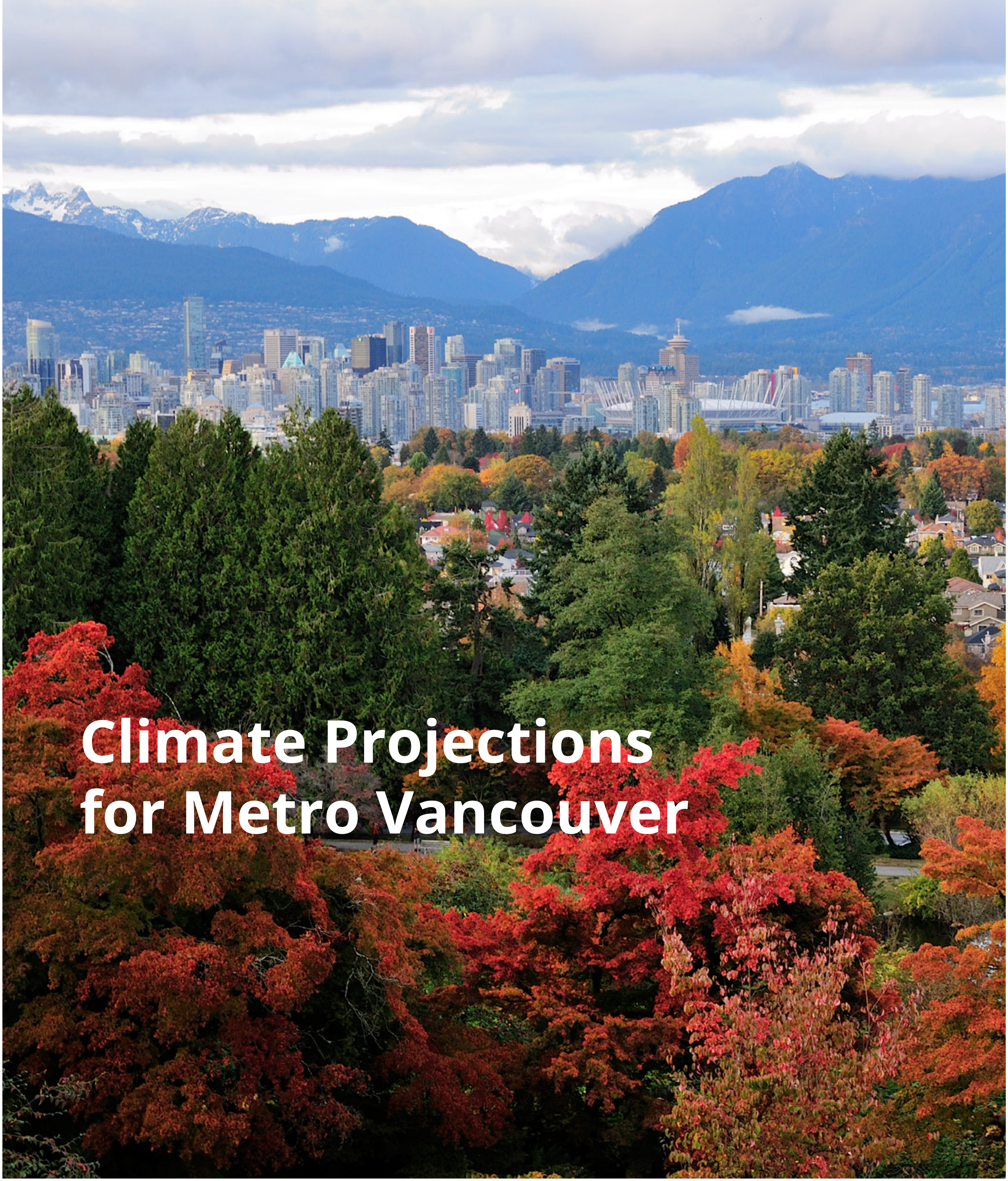
metrovancouver



Climate Projections for Metro Vancouver

SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Acknowledgements

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List of Acronyms

BCCAQ	Bias Correction/Constructed Analogues with Quantile mapping reordering
CMIP5	Coupled Model Intercomparison Project 5
ENSO	El Niño-Southern Oscillation
ETCCDI	Expert Team on Climate Change Detection and Indices
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
IPCC	Intergovernmental Panel on Climate Change
PCIC	Pacific Climate Impacts Consortium
PDO	Pacific Decadal Oscillation
RCP	Representative Concentration Pathway

Executive Summary

Temperatures in Metro Vancouver are warming. Global climate models project an average increase of about 3°C in our region by the 2050s. Metro Vancouver's ability to adapt to climate change requires specific information on how changes in temperature and precipitation will play out locally, how expected changes may vary throughout the seasons, and about new climate extremes. Work has been completed by the Pacific Climate Impacts Consortium (PCIC) to understand the details of how our climate may change by the 2050s and 2080s.

High-level changes for temperature and precipitation for the 2050s indicate that as our climate warms, our region can expect more than a doubling in the number of summer days above 25°C, from an average of 22 days per year to 55 days per year. The 1-in-20 hottest temperature (i.e., a temperature that has a 5% chance of occurring in any year) is projected to increase from 34°C to 38°C by the 2050s. This projected warming has implications for future energy supply, as heating demand for buildings will decrease by 29%, while cooling demand will increase to nearly 6 times what is currently required. This warming also translates into changes that are important to our ecosystems, including a 20% increase in the length of the growing season and a 45% increase in growing degree days. Warmer winters mean the region will experience a 60% decrease in the number of frost days, affecting ecosystems, infrastructure, and our economy.

A modest 5% increase in annual precipitation is projected in our region by the 2050s, though indications of when that precipitation will occur are projected to change in important ways. October and November are expected to see the greatest increase in precipitation, with precipitation expected to fall increasingly during extreme events. Approximately 30% more precipitation can be expected to fall on the 95th percentile wettest days, and approximately 60% more on the 99th percentile wettest days. The amount of rain falling in a 1-in-20 event could increase by 30% by the 2050s. Despite the projected increased intensity of wet events, the amount of rain in summer is expected to decrease by 20%, lengthening dry-spell duration by about 20%, from 21 consecutive days to 26 days.

Most of the projected climate changes described in this report will be felt more or less uniformly throughout the region. Certain impacts, however, may differ substantially between low-lying areas where the majority of the population is situated, and high elevations such as the slopes of the North Shore. In particular, the wettest areas in the local mountains will become even wetter. However, with warmer temperatures and more precipitation falling as rain, the April 1 snowpack depth in the watersheds is projected to decrease almost 60% by the 2050s. The most dramatic regional differences are for frost days and growing-season length, where high elevations show about double the change of low elevations, because temperatures will rise above thresholds that were rarely experienced in the past.

The projected changes to climate will have multiple impacts in our region. This report provides information to support our region to adapt to the changes ahead.

Introduction

Today, new information is available for producing high resolution regional climate projections. This report provides our region with an improved understanding of projected local climate change trends in temperature, precipitation, and related indices of extremes. While sea level rise is an important aspect of climate change with significant regional impacts, it is not addressed in this report as it does not require the same type of regional downscaling.

Information provided in this document is intended to describe a probable future and enable our region's planners, engineers, and policy makers to make better-informed decisions on how to plan and adapt to changes ahead. This information could support development of design guidelines for future planning.

This work offers information on multiple indicators that represent key properties of our climate system, which together tell a story of how our climate is expected to change over time. Cross-cutting themes emerge that demand attention from those charged with planning for the future. These include the provision of services to support safe human settlements, the health of our population, substantial shifts to our ecosystems, and the related economic impacts of those shifts.

In the following sections, you will find a broad, general description of our changing climate, followed by detailed descriptions of specific climate indicators. This is followed with a thematic discussion of potential impacts of climate change that we can expect to experience in our region in years to come.

Methodology

Climate Scenario Selection

Various future trajectories of greenhouse gas (GHG) emissions are possible, and depend directly on global political initiatives and socio-economic changes that will occur over the coming years. This report presents the internationally recognized "business as usual" greenhouse gas emissions scenario, known as Representative Concentration Pathway 8.5 (RCP8.5). Additional information from lower emissions scenarios (RCPs 4.5 and 2.6) is available for sensitivity analysis and to illustrate the relationship between adaptation and greenhouse gas emissions reductions, or mitigation (see Appendix 1).

In general terms, RCP8.5 corresponds to "business as usual" GHG emissions for the remainder of the century. The RCP4.5 "medium stabilization" scenario represents mitigation efforts that result in about half of the emissions compared to the RCP8.5 scenario. Substantial and sustained reductions in GHG emissions—for example, extensive adoption of biofuels and vegetarianism, along with carbon capture and storage—would be required to achieve RCP2.6, which is the only pathway that would keep global warming below 2°C above pre-industrial temperatures. The projected global temperature change for each pathway is illustrated below.

Representative Concentration Pathways (RCPs)

RCPs describe potential 21st century scenarios of GHG emissions, atmospheric GHG concentrations, air pollutant emissions, and land use. These RCPs are used for making projections, and are based on the factors that drive anthropogenic GHG emissions: population size, economic activity, lifestyle, energy use, land use patterns, technology adoption, and climate policy. Each of the RCP emissions pathways is achievable, and directly relates to the choices made by global society.

While recent commitments, including the 2015 COP21 Paris Agreement, correspond with RCP2.6, to date public policy continues to reflect the RCP8.5 pathway. It is prudent to plan for an RCP8.5 future until global mitigation actions begin to catch up with commitments.

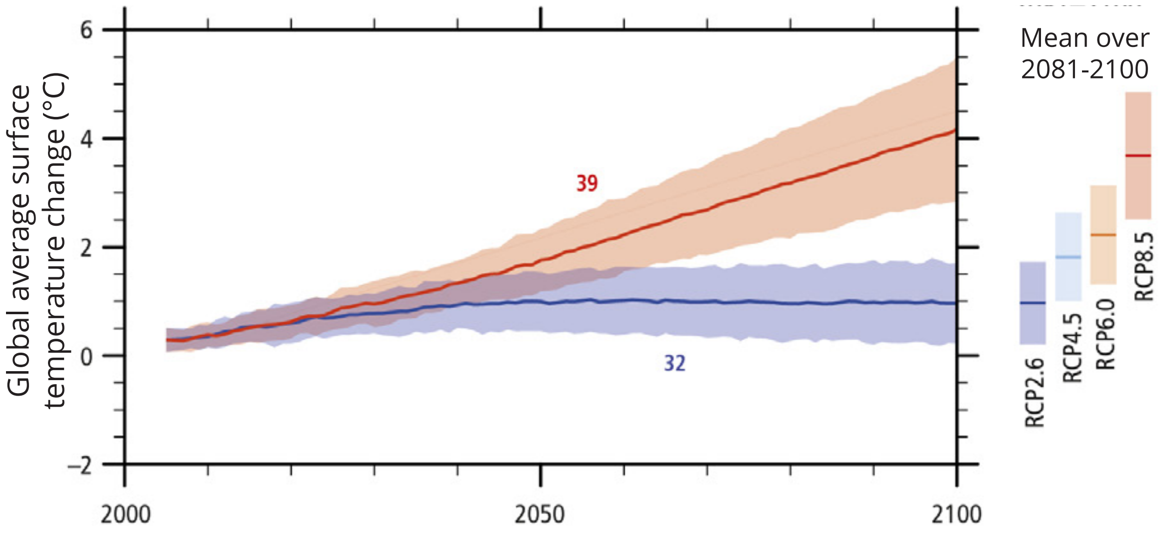


Figure SPM.6(a) from IPCC's Climate Change 2014: Synthesis Report shows modeled global average surface temperature change relative to 1986-2005. The mean of the projections (lines) and a measure of uncertainty (shading) are shown for RCP8.5 (red) and RCP2.6 (blue). The number of climate models used to calculate the mean is indicated.

Climate Model Selection

Many different, highly sophisticated models are used to simulate how the earth's climate will respond to changes in greenhouse gas concentrations, each with different strengths and weaknesses. To manage the uncertainty associated with modelling, it is best practice to apply an ensemble approach that uses several models to describe the bounds of projected climate change.

About Climate Models

More information about climate models is available from the Pacific Institute for Climate Solutions' Climate Insights 101 course.

- Global climate models: http://pics.uvic.ca/insights/module1_lesson4/player.html
- Regional climate modelling and impacts in British Columbia: http://pics.uvic.ca/education/climate-insights-101#quicktabs-climate_insights_101=1

The results in this report are based on a subset of climate models selected from the Coupled Model Intercomparison Project 5 (CMIP5). The CMIP5 climate models were first screened according to their ability to replicate historical data, and from them, the ensemble of 12 models was chosen to provide the widest range of projected change for a set of climate parameters.

Information from the large-scale global climate models was translated into predictions at local scales using a procedure called downscaling. The model projections were downscaled to a 10 km grid by making use of a historical daily time series (ANUSPLIN) in conjunction with the climate model projections. BCCAQ statistical downscaling was used, which is a hybrid climate analogue/quantile mapping method. Daily temperature and precipitation observations and future projections at 10 km resolution were then draped over an 800 m grid (PRISM) of 1971–2000 average temperature or precipitation to generate high-resolution maps.

Indicator Derivation

The historical baseline period used for all indicators in the report is 1971–2000. Values are averaged over this 30-year period to smooth out annual variability. The future projections are for the 2050s (which is an average of modelled values over the 2041–2070 period) and 2080s (2071–2100). The three RCP scenarios have somewhat similar greenhouse gas concentrations in the 2050s, but diverge considerably by the 2080s. Indicators of climate change take a similar divergent pattern by the 2080s.

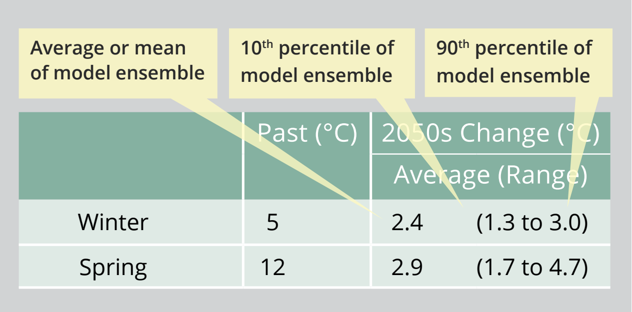
Many of the indicators of extreme events used in this report are derived using the definitions recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI), known as the CLIMDEX indices[1]. The indicator names used in this report have been translated into plain language, with the original CLIMDEX names provided in the tables for reference. Some indicators are defined by ETCCDI on a monthly basis only such as TXx (monthly maximum daytime high temperature). In some cases, we consider seasonal and annual versions of CLIMDEX indices by taking the corresponding maximum (or minimum) from the highest (or lowest) month in that season or year.

Sea level rise, which does not require the same downscaling to examine regional impacts, was not included in this study. Projections of rising ocean levels are addressed by provincial guidelines.[2] Some adaptation planning will require detailed assessments of sea level rise in combination with other local conditions such as subsidence and wave effects.

How to Read the Figures and Tables

The following methods were used when developing the values shown in the tables, maps, and plots in this report:

- Values for each time period (past, 2050s, and 2080s) are averaged over each 30-year period. The 30-year period used to calculate past values is 1971–2000; the 2050s refer to 2041–2070, and the 2080s refer to 2071–2100.
- Seasons are presented as winter (December-January-February), spring (March-April-May), summer (June-July-August), and fall (September-October-November).
- In tables throughout the document, projected change is given for the mean of the model ensemble along with the range (10th to 90th percentile) of the model ensemble. The 10th to 90th percentile range describes the uncertainty among the models and natural climate variability.



	Past (°C)	2050s Change (°C)	
		Average	(Range)
Winter	5	2.4	(1.3 to 3.0)
Spring	12	2.9	(1.7 to 4.7)

- Values in tables are averaged over the entire region (within the regional boundary shown on the maps), unless labelled as low elevation or high elevation.
- In this report, lower-elevation values are averaged within the geographic boundaries of the City of Vancouver, while higher-elevation values are averaged within the boundaries of the District of North Vancouver. These municipalities were being analyzed for other studies, and were used to represent lower- and higher-elevation areas of the region.

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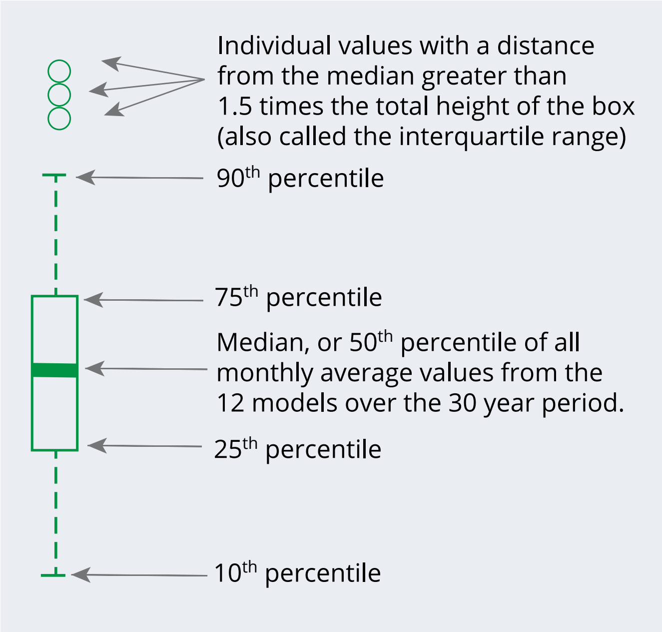
[1] http://www.climdex.org/indices.htm

[2] http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/guidelines_for_mgr_coastal_flood_land_use-2012.pdf

- Maps show only the mean values of the model ensemble. Maps are provided in the body of the report when they add meaning to data interpretation, with additional maps for remaining indicators presented in Appendix 2.
- For the 1-in-20 events described in this report, the "5% chance of occurrence" is based on an average over each 30-year period. To be precise, since climate change will occur throughout that time, there is slightly less than a 5% chance of such an event occurring at the beginning of the period and more than 5% chance at the end of the period, with an average 5% chance over the period.

This report provides several box-and-whisker plots to illustrate year-to-year and model-to-model variability over time. The diagram below illustrates how these plots are to be interpreted.



A Note on Interpretation

This report tells the story of how we can expect temperature and precipitation to change in the Metro Vancouver region. When reviewing the data provided in the tables and figures below, it is important to note the following:

- The 10th to 90th percentile values projected by the ensemble are important for adaptation planning, as they take into account the range of uncertainty when projecting future climate change. Risk managers may find it appropriate to consider 90th percentile values when planning critical infrastructure investments.
- For some indicators, values for specific geographic areas may be more appropriate than the regional averages presented in the tables. These values can be obtained by looking at the maps presented in the report body and in Appendix 2.

General Climate Projections for Metro Vancouver

The Metro Vancouver region can expect changes to our climate in the coming years. At a broad level, this will mean:

- warmer temperatures,
- a decrease in snowpack,
- longer dry spells in summer months,
- more precipitation in fall, winter, and spring, and,
- more intense extreme events.

These changes will not always happen consistently over the region or over time as seasonal and yearly variations will occur. For most variables, projected change appears somewhat different from the past by the 2050s, and by the 2080s, projections indicate substantial changes, resulting in a very different lived experience than the Metro Vancouver of today. This is particularly true for the temperature related variables.

This section of the report presents general projections, and is followed by sections with more detailed climate indicators including indices of extremes for precipitation, summer temperatures and winter temperatures. Each section includes a definition of the indicator and a summary of projected values.

Warmer Temperatures

ABOUT THESE INDICATORS

Daytime high and nighttime low temperatures are averaged over each month, each season, or annually in the tables and plots below.

PROJECTIONS

All models project daytime high and nighttime low temperatures to rise. While temperature can be expected to increase year round, the greatest increases will occur in the summer months. By the 2050s, daytime high temperatures will be substantially warmer (an increase of 3.7°C) in summer. By the 2080s, we can expect summer daytime highs to increase by 6°C.

Nighttime lows are also projected to rise by approximately 3°C in all seasons by the 2050s, resulting in an average winter low of 2°C, compared to an average winter low below zero in the past. The winter nighttime low can be expected to increase to 4°C by 2080s. Summer nighttime lows are also projected to increase dramatically, from 10°C in the past to 16°C by the 2080s.

Maps indicate that warming can be expected uniformly throughout the region, with the warmest areas expected in the valleys and low-lying areas. In the future, only the tops of mountains will have temperatures below zero in the winter, on average.

TABLE 1: AVERAGE DAYTIME HIGH TEMPERATURE

	Past (°C)	2050s Change (°C)		2080s Change (°C)	
		Average	(Range)	Average	(Range)
Winter	5	2.4	(1.3 to 3.0)	4.4	(2.8 to 5.7)
Spring	12	2.9	(1.7 to 4.7)	4.7	(2.8 to 7.3)
Summer	21	3.7	(2.4 to 5.2)	6.0	(3.7 to 8.4)
Fall	13	2.8	(1.3 to 3.9)	4.5	(2.9 to 6.2)
Annual	13	2.9	(1.6 to 4.2)	4.9	(3.0 to 6.6)

TABLE 2: AVERAGE NIGHTTIME LOW TEMPERATURE

	Past (°C)	2050s Change (°C)		2080s Change (°C)	
		Average	(Range)	Average	(Range)
Winter	-1	2.9	(1.8 to 3.5)	4.9	(3.6 to 5.7)
Spring	3	2.9	(2.0 to 3.8)	4.6	(3.2 to 6.0)
Summer	10	3.2	(1.9 to 4.7)	5.2	(3.5 to 7.7)
Fall	5	2.8	(1.7 to 4.0)	4.5	(3.1 to 6.0)
Annual	4	2.9	(1.9 to 4.0)	4.8	(3.3 to 6.3)

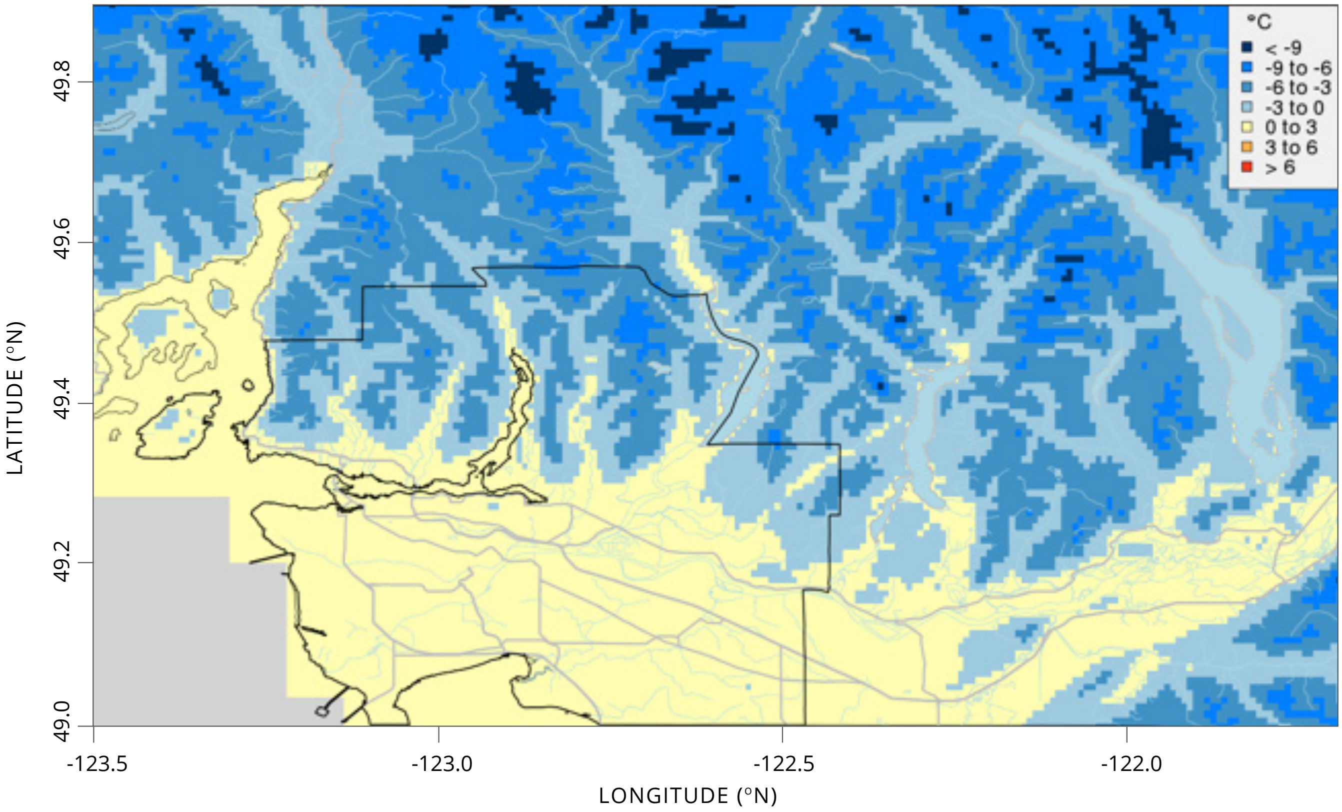


FIGURE 1: WINTER NIGHTTIME LOW TEMPERATURE – PAST

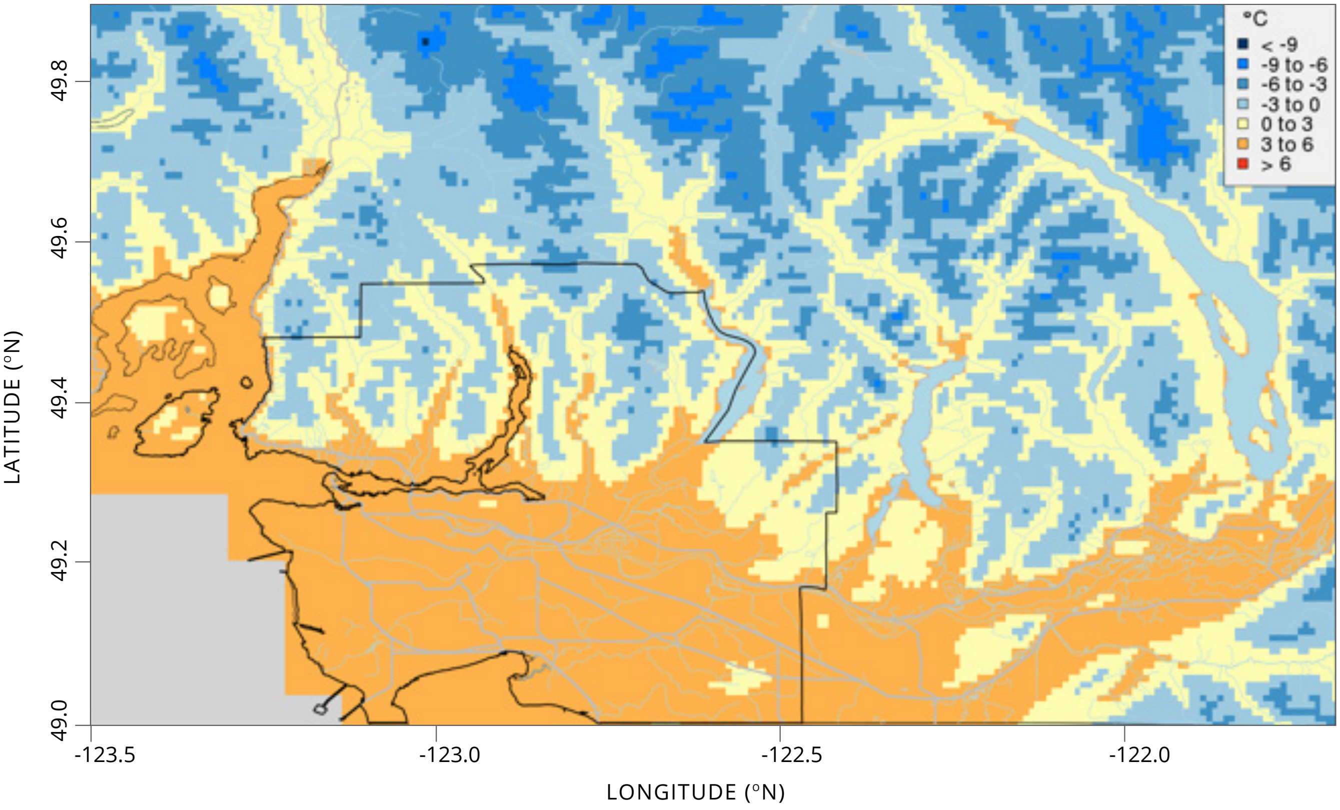


FIGURE 2: WINTER NIGHTTIME LOW TEMPERATURE – FUTURE (2050s)

Seasonal Variability in Temperature

The box-and-whisker plots below of monthly high and low temperatures show that the new normal for the region may be very unlike the past. In these plots, the larger spread in future boxes could indicate that some years may be quite warm when others are not, or could mean there is more uncertainty in how the climate will respond to increasing atmospheric greenhouse gas concentrations.

The daytime high temperature plot (Figure 3) shows that the median monthly average daytime high in the 2080s will be hotter than the 90th percentile of monthly averages in the past, notably in July, August, and September. In the 2080s, most September temperatures will be hotter than August temperatures would have been in the past. In the 2080s, average daytime highs in January will be similar to those of March in the past.

