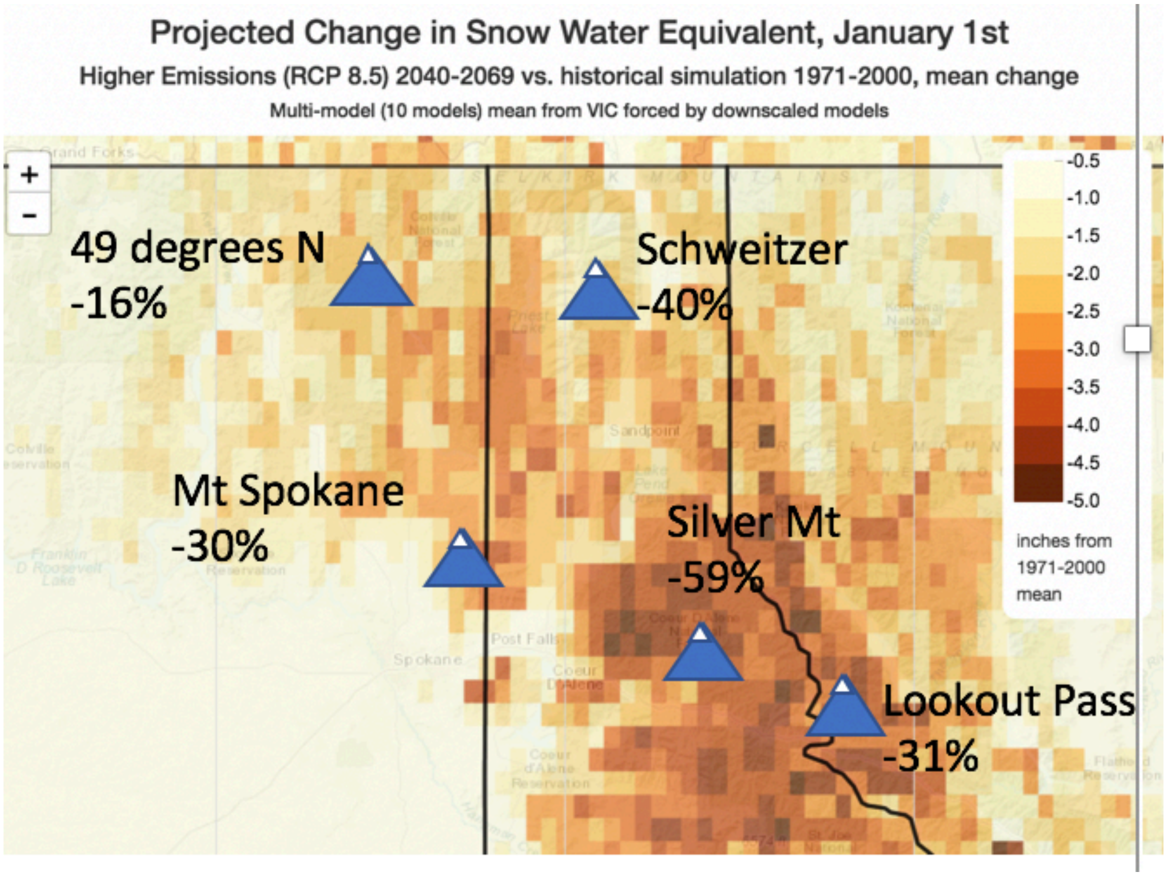

Figure 12: Projected future January 1st snow water equivalent (SWE) (in inches and as percentage change from the simulated historical period 1971–2000) for all five Spokane-area ski resorts for the middle of this century (2040–2069) under the high emissions scenario (RCP 8.5). The percent changes shown here represent the multi-model mean resulting from 10 climate models. Source: The Climate Mapper Tool (https://climatetoolbox.org/tool/Climate-Mapper),The Climate Toolbox.

