Climate Projections for the Regional District of Nanaimo

Regional District of Nanaimo

Pacific Climate Impacts Consortium

Executive Summary

The Earth's climate system is warming, and signs of climate change are increasingly evident worldwide. The Regional District of Nanaimo (RDN), located on eastern Vancouver Island, is no exception. How these changes impact our region will depend – in part – on how well we understand and prepare for them. Using the latest generation of comprehensive global climate models, the RDN worked with the Pacific Climate Impacts Consortium (PCIC) to prepare this report describing anticipated climate change in our region. These results will be used to inform regional hazard, vulnerability and risk assessments, infrastructure design, decision-making, and planning in the region, with the goal of improving our resilience to climate change.

The results of this study show that with continued high global emissions, our region can expect:

- Hotter summer temperatures, with more extreme heat days and heatwaves
- Warmer nights and a longer growing season
- Warmer winter temperatures and less days with ice or frost
- Less rain and more dry days in the summer
- More precipitation in fall, winter, and spring
- More precipitation falling as rain instead of snow
- More rain delivered in extreme rainfall events

By the 2050s (about 30 years from now), the number of summer days above 25°C are projected to triple from an average of 11 to 35 days per year. Our region can expect more heat waves, with the temperature for the 1-in-20-year hottest day projected to increase from 32°C to 35°C. While historical nighttime low temperatures nearly always fell below 16°C—the lower temperature threshold for heat warnings in our region—such temperate nights are projected to occur up to 12 times per year by the 2050s. Higher temperatures will increase the growing season length in our region by about 55 days (+23%), lessen the number of days with ice or frost, and shift heating and cooling demand across our region. This projected warming will have important implications for regional ecosystems, watersheds, community health and safety, agriculture, horticulture, infrastructure, and more.

While total annual precipitation is projected to increase modestly over the coming decades (+5% by the 2050s and +11% by the 2080s), this masks more substantial seasonal changes. First, warmer temperatures mean that more precipitation will fall as rain instead of snow. While winter rainfall is projected to increase by 34% by the 2050s, snowfall is projected to decline by about 50%. Second, more of this rainfall is expected to occur during extreme events such as storms and landfalling atmospheric rivers, with 30% more rainfall on very wet days and a 23% increase in rainfall on the 1-in-20-year wettest day by mid-century. Finally, total rainfall in the summer is expected to decrease by about 10% by the 2050s and dry spells are expected to last longer. This is important for the Regional District, which already sees very limited summer rainfall across the region.

While these changes are expected to occur region-wide, the maps produced for this report show subregional variations that may be important for local planning. For example, low-lying coastal areas that currently display the warmest temperatures in the region—and where most of the population and agriculture is situated—will also have the highest future temperatures and be more likely to exceed thresholds for heat warnings. That said, the downscaling approach used to produce these maps is limited by available data, and thus the results should be used with caution. Planning and preparation efforts should focus more on broad scale, regional changes for effective climate adaptation.

Information within this report and the accompanying data provide decision makers and community partners with an improved understanding of projected climate change and related impacts for our region. The report complements the RDN's efforts to assess climate-related risks in the District, identify where changes in risk might occur, and to implement policies and programs that help us adapt to these changes. This includes: (i) updating flood plain maps for the Nanaimo, Little Qualicum, and Englishman Rivers; (ii) mapping areas of the Regional District where sea level rise is likely to cause coastal flooding, and; (iii) modeling groundwater dynamics to understand how this resource might respond to future population growth in a changing climate. This information will be used to help the Regional District plan and update its own infrastructure so that it is climate-ready, and to guide future development towards sustainable areas (e.g., outside of flood plains and coastal inundation areas). The Regional District also connects residents with the information they need to improve the climate resilience of their own properties, including the mapping information above, and through focused outreach like our FireSmart, WaterSmart, and Climate Resilient Buildings programs. This report is designed to complement these efforts.

CONTRIBUTING AUTHORS

Charles Curry and Stephen Sobie from the Pacific Climate Impacts Consortium (PCIC) conducted climate model downscaling, data analysis & interpretation and generated all data products, including maps, figures, and tables, for the report. Charles Curry and Izzy Farmer (PCIC) served as lead writers for this report, with design and layout by Michael Shumlich (PCIC). Jessica Beaubier from the RDN was the project manager for this assessment.

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PHOTO CREDITS

Photos appearing in this report were contributed by the Regional District of Nanaimo, Charles Curry, Peter Harris, James Hiebert and Michael Shumlich.

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1. Introduction

In recent decades, rising global mean temperature has been clearly linked to increased atmospheric concentrations of greenhouse gases (GHGs) and other pollutants from human activity.[1] To date, the global average temperature has increased by over 1°C, and this warming is expected to continue unless we make significant cuts to carbon emissions globally. Understanding and monitoring the regional and local manifestations of climate change is important for supporting safe and resilient communities in this time of change.

Like other populated areas worldwide, the Regional District of Nanaimo (RDN) requires up-to-date, science-based, mapped information to enable effective planning and policy decisions in a changing climate. To this end, the RDN has partnered with the Pacific Climate Impacts Consortium (PCIC) to produce high-resolution climate projections for our region. These projections are based on the latest generation of comprehensive global climate models (i.e., CMIP6) and provide a picture for how our climate may change throughout the remainder of this century.

The RDN spans an area of 2,038 km^2 and elevations of up to 1820 m above sea level (see Figure 1). Since 1950, air temperature observations over Vancouver Island have increased by about 0.26 ± 0.07 °C per decade.[2] This regional warming is expected to affect other climate variables, such as rainfall, and this study explores some of those changes using state-of-the-art climate model projections for the area.

A selected number of climate indicators are offered in this report to illustrate how our climate is expected to change over time. In the first section, Chapter 2 provides a brief description of the study methodology and support for interpreting figures and tables. Chapters 3 through 6 contain an analysis of the selected climate indicators, including information about summer temperatures, winter temperatures, precipitation, and climate extremes. Each section includes a description of each indicator and a summary of how it is projected to change in our region for one or more future time periods.

In the second section of this report, Chapter 7 identifies potential climate change impacts expected across our

1. Gulev, S.K., et al., 2021: Changing State of the Climate System. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 287–422, doi: 10.1017/9781009157896.004.
2. Results of an analysis conducted by PCIC for the annual "State of the Pacific Ocean" report; see Curry, C.L. and Lao, I., "Land temperature and hydrological conditions in 2022," pp 17-21. In: Boldt, J.L., Joyce, E., Tucker, S., and Gauthier, S. (Eds.), *State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2022*. Can. Tech. Rep. Fish. Aquat. Sci. 3542: viii + 312 p. (2023). The nearby Lower Fraser Valley displays a larger trend of magnitude 0.42 ± 0.07 °C per decade, which may be more similar to what the RDN has experienced, rather than the average over Vancouver Island

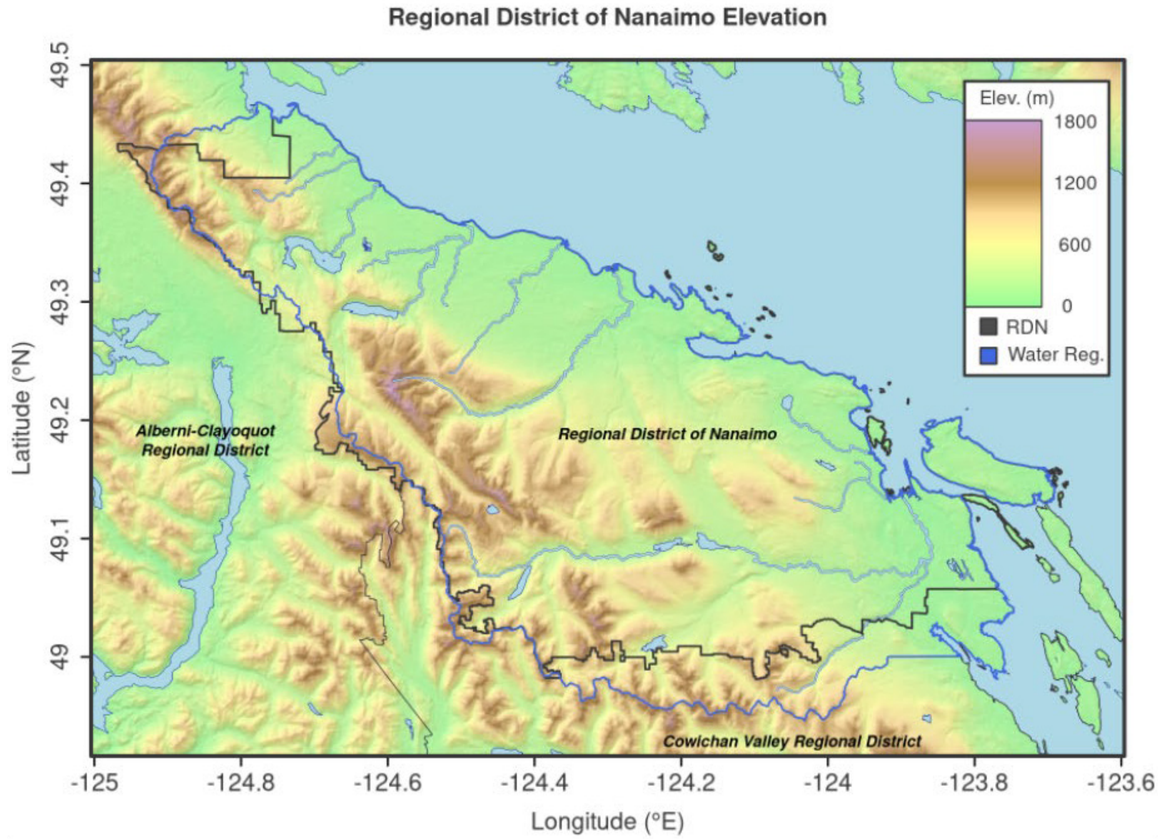


Figure 1. Area of interest, the Regional District of Nanaimo, with background relief (elevation) map. The Regional District boundary is shown with an irregular black curve, while the outer boundary of the water regions located within the District boundary is shown by the irregular blue curve.

region. These impacts are categorized by different sectors, including water supply and demand, rainwater and flood management, health and well-being, ecosystems and species, buildings and energy systems, transportation, agriculture and food security, and parks and recreation. Where possible, the impacts have been considered using an equity lens that reflects how vulnerable populations are often most exposed to the impacts of climate change while having limited resources to prepare and respond to it.

This report and its supplementary data will support decision making on climate adaptation throughout the region and help community partners better understand how their work may be affected by the changing climate. It should be noted that the information provided in this report is limited to changes in *temperature and precipitation only*. Other climate-related phenomena, like surface hydrology, changes in atmospheric dynamics and wind, humidity and drought, sea level rise and storm surge require different modelling techniques and are not included in the scope of this project. Therefore, this report should be used alongside other resources to help prepare our region for the impacts of climate change. These include:

- Coastal inundation mapping to identify areas in the RDN at greater risk of flooding from sea level rise
- Updated floodplain maps and development bylaws for the Nanaimo, Englishman and Little Qualicum Rivers, and
- Completed water budgets for the Nanoose and French Creek areas to understand how groundwater dynamics may change with anticipated growth and climate change

The information in this report should be used with careful consideration of the local context. All users should understand the limitations and uncertainties associated with climate projections information. For guidance on how to use climate information for adaptation planning, see the appendices appearing at the end of this report. It is hoped that this guidance will support the use of this report by a wide audience.

2. Methods and Presentation

2.1 Climate Model Projections

The climate projections in this report are based on an ensemble of 9 global climate models (GCMs). These models are drawn from a larger collection of models developed during the Sixth Coupled Model Intercomparison Project (CMIP6), coordinated by the World Climate Research Programme. The climate projections presented here are based on a high greenhouse gas emissions scenario, known as the Shared Socioeconomic Pathway 5-8.5 (SSP585), which describes a trajectory of future emissions spurred by continued and expanded use of fossil fuels worldwide. Two other scenarios are also presented in the data package accompanying the report: a medium-intensity emissions pathway, SSP245, and a low-intensity pathway, SSP126, which covers the possibility of a low-carbon technology transformation of worldwide energy systems.[3] Planning

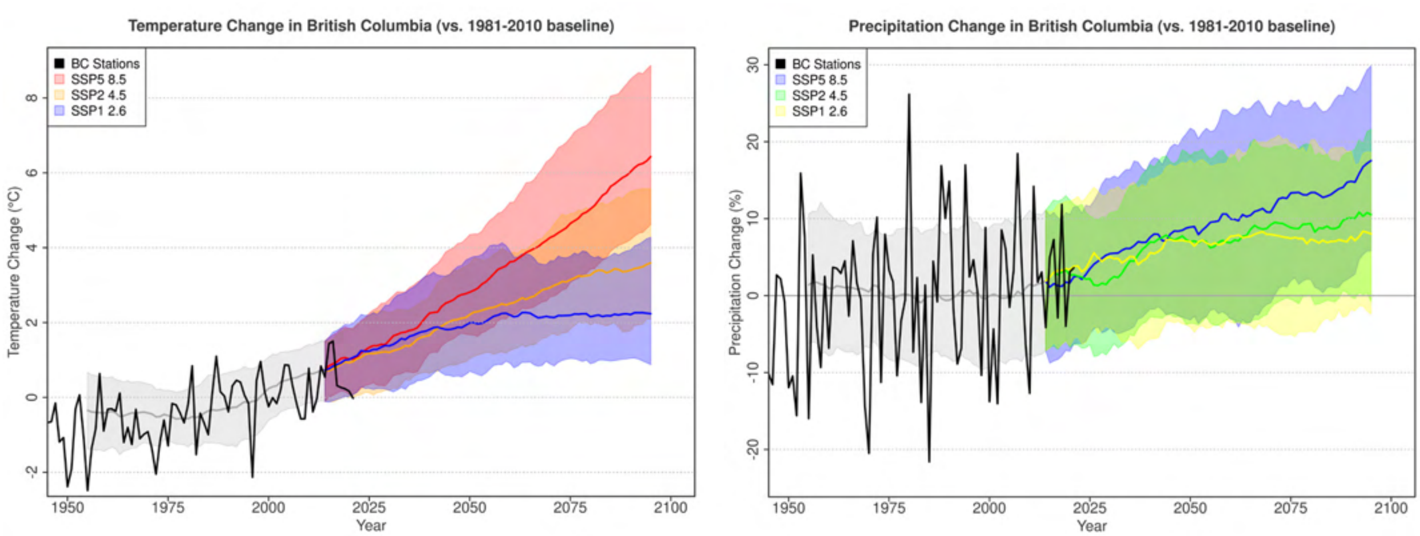


Figure 2. Changes in annual mean air temperature (left) and total precipitation (right) relative to their values in 1981-2010, averaged over all of BC. The black curves show historical values obtained from the station data in BC from 1948-2021, while the coloured curves show median GCM projections under the three development pathways (SSPs) from 2015-2100. The shaded areas show the 10th-90th percentile range in model-simulated results over the historical and future periods, for each SSP.

3. An accessible description of the SSPs may be found at https://climatedata.ca/resource/understanding-shared-socio-economic-pathways-ssps/.

based on climate projections under SSP585 could be considered a "no regrets" strategy for adaptation. By the end of the century under SSP585, global mean surface air temperature reaches a level 4.4 °C higher than the 1850-1900 average. In British Columbia (BC), the expected increase is even larger: the evolution of air temperature and precipitation for BC under the three emissions scenarios are shown in Figure 2.

Each GCM represents the climate system using a global, horizontal grid with a limiting resolution between 100 km and 250 km, depending on the model. These coarse-grained data are first bias-corrected against available observations (spanning 1950-2012) and then statistically downscaled to 10 km resolution.[4] In a second step, the model data are further downscaled to a resolution of 800m using fine-scale climatological maps for the Regional District of Nanaimo. It should be recognized that while the latter account for fine-scale topography, important features of, and influences on, local daily climate are not represented in the dataset.[5]

Downscaled climate model results are presented for three 30-year periods: the historical reference period, 1981-2010 (referred to as the "Past" or "1990s" for short), the near future, 2021-2050 (the "2030s"), mid-century, 2041-2070 (the "2050s") and the end-of-century, 2071-2100 (the "2080s"). These 30-year periods are selected to smooth out year-to-year climate variability, and to provide a long enough period to characterize the behaviour of fairly rare events. The seasonal definitions used are "meteorological" seasons: i.e., winter (December 1 to February 28), spring (March 1 to May 31), summer (June 1 to August 31) and fall (September 1 to November 30). A range of indices are computed from daily temperature and precipitation to describe various aspects of the climate. The median estimates from the climate model ensemble are typically emphasized, with the 10^{th} to 90^{th} percentile ranges over the ensemble also provided where appropriate.

It is important to recognize that not all projected changes emerging from the climate model ensemble are necessarily substantial. For a given variable, location, and emissions pathway, each model produces a projected future climate, resulting in a range of possible outcomes. Since no single model is "right," the median value of the ensemble can be used as a practical best-guess projection, with the 10th to 90th percentile range indicating the spread amongst the models. If the range includes zero change, meaning that not all models agree on the sign of the change, then relatively low confidence should be placed in the median value. In the relatively rare cases when less than half of the models agree on the sign of change, users are alerted to the reduced confidence via a printed message on the maps.

2.2 Interpreting Figures and Tables

This report presents results for a number of key indicators, derived from the model-simulated daily temperature and precipitation. It represents a "highlight reel" of the much more extensive set of climate indices delivered for this project. These variables have been selected in consultation with RDN staff either because they have implications for a range of climate-related impacts, because they feature particularly large changes from recent historical conditions, or both. In the following chapters, a plain language definition is provided for each indicator, followed by a summary of its projected change for the 2030s, 2050s, and 2080s under a high emissions scenario (SSP585). Detailed definitions of all indicators are provided in Appendix F.

Most of the figures presented in this report are maps that show the RDN and surrounding area. On each map, colour contours indicate values of the indicated climate variable, with a nominal limiting resolution of 800m. Due to the limitations of the downscaling methodology mentioned above, along with the inherent uncertainty in future outcomes, the exact position of contours on the maps should not be taken literally. All maps show a number for the area average in the bottom left corner. This number is averaged over the entire RDN, which is the area inside of the black curve.

Two types of maps are presented throughout this report. Single period maps show the absolute value of a given

4. Details on the downscaling methods used at PCIC may be found on the Data Portal section of our website, pacificclimate.org.
5. Examples of these being realistic day-to-day variability and co-variability between nearby locations, and fine-scale land cover type. It should also be recognized that since the models are bias-corrected to daily observations spanning a specific time period, here 1950-2012, more recent observations will not be reflected in results displayed for the "Past."

variable for a select time period (e.g., "Past: 1990s" or "Projection: 2050s"). Future change maps show the difference between historical and future-projected time periods (e.g., "Projected Change: 2050s - 1990s,"). The units for the future change maps may also be presented in relative terms, such as percent change. In the interest of concision, all future change maps shown in this summary report are for the 2050s under a high emissions scenario (SSP585). For most indicators, the magnitude of change under a high emissions scenario (SSP585) should be roughly comparable to that projected for the 2080s under a moderate emissions scenario (SSP245).

This report provides several box-and-whisker plots illustrating year-to-year and model-to-model variability over time. These plots represent regional averages for a given variable. Figure 3 illustrates how these plots should be interpreted.

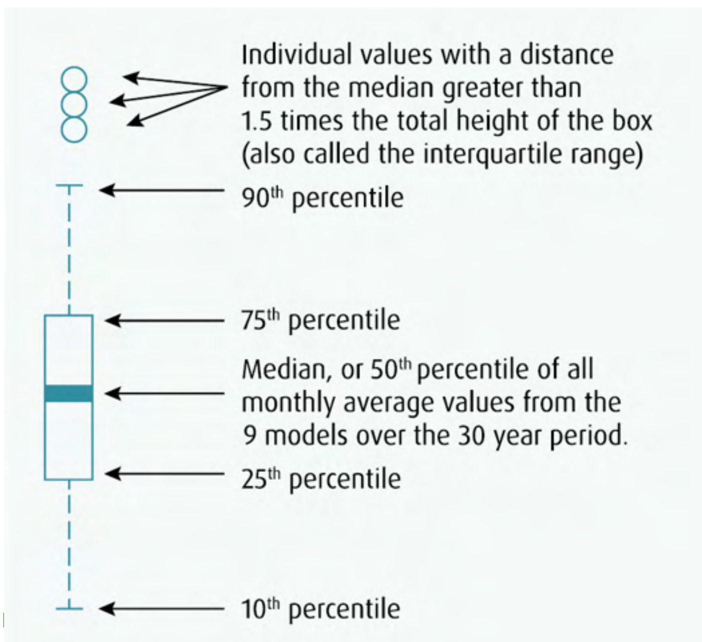
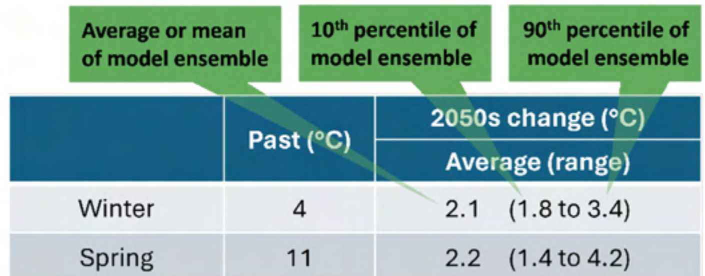


Figure 3. Interpreting a box-and-whisker plot.

Tables throughout the report present numerical results that have been averaged over the entire region (i.e., within the regional boundary shown on each map). These tables show the median values with the 10th and 90th percentile ranges provided in parentheses (see Figure 4). When cited in the text, table values are often rounded to indicate the likely precision of the quantity being discussed, given the known model uncertainties. For example, a temperature of 29.8°C would be cited as 30°C, and 2717 degree-days would become 2715 degree-days. Usually, only the median values are cited in the text summary of projected changes. However, because the 10th and 90th percentile ranges also reflect possible future behaviour, they should not be ignored. This is particularly true when the climate variable in question might enter critical decision-making.



	Past (°C)	2050s change (°C) Average (range)
Winter	4	2.1 (1.8 to 3.4)
Spring	11	2.2 (1.4 to 4.2)

Figure 4. Interpreting tabular data.

Seasonal differences have been provided in the tables where appropriate. For certain variables, the tables may also present subregional results for low elevation ("Lowlands", < 450m) and high elevation areas ("Highlands", > 450m) (see Figure 5). The complete data package also includes subregional breakdowns by watershed, according to the subbasins. For more information about what is included in the complete data package, see Appendix B.

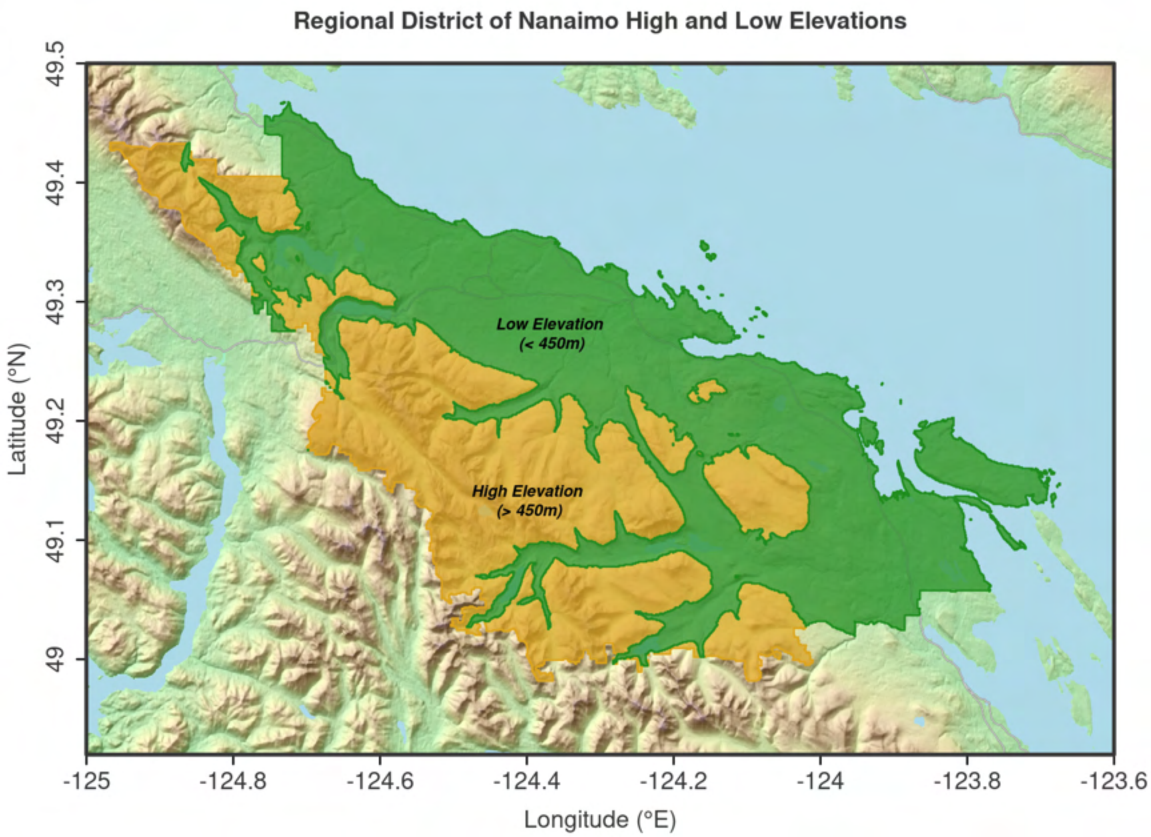


Figure 5. Division of the RDN into high (light brown) and low elevation (green) areas, using a value of 450m to divide the two.

3. General Climate Projections

3.1 Warmer Temperatures

We begin by examining future temperature change over the region. *Daytime High Temperatures* and *Nighttime Low Temperatures* are averaged over each season and annually in the tables and maps below.

In concert with global and regional warming, both daytime and nighttime temperatures are projected to increase in the RDN in the future, as detailed in Tables 1 and 2. The accompanying maps show the spatial pattern of Past and future projected temperatures for summer and winter throughout the region.

Projections

In the Past, winter daytime high temperatures in the RDN averaged around 4°C, while winter nighttime low temperatures averaged around −0.5°C. The median future-projected daytime high temperature increases to around 6°C by the 2050s and to 7.5°C by the 2080s. The median future-projected nighttime low temperature reaches around +1.5°C by the 2050s and to 3°C by the 2080s. Since the precise temperature near 0°C determines the phase of precipitation, we can anticipate that this local warming will affect the frequency of snowfall in the region, as detailed further below.

By season, the largest projected temperature increase in the RDN is expected in summer, for both daytime highs and nighttime lows. The daily high is projected to rise from a Past median value of 20°C to 23°C by the 2050s and to nearly 25°C by the 2080s. Similarly, the median nighttime low temperature of 10°C in summer is projected to increase to nearly 13°C in the 2050s and to almost 15°C in the 2080s.

