Fraser Basin Council

Climate Projections for the BC Northeast Region

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Acknowledgements

This report was developed as a collaboration between the members of the Northeast Climate Risk Network including the District of Chetwynd, City of Fort St. John, City of Dawson Creek, Village of Pouce Coupe, Northern Rockies Regional Municipality and District of Tumbler Ridge.

Contributing authors to this report include Trevor Murdock, Arelia Schoeneberg and Steve Sobie from the Pacific Climate Impacts Consortium (PCIC), who provided regional downscaled climate projections at locally relevant scales, Gillian Aubie Vines from Pinna Sustainability, who served as the lead writer of this report, as well as Victor Shopland from the City of Fort St. John, Chelsea Mottishaw from the City of Dawson Creek and Carol Newsom from the District of Chetwynd who represented the communities in the Northeast Climate Risk Network on the writing team. Cait Murphy and Jim Vanderwal from the Fraser Basin Council managed the project.

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Executive Summary

Climate change is challenging industry and communities across the Northeast region of the province. Wildfires, hail storms, and floods have already challenged local infrastructure and posed health risks to communities. Projected climate change for the region includes increases in frequency and intensity of extremes. Ensuring the region is as prepared as possible for future climate events is critical to maintaining a thriving community, robust natural environment, and vibrant economy. As prepared as possible means the region understands how the climate is changing, and is working together to increase resiliency, and to improve natural and physical infrastructure. Early efforts will reduce the reliance on emergency management and support the ability to thrive over time. Local governments in the region are taking a proactive approach to understanding how climate change will pose risks to Northeast communities and are planning together to build resiliency across the region.

This document is intended to offer science-based information on how the Northeast's climate is changing and expected to change over the 21st century. Designing to current and future climate parameters is anticipated to be markedly more cost effective than reacting to climate shocks and stresses over time. In the report, climate projections for the 2020s are offered to represent current climate conditions; projections for the 2050s illustrate the trajectory of change regardless of global emissions reductions; and projections for the 2080s illustrate our likely "business as usual" future climate scenario by late century. The 2020s projections are useful as they more accurately depict the current state of climate than historical observed baseline data. The 2050s projections are useful for medium-term planning and infrastructure purposes, while the 2080s provide guidance for long-term infrastructure decisions.

The global climate model projections used in this report offer useful insights into future climate conditions. The Northeast region can expect significant changes to its climate in the coming decades, including:

- **Increased precipitation across all seasons.** The largest increases in precipitation will take place during the spring and autumn months where, on average, the region can expect 30% more during these seasons by the 2080s. This can lead to more frequent ***flooding*** and stress to ecosystems.
- **Summer is expected to remain the wettest season, though by a smaller margin.** Even though precipitation is projected to increase slightly over summer months, on average, normal seasonal variability in precipitation plus hotter temperatures (and thus increased evaporation) could lead to drier, hotter summers, posing ***increased risk of wildfire and associated health impacts.***
- **Summers will be considerably warmer.** In the past, the region experienced an average of 12 days over 25°C annually. We can expect 32 days by the 2050s, and 49 days by the 2080s. Lower elevations, where the majority of the population resides, are expected to experience 40 days above 25°C by the 2050s and 60 days by the 2080s, with 10 days above 30°C by the 2050s and an astounding ***21 days over 30°C by late century.*** By the 2080s, summer temperatures in Fort St. John are projected to be about as warm as Kelowna's past summers (1980s). Temperatures projected will ***trigger significant heat stress*** across the region. The ability to provide clean drinking water as a shared resource to communities, industry, and agriculture may be strained. Higher demand for water during longer, hotter summers, as well as during dry spells, could create ***challenges for water supply, water quality, livestock, and crop yields.***
- **Winter temperatures are also projected to warm.** By the 2080s, January temperatures are projected to feel like March temperatures of the past, with warmer nights, 28% fewer frost days, and 37% longer growing seasons than the past.

Recent Climate Events

- Annual near-flood events across region
- 2016 Dawson Creek flood
- 2016 Chetwynd flood
- 2014 regional drought
- 2017 Pouce Coupe hail storm

More winter precipitation and later onset of freezing temperatures could potentially lead to ***additional annual freeze-thaw cycles and more frequent rain-on-snow events.*** Shifting seasonal temperatures could also result in premature pollination of crops and increased invasive species and pests, impacting agriculture production.

- **More extreme storm events in the future.** As the climate warms, more moisture is held in the atmosphere resulting in more intense precipitation during extreme events. Future storms may also bring stronger winds and hail events. These events will challenge regional infrastructure and may ***overwhelm sewerage and drainage systems.***
- **Physical and mental health effects.** As populations struggle to meet the new climate reality and recreation patterns are challenged by extreme events, the ***physical and mental health of Northeast residents may be challenged.*** For example, residents' usual outdoor activities, recreation, or community events may need to be postponed/cancelled due to wildfire and smoke. Other extreme weather events of concern include floods, high winds, and drought.
- **Summer streamflow to decrease in all basins.** Warmer temperatures means that relatively more precipitation will fall as rain rather than snow, which in general means an increase in winter runoff, reduced snowpack, and ***an earlier freshet.*** Less water stored over winter and melted earlier in the year also means reduced summer streamflow. These changes will be exacerbated by increased evaporation, leading to ***increased stress to water systems,*** even if summer precipitation is projected to increase slightly.

The intent of this document is to enable better-informed decisions across the region, ensuring Northeast communities, industries, and ways of life can be sustained over time. Work to understand and reduce local vulnerabilities will prepare the region for the changes ahead.

Chapter 1 – Introduction

Climate change is challenging industry and communities across the Northeast region of the province. Wildfires, hail storms, and floods have already challenged local infrastructure and posed health risks to communities. The communities of Chetwynd, Dawson Creek, Fort St. John, Northern Rockies Regional Municipality, Tumbler Ridge, and Pouce Coupe are working together to understand how climate change will shape the region over time, and how to improve risk management practices in preparation for future climate.