Table 4:Projected future January 1st snow water equivalent (SWE) at all five Spokane-area resorts expressed as percentage from the historical period 1971–2000 for the years 2040–2069 under both the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5) Source: The Climate Mapper Tool (https://climatetoolbox.org/tool/Climate-Mapper), The Climate Toolbox.

Resort	**RCP 4.5 2040–2069 Project Future January 1st Snow Water Equivalent (SWE) Percent Change (%)**	**RCP 8.5 2040–2069 Projected Future January 1st Snow Water Equivalent (SWE) Percent Change (%)**
Mt. Spokane	-9%	-30%
49 Degrees North	–5%	-16%
Silver Mountain	-25%	- 59%
Schweitzer Mountain	-13%	-40%
Lookout Pass	-9%	-31%

Projected Future Climate—Rise in Mean Temperature and Fewer Freezing Days Limits Snowfall and Snowmaking Opportunities

Variables: *Mean Winter (December–February) Temperature*; *Days with a Minimum Temperature Above 32°F*

Finding: By mid-century (2040–2069), mean winter (December–February) temperatures at Mt. Spokane are projected to rise from a historical (1971–2000) mean of 25.9 degrees Fahrenheit to 30.6 °F under the lower emissions scenario (RCP 4.5) and 31.8 °F under the high emissions scenario (RCP 8.5).

Finding: Mt. Spokane is projected to see 41 to 58 fewer freezing days by mid-century (2040–2069), compared to the last third of the twentieth century (1971–2000).

Finding: Precipitation projections for Spokane show a slight increase in annual precipitation, with a slight increase in precipitation during the fall, winter, and spring months, and a slight decrease in precipitation during the summer months.

Finding: Given what we know about both temperature and precipitation projections for this century, investments in snowmaking equipment might be ill-advised for all five Spokane-area ski resorts.

Justification: To have more control over the start of the ski season, many ski resorts in the Pacific Northwest have chosen to purchase costly snowmaking equipment. According to a 2015 report in the *Spokesman-Review*, a feasibility study commissioned by the Bogus Basin ski resort in southern Idaho concluded that the resort would need "extensive snowmaking to be a sustainable business" **(Russell 2015)**. Snowmaking equipment has already been deployed on runs at Schweitzer Mountain, Silver Mountain, and 49 Degrees North (**Russell 2015**). As of October 2019, both Mt. Spokane (**Copeland 2019**) and Lookout Pass (**Sawyer 2019**) do not use snowmaking equipment in their operations. Advances in snowmaking technology have brought down prices, but the systems still cost millions of dollars. For instance, at the time of the 2015 reporting by the *Spokesman-Review*, "first phase of its snowmaking system" at Bogus Basin was estimated to cost $4 million to install **(Russell 2015)**. However, given what we know about both temperature and precipitation projections for this century, investments in snowmaking equipment might be ill-advised for many ski resorts in the Pacific Northwest. Projected changes in temperature could create conditions where, even with expensive snowmaking equipment, it may not be possible to create snow, especially early in the season.

When considering whether to buy costly snowmaking equipment, ski resorts in the Spokane area would be well-advised to consider two climate factors: precipitation and temperature.

Snowmaking is best employed when winter season precipitation is low and temperatures remain low enough to make snow. Over the course of this century, Spokane and the Pacific Northwest generally are projected to have both adequate amounts of precipitation during the winter months and temperatures that will likely be too warm for snowmaking.

The ***Precipitation*** chapter of this report found that precipitation projections for Spokane show a slight increase in annual precipitation, with a slight increase in precipitation during the fall, winter, and spring months, and a slight decrease in precipitation during the summer months. However, these projections do not preclude the existence of periodic future droughts due to low precipitation. Snowmaking is best employed when precipitation levels are low and temperatures also remain low. If we consider just precipitation on its own, snowmaking would only be advisable during periods when precipitation during the winter months was lower than the projected average, in other words, during the less-frequent occurrences of periodic precipitation droughts. However, when we consider precipitation projections in conjunction with temperature projections, snowmaking becomes less advisable.