TABLE 1: REGIONAL AVERAGE DAYTIME HIGH TEMPERATURE (TX)

	Past (°C)	2050s (°C)	2080s (°C)	2050s Change (°C)	2080s Change (°C)
Winter	4	6	8	2.1 (1.8 to 3.4)	3.6 (3.0 to 6.6)
Spring	11	13	14.5	2.2 (1.4 to 4.2)	3.6 (2.8 to 6.6)
Summer	20	23	25	3.0 (2.3 to 5.4)	4.7 (4.2 to 8.9)
Fall	12	15	16	2.7 (2.2 to 4.7)	3.9 (3.6 to 7.3)
Annual	12	14	16	2.4 (2.0 to 4.6)	3.8 (3.5 to 7.3)

TABLE 2: REGIONAL AVERAGE NIGHTTIME LOW TEMPERATURE (TN)

	Past (°C)	2050s (°C)	2080s (°C)	2050s Change (°C)	2080s Change (°C)
Winter	−0.5	1.5	3	2.0 (1.8 to 3.7)	3.6 (3.4 to 7.1)
Spring	3	5	6	2.2 (1.4 to 3.7)	3.3 (2.9 to 5.9)
Summer	10	13	15	2.7 (2.3 to 4.4)	4.7 (3.9 to 7.6)
Fall	5	8	9	2.9 (2.2 to 4.8)	4.2 (3.7 to 7.3)
Annual	4	7	8	2.4 (2.0 to 4.3)	3.9 (3.6 to 6.8)

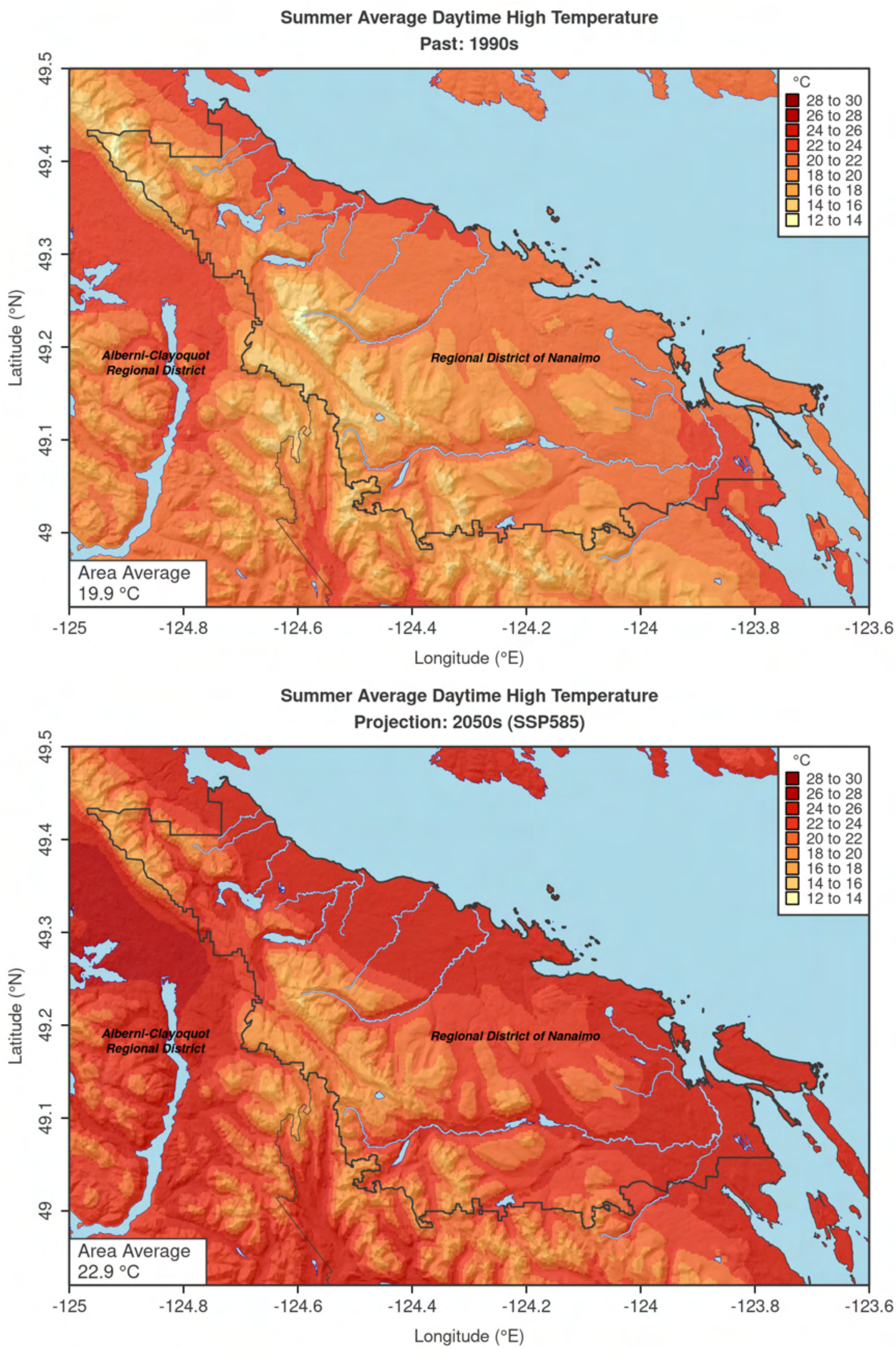
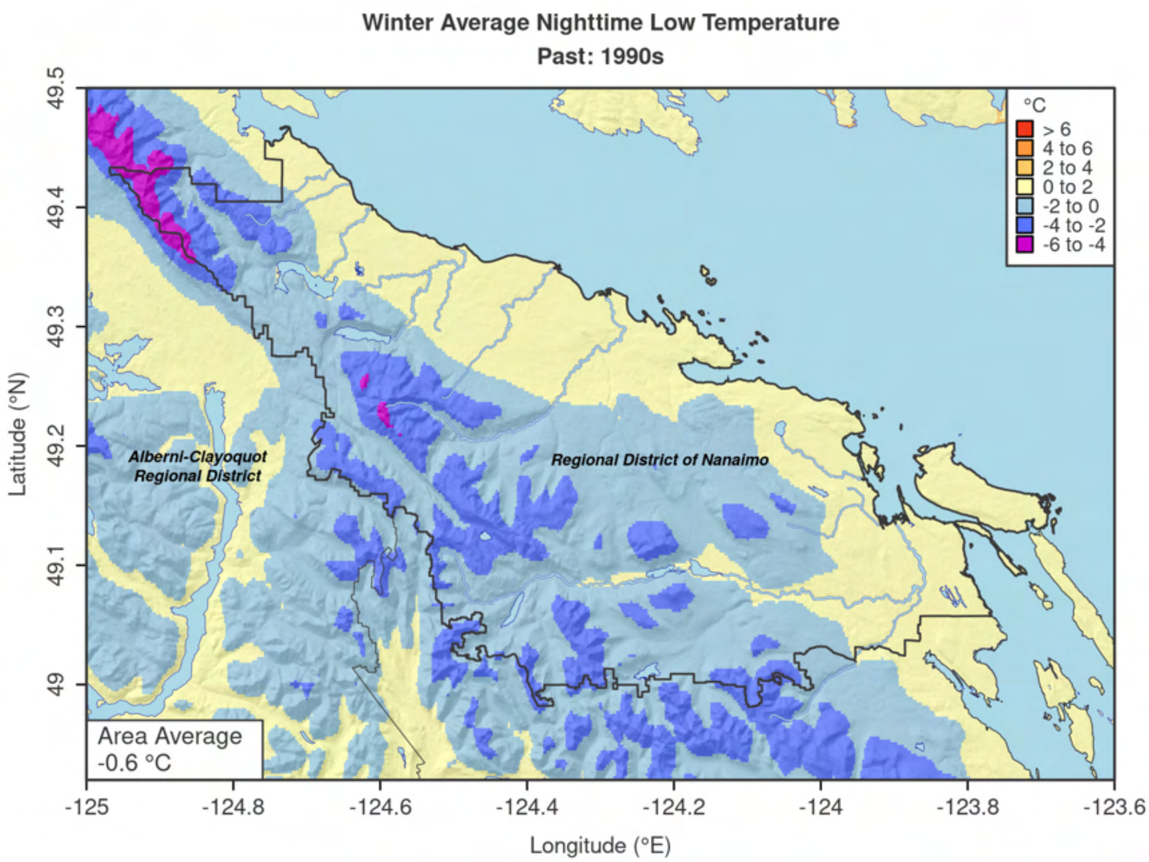


Figure 6. *Upper*: Summer average daytime high temperature in the Past. *Lower*: Projected summer average daytime high temperature in the 2050s.



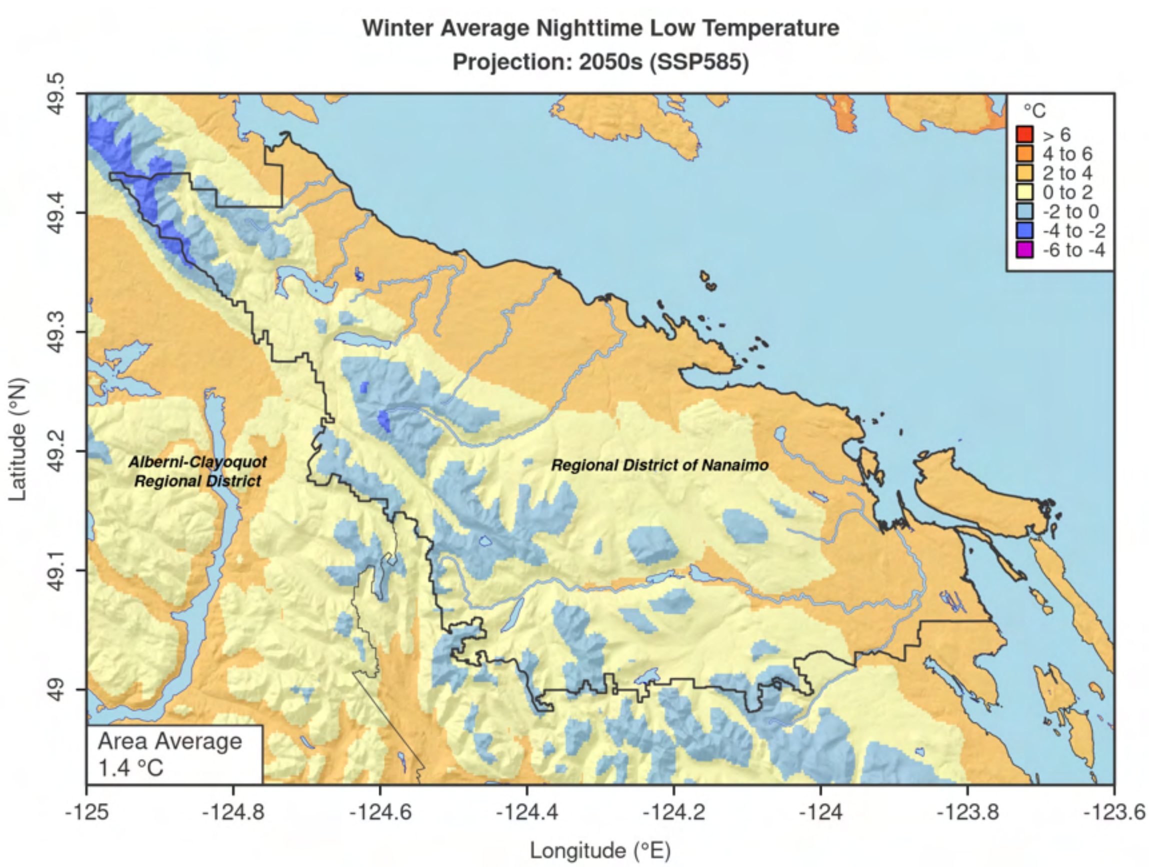
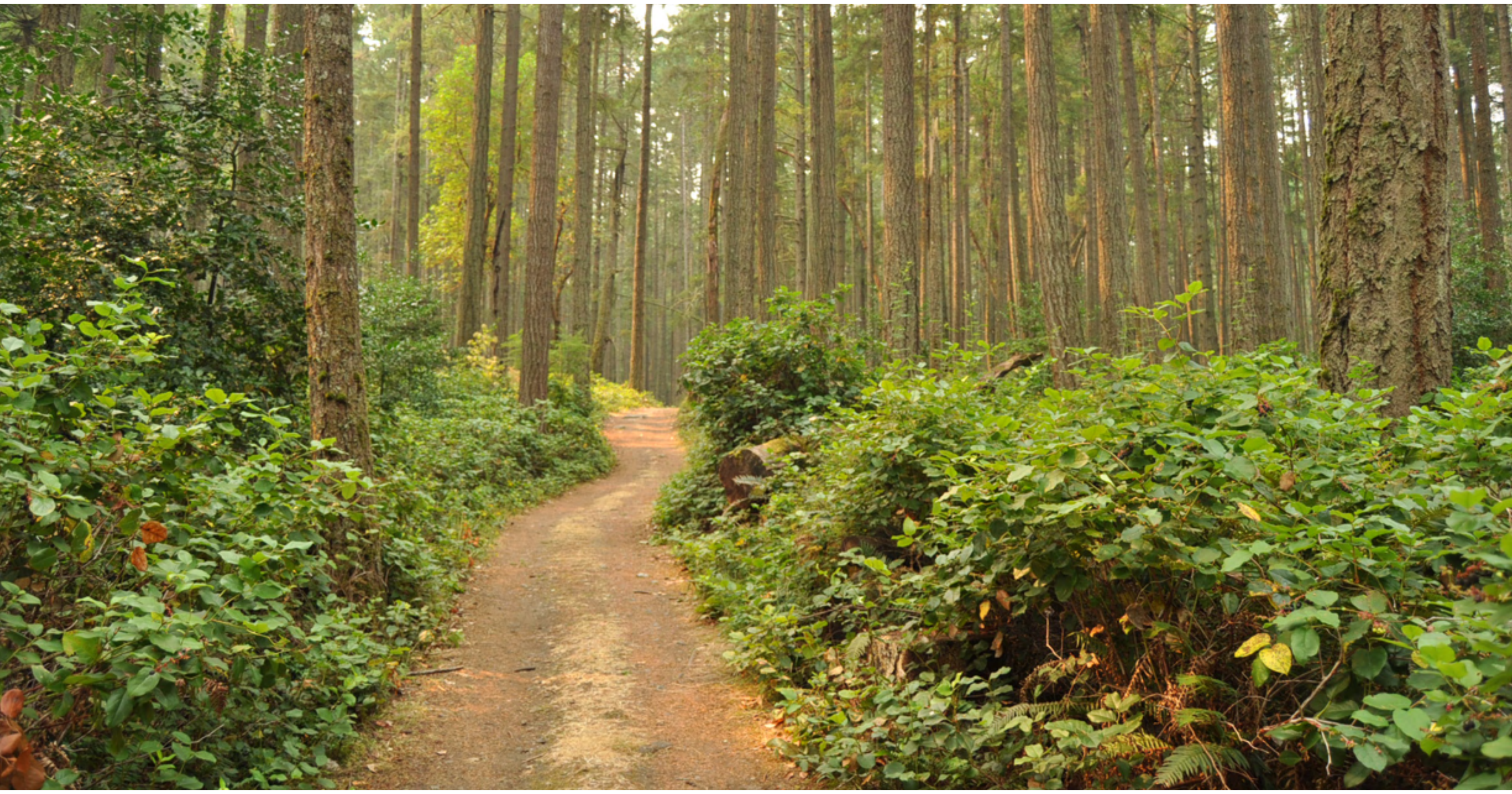


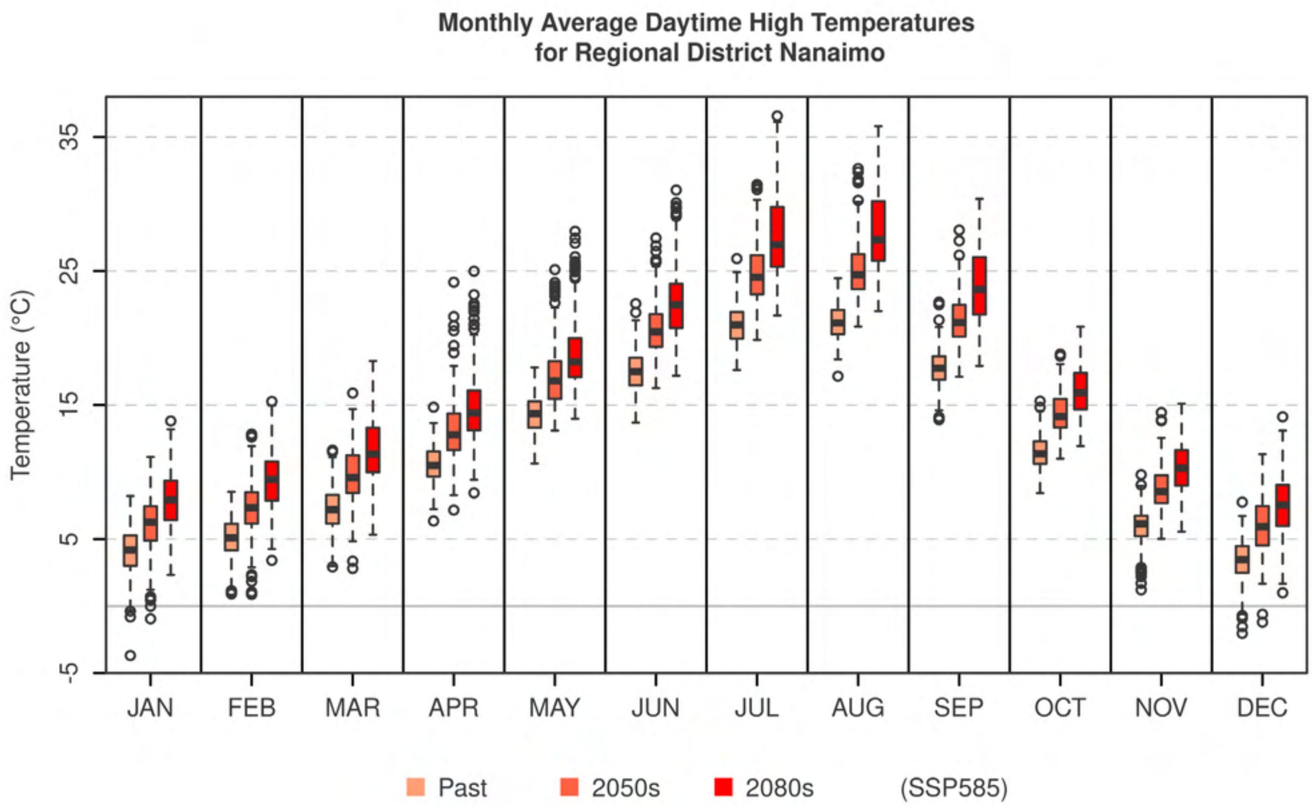
Figure 7. *Upper*: Winter average nighttime low temperature in the Past. *Lower*: Projected winter average nighttime low temperature in the 2050s.

3.2 Seasonal Temperature Change and Variability

Future-projected temperatures are compared with Past temperatures on a monthly basis in the figure below. The box-and-whisker plots reflect both year-to-year and model-to-model variability in all 30 Januarys, Februarys, etc., over the Past and future periods. Some features worth noting are:

- Freezing temperatures in December and January become increasingly rare in the future.
- Spring—loosely defined as the beginning of the growing season, when daily mean temperature consistently exceeds 5°C; see Chapter 5: Summer Temperature Indicators—begins earlier in the future, while fall—defined similarly as the end of the growing season—ends later, resulting in an effectively shorter winter season.
- The frequency of high extremes in summer increases notably, with July and August average daytime high temperatures exceeding 23°C in about 75% of models and years by the 2050s.





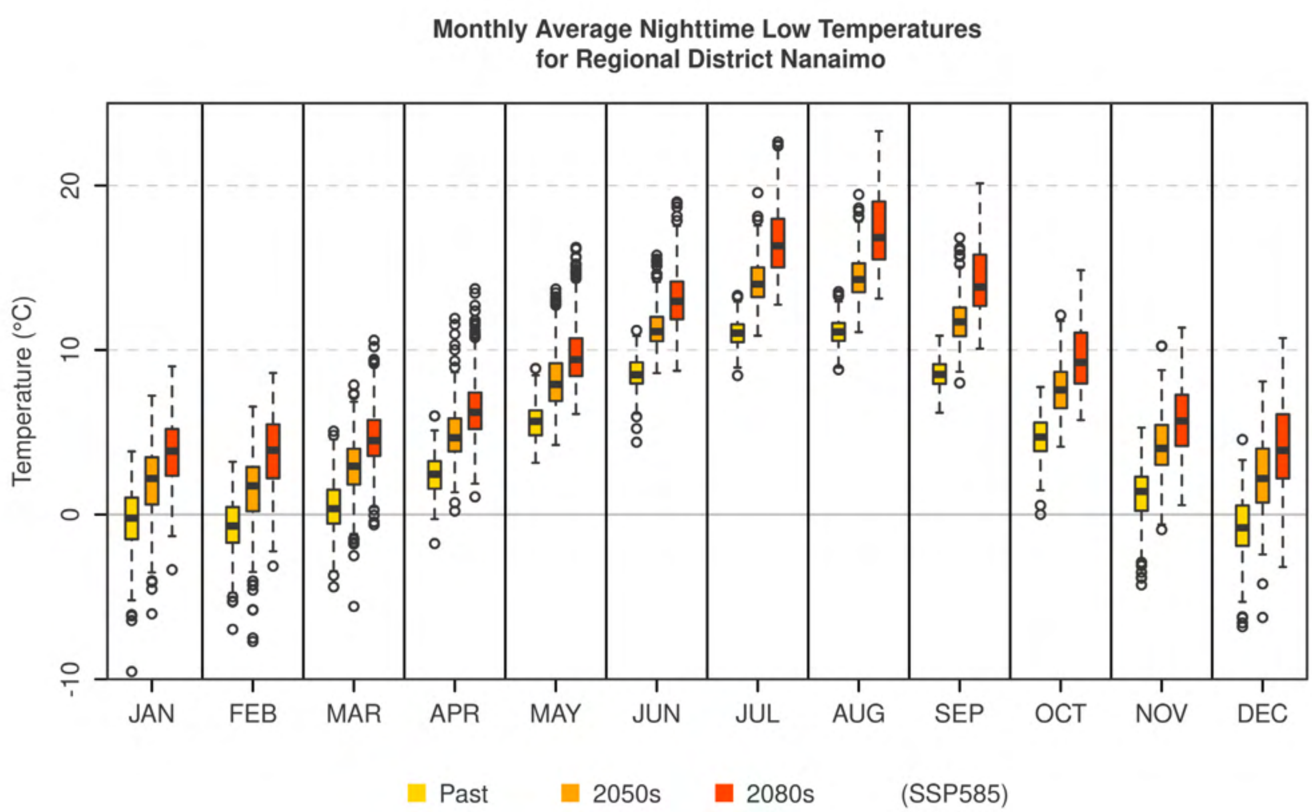


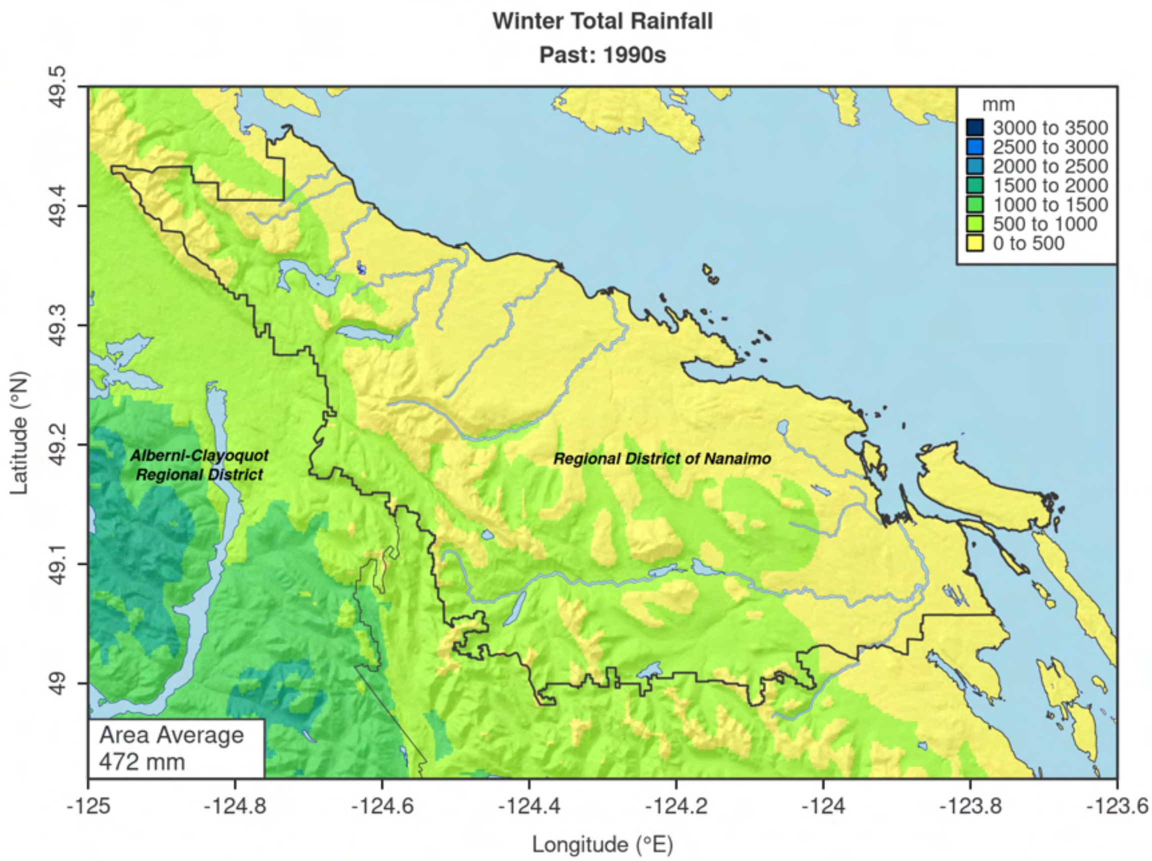
Figure 8. *Upper*: Annual cycle of monthly mean daytime high temperature in the Past, 2050s and 2080s periods under the SSP585 scenario. *Lower*: Annual cycle of monthly mean nighttime low temperature in the Past, 2050s and 2080s periods under the SSP585 scenario.

3.3 Wetter Winters, Drier Summers

Precipitation is the sum of rainfall and snowfall (expressed as water equivalent). Precipitation in the RDN has a strong seasonality, characterized by wet winters and dry summers. In the future projections, this behaviour is reinforced, so that winter becomes wetter (as do spring and fall) while summer becomes drier.

Projections

In tandem with the higher summer temperatures mentioned above—which increase potential evaporation—reduced summer rainfall heightens the possibility of drought conditions. Rainfall increases are highest in winter, displaying a 34% increase by the 2050s. Since the median increase in total winter precipitation by then is only +1%, we conclude that this is primarily due to the conversion of snow to rain under warmer winter conditions. While snowfall comprised about 21% of total precipitation in the Past, it amounts to only 9% in the 2050s. By the 2080s, the RDN should receive less snow in winter than it did in spring and fall in the Past.