Information provided in this report is intended to illustrate likely future conditions, in order to provide decision makers important context on future climate conditions when making planning- and infrastructure-related decisions. Regional projections for numerous climate indicators related to temperature, precipitation, and indices of extremes demonstrate details of how the Northeast climate will likely change by the 2020s, 2050s, and 2080s. High-level comments on the impacts that could be associated with these changes are also presented as a first step in working collaboratively as a region to take a risk management approach to respond in advance to climate-related disasters.

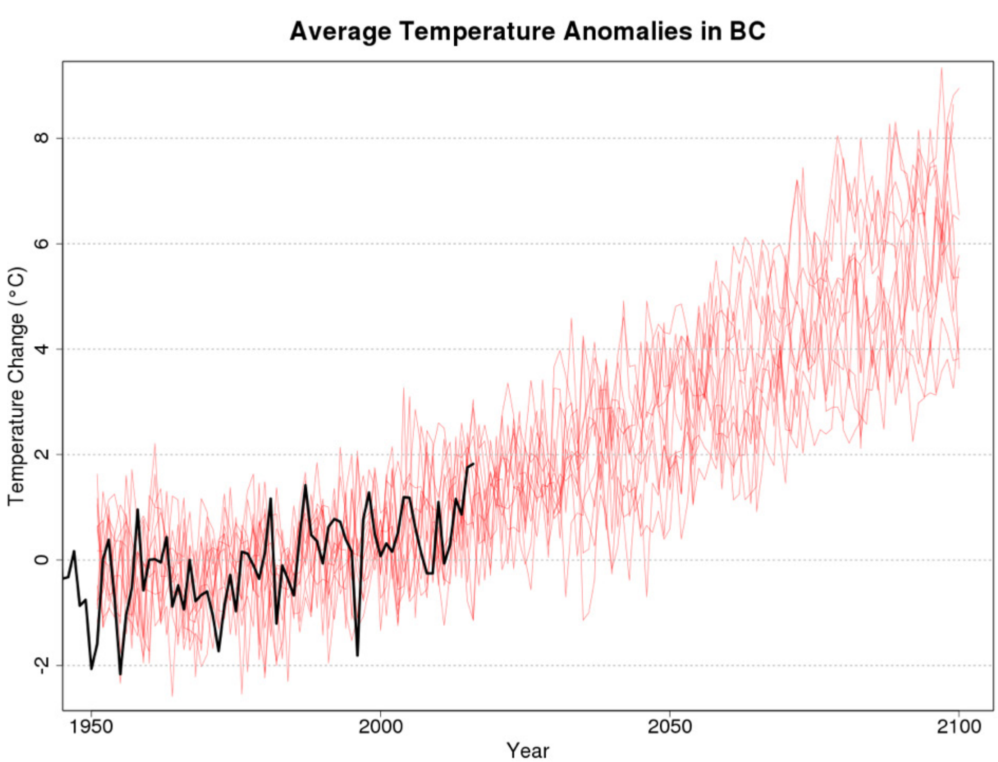
Data in the report is broken into regional (representing the entire Northeast), lowlands (representing the Peace River plateau), and highlands (representing mountainous areas). Results in the report are in some cases given by season: Winter is defined as December, January, and February [DJF], spring represents March, April, and May [MAM], summer represents June, July, and August [JJA], and autumn represents September, October, and November [SON].

Projections specific to participating communities are presented in the Technical Appendix and are intended to inform community-level vulnerability and risk assessments and planning. This document is not intended to offer a prediction of specific impacts or serve directly as design guidelines for future planning.

Understanding the Path of Climate Change

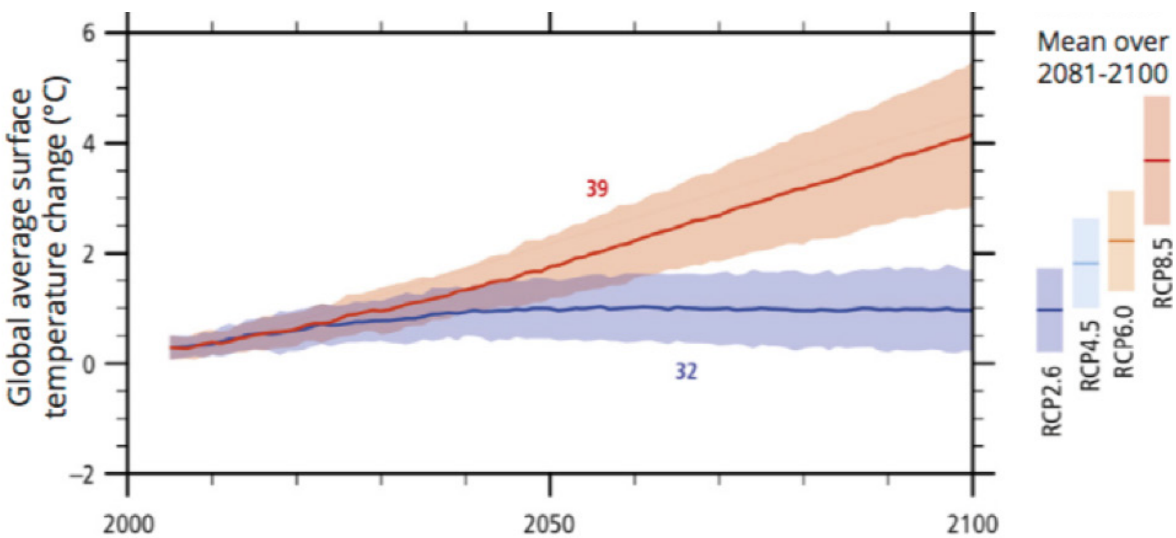
As illustrated in the graphic below, changes to the climate will not follow a linear path, but be fraught with more extreme weather each year, and large year-to-year swings in weather. As the changes outlined in this report will not always happen consistently over the region or over time, planners and managers will need to prepare for uncertainty and variability across seasons, and year after year (Figure 1).