Standard snowmaking equipment requires temperatures below 30 °F, ideally in the 20s or teens Fahrenheit (**Wobus et al., 2017**). Working from this knowledge, our team addressed the question of snowmaking by analyzing mean temperature (***Table 5***) and days above freezing (***Table 6***). By mid-century (2040–2069), the mean temperature during the prime ski season (December–February) at all five Spokane-area ski resorts is projected to rise under both the lower (RCP 4.5) and high emissions scenario (RCP 8.5). At Mt. Spokane, the mean temperature is expected to rise from a historical mean of 25.9 °F to 30.6 °F under RCP 4.5 and to 31.8 °F under RCP 8.5. By late century (2070–2099), the difference between the two scenarios becomes more notable with 31.5 °F projected for RCP 4.5 and 35.4 °F for RCP 8.5. The pattern observed for Mt. Spokane was true for all five resorts. All five resorts see more warming under RCP 8.5 than they do under RCP 4.5 (***Table 5***).

Table 5: Simulated historical mean winter (December–February) temperature (in degrees Fahrenheit) at all five Spokane-area ski resorts for the years 1971–2000; and projected future mean temperature at all five Spokane-area ski resorts for both the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5) for the years 2040–2069 and 2070–2099. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

Resort	**1971-2000 Simulated Historical December–February Mean Temperature Degrees Fahrenheit** (°F)	**RCP 4.5 2040–2069 Projected Future December–February Mean Temperature** (°F)	**RCP 8.5 2040-2069 Projected Future (RCP 8.5) December–February Mean Temperature** (°F)	**RCP 4.5 2070–2099 Projected Future December–February Mean Temperature** (°F)	**RCP 8.5 2070–2099 Projected Future December–February Mean Temperature** (°F)
Mt. Spokane	25.9 °F	30.6 °F	31.8 °F	31.5°F	35.4°F
49 Degrees North	23.8 °F	28.5°F	29.7°F	29.5°F	33.4°F
Silver Mountain	28.2 °F	32.9°F	34.1 °F	33.8 °F	37.6°F
Schweitzer Mountain	24.9 °F	29.6°F	30.8°F	30.5°F	34.5 °F
Lookout Pass	24.4 °F	20.0 °F	30.2°F	30.0 °F	33.9 °F

Another way to examine the projected rise in temperatures at the five Spokane-area ski resorts is to examine the number of days with freezing conditions. To do this, our team used the Toolbox variable *Days with a Minimum Temperature Above 32 °F* (***Table 6***). All five Spokane-area ski resorts are projected to see an increase in the number of days above freezing under both RCP 4.5 and RCP 8.5 when compared to the historical average, according to our analysis. Consider just Mt. Spokane, which is projected to see an increase in the number of days above freezing from a historical (1971–2000) mean of 196 days to 238 days by mid-century (2040–2069) under RCP 4.5 and 254 days by mid-century under RCP 8.5. For further illustration these numbers can be seen in ***Figure 13*** (RCP 4.5) and ***Figure 14*** **(**RCP 8.5**)**. These numbers can be inverted (assuming a 365-day year) to infer projections of the number of days below freezing at Mt. Spokane at mid-century from a historical average of 169 days a year to 127 days under RCP 4.5 and 111 freezing days under RCP 8.5. In other words, Mt. Spokane is projected to see 42 (RCP 4.5) to 58 (RCP 8.5) fewer freezing days by mid-century compared to 1971–2000.

The projected rise in temperature (as illustrated by both the rise in mean temperature and the increase in the number of days above freezing/fewer days below freezing), suggests that there will be fewer days in the future that will be cold enough to make snow. Moreover, there are expected to be more winter days when snow is melting at Mt. Spokane and the other four Spokane-area resorts. This will likely result in less commerce around winter sports (lift tickets, lodging, food, equipment, etc.) and is expected to negatively impact local businesses. Due to increased temperatures, it is likely to be increasingly difficult to make snow for much of the season. Considering the projected increase in temperatures alongside the projected increase in winter precipitation, snowmaking is unlikely to be advisable even if a resort goes to the time and expense of installing the infrastructure to do so.