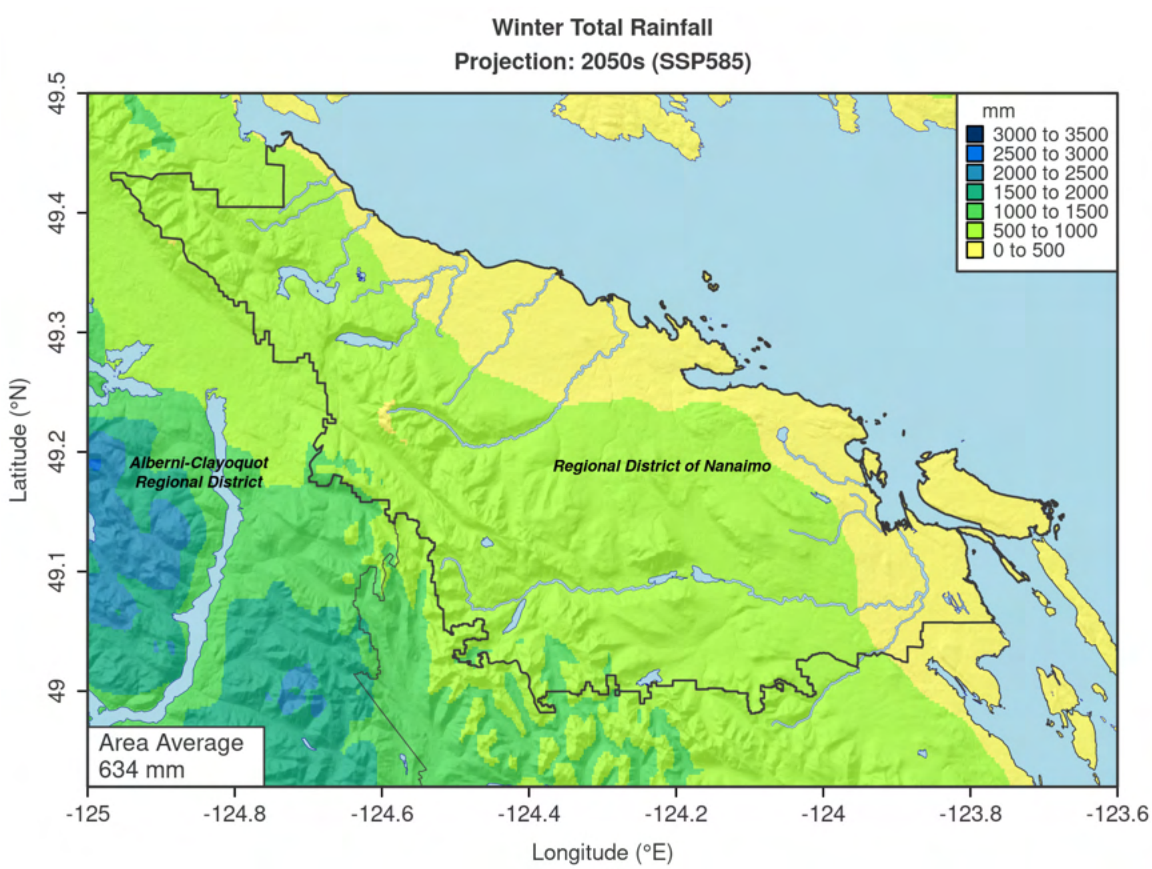


Figure 9. *Upper*: Winter rainfall in the Past. *Lower*: Projected winter rainfall in the 2050s.

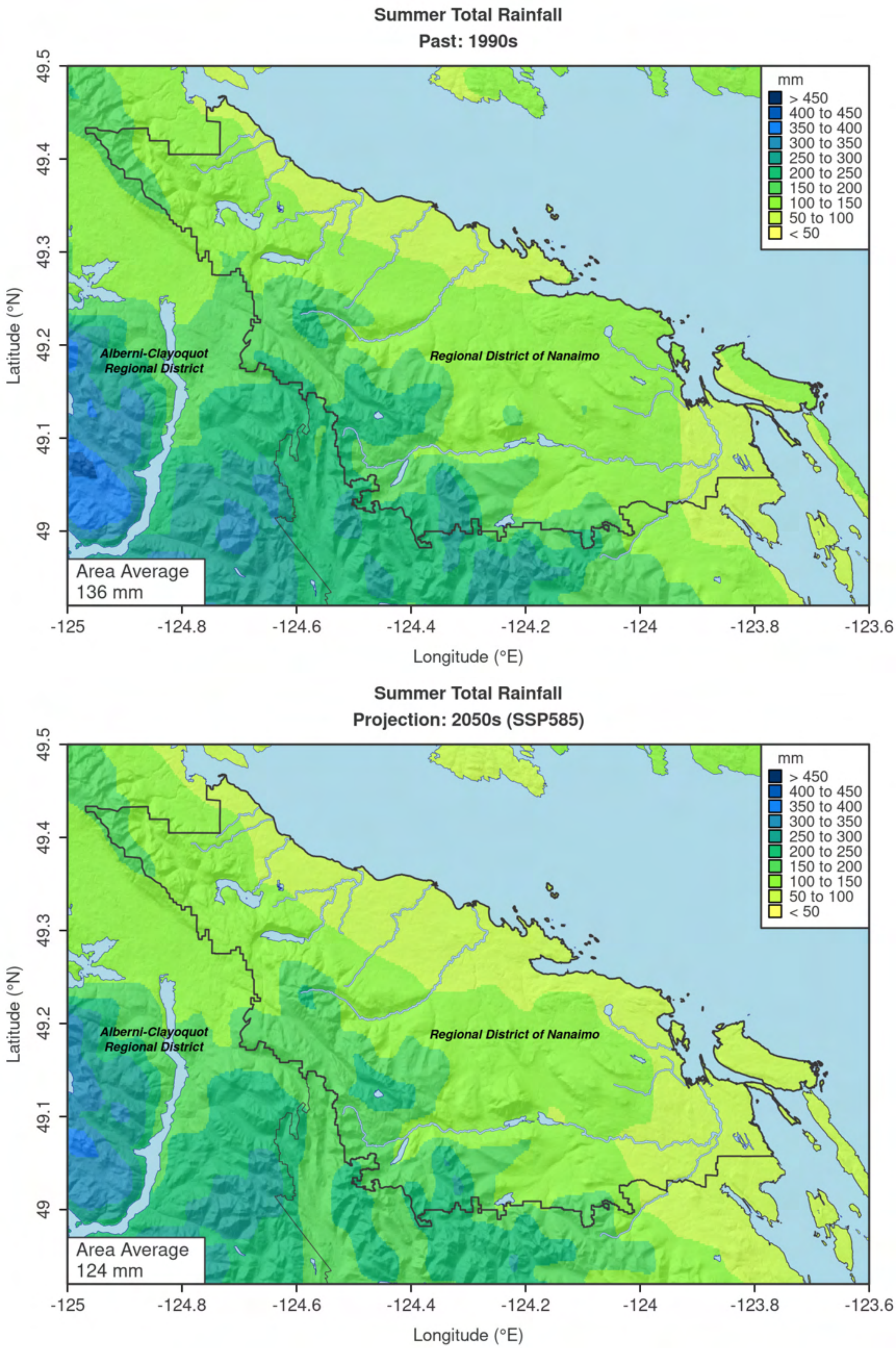


Figure 10. *Upper*: Summer rainfall in the Past. *Lower*: Projected summer rainfall in the 2050s.

TABLE 3: AVERAGE PRECIPITATION (RAIN AND SNOW) OVER THE RDN

	Past (mm)	2050s (mm)	2080s (mm)	2050s Change (%)	2080s Change (%)
Winter					
Rain	472	634	864	34 (24 to 54)	55 (40 to 77)
Snow	262	132	71	−50 (-76 to -40)	−73 (-96 to -67)
Spring					
Rain	318	375	400	18 (12 to 27)	26 (11 to 35)
Snow	60	22	9	−63 (-83 to -36)	−85 (-98 to -69)
Summer					
Rain	136	124	129	−9 (-27 to 0)	−14 (-38 to -5)
Fall					
Rain	479	573	770	20 (14 to 30)	32 (18 to 42)
Snow	54	15	9	−72 (-92 to -54)	−83 (-99 to -77)
Annual					
Rain	1401	1706	1891	22 (15 to 34)	35 (23 to 42)
Snow	380	167	90	−56 (-79 to -43)	−76 (-96 to -69)
Precipitation*	1782	1876	1983	5 (1 to 14)	11 (1 to 15)

* Note that in future, the summed medians of rain and snow may not equal the median precipitation, since the distribution of the two quantities may vary across the model ensemble.

3.4 Seasonal Precipitation Change and Variability

While precipitation in the RDN exhibits a notable seasonality, with far larger amounts in the colder months, this occurs against the background of high year-to-year variability. As a result, a climate change signal is more difficult to distinguish in precipitation than in temperature. One exception is the projected strong decline in snowfall, summarized in Table 3 and later in Figure 19. Combined with an increase in annual total precipitation of +5%, the resulting median projection of annual total rainfall for the entire region in the 2050s is +22%. The figure below shows model estimates of monthly total rainfall in the Past and both future periods. While median values increase in the colder months throughout the century, what is more striking are the changes in variability (occurring across both individual models and years, as shown for temperature above). For example, we note the occurrence of higher extreme monthly rainfall amounts in future periods, especially during the autumn months; some November and December rainfall totals could reach 600 mm in future, compared to around 400-500 mm in the Past.[6]

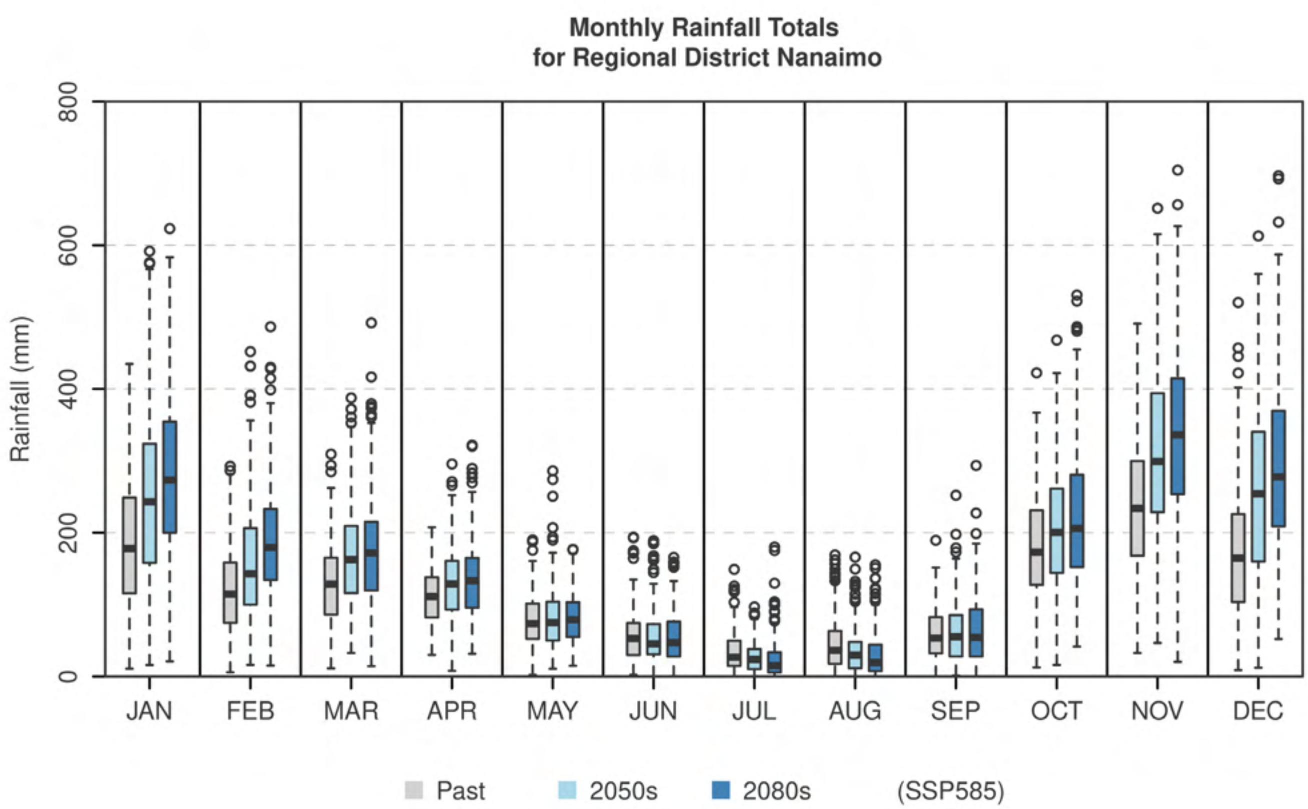
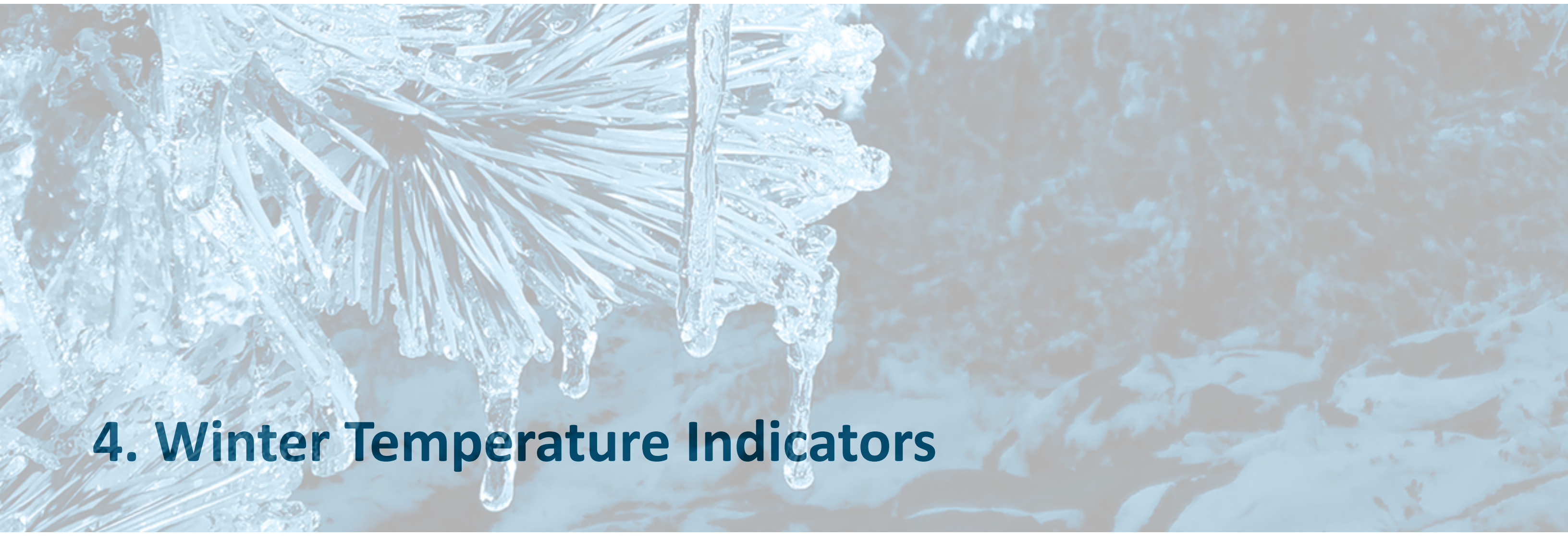


Figure 11. Annual cycle of total monthly rainfall in the Past, 2050s and 2080s periods.

6. 90th percentile values are cited. These totals are averaged across the RDN, with Past November values spanning a large range from the wetter southwest (~600 mm) to the drier east (~400 mm). For reference, the highest recorded November precipitation at Nanaimo International Airport is 477 mm (in 1983).



4. Winter Temperature Indicators

4.1 Warmest Winter Day, Coldest Winter Night

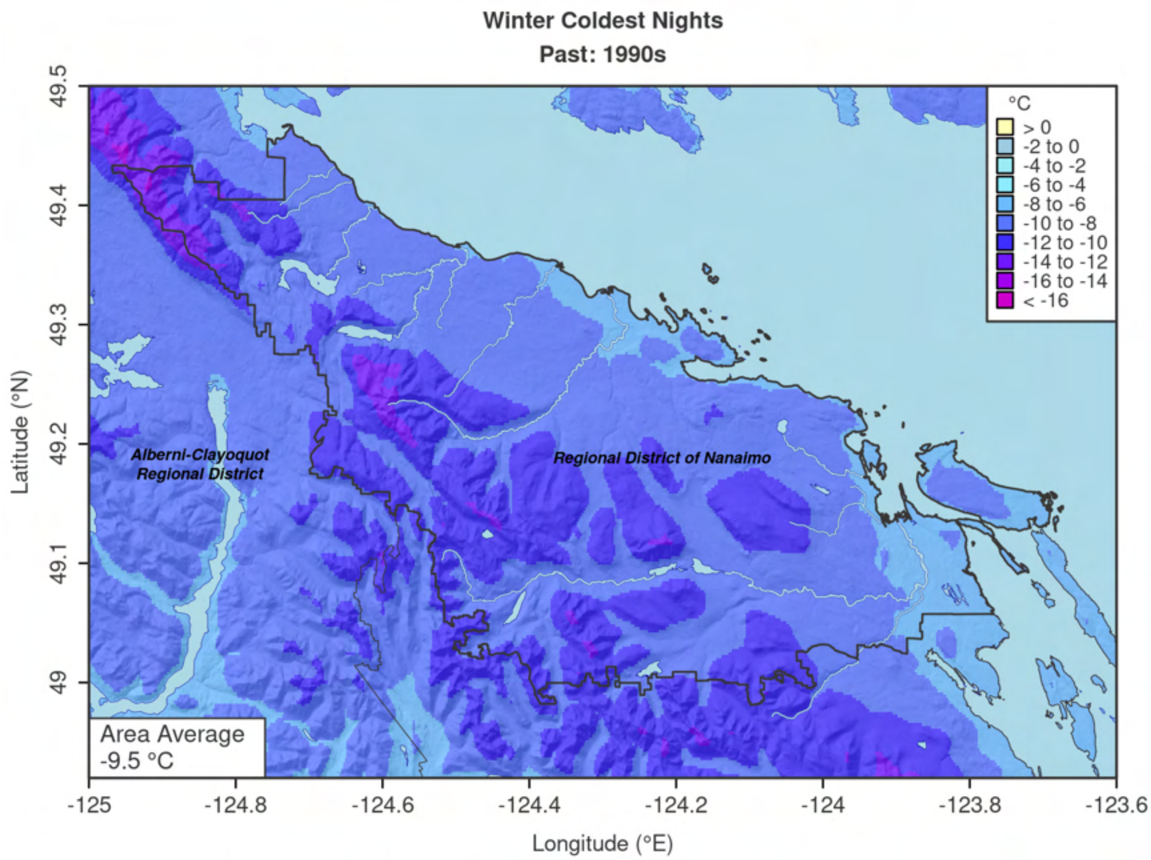
The *Warmest Winter Day* is the highest daily maximum temperature recorded during the winter months, in an typical year. When considered along with the Coldest Winter Night (i.e., lowest daily minimum temperature), these indicators describe the projected “new normal” for winters in our region.

Projections

By the 2050s, we can expect to see the warmest winter daytime temperature to rise from its Past value of 10°C to about 12°C, with a further increase to about 14°C by the 2080s.

In the Past, the coldest winter night had a temperature of about −9.5°C. Models project winter lows to increase by roughly 3.5°C by the 2050s, to −6°C, and by 6.5°C by the 2080s, to −3°C. The maps below illustrate this warming by the 2050s, and how it varies across the region according to elevation and proximity to the ocean.

Warming winter temperatures will lead to an increased fraction of precipitation falling as rain instead of snow. Snow accumulation events, which typically occur a few times each winter in the region, will still occur, but less frequently.



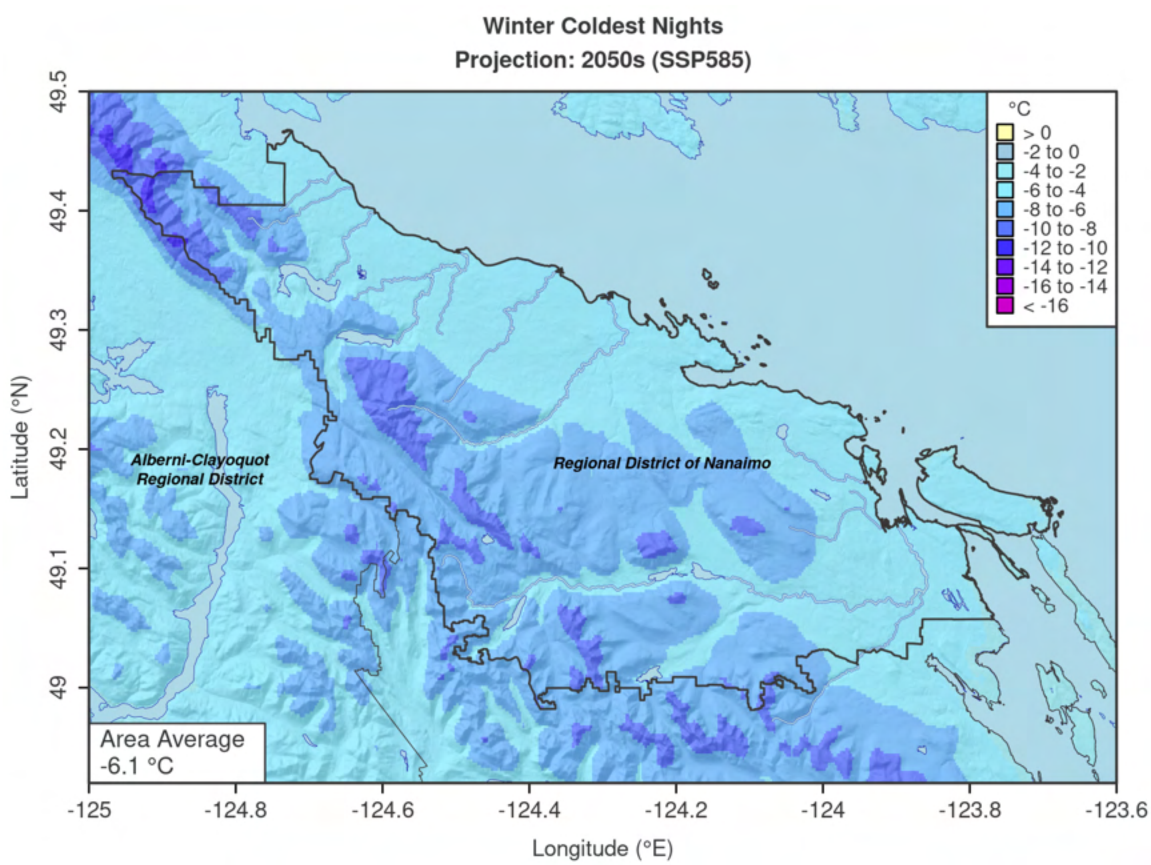


Figure 12. *Upper*: Coldest winter night in the Past. *Lower*: Projected coldest winter night in the 2050s.

4.2 1-in-20-Year Coldest Nighttime Low Temperature

This indicator describes extreme cold temperatures so low that they are expected to occur only once every 20 years in the historical climate. Equivalently, in the recent past, the *1-in-20 Year Coldest Night* had a 5% chance of occurring in any given year.[7]

Projections

In the Past, the 1-in-20 coldest night had a temperature of around −17°C. In the future, the 1-in-20 coldest night across the region will increase by about 5°C by the 2050s and by about 8.5°C by the 2080s.

TABLE 4: WARMER WINTER EXTREME TEMPERATURES

	Past (°C)	2050s (°C)	2080s (°C)	2050s Change (°C)	2080s Change (°C)
Warmest winter day	10	12	14	2 (1.8 to 4.1)	4 (3.2 to 6.7)
Coldest winter night	−9.5	−6	−3	3.5 (3 to 5.2)	6.5 (5.7 to 11)
1-in-20 coldest nighttime low	−17	−12	−8.5	5 (3 to 6.6)	8.5 (7 to 13)

4.3 Frost Days and Ice Days

Frost Days is an annual count of days when the daily minimum temperature is less than 0°C which may result in frost at ground level. This indicator is useful to help predict how changes in the number of days with minimal temperatures below freezing could affect native and agricultural plant species.

Ice Days occur when daytime high temperatures do not exceed 0°C. While some of the same effects are expected as for frost days, these freezing temperatures may also affect transportation via the increased chance of icy road conditions.

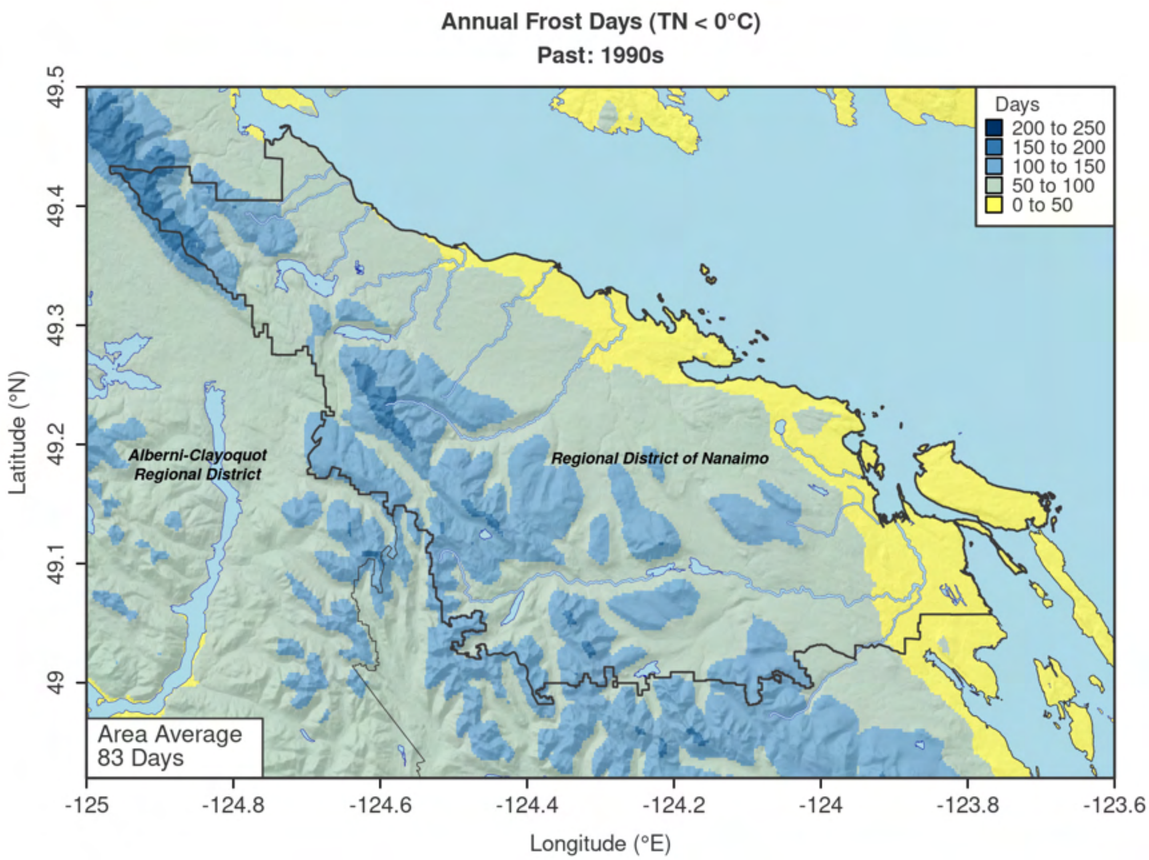
Projections

In the Past, the RDN experienced an average of 83 frost days and 13 ice days per year. In the 2050s, we should expect far fewer such days: around half as many frost days by the 2050s and around one-quarter as many by the 2080s. Ice days may be very rare by the mid- to late-century.