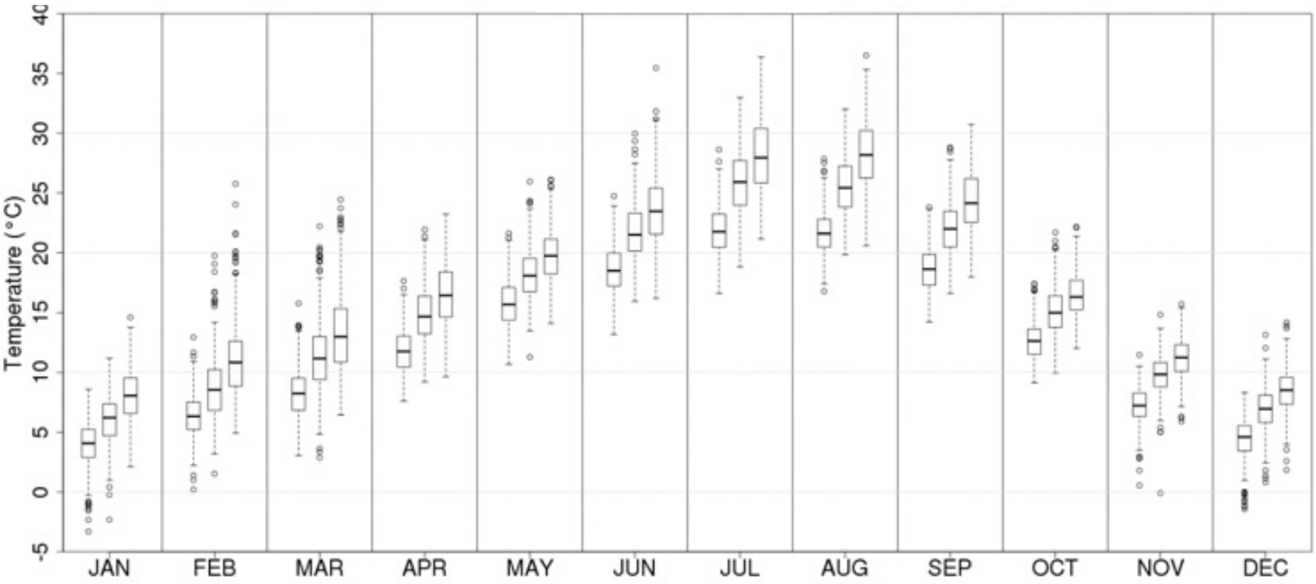


FIGURE 3: MONTHLY DAYTIME HIGH TEMPERATURE – PAST, 2050s, AND 2080s

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

In terms of nighttime lows (Figure 4), about 75% of past January average temperatures were below freezing for the region as a whole. By the 2050s, 90% of January and December average nighttime lows are expected to be above freezing. In past summers, cooler nighttime temperatures offered relief from hot days. By the 2050s, over 90% of monthly average nighttime lows are hotter than the hottest 10% in the past, for April through October. These projections indicate a future that has little in common with our current climate in terms of nighttime low temperatures.

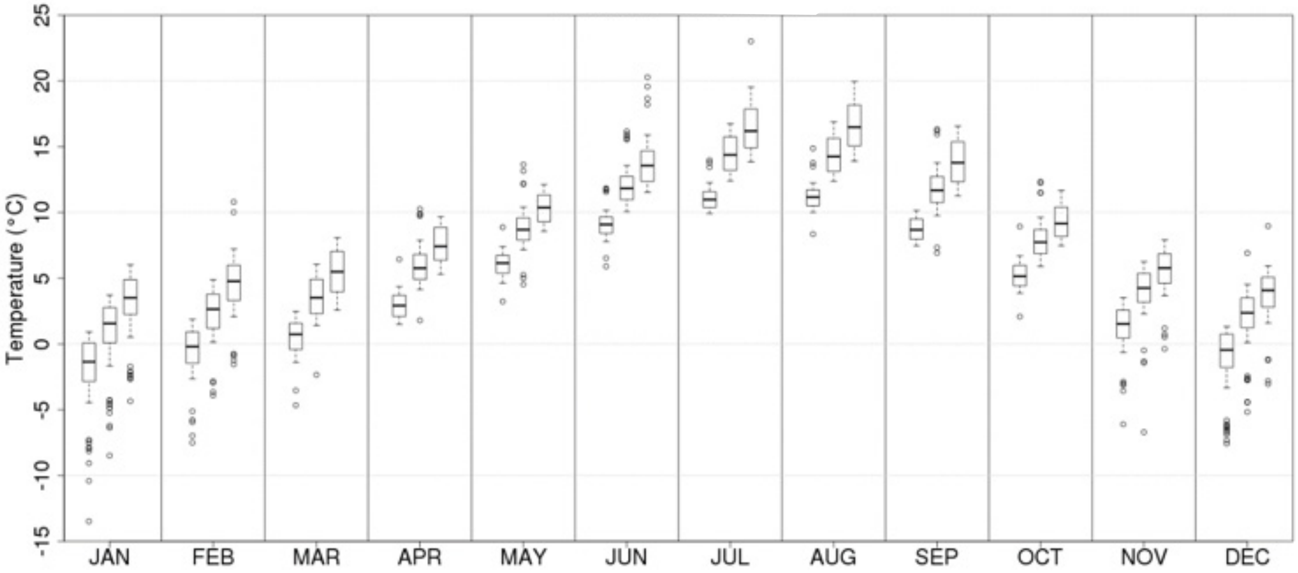


FIGURE 4: MONTHLY NIGHTTIME LOW TEMPERATURE — PAST, 2050s, AND 2080s

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

Wetter Winters, Drier Summers

ABOUT THIS INDICATOR

Total precipitation is all precipitation summed over a month, season, or year, including rain and snow water equivalent. This is a high-level indicator of how precipitation patterns are projected to change.

PROJECTIONS

Projections indicate that our region will experience an increase in total annual precipitation of a modest 5% by the 2050s, and a more substantial increase of 11% by the 2080s. While these increases alone are not a dramatic departure from the past, the increase in precipitation will be distributed unevenly over the seasons.

In our region, most rain falls over the winter months, and this will continue to occur in the future. The largest percentage increase in rainfall will occur in the fall season, increasing 11% by the 2050s and 20% by the 2080s. Winter and spring precipitation will both increase as well. Summer, already our region's driest season, will experience a decline of 19% by the 2050s, and a decline of 29% by the 2080s. While the models indicate a range of possible change, they mostly agree about the direction of change for each season.

TABLE 3: TOTAL PRECIPITATION OVER SEASONS AND YEAR

	Past (mm)	2050s (mm)	2080s (mm)	2050s Percent Change (%)		2080s Percent Change (%)	
				Average	(Range)	Average	(Range)
Fall	580	642	693	11	(-1 to 24)	20	(10 to 38)
Winter	683	714	780	5	(-3 to 12)	14	(2 to 27)
Spring	400	430	447	8	(-4 to 15)	12	(3 to 25)
Summer	206	168	147	-19	(-41 to 1)	-29	(-53 to -6)
Annual	1869	1953	2068	5	(-1 to 9)	11	(2 to 17)

The maps below show the amount of precipitation that is projected to fall and indicates that the wetter areas are expected to experience the largest increases in precipitation.

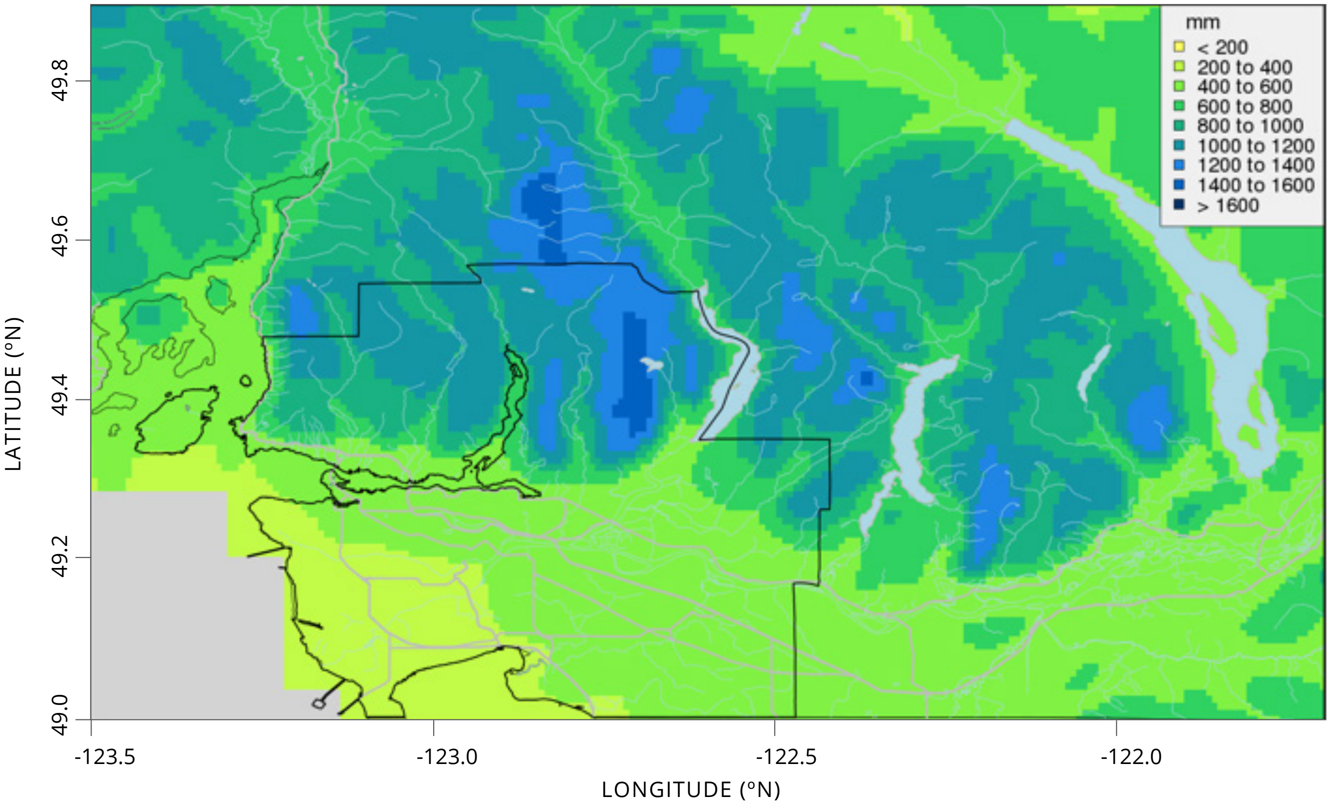


FIGURE 5: FALL PRECIPITATION – PAST

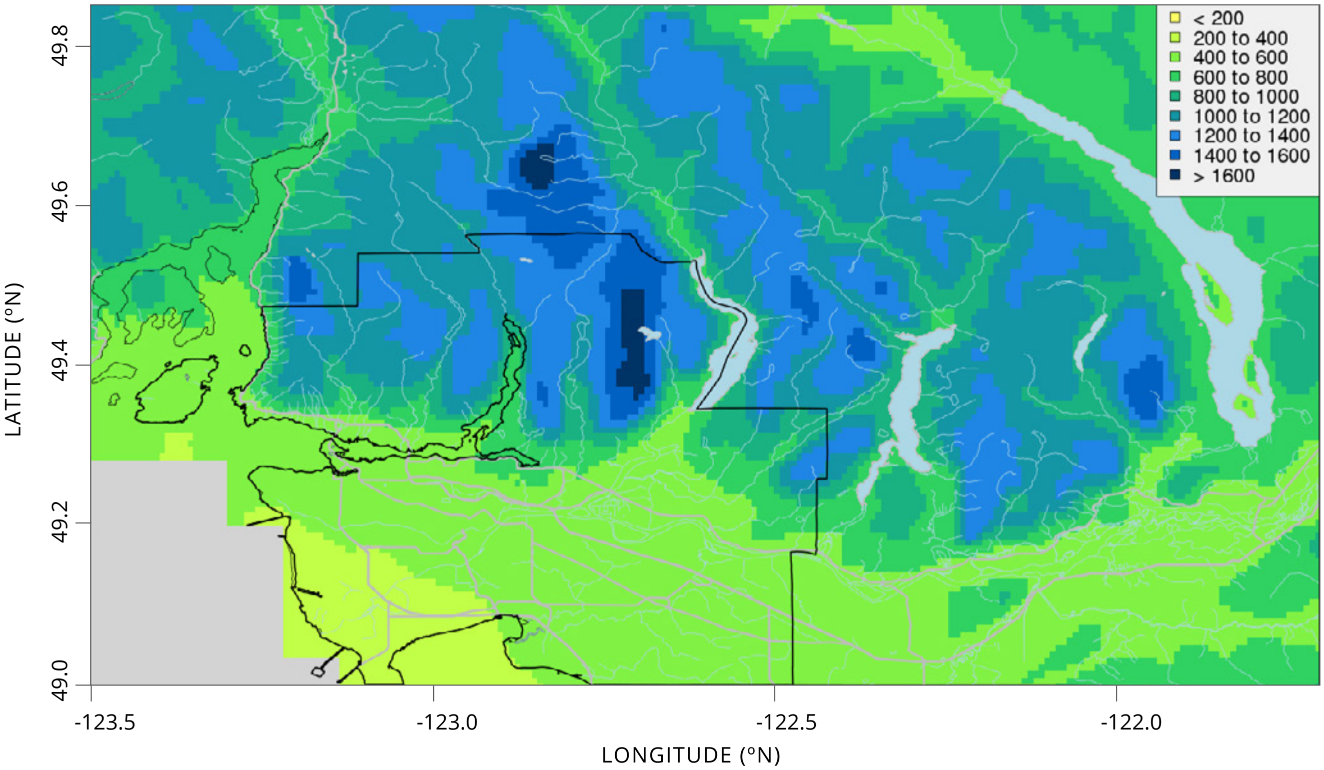


FIGURE 6: FALL PRECIPITATION – FUTURE (2050s)

Seasonal Variability in Precipitation

When examining monthly precipitation values in the plot below (Figure 7), we see that increases in precipitation amounts within a season are not uniform across months. For example, the fall months show a divergent pattern: September shows a reduction in precipitation, while October and November show the largest increases in precipitation. December and January show the largest increases in winter precipitation.

The plot also indicates the potential for much drier summer months than we have ever experienced. September is projected to get drier over time, extending the dry season into the fall. The models illustrate that we can expect more precipitation in the already wet seasons, less precipitation in already dry summers, and considerably more rain falling in some years, while other years will experience droughts.

In southwestern BC, year-to-year precipitation variability is regulated by two global climate patterns: the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO). PDO has varied between warm and cool phases a few times over the last century. ENSO varies between three phases: neutral years, El Niño events that typically mean a warmer and drier winter and spring, and La Niña events that are cooler and wetter. The magnitude of the natural variability of PDO and ENSO cycles is comparable to the projected changes due to climate change in some cases.The effects of ENSO and PDO tend to cancel out in the projections shown in the tables and maps of this report, since those values are averaged over 30 years.

In the future, the decadal and year-to-year variability of the PDO and ENSO patterns will be felt on top of the "new normal" reflected by the future projections. The ranges in the box-and-whisker plot below illustrate year-to-year variability including contributions from ENSO within each 30-year period.

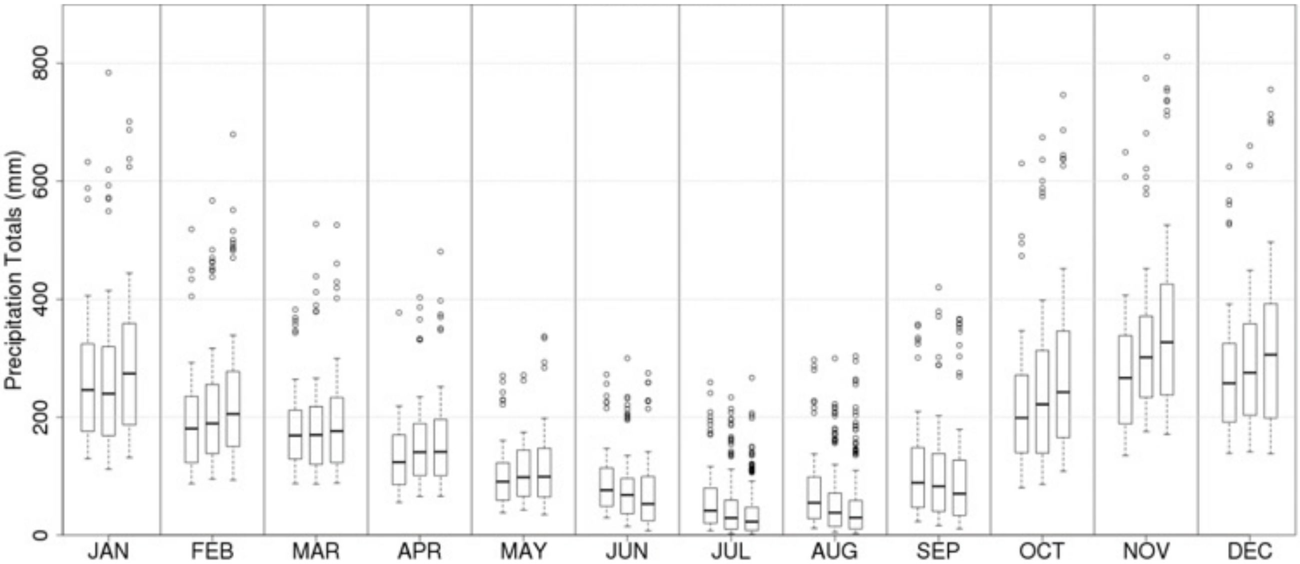


FIGURE 7:   MONTHLY TOTAL PRECIPITATION – PAST, 2050s, AND 2080s

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

Precipitation Indicators

Metro Vancouver's drinking water comes from three mountain reservoirs supplied by rainfall and snowmelt in the watersheds. Changes in precipitation patterns will have impacts on water supply.

Drainage and stormwater infrastructure in the region is designed to withstand extreme weather events. As the climate warms, more moisture is held in the atmosphere and released during precipitation events, resulting in more intense future storm events. New thresholds for extreme weather events will challenge regional infrastructure, such as sewage and drainage systems.

Snowpack

ABOUT THIS INDICATOR

Snowpack refers to the depth of snow on the ground, either daily depths averaged over a season, or in the case of the April 1 and May 1 snowpack, the snow depth on that specific date. This indicator is measured within the boundaries of the three watersheds that supply the majority of Metro Vancouver's drinking water. In this context, the snowpack indicator provides a measure to assist in determining how much snowmelt will be available in the watersheds to flow into our region's reservoirs.

PROJECTIONS

Snowpack is projected to decrease significantly over time. Our region's snowpack is typically highest in the spring months, after snow has accumulated over the winter and early spring, with past spring snowpack depth measuring 266 cm. In the winter months, projections indicate a 56% decrease in snowpack by the 2050s, resulting in much lower spring and summer snow levels. This trend is expected to magnify by the 2080s with a 77% decrease in winter snowpack and 84% decrease in spring snowpack, averaged across the three watersheds.

TABLE 4: SEASONAL SNOWPACK DEPTH (WATERSHED AVERAGE)

	Past (cm)	2050s (cm)	2080s (cm)	2050s Percent Change (%)		2080s Percent Change (%)	
				Average	(Range)	Average	(Range)
Winter	208	93	49	-56	(-63 to -45)	-77	(-86 to -59)
Spring	266	102	43	-62	(-72 to -51)	-84	(-94 to -67)
Summer	73	11	3	-86	(-94 to -80)	-97	(-99 to -92)
Fall	37	10	5	-75	(-82 to -65)	-87	(-94 to -77)

Looking more closely at spring snowpack in the watersheds, the April 1 snow depth will decrease by 58% by the 2050s, from 292 cm to 123 cm, and by 82% by the 2080s, to 56 cm. The May 1 snow depth will diminish even more—a decrease of 66% by the 2050s, and 87% by the 2080s. The following table shows the changes for each of Metro Vancouver's three watersheds (Capilano, Seymour, and Coquitlam). The boundaries of these watersheds are illustrated on the maps below.

TABLE 5: APRIL 1 AND MAY 1 SNOWPACK IN THE WATERSHEDS

		Past (cm)	2050s (cm)	2080s (cm)	2050s Percent Change (%)		2080s Percent Change (%)	
					Average	(Range)	Average	(Range)
April 1	Watersheds average	292	123	56	-58	(-71 to -46)	-82	(-94 to -61)
	Capilano	256	105	45	-59	(-73 to -47)	-83	(-95 to -64)
	Seymour	274	115	47	-59	(-73 to -46)	-84	(-96 to -63)
	Coquitlam	336	144	71	-57	(-70 to -44)	-80	(-92 to -57)
May 1	Watersheds average	264	93	37	-66	(-78 to -54)	-87	(-96 to -73)
	Capilano	229	77	29	-67	(-80 to -56)	-88	(-97 to -76)
	Seymour	244	81	28	-67	(-81 to -56)	-89	(-98 to -76)
	Coquitlam	308	114	51	-64	(-76 to -52)	-84	(-94 to -69)

The maps below illustrate the snowline moving up the mountains as the spring snowpack diminishes into the future. The values presented in the tables above are calculated within the boundaries of the watersheds shown on the maps. Note that the white areas on the map represent areas where snowpack is nearly permanent, i.e., at or near glaciers. The snowpack model does not apply in these locations. Snow depths in these locations are omitted from the calculation of values in the tables above. However, the area of permanent snow (glaciers) are shown to decrease over time.

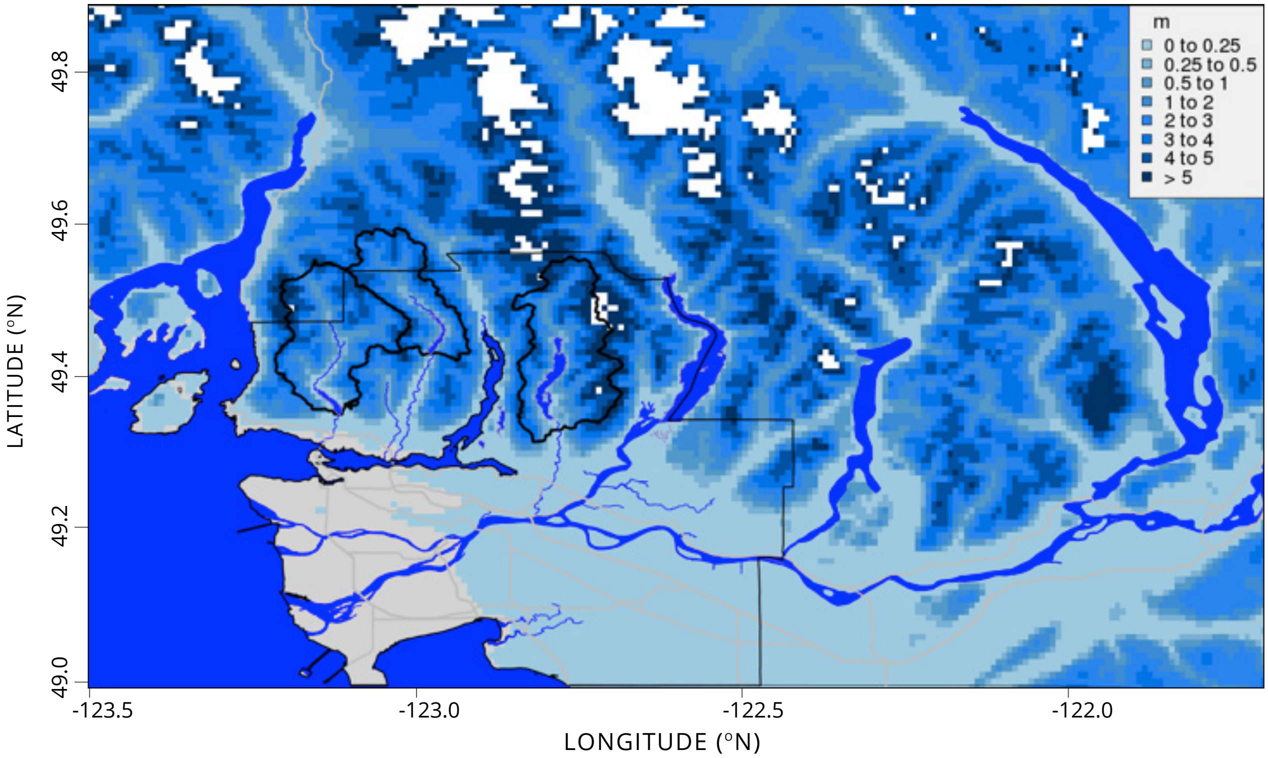


FIGURE 8: APRIL 1 SNOWPACK – PAST

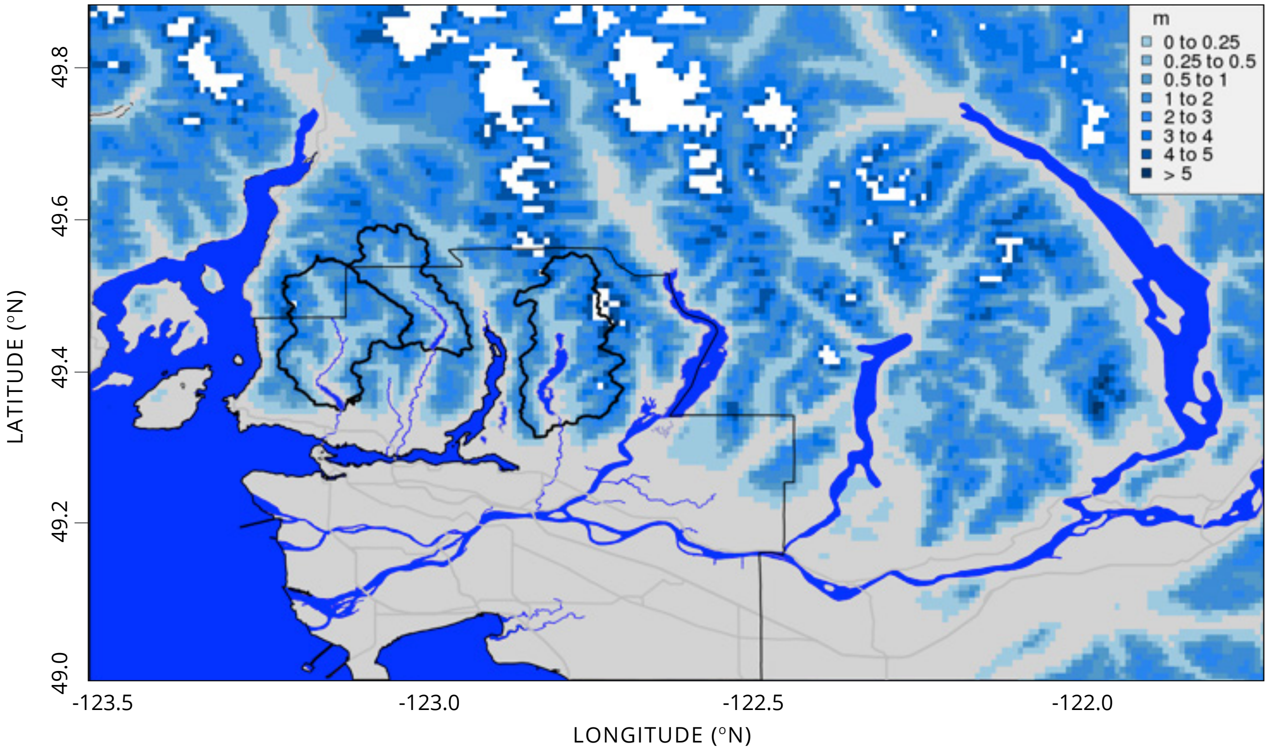


FIGURE 9: APRIL 1 SNOWPACK – FUTURE (2050s)

Dry Spells

ABOUT THIS INDICATOR

Dry spells is a measure of the number of consecutive days where daily precipitation is less than 1 mm. The value denotes the longest stretch of dry days in a year, typically in summer. This indicator reflects times of the year when reservoirs are not recharged by rainfall. This number does not indicate extreme droughts, as it is averaged over the 30-year period.

PROJECTIONS

The past average longest period of consecutive days without rain (under 1 mm) in our region is 21 days. Dry spells on average are expected to increase to 26 days by the 2050s, and 29 days by the 2080s.

TABLE 6: ANNUAL DRY SPELLS

CLIMDEX index: CDD	Past (days)	2050s (days)	2080s (days)	2050s Percent Change (%)		2080s Percent Change (%)	
				Average	(Range)	Average	(Range)
Dry Spell duration	21	26	29	22	(3 to 40)	37	(16 to 65)

Single-Day Maximum Precipitation

ABOUT THIS INDICATOR

Single-day maximum precipitation describes the largest amount of rain that falls on any single day in the year. This value is used to understand how extreme precipitation will change over time.

PROJECTIONS

As noted previously in the General Climate Projections section, a modest increase (5%) in total annual precipitation is expected by the 2050s. Models project that the increase will be concentrated into the wettest days. The wettest single day of the year will see 17% more rain by the 2050s, and 32% more by the 2080s.

Five-Day Maximum Precipitation

ABOUT THIS INDICATOR

Five-day maximum precipitation describes the largest amount of rain that falls over a period of 5 consecutive days in the year.

PROJECTIONS

Again, as noted earlier, a modest increase (5%) in total annual precipitation is expected by the 2050s, with models projecting the increase will be concentrated into the wettest days. The amount of rain in the wettest 5-day period will increase by 12% by the 2050s, and 25% by the 2080s.

95th Percentile Wettest Days Precipitation

ABOUT THIS INDICATOR

The 95th percentile wettest days precipitation indicator points to the total amount of rain that falls on the wettest days of the year, specifically on days when precipitation exceeds a threshold set by the annual 95th percentile of wet days during the baseline period (1971–2000). This measure indicates how much total annual precipitation falls during these heavy events, which is a combination of both how often these events occur that exceed the 95th percentile threshold amount, and the size of these events.

PROJECTIONS

The wettest periods in our region are projected to become wetter. The wettest days that exceed the baseline 95th percentile threshold will produce 32% more rain by the 2050s, and 62% more rain by the 2080s.