Figure 1: Year-to-Year Climate Variation & Anomalies for 12 Global Climate Model Projections Following RCP8.5



How Much Will Our Climate Change?

The extent of how much the climate changes over time depends directly on global political initiatives and socio-economic changes that will occur over the coming years. While various future trajectories of greenhouse gas (GHG) emissions are possible, this report presents the internationally recognized "business as usual" greenhouse gas emissions scenario for the remainder of this century, known as Representative Concentration Pathway 8.5 (RCP8.5). The RCP4.5 "medium stabilization" scenario represents mitigation efforts that result in about half of the emissions compared to the RCP8.5 scenario. Substantial and sustained reductions in GHG emissions—for example, extensive adoption of biofuels and vegetarianism, along with carbon capture and storage—would be required to achieve RCP2.6, which is the only pathway that would keep global warming below 2°C above pre-industrial temperatures. The projected global temperature change for each pathway (below) illustrates moderate change is expected by the 2050s regardless of which GHG trajectory followed, but significant differences can be expected by the end of the century. This graphic also illustrates the importance of aggressive mitigation as a primary adaptation strategy in order to work towards the lowest RCP possible.



Detailed information on climate scenario and model selection, indicator derivation, and interpretation can be found in Appendix 1 – Methodology.

Chapter 2 — Overview Of Climate Projections For The Northeast

The Northeast region can expect noticeable changes to its climate in the coming decades. The major trend will tend towards ***warmer temperatures across all seasons and increased precipitation year-round.*** The region will still experience ***year-to-year variability,*** meaning some years will be warm, and others will be cold. Additionally, projections point to an increase in ***intensity and frequency of extreme weather and storm events.***

For most variables, projected change appears somewhat different from the past by the 2050s. By the 2080s, projections indicate substantial changes, resulting in a ***very different lived experience than that of the Northeast region of today.*** This is particularly true for the temperature-related variables, as the projected change is larger, compared to the year-to-year variability, for temperature than for precipitation.

For most variables, projected change appears somewhat different from the past by the 2050s. By the 2080s, projections indicate substantial changes, resulting in a very different lived experience than that of the Northeast region of today. This is particularly true for the temperature-related variables, as the projected change is larger, compared to the year-to-year variability, for temperature than for precipitation.

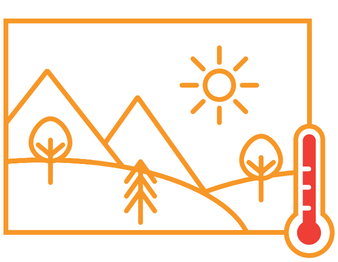
A high-level overview of regional climate projections includes:

- **Warmer temperatures year-round:** Future winter daytime and nighttime temperatures will be similar to past autumn temperatures. In the past we experienced an average of 16 days with temperatures above 25°C. We can expect 40 days by the 2050s, and a quadrupling (to 60) in days above 25°C in the lowlands by the 2080s, on average.
- **Winter temperatures are also projected to warm:** More winter precipitation in combination with shifting winter temperatures could result in additional annual freeze-thaw cycles and more frequent rain-on-snow events. By late-century, January temperatures will feel like March temperatures of the past.
- **Increased precipitation across all seasons:** The largest increases in precipitation will take place during the spring and autumn months where, on average, the region can expect 30% more during these seasons by the 2080s. Warmer temperatures will cause more of the precipitation to fall as rain than snow.
- **Summer is expected to remain the wettest season, though by a smaller margin:** Normal seasonal variability in precipitation can lead to some drier, hotter summers.
- **Summers will be considerably warmer:** By mid-century, we can expect average summer hottest days to be almost 4°C warmer, and by late-century, summer temperatures in the region will be more like the Okanagan region of the past.
- **Streamflow will decrease:** Because of the above changes in temperature and precipitation, streamflow will decrease by roughly a quarter compared to the past, on average, in summer and increase in the rest of the year.

Warmer Temperatures

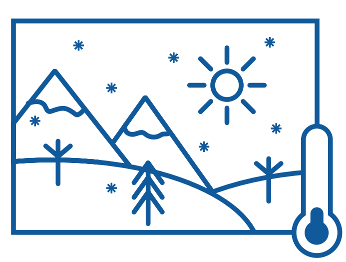
About these Indicators

Hottest Day (TXx) refers to the hottest daytime high temperature of the season (or year) while ***Hottest Night*** (TNx) refers to the hottest nighttime low temperature of the season (or year). Hottest day and hottest night are usually experienced during the summer months. ***Coldest Day*** (TXn) refers to the lowest daytime temperature, while ***Coldest Night*** (TNn) refers to the lowest nighttime temperature. These measures help the region prepare for new climate conditions year-round. Taken together, these indicators illustrate how daily and seasonal extreme temperature changes are projected to unfold over time.



Hottest Day (TXx)

Hottest Night (TNx)



Coldest Day (TXn)

Coldest Night (TNn)

Projections:

- New climate conditions for the region may be very unlike the past.
- Hottest Day (TXx) and Hottest Night (TNx) are projected to warm across all seasons, but particularly in summer. Hottest summer day is projected to warm slightly more (3.7°C) than hottest summer night (3.3°C) by the 2050s.
- Coldest Day (TXn) and Coldest Night (TNn) are also projected to warm in all seasons. Springs, winters, and autumns are projected to warm more rapidly than summers.
- Hottest Night (TNx) in winter (DJF) and Coldest Night (TNn) in summer (JJA) have historically been below freezing (with 1971–2000 baseline values of -1.0°C and -0.4°C for the region). Both are projected to warm enough to bring each above freezing.
- By the 2080s, future January temperatures will be similar to March temperatures of the past (See box-and-whisker plots in Figure 2 and Figure 3).