TABLE 5: ANNUAL FROST AND ICE DAYS

	Past (days)	2050s (days)	2080s (days)	2050s Change (days)	2080s Change (days)
Frost Days (days with daily minimum temperature TN < 0°C)					
RDN	83	41	24	−42 (−64 to −33)	−59 (−77 to −56)
Lowlands	59	23	10	−36 (−51 to −28)	−49 (−57 to −47)
Highlands	113	64	41	−49 (−82 to −40)	−72 (−105 to −66)
Ice Days (days with daytime high temperatures TX < 0°C)					
RDN	13	5	2	−8 (−10 to −6)	−11 (−12 to −9)

7. Note that the occurrence of such an event in one year doesn't preclude its occurrence in the following years, which is why the annual exceedance probability (i.e. 5% chance, in this case) is a helpful equivalent measure.



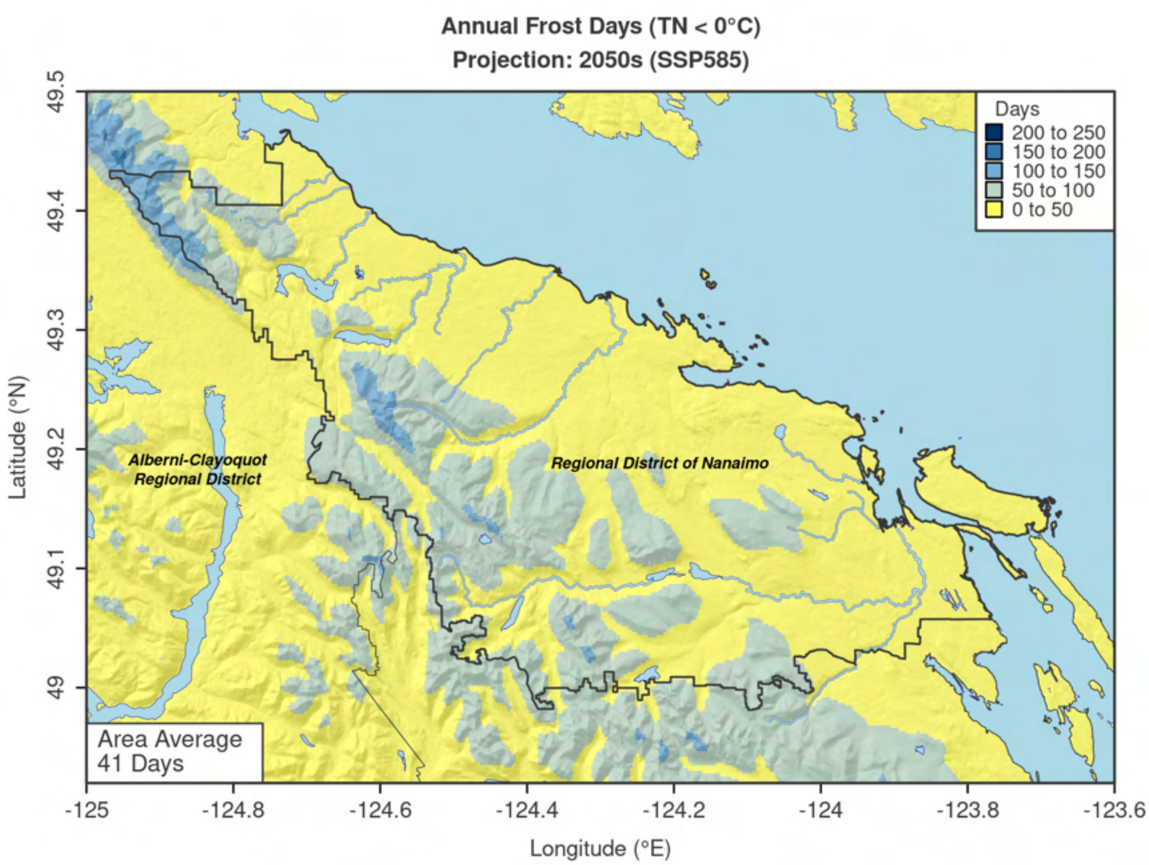


Figure 13. *Upper*: Number of annual frost days (days where the nighttime low temperature (TN) < 0°C) in the Past. *Lower*: Projected number of annual frost days in the 2050s.

4.4 Heating Degree Days

Heating Degree Days (HDD) are calculated by summing the number of degrees that the daily mean temperature falls below 18°C for every day in a year.[8] This measure is commonly used to estimate the heating demand for buildings in the cooler months.

Projections

In the Past, the RDN had a median of roughly 3670 HDD.[9] The median future-projected HDD decreases to 2905 (a 21% decrease) by the 2050s and to 2500 (a 32% decrease) by the 2080s. Due to its cumulative nature, a reduction in HDD is amongst the clearest indicators of warming, both in recent historical observations and in model projections. In addition, it should be noted that HDD varies considerably from high elevation (higher values) to low elevation (lower values) over the region.

Note that while mean winter temperatures will warm throughout the coming decades, the RDN's continued exposure to easterly polar outflows from Northwestern Canada through the Cascade Range suggests that the potential for multi-day cold snaps will persist in the future, though they should be less frequent. For this reason, building heating systems will still need to be responsive to occasional sub-zero winter temperatures.

TABLE 6: HEATING DEGREE DAYS

	Past (°C-days)	2050s (°C-days)	2080s (°C-days)	2050s Change (%)	2080s Change (%)
RDN	3670	2905	2500	−21 (−37 to −18)	−32 (−54 to −30)
Lowlands	3220	2490	2130	−23 (−40 to −20)	−32 (−54 to −30)
Highlands	4245	3445	2980	−19 (−35 to −17)	−30 (−50 to −28)

8. For example, if the daily mean temperature on January 1 is 10°C, followed by one day of 4°C, two days of −1°C and three days of 0°C, then HDD for that week are calculated as: (18−10) + (18−4) + 2 × (18−(−1)) + 3 × (18−0) = 114 degree-days. Note that days with a temperature equal to or greater than 18°C are not counted.
9. Someone consulting the tables for the National Building Code of Canada (NBCC, 2015) will see a different value of HDD listed for the downtown Nanaimo location than the Past values cited in Table 6. One reason for this is the larger area covered by our subregions, which include higher-elevation areas. Another is the different methodology and period of observations used to calculate HDD in the NBCC. As our estimate depends to some extent on coarse-grained climate models, while the NBCC employs interpolated station data, the NBCC value would normally be considered more reliable at the stated location. For those interested in future HDD estimates, the relative differences from Past values can be used for HDD projections, regardless of which baseline value is used.

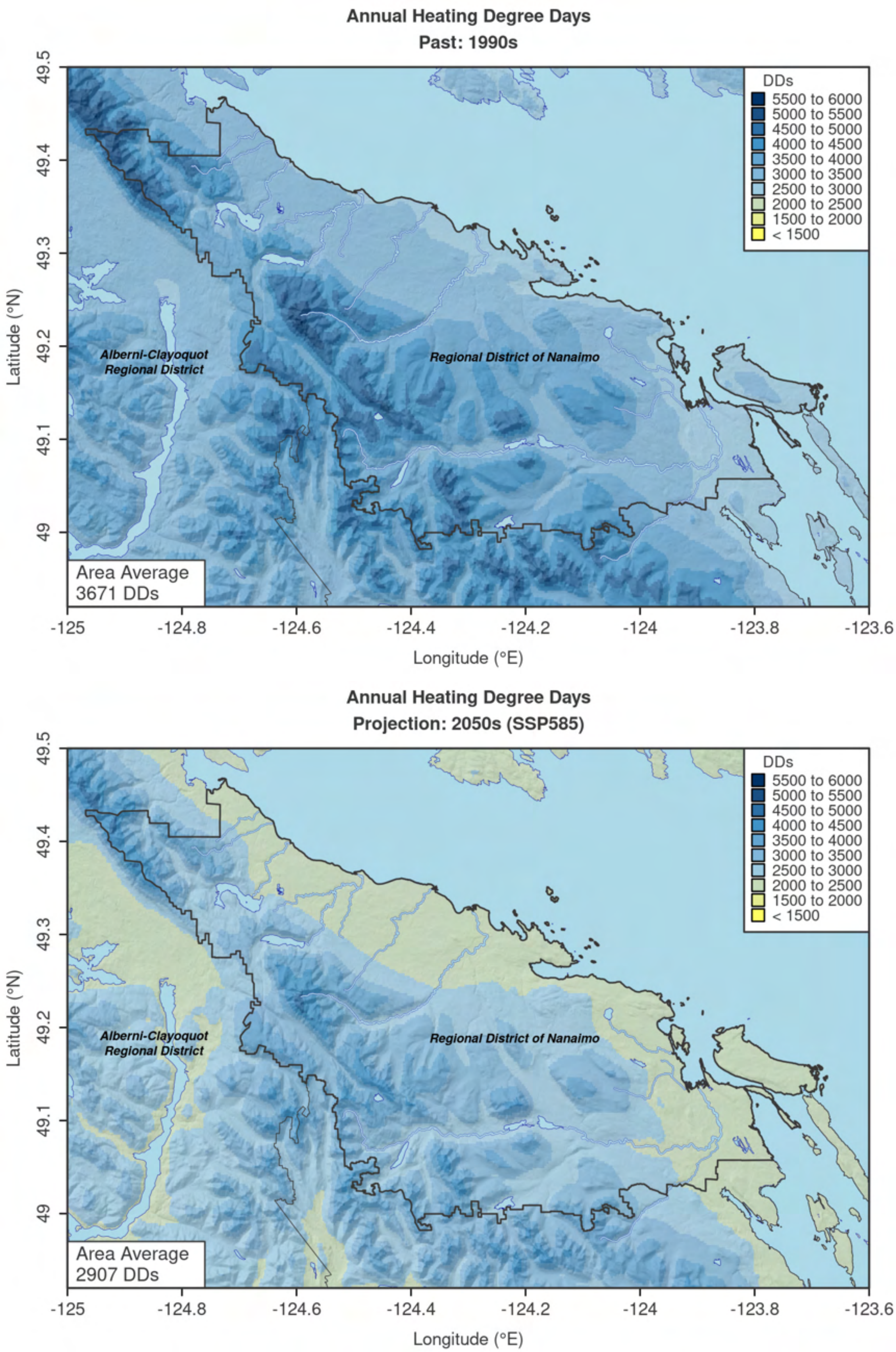


Figure 14. *Upper*: Annual number of heating degree days (HDD) in the Past. *Lower*: Projected annual number of HDD in the 2050s. HDD are the total number of degrees that the daily mean temperature is below 18°C for every day in a year.

5. Summer Temperature Indicators

5.1 Growing Season Length

Growing Season Length (GSL) is an annual measure indicating the period when temperatures are warm enough for most vegetation to grow. The GSL is the number of days between the first span of at least 6 consecutive days with daily average temperatures above 5°C, and the first span, after July 1, of 6 days with temperatures below 5°C. This measure helps to highlight how forested areas, agricultural and landscaped areas, grasses, weeds (and their pollens) may be affected by climate change.

Projections

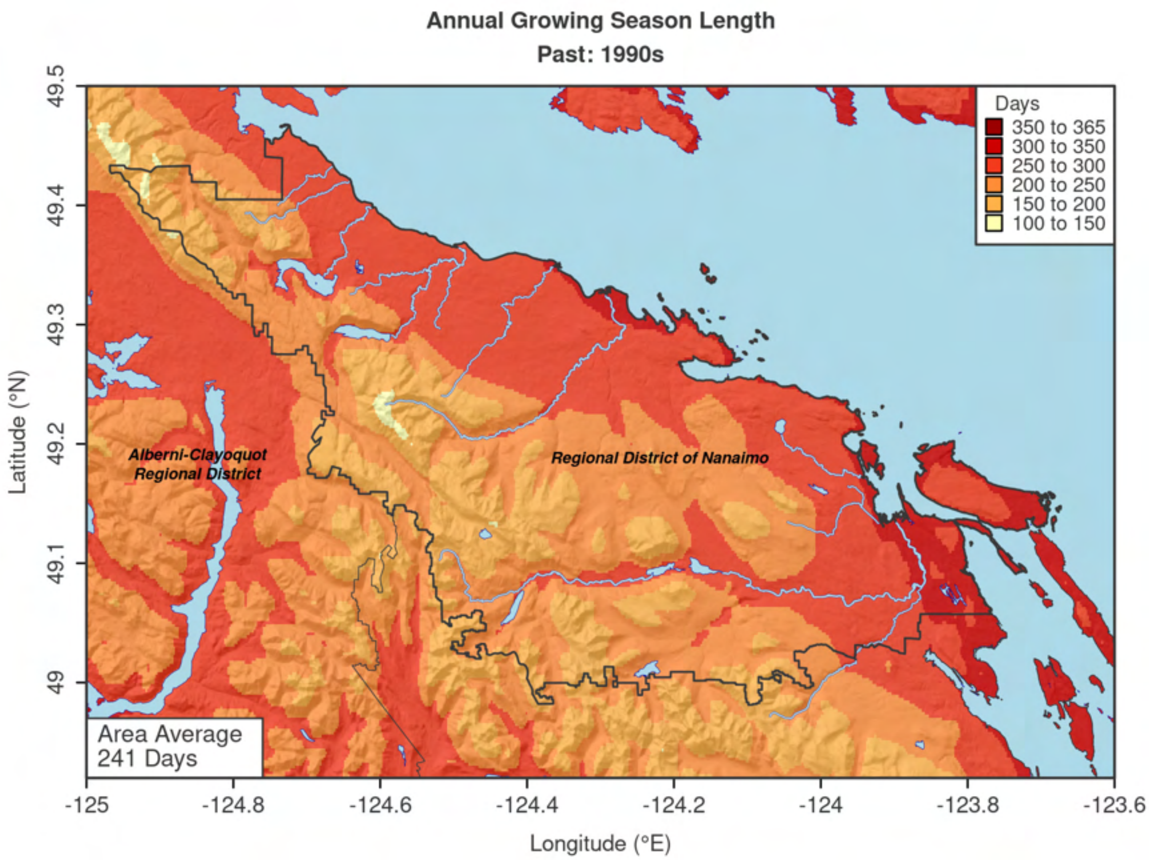
In the Past, the growing season lasted roughly 240 days in the RDN. The median future-projected growing season increases by 55 days to 295 days by the 2050s and by 80 days to around 320 days by the 2080s.

Other things being equal, a longer GSL implies potentially more productive vegetation in the future. However, since GSL uses only a lower temperature threshold (and not an upper threshold to account for heat stress) and ignores changes in precipitation, it should be considered an upper limit for estimates of future productivity.

A related measure to GSL is the length of the frost-free season, which uses a lower threshold of 0°C for minimum daily temperature. As mentioned above, frost days will become increasingly rare in the future, resulting in frost-free conditions nearly year-round in the RDN by the 2080s.

TABLE 7: GROWING SEASON LENGTH

	Past (days)	2050s (days)	2080s (days)	2050s Change (days)	2080s Change (days)
RDN	240	295	320	55 (42 to 82)	80 (71 to 113)
Lowlands	275	325	343	50 (36 to 70)	70 (59 to 85)



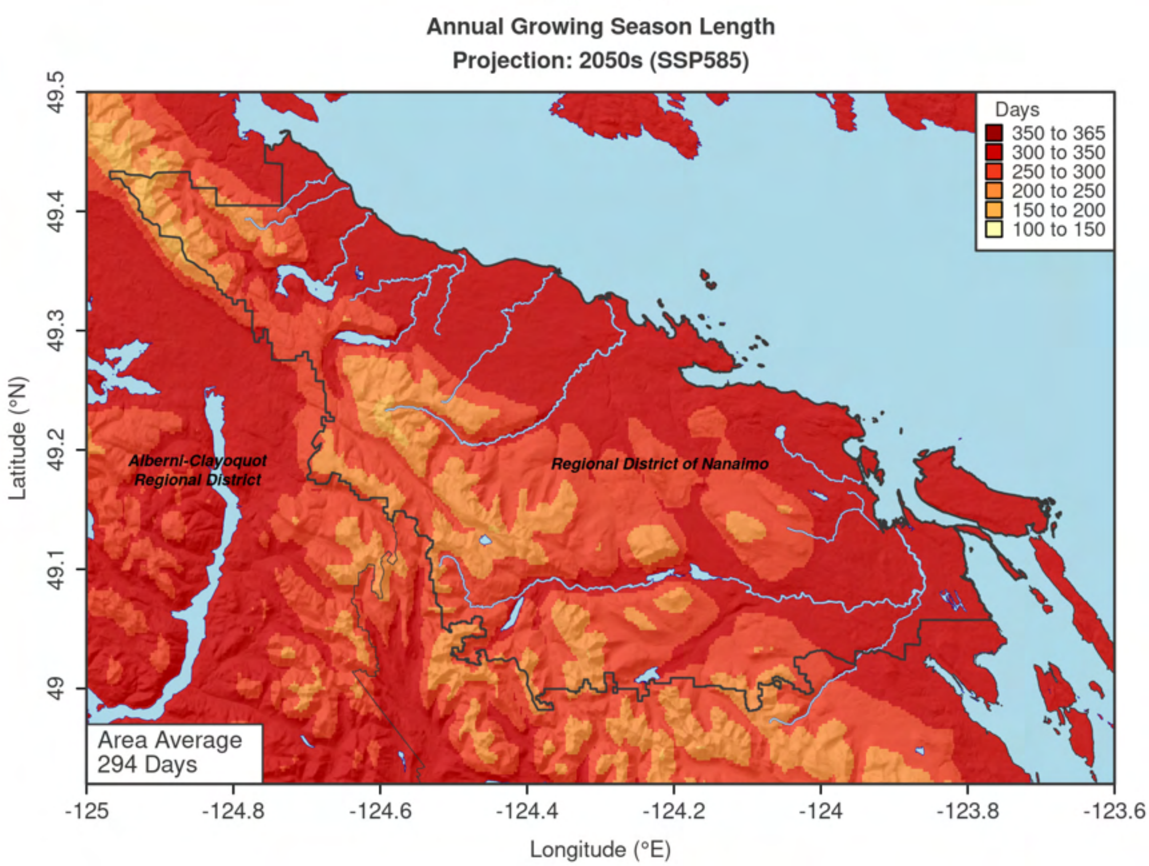


Figure 15. *Upper*: Annual growing season length (GSL) in the Past. *Lower*: Projected (increased) annual GSL growing season length by the 2050s. GSL is a measure of the period when temperatures are warm enough for most vegetation to grow.

5.2 Cooling Degree Days

The opposite of HDD, *Cooling Degree Days* are calculated by summing the number of degrees that the daily mean temperature exceeds 18°C for every day in a year.[10] This measure is commonly used to estimate the demand for mechanical cooling (i.e., air conditioning) in buildings in the warmer months.

Projections

In the Past, the RDN typically had around 25 cooling degree days, with the vast majority of such days occurring in summer. The median future-projected cooling degree days increase to about 140 (a nearly 6-fold increase) by the 2050s and to roughly 260 (a greater than 10-fold increase) by the 2080s. While most such days will continue to occur in summer, they will increasingly occur during late spring and early fall.

Like the projected decrease in HDD, an increase in cooling degree days is among the clearest indicators of warming, both in recent historical observations and model projections. Moreover, the magnitude of increase varies considerably from higher (lower values) to lower (higher values) elevations across the RDN. To the extent that this index correlates with demand for cooling, new buildings may need to be designed differently to maintain thermal comfort.

TABLE 8: COOLING DEGREE DAYS

	Past (°C-days)	2050s (°C-days)	2080s (°C-days)	2050s Change (°C-days)		2080s Change (°C-days)	
RDN	25	140	260	115	(72 to 259)	235	(195 to 615)
Lowlands	35	205	355	170	(107 to 345)	320	(266 to 749)

10. For example, if the daily mean temperature on July 1 is 20°C, followed by three days of 21°C, one day of 25°C and two days of 16°C, then the cooling degree days for that week are calculated as: (20−18) + 3 × (21−18) + (25−18) = 18 degree-days. Note that days with temperature equal to or less than 18°C are not counted.

5.3 Measures of Extreme Heat

These indicators highlight the most extreme warm temperatures occurring in the region. The results in the table below are for the Lowlands of RDN, which has the highest population and can expect to witness the most significant changes to measures of extreme heat in the future. Three single-day extreme heat measures are included in Table 9. These are (i) the peak temperature of the hottest day of the year (not necessarily occurring during a heatwave); (ii) the number of days with a daytime high temperature greater than 25°C (*Summer Days*), and (iii) the number of nights with a nighttime low temperature greater than 16°C (*Temperate Nights*). Episodes of multi-day extreme heat, which were rare in the Past, are captured by several heatwave (HW) indicators defined in the Appendix. These are partly based on threshold temperatures for emergency health alerts used specifically in BC.[11] As with the variables discussed above, each of the indices describes a typical year within the indicated 30-year period.

Projections

In the Past, there were typically around 17 days per year with a high temperature exceeding 25°C in the RDN Lowlands, and rarely did nighttime temperatures rise above 16°C. The median future-projected number of summer days increases to roughly 50 per year by the 2050s and 70 per year by the 2080s. In concert with this, temperate nights are projected to occur more frequently in the coming decades, with a frequency of 19 per year in the 2050s and 54 per year in the 2080s.

In the Past, the RDN Lowlands typically witnessed roughly one heatwave per year that lasted up to 3 days and had a peak daily temperature of around 30°C. The median future-projected number of heatwaves increases to roughly 4 per year by the 2050s and 6 per year by the 2080s. Heatwaves are also projected to increase in length in the future (approaching 9 consecutive days or more by the 2080s) and will feature both warmer daytime and nighttime temperatures. It is clear that residents of the area will need to adapt to more frequent, longer, and intense heatwaves in future.

TABLE 9: MEASURES OF EXTREME HEAT FOR RDN LOWLANDS

Index	Description	Past	2030s	2050s	2080s
HWD	Number of days classified as a heat wave (days)	1	5 (3 to 13)	12 (7 to 34)	27 (21 to 79)
HWXL	Maximum length of heat wave (days)[12]	3	4 (3 to 6)	5 (4 to 13)	9 (7 to 46)
HWN	Annual number of heat waves	1	2 (1 to 4)	4 (2 to 6)	6 (4 to 7)
TXX	Maximum temperature on hottest day of the year (°C)	30	32 (31 to 33)	33 (32 to 26)	35 (34 to 39)
SU	Number of days with maximum temperature > 25°C	17	36 (28 to 51)	49 (38 to 79)	70 (64 to 113)
TR16C	Number of nights with minimum temperature > 16°C	1	7 (5 to 17)	19 (12 to 50)	54 (40 to 103)

11. See the report, BC Provincial Heat Alert and Response System (BC HARS): 2023, May 2023. Available at: htp://www.bccdc.ca/health-professionals/professional-resources/heat-event-response-planning. The lower threshold temperatures used in our HW definition, which is intended for use throughout BC, are TX = 28°C and TN = 13°C. In addition, a HW must: 1) last at least 2 full days; and 2) have TX and TN exceeding their 95th percentile values in the Past.
12. It may seem strange that HWD < HWXL in the Past, but this is an artifact of small number statistics. Some years in the Past contained no HWs, leading to a mean annual value of 0.6 for HWD (rounded to 1 in the table, since some years had a HW). Nevertheless, one or more years had HW lengths of 2 or 3 days, leading to the mean HWXL = 2.8 days (rounded to 3) over the 30-year period. As the number of HWs increases in future years of the simulations, the expected behaviour HWD > HWXL emerges.

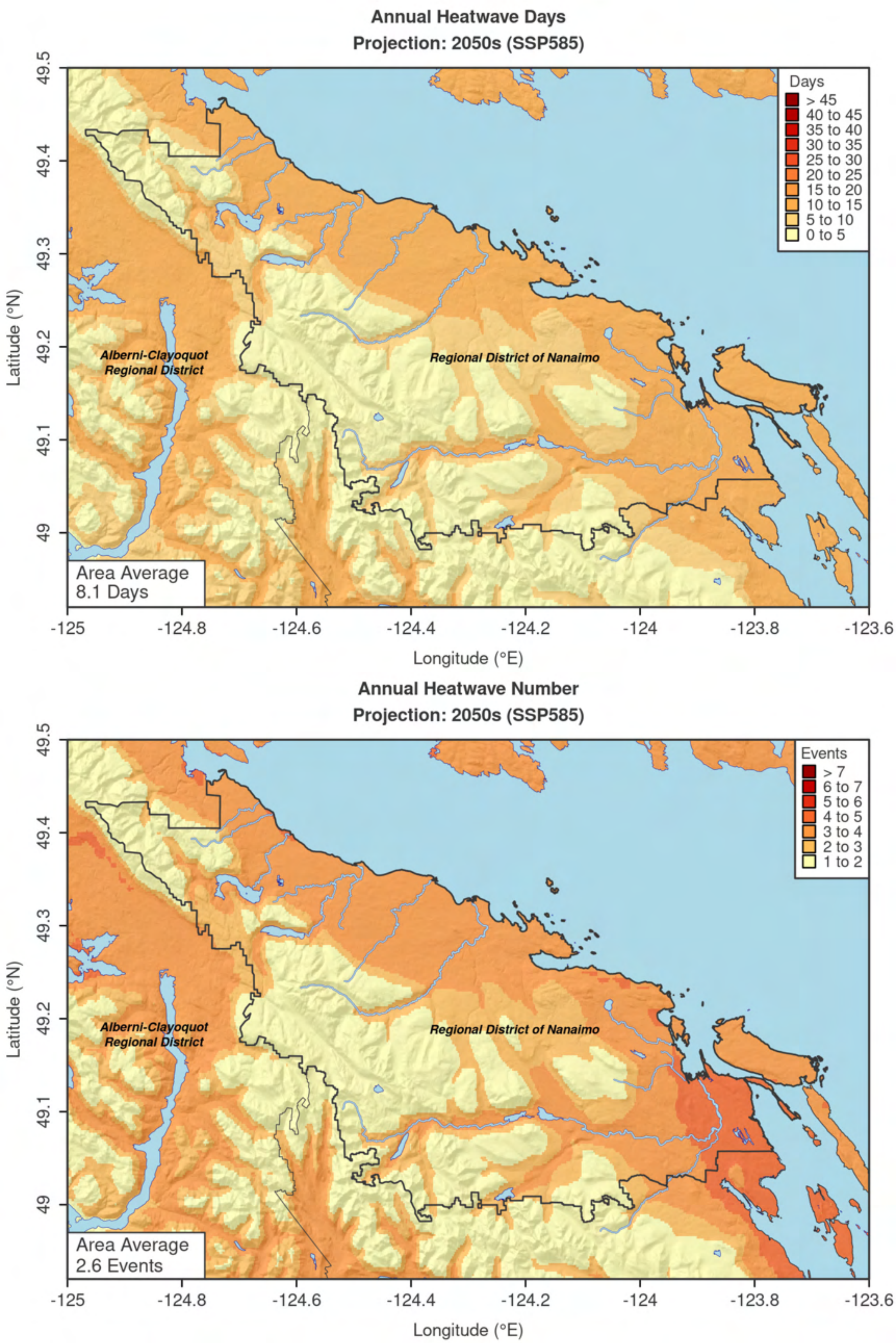


Figure 16. Projected annual count of heatwave days (*upper*) and number of annual heatwaves (*lower*) in the 2050s. Note that: (i) for both measures, counts in the Past are very low (about 1 per year) and uniform throughout the RDN; and (ii) average values for Lowlands (Table 9) are larger than RDN averages shown on the maps.