99th Percentile Wettest Days Precipitation

ABOUT THIS INDICATOR

The 99th percentile wettest days precipitation indicator points to the total amount of rain that falls on the wettest days of the year, specifically on days when precipitation exceeds a threshold set by the annual 99th percentile of wet days during the baseline period (1971–2000). This measure indicates how much total annual precipitation falls during these heavy events, which is a combination of both how often these events occur that exceed the 99th percentile threshold amount, and the size of these events.

PROJECTIONS

The 99th percentile wettest days that exceed the baseline 99th percentile threshold are projected to produce 61% more rain by the 2050s, and 127% more rain by the 2080s than in the past. These projected large increases mean that we can expect more frequent and more intense storms in the future.

TABLE 7: EXTREME RAINFALL

	CLIMDEX index	Past (mm)	2050s Percent Change (%)		2080s Percent Change (%)	
			Average	(Range)	Average	(Range)
Single-day maximum precipitation	Rx1day	69	17	(6 to 31)	32	(16 to 43)
Five-day maximum precipitation	Rx5day	159	12	(4 to 20)	25	(13 to 35)
95th percentile wettest days precipitation	R95pTOT	398	32	(6 to 58)	62	(37 to 89)
99th percentile wettest days precipitation	R99pTOT	122	61	(24 to 119)	127	(79 to 200)

1-in-20 Wettest Day

ABOUT THIS INDICATOR

The 1-in-20 wettest day is the day so wet that it has only a one-in-twenty chance of occurring in a given year. That is, there is a 5% chance in any year that a one-day rainfall event of this magnitude will occur. This indicator points to what we can expect in terms of extreme one-day precipitation events in our region.

PROJECTIONS

Significantly more precipitation is expected to fall during the 1-in-20 (or 5% chance) wettest day extreme storm events in the future. Larger 1-in-20 wettest day events could mean up to 36% more rain in low-lying areas by the 2050s, and 59% by the 2080s. In the past, on average, 154 mm of precipitation fell during the entire month of January—by the 2080s, there will be a 5% chance that this amount of rain could fall in a one-day event. In addition to more precipitation during future 1-in-20 events, these findings also indicate that what was previously characterized as a 1-in-20 event will happen more often.

TABLE 8: 1-IN-20 WETTEST DAY

	Past (mm)	2050s Change (mm)		2080s Change (mm)	
		Average	(Range)	Average	(Range)
Region	105	30	(7 to 43)	46	(24 to 70)
Low elevations	89	31	(8 to 50)	51	(30 to 86)
High elevations	121	23	(7 to 38)	38	(16 to 60)

The maps below indicate that the greatest change in 1-in-20 wettest day rainfall will occur where heavy rain already falls. The biggest changes are in the mountains between Coquitlam Lake and Pitt Lake, and other high points to the east of the region.

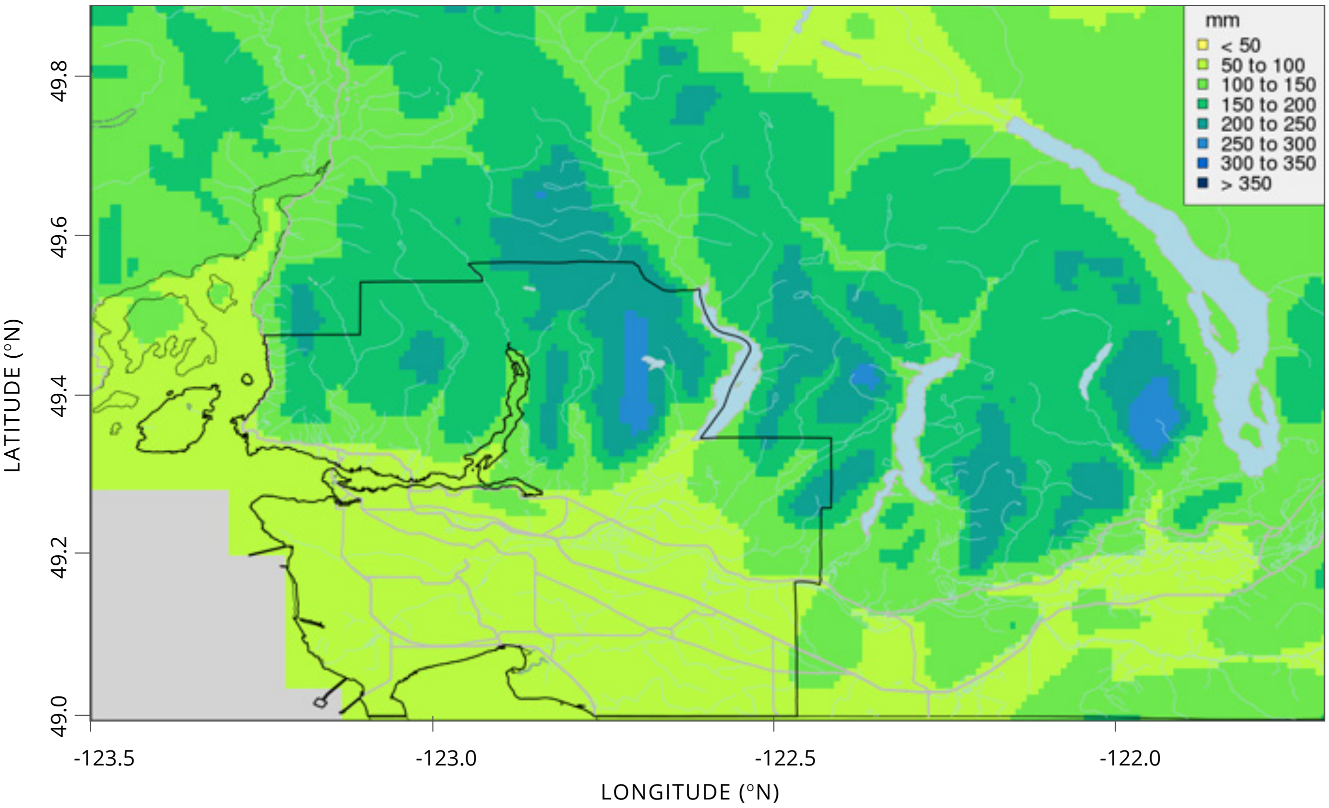


FIGURE 10: 1-IN-20 WETTEST DAY – PAST

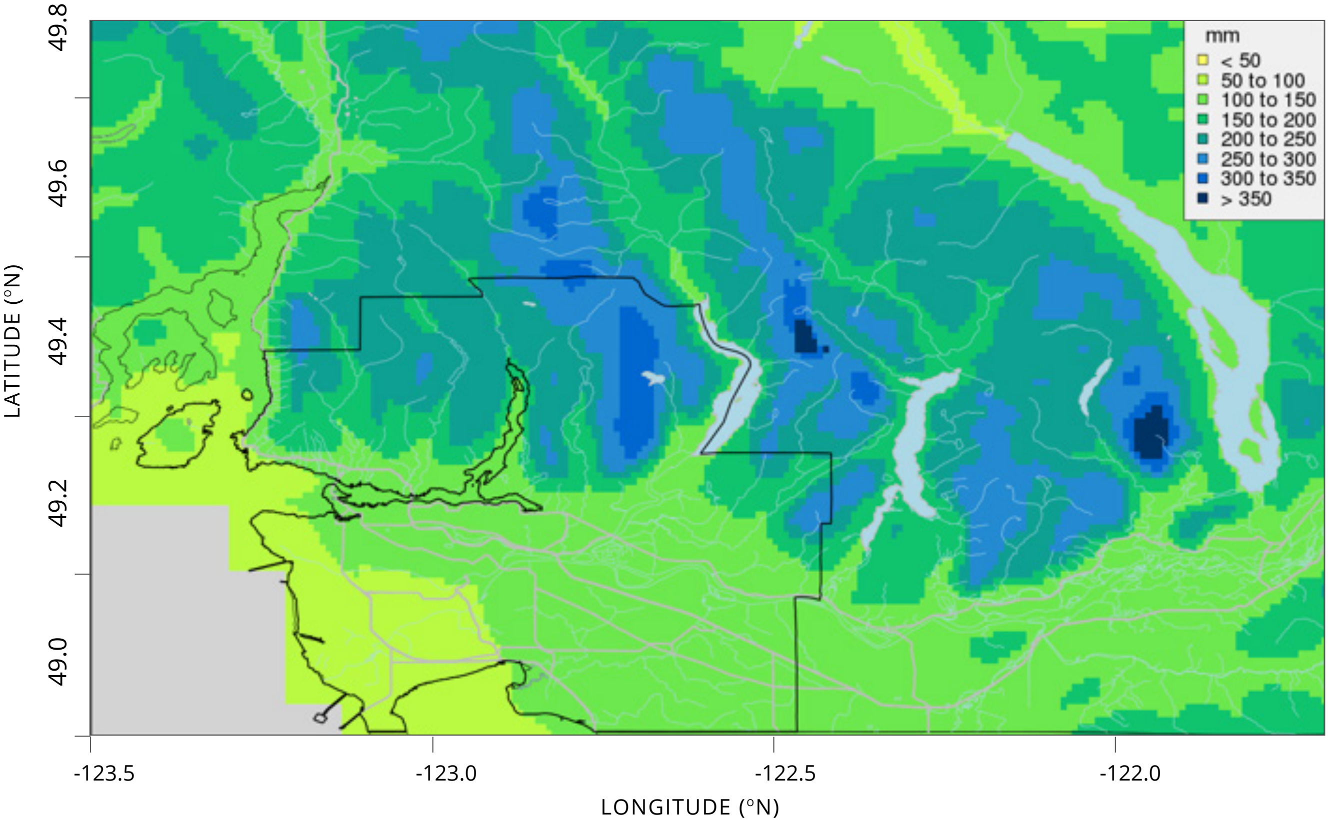


FIGURE 11: 1-IN-20 WETTEST DAY – FUTURE (2050s)

Summer Temperature Indicators

The downscaled outputs from the climate models project increases in average summer (June-July-August) daytime high temperatures that suggest Vancouver would be warmer than present-day San Diego by the 2050s, and even warmer by the 2080s. While warmer temperatures may have benefits and be welcomed in some ways, they will also need careful consideration when planning for a growing population in the region

Descriptions of these indicators are offered below, and values for these projections are given in Table 9: Hot Summers Indicators.

Summer Days

ABOUT THIS INDICATOR

Summer days tells us how many days reach temperatures over 25°C in any one year. This measure indicates how often we can expect "summer weather" to occur in the future.

PROJECTIONS

In the past, our region experienced 22 summer days a year, and we can expect significantly more summer days in the future. Models project more than double the number of summer days by the 2050s, and more than triple by the 2080s. This means that future summers may have 55 days above 25°C by the 2050s, and 79 days by the 2080s.

The maps for summer days included below show that the number of hot days will be highest in the eastern reaches of the Fraser Valley, though the greatest change will be in Metro Vancouver, where the number of summer days was lower in the past.

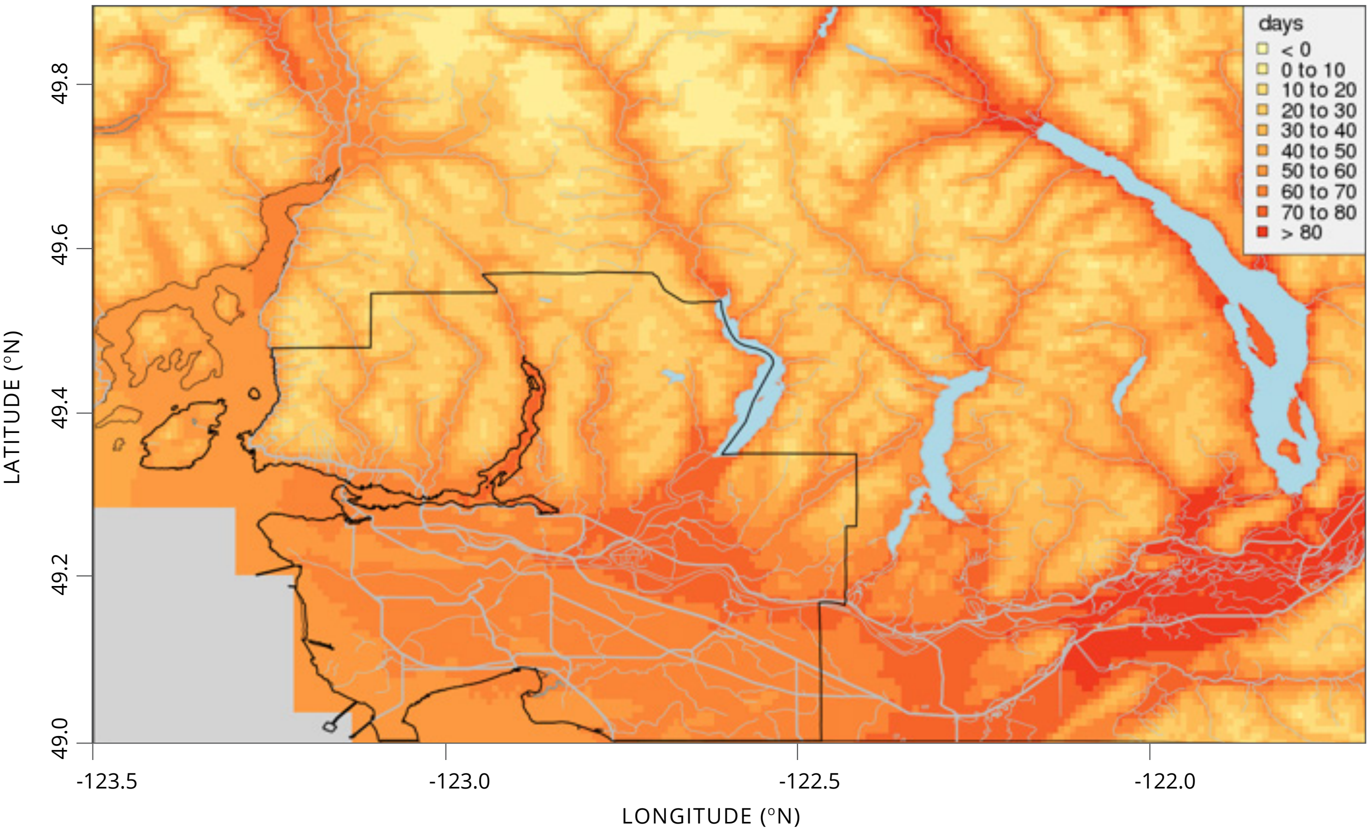


FIGURE 12: SUMMER DAYS – FUTURE (2050s)

Tropical Nights

ABOUT THIS INDICATOR

Tropical nights refers to the number of days in a year when the nighttime low temperature is greater than 20°C. This measure is important when designing cooling systems for buildings, as nighttime temperatures will not aid in indoor cooling on these nights.

PROJECTIONS

In the past, our region experienced no nighttime lows warmer than 20°C, or tropical nights, on average. By the 2050s, it is expected that lower elevations in our region may experience 4 tropical nights a year (projections range from 0 to 10 nights, depending on the model), and by the 2080s, that number will increase to 19 (range of 2 to 48 nights).

Heat Days

ABOUT THIS INDICATOR

Heat days refers to the number of days where the daytime temperature exceeds 30°C. This indicator is useful to show "heat zones" for plants, because some plants experience physiological stress at temperatures above 30°C.

PROJECTIONS

In the past, our region experienced 2 heat days per year, or days with temperature above 30°C, on average. By the 2050s, we can expect 14 heat days per year. This is projected to increase to 29 heat days per year by the 2080s.

Hottest day

ABOUT THIS INDICATOR

Hottest day refers to the highest daytime high temperature of the year, usually experienced during the summer months. The annual high for each year is an indicator of extreme temperatures and is averaged over a 30-year period here.

PROJECTIONS

The past hottest day temperature was 31°C for the region. This will increase to about 35°C by the 2050s, and to 37°C by 2080s. Like summer days (shown in Figure 10) the highest increases can be expected in our region's valleys and in locations further from the ocean.

1-in-20 Hottest day

ABOUT THIS INDICATOR

1-in-20 hottest day refers to a day so hot that it has only a one-in-twenty chance of occurring in a given year. That is, there is a 5% chance in any year that temperatures could reach this magnitude. This indicator points to what we can expect in terms of extreme temperature highs in our region.

PROJECTIONS

As temperatures increase, so will extreme heat events. Our past 1-in-20 hottest day temperature is 34°C. By the 2050s we can expect this value to increase to 39°C, and to 41°C by the 2080s. The range in models suggests that temperatures may even rise to 43°C by the 2080s. This is a significant departure from what the region is accustomed to experiencing.

The 1-in-20 hottest day temperatures will affect the entire region, and like other hot summer indicators, will most affect our region's valleys and other areas furthest from the cooling effect of the ocean.

TABLE 9: HOT SUMMERS INDICATORS

	CLIMDEX index	Past	2050s	2080s	2050s Change		2080s Change	
					Average	(Range)	Average	(Range)
Summer days (# of days >25°C)	SU	22	55	79	33	(20 to 46)	57	(34 to 80)
Tropical nights (# of nights >20°C)	TR	0	2	11	2	(20 to 46)	11	(1 to 30)
Heat days (# of days >30°C)		2	14	29	12	(0 to 5)	27	(14 to 46)
Hottest day (°C)	1-yr TX$_x$	31	35	37	3.9	(5 to 18)	6.4	(4.4 to 8.5)
1-in-20 hottest day (°C)		34	39	41	4.6	(2.5 to 4.8)	6.9	(4.2 to 9.1)

Growing Season Length

ABOUT THIS INDICATOR

Growing season length is an annual measure that counts the number of days between the first span of at least 6 days with a daily average temperature greater than 5°C, and first span after July 1 of 6 days with a temperature less than 5°C. It indicates the length of the growing season for typical plants or crops in our region.

PROJECTIONS

In the past, our region had an average of 252 days in the growing season. In lower elevations 45 days will be added to the growing season by the 2050s, and 56 days by the 2080s, resulting in nearly a year-round growing season of 357 days on average. In forest ecosystems at higher elevations, the growing season will lengthen by more days as higher temperatures creep up the mountains and more days tip over the 5°C threshold. By the 2080s, we will see a growing-season length of 325 days at higher elevations, which is more than we saw in the past at lower elevations.

TABLE 10: GROWING SEASON LENGTH

CLIMDEX index: GSL	Past (days)	2050s (days)	2080s (days)	2050s Change (days)		2080s Change (days)	
				Average	(Range)	Average	(Range)
Region	252	304	331	52	(38 to 62)	79	(66 to 87)
Low elev.	301	346	357	45	(39 to 52)	56	(50 to 62)
High elev.	217	281	325	64	(43 to 82)	108	(90 to 123)

Growing Degree Days

ABOUT THIS INDICATOR

Growing degree days are a measure of heat accumulation that is useful for agriculture and horticulture. Growing degree days calculated here by how warm daily temperatures are compared to a base temperature of 5°C (although different base temperatures may be useful for different crops). For example, if a day had an average temperature of 11°C, that day would have a value of 6 growing degree days. Annual growing degree days are accumulated this way for each day of the year and then summed. This measure is a useful indicator of opportunities for agriculture, as well as the potential for invasive species to thrive.

PROJECTIONS

In the past, there were 1738 growing degree days in our region. Projections indicate increases in growing degree days throughout the region. By the 2050s, we can expect 47% more growing degree days, and 82% more growing degree days by the 2080s. The lower elevations will experience a larger absolute change in growing degree days, while mountain areas show a larger percentage change.

TABLE 11: GROWING DEGREE DAYS

	Past (degree days)	2050s (degree days)	2080s (degree days)	2050s Change (degree days)		2080s Change (degree days)	
				Average	(Range)	Average	(Range)
Region	1738	2532	3157	824	(462 to 1182)	1419	(883 to 1922)
Low elev.	2122	3051	3689	929	(548 to 1300)	1567	(1002 to 2096)
High elev.	1467	2228	2801	761	(411 to 1114)	1334	(814 to 1829)

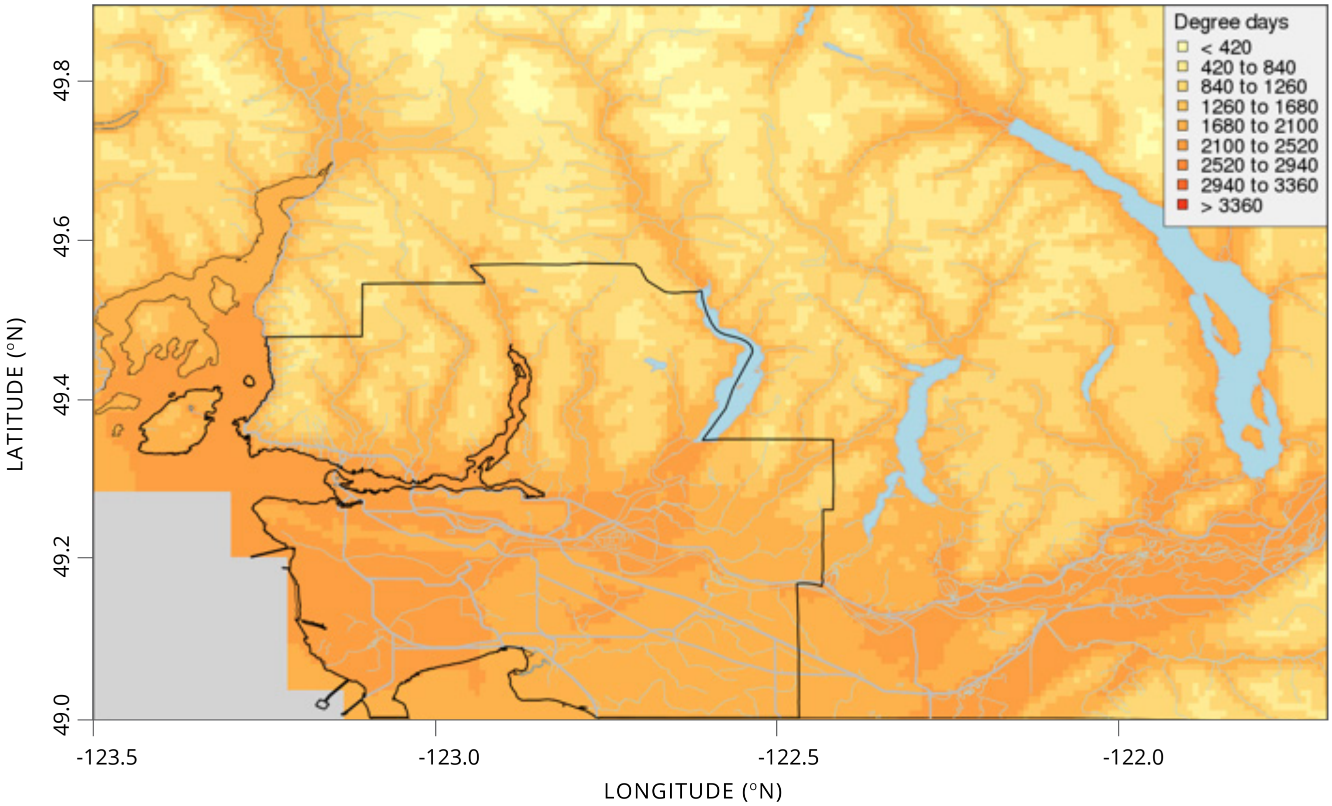


FIGURE 13: GROWING DEGREE DAYS – PAST

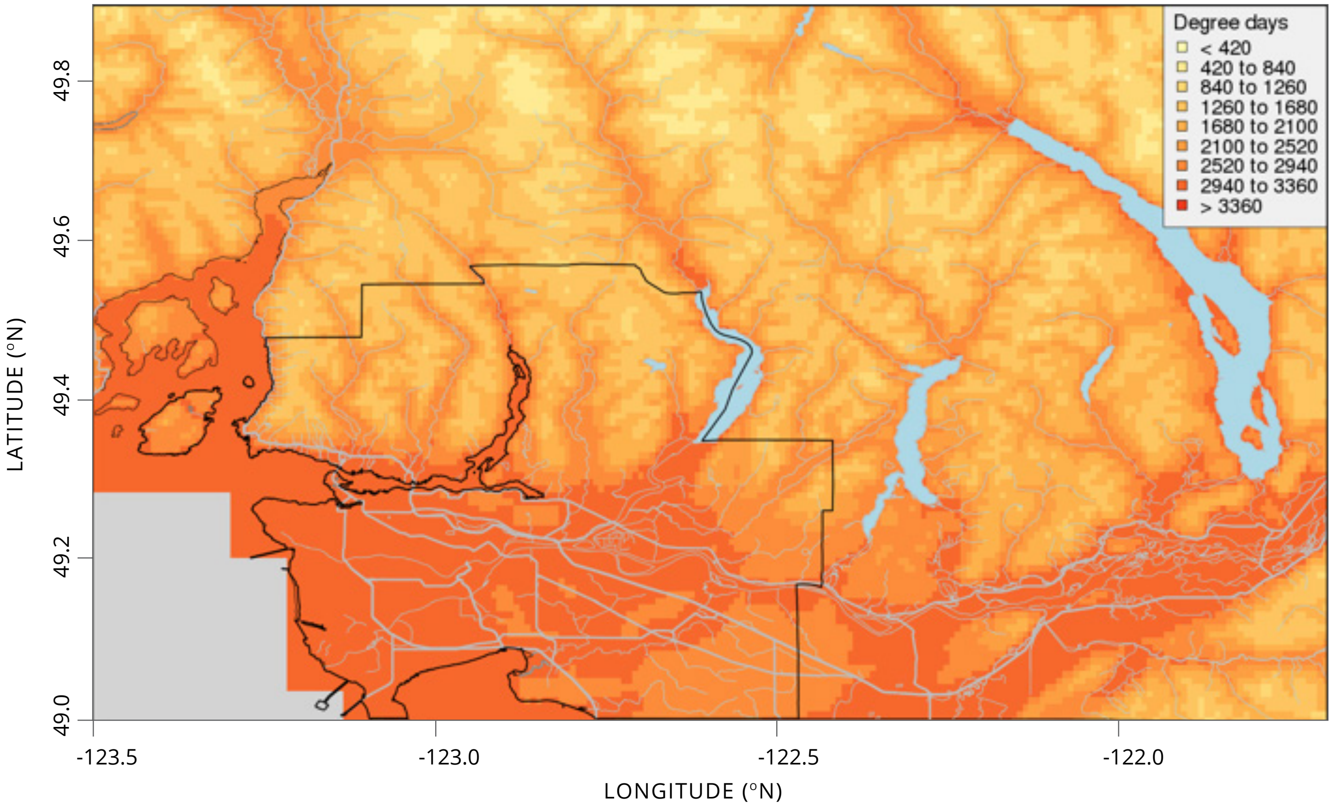


FIGURE 14: GROWING DEGREE DAYS PAST– FUTURE (2050s)

Cooling Degree Days

ABOUT THIS INDICATOR

Cooling degree days is a measure of how hot it gets and for how many days. More specifically, it is a total of the number of degrees above 18°C that occur daily, summed over each day of the year, and provides an indication of when cooling might be required in buildings. Cooling degree days are useful indicators of energy demands for mechanical cooling. This information is important when planning heating, ventilation, and air conditioning (HVAC) systems, building design, energy systems, and related infrastructure.

PROJECTIONS

Historically there has been very little cooling demand in our region. This is reflected in the baseline average of 49 cooling degree days in the past. It is projected that there will be a 380% increase in cooling degree days by the 2050s, and a 784% increase by the 2080s. The large relative increases are partly the result of the fact that the historical baselines are so small. These increases represent a considerable departure from the past.

Areas of lower elevation, where most buildings are located, will have more cooling demand than present-day Kamloops by the 2050s, and a higher cooling demand than present-day San Diego by the 2080s.

TABLE 12: COOLING DEGREE DAYS

	Past (degree days)	2050s (degree days)	2080s (degree days)	2050s Change (degree days)		2080s Change (degree days)	
				Average	(Range)	Average	(Range)
Region	49	235	433	186	(81 to 295)	385	(184 to 606)
Low elev.	58	300	535	242	(106 to 374)	477	(243 to 742)
High elev.	36	177	346	141	(58 to 229)	310	(137 to 496)

The maps below indicate that warmer areas are getting warmer, particularly on south facing slopes and furthest from the ocean.