Table 6: Simulated historical number of days annually above 32°F or the years 1971–2000 and projected future number of days annually above 32°F for all five Spokane-area ski resorts for both the lower emissions scenario (RCP 4.5) and the high emissions scenario (RCP 8.5) for the years 2040–2069 and 2070–2099. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

Resort	1971–2000 Simulated Historical Number of days with Min Temp above 32 °F (days)	RCP 4.5 2040–2069 Projected Number of Future Days with Min Temp above 32 °F (days)	RCP 8.5 2040–2069 Projected Number of Future Days with Min Temp above 32 °F (days)	RCP 4.5 2070–2099 Projected Number of Future Days with Min Temp above 32 °F (days)	RCP 8.5 2070–2099 Projected Number of Future Days with Min Temp above 32 °F (days)
Mt. Spokane	196 days	238 days	254 days	251 days	293 days
49 Degrees North	166 days	201 days	247 days	213 days	255 days
Silver Mountain	204 days	257 days	273 days	270 days	308 days
Schweitzer Mountain	182 days	261 days	278 days	238 days	282 days
Lookout Pass	185 days	227 days	242 days	240 days	282 days

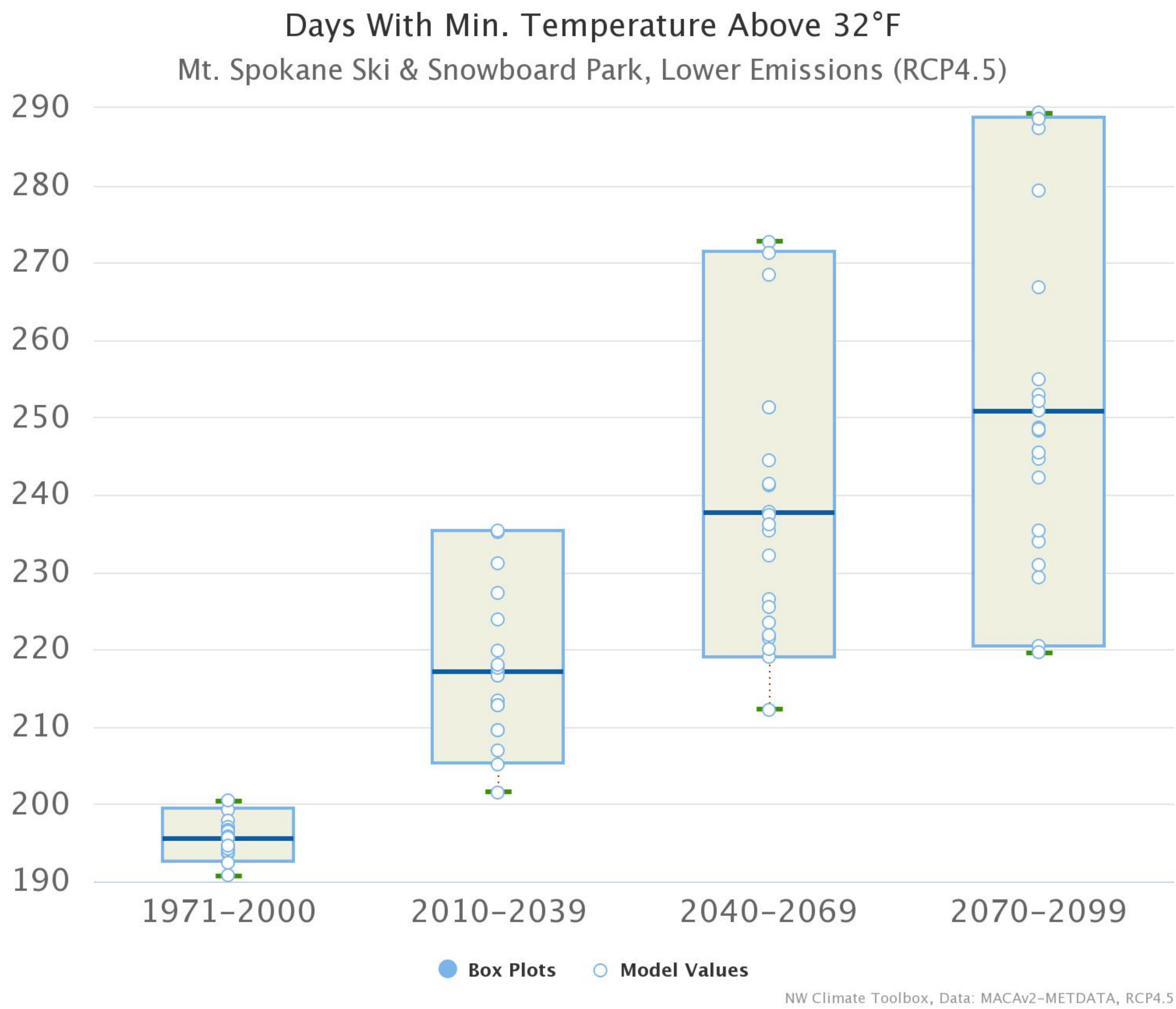

Figure13: Number of days above freezing at Mt. Spokane simulated for historical years 1971–2000 and projected future years 2010–2039, 2040–2069, and 2070–2099 under the lower emissions scenario (RCP 4.5). The number of days is displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). The results of each of the 20 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