5.4 The 1-in-20-Year Annual Hottest Day

The *1-in-20 Year Hottest Day* describes extreme daily high temperatures so warm that they are expected to occur only once every 20 years in the historical climate. In other words, the 1-in-20 Year Hottest Day presently has a 5% chance of occurring in any given year. The figure below shows the projected changes in this type of event in two ways: first, in terms of how frequently an event of the same daily maximum temperautre (TX) value occurs in the future; and second, in terms of how much TX increases for an event occurring with the same frequency (or annual probability) in the future.

For example, in the Past, a daily maximum temperature of 32°C or higher occurred once every 20 years or so in the RDN, or with a 5% annual exceedance probability (AEP). In the projections for the 2050s, this temperature is exceeded nearly 10 times in a 20-year period, or with a 50% AEP. Alternatively, one can say based on the same projections that in the 2050s, the magnitude of a 1-in-20-year (5% AEP) event increases to around 35°C (see the 'Return Levels' tab in the SSP585 Summary Table of the data package).

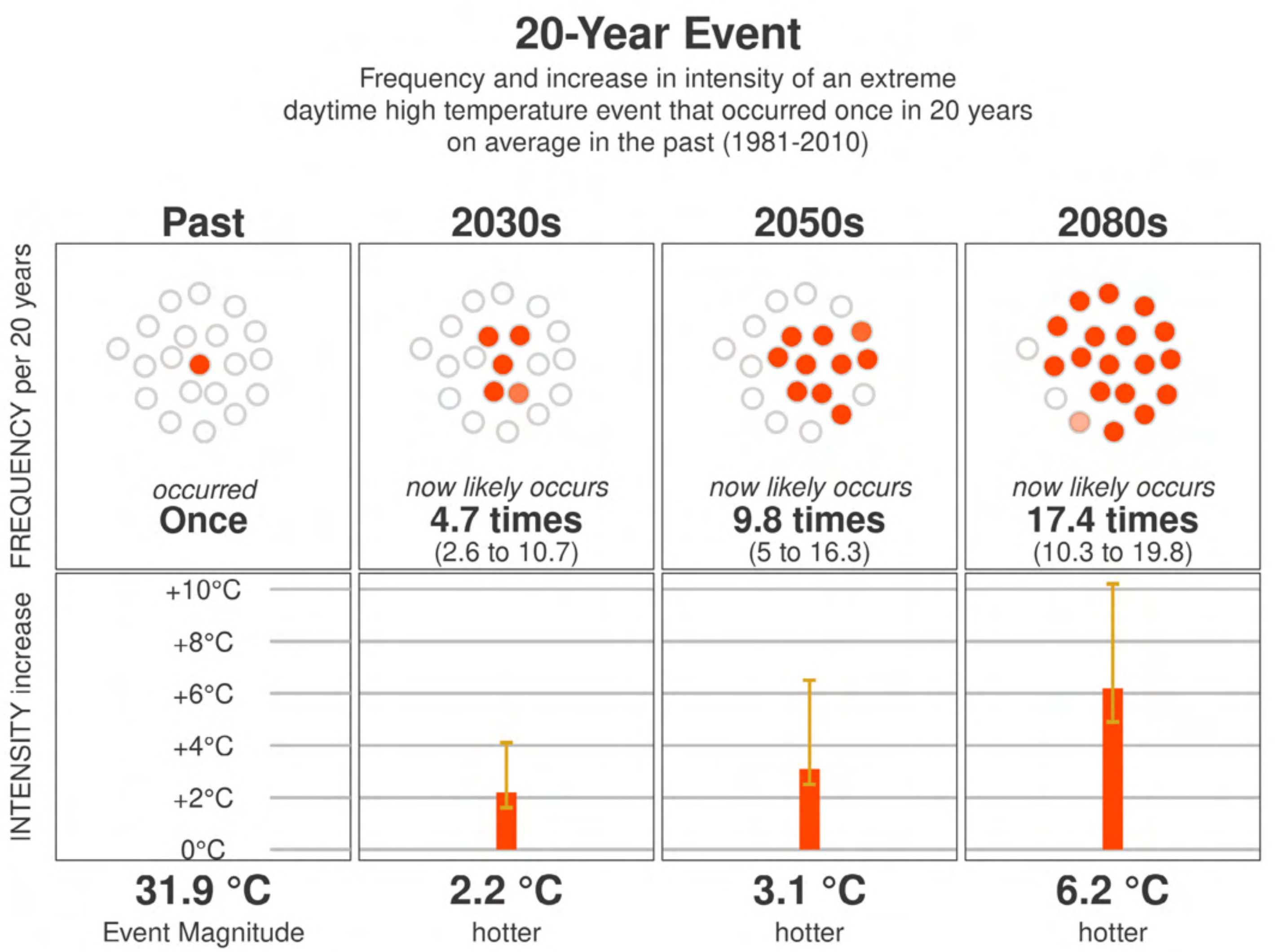


Figure 17. *Upper panels*: Frequency of a 1-in-20 year daily maximum temperature (TX) event in the Past and projected frequency of the same magnitude event (i.e. TX = 32°C) in the three future periods. *Lower panels*: Increase in magnitude of a 1-in-20-year TX event from the Past to future periods. Figure design is taken from similar infographics in the IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3-32, doi:10.1017/9781009157896.001.

6. Precipitation Indicators

6.1 Dry Spells

The *Consecutive Dry Days* indicator tracks the annual longest string of days with less than 1 mm of precipitation.

Projections

In the Past, the median dry spell length in the RDN was 24 days. The median future-projected dry spell length increases by 4% to 25 days (range 22 to 33 days) by the 2050s and by 21% to 29 days (range 26 to 44 days) by the 2080s.

The increase in dry spell length is consistent with the higher summer temperatures and reduced summer rainfall highlighted in the previous chapters. The map of consecutive dry days is quite uniform throughout the RDN, as are its changes in both future periods.

6.2 Snowfall

Snowfall is inferred from the downscaled total daily precipitation and temperature, using a widely validated empirical relationship.[13]

Projections

In the Past, the median annual snowfall in the RDN was around 380 mm (snow water equivalent, or SWE). The median future-projected snowfall decreases by 55% to around 165 mm (range 78 to 213 mm) by the 2050s and by 75% to just 90 mm (range 7 to 60 mm) by the 2080s. Due to the robust projection of an increase in cold season temperature (Chapters 3 and 4), the expectation of a smaller fraction of precipitation falling as snow in future decades is reasonable, even if its magnitude is somewhat uncertain.

Of more concern is the limited model ability to simulate the unique conditions that lead to the rare, but sometimes heavy, snowfalls in southwest BC. The CMIP6 models used in this study are probably not able to capture this behaviour very well, meaning that the change in frequency of winter storms resulting in heavy snowfall is largely unknown.

13. Dai, A. (2008). "Temperature and pressure dependence of the rain-snow phase transition over land and ocean," *Geophysical Research Letters*, 35(12). Snowfall projections should be taken with special caution, for two reasons. First, the amount of total precipitation that falls as snow is a sensitive function of local temperature, so whatever temperature biases remain after the downscaling procedure result in uncertainty in snowfall. Over time, however, as local temperatures exceed 0°C more often in winter, this uncertainty decreases.

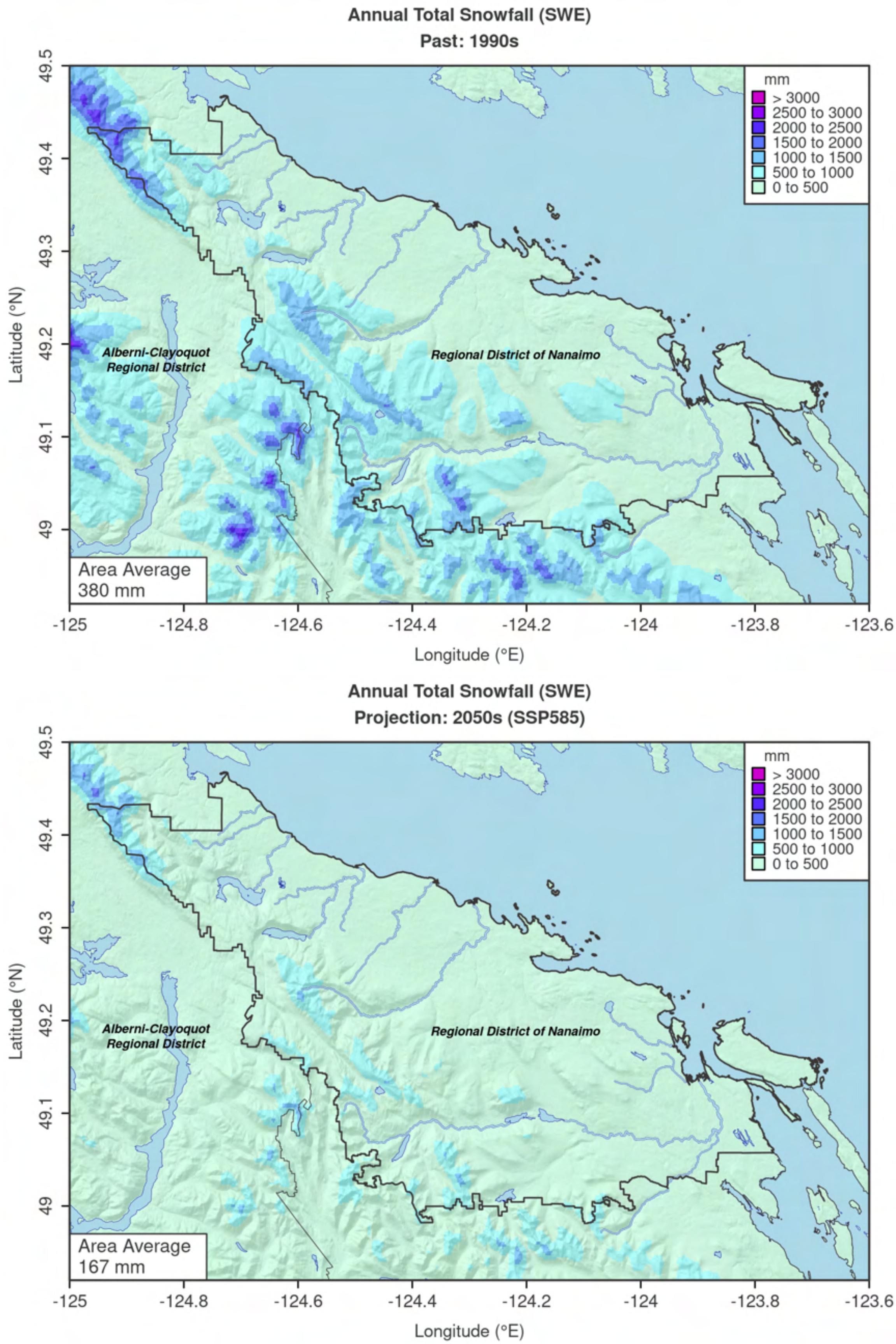


Figure 18. *Upper*: Annual total snowfall in the Past. *Lower*: Projected snowfall in the 2050s.

6.3 Annual Maximum One-Day and 5-Day Precipitation and 95th-percentile Wettest Days

These indicators describe the largest precipitation events of the year. The *Annual Maximum One-Day Precipitation* (RX1DAY) is self-explanatory, while the *Annual Maximum 5-Day Precipitation* (RX5DAY) tracks the accumulated amount over consecutive 5-day periods during the year. If we compute the 95th percentile of daily precipitation over all wet days in the Past (i.e. those with a daily amount of at least 1 mm), and then sum the amounts over that threshold that fell on especially wet days, then we obtain the *95th-percentile Wettest Days* (R95P) index. Note that R95P is potentially composed of several large precipitation events in a typical year and does not (usually) describe single storms.

All amounts in Table 10 reflect the systematic difference in precipitation amount from west (high) to east (low) across the RDN. Across the region, percent increases for the 2050s differ somewhat for each index: from around 15% for RX1DAY, to 11-14% for RX5DAY to around 30-35% for R95P. Changes for the 2080s are correspondingly larger, as shown in the table.

TABLE 10: ANNUAL EXTREME PRECIPITATION INDICES

	Past (mm)	2050s (mm)	2080s (mm)	2050s Change (%)	2080s Change (%)
One-day maximum precipitation (RX1DAY)					
RDN*	55	63	66	15 (8 to 22)	20 (15 to 32)
Lowlands	45	52	55	16 (8 to 23)	22 (15 to 32)
Highlands	67	77	81	15 (9 to 23)	21 (15 to 33)
5-day maximum precipitation (RX5DAY)					
RDN	140	157	162	12 (5 to 25)	22 (20 to 33)
Lowlands	111	126	129	14 (6 to 25)	16 (14 to 23)
Highlands	177	197	205	11 (5 to 24)	16 (14 to 24)
95th Percentile Wettest Days (R95P)					
RDN	351	466	502	33 (18 to 48)	43 (36 to 75)
Lowlands	269	353	381	31 (17 to 45)	42 (33 to 72)
Highlands	454	611	661	35 (19 to 50)	46 (38 to 77)

* Values for the seven Water Regions comprising the RDN are provided in the data deliverable spreadsheets.

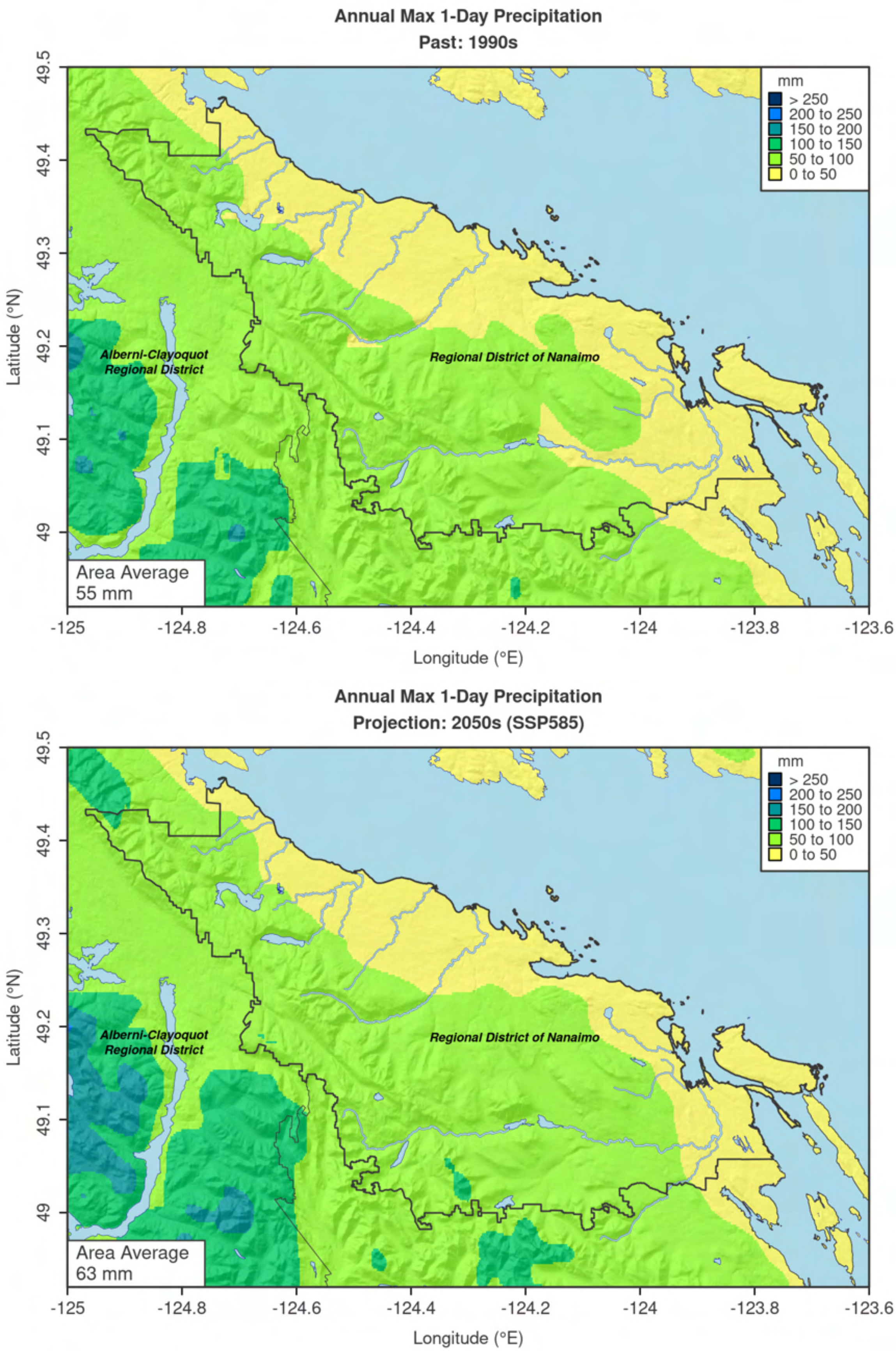


Figure 19. Annual maximum 1-day precipitation in the Past (*upper*) and in the 2050s (*lower*).

6.4 The 1-in-20 Year Wettest Day and 1-in-20 Year Wettest 5-Day Period

The *1-in-20 Year Wettest Day* and the *1-in-20 Year Wettest 5 Days* describe rainfall events so extreme that they are expected to occur only once every 20 years in the Past climate. In other words, these events have a 5% chance of occurring in any given year in the Past. The *1-in-20 Year Wettest Day* describes the maximum amount of rainfall occurring in a single day. The *1-in-20 Year Wettest 5 Days* describes the maximum amount of rainfall occurring over a 5-day period.

Projections

In the Past, the median 1-in-20 Year, single-day rainfall in the RDN was around 75 mm, while the median 1-in-20 year, 5-day rainfall was about 185 mm. The median future-projected 1-in-20 Year, single-day rainfall increases by 23% to around 95 mm by the 2050s and by 30% to about 100 mm by the 2080s. The median future-projected 1-in-20 Year, 5-day rainfall increases by 22% to around 225 mm by the 2050s and by 24% to about 230 mm by the 2080s. As shown in the maps above, the absolute rainfall amounts for both indices are considerably larger in the Highlands than in the Lowlands, as expected.

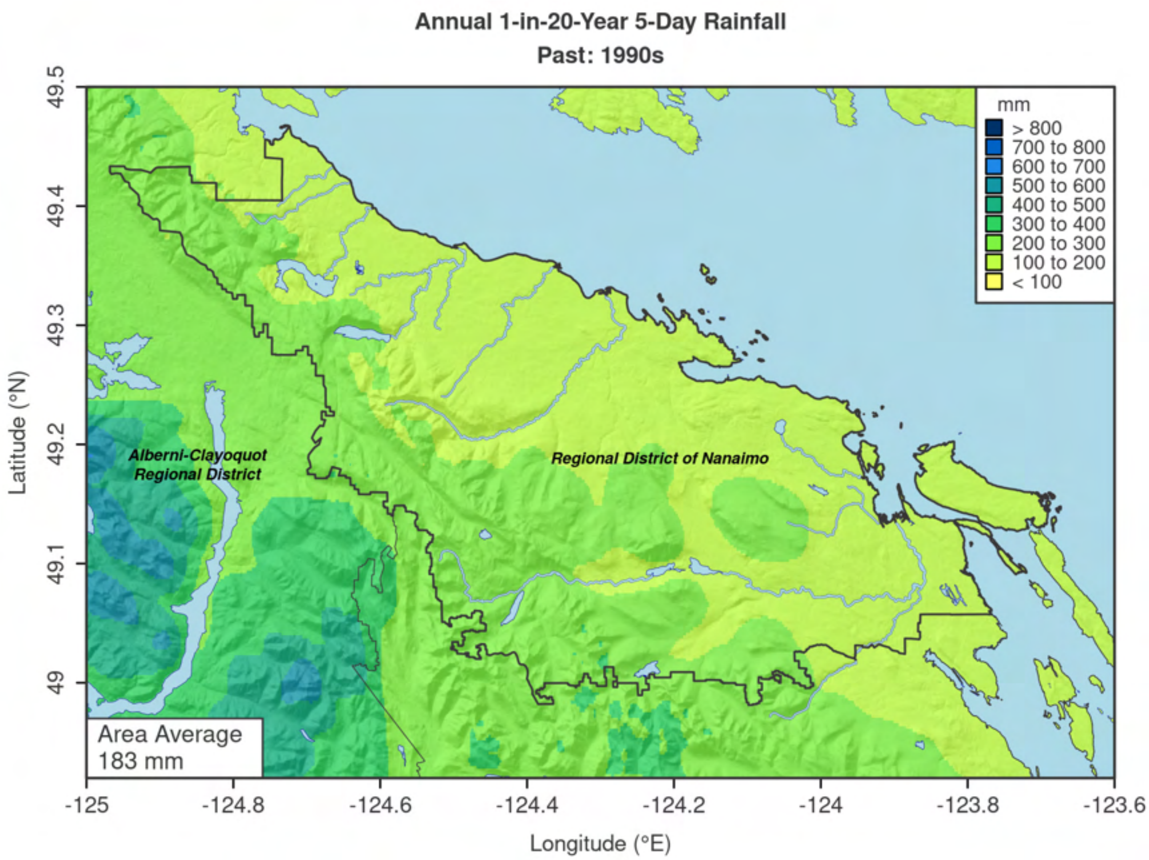
By comparing these results with those shown in Table 3 of Chapter 3, it is evident that the relative changes in extreme rainfall indices are larger than those for seasonal or annual mean rainfall. This occurs due to the different mechanisms that control how extreme (e.g., daily) and average (e.g., monthly to annual) precipitation respond to warming.

As in the case of rare temperature events, one may express these changes in extreme rainfall in a more visually compelling way, as in Figure 20.

TABLE 11: 20-YEAR RETURN LEVEL RAINFALL

	Past (mm)	2050s (mm)	2080s (mm)	2050s Change (%)	2080s Change (%)
1-in 20 Year Maximum 1-day Rainfall (“Wettest Day”)					
RDN*	77	95	100	23 (14 to 30)	30 (16 to 39)
Lowlands	66	80	84	21 (11 to 27)	27 (17 to 35)
Highlands	90	114	120	27 (18 to 34)	33 (20 to 44)
1-in 20 Year Maximum 5-day Rainfall (“Wettest 5 Days”)					
RDN	183	224	227	22 (8 to 39)	24 (15 to 36)
Lowlands	151	183	182	21 (5 to 34)	21 (13 to 33)
Highlands	223	276	284	24 (10 to 43)	27 (17 to 39)

* Values for the seven Water Regions comprising the RDN are provided in the data deliverable spreadsheets.



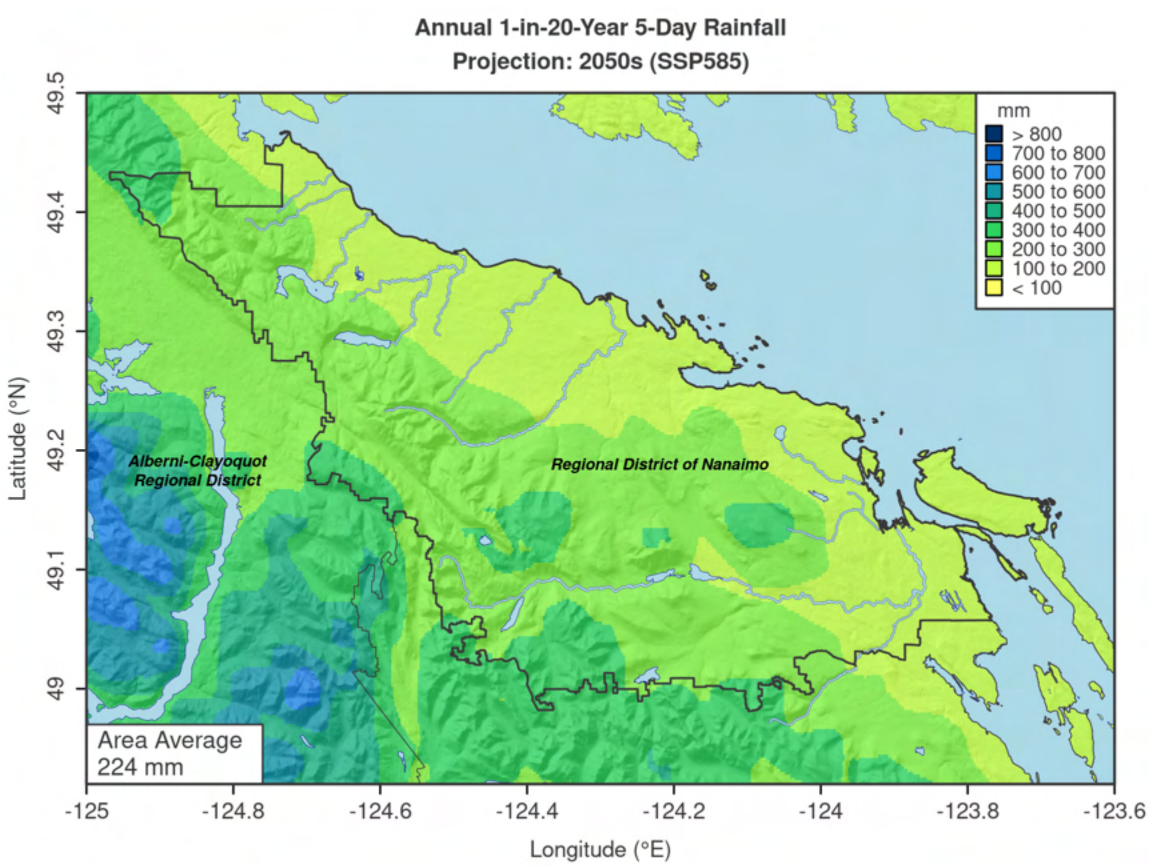


Figure 20. Left: 1-in-20 year, maximum 5-day rainfall in the Past (*left*) and in the 2050s (*right*).