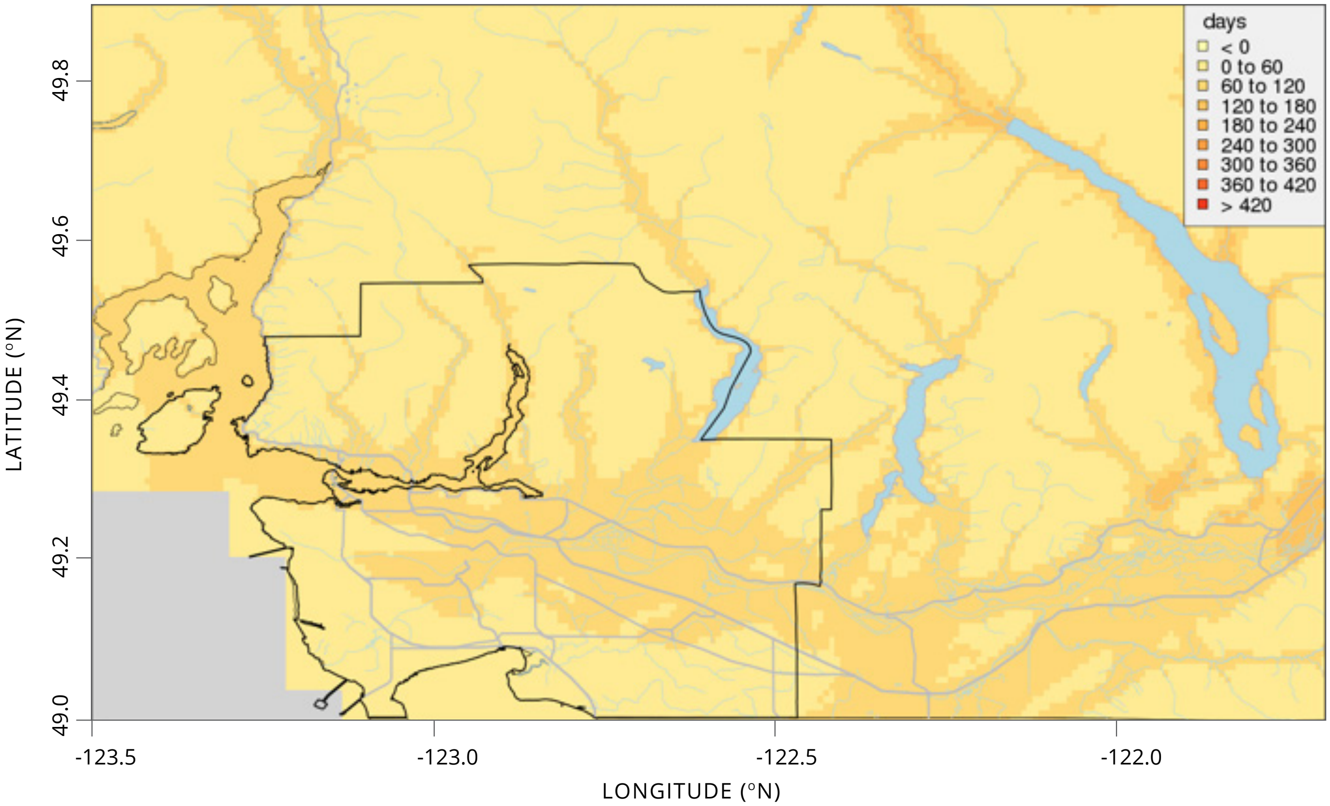


FIGURE 15: COOLING DEGREE DAYS – PAST

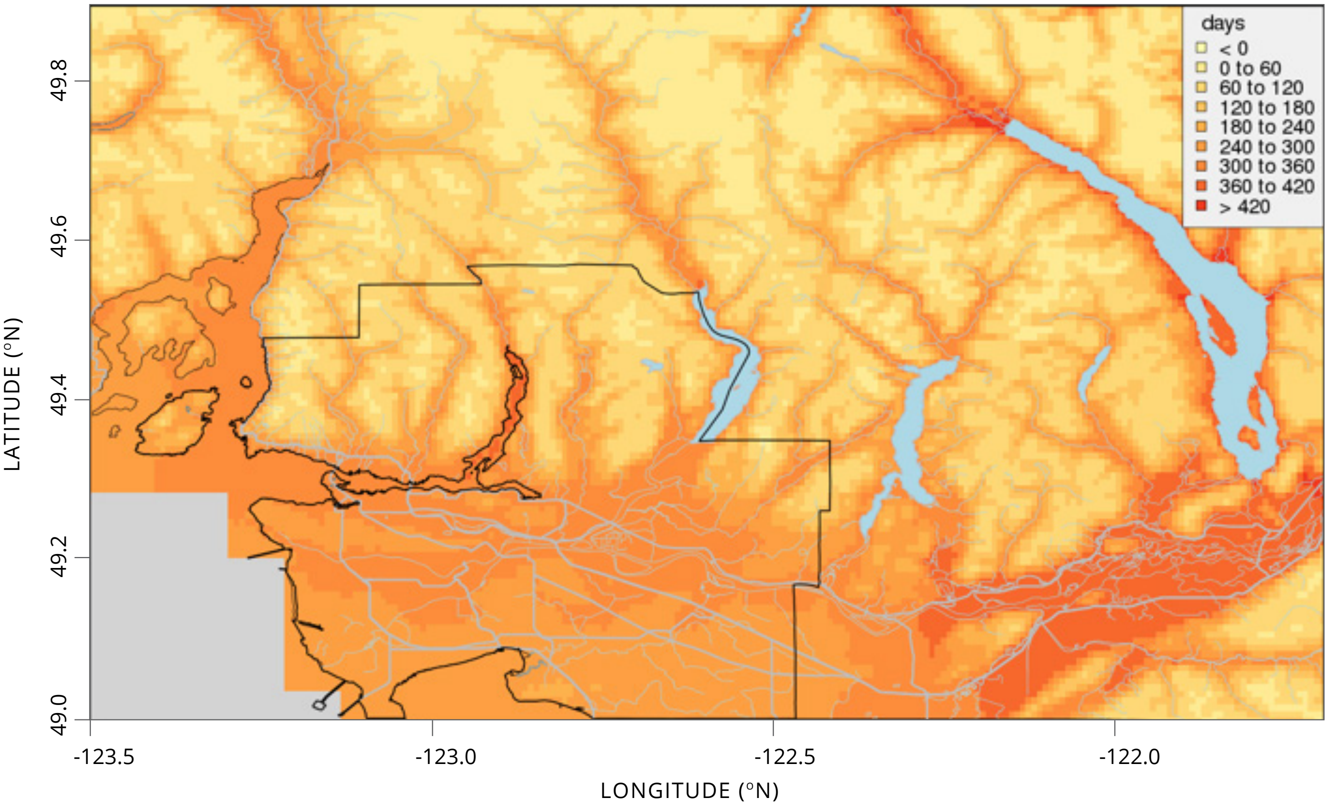


FIGURE 16: COOLING DEGREE DAYS – FUTURE (2050s)

Winter Temperature Indicators

Future climate projections suggest our region will see warmer winter months. These indicators provide insight into the "new normal" for winter temperature in our region.

Warmest Winter Day

ABOUT THIS INDICATOR

Warmest winter day is the highest temperature recorded during the winter months, in an average year. When considered in combination with the coldest night, this indicator is useful to describe the projected "new normal" for winters in our region.

PROJECTIONS

By the 2050s, we can expect to see the warmest winter temperature rise from 12°C to about 15°C. This value may increase to about 18°C by the 2080s.

Coldest Night

ABOUT THIS INDICATOR

Coldest night refers to the lowest temperature of the year, in an average year, usually experienced at nighttime during the winter months. This indicator points to the lowest threshold of winter temperatures, and when considered along with the warmest winter day, helps describe the projected "new normal" for winters in our region.

PROJECTIONS

In the past, the coldest night had a temperature of -13°C. Models project annual lows to increase by roughly 5°C by the 2050s, to -8°C, and by 8°C by the 2080s, to -5°C.

1-in-20 Coldest Night

ABOUT THIS INDICATOR

1-in-20 coldest night refers to a nighttime low temperature so cold that it has only a one-in-twenty chance of occurring in a given year. That is, there is a 5% chance in any year that a minimum temperature of this value will occur. This indicator is a marker of extreme winter cold temperatures.

PROJECTIONS

The 1-in-20 coldest night across the region will increase by 5°C by the 2050s to -15°C, and 8°C by the 2080s to 12°C. The winter nighttime low (-13°C) that in the past occurred roughly once per year will, by the end of the century, be experienced roughly once every 20 years.

TABLE 13: WARMER WINTER DAYS

	Climdex index	Past (°C)	2050s (°C)	2080s (°C)	2050s Change (°C)		2080s Change (°C)	
					Average	(Range)	Average	(Range)
Warmest winter day	TX_x	12	15	18	2.8	(0.6 to 4.0)	5.7	(2.0 to 10.1)
Coldest winter night	TN_n	-13	-8	-5	5.1	(3.5 to 6.6)	8.1	(6.6 to 9.6)
1-in-20 coldest nighttime low		-20	-15	-12	4.9	(3.0 to 7.5)	8.0	(4.7 to 10.4)

Frost Days

ABOUT THIS INDICATOR

Frost days is an annual count of days when the daily minimum temperature is less than 0°C, which may result in frost on the ground. This indicator is useful when predicting how pests and invasive species may thrive in our shifting ecosystems.

PROJECTIONS

In the past, Metro Vancouver had 79 frost days a year. Lower elevations experienced only 39 frost days, while higher elevations had 92 frost days. Future projections indicate conditions where the "new normal" is a climate that is almost entirely frost-free in lower elevations. The region may expect 33 frost days by the 2050s, and 17 by the 2080s. The maps below illustrate that the loss of frost days will be most dramatic at higher elevations.

TABLE 14: FROST DAYS

CLIMDEX index: FD	Past (days)	2050s (days)	2080s (days)	2050s Change (days)		2080s Change (days)	
				Average	(Range)	Average	(Range)
Region	79	33	17	-47	(-54 to -37)	-63	(-68 to -52)
Low elev.	39	11	4	-28	(-33 to -23)	-35	(-38 to -30)
High elev.	92	34	16	-58	(-68 to -46)	-76	(-83 to -63)

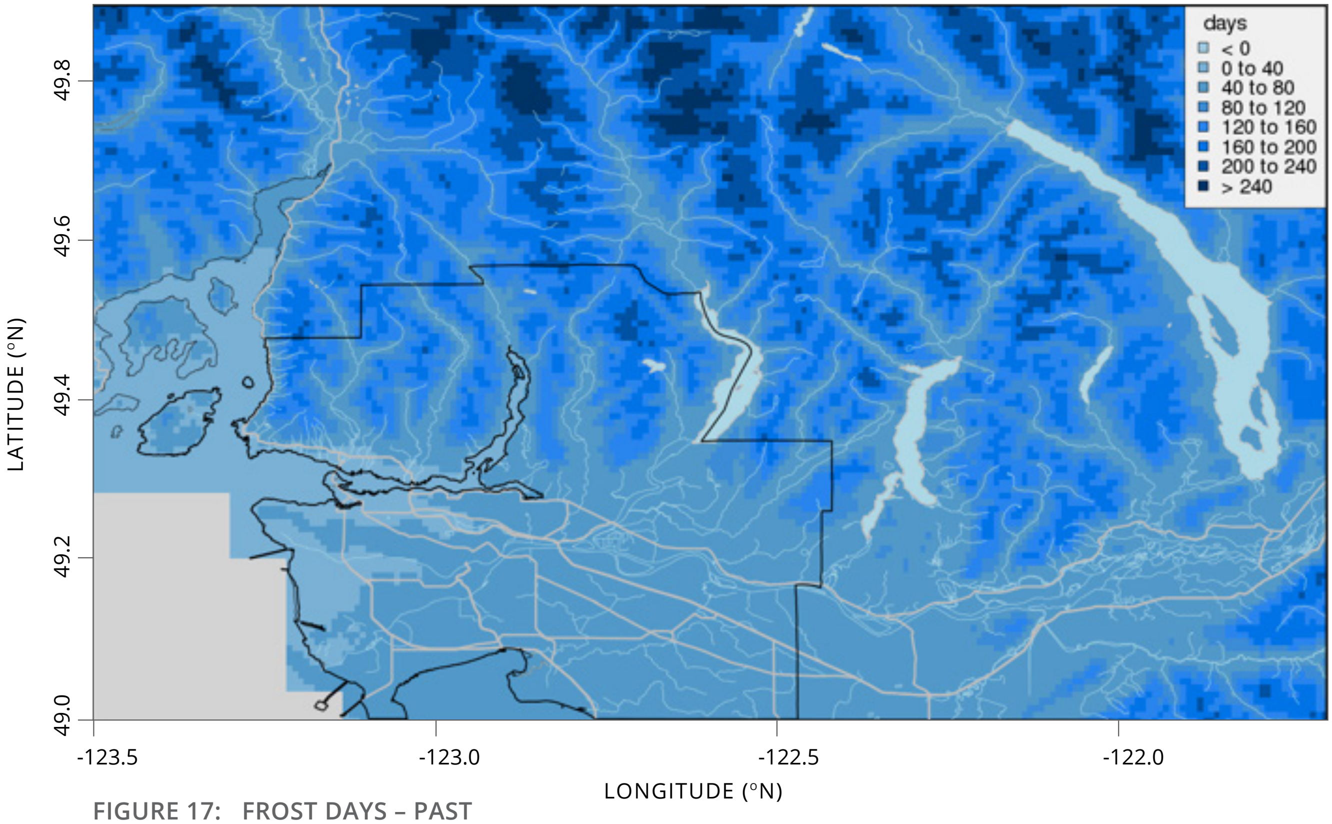


FIGURE 17: FROST DAYS – PAST

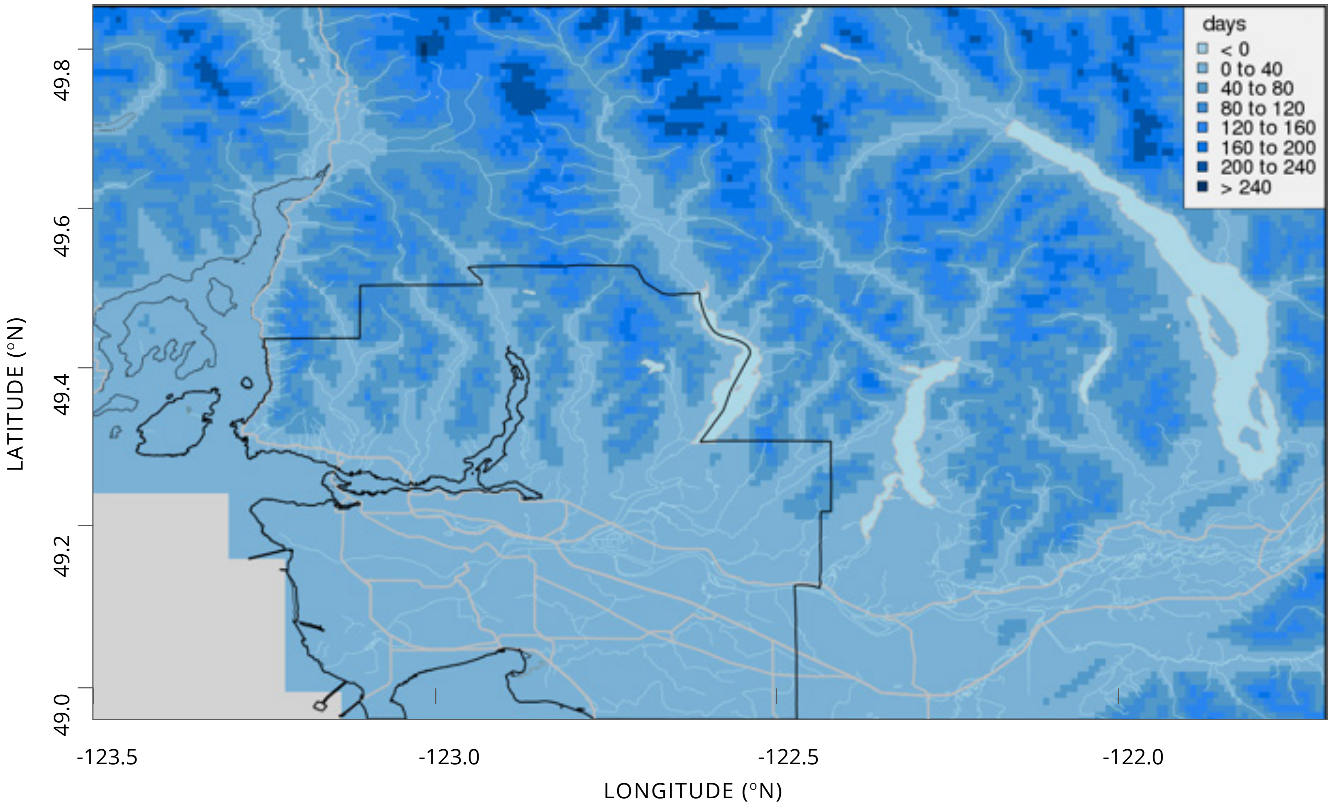


FIGURE 18: FROST DAYS – FUTURE (2050s)

Ice Days

ABOUT THIS INDICATOR

Ice days is an annual count of days when the daily maximum temperature is less than 0°C. This indicator is useful when predicting snow formation and retention.

PROJECTIONS

In the past, Metro Vancouver had 12 ice days per year, mainly in areas of higher elevation. Future projections indicate a "new normal" where higher elevation areas experience very few days when the daily high temperature remains below freezing. The region may expect 4 ice days by the 2050s, and 2 by the 2080s.

TABLE 15: ICE DAYS

CLIMDEX index: ID	Past (days)	2050s (days)	2080s (days)	2050s Change (days)		2080s Change (degree days)	
				Average	(Range)	Average	(Range)
Region	12	4	2	-8	(-10 to -5)	-11	(-12 to -8)
Low elev.	4	2	1	-3	(-3 to -1)	-3	(-4 to -3)
High elev.	13	4	2	-9	(-11 to -5)	-11	(-13 to -9)

Heating Degree Days

ABOUT THIS INDICATOR

Heating degree days is a measure of how cold it gets and for how many days. When the temperature is below 18°C, indoor heating is likely required to compensate for cold outdoor temperatures, and the further below this threshold, the more heat is required. In specific terms, it is a total of the number of degrees below 18°C that occur daily, summed for each day of the year. The lower the number of heating degree days, the less energy is required for heating buildings.

PROJECTIONS

Metro Vancouver experiences many heating degree days compared to cooling degree days. Our past regional annual average of heating degree days is 3489. Heating degree days are projected to decrease by 25% by 2050s, and by 40% by the 2080s

TABLE 16: HEATING DEGREE DAYS

	Past (degree days)	2050s (degree days)	2080s (degree days)	2050s Change (degree days)		2080s Change (degree days)	
				Average	(Range)	Average	(Range)
Region	3489	2605	2112	-884	(-1170 to -560)	-1377	(-1751 to -964)
Low elev.	2865	2045	1605	-820	(-1068 to -535)	-1260	(-1606 to -891)
High elev.	3834	2907	2383	-927	(-1241 to -583)	-1451	(-1858 to -1015)

Regional Impacts of Climate Change

The projected changes to our climate discussed in this report will have multiple impacts in our region. This report provides information about the future climate that needs to be considered by planners in these areas:

- water supply and demand,
- sewage and drainage,
- ecosystems and agriculture,
- air quality and human health,
- buildings and energy systems, and,
- transportation, recreation, and tourism.

The information in this report is particularity pertinent to those involved in providing adequate infrastructure to support safe human settlements, those concerned with the health of our population and ecosystems, and those anticipating economic impacts of our changing climate.

Water Supply and Demand

The majority of the region's drinking water comes from mountain reservoirs fed by rainfall and snowmelt. An increase in daytime high and nighttime low temperatures will cause more precipitation to fall as rain in the winter months. Rather than winter precipitation falling as snow to build a strong snowpack, winter rains and warmer temperatures will erode the winter snowpack and have a negative effect on the depth and duration of the snowpack into the spring and summer months.

Monthly precipitation projections also indicate drier summers that could extend later into the year. At current levels of water use in our region, warmer annual temperatures and longer dry spells over the summer months, combined with reductions in snowpack, could put strain on the existing water supply during times of the year when temperatures are high and water is in greatest demand.

Despite water conservation efforts, water demand is anticipated to increase to meet the needs of a growing population. Warmer summer temperatures and extended droughts could intensify these trends, potentially leading to increased water demand for outdoor water use and recreational activities.

Increases in the magnitude of extreme rainfall events may increase the possibility of landslides in our region's mountain areas, which could introduce additional turbidity into drinking water reservoirs.

Sewerage and Drainage

The extreme rainfall indicators illustrate future extreme events may be beyond the frequency and intensity of events for which we are currently prepared. If they were to be managed by our current infrastructure, we could expect periods of flooding, damage to property, and risks to human health.

Increases in storm intensity will put significant pressure on our region's sewerage and drainage systems. During intense rainfall events, storm sewers and urban streams can overflow and cause overland flooding. In addition, some areas of the region still have combined sewers that carry both sewage and stormwater in a single pipe. During heavy rainfall, combined sewers can fill up with more water than they can handle, and discharge directly into the nearest body of water. Wastewater treatment plants that are largely served by combined sewers will experience periods of higher inflows, which result in diminished treatment efficiency, more frequently.

Extreme precipitation events may also affect slope stability, increase erosion and risk of landslides, and cause flooding in low-lying areas. This may cause damage to personal property and public infrastructure, and could compromise the health of streams, rivers, parklands, and their inhabitants.

While this report did not calculate future 1-in-50 year (2% probability of exceedance) and 1-in-100 year (1% probability of exceedance) events, we can expect even larger relative changes in those events compared to the changes in the 1-in-20 (5% probability of exceedance) events projected in this study. It can also be assumed that trends related to extreme events and their relative intensity will continue past the end-of-century timeframe presented in this report. This information offers important context for those who design stormwater and other critical infrastructure in our region, and merits further detailed study to inform future design criteria, especially for infrastructure that is expected to last for many decades.

Ecosystems

Temperature increases and changes in precipitation over the seasons will affect our regional ecosystems, including mountain and urban forests, parklands, and wetlands. As our climate shifts, the plants, trees, and pests that thrive here will also change. While some species will thrive, others will decline, and aspects of our local ecosystems will change significantly.

The decrease in snowpack, frost days, and summer precipitation, combined with increasing temperatures, will cause stress to some forests that may cause tree growth to decline and mortality rates in vulnerable species to rise. Certain tree species in the region's mountains may migrate to different elevations in search of suitable temperature and precipitation conditions. Pests, such as forest insects, that are currently managed by cold temperatures may experience outbreaks. Also, invasive species may be better able to thrive in changing conditions and may out-compete native species. Additionally, with the reduction of precipitation over the increasingly warm summer months, we can expect an increase in wildfire risk, which could dramatically affect the forest structure.

Prolonged dry spells, stressed reservoirs, and warmer summer temperatures will also reduce soil moisture in the summer, which, coupled with limited supplemental watering, could result in widespread decline in urban tree growth and increased tree mortality. Longer drought periods, coupled with more intense precipitation at other times, will cause stress to plants, animals, and wetlands, will have an impact on soil chemistry and the soil's capacity to retain water, and will contribute to the frequency and severity of flooding.

Hotter summers with less precipitation will have a negative impact on terrestrial and aquatic species. For terrestrial species, decreased plant growth, heat stress, and scarcity of water reduce the quality of forage crops, causing increased competition for resources. Decreasing streamflow, warmer water temperatures, and an earlier freshet will cause stress to many aquatic species.

Agriculture

Changes in temperature and precipitation over the coming decades will have many positive and negative impacts on agriculture. Increasing temperatures can lead to higher crop productivity and a greater range of crops. Agricultural producers will feel a shift in costs, as energy for heating greenhouses will decrease in cooler months, and cooling needs for greenhouses and livestock facilities will increase during the summer season. As high temperatures become more variable with an increasing frequency of extreme events, plants may suffer from heat stress and sun scald, and the demand for heat-tolerant plants will increase.

Increasing spring precipitation, and increases in extreme precipitation will also increase the potential for waterlogged soils, flooding, inadequate soil drainage, soil compaction, and leaching of nutrients from farmland. Longer summer drought conditions, combined with extreme rain, will stress soil structure, necessitating additional soil conditioning and supplementary irrigation.

More growing degree days and a reduction of frost days will create a longer growing season in our region. Agricultural producers will be able to take advantage of new opportunities to grow different, and perhaps more valuable, crops, and can expect earlier harvests, and potentially year-round productive growing. This benefit will be coupled with increased pests and plant diseases, which can threaten plant health and crop productivity. Additionally, variations in temperature and precipitation may cause pollinators to emerge at inappropriate times and be unable to serve their vital role.

Air Quality and Human Health

Temperature and precipitation have a direct relationship with air quality and human health in our region. As noted above, hotter, drier summer conditions, combined with decreased snowpack, may lead to an increase in wildfire activity within the region and in other areas that can bring smoke to the region from considerable distances. Air quality is impacted by wildfires, which contribute a significant amount of particulate matter into our air, causing an increase in adverse health impacts and visual haze. Particulate matter from wildfires is a known human carcinogen, and may become a greater health concern as temperatures rise.

Air quality will suffer as concentrations of ground-level ozone, a critical component of haze or smog, increase with temperature. Ozone is not directly emitted from human activities, but rather forms when other pollutants (nitrogen oxides and volatile organic compounds) react in sunlight on warm days. Levels of ozone tend to be elevated during midday on hot summer days, as the reaction accelerates above 25°C. People with lung disease, children, older adults, and people who are active outdoors may be particularly sensitive to future elevated ozone levels.

Hotter, drier summers will also cause heat stress and have an impact on human health. Although heat stress may appear less threatening on the coast than in areas that already experience hot summers, stress levels remain high because much of the population is more accustomed to mild temperatures and is not prepared to accommodate high temperatures. Non-respiratory emergency room visits in Vancouver currently increase with high summer temperatures, and are expected to increase further with an aging population.

Warmer winters will result in less use of fireplaces and wood stoves for heating, thereby improving winter air quality in urban areas and reducing human exposure to smoke from wood-burning appliances. Wood smoke contains particulate matter that has been linked to lung disease and heart disease, and is carcinogenic to humans when inhaled.

Buildings and Energy Systems

Substantial shifts in energy demand are anticipated as a result of increasing temperatures, with heating demands decreasing and cooling demands increasing over time. In the future, less natural gas, electricity, and wood fuel will be used for winter heating, and our built infrastructure will need to be designed to accommodate increasing cooling demand. Currently, many commercial buildings already use energy for cooling, though residential buildings are largely cooled by night air. As cooling degree days increase along with a rise in the number of tropical nights, the ability of buildings to cool without mechanical systems will decrease, and energy use for air conditioning may increase.

Long-term planning of energy infrastructure could be significantly affected by the projected major shift in heating requirements. As buildings require more energy for cooling, summer energy supply may become a challenge for our province, as BC's energy infrastructure has been built to accommodate peak demand in winter. This could be further exacerbated if cooling demand in residential buildings increases in other regions, and if hydropower capacity is decreased due to reduced snowpack and receding glaciers that feed storage reservoirs. Seasonal and longer-term energy demands in buildings will change across the province in response to warmer temperatures.

The business case for energy efficient buildings will also improve as our energy infrastructure is challenged. Installing natural and/or passive shading and green roofs on the current and future building stock could become more cost effective and could "future-proof" buildings for climate change.

Transportation, Recreation, and Tourism

Warmer winters and less frost may provide more opportunities for year-round active transportation (cycling and walking), and may improve safety for all road users. Additionally, as freeze-thaw cycles become more infrequent, roads may require less maintenance from winter cracking.

Warmer winters may have a negative impact on local snowsport operators, possibly causing a decrease in winter tourism due to inadequate snowfall and the reduction in the number of suitable skiing days. Conversely, warmer temperatures and drier summers may benefit tourism opportunities in the summer season.

Summary and Recommendations

This report uses current climate model outcomes to provide a "best guess" snapshot of how climate change will unfold in Metro Vancouver over the coming decades. The following projections were identified, and are worthy of attention by planners, decision makers, and infrastructure managers in the region.

All models project daytime high and nighttime low temperatures to rise. While temperature can be expected to increase year round, the greatest increases will occur in the summer months. Monthly high and low temperatures show that the "new normal" for the region may be very unlike the past. Rising temperatures will lead to:

- hotter summer days and nights,
- milder winters including a considerable reduction in frost days, and
- a significantly reduced spring snowpack.

Our region will experience a modest increase in annual precipitation by the 2050s, though the increase in precipitation will be distributed unevenly over the seasons. The largest increases will occur in the fall season, while rain will decrease significantly in the summer months. Our region can expect:

- stronger and more frequent extreme rainfall events,
- longer summer dry spells and an extension of the dry season into September, and
- less precipitation falling as snow in the winter months.

These changes will have multiple impacts on our region, some of which can be accommodated through long-range planning and early adaptation efforts. Metro Vancouver will use these projections in incorporating climate change adaptation into planning cycles and ongoing activities, and will update this resource to ensure its relevance using new regionally downscaled projections after each new Intergovernmental Panel on Climate Change (IPCC) report is released (approximately every 5 to 7 years).

As Metro Vancouver and member municipalities plan to adapt to climate change, early action will enable our region to best prepare for the changes ahead and increase resilience. Decision-makers need to consider the sensitivity of the systems they manage to the possible range of future climate in the region. Risk management approaches should be applied to address the uncertainty of climate risks. Vulnerability assessments may be conducted to set priorities for more detailed studies and monitoring, to understand the economic costs of climate impacts, and to inform policy, as well as planning and implementation of adaptation actions. Adaptation actions should be chosen that perform well across the range of uncertainty, to ensure robust systems. Flexibility in adaptation planning will allow the region to evolve as the future climate unfolds.

Appendix 1: RCP4.5 and RCP2.6 Tables and Figures

This appendix presents climate projections for two alternate greenhouse gas emissions scenarios, RCP4.5 and RCP2.6, using the same ensemble of models described in the Methodology section. The report body presented climate projections for the RCP8.5 "business-as-usual" emissions scenario, which corresponds to a world where the rate of emissions remains similar to present day. Under RCP4.5, total emissions to the end of the century would be cut in half compared to the RCP8.5 scenario. The RCP2.6 emissions scenario assumes that the world would achieve substantial and sustained reductions in emissions starting in the present decade. For all three scenarios, atmospheric greenhouse gas concentrations and the resulting changes in climate are somewhat similar until the 2050s, but diverge considerably by the 2080s. It is worth pointing out that even under the RCP2.6 emissions scenario, our regional climate will still change compared to the past baseline, due to a continued increase in atmospheric greenhouse gas concentrations until about the 2050s.

Some form of adaptation will be required regardless of socioeconomic, technological, and policy changes in coming decades. The RCP4.5 and RCP2.6 scenarios can be useful to compare relative risks for a range of possible futures. They are also useful to compare the costs and benefits of mitigation with the costs of adapting to a substantially different climate if mitigation actions are not pursued.

The sections and tables in this appendix are organized and numbered to mirror the corresponding sections and tables in the main body of the report, for ease of comparison. The descriptions of each indicator are not repeated here, and tables are presented without a written explanation of the projections.