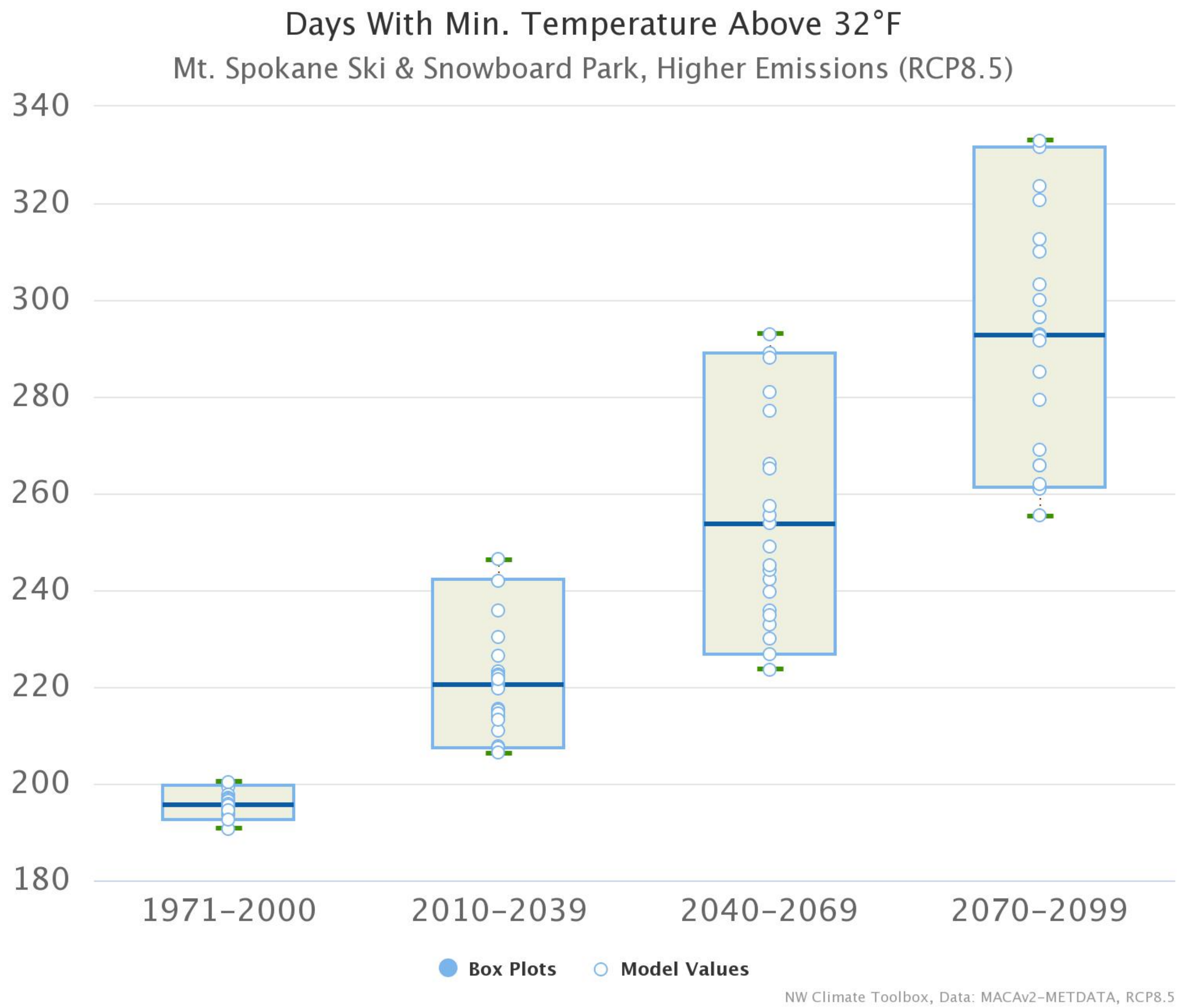

Figure 14: Number of days above freezing at Mt. Spokane simulated for historical years 1971–2000 and projected future years 2010–2039, 2040–2069, and 2070–2099 under the high emissions scenario (RCP 8.5). The number of days is displayed on the y-axis (left vertical). Years are displayed on the x-axis (bottom horizontal). The results of each of the 20 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. The results of each of the 20 models used in the analysis are represented by individual points. The multi-model mean is indicated by a solid bar. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

Conclusion—Impacts to Snow-Based Recreation

"Future risks from climate change depend primarily on decisions made today."

—Fourth National Climate Assessment

Planning on the part of winter recreation industries in the Spokane-region will be necessary to accommodate warmer winters with less snow and more rain. It would be wise for Spokane's ski resorts to begin to diversify their business models to emphasize warmer weather recreation activities. In the next 30–60 years, it would also be prudent for resorts to reconsider expanding operations and especially costly investments in snowmaking equipment that may not be viable later in the century.

The future viability of winter recreation in the Spokane area is dependent on future emissions levels, namely whether we stay on the high emissions path of RCP 8.5 or reduce emissions and move to the lower emissions path of RCP 4.5. Our research suggests that reducing greenhouse gas emissions—moving from our current path on the high emissions scenario (RCP 8.5) to the lower