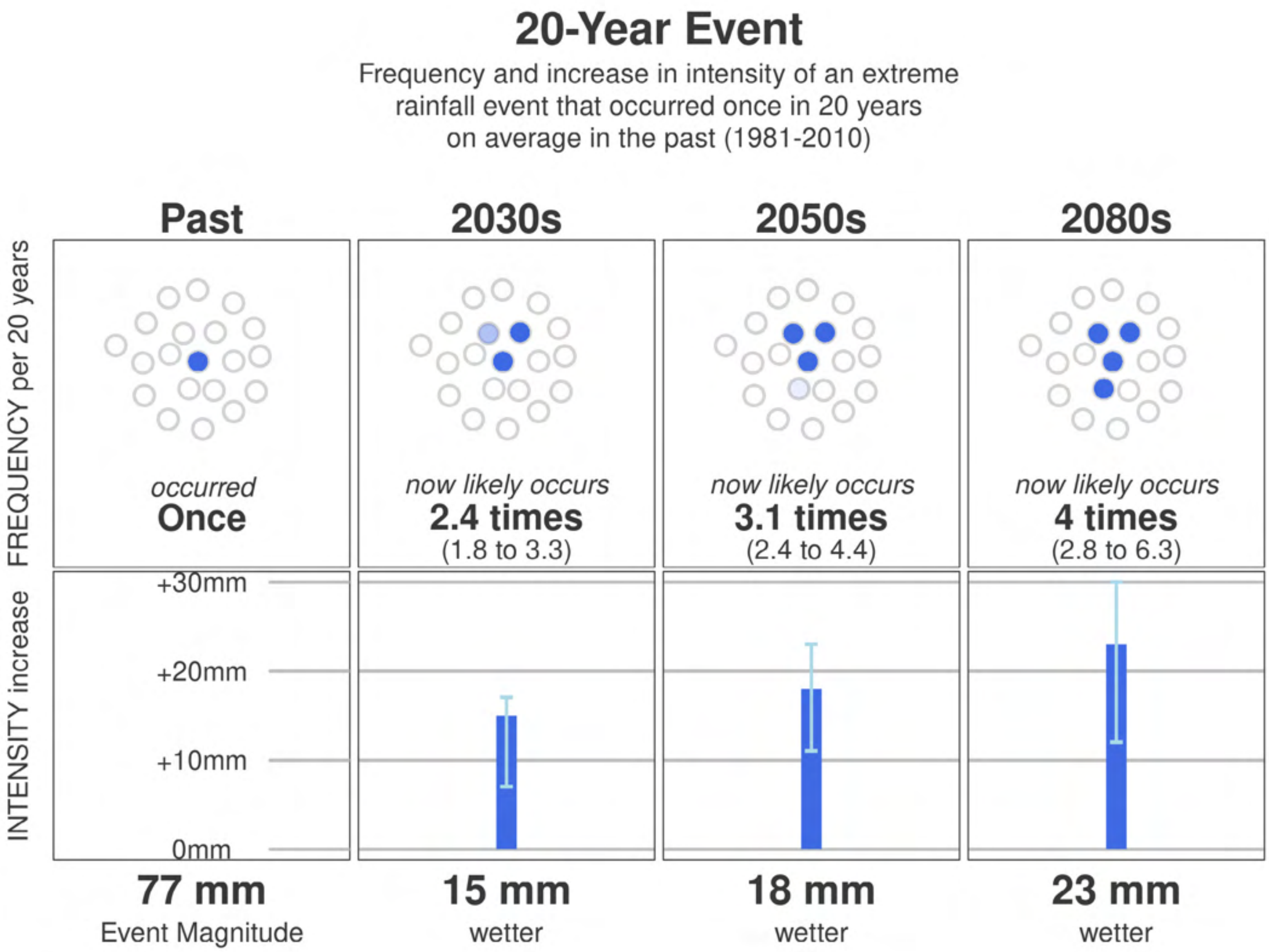


Figure 21. *Upper panels*: Frequency of a 1-in-20 year daily maximum rainfall event in the Past and projected frequency of the same magnitude event (i.e. 77 mm) in the three future periods. *Lower panels*: Increase in magnitude of a 1-in-20-year single-day rainfall event from the Past to future periods. Figure design is taken from similar infographics in the IPCC, 2021: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3-32, doi:10.1017/9781009157896.001.

7. Regional Impacts

This chapter provides a brief overview of climate impacts expected across our region. It is not a complete assessment of expected impacts. Rather, this chapter is intended to spark deeper discussion among decision makers and community leaders on how to prepare for the interrelated climate impacts facing our region. It should be considered a starting point for further analysis of climate impacts and adaptation planning that engages relevant partners and stakeholders.

Communities across the Regional District are already witnessing and experiencing impacts from climate change. The projected changes outlined in this report are expected to have diverse impacts across the region over the coming decades. Collective efforts to reduce emissions and slow the rate of global warming will be necessary to lessen the severity of these impacts. Equally important will be actions that increase resilience and reduce the vulnerability of ecosystems, local infrastructure, and people to climate change.

> The case for investing in climate adaptation is clear. For every **$1** spent on adaptation measures today, **$13** to **$15** is estimated to be returned in future years through direct and indirect benefits.

Investing in climate adaptation can help safeguard communities now and into the future. It also presents an opportunity to support thriving communities and economies for generations to come. Adaptation actions can protect and sustain natural ecosystems, increase the resiliency of food systems, and improve the efficiency of energy and water use. Importantly, there is no "one-size-fits-all" approach: adaptation can take many forms depending on the unique political, cultural, and economic context of each community.

With continued high global emissions, the Regional District can expect warmer year-round temperatures, shifting precipitation patterns and more noticeable climate extremes in the future. In general, winters will become warmer with less snowfall and more heavy rainfall occurring during the wetter months. Summers will become hotter, with less rainfall and more frequent heat waves that are longer and more intense, on average. Because of natural climate variability, the changes projected for the region may not be consistent from one year to the next. Although we can anticipate most winters to be warmer and wetter, some winters may be drier or colder than average, especially in the near term. Similarly, while we can expect most summers to become increasingly hot and dry, we may witness future summers that are wetter and cooler than average. Adaptation strategies must consider this complexity.

The Importance of Equity

The impacts discussed in this chapter will not be experienced equally across the region. People facing the greatest burdens are often the ones who are most affected by climate change, particularly for impacts that build on each other. During and after climate-related events, some people and communities experience unequal impacts because of existing vulnerabilities that often overlap, including:

- People who experience poverty, colonization, racism, inadequate housing, and a lack of access to health care
- People who are most likely to be exposed to climate impacts because of where and how they live and work
- People living with disabilities, chronic diseases, and mental illnesses
- Babies in the womb, pregnant people, infants, children, and older adults[14]

Climate equity[15] is the goal of recognizing and addressing the unequal burdens made worse by climate change, while ensuring that all people share the benefits of climate protection efforts. Achieving climate equity means that all people in our region have access to a safe, healthy, and fair environment.

Climate equity can be woven into the broader efforts to address the socioeconomic, sociocultural, and physical impacts of climate change. This will require collaboration across various sectors to understand where climate change intersects with other crises (e.g., housing, mental health), and to address these issues holistically.

14. Climate Change and Health. http://www.bccdc.ca/health-info/prevention-public-health/climate-change-health
15. Climate Equity. https://www.epa.gov/climateimpacts/climate-equity

Water Supply and Demand

Context

RDN has seven major basins, or water regions, encompassing all four municipalities and seven electoral areas. Within the RDN, there is no single water supply provider, and many residents rely on groundwater for their domestic water supply either from a community system, or from their own private well. Water sources are recharged during the wet season through a combination of rainfall, groundwater, and snowmelt. Rivers are not only sources of community water supply but support important ecosystems and are home to Pacific Salmon. Groundwater plays an important role to some of the region's rivers and creeks, contributing to stream baseflows during the summer months. Groundwater conservation and aquifer recharge are essential to the climate resilience of aquatic habitats and community water supplies.

Impacts

By the 2050s, the RDN can expect more precipitation during heavy rainfall events (e.g., landfalling atmospheric rivers). As a result, more water may be lost to runoff, particularly in areas where precipitation falls over bedrock or other hard surfaces. Higher stream flows resulting from heavy rainfall can increase the amount of organic material and sediment entering water supply systems, complicating water treatment processes. To maintain water quality, the effects of heavy rainfall should continue to be considered in the planning and management of water supply systems and private wells across the region. For example, in some reservoirs in the RDN, membrane filtration has been installed to mitigate the effects of high turbidity events.

> Across the region, impacts to water supply may be particularly challenging for people who rely on small water systems, like private wells. These systems may be less resilient to shifting precipitation patterns and may not recharge sufficiently in future years. In coastal areas, overdrawing groundwater can lead to saltwater intrusion – an impact that is compounded by rising sea levels.

As winter temperatures warm, precipitation is more likely to fall as rain instead of snow. This can lead to less snowfall accumulation at higher elevations and greater runoff, reducing surface and groundwater supply for the summer. In the spring, warmer temperatures can directly influence water levels in upper dam watersheds due to the combination of less snowfall accumulation and rapid melting. Water availability in these areas may be particularly challenging when periods of peak community water demand coincide with critical environmental flow requirements for aquatic species, such as salmonids.

When water demand is highest during the summer months, less rainfall and longer dry spells may stress water resources needed for community use, agricultural irrigation, and the essential baseflows that support aquatic ecosystems. Hotter temperatures and drier conditions may also increase the likelihood of wildfire in the region. Although fire is a natural and essential process in wildlands, it can pose a threat to water supply by increasing erosion and nutrient/sediment transport, impacting watershed health.

While the region can expect more rainfall in three out of four seasons, the distribution of when and how it is received may pose the biggest challenge to water supply. Regionally coordinated adaptation strategies that increase water storage capacity by both natural and engineered means will become increasingly important. This includes opportunities to protect and restore soils, forests, lakes, aquifers, and wetlands, as well as expand engineered infrastructure—such as reservoirs, cisterns, and bioretention ponds. Given the greater likelihood of drought in the summer months, water conservation initiatives should remain a priority for the region. Demand management strategies that reduce outdoor water use, such as offering incentives for efficient landscaping and design, and enacting policies to limit landscaping that excessively consume potable water for non-essential purposes (e.g., maintaining green lawns), will be increasingly important. Water stewardship rebate programs are already available for residents to improve their water efficiency.

Rainwater and Flood Management

Context

Central Vancouver Island, where the RDN is located, is characterized as a rain-driven system. Flooding most often results from intense rainstorms occurring in late fall and through the winter (i.e., November to February). In late winter and early spring, snow accumulation combined with warm air and wet conditions can result in significant snowmelt, leading to extreme flows in rivers across the region. This can create flood conditions in many watersheds at the same time. Three major river systems in the region (Nanaimo River, Englishman River, and Little Qualicum River) are prone to annual flooding. Floodplain maps for these rivers have been recently updated, but this has not yet been done for other rivers and watercourses in the RDN. Natural, unaltered watersheds play an important role in rainwater management by protecting water quality and reducing flood risk during periods of heavy rainfall. In settlement areas, hard surfaces such as pavement and roofs prevent rainfall from naturally soaking into the ground and can contribute to flooding during heavy rainfall events.

Heavy precipitation falling in a watershed can combine with coastal phenomena (i.e., storm surge, high-tides, and wave effects) to worsen total water levels and/or flooding. Similarly, expected sea level rise in the region may increase the frequency and magnitude of coastal flood events.

Impacts

Some communities in the RDN have already experienced impacts associated with high water levels. In the future, our region can expect more intense rainfall to put significant pressure on aging and undersized stormwater infrastructure. Where drainage systems become overwhelmed, heavy rainfall can cause flooding in areas where it has not happened before. More heavy rainfall may also cause rivers, streams, wetlands, and lakes to overflow, which can have cascading effects on the surrounding environment. For example, water-logged soils can cause more runoff and increase erosion, leading to slope instability and landslides that could harm people and homes. These effects can impact drinking water quality, aquatic ecosystems, and any surrounding infrastructure.

Low-lying coastal areas in the RDN are at an increased risk of flooding during heavy rainfall events due to their topography and proximity to the ocean, particularly when

> Flooding often adversely impacts communities with lower socioeconomic advantages who also have fewer resources at their disposal. The ability to recover from these events is rooted in community connectedness and sense of belonging. The RDN recognizes Snuneymuxw, Snaw-Naw-As and Qualicum Reserve Lands are impacted by annual flood events.

heavy rainfall occurs at the same time as high tides and onshore winds. To better understand flood hazards, the RDN completed four projects involving flood analysis and hydrological modeling to develop coastal and river flood hazard maps. This information was used to update land use policies and bylaws that regulate new development in flood prone areas.

Warmer temperatures, less rainfall, and extended dry spells in the summer can also influence the downstream effects of rainwater. When heavy rainfall occurs after long periods of dry weather, the “first flush” of surface runoff can carry high levels of contaminants that have accumulated on hard surfaces due to a lack of rain. This runoff can enter surface waters and harm aquatic ecosystems. In all seasons of the year, higher water temperatures and increased stormwater runoff of nutrients can make conditions more favorable for algal blooms – a growing issue that impacts water quality, ecosystems, recreation, and human health.

Appropriate changes to stormwater infrastructure (e.g., culverts, storm drains, etc.) will be required to prepare for higher single- and multi-day rainfall amounts across the region. Other important strategies to manage extreme precipitation and reduce the effects of flooding and runoff include green infrastructure (e.g., green roofs, rain gardens, etc.) and more permeable, low impact development.

For additional resources to support rainwater and flood management in a changing climate, see Appendix D.

Health and Well-being

Context

The Regional District has a growing population, with the City of Nanaimo ranked among the five fastest growing populations in BC.[16] While the region has typically had excellent air quality and comfortable temperatures in the past, recent years have featured hotter summers and numerous instances of air pollution from wildfire smoke, often arriving from other regions. Major flooding can result in population displacement and damage to cultural resources.

Impacts

Climate change has the potential to undermine factors that support individual and community wellness, such as food security, social connectedness, access to transportation, connection to the land, working conditions, and housing quality and security. Climate change can also place additional strain on healthcare and social systems that are necessary for good health and well-being.

By the 2050s, our region can expect hotter summer temperatures, with more days exceeding 25°C and more nights where the temperature stays above 16°C. Our region can also anticipate more frequent heat waves that are longer and more intense. These projected changes will increase the risk of heat-related stress and illnesses, particularly among equity-denied populations such as seniors, those living with mental illnesses, those who use substances, and people living in poor quality housing.[17] In June 2021, an unprecedented[18] "heat dome" event had severe implications for health and well-being, resulting in over 600 heat-related mortalities across BC. Nearly all (98%) of mortalities caused by this event occurred within private residences.[19] The urban heat island effect can drive up summer temperatures further in high-density areas with paved, dark surfaces. Ensuring equitable access to cool environments, including safe housing that protects against overheating, will be critical for reducing heat-related risks in the region.

Hotter temperatures and less summer rainfall may increasingly promote conditions for wildfire in our region and across the Pacific Northwest. Wildfire occurring in our region can pose direct risk to people and homes, resulting in displacement and property damage. Wildfire smoke travelling from neighbouring regions can irritate the lungs, cause inflammation, and alter immune function, particularly for people with pre-existing health conditions. During periods of extreme heat, air quality can be further degraded by other pollutants that become more concentrated when temperatures are high (e.g., ground-level ozone, pollen, mold, and mildew).

16. Nanaimo Foundation. 2023. Nanaimo's Vital Signs. https://www.nanaimofoundation.com/vital-signs/
17. City of Nanaimo, 2023. Summary and Recommendations Final Report: Extreme Heat Mapping, Assessment, and Planning.
18. The unprecedented nature of the June 2021 heat dome makes it difficult to estimate its return period or its annual probability of occurrence. Based on the analysis of historical data from two nearby locations it was estimated as a 1-in-300-year (or 0.3% annually) at Seattle-Tacoma Airport to a 1-in-1000-year event (or 0.1% annually) in New Westminster (Philip et al., 2022; DOI: 10.5194/esd-13-1689-2022). While the capital region can expect more frequent extreme temperatures in the future, estimates for how often an event of this magnitude will occur are difficult because historical records are far shorter than the estimated return periods for this event.
19. British Columbia Coroners Service. 2022. Extreme heat and human mortality: A review of heat-related deaths in BC in Summer 2021.

Living through an extreme weather event or grappling with uncertainty about the future can impact mental health and wellbeing, manifesting as stress, anxiety, fear, exhaustion, or worse. For example, those who use substances may be at higher risk of heat-related death due to inhibition of senses and the inability to recognize a health emergency. People facing displacement or property loss during an emergency event may also endure significant and lasting trauma. Coast Salish First Nations may be particularly impacted through disproportionate vulnerability to flood-related evacuations and potential for climate change to impact culturally important areas and traditional practices. Extreme events can also impact individual livelihoods for people working in resource-based industries, including farmers and forestry workers.

Ecosystems and Species

Context

Most of the RDN has a Mediterranean-like climate that allows for diverse flora and fauna to thrive. Our region is home to a variety of ecosystems, including Douglas Fir, Garry Oak, wetlands, alpine, shorelines, and more. Healthy ecosystems support the wellbeing and prosperity of our region through flood mitigation, temperature regulation, and more. At the time of this report, of the 416 plants, birds, animals, and insects recorded on the BC Species and Ecosystems Explorer for the region, 204 are considered endangered or threatened and 183 are of special concern. Natural asset protection on public and private lands is needed to maintain ecosystems and safeguard these essential services.

> The impacts of climate change on ecosystems and biodiversity are compounded by environmental changes from human development. Notably, changes in land-use can fragment ecosystems, diminishing their resiliency to regional climate impacts.

Impacts

The RDN can expect ecosystems, species and their interconnected ecological relationships and processes to be influenced by warming temperatures and shifting precipitation patterns across the region. Because ecological systems are highly complex, it will be difficult to make specific predictions for how they will be impacted by the future climate. The speed and scale of the projected changes may exceed the adaptive capacities of many species, shifting the overall ecological landscape. Specialist species may be particularly vulnerable, resulting in a decline in regional biodiversity and creating new opportunities for invasive species to thrive. Warming year-round temperatures may upset the timing of ecological processes that rely on temperature cues (e.g., predator/prey, parasite/host, and pollinator dynamics), which could lead to population declines for certain species, and/or outbreaks of species that are considered pests.

In the summer, hotter and drier conditions will continue to stress trees and other terrestrial and riparian (streamside) vegetation, especially for species that are sensitive to drought such as the Western Red Cedar. Drought conditions can also slow the decomposition of bacteria, fungi, and other soil organisms, thereby reducing available nutrients, and adding further stress to certain species. Stressed plants may become more vulnerable to competition with other species, including damage from insects and diseases.

Rising temperatures will increase water temperatures in both freshwater and marine environments, which may be problematic for fish species requiring cool waters to thrive. In extreme cases, warm water may combine with low water levels during critical periods (i.e., during periods of competing demand for drinking water and agricultural irrigation), leading to increased species mortality.

Buildings and Energy Systems

Context

In the climate of the past, most buildings and homes did not require active cooling capacity. During the 2021 heat dome, 98% of heat-related deaths happened in private residences, prompting an urgent need to implement cooling measures in homes across the region. Retrofit programs and new building policies are leading to building envelope considerations and a greater adoption of low emissions heat pumps that support thermal comfort and energy efficiency. Across our region, buildings and homes situated in coastal areas and on flood plains are at greater risk of flooding.

Impacts

By 2050, the RDN can expect heavier rainfall, increasing the risk of flooding in the fall, winter, and early spring. Flooding can damage buildings and, in extreme cases, can result in property loss – especially where development is located on flood plains. In coastal areas, these effects may be worsened by rising sea levels. Buildings and homes across our region may also be impacted by other extreme events including extended heat waves, which can stress foundations and building materials, and wildfire.

In the coming decades, increasing temperatures will alter both seasonal and long-term energy demands. As temperatures warm in the colder months, our region can expect a decrease in the demand for heating. In the summer, hotter temperatures will significantly increase cooling demand. This will have implications for overheating risk for buildings that lack active or passive cooling measures. Certain units are particularly vulnerable to overheating, such as older apartment buildings that often lack air conditioning and are not designed to handle hot temperatures. As a result, some residents may be at greater risk of heat-related illnesses and mortality.

> Under continued high global emissions, by the 2050s, the RDN can expect:
>
> - Heating Degree Days to decrease by 0.8X
> - Cooling Degree Days to increase by 6X

The projected climate changes bolster the case for investing in well-designed, resilient buildings that are located outside of high-risk areas, such as flood plains, low coastal areas, and steep slopes. Resilience measures will be particularly important for safeguarding high priority buildings, including hospitals, community gathering spaces, and long-term care facilities. The Regional District and member municipalities may also need to renovate local government infrastructure, such as community centres, to improve resilience to climate extremes and ensure the flexibility to provide cooling spaces for residents.

For additional resources to support future-ready buildings and energy systems, see Appendix D.

Transportation Networks

Context

The RDN is an important service hub on Central Vancouver Island. A significant portion of the fuel, freight and passenger traffic destined for Central and Northern Vancouver Island follow transportation routes going through our region. The RDN operates an integrated transit system (the Regional District of Nanaimo Transit System) that serves urban, interregional, and rural areas. Roads and highways are primarily maintained by the provincial government in rural areas, and by municipalities in incorporated areas. Because our region is located on an island, it is vulnerable to significant transportation disruptions (e.g., to BC ferries, or along major transportation corridors) that can complicate responses to emergency and extreme events. Transportation disruptions can also impact access to essential goods and services for people across the Vancouver Island region.

Impacts

In the future, warmer winter temperatures could potentially reduce the costs associated with snow removal and the repair of roads affected by freeze-thaw cycles. However, it is important to note that the equipment required to address severe weather conditions will need to be maintained until at least mid-century due to natural climate variability.

Heavier rainfall in the colder months may threaten transportation infrastructure in our region, including sidewalks and roadways, increasing the costs associated with maintenance and repair. In extreme cases, damage from flooding and runoff to major transportation corridors could have substantial impacts to livelihoods across the region, as many residents commute to and from the region for work or to access important health services.

The absence of rain can also impact transportation networks. In the warmer months, less summer rainfall and hotter temperatures can lead to road closures from increased wildfire risk. In 2023, the Cameron Bluffs wildfire caused a prolonged shut down of Highway 4 – a major transportation corridor between Central Vancouver Island and communities on the West Coast. The disruption reverberated through the local supply chain and forced a lengthy detour for essential purposes only. This example highlights how extreme weather events can have serious impacts on transportation.

Maintaining a healthy, safe, and accessible public transportation network is crucial for supporting the reduction of GHG emissions across the region. In the future, warming temperatures may enhance the appeal for residents to choose active transportation methods during the colder months of the year. However, heavier rainfall, hotter temperatures, and poor air quality from wildfire smoke may equally deter residents from using active transportation. During the wet season, heavier rainfall events may necessitate the management of localized flooding and erosion along active transportation corridors. In summer, adequate cooling infrastructure, including water stations, shade structures and greater tree canopy cover will be important for supporting active transportation that is healthy and safe.

Agriculture and Food Security

Context

Roughly 10 percent of the land area within the RDN is provincially designated as Agricultural Land Reserve (ALR), with some additional areas being farmed outside of the ALR. Most farms are small- to medium-scale, family-run operations. Agriculture is intricately tied to seasonal timing, including growing season duration, typical average temperatures, and the intensity of hot and cold periods. These elements collectively influence the suitability of crops for cultivation across the region. In addition to land-based agriculture, aquaculture is a major contributor to food production in the region. Aquaculture is similarly influenced by climatic changes and is particularly sensitive to increases in stormwater runoff.

Impacts

By the 2050s, the RDN can expect to see a longer and warmer growing season, characterized by fewer days below freezing and an earlier onset of spring. A longer growing season has the potential to enhance agricultural productivity in the coming years. However, the projected changes will also bring greater uncertainty as temperatures in the summer become hotter and precipitation patterns change. Growing season length, on its own, should be considered an upper limit for estimates of future productivity since this measure only uses a lower temperature threshold and does not include precipitation change. In addition, shifting seasonal conditions may cause pollinating species to emerge at mis-aligned times, impacting crop yields.

In the summer, hotter temperatures and reduced precipitation may cause adverse impacts that undermine agricultural productivity, such as sun scald and heat stress. Drought conditions may also generate competition for water resources during important times of the year, such as when irrigation demand coincides with critical flow periods for aquatic habitats. During periods of water scarcity, regulatory agencies will need to simultaneously consider agricultural use impacting stream flows and the need to ensure water availability to support food security. As growing seasons become hotter and drier in the future, adaptation strategies that reduce agricultural water demand, such as on-farm water storage, hydroponics, or switching to drought resistant crops, will be essential for supporting climate resilience.

In the fall and winter, heavier rainfall may increase the risk of flooding, which can lead to crop damage or loss. The surfeit of water may also create opportunities for plant diseases and pests to flourish. Increased stormwater runoff onto and from agricultural land may increase soil erosion, compromising the long-term productivity of the land. Stormwater runoff may also leach essential soil nutrients into surrounding waters, threatening nearby aquaculture and natural ecosystems. Impacts to aquaculture may be compounded by climate-related changes to ocean processes, such as warming sea surface temperatures and acidification.

Compounding Impacts

The impacts listed throughout this chapter occur within a dynamic and increasingly complex global system. These impacts may be more severe due to the combined influence of multiple issues that build on each other (compound). Some examples include, but are not limited to:

- Periods of dry weather combined with seasonally high temperatures may increase the likelihood of drought
- Long periods of drought can change soil conditions and prevent infiltration of heavy rainfall, making localized flooding worse
- More hard surfaces (e.g., roads and parking lots) and areas cleared for development can increase stormwater runoff
- Warmer water temperatures with increased stormwater runoff can create unfavorable conditions for aquatic habitats
- Wildfire smoke during extreme heat events can make health conditions like asthma or heart issues worse and contribute to social isolation as residents stay indoors more
- Successive seasons marked by extreme events that activate an emergency response can overwhelm staff capacity and deplete emergency management resources

8. Summary and Recommendations

This report uses the most up-to-date climate model projections to examine how climate change may unfold across the Regional District of Nanaimo in the coming decades. Our region can expect an increase in daytime and nighttime temperatures throughout the year. In the summer months, this implies hotter daily highs, warmer nights, and more numerous and longer multi-day heatwaves. In the future, winters will become milder overall with a steep reduction in frost days and snowfall.

Our region can expect a modest increase in annual precipitation in the future that will be distributed unevenly across seasons. Warmer cold season temperatures will result in less snowfall and increased rainfall, especially in winter. Whereas rainfall is projected to increase in the fall, winter and spring, our region can expect less rainfall and longer dry spells in the summer. This is important because summer rainfall in our region is already very limited and, in the warmer months, dry spells may be compounded by increasing temperatures. Across our region, the magnitude and character of these changes will vary locally.