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General Climate Projections

Warmer Temperatures

TABLE A1 AVERAGE DAYTIME HIGH TEMPERATURE

	Past (°C)	RCP4.5		RCP2.6	
		2050s Change (°C)	2080s Change (°C)	2050s Change (°C)	2080s Change (°C)
		Average (Range)	Average (Range)	Average (Range)	Average (Range)
Winter	5	1.9 (1.1 to 2.5)	2.4 (1.5 to 3.1)	1.5 (0.9 to 2.0)	1.7 (1.0 to 2.3)
Spring	12	2.5 (1.5 to 3.9)	3.1 (2.1 to 4.9)	1.7 (1.1 to 2.6)	1.9 (1.1 to 2.7)
Summer	21	2.7 (1.5 to 3.9)	3.3 (1.9 to 5.1)	1.9 (1.0 to 3.1)	1.6 (0.5 to 3.0)
Fall	13	2.0 (0.9 to 2.7)	2.6 (1.7 to 3.4)	1.5 (0.7 to 2.1)	1.5 (0.7 to 2.1)
Annual	13	2.3 (1.2 to 3.0)	2.8 (1.8 to 4.0)	1.6 (1.0 to 2.3)	1.7 (0.9 to 2.5)

TABLE A2 AVERAGE NIGHTTIME LOW TEMPERATURE

	Past (°C)	RCP4.5		RCP2.6	
		2050s Change (°C)	2080s Change (°C)	2050s Change (°C)	2080s Change (°C)
		Average (Range)	Average (Range)	Average (Range)	Average (Range)
Winter	-1	2.3 (1.6 to 3.0)	2.9 (1.8 to 3.8)	1.9 (1.3 to 2.4)	2.1 (1.5 to 2.7)
Spring	3	2.3 (1.6 to 2.9)	3.0 (2.3 to 3.9)	1.8 (1.5 to 2.3)	2.0 (1.4 to 2.9)
Summer	10	2.2 (1.3 to 3.3)	2.9 (1.9 to 4.4)	1.7 (1.1 to 2.7)	1.7 (1.1 to 2.7)
Fall	5	2.0 (1.1 to 2.8)	2.6 (1.8 to 3.5)	1.5 (0.9 to 2.1)	1.6 (0.9 to 2.4)
Annual	4	2.2 (1.4 to 2.9)	2.8 (2.0 to 3.7)	1.7 (1.4 to 2.3)	1.9 (1.3 to 2.5)

Seasonal Variability in Temperatures

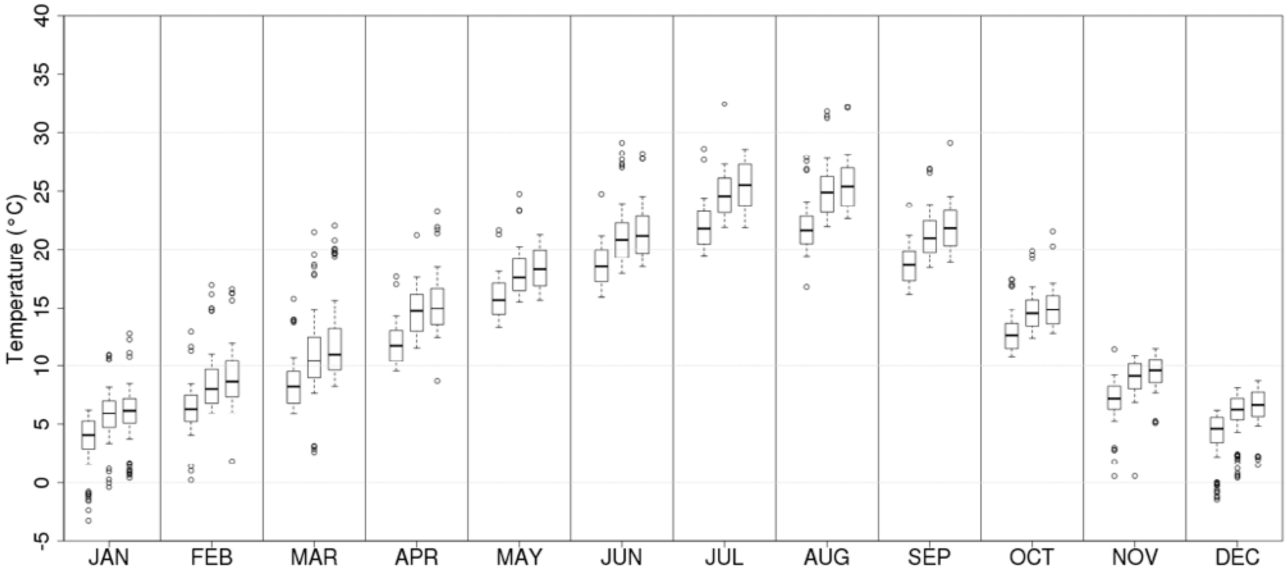

FIGURE A1 MONTHLY DAYTIME HIGH TEMPERATURE FOR RCP4.5

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

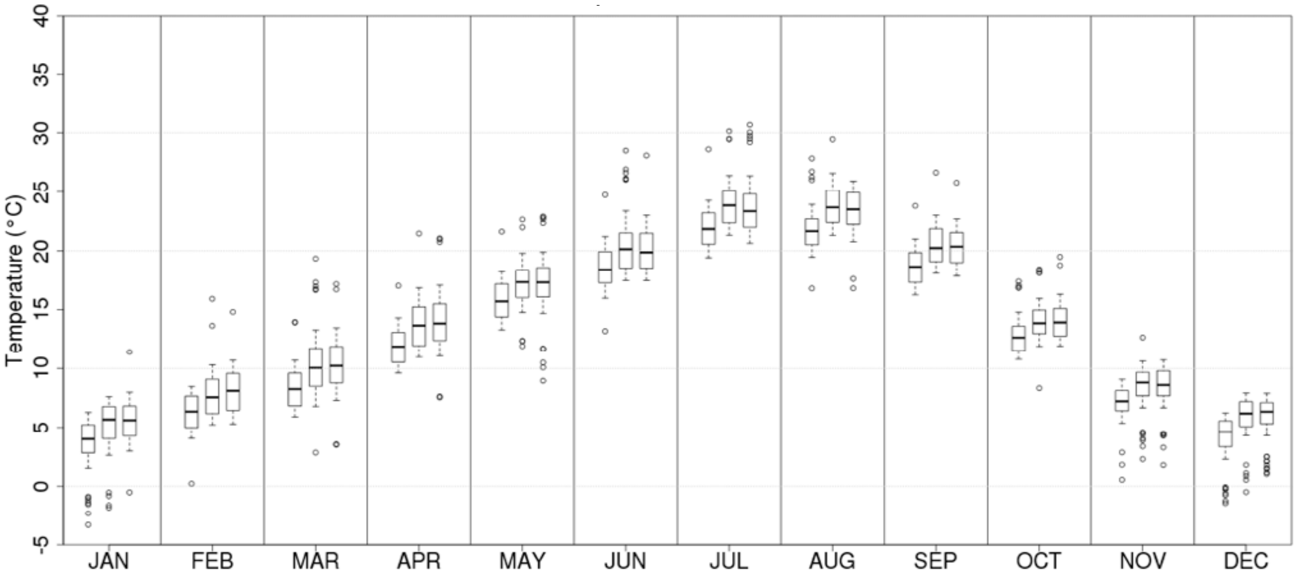

FIGURE A2 MONTHLY DAYTIME HIGH TEMPERATURE FOR RCP2.6

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

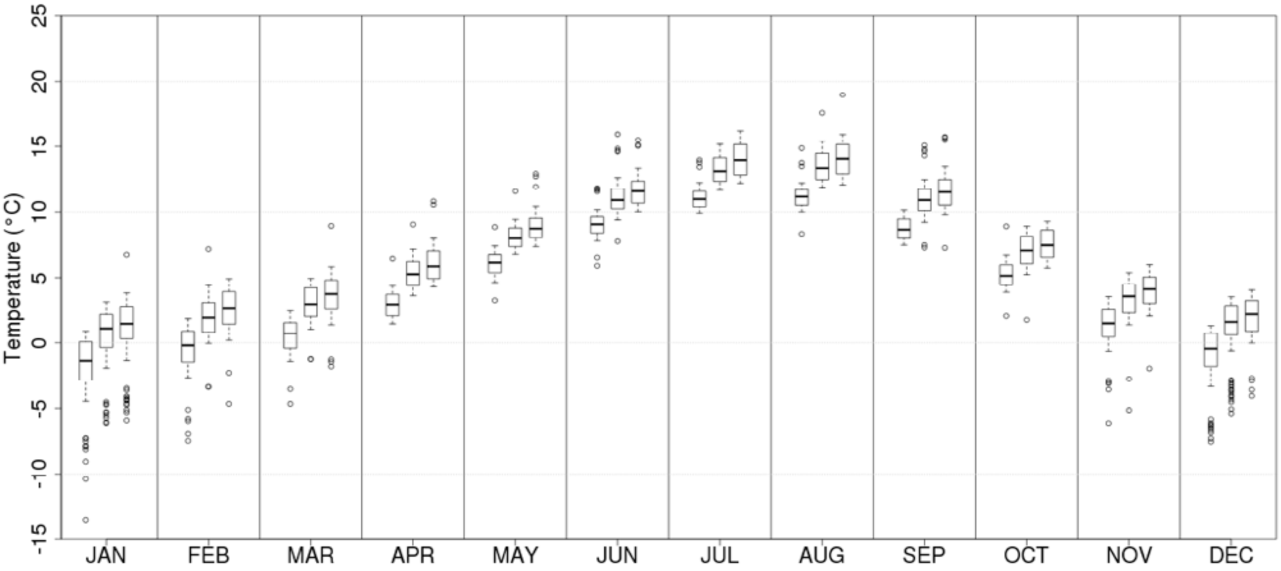

FIGURE A3 MONTHLY NIGHTTIME LOW TEMPERATURE FOR RCP4.5

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

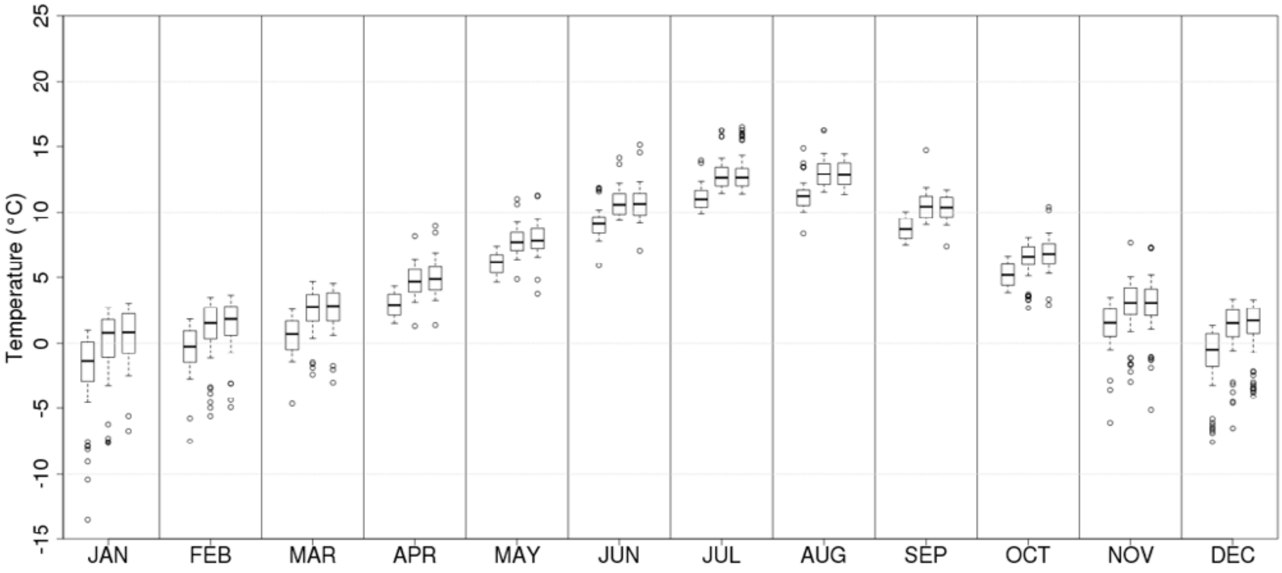

FIGURE A4 MONTHLY NIGHTTIME LOW TEMPERATURE FOR RCP2.6

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

Wetter Winters, Drier Summers

TABLE A3 TOTAL PRECIPITATION OVER SEASONS AND YEAR

	Past (mm)	RCP4.5				RCP2.6			
		2050s Percent Change (%)		2080s Percent Change (%)		2050s Percent Change (%)		2080s Percent Change (%)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Fall	580	6	(-1 to 19)	15	(0 to 27)	11	(-3 to 25)	12	(2 to 28)
Winter	683	9	(-2 to 22)	8	(-6 to 16)	6	(-6 to 15)	6	(1 to 11)
Spring	400	7	(2 to 15)	9	(1 to 16)	8	(3 to 15)	6	(-1 to 13)
Summer	206	-15	(-39 to 2)	-15	(-35 to 10)	-8	(-25 to 14)	-1	(-25 to 13)
Annual	1869	5	(0 to 11)	8	(4 to 13)	7	(0 to 13)	7	(3 to 11)

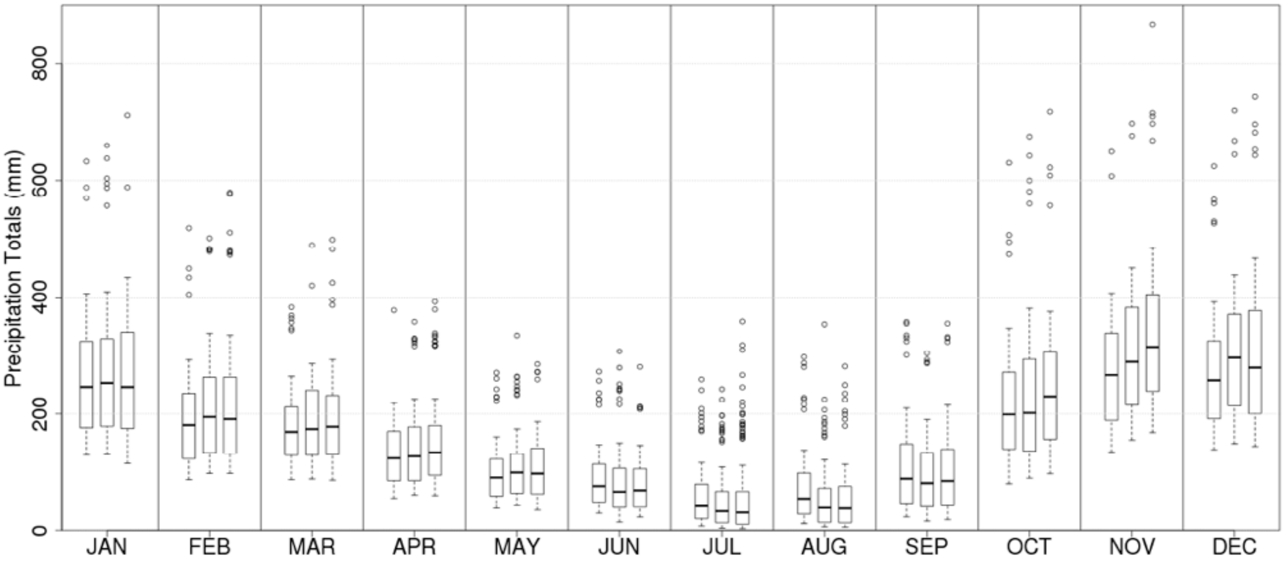

FIGURE A5 MONTHLY TOTAL PRECIPITATION FOR RCP4.5

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

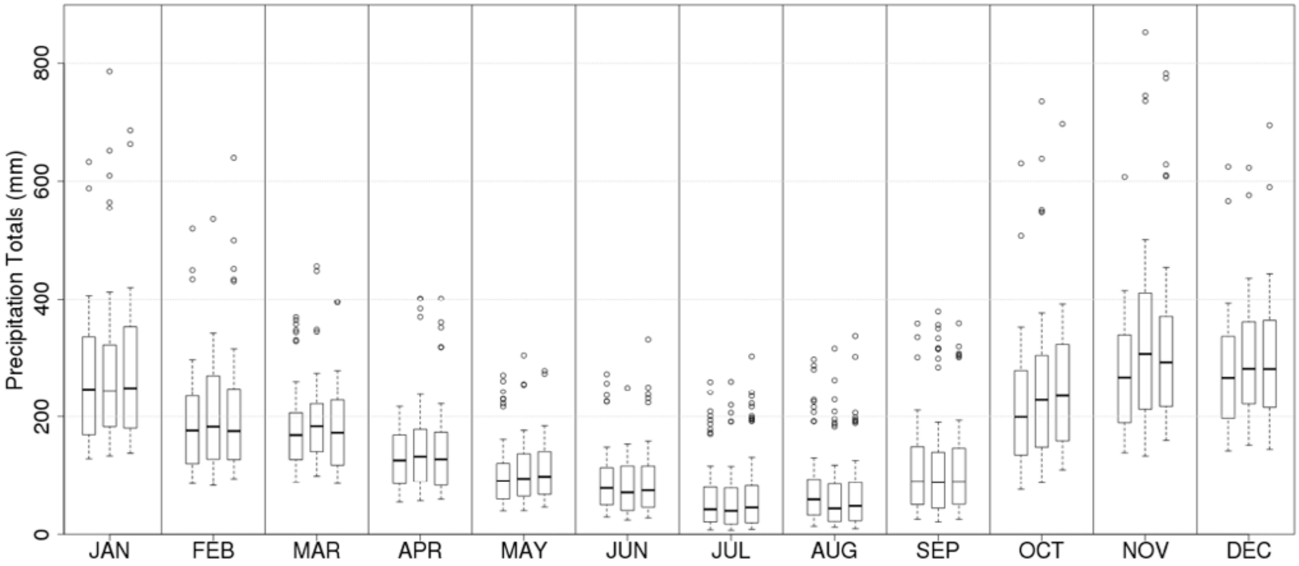

FIGURE A6 MONTHLY TOTAL PRECIPITATION FOR RCP2.6

Boxes from left to right in each month indicate past, 2050s, 2080s. Further explanation of how to read the box-and-whisker plots is provided above in the Methodology section.

Precipitation Indicators

Note: the snowpack model was not run for the RCP4.5 and RCP2.6 scenarios. Table numbering intentionally skips A4 and A5 to maintain consistency.

TABLE A6 ANNUAL DRY SPELLS

CLIMDEX index: CDD	Past (days)	RCP4.5				RCP2.6			
		2050s Percent Change (%)		2080s Percent Change (%)		2050s Percent Change (%)		2080s Percent Change (%)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Dry spell duration	21	16	(-1 to 35)	21	(6 to 34)	4	(-11 to 18)	3	(-7 to 12)

TABLE A7 EXTREME RAINFALL

	Climdex Index	Past (mm)	RCP4.5				RCP2.6			
			2050s Percent Change (%)		2080s Percent Change (%)		2050s Percent Change (%)		2080s Percent Change (%)	
			Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
One-day maximum precipitation	Rx1day	69	15	(7 to 24)	20	(12 to 30)	12	(1 to 22)	12	(1 to 21)
Five-day maximum precipitation	Rx5day	159	10	(2 to 20)	15	(4 to 26)	10	(1 to 18)	9	(-2 to 20)
95th percentile wettest days precipitation	R95pTOT	398	29	(12 to 56)	43	(25 to 57)	29	(5 to 49)	28	(10 to 55)
99th percentile wettest days precipitation	R99pTOT	122	45	(15 to 62)	79	(43 to 111)	47	(12 to 82)	49	(15 to 96)

TABLE A8 1-IN-20 WETTEST DAY

	Past (mm)	RCP4.5				RCP2.6			
		2050s Percent Change (%)		2080s Percent Change (%)		2050s Percent Change (%)		2080s Percent Change (%)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	105	31	(3 to 45)	32	(17 to 51)	20	(7 to 31)	16	(-3 to 35)
Low elevations	89	28	(-2 to 47)	34	(12 to 55)	20	(11 to 28)	14	(-7 to 33)
High elevations	121	25	(9 to 39)	29	(16 to 49)	16	(4 to 30)	11	(-5 to 36)

Summer Temperature Indicators

Note: the Heat Days indicator was not computed for the other emissions scenarios.

TABLE A9 HOT SUMMERS INDICATORS

	CLIMDEX index	Past	RCP4.5				RCP2.6			
			2050s Change		2080s Change		2050s Change		2080s Change	
			Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Summer days (# of days >25°C)	SU	22	31	(3 to 45)	32	(17 to 51)	20	(7 to 31)	16	(-3 to 35)
Tropical nights (# of nights >20°C)	TR	0	28	(-2 to 47)	34	(12 to 55)	20	(11 to 28)	14	(-7 to 33)
Hottest day (°C)	1-yr TX_x	31	25	(9 to 39)	29	(16 to 49)	16	(4 to 30)	11	(-5 to 36)
1-in-20 hottest day (°C)		34	3.3	(1.6 to 4.8)	4.1	(2.4 to 5.6)	2.1	(0.4 to 3.8)	2.5	(0.6 to 4.5)

TABLE A10 GROWING SEASON LENGTH

Climdex index: GSL	Past (days)	RCP4.5				RCP2.6			
		2050s Change (days)		2080s Change (days)		2050s Change (days)		2080s Change (days)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	252	42	(29 to 50)	52	(41 to 61)	33	(27 to 41)	37	(28 to 45)
Low elevations	301	38	(30 to 43)	43	(36 to 50)	33	(27 to 38)	36	(31 to 42)
High elevations	217	49	(24 to 66)	65	(49 to 81)	38	(27 to 53)	42	(26 to 54)

TABLE A11 GROWING DEGREE DAYS

	Past (degree days)	RCP4.5				RCP4.5			
		2050s Change (degree days)		2080s Change (degree days)		2050s Change (degree days)		2080s Change (degree days)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	1738	606	(331 to 826)	785	(516 to 1061)	449	(304 to 648)	456	(275 to 662)
Low elevations	2122	681	(393 to 919)	888	(600 to 1179)	511	(364 to 711)	535	(341 to 756)
High elevations	1467	557	(294 to 758)	722	(465 to 997)	408	(269 to 617)	410	(234 to 621)

TABLE A12 COOLING DEGREE DAYS

	Past (degree days)	RCP4.5				RCP2.6			
		2050s Change (degree days)		2080s Change (degree days)		2050s Change (degree days)		2080s Change (degree days)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	1738	112	(46 to 170)	160	(77 to 247)	75	(35 to 124)	67	(28 to 122)
Low elevations	2122	146	(63 to 221)	211	(106 to 326)	97	(46 to 158)	92	(39 to 165)
High elevations	1467	83	(33 to 131)	119	(54 to 185)	56	(25 to 96)	48	(20 to 90)

Winter Temperature Indicators

TABLE A13 WARMER WINTERS INDICATORS

	CLIMDEX index	Past (°C)	RCP4.5				RCP2.6			
			2050s Change (°C)		2080s Change (°C)		2050s Change (°C)		2080s Change (°C)	
			Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Warmest winter day	TX_x	12	2.1	(0.7 to 3.1)	3.0	(1.7 to 4.8)	1.3	(0.5 to 2)	1.9	(0.5 to 2.9)
Coldest winter night	TN_n	-13	4.1	(3 to 5.7)	4.7	(3.4 to 6.4)	3.1	(1.8 to 4.7)	3.5	(2 to 5.1)
1-in-20 coldest nighttime low		-20	2.9	(-0.8 to 5.4)	4.1	(2.3 to 6.3)	1.9	(-0.4 to 4.2)	2.6	(1 to 5.1)

TABLE A14 FROST DAYS

CLIMDEX index: FD	Past (days)	RCP4.5				RCP2.6			
		2050s Change (days)		2080s Change (days)		2050s Change (days)		2080s Change (days)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	79	-39	(-45 to -27)	-46	(-55 to -36)	-33	(-38 to -26)	-36	(-42 to -26)
Low elevations	39	-25	(-28 to -19)	-28	(-31 to -23)	-22	(-26 to -16)	-24	(-29 to -17)
High elevations	92	-48	(-58 to -34)	-58	(-69 to -44)	-41	(-47 to -33)	-45	(-55 to -32)

TABLE A15 ICE DAYS

CLIMDEX index: ID	Past (days)	RCP4.5				RCP2.6			
		2050s Change (days)		2080s Change (days)		2050s Change (days)		2080s Change (days)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	12	-7	(-9 to -5)	-8	(-10 to -6)	-6	(-8 to -4)	-6	(-8 to -3)
Low elevations	4	-2	(-3 to -1)	-3	(-4 to -1)	-2	(-3 to -1)	-2	(-3 to -1)
High elevations	13	-8	(-10 to -5)	-9	(-11 to -6)	-6	(-9 to -4)	-7	(-10 to -4)

TABLE A16 HEATING DEGREE DAYS

	Past (degree days)	RCP4.5				RCP2.6			
		2050s Change (degree days)		2080s Change (degree days)		2050s Change (degree days)		2080s Change (degree days)	
		Average	(Range)	Average	(Range)	Average	(Range)	Average	(Range)
Region	3489	-701	(-870 to -421)	-870	(-1075 to -621)	-543	(-703 to -407)	-577	(-769 to -359)
Low elevations	2865	-651	(-795 to -404)	-810	(-998 to -588)	-509	(-654 to -394)	-550	(-736 to -351)
High elevations	3834	-730	(-916 to -436)	-909	(-1134 to -647)	-563	(-736 to -420)	-595	(-797 to -373)

Appendix 2:
RCP8.5 Supplementary Maps

This appendix presents the regionally downscaled model output for RCP8.5 in the form of maps for select indicators described in the report. Maps are presented here only when they show sufficient geographic variation to add valuable information to the regional averages presented in tables. For many indicators, either the values or the projected changes in values are quite uniform across the region. In these cases, maps that do not add spatial information have been omitted. Maps that were included in the report body are not repeated in this Appendix.

Different types of maps are presented for each selected indicator to add the most meaning to the interpretation. The types of maps include:

- Past: shows the indicator values averaged over the 30-year baseline period (1971–2000)
- Future: shows the projected value of the indicator for the RCP8.5 emissions scenario for the 2050s (averaged over the 30-year period 2041–2070)
- Anomalies: shows the difference in values between the future projections and the past baseline, in the units of the indicator (i.e., degrees Celsius, millimetres of precipitation, centimetres of snowpack, number of days, or degree days). Positive values indicate an increase from the past to the future.