emissions scenario (RCP 4.5)—could mean the difference between a degraded but viable ski industry (RCP 4.5) and a nonviable ski industry (RCP 8.5) for all five resorts. It is also clear that without considerable reductions in emissions, snow-dependent recreation will not be viable within a few decades.

This would suggest that ski industries, skiers, snowboarders, and others who enjoy winter recreation should be aware that systemic societal transformations are necessary to achieve a future closer to the lower emission scenario (RCP 4.5), and thus a climate that supports viable winter recreation activities, industries, and jobs.

The "business-as-usual" high emission scenario (RCP 8.5) is possible, but not inevitable. The negative outcomes of human-caused climate change can be mitigated by swift and significant reductions in greenhouse gas emissions. Individual choices, business practices and government policy are all necessary components of an effective strategy to prevent the climate impacts associated with the high emissions scenario. Many solutions to prevent dangerous climate conditions are currently available, but these solutions require ongoing commitment, financial support, and political will to ensure effective implementation.

Recommended Resilience Actions

It is with the above findings in mind that we recommend the following resilience actions:

- **Reduce Emissions**—The primary action for lessening the impacts to Spokane's winter sports industry associated with projected higher temperatures is to reduce greenhouse gas emissions, specifically to move away from the high emissions scenario (RCP 8.5) to the lower emissions scenario (RCP 4.5).