Early action on climate adaptation will enable our region to best prepare for the changes ahead and increase climate resilience. The information provided in Chapter 7 (Regional Impacts) is intended to guide further discussion among decision makers, residents, and community partners across the region. Importantly, adaptation can take many forms depending on the unique context of each community.

The regional impacts outlined in this report should be considered a starting point for further analysis of climate impacts and adaptation planning that engages relevant stakeholders and is tailored to the local context.

The Regional District of Nanaimo will use these projections to form the basis of future decisions on short- and long-term adaptation planning, risk assessment work, and policy development to build local climate resilience. Where appropriate, the Regional District will also encourage consultants and local government staff to use these projections as a common reference.

> This report highlights regional projections for the 2030s, 2050s and 2080s under a high emissions scenario (SSP5-8.5), but alternative scenarios were also considered for this project. The complete data package includes information for low (SSP1-2.6) and , moderate (SSP2-4.5) emissions scenarios. It also includes separate assessments for hydrologic basins within the RDN. The Appendices to this report provide guidance for understanding and using climate projections, information about what is included in the complete data package and point to further online resources that support this work. For additional questions, see the FAQ document.

Appendix A: Backgrounder on Future Climate Data

The Earth's climate is changing due to the burning of fossil fuels, which emit greenhouse gases (GHGs) and aerosols into the atmosphere. Over the past century, these emissions have raised atmospheric GHG concentrations well above preindustrial levels, which has led to widespread warming over Earth's surface.

The global average temperature has increased by over 1°C to date, and Canada is warming even faster (Figure A1). This warming has resulted in widespread impacts in Canada and across the globe, and it is directly proportional to the total amount of GHGs emitted since the beginning of the industrial era. While a 1°C temperature change at your location may not feel like much, changes of only 1 or 2°C on a global scale are very substantial because they are averaged over the globe and a long period of time.

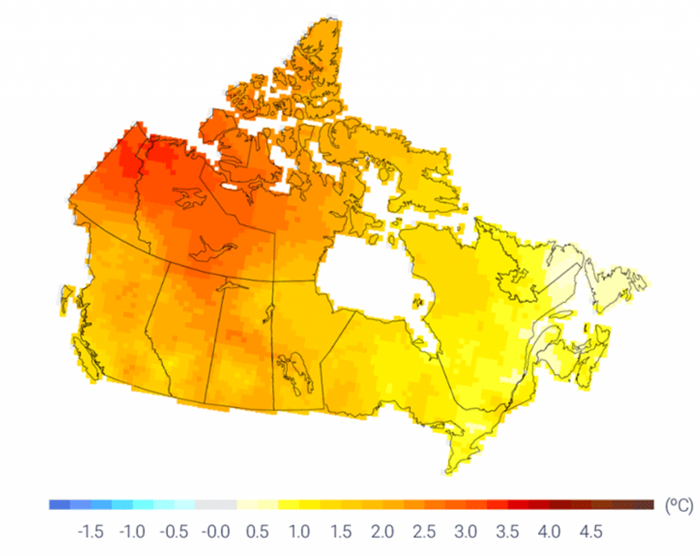


Figure A1. Warming in Canada between 1948-2018.

BOX 1. UNDERSTANDING WEATHER, CLIMATE, NATURAL VARIABILITY AND CLIMATE CHANGE

To understand climate change, it is important to distinguish between weather and climate, and the natural and human influences that affect the climate on different time scales:

- *Weather* is what we experience when we step outside. It consists of short-term (minutes to days) variations in the atmosphere.
- *Climate* is the general state of weather, including its extremes, over periods ranging from months to many years. Climate can be thought of as the statistics of weather. Descriptions of normal climate conditions at a particular location are often derived from nearby weather observations and collected over long time periods – typically 30 years or more.
- *Natural climate variability* causes fluctuations in climate conditions that can span a few months to a few decades or longer. Natural climate variability is not influenced by human activity, but its influence can either mask or enhance human-induced climate change for the periods over which it occurs. Natural climate variability can also affect seasonal weather (e.g., El Niño/La Niña cycles).
- *Climate change* refers to changes in the state of the climate that persist over an extended period. Both natural processes and human influence can result in changes in climate. Climate science indicates that human influence is the unequivocal cause of the global warming that has been observed since the beginning of the

Figure A2. Timescales for weather, climate, natural climate variability, and climate change.

What is Future Climate Data?

It has long been common practice for practitioners and decision-makers to use historical climate observations to assess future climate-related risks. Because the climate is changing, historical climate observations are no longer sufficient for assessing future risk. Engineers, planners, and decision-makers are increasingly using information about the future climate in combination with historical observations to understand how much climate change they can expect to encounter over the coming decades, and how this will impact risk.

The extent of further warming and associated climate changes will depend on the amount of GHGs emitted globally, now and in the future. Because it is impossible to predict the exact societal conditions that will influence global GHG emissions, a range of potential futures, or emissions scenarios, have been developed to project future climate change. These scenarios are based on assumptions about population growth, climate policy, land use changes, energy intensity, economic activity, and more, that lead to different levels of global GHG emissions. The emissions scenarios used in this assessment are known as Shared Socio-economic Pathways, or SSPs for short – but more on that later.

Scientists develop global climate models (GCMs) to simulate Earth's future climate in detail under each of the various emissions scenarios. These models allow us to understand how the climate system functions and to project future climate change. GCMs are extensively tested against historical observations and compared to one another. Through the Coupled Model Intercomparison Project (CMIP), we can simulate the future climate using an ensemble of different GCMs that describe a range of plausible climate futures. (Note: because there are a limited number of GCMs and they are a simulation of the climate system, they cannot provide the full range of climate futures.)

Figure A3 below shows an ensemble of 24 individual GCMs to describe a range of plausible future conditions. Each red line represents an individual GCM projection, developed by research groups from around the world. The solid black line in this case represents the ensemble median, with the lower and upper dotted lines showing the 10th to 90th percentile range of the model ensemble.

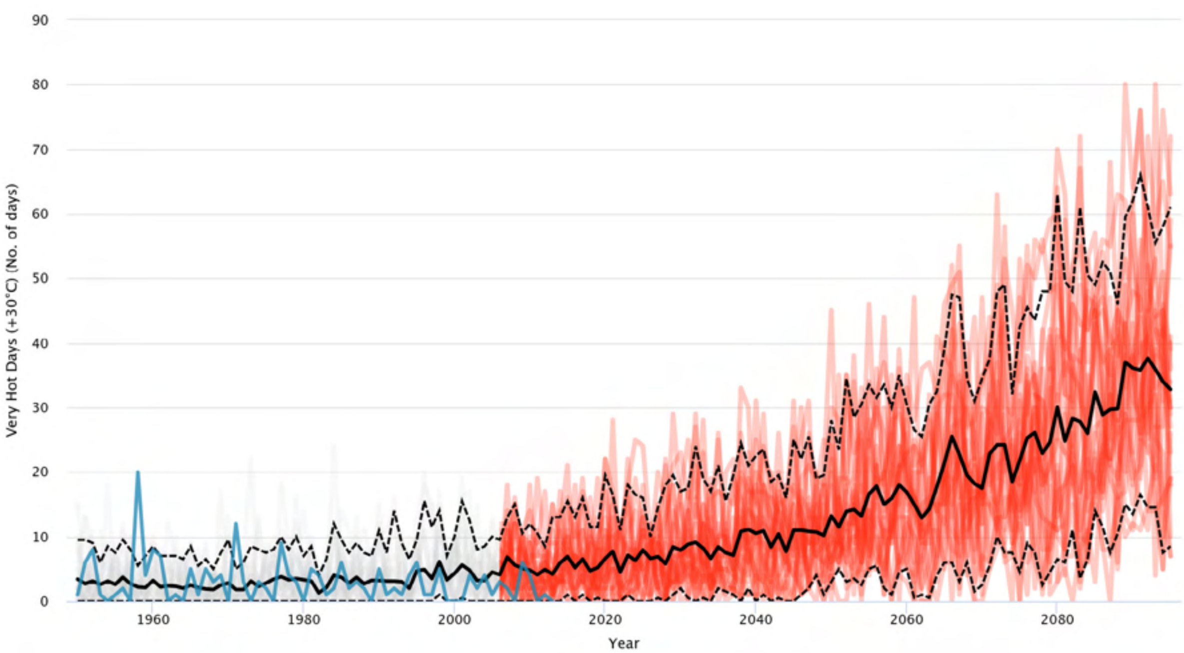


Figure A3. Example of a GCM ensemble.[20] Each red line represents a single GCM projection for the number of annual days with a maximum temperature exceeding 30°C in British Columbia. The solid black line is the median and the dotted lines are the 10th (lower range) and 90th (upper range) percentile values across all GCMs in the ensemble.

20. Retrieved from ClimateAtlas.ca, using modelled data from PCIC.

Understanding Shared Socio-economic Pathways

As noted above, to project the future climate, GCMs need input about the amount of future industrial emissions. Shared socio-economic pathways (or SSPs, Figure A3a) are such inputs, providing emissions scenarios based on assumptions of various societal decisions, including:

1. how population, education, energy use, technology – and more – may change over the next century, and;
2. the level of ambition for mitigating climate change globally.

The SSPs used in CMIP6 simulations are a set of five main socioeconomic pathways (SSP1 through SSP5) that illustrate different ways in which global societies may develop. They are the successors to the previous emissions scenarios used in CMIP5 called Representative Concentration Pathways, or RCPs. Figures A4a and A4b illustrate projections for GHG emissions and temperature under various SSPs. Here, it is important to note that global temperature projections for the near future are similar across different SSPs. The projections begin to diverge more meaningfully around 2050 (Figure A4b).

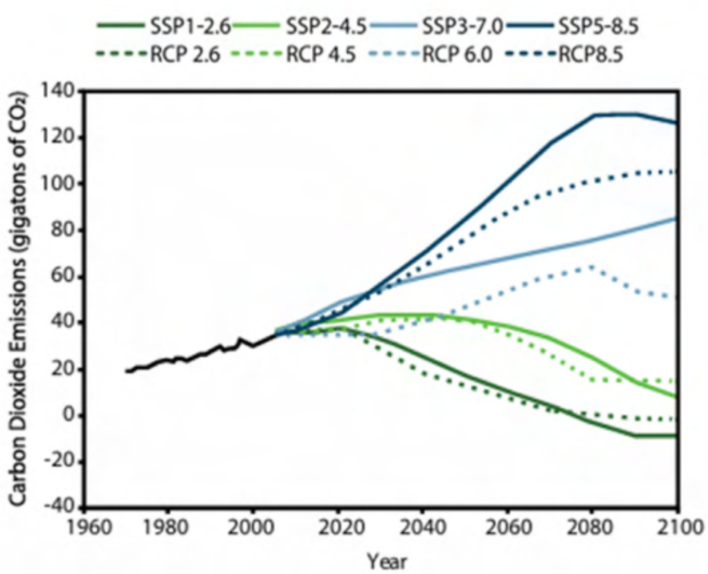


Figure A4a. SSP scenarios used by CMIP6 models for global CO2 emissions by the end of this century. The scenarios used for CMIP5 (RCPs) are also shown.

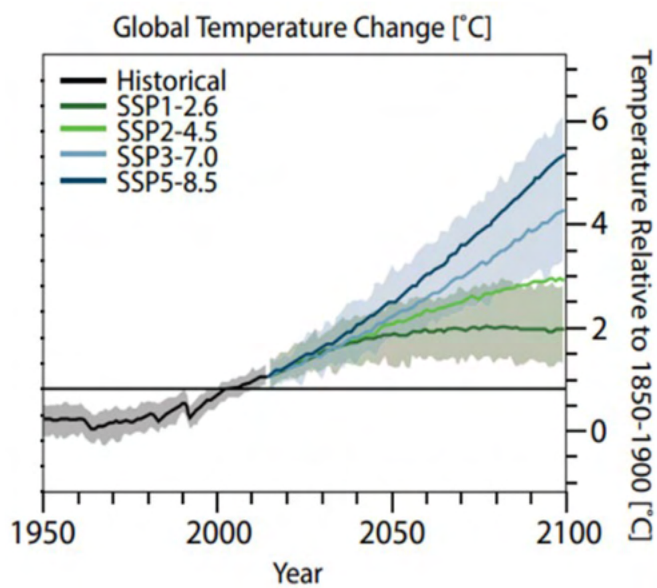


Figure A4b. Historical and future temperature change from 1950-2100, relative to 1850-1900. After 2014, models are driven by the SSP scenarios indicated, with ranges shown for SSP1-2.6 and SSP3-7.0. The horizontal line shows temperature change that has occurred up to 1995-2014 (about +0.85°C).

Future Climate Uncertainty

While we know the future climate will be different from the climate of the past, we cannot precisely predict what the future climate will look like. There are three main sources of uncertainty inherent in future climate data: natural climate variability, model uncertainty, and scenario uncertainty. In the following sections, we provide support for making decisions in the presence of scenario uncertainty.

- Natural climate variability (as discussed above) refers to climatic fluctuations that occur without any human influence (i.e., independent of GHG emissions). Natural climate variability is largely unpredictable and can mask or enhance human-induced climate change.
- Model uncertainty arises because models can only represent the climate and earth system to a certain degree. Although they are highly sophisticated tools, GCMs can differ from reality. Furthermore, not all models represent the system processes in the same way, nor do all include the same processes. To help address model uncertainty, it is best practice to use an ensemble (i.e., a set of multiple GCMs), to display a range of possible futures. PCIC uses an ensemble of 9 GCMs that are best suited to analyses focused on British Columbia.
- Scenario uncertainty arises because different emissions scenarios lead to different levels of climate response, and it is not possible to know what global emissions will be in the future. The emissions pathway of the future depends on a wide range of policy decisions and socioeconomic factors that are impossible to predict. To help address scenario uncertainty, it is best to evaluate future projections under more than one emissions pathway.

> Uncertainty should not stand in the way of action. Decision makers should use climate projections as a guide to the future but should not discount the possibility of changes occurring outside the projected range when managing

Appendix B: What Data Should I Use?

The decision tree shown in Figure B1 can help determine which data and information from this assessment might be most useful for a given application. Before using climate projections, it is important to do appropriate background reading, identify relevant stakeholders and determine the appropriate level of stakeholder engagement. Stakeholder engagement is important for ensuring that the projected changes are both meaningful and well-suited to your context.

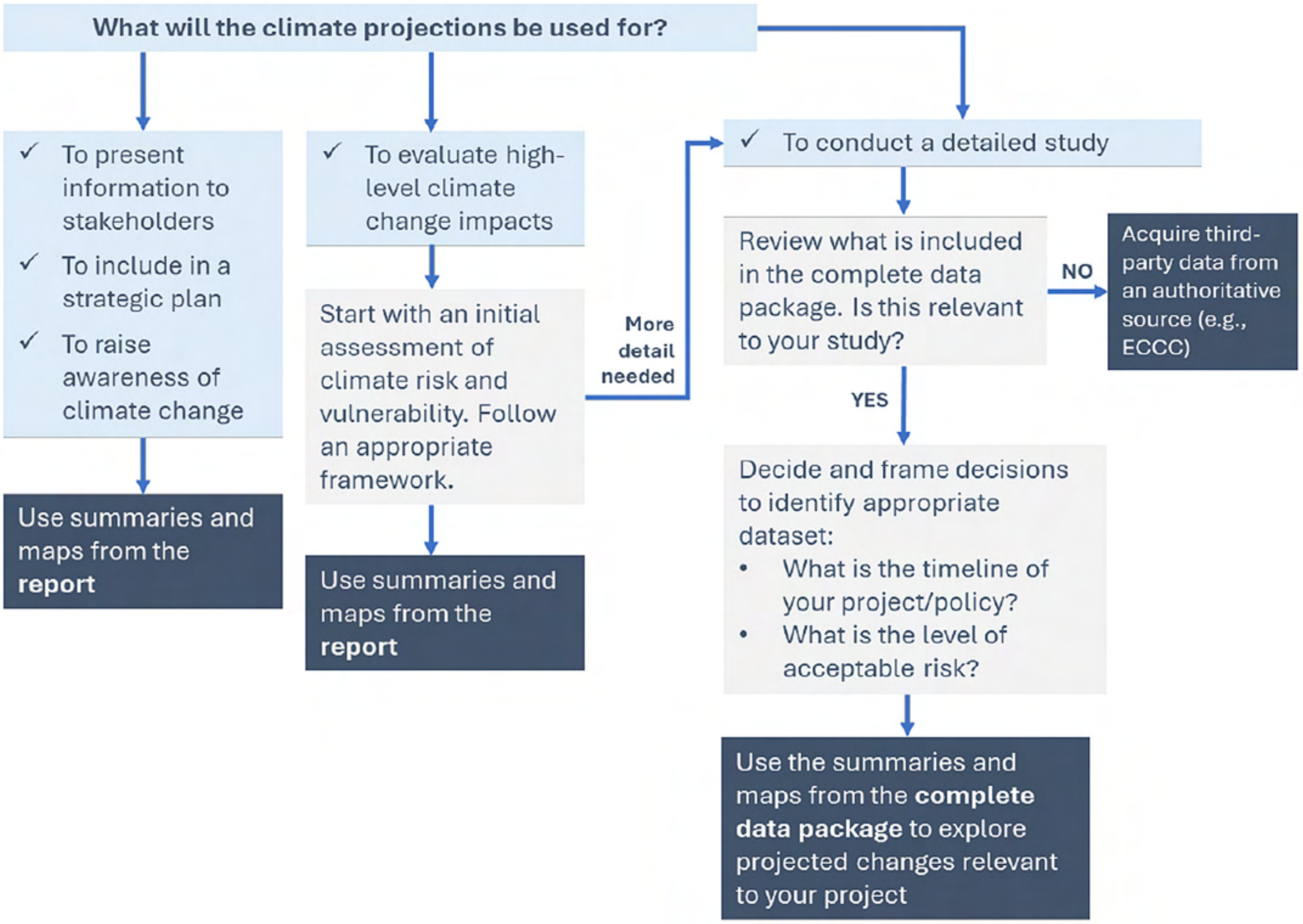


Figure B1. Decision tree for using climate projections data. This decision tree has been adapted from the Victoria (Australia) Climate Projections 2019 Technical Report (Clarke et al., 2019).

Users accessing the complete data package should reference the Data Descriptor Document.

Contact sustainability@rdn.bc.ca for more information.

What is Provided in the Complete Data Package?

This report highlights projected changes for a host of indices derived from temperature and precipitation under the highest emissions scenario (SSP5-8.5), mostly for the 2050s. The complete data package contains summary tables (Excel XLSX) and maps (PNG) for the following additional time periods, scenarios and sub-regional breakdowns:

- The Regional District of Nanaimo and nine smaller sub-regions (see Figure B2 below)
    - Seven water regions
        - Big Qualicum
        - Little Qualicum
        - French Creek
        - Englishman River
        - Nanoose-Wellington
        - Nanaimo River
        - Gabriola Island
    - High (> 450 m) and low (< 450 m) elevation areas

- Four time periods
    - 1981-2010 or “1990s” (baseline period)
    - 2021-2050 or “2030s”
    - 2041-2070 or “2050s”
    - 2071-2100 or “2080s”

- Three emissions scenarios
    - Low: SSP1-2.6
    - Moderate: SSP2-4.5
    - High: SSP5-8.5

- 77 indices derived from temperature and precipitation (see Appendix F for a complete list)

Gridded data (NetCDF) is also available for all 77 climate indices projected to the 2050s under a high emissions scenario (SSP5-8.5). Contact sustainability@rdn.bc.ca to access the complete data package and/or the gridded data.

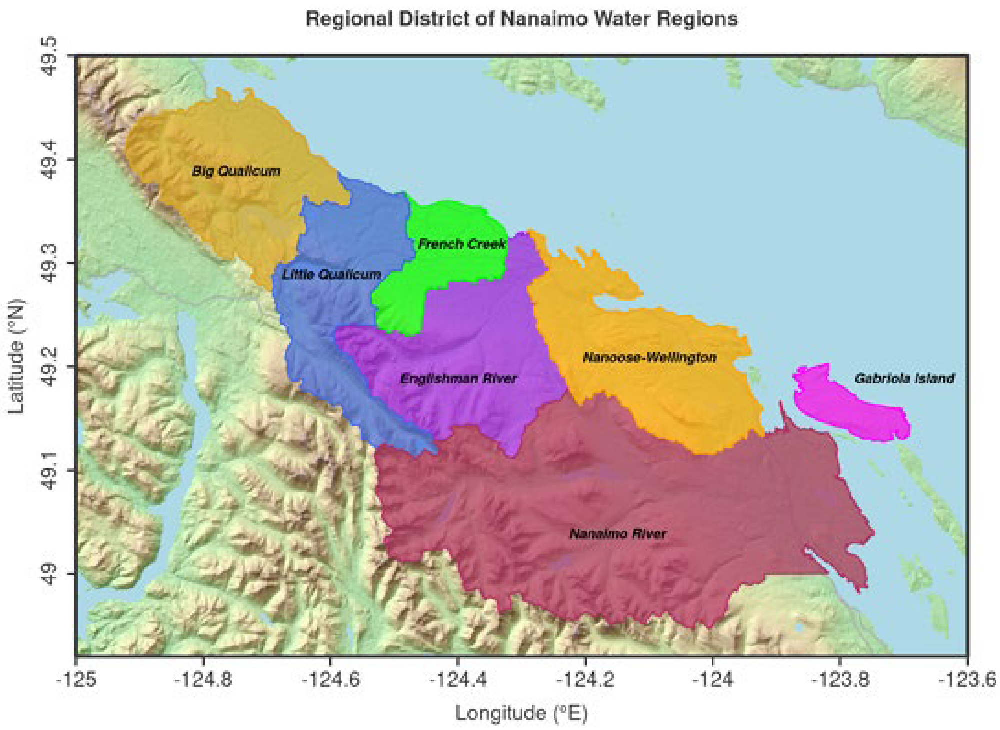


Figure B2a. Map of the seven water regions for the Regional District of Nanaimo. Separate summary tables are provided for each water region in addition to the tables produced for the entire Regional District.

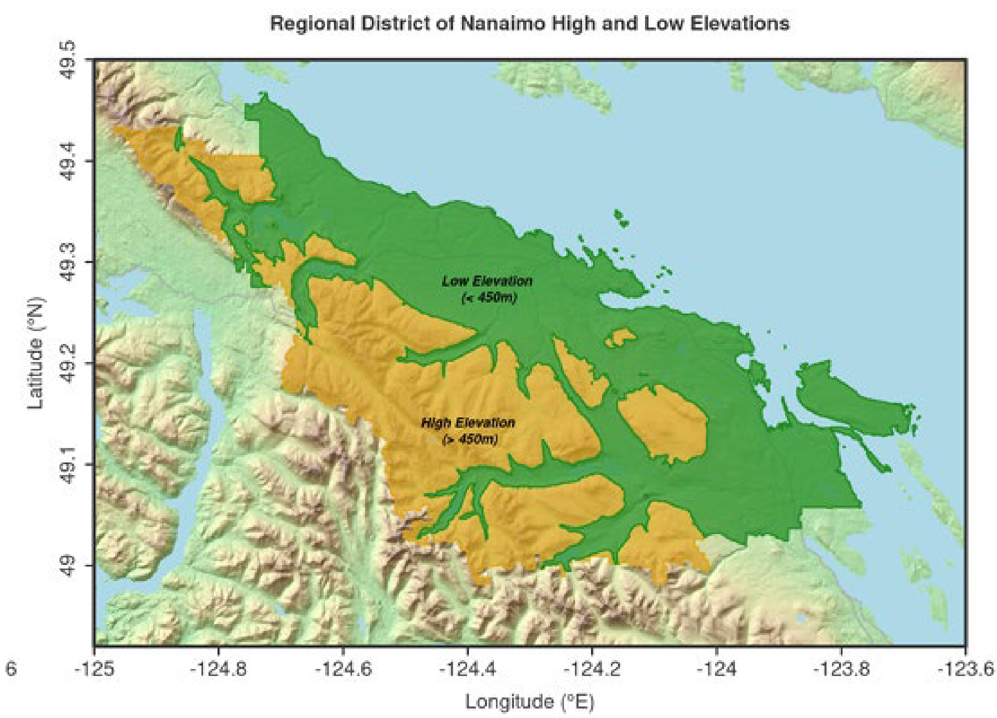


Figure B2b. Map of high elevation (> 450 m) and low elevation areas for the Regional District of Nanaimo. Separate summary tables are provided for each water region in addition to the tables produced for the entire Regional District.

Appendix C: Guidance for Using Climate Projections

Key Messages

- Projections of future climate are complex, and you will likely need advice and guidance from experts in the field. Allow adequate time for consultation.

- The climate has always been naturally variable. This variability now occurs on top of greenhouse-gas/aerosol forced trends. Over shorter time scales, climate variability can mask long-term trends.

- Since we do not know what future global emissions will be, climate projections are produced for a number of possible scenarios. In the CMIP6 ensemble, near-term projections are similar and diverge more clearly by the middle of this century (e.g., the 2050s).

- This assessment provides downscaled climate projections for variables derived from temperature and precipitation only. Variables related to other climate-related hazards, such as sea level rise or windstorms, are not provided. For supplemental resources, see Appendix D: Further Resources.

- While climate models are run under different emissions scenarios, there is no such thing as a 'most likely' scenario. Selecting an emissions scenario is highly context-dependent and will depend on considerations such as risk tolerance and the life cycle of your project or policy.

- Consider multiple climate variables or indices to get a more complete picture for different manifestations of change. Review annual and seasonal projections to get a sense of how projections vary depending on the time of year.

- In many cases, using only the median climate projections will not be appropriate. Ensure the ranges of projected change (10th and 90th percentiles) are adequately accounted for in your assessment. Do not entirely discount changes above or below the projected range when managing risk – especially for high-impact, low-likelihood events.

Understanding Climate Risk

As shown in Figure C1, climate risk depends on the complex interaction between hazards affected by climate change and natural climate variability, exposure to these hazards, and the vulnerability of the exposed elements. For example, a hazard (e.g., extreme heat) may impact a community more due to its exposure (e.g., occurring in a densely populated area) and/or vulnerability (e.g., demographic factors influencing heat sensitivity).data.