Table 1: Hottest Day (TXx)

	Past (C°)		2020 Change	2050 Change	2080 Change
Spring	22.1	Average (C°) Range (C°)	1.4 (0 to 3)	2.6 (1 to 4)	4.4 (1 to 7)
Summer	27.9	Average (C°) Range (C°)	1.6 (1 to 3)	3.7 (1 to 7)	6.0 (3 to 10)
Autumn	21.4	Average (C°) Range (C°)	1.5 (1 to 3)	3.2 (2 to 5)	5.3 (3 to 8)
Winter	8.3	Average (C°) Range (C°)	0.7 (0 to 2)	1.5 (0 to 3)	2.5 (1 to 4)
Annual	28.0	Average (C°) Range (C°)	1.6 (1 to 3)	3.7 (1 to 6)	6.0 (3 to 10)

Table 2: Hottest Night (TNx)

	Past (C°)		2020 Change	2050 Change	2080 Change
Spring	7.4	Average (C°) Range (C°)	1.3 (1 to 2)	2.5 (1 to 4)	4.5 (3 to 6)
Summer	12.9	Average (C°) Range (C°)	1.5 (1 to 2)	3.3 (2 to 5)	5.4 (3 to 8)
Autumn	8.2	Average (C°) Range (C°)	1.5 (1 to 2)	3.1 (2 to 4)	5.0 (3 to 7)
Winter	-1.0	Average (C°) Range (C°)	1.4 (0 to 2)	2.4 (0 to 4)	3.9 (1 to 7)
Annual	13.0	Average (C°) Range (C°)	1.5 (1 to 2)	3 (2 to 5)	5.3 (3 to 8)

Table 3: Coldest Days (TXn)

	Past (C°)		2020 Change	2050 Change	2080 Change
Spring	-15.3	Average (C°) Range (C°)	2.2 (0 to 4)	4.5 (3 to 7)	6.8 (4 to 10)
Summer	8.6	Average (C°) Range (C°)	1.0 (1 to 2)	2.4 (2 to 3)	4.4 (3 to 6)
Autumn	-19.7	Average (C°) Range (C°)	3.2 (2 to 4)	6.1 (5 to 7)	9.3 (8 to 11)
Winter	-29.4	Average (C°) Range (C°)	3.1 (1 to 5)	6.2 (5 to 8)	9.8 (8 to 12)
Annual	-29.9	Average (C°) Range (C°)	3.1 (2 to 5)	6.2 (4 to 8)	9.8 (9 to 12)

Table 4: Coldest Nights (TNn)

	Past (C°)		2020 Change	2050 Change	2080 Change
Spring	-28.7	Average (C°) Range (C°)	2.8 (0 to 5)	5.7 (4 to 8)	8.9 (6 to 13)
Summer	-0.4	Average (C°) Range (C°)	1.3 (1 to 2)	2.9 (2 to 4)	4.9 (4 to 7)
Autumn	-28.7	Average (C°) Range (C°)	3.4 (1 to 5)	6.8 (5 to 8)	10.5 (9 to 13)
Winter	-38.1	Average (C°) Range (C°)	3.4 (2 to 5)	6.5 (5 to 8)	10.6 (9 to 12)
Annual	-38.8	Average (C°) Range (C°)	3.2 (2 to 5)	6.3 (5 to 8)	10.3 (9 to 12)