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Precipitation Indicators

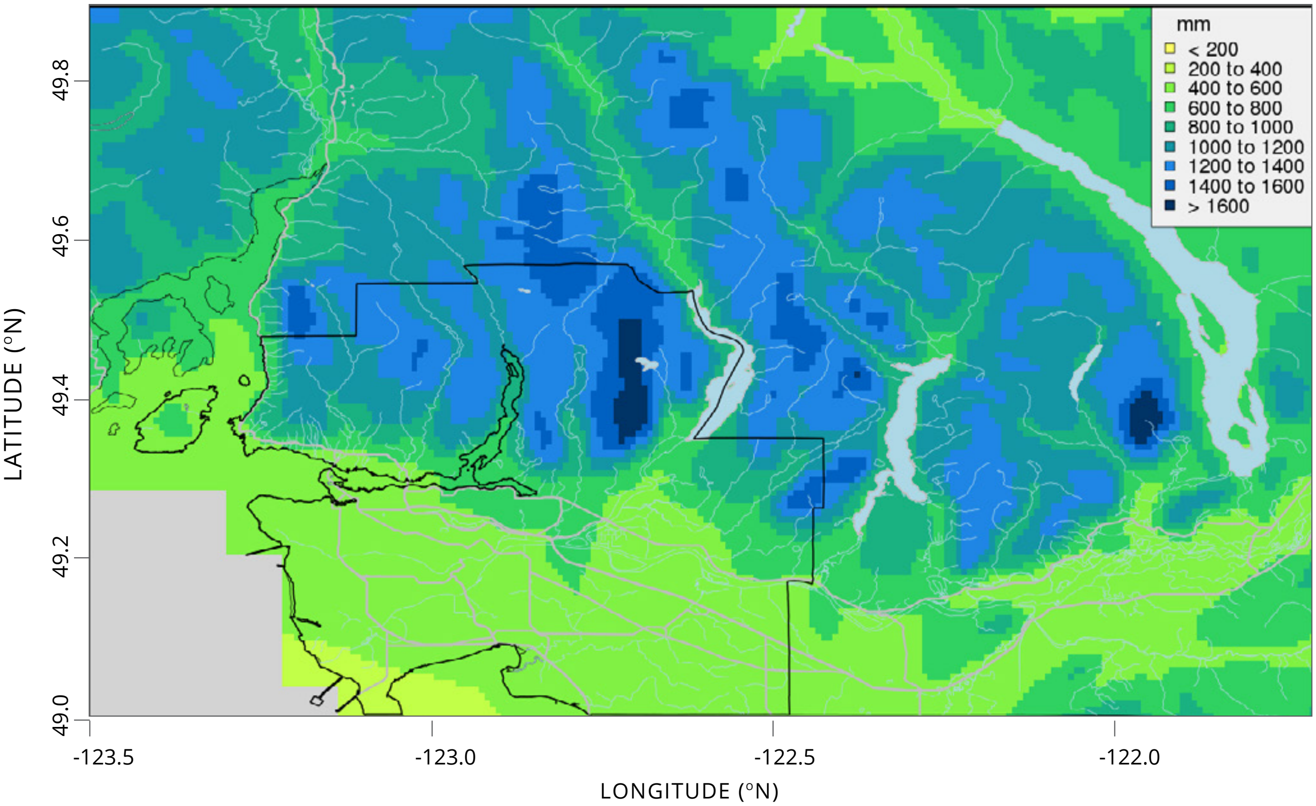

FIGURE A7: WINTER PRECIPITATION – PAST

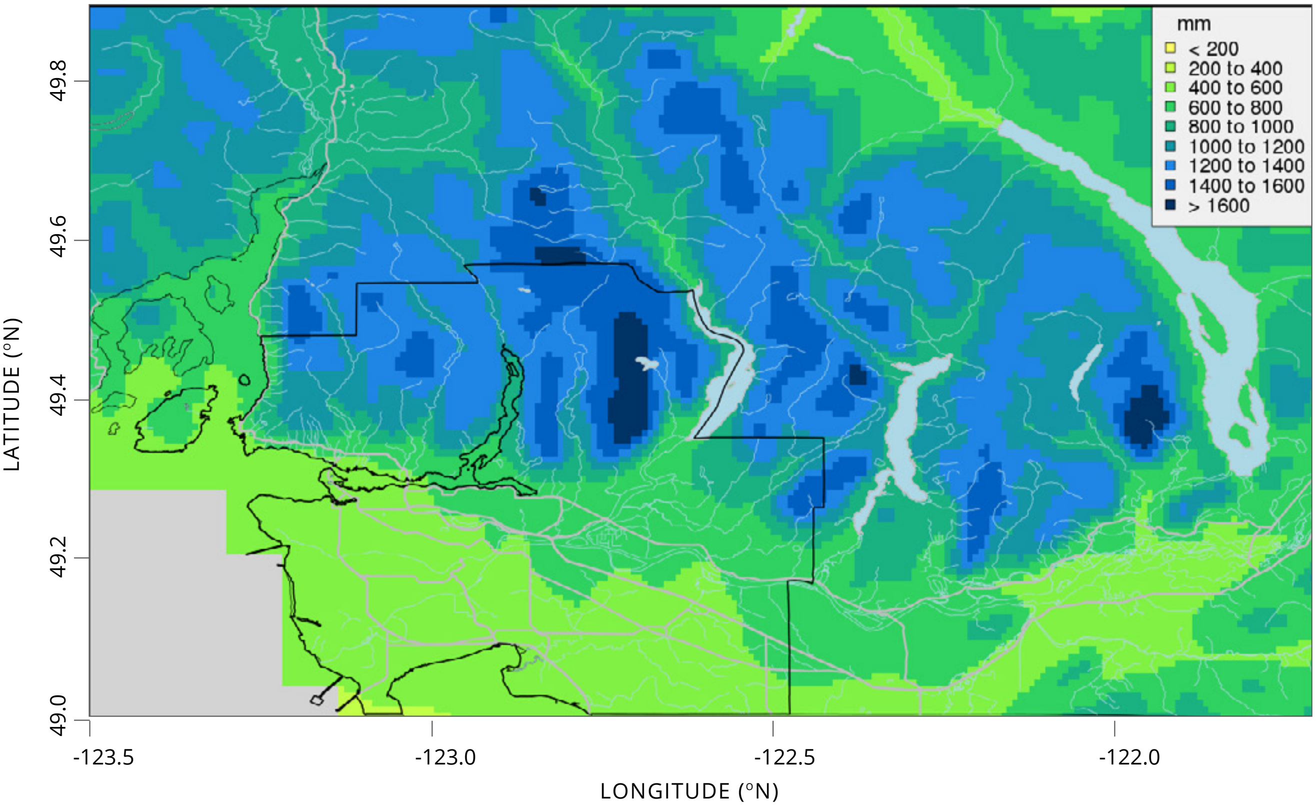

FIGURE A8: WINTER PRECIPITATION – FUTURE (2050s)

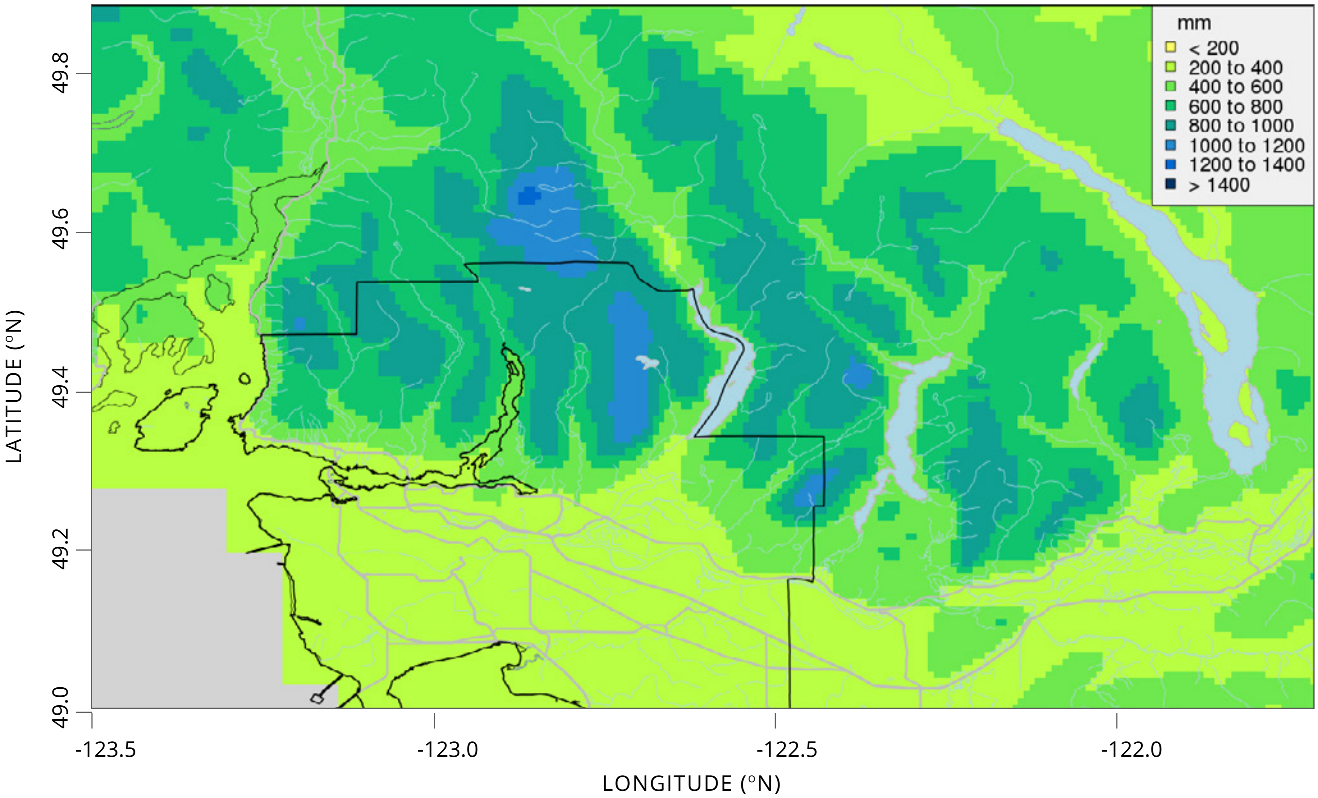

FIGURE A9: SPRING PRECIPITATION – PAST

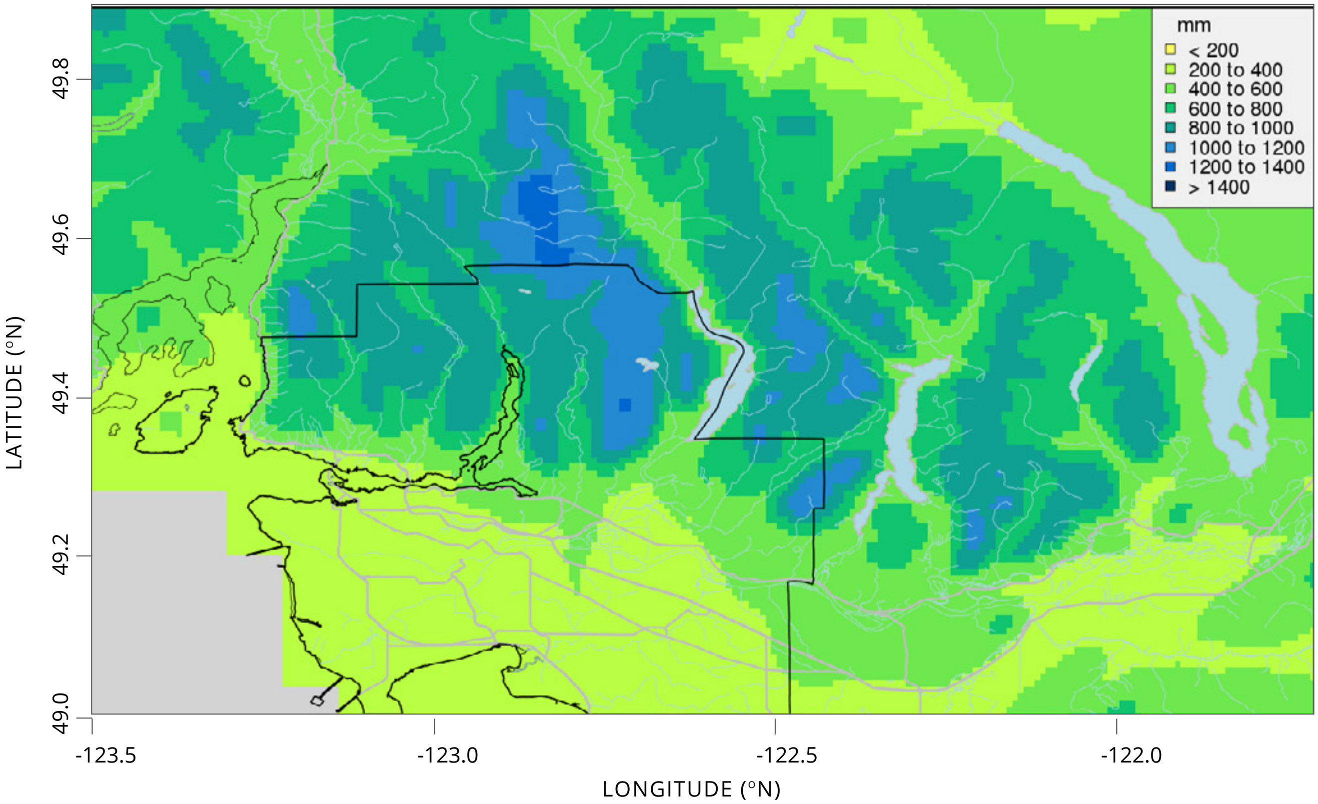

FIGURE A10: SPRING PRECIPITATION – FUTURE (2050s)

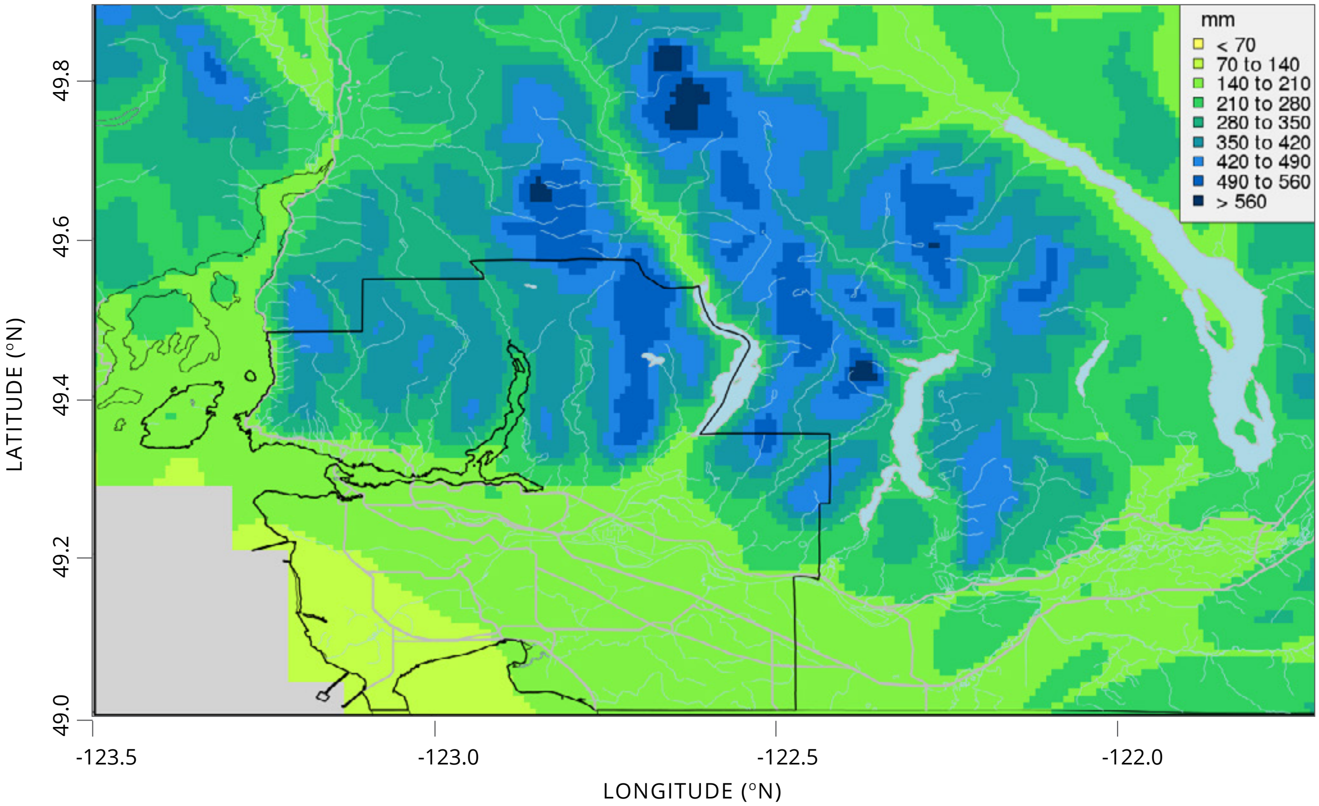

FIGURE A11: SUMMER PRECIPITATION – PAST

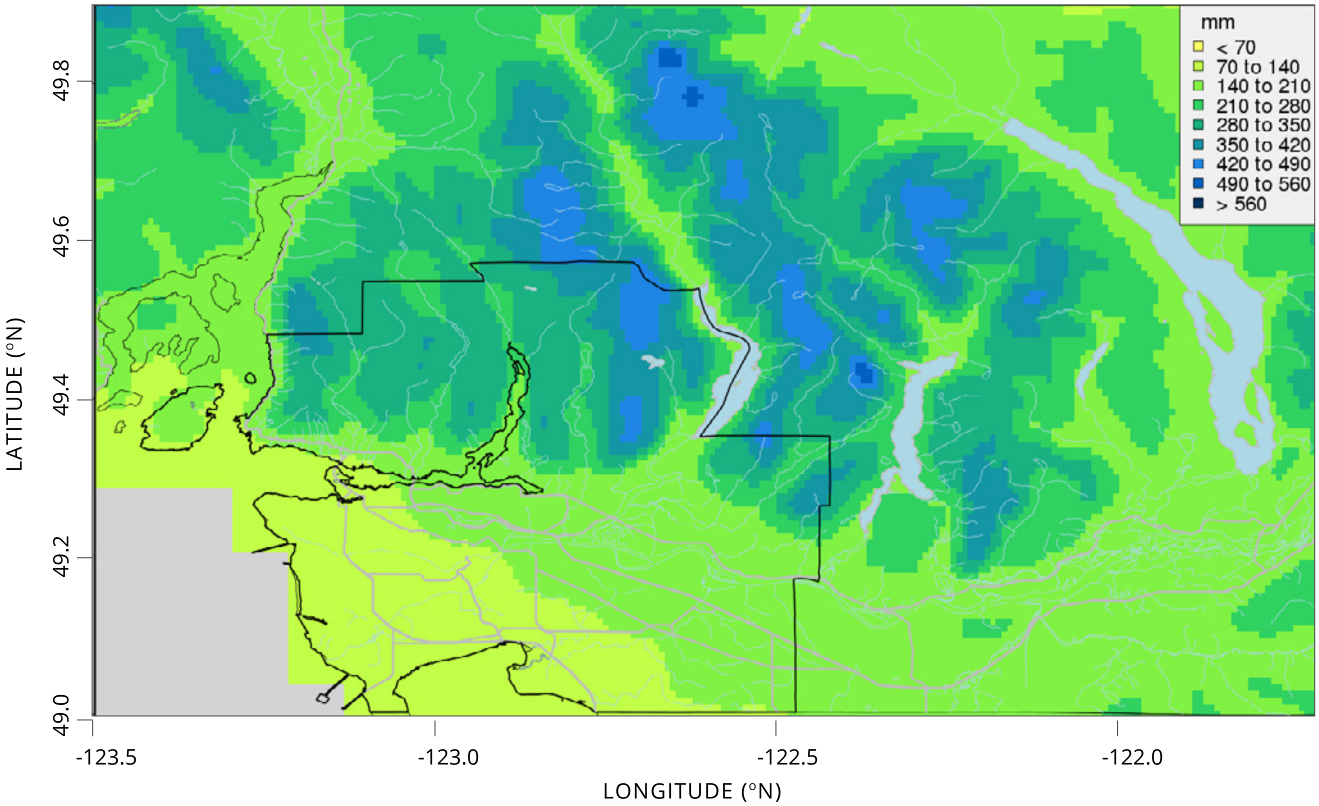

FIGURE A12: SUMMER PRECIPITATION – FUTURE (2050s)

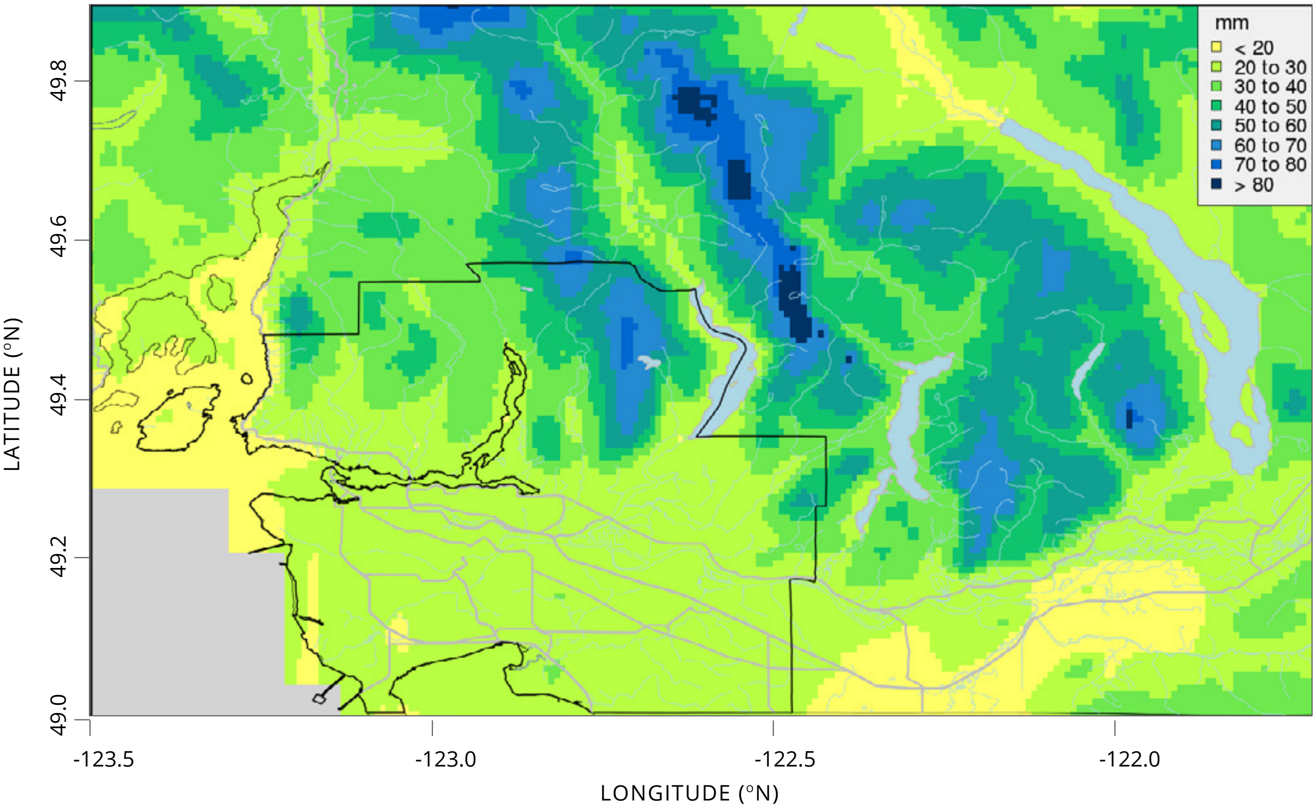

FIGURE A13: 1-IN-20 WETTEST DAY ANOMALIES

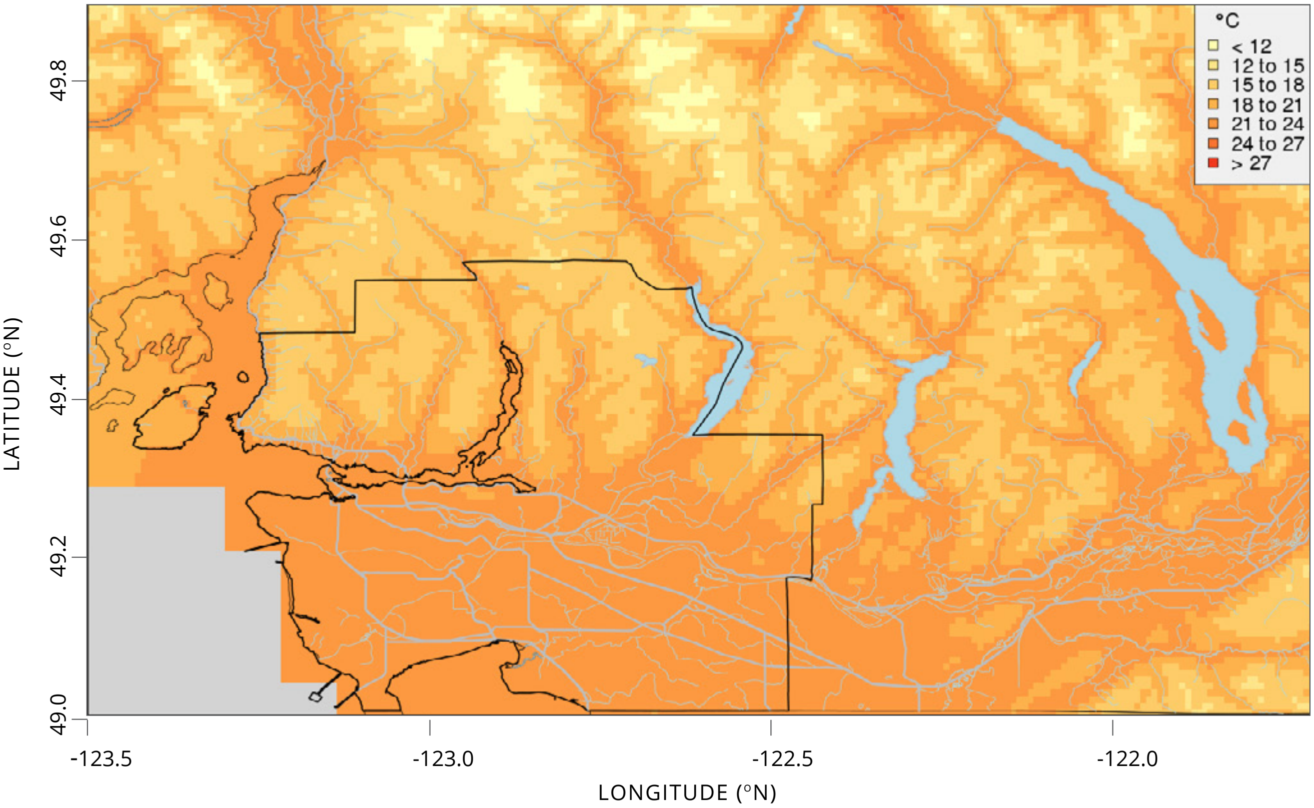

FIGURE A14: SUMMER AVERAGE DAYTIME HIGH TEMPERATURE – PAST

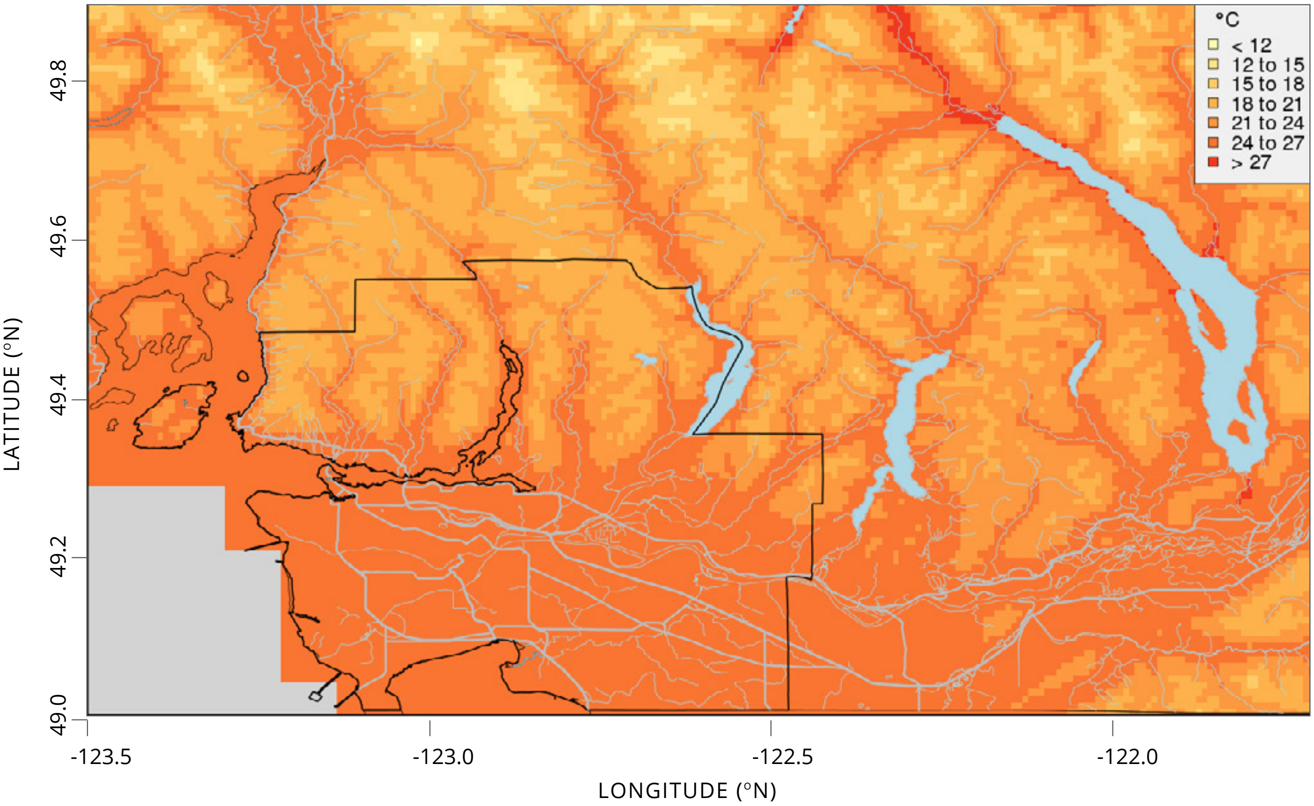

FIGURE A15: SUMMER AVERAGE DAYTIME HIGH TEMPERATURE – FUTURE (2050s)