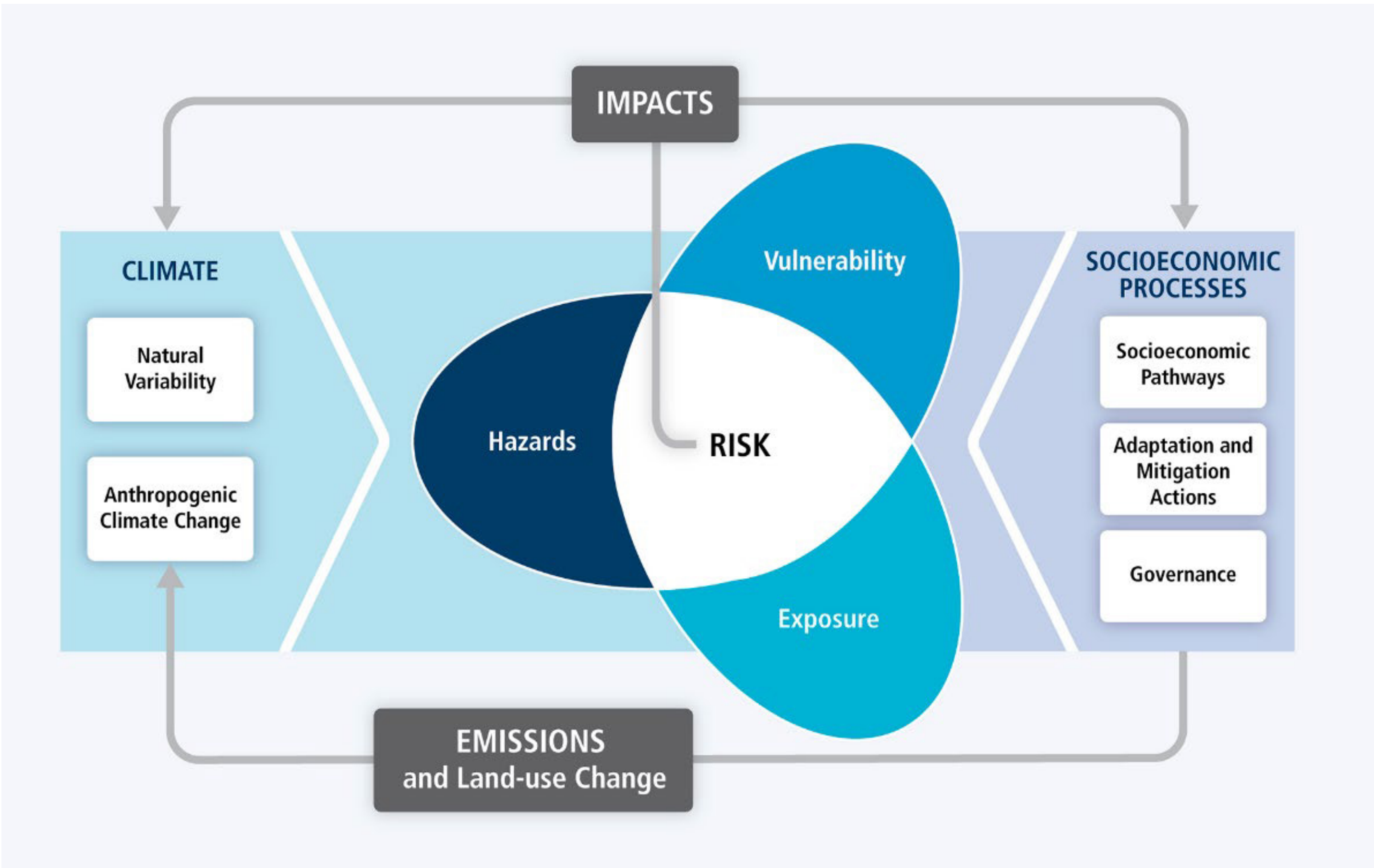


Figure C1. Climate risk envisioned as the overlap of hazard, exposure, and vulnerability.[21]

While future climate data can support the assessment of hazards affected by future climate change, there are different approaches to understanding climate risk. Decision-making about climate risk often involves a combination of top-down and bottom-up approaches.

- Top-down approaches start with an analysis of potential climate change that can be used to guide actions and decisions.
- Bottom-up approaches start with the project, policy or activity of interest and analyse the factors and conditions that impact the exposure, vulnerability and resilience of systems. These approaches look for pathways to reduce exposure and vulnerability while increasing the capacity to cope (irrespective of the future climate hazard).

Hence, future climate data can be used to inform a top-down approach to assessing climate risk.

21. IPCC, 2014: Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Which Emissions Scenario(s) Should I Use?

Climate projections are generated by different climate models and using a range of emissions scenarios. Differences in the projections due to the use of different climate models reflect the fact that we still have an incomplete understanding of how the climate system functions, and differences due to the choice of emissions scenarios reflect the fact that we have only imperfect knowledge of how society, its land use practices, and its emissions may change in the future. Given these diverse sources of uncertainty, it is best to examine a range of possible futures as represented by different climate models and emissions scenarios.

To reduce climate model uncertainty, PCIC has selected a range of climate models that are best suited to regions in BC. Ultimately, deciding on which emissions scenario(s) to assess will depend on the context of your project or policy, including your risk tolerance and time horizon, as discussed next.

Time Horizon

Users of climate projections should consider the time horizon, or life cycle, relevant to their project or policy before selecting a future scenario. This could be the expected lifetime of a given piece of infrastructure, or a policy that needs to be responsive to changing external conditions. As highlighted above in Understanding Shared Socioeconomic Pathways, in the near term – up to a few decades into the future – climate projections do not differ meaningfully across SSP scenarios. This is true at both the global and regional scales. Hence, if there is a recurring opportunity to review a given decision every 2 to 3 decades, then the choice of emissions scenario may be less relevant. An example of a recurring decision might be the choice of paving material to use when repaving a roadway. On the other hand, if an infrastructure element is expected to last 50 to 75 years, the choice of scenario becomes more critical because projected changes from different scenarios will differ substantially by the end-of-life of the structure. An example of a long-term infrastructure design decision might be determining the capacity of an upgraded storm sewer. Hence, planners and designers may be able to minimize the role of scenario uncertainty in adaptation planning by first determining the decision-making timeframe.

Level of Acceptable Risk

Climate scientists can help practitioners and decision makers understand how climate-related hazards that affect the assets they are responsible for (i.e., systems, infrastructure, or policy) may change in the future. This requires dialog among practitioners, decision makers and climate scientists to understand and describe the potential impacts of projected climate change under different emissions scenarios. Because climate scientists are not experts on how risk to assets will materialize, it remains the responsibility of practitioners and decision makers to manage future climate-related risks to their assets.

When assessing future scenarios, decision makers should consider four questions:

1. “What components of my project are vulnerable to climate change?”
2. “How likely is it that society will follow a future emissions pathway that will intensity the hazards to which my assets will be exposed?”
3. “What level of risk am I comfortable assuming?”
4. “What is the trade-off between risk and cost?”

Regardless of the rationale used, understanding the level of risk that is appropriate to your work is complex. It will undoubtedly require engagement with diverse partners and stakeholder groups to understand the range of potential impacts.

Scenario Choice

Ideally, public assets should be managed in a way that limits their vulnerability to plausible future hazards. Climate science has not yet ruled out the plausibility of any of the main socio-economic pathway scenarios that were considered in the most recent IPCC assessment. The choice of scenario will depend critically on the climate hazards that would affect the asset of interest. This is because some hazards will likely decline, such as extreme snow loads on buildings that could cause building collapse, while others, related to heat stress, intense rainfall, and flash flooding, will increase. If an asset is affected by both decreasing and increasing hazards, then the approach that would most completely limit vulnerability to future hazards would involve using a no change (historical climate) scenario for declining hazards, and a rapid change, high emissions scenario (e.g., SSP5-8.5) for increasing hazards.

Tips for Using Climate Data

View multiple variables (indices) within each category

To get a more complete understanding of projected changes, users should consider multiple climate variables. For example, if you want to know how precipitation will change in your region, review both a frequency-based variable (e.g., Number of Wet Days > 20 mm) and a volume-based variable (e.g., Total Precipitation). The Hazard Reference Tables (Appendix E) can help users identify which climate variables may be best suited to a particular context or application.

Review both annual and seasonal data

Annual mean changes can mask important seasonal behaviour. For example, a small annual mean precipitation projection might contain a substantial reduction in the summer along with a projected increase in the fall, winter, or spring. Therefore, users should assess both annual and seasonal projections for certain climate variables.

Select a relevant time period

The complete data package offers projections for the "2030s" (2021-2050), "2050s" (2041-2070) and "2080s" (2071-2100). As highlighted above, users should select the period that is most appropriate to the entire life cycle of their project or policy.

Determine an appropriate emissions scenario(s)

There is no right or wrong emissions scenario to use in decision-making: all scenarios represent possible futures and decision-making is highly context dependent. Selecting a scenario requires consideration of risk tolerance, sensitivity to climate impacts and extreme events, the time horizon of the project, and more. It can be useful to remember that planning for a high emissions scenario can help ensure that adaptation measures are resilient for a longer period of time if, in fact, a lower emissions scenario were to play out.

Examine both means and extremes

The median, 10th percentile, and 90th percentile values have been provided in all summary tables for this assessment. Depending on the application, one, two or all three of these values may be important. For instance, if one were designing a building for general use (e.g., retail space, detached home) with an anticipate lifetime of 50 years or so, then the change in the median of Cooling Degree Days (CDDcool18C) under SSP5-8.5 might be appropriate to consider. Alternatively, if the building were classified as critical, long-lived infrastructure (e.g., a hospital, or power plant) then it might be more appropriate to design to the 90th percentile value for that climate index, to capture the upper range of possibility.

Appendix D: Further Resources

There are a growing number of guidance materials, learning resources, and data tools available to support the use of climate projections for regional assessments. Below is a non-exhaustive list of open access resources suited to a broad range of users.

Additional Climate Projections Tools & Resources
ClimateData.ca *User-friendly tool for exploring climate projections and related data* Developed and maintained by the Canadian Centre for Climate Services, a team of information and outreach specialists at Environment and Climate Change Canada (ECCC), ClimateData.ca is an online, user-friendly data portal providing future climate projections for regions across Canada. Users can explore gridded data at small scales or aggregated by watershed, census subdivision, or health region. ClimateData.ca provides plain language descriptions for all climate variables and has various options for visualizing and analyzing climate data. Temperature and precipitation-based variables (the same as those provided by PCIC) as well as humidex, relative sea level change and climate change-scaled IDF data are available. ClimateData.ca also includes a comprehensive learning zone (climatedata.ca/learn) that is regularly updated to support climate data users in a variety of applications, including some sector-specific information, as well as a Climate Services Support Desk for general or technical inquiries. The site is continuously evolving with more content and features in development.
PCIC Climate Explorer *Useful for intermediate or advanced users analyzing a specific location* PCIC Climate Explorer (PCEX) is an online map-based tool for viewing gridded historical climate data and future projections at any location of interest across Canada. Users can select an arbitrary region on the map, compare climate variables for that region, and download the results in Excel formats. Additional variables for extreme precipitation and streamflow are also available.
ClimateAtlas.ca *Useful for creating communications materials and learning more about climate adaptation* ClimateAtlas.ca is an interactive tool combining climate projections (again using PCIC's data), mapping, and storytelling to inspire local, regional, and national action and solutions. Users can explore videos, articles, educator resources, and various topic including Indigenous knowledges, agriculture, and health.

Additional Climate Projections Tools & Resources
Spatial Analogues Tool* (ClimateData.ca) Useful for visualizing the future climate at a target location. With this tool, starting with a target city of interest**, users can search for other cities where the historical climate closely matches the future projected climate of the target city. Users can search for spatial analogues under a low or high emissions scenario and considering up to four different climate indices. For example, one combination of indices suggests that by the 2050s, Quebec City may have a climate similar to present-day Boston. By examining how Boston has adapted to its current climate, planners in Quebec City might gain insights on how to prepare and adapt to climate change. *This tool is a beta app, meaning it is a new tool being carefully monitored and is still under development. **Target cities for British Columbia are presently limited to: Victoria, Vancouver, Abbotsford, Kelowna, and Prince George.

Infrastructure Design Resources
PCIC Design Value Explorer (DVE) *Engineering design professionals can access future-projected climatic design values* The DVE is an online, open-access technical tool for assessing 19 climate design values based on observed data and projections of how they may change in the future. It provides engineers, architects, planners, and other professionals with quantitative, fine-scale historical and future-projected climate information for designing buildings and infrastructure.
PCIC Future-Shifted Weather Files *Energy modelers can access future-projected weather files* Weather data adjusted for climate change has been produced for three time periods (2020s, 2050s, and 2080s) using the high emissions pathway RCP8.5 (CMIP5). Data are available for several hundred weather stations across Canada. Future-shifted weather files can help building designers simulate building performance under a changing climate, supporting resilient design. Further work is underway to update the weather files for CMIP6-SSPs and to create weather files that capture both mean change and extreme events.

Infrastructure Design Resources
CSA PLUS 4013-19: Development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information: Guideline for Canadian water resource practitioners* *Guidance for Canadian water resource practitioners to better incorporate climate change into IDF information* Technical guidance from the Canadian Standards Association (CSA)—informed by scientists at ECCC and other subject matter experts— for the development, interpretation, and use of rainfall intensity-duration-frequency (IDF) information. Chapters 5 and 6 include guidance for how to incorporate climate change into the formulation and application of IDF information. *Access fee required
Short-Duration Rainfall IDF Data (ClimateData.ca) *Users can explore historical and climate change-scaled IDF information for weather stations across Canada* ClimateData.ca offers easy access to historical short-duration rainfall IDF data (from 1 to 24 hours) and projected rainfall amounts under low, moderate, and high emissions scenarios at locations across Canada (12 locations within the capital region). This IDF information is consistent with the above-mentioned CSA guidance. Users can download a zip file containing all the historical and future estimated values. In addition, the Learning Zone on ClimateData.ca has a topic dedicated to using IDF rainfall data to account for a changing climate. For more information on this product and about designing future-ready buildings, visit ClimateData.ca/learn/

Appendix E: Hazard Reference Tables

The Hazard Reference Tables help users identify which climate variables included in the complete data package may be best suited to a particular context or application. Users should use the short name (left column) to navigate to the appropriate variable in the complete data package.

Seasonal Patterns and Climate Change

- Increasing temperatures year-round
- Fewer frost days and a longer growing season
- Shifting heating and cooling demands

Key sectors: Agriculture, Biodiversity, Parks, Infrastructure

TEMPERATURE	
TX	Daytime high temperature, averaged over all days in a year or season
TM	Mean daily temperature, averaged over all days in a year or season
TN	Daytime low temperature, averaged over all days in a year or season
SEASONAL	
FD Frost Days	Number of days in a year when the minimum temperature is below 0°C
ID Ice Days	Number of days in a year when the maximum temperature is below 0°C
GSL Growing Season Length	Number of days between: (i) the first span of 6 or more days in the year with a daily minimum temperature > 5°C and (ii) the first span after July 1st of 6 or more days with a daily minimum temperature < 5°C.
WSDI Warm Spells	A “warm spell” is defined as 6 or more consecutive days when the daily maximum temperature exceeds the 90th percentile value of the historical baseline. This index measures the number of days in a typical year that a warm spell occurs. (A warm spell can occur at any time of year).
CSDI Cold Spells	A “cold spell” is defined as 6 or more consecutive days when the daily minimum temperature is less than the 10th percentile value of the historical baseline. This index measures the number of days in a typical year that a cold spell occurs. (A cold spell can occur at any time of year).
DESIGN	
HDDheat18C Heating Degree Days	Number of degree days below 18°C in a year. A rough estimate for the energy demand needed to heat a building in a typical year.
CDDcold18C Cooling Degree Days	Number of degree days above 18°C in a year. A rough estimate for the energy demand needed to cool a building in a typical year.

Increasing Temperatures and Extreme Heat

- Hotter daytime temperatures
- Warmer nighttime temperatures
- Heat waves becoming hotter and more frequent

Key Sectors: Emergency Management, Health, Biodiversity, Watershed

DAYTIME TEMPERATURES	
TX	Daytime high temperature, averaged over all days in a year or season
TXx	Hottest daytime high temperature in a year or season
SU Summer Days	Number of days in a typical year when the daytime high is above 25°C
SU30 Hot Summer Days	Number of days in a typical year when the daytime high is above 30°C
NIGHTTIME TEMPERATURES	
TN	Daily minimum temperature in a typical year or season
TNx	Warmest nighttime low temperature in a typical year or season
TR16C Temperate Nights	Number of days in a year when the nighttime low stays above 16°C
TR Tropical Nights	Number of days in a year when the nighttime low stays above 20°C
HEAT EXTREMES	
HWD Heat Wave Days	Number of days in a typical year classified as a “heat wave”
HWN Heatwave Number	Number of distinct heat wave events in a typical year
HWXL Heatwave Length	Length (in days) of the longest heat wave in a typical year
TXH Heatwave Intensity (Day)	Daytime high temperature averaged across all heat waves in a typical year
TNH Heatwave Intensity (Night)	Nighttime low temperature averaged across all heat waves in a typical year
TXHX	Daytime high temperature during the most extreme heat wave in a year
TNHX	Nighttime low temperature during the most extreme heat wave in a year
Return Periods (various)	The data package provides return levels and return period changes for the 5-, 10-, 20-, and 30-year Hottest Day.

Extreme Precipitation and Flooding

In this data package, there are no direct indices for flooding. Rainfall extremes may trigger flooding under certain circumstances.

- More precipitation occurring over short time periods
- More days with heavy rainfall

Key sectors: Public Works/Engineering, Infrastructure, Biodiversity, Health, Agriculture, Watershed

PRECIPITATION	
PR Total Precipitation	Total precipitation in a typical year or season
RAIN Total Rainfall	Total rainfall in a typical year or season
SNOW Total Snowfall	Total snowfall in a typical year or season
RAINFALL EXTREMES	
RX1DAY	Maximum amount of precipitation (in mm) occurring in a single day in a typical year
RX5DAY	Maximum amount of precipitation (in mm) occurring over a 5-day period in a typical year
R10MM	Number of days in a typical year that receive more than 10mm of total precipitation
R20MM	Number of days in a typical year that receive more than 20mm of total precipitation
R95P / R95DAYS	Amount of precipitation over the year that exceeds the 95th percentile of historical (baseline) daily precipitation / Number of days in a typical year that exceed this amount
R99P / R99DAYS	Amount of precipitation over the year that exceeds the 99th percentile of historical (baseline) daily precipitation / Number of days in a typical year that exceed this amount
Return Periods (various)	The data package provides 5-, 10-, 20-, 30-, and 50-year return periods for annual wettest 1-, 2-, and 5-day rainfall events. It also provides changes to rainfall return periods for an event of given magnitude.

Drought

In this data package, there are no direct drought variables. Hotter temperatures, less rainfall and reduced snowpack may lead to drought conditions in the warmer months.

Key Sectors: Agriculture, Biodiversity, Health, Watershed

PRECIPITATION	
PR – Summer Total Precipitation in Summer	Total precipitation in a typical summer (may also be important to consider PR for spring and fall)
SNOW Total Snowfall	Total snowfall (fall—winter—spring)
CDD Consecutive Dry Days	Number of days comprising the longest "dry spell" in a typical year. Dry spells are defined as consecutive days with less than 1mm of total precipitation.
TEMPERATURE	
TX	Daytime high temperature in a typical year or season
TXx	Hottest daytime high temperature in a typical year or season
SU Summer Days	Number of days in a typical year when the daytime high is above 25°C

Wildfire & Air Quality

In this data package, there are no direct wildfire variables. Hotter temperatures and less rainfall in the warmer months may lead to more favourable conditions for wildfire.

Key Sectors: Health, Biodiversity, Infrastructure, Agriculture

Variables listed under Drought (see above) can also be considered as informative for Wildfire. Additional variables such as humidity, wind speed, and wind direction must also be considered in order to establish favourable conditions for Wildfire. The Canadian Forest Service has analyzed such historical data to develop Fire Weather Normals, which provide insight into how "fire weather" varies spatially and throughout the year.
See https://cwfis.cfs.nrcan.gc.ca/ha/fwnormals for more.

Future-projected temperature and precipitation conditions that may be favourable to increased incidence of Wildfire may be obtained from other regional climate projections reports in BC, including:

- Climate Projections for the Cowichan Valley Regional District
- Climate Projections for the Capital Region
- Climate Projections for BC Northeast Region
- Climate Projections for the Okanagan Region
- Climate Projections for Metro Vancouver

Appendix F: Complete List of Climate Indices

SHORT NAME	VARIABLE	DEFINITION	UNITS
		Standard	
PR	Precipitation	Annual/seasonal precipitation totals	mm
RAIN	Rainfall	Annual/seasonal rainfall portion of precipitation using temperature-based rain-snow partitioning	mm
TM	Daily Average Temperature	Annual/seasonal daily average temperature	°C
TX	Daily Maximum Temperature	Annual/seasonal average daily maximum temperature	°C
TN	Daily Minimum Temperature (usually overnight)	Annual/seasonal average daily minimum temperature	°C
		Climdex: Temperature-based	
TXX	Maximum TX	Annual/seasonal maximum of TX	°C
TNN	Minimum TN	Annual/seasonal minimum of TN	°C
TXN	Minimum TX	Annual/seasonal minimum of TX	°C
TNX	Maximum TN	Annual/seasonal maximum of TN	°C
TX90P	Hot Days	Annual percentage of days with TX > 90^{th} historical percentile	%
TX10P	Cool Days	Annual percentage of days with TX < 10^{th} historical percentile	%
TN90P	Warm Nights	Annual percentage of days with TN > 90^{th} historical percentile	%
TN10P	Cold Nights	Annual percentage of days with TN < 10^{th} historical percentile	%
DTR	Diurnal Temperature Range	Annual/seasonal diurnal temperature range, TX – TN	°C
SU	Summer Days	Annual number of days with TX > 25 °C	days
SU30	Hot Summer Days	Annual number of days with TX > 30 °C	days
TR	Tropical Nights	Annual number of days with TN > 20 °C	days
TR16C	Temperate Nights	Annual number of days with TN > 16 °C	days
ID	Ice Days	Annual number of days with TX < 0 °C	days
FD	Frost Days	Annual number of days with TN < 0 °C	days
CSDI	Cold Spells	Annual count of days with at least 6 consecutive days when TN < 10^{th} historical percentile	days
WSDI	Warm Spells	Annual count of days with at least 6 consecutive days when TX > 90^{th} historical percentile	days
GSL	Growing Season Length	Growing season length (number of days between first span of at least 6 days with TM > 5 °C and first span after July 1st of 6 days with TM < 5 °C)	days

Climdex: Precipitation-based			
CDD	Consecutive Dry Days	Annual maximum length of consecutive dry days (PR < 1 mm)	days
CWD	Consecutive Wet Days	Annual maximum length of consecutive wet days (PR ≥ 1 mm)	days
SDII	Simple Daily Precipitation Intensity Index	Annual average PR on days with PR ≥ 1mm	mm
R1MM	Precipitation ≥ 1mm	Annual count of days with PR ≥ 1mm	days
R10MM	Precipitation ≥ 10mm	Annual count of days with PR ≥ 10mm	days
R20MM	Precipitation ≥ 20mm	Annual count of days with PR ≥ 20mm	days
RX1DAY	Maximum 1-Day PR	Annual/seasonal maximum 1-day PR	mm
RX2DAY	Maximum 2-Day PR	Annual/seasonal maximum 2-day PR	mm
RX5DAY	Maximum 5-Day PR	Annual/seasonal maximum 5-day PR	mm
RN1DAY	Maximum 1-Day RAIN	Annual/seasonal maximum 1-day rainfall	mm
RN2DAY	Maximum 2-Day RAIN	Annual/seasonal maximum 2-day rainfall	mm
RN5DAY	Maximum 5-Day RAIN	Annual/seasonal maximum 5-day rainfall	mm
R95P	Very Wet Day PR	Annual total PR when PR > 95^{th} percentile of daily PR in historical period	mm
R95DAYS	Very Wet Days	Annual number of days when PR > 95^{th} percentile of daily PR in historical period	days
R99P	Extreme Wet Day PR	Annual total PR when PR > 99^{th} percentile of daily PR in historical period	mm
R99DAYS	Extreme Wet Days	Annual number of days when PR > 99^{th} percentile of daily PR in historical period	days
Degree Days			
CDDcold18C	Cooling Degree Days	Annual, cumulative TM difference above 18 °C	°C-days
GDDgrow5C	Growing Degree Days	Annual, cumulative TM difference above 5 °C	°C-days
HDDheat18C	Heating Degree Days	Annual, cumulative TM difference below 18 °C	°C-days
FDDfreeze0C	Freezing Degree Days	Annual, cumulative TM difference below 0 °C	°C-days
Degree Days			
HWD	Heatwave (HW) days	Annual count of HW days, where a HW is defined as both TX and TN exceeding: 1) their 95^{th} percentiles (historical), AND; 2) BC HARS thresholds[22] for at least 2 consecutive days.	days

22. The lower threshold temperatures used in our HW definition, which is intended for use throughout BC, are TX = 28°C and TN = 13°C. These are the lowest temperatures found in any region of the map in Figure 3, page 14 of the 2023 report, BC Provincial Heat Alert and Response System (BC HARS): 2023, May 2023. Available at: http://www.bccdc.ca/health-professionals/professional-resources/heat-event-response-planning.

HWN	HW number	Annual number of distinct HWs	#
HWXL	HW duration	Annual maximum HW length	days
TNH	HW intensity (night)	Average TN over all HWs in a year	°C
TXH	HW intensity (day)	Average TX over all HWs in a year	°C
TNHX	Maximum TNH	Average TN during most extreme HW in a year	°C
TXHX	Minimum TNH	Average TX during most extreme HW in a year	°C
HWDD	HW degree days	Annual, cumulative TM difference above HW threshold	°C-days
Return Levels			
TX_RP5	5-Year return level of TX	5-Year return level of TX	°C
TX_RP10	10-Year return level of TX	10-Year return level of TX	°C
TX_RP20	20-Year return level of TX	20-Year return level of TX	°C
TX_RP25	25-Year return level of TX	25-Year return level of TX	°C
TX_RP30	30-Year return level of TX	30-Year return level of TX	°C
TN_RP5	5-Year return level of TN	5-Year return level of TN	°C
TN_RP10	10-Year return level of TN	10-Year return level of TN	°C
TN_RP20	20-Year return level of TN	20-Year return level of TN	°C
TN_RP25	25-Year return level of TN	25-Year return level of TN	°C
TN_RP30	30-Year return level of TN	30-Year return level of TN	°C
RN1_RP5	5-Year return level of RN1DAY	5-Year return level of RN1DAY	mm
RN1_RP10	10-Year return level of RN1DAY	10-Year return level of RN1DAY	mm
RN1_RP20	20-Year return level of RN1DAY	20-Year return level of RN1DAY	mm
RN1_RP30	30-Year return level of RN1DAY	30-Year return level of RN1DAY	mm
RN1_RP50	50-Year return level of RN1DAY	50-Year return level of RN1DAY	mm
RN2_RP5	5-Year return level of RN2DAY	5-Year return level of RN2DAY	mm

RN2_RP10	10-Year return level of RN2DAY	10-Year return level of RN2DAY	mm
RN2_RP20	20-Year return level of RN2DAY	20-Year return level of RN2DAY	mm
RN2_RP30	30-Year return level of RN2DAY	30-Year return level of RN2DAY	mm
RN2_RP50	50-Year return level of RN2DAY	50-Year return level of RN2DAY	mm
RN5_RP5	5-Year return level of RN5DAY	5-Year return level of RN5DAY	mm
RN5_RP10	10-Year return level of RN5DAY	10-Year return level of RN5DAY	mm
RN5_RP20	20-Year return level of RN5DAY	20-Year return level of RN5DAY	mm
RN5_RP30	30-Year return level of RN5DAY	30-Year return level of RN5DAY	mm
RN5_RP50	50-Year return level of RN5DAY	50-Year return level of RN5DAY	mm