Figure 2: Monthly Daytime High Temperature – Past, 2050S, & 2080S

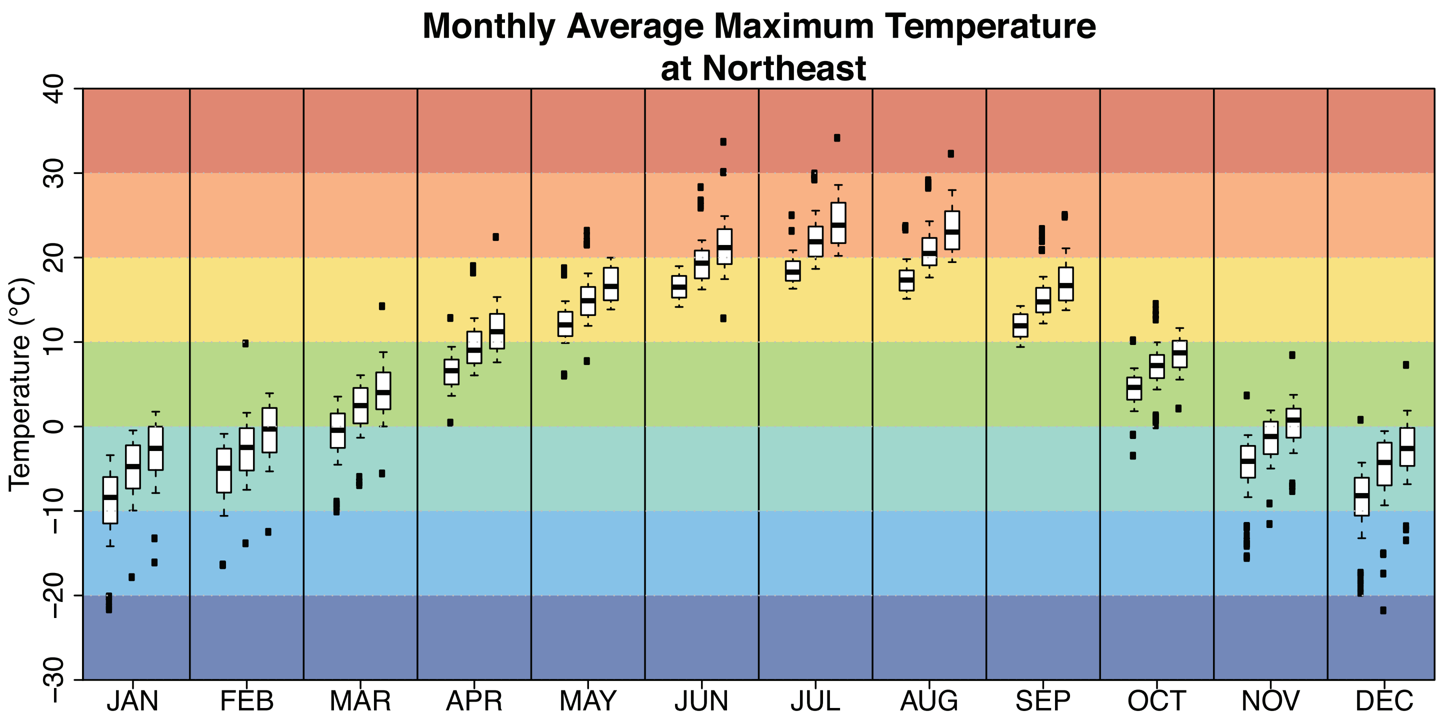
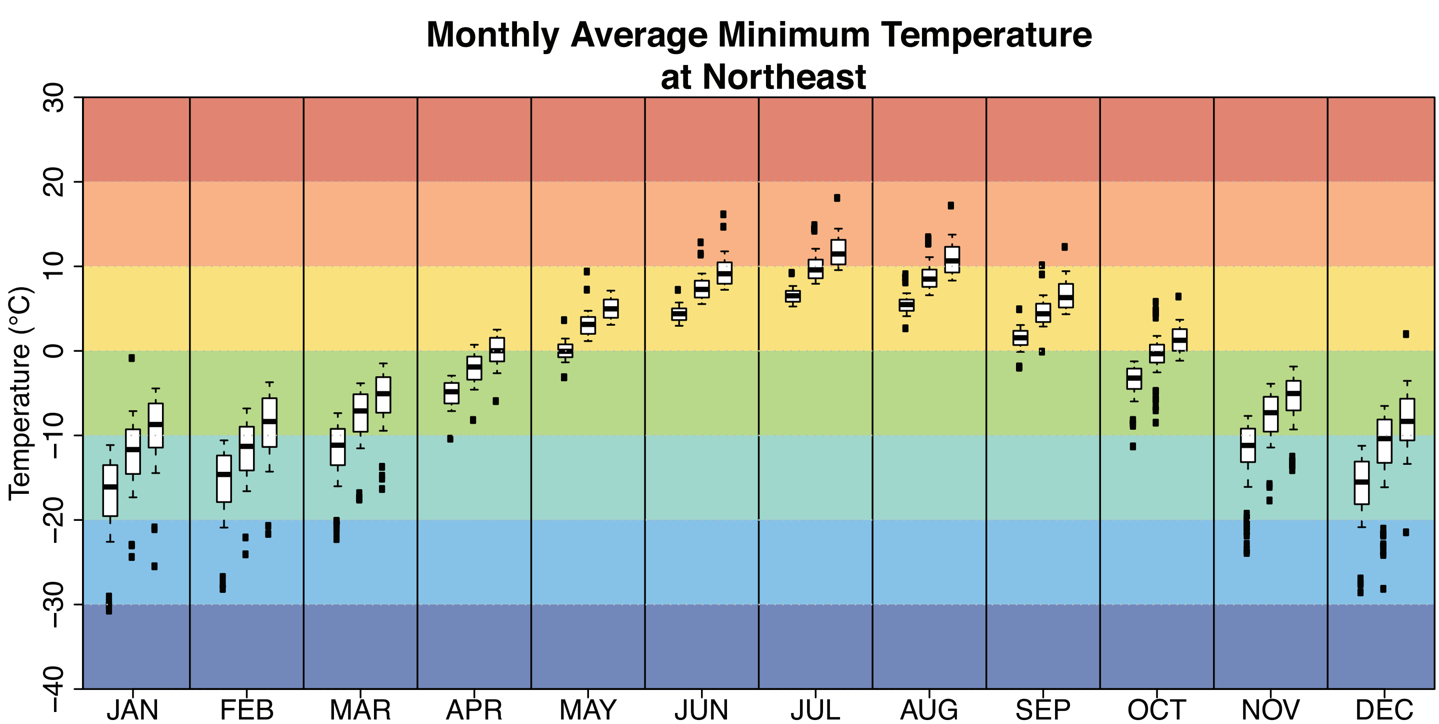


Figure 3: Monthly Nighttime Low Temperature – Past, 2050s, & 2080s



The box-and-whisker plots of monthly daytime high and nighttime low temperatures provide a comparison of the potential year-to-year variability in the future to that experienced in the past. Boxes from left to right in each month indicate past, 2050s, and 2080s. Further explanation of how to read the box-and-whisker plots is provided in Appendix 1 - Methodology.

More Precipitation

About this Indicator

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

Projections:

- Precipitation increases can be expected year-round.
- Largest increases during the spring and autumn months. On average, the region can expect 30% more during these seasons by the 2080s.
- On average, summer will remain the wettest season, but by a smaller margin.
- While projections indicate an increase in precipitation year-round, the range in models and natural year-to-year variation could result in some years experiencing extended periods without precipitation.
- By the late century, October will be the wettest month of the year, on average (Figure 5).

Table 5: Total Seasonal Precipitation

	Past (mm)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Spring	111	Average Range	7% (4 to 12)	19% (10 to 24)	29% (19 to 38)
Summer	236	Average Range	4% (-4 to 12)	7% (-1 to 15)	5% (-2 to 11)
Autumn	142	Average Range	6% (0 to 15)	15% (6 to 24)	30% (13 to 49)
Winter	105	Average Range	9% (2 to 19)	11% (4 to 22)	20% (15 to 28)

The maps below indicate that the wetter, mountainous areas are expected to experience the largest increases in precipitation.