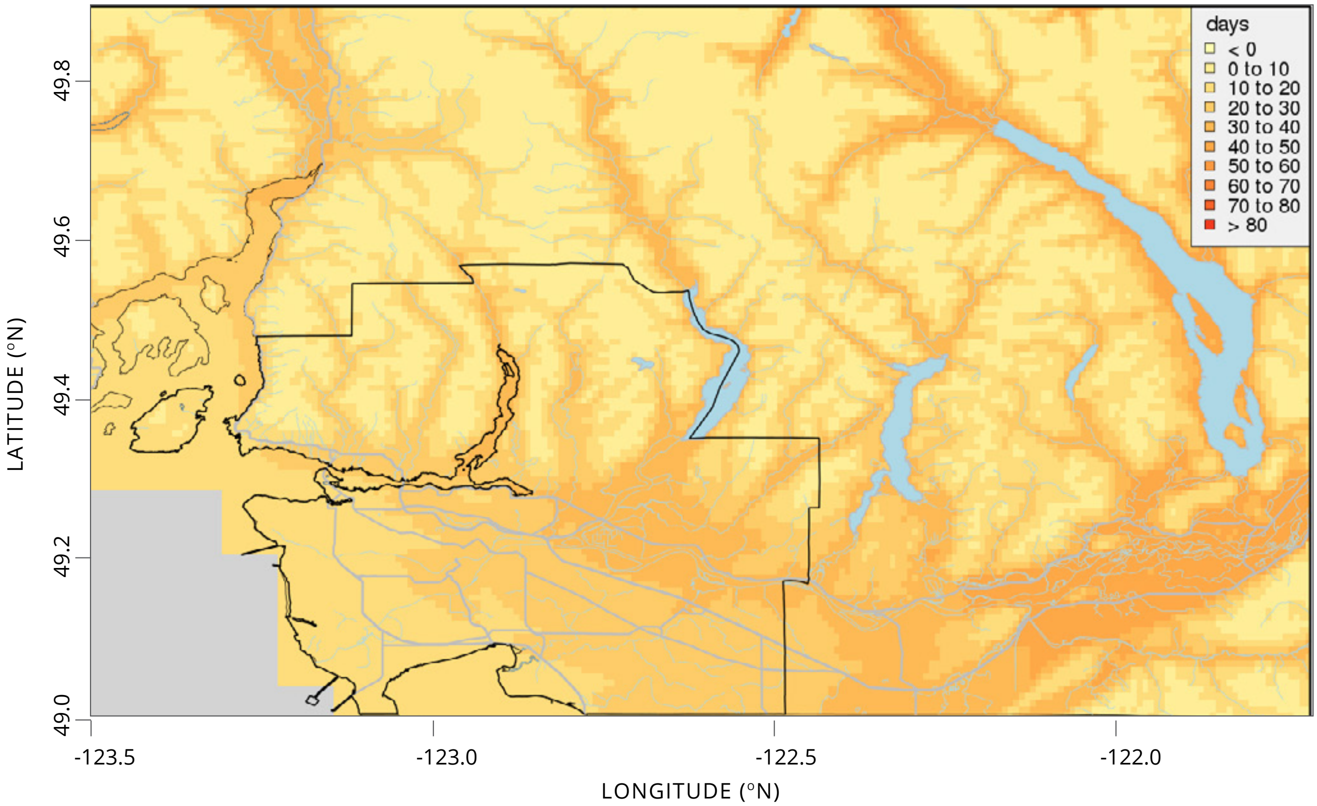

FIGURE A16: SUMMER DAYS – PAST

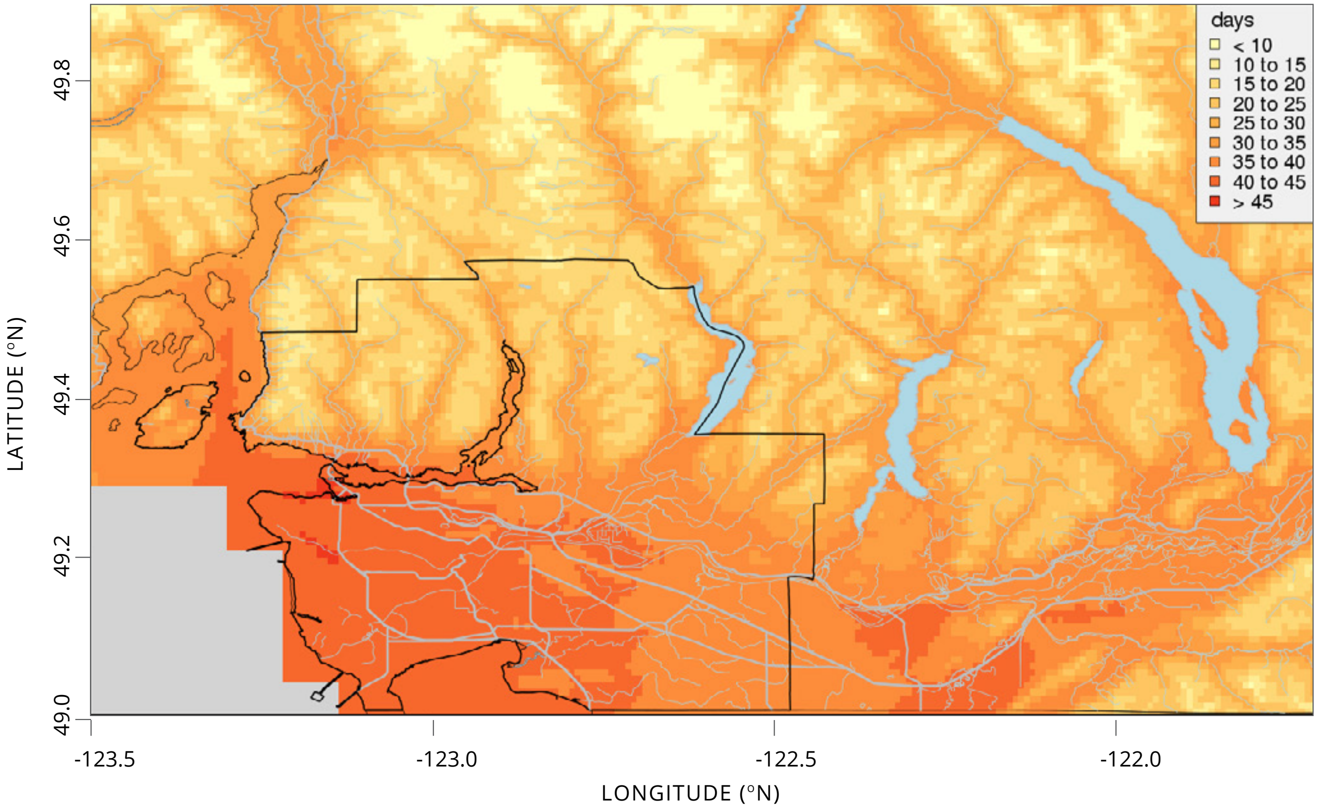

FIGURE A17: SUMMER DAYS – ANOMALIES

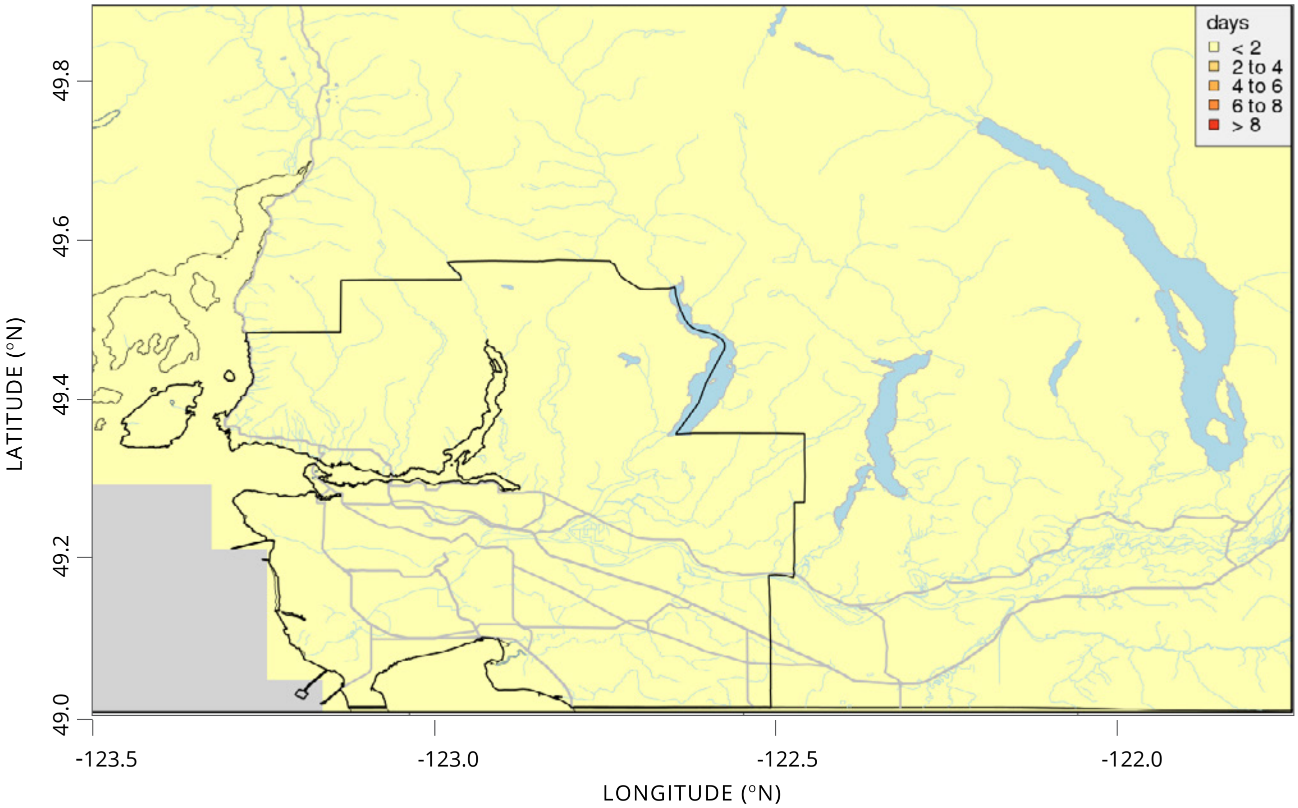

FIGURE A18: TROPICAL NIGHTS – PAST

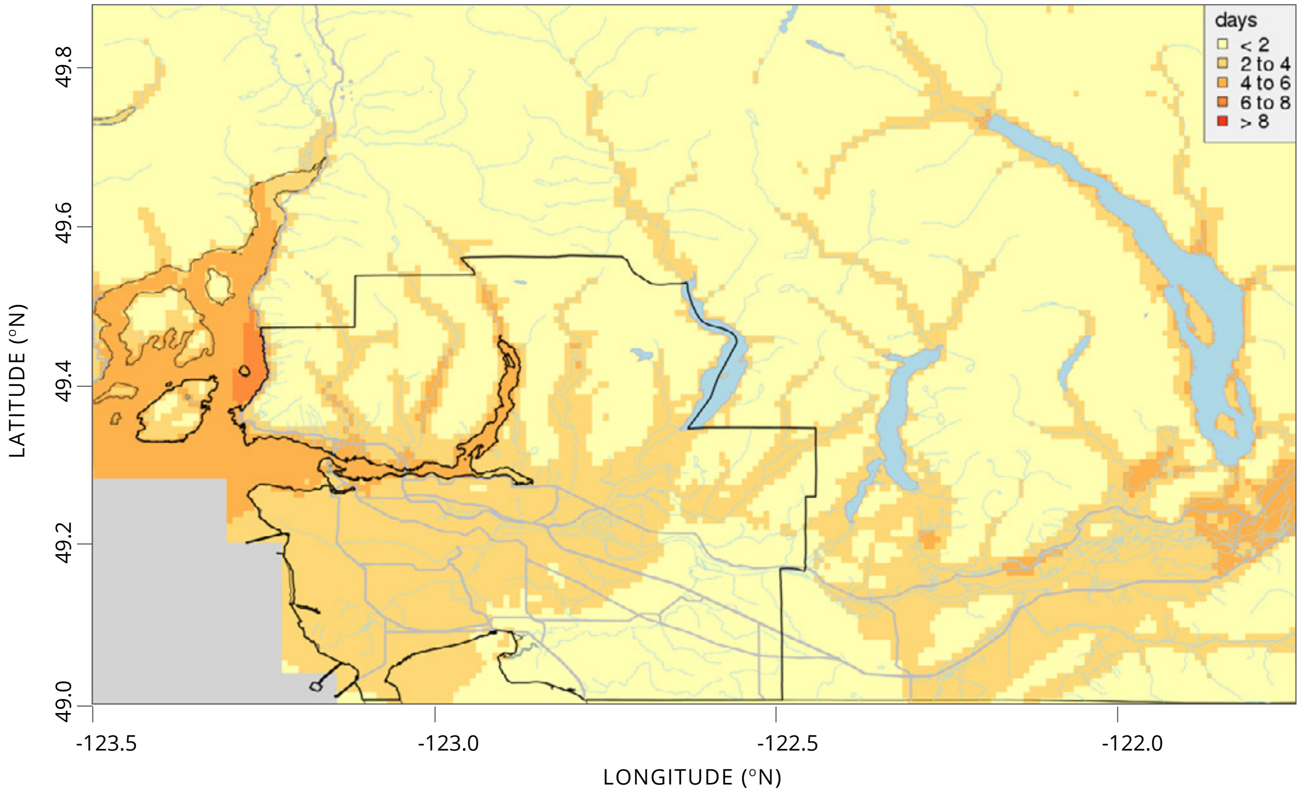

FIGURE A19: TROPICAL NIGHTS – FUTURE (2050s)

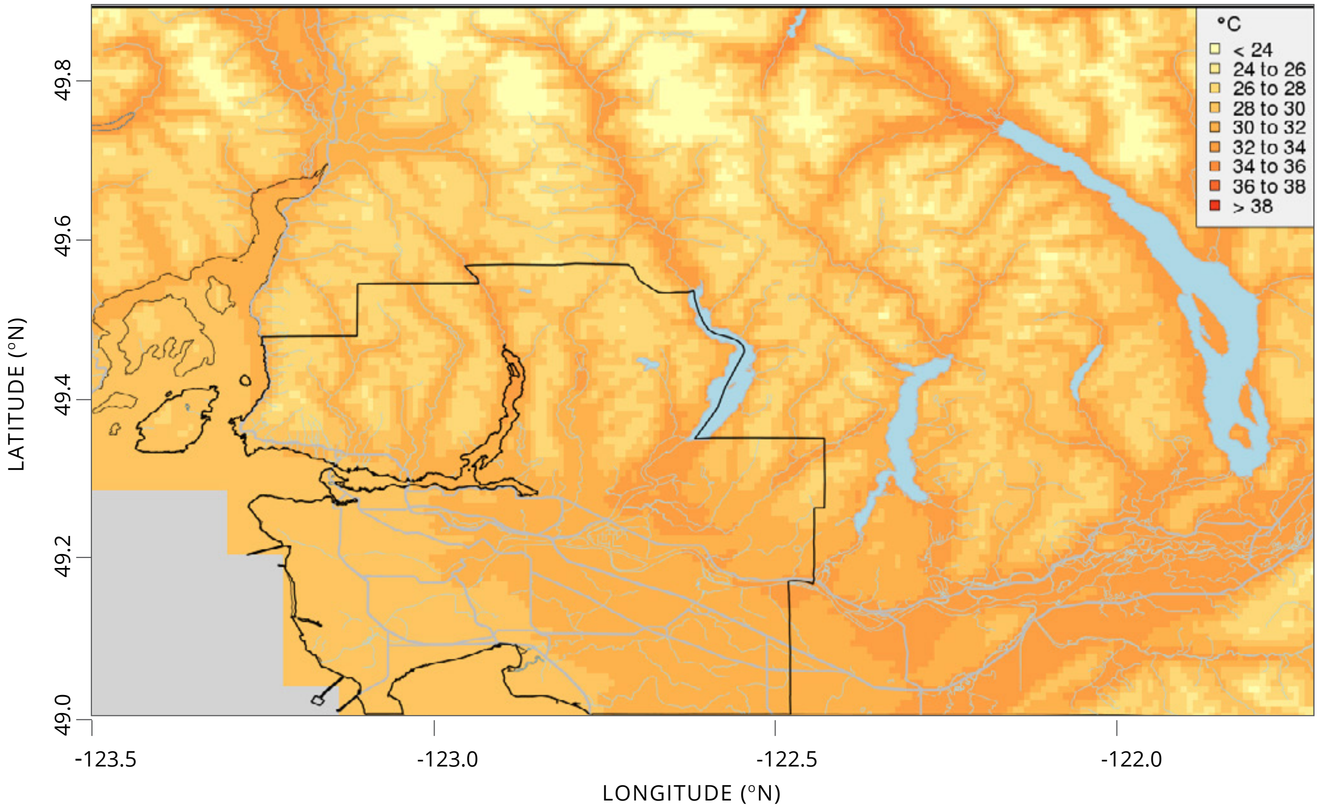

FIGURE A20: HOTTEST DAY – PAST

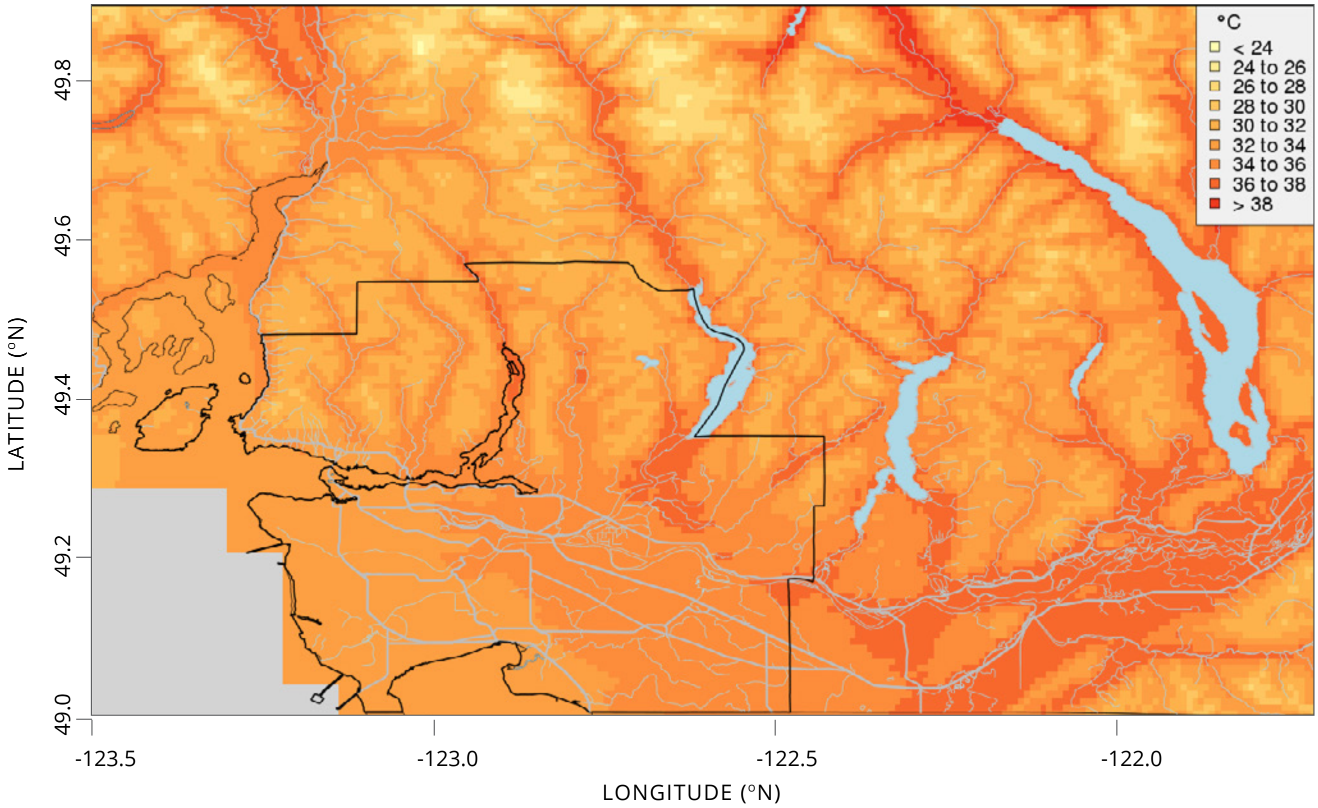

FIGURE A21: HOTTEST DAY – FUTURE (2050s)

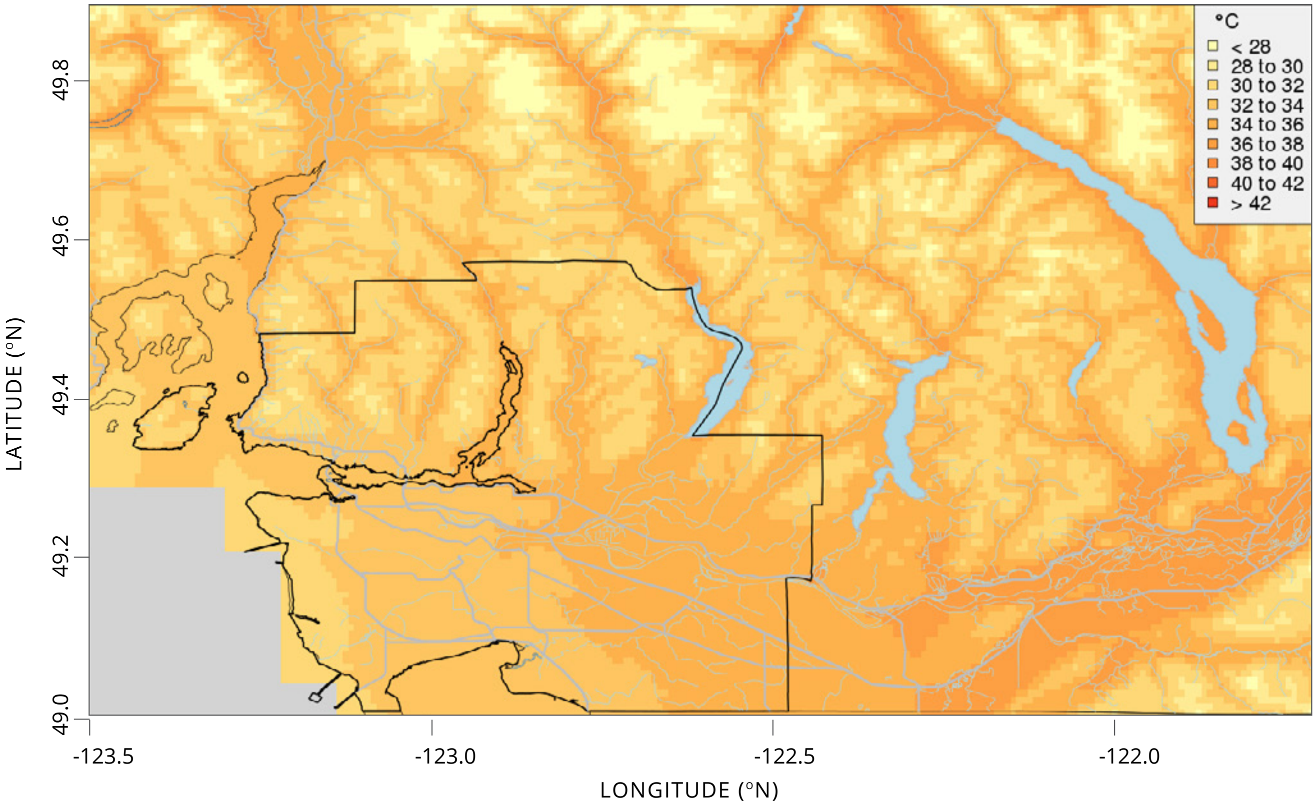

FIGURE A22: 1-IN-20 HOTTEST DAY– PAST

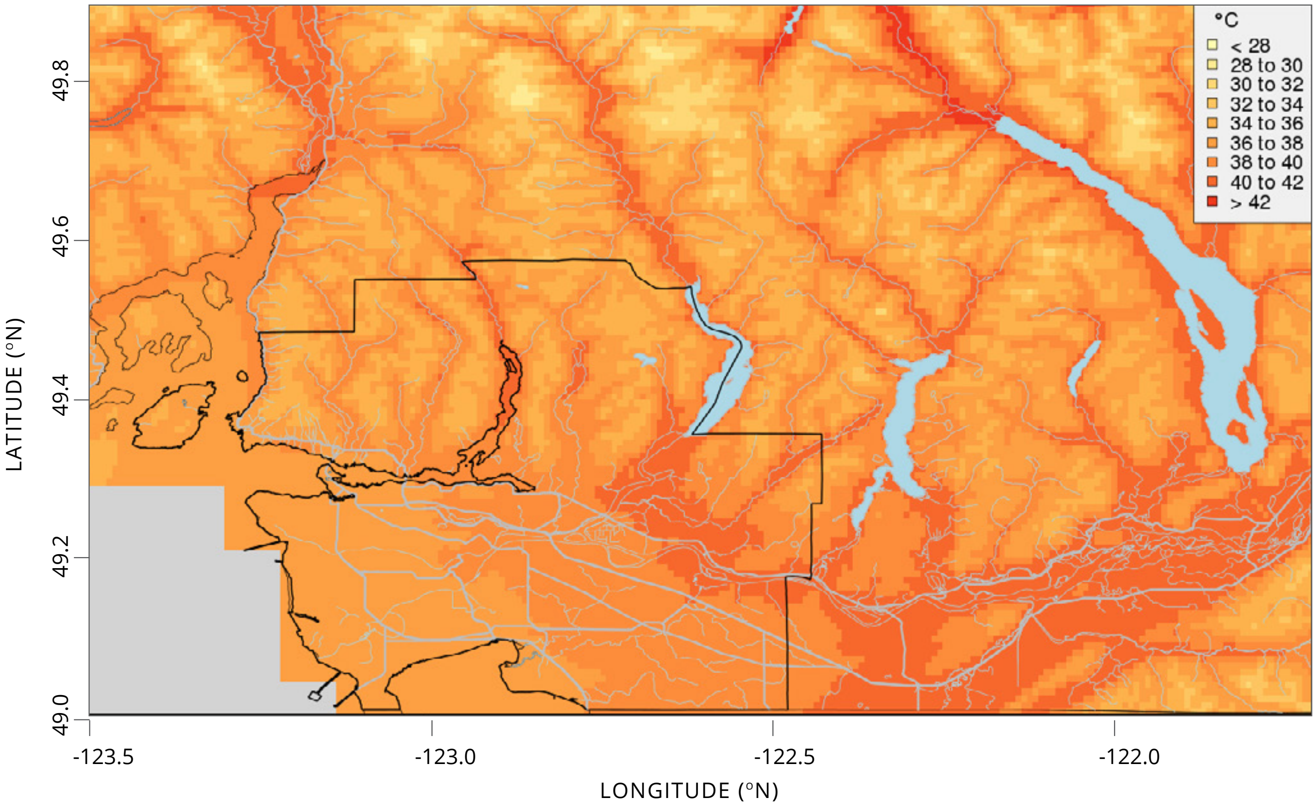

FIGURE A23: 1-IN-20 HOTTEST DAY– FUTURE (2050s)

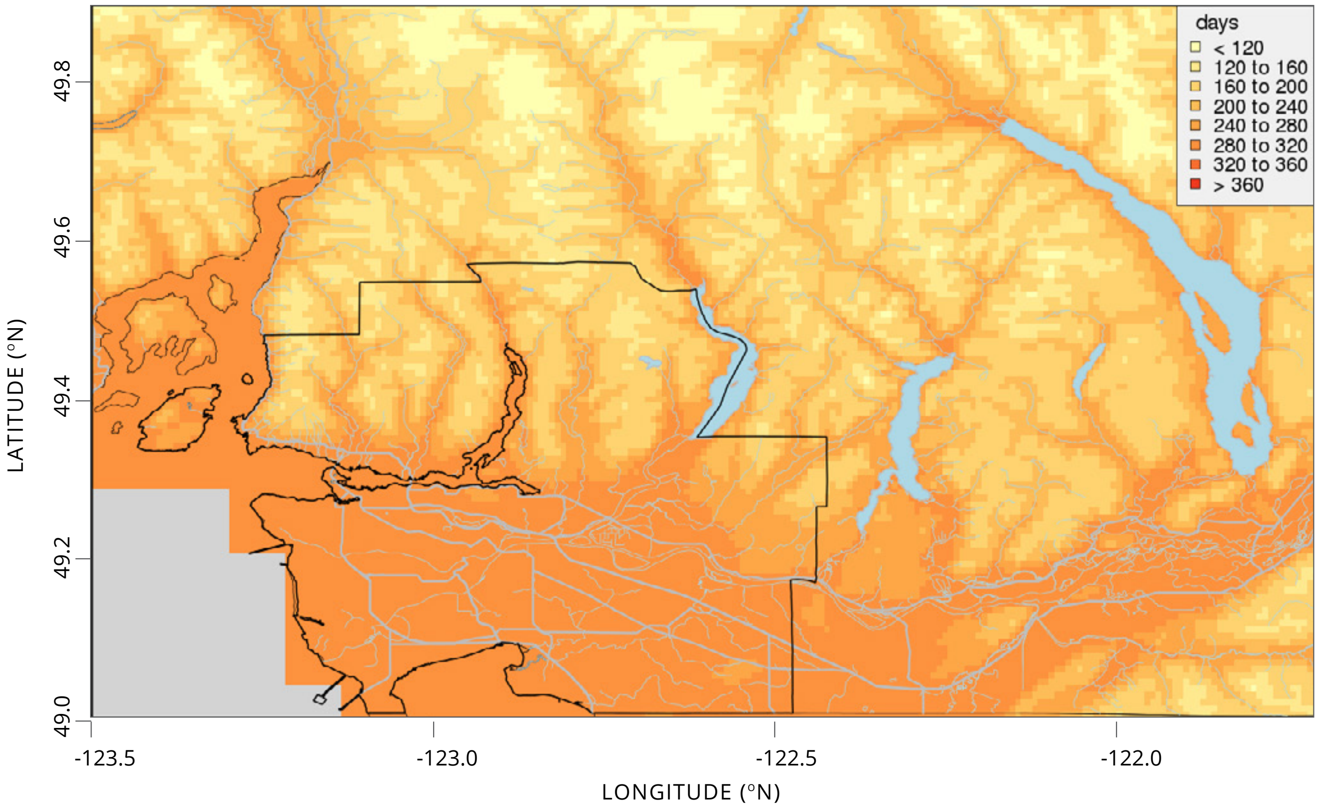

FIGURE A24: GROWING SEASON LENGTH – PAST

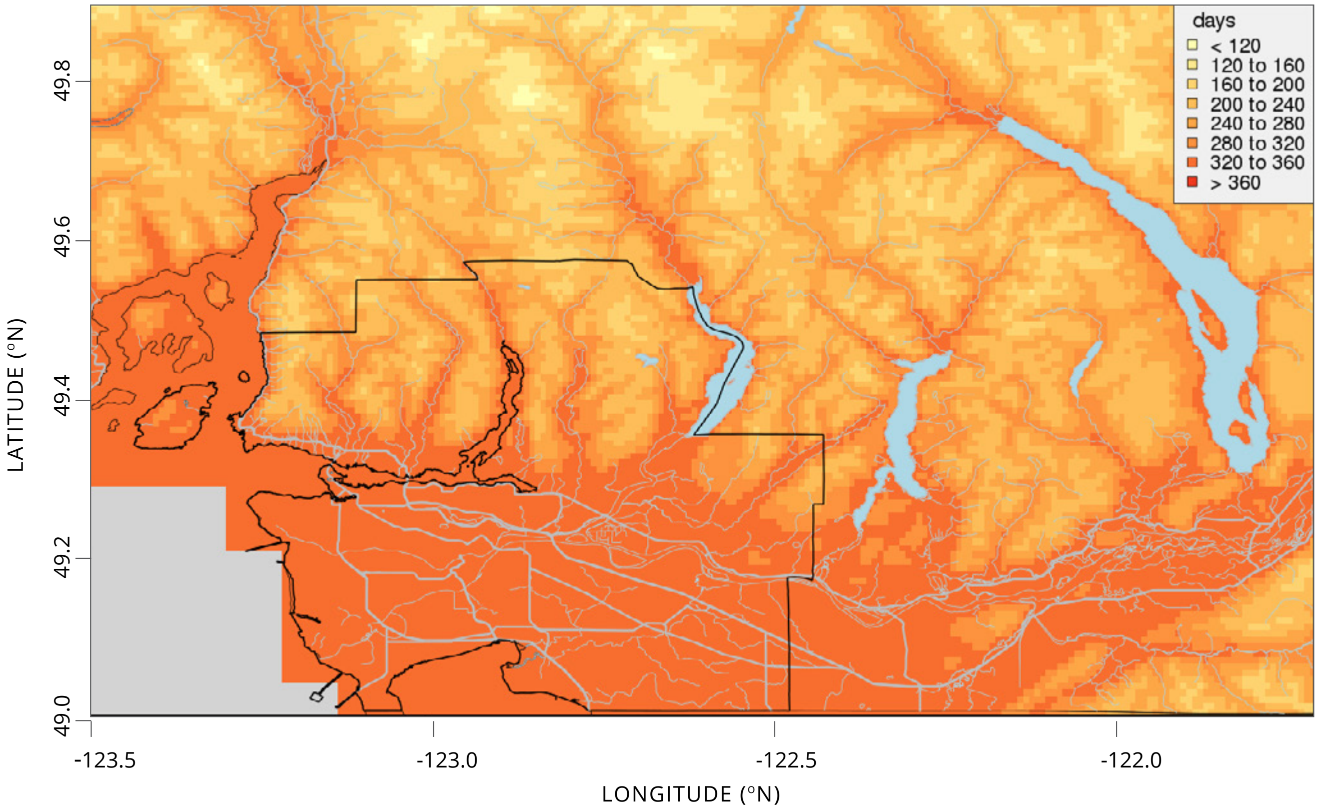

FIGURE A25: GROWING SEASON LENGTH – FUTURE (2050s)