- **Prepare for Shorter Seasons**—As temperatures in the Spokane region continue to rise, Spokane's regional snow-dependent recreation industries—including skiing, snowboarding, snowshoeing, and snowmobiling—need to prepare for snow seasons that start later, are shorter, have less snow, and potentially provide fewer days cold enough to make snow.

- **Diversify**—Winter recreation industries in the Spokane region should consider diversifying their business model, including emphasizing warmer weather recreation activities.

Discussion—More Research Needed to Determine the Projected Future Length of the Ski Season

As part of our initial analysis our team worked to establish the projected length of the ski season. To do this, we examined the date of the first freeze of the snow season in the fall (*first fall freeze*) and the date of the last freeze of the snow season in the spring (*last spring freeze*) and then calculated the number of days between the two dates to determine the number of days with freezing conditions. Not surprisingly, the projected length of time during which freezing conditions are likely to occur in the future is expected to shrink under projected warming. ***Table 7*** illustrates how freezing conditions at Mt. Spokane are likely to shrink under projected future warming. During the last third of the twentieth century (1971–2000), the date of the first fall freeze at Mt. Spokane was around October 1st (the 274th day of the year) while the date of the last spring freeze was around May 16th (136th day of the year) (***Table 7***). By mid-century (2040–2069) under the lower emissions scenario (RCP 4.5), the first fall freeze at Mt. Spokane is projected to be October 12th (11 days later than historical). Under the high emissions scenario (RCP 8.5), the date of the first fall freeze at mid-century moves to October 16th (15 days later than historical). During the same mid-century timeframe, the last spring freeze is projected to be 18 (RCP 4.5) to 24 (RCP 8.5) days earlier (***Table* 7**). If we take the first fall freeze and last spring freeze data together, by the mid-century freezing conditions on Mt. Spokane could shrink by 29 (RCP 4.5) to 38 (RCP 8.5) days. In other words, within just a few decades, the number of days with freezing conditions at Mt. Spokane could be a month (or more) shorter than they were during the last three decades of the 20th century. We caution that this measure is not directly translatable into seasonal windows or days conducive for precipitation to fall as snow or for snowmaking. This analysis also did not give us a clear picture of how the length of the ski season might change under warming conditions. However, the dates of the first and last freeze do demonstrate that the length of the Spokane-area snow season—which can only start when conditions are cold enough—is likely to shrink at Mt. Spokane under projected temperature increases.

Because the total length of the ski season is critical for the future viability of snow-based recreation at all five Spokane-area ski resorts, we are recommending a further analysis that would link the projected decline in freezing conditions to the projected length of the ski season.

Table 7: First fall freeze (as calendar date and number of days after January 1st) and last spring freeze (as calendar date and number of days after January 1st) at Mt. Spokane the simulated historical period 1971–2000, and projected future years 2010–2039, 2040–2069, and 2070–2099 for both emissions scenarios (RCP 4.5 and RCP 8.5). Calendar dates are based on non-leap years. Source: Future Boxplots Tool (https://climatetoolbox.org/tool/Future-Boxplots), The Climate Toolbox.

Time Period	First Fall Freeze Calendar Date & Number of Days after Jan 1st	Last Spring Freeze Calendar Date & Number of |Days after Jan 1st
1971–2000	Oct. 1st 274 days	May 16th 136 days
RCP 4.5 2010–2039	Oct. 6th 279 days	May 8th 128 days
RCP 4.5 2040-–2069	Oct. 12th 285 days	Apr. 28th 118 days
RCP 4.5 2070–2099	Oct. 5th 278 days	Apr. 21st 111 days
RCP 8.5 2010–2039	Oct. 9th 282 days	May 7th 127 days

RCP 8.5 2040–2069	Oct. 16th 289 days	Apr. 22nd 112 days

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CIRC-Related Data Sources:

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