Figure 4: Fall Precipitation – Past & Percent Change (2050s)

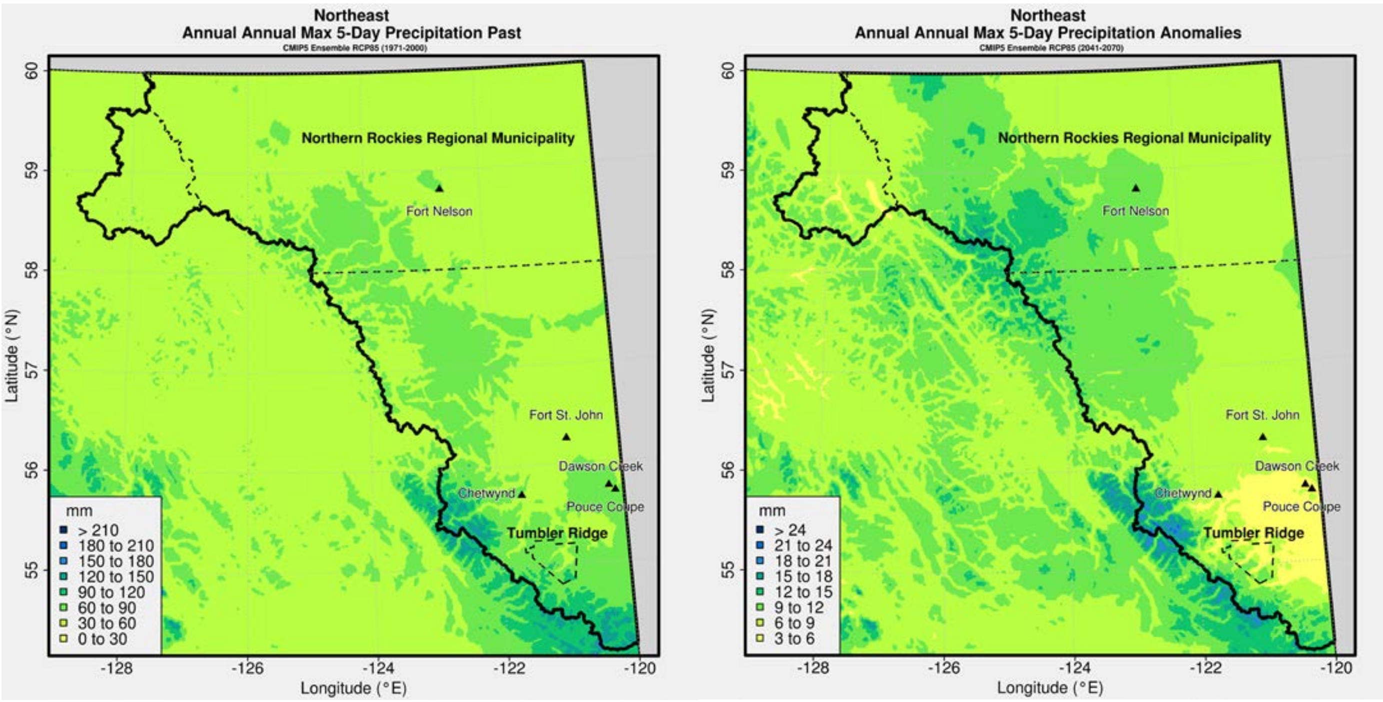
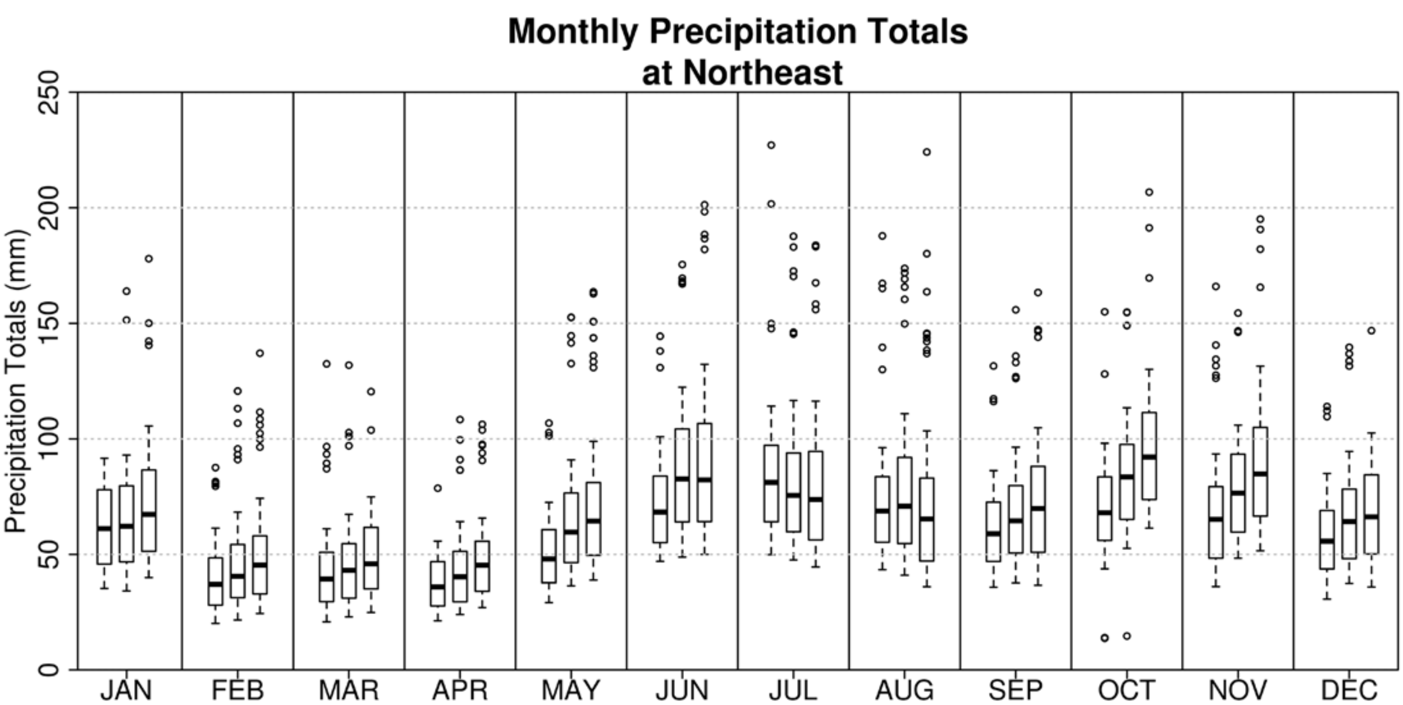