Winter Temperature Indicators

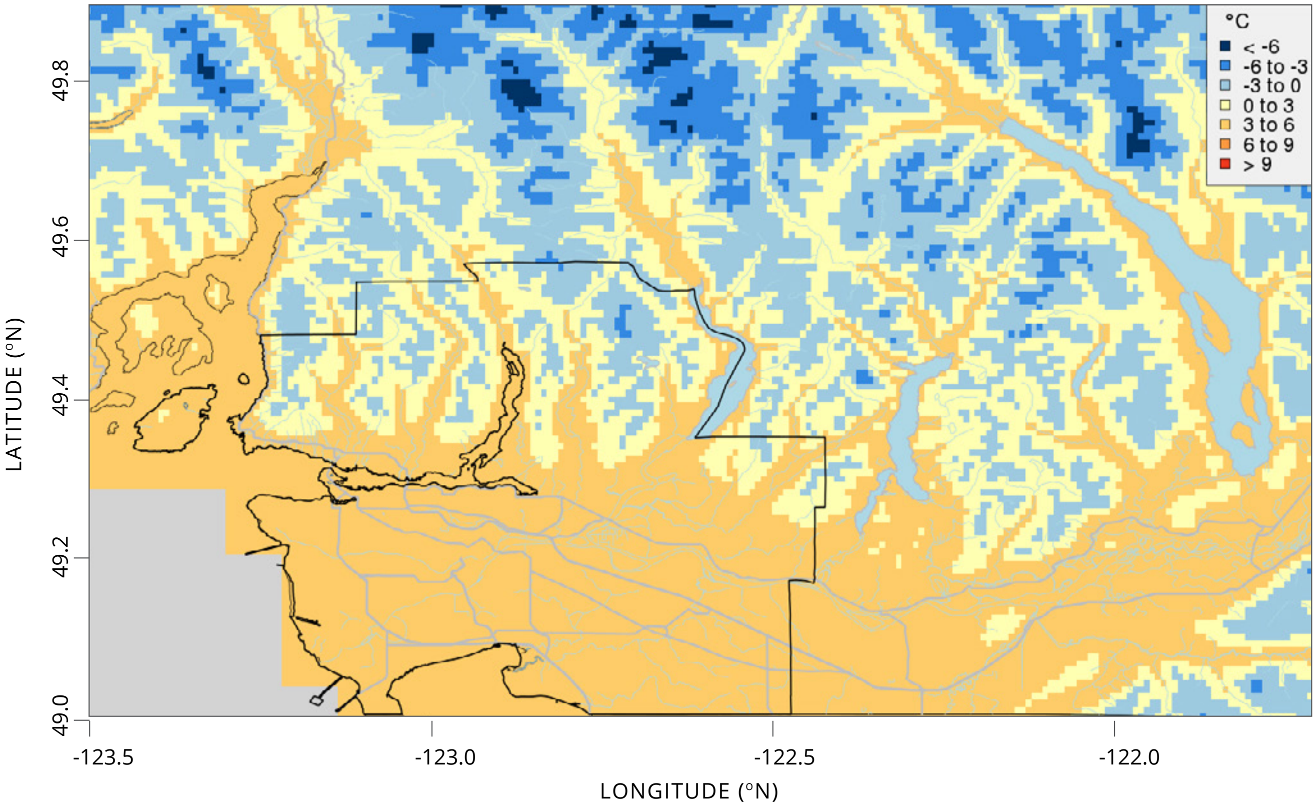

FIGURE A26: SPRING NIGHTTIME LOW TEMPERATURE – PAST

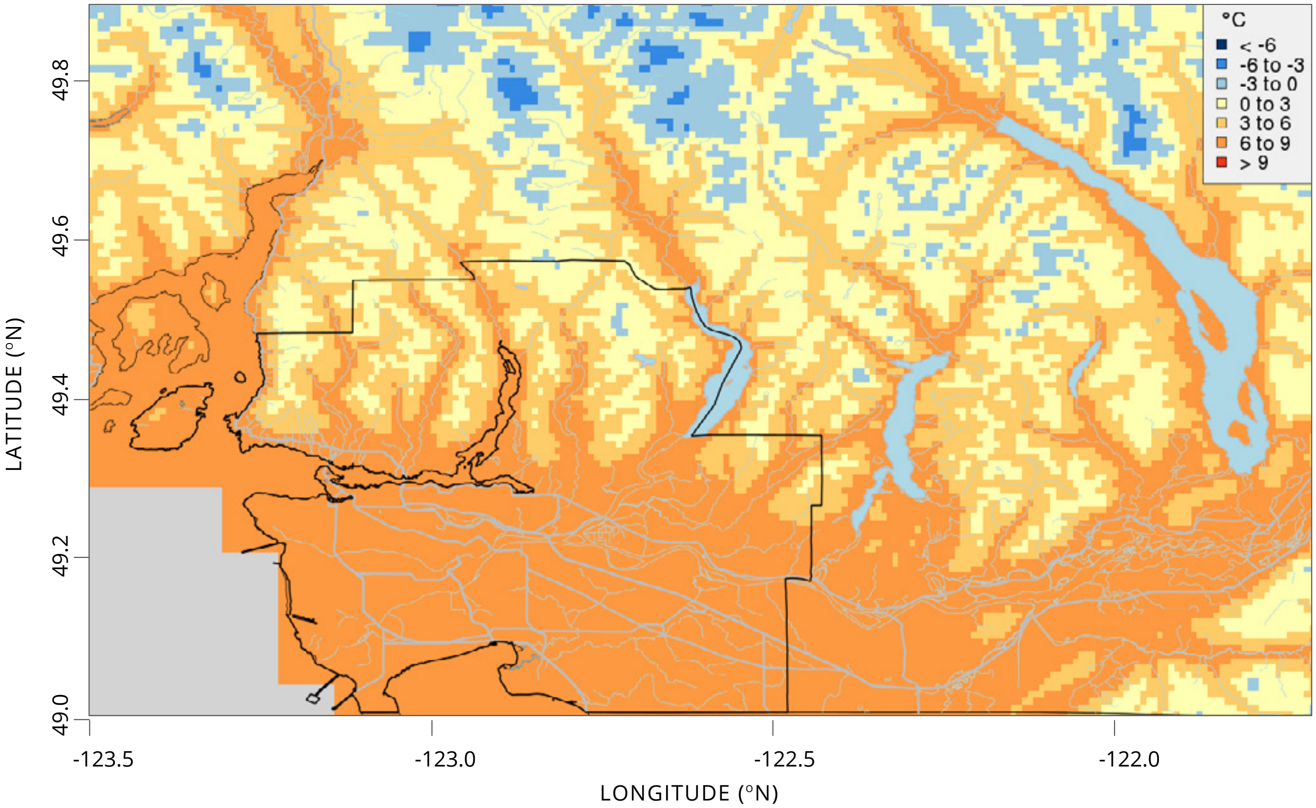

FIGURE A27: SPRING NIGHTTIME LOW TEMPERATURE – FUTURE (2050s)

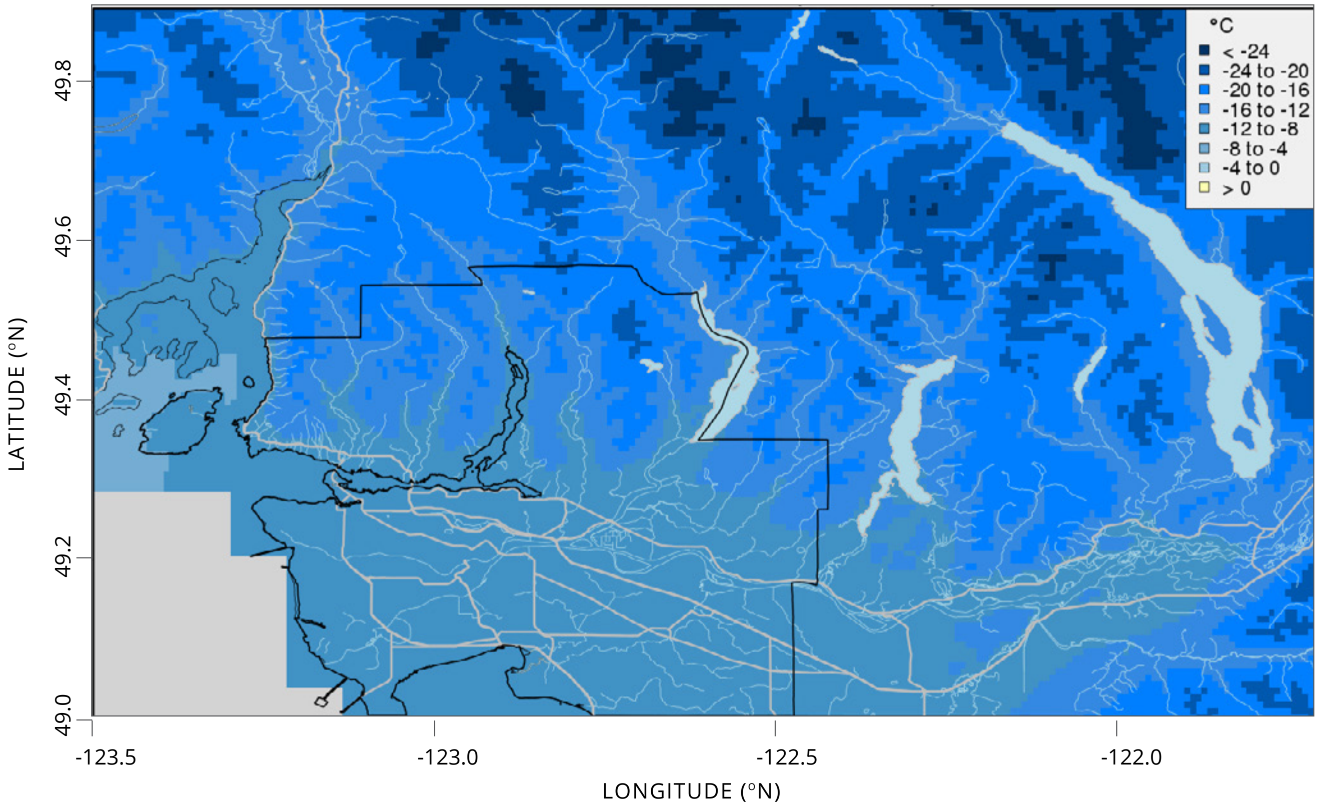

FIGURE A28: COLDEST NIGHT– PAST

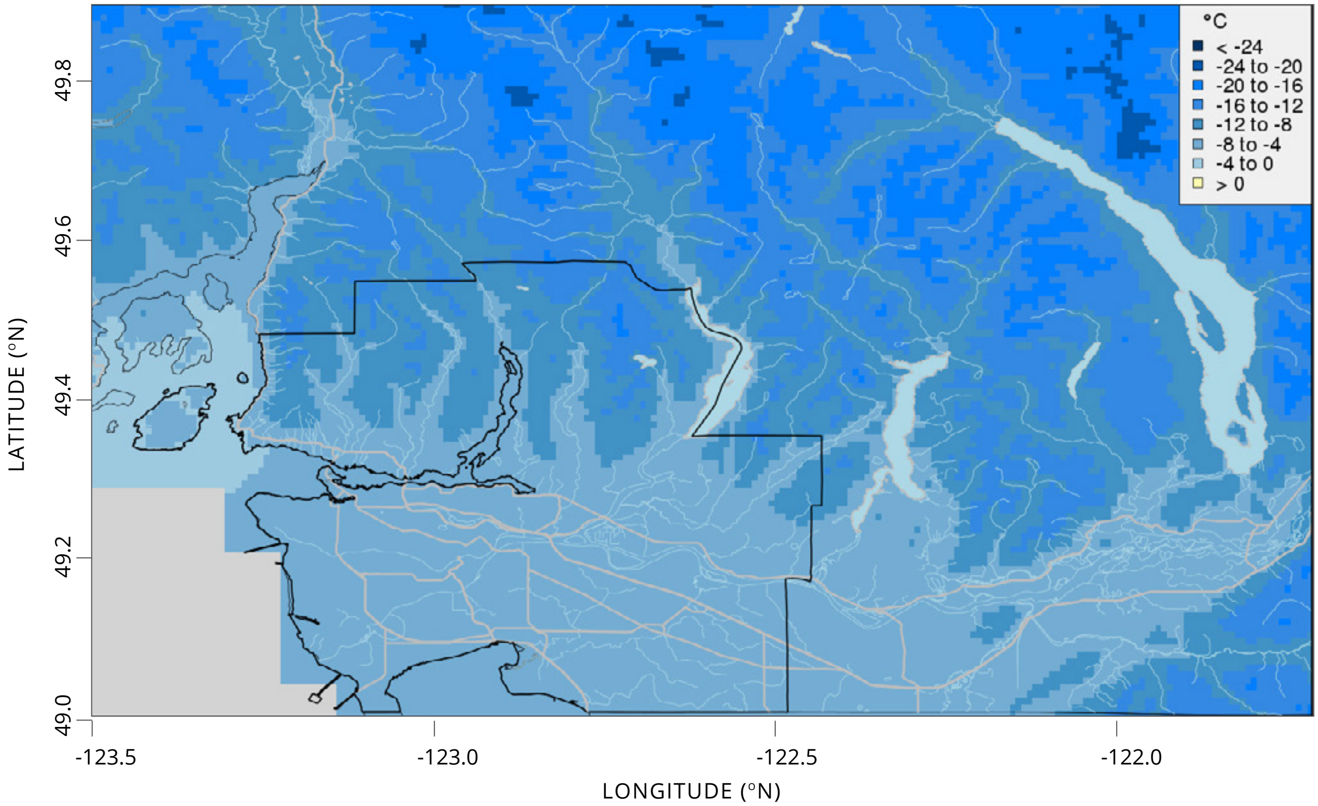

FIGURE A29: COLDEST NIGHT – FUTURE (2050s)

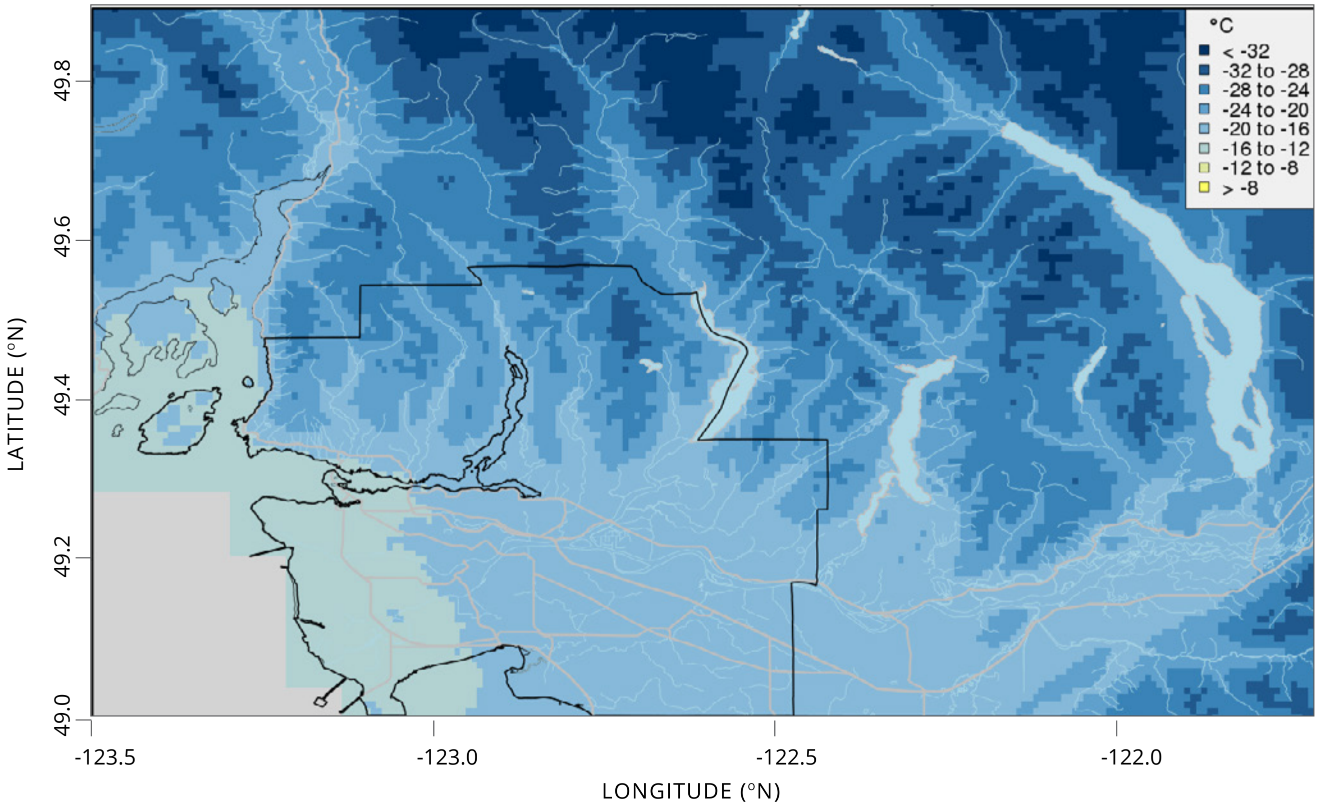

FIGURE A30: 1-IN-20 COLDEST NIGHT– PAST

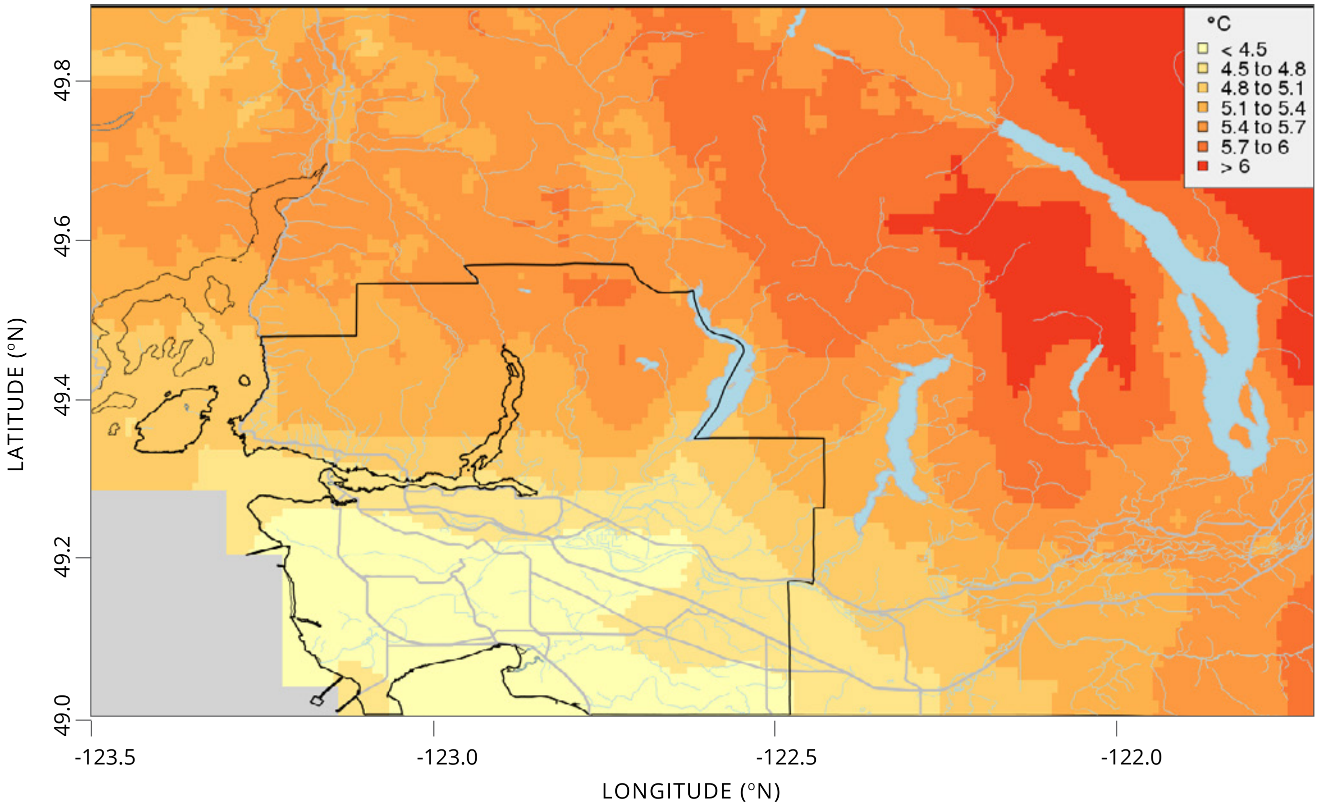

FIGURE A31: 1-IN-20 COLDEST NIGHT – ANOMALIES

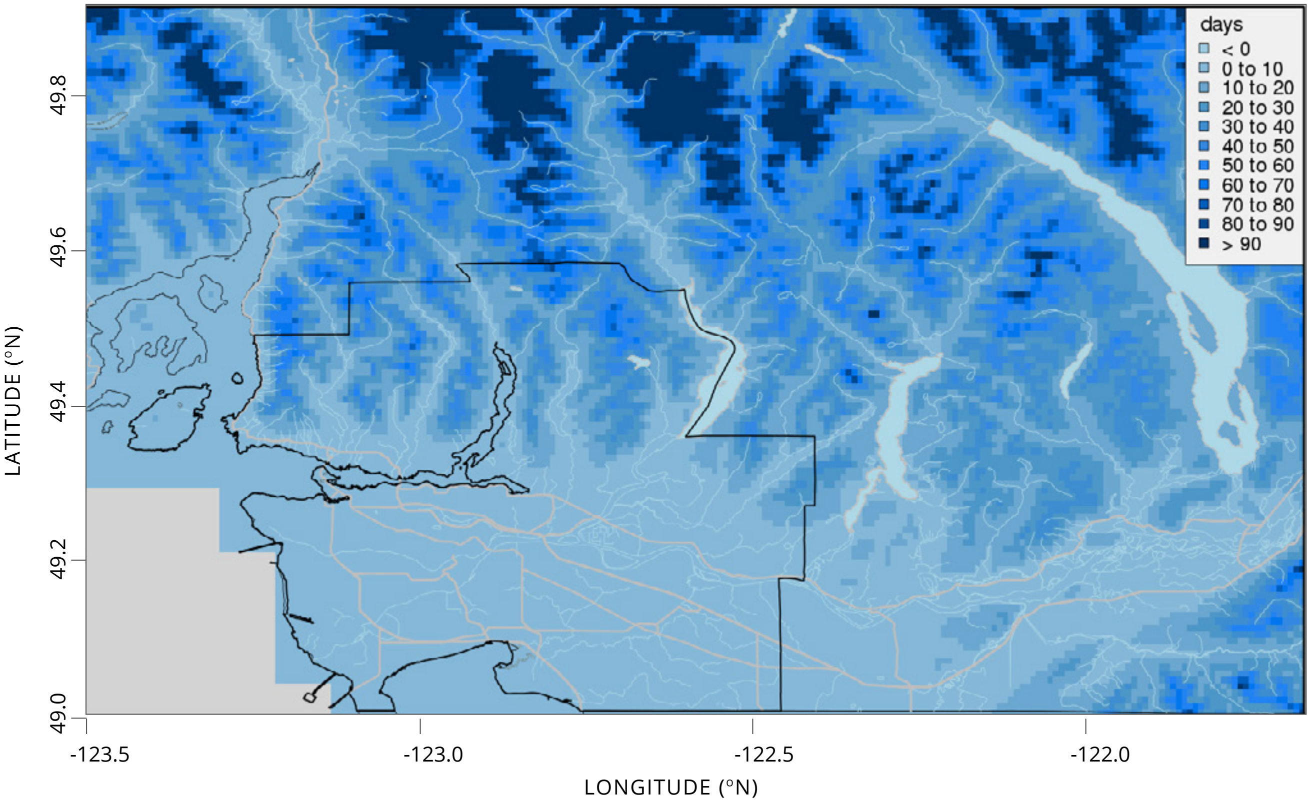

FIGURE A32: ICE DAYS – PAST

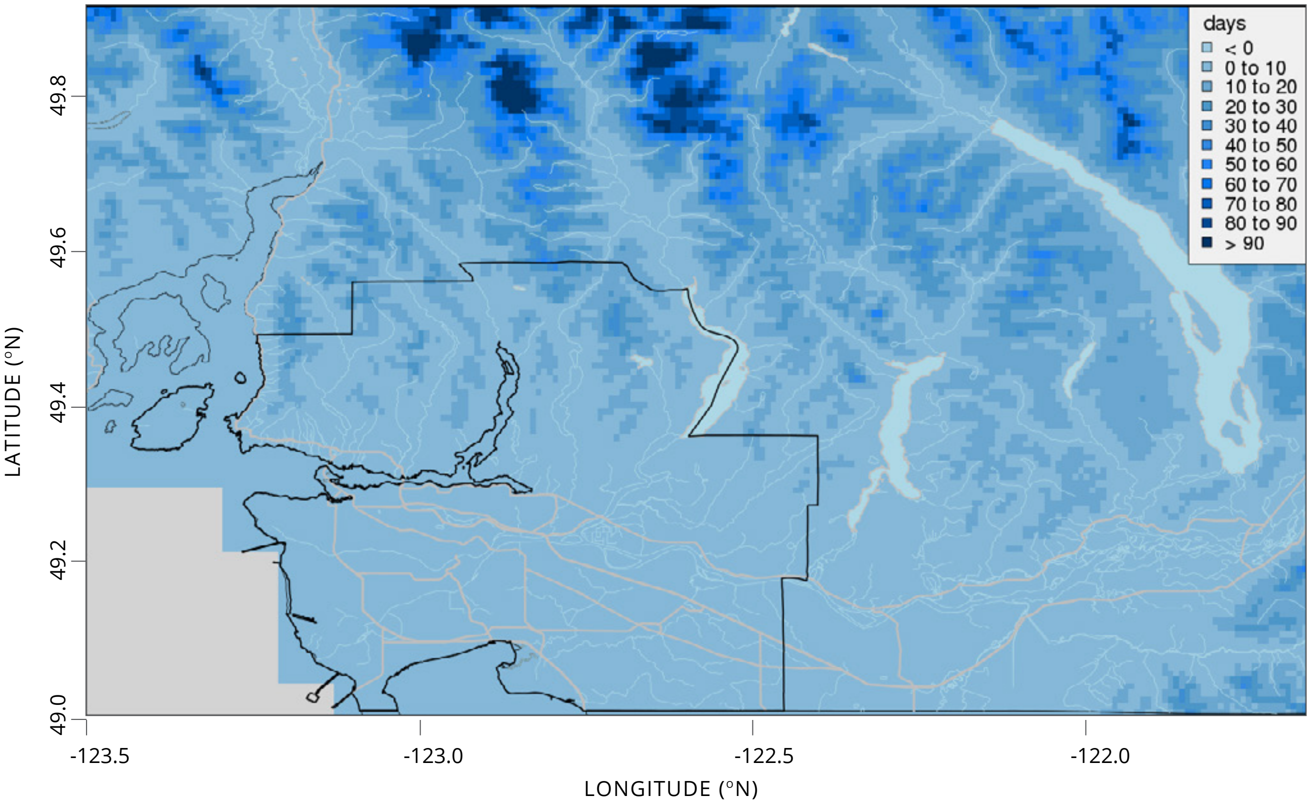

FIGURE A33: ICE DAYS – FUTURE (2050s)

June 2016

Notes