Figure 5: Monthly Total Precipitation – Past, 2050s, & 2080s



Chapter 3 — Summer Temperature Indicators

As referenced in the previous section, summer temperatures are expected to warm considerably over time, indicating that new climate conditions in summer will be very unlike the past. This section further describes changes in summer temperature, and provides descriptions of the indicators and values relating to future average and extreme summer temperatures. Indicators were selected based on their ability to provide insight into energy management and building design, public and ecosystem health, agricultural productivity, and other economic activities.

Days Above 25°C

About this Indicator

Days above 25°C indicates how many days reach temperatures over 25°C per year. This measure indicates how often the region can expect warm summer weather to occur in the future.

Projections

- In the past, the region experienced, on average, 12 days above 25°C. The Northeast can expect, on average, 32 days per year above 25°C by the 2050s, and 49 days per year by the 2080s.
- The greatest increases will occur in the lowlands (Table 6).
- In the past, lowlands experienced 16 days above 25°C. By the 2050s, the lowlands can expect 40 days above 25°C, and 60 days by the 2080s, on average. This is nearly 4 times as many days above 25°C as in the past for the populated and agricultural areas by late century.
- In contrast, the highlands experienced, on average, 5 days in the past and will experience 17 days by the 2050s and 31 days by the 2080s.

Table 6: Summer Days Above 25°C

	Past (days)		2020 Change	2050 Change	2080 Change
Regional	12	Average (days) Range (days)	8 (2 to 11)	20 (7 to 24)	37 (14 to 62)
Lowlands	16	Average (days) Range (days)	10 (3 to 15)	24 (9 to 41)	44 (19 to 70)
Highlands	5	Average (days) Range (days)	4 (1 to 7)	12 (3 to 23)	26 (8 to 48)

Days Above 30°C

About this Indicator

Days above 30°C indicates how many days reach temperatures over 30°C in any one year. This indicator of extreme heat is important to public health as temperatures at or near 30°C can cause heat stress in vulnerable populations.

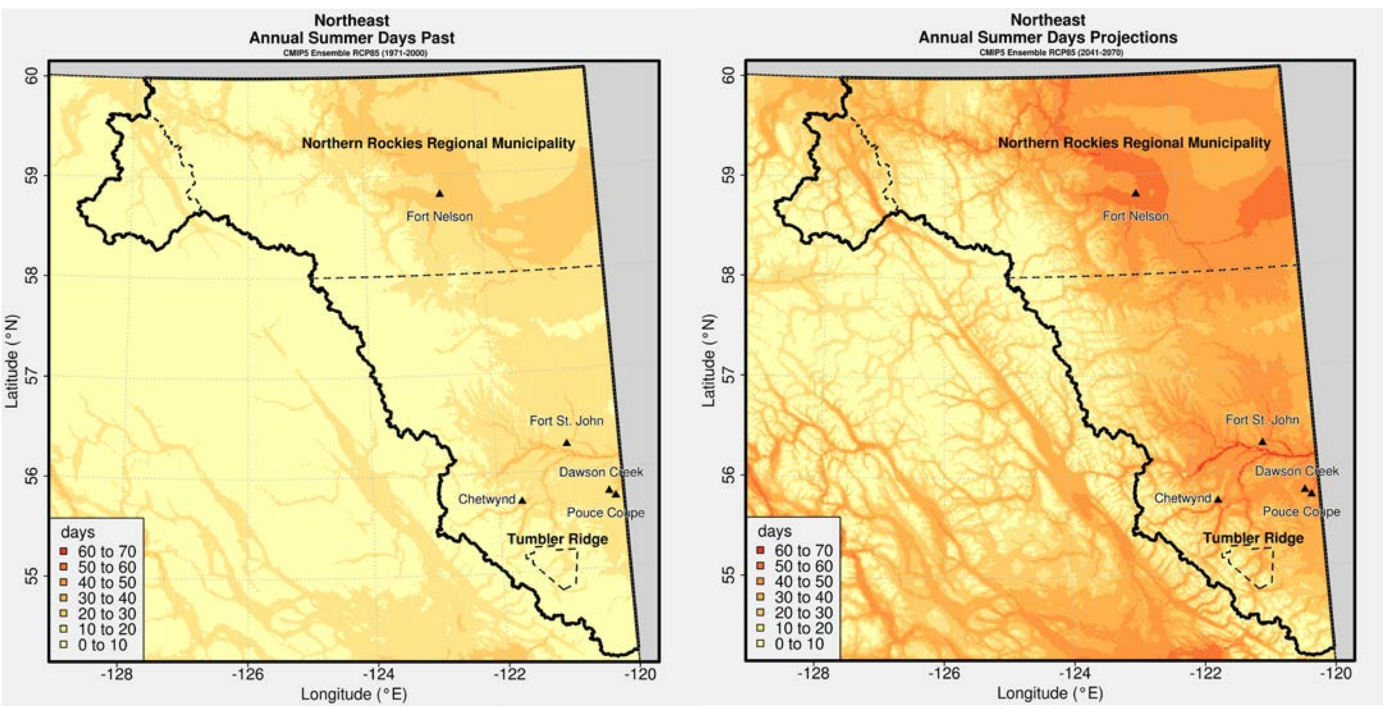
Projections

- In the past, the region experienced 1 day per year, on average, above 30°C. By the 2050s, the region can expect 7 days above 30°C per year, on average, and 17 days per year by the 2080s. This marks a considerable change.
- The greatest increases will occur at the lower elevations throughout the region, which can expect 10 days over 30°C, on average, by the 2050s, and ***21 days over 30°C, on average, by the 2080s.***
- The highlands will also experience an increase in days above 30°C, but this increase will be much less than in the lowlands.

Table 7: Summer Days Above 30°C

	Past (days)		2020 Change	2050 Change	2080 Change
Regional	1	Average (days) Range (days)	2 (0 to 3)	6 (1 to 13)	16 (3 to 33)
Lowlands	1	Average (days) Range (days)	2 (1 to 4)	9 (2 to 17)	20 (4 to 41)
Highlands	0	Average (days) Range (days)	1 (0 to 1)	3 (0 to 7)	9 (1 to 20)

Figure 6: Days Above 25°C – Past & Future (2050s)



1-in-20 Hottest Day

About this Indicator

1-in-20 hottest day refers to a day so hot that it has only a 1-in-20 chance of occurring in a given year. That is, there is a 5% chance in any year that a daytime high temperature could reach this threshold. This indicator illustrates what extreme heat events will feel like over time, and will be useful for health, agriculture, forestry, and natural ecosystems.

Projections

- In the past, the regional average 1-in-20 hottest day was 31°C. In the future, the region can expect this to increase by 5°C, to 36°C, by the 2050s, and by 7°C, to 38°C, by the 2080s. This change is quite consistent across the region.

Growing Season Length

About this Indicator

Growing season length is an annual measure that counts the number of days between the first span of at least 6 days with a daily average temperature greater than 5°C and the first span after July 1 of 6 days with temperature less than 5°C. It indicates the length of the growing season for typical plants or crops. This measure helps us to understand how opportunities for agriculture may be affected.

Projections

- In the past, the region experienced an average of 160 days in the growing season at lower elevations where farming occurs.
- Across the Northeast, the region can expect this to increase to an average of 178 growing season days a year by the 2050s, and 198 by the 2080s (see Figure 13 in Appendix 2).
- The region can expect 189 growing season days in the lowlands, and 162 in the highlands by the 2050s.
- While the largest number of growing season days will occur in the lowlands, the largest increase will occur in the highlands, potentially stressing ecosystems (see data for highlands in Appendix 2).

Table 8: Growing Season Length

	Past (days)		2020 Change	2050 Change	2080 Change
Regional	145	Average (days) Range (days)	16 (9 to 22)	33 (22 to 44)	53 (37 to 69)
Lowlands	160	Average (days) Range (days)	14 (7 to 21)	29 (19 to 41)	45 (31 to 60)

Growing Degree Days

About this Indicator

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

Projections

- In the past, the region experienced, on average, 930 growing degree days. In the future, this number can be expected to increase by approximately 50% by the 2050s, and nearly double to 1800 growing degree days by the 2080s.
- By the 2050s, lower elevations can expect over 50% more growing degree days (1500), and by the 2080s, lower elevations can expect over 2000 growing degree days, an 81% increase from the past.
- By the 2080s, higher elevations will experience growing degree days larger than lowland values of the past (Table 9).

Table 9: Growing Degree Days

	Past (days)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Regional	930	Average Range	23% (12 to 32)	53% (29 to 82)	92% (53 to 138)
Lowlands	1100	Average Range	21% (11 to 29)	47% (26 to 71)	81% (46 to 122)
Highlands	660	Average Range	29% (15 to 41)	68% (38 to 108)	121% (71 to 181)

Cooling Degree Days

About this Indicator

Cooling degree days refers to the number of degrees that a day's average temperature is above 18°C. To determine the number of cooling degree days in a month, the number of degrees that the daily temperature is over 18°C for each day would be added to give a total value. This measure is used to estimate the use of air conditioning to cool buildings.

Projections

- Historically, there has been little demand for cooling in this region (an average of 12 cooling degree days).
- The region can expect an increase of 70 more cooling degree days by the 2050s, and 171 more by the 2080s.
- Lowlands are expected to experience the largest increases in cooling degree days (see Table 10).
- These increases represent a considerable change in cooling demand from the past.

Table 10: Cooling Degree Days

	Past (degree days)		2020 Change	2050 Change	2080 Change
Regional	12	Average (degree days) Range (degree days)	20 (6 to 31)	70 (24 to 132)	171 (54 to 322)
Lowlands	18	Average (degree days) Range (degree days)	27 (8 to 43)	94 (34 to 173)	220 (74 to 402)
Highlands	3	Average (degree days) Range (degree days)	7 (2 to 12)	33 (8 to 69)	94 (22 to 198)

*Actual change is shown (not percent change) due to low baseline values.

Chapter 4 — Winter Temperature Indicators

As has been noted above, winter temperatures are projected to warm. By the 2080s, January temperatures will feel like March temperatures of the past, with warmer nights and fewer frost days. These changes will likely lengthen the growing season. This section further describes changes in winter temperatures, with indicators that provide insight into average and extreme winter temperatures in the future across the Northeast region. The indicators in this chapter were selected because together they provide an enhanced understanding of how Northeast winters can be expected to change over time.

1-in-20 Coldest Night

About this Indicator

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

Projections

- The past 1-in-20 coldest night was almost -44°C. This will warm to -38°C by the 2050s and to -34°C by the 2080s.

Figure 7: Coldest Winter Nights (TNn) - Past & Future (2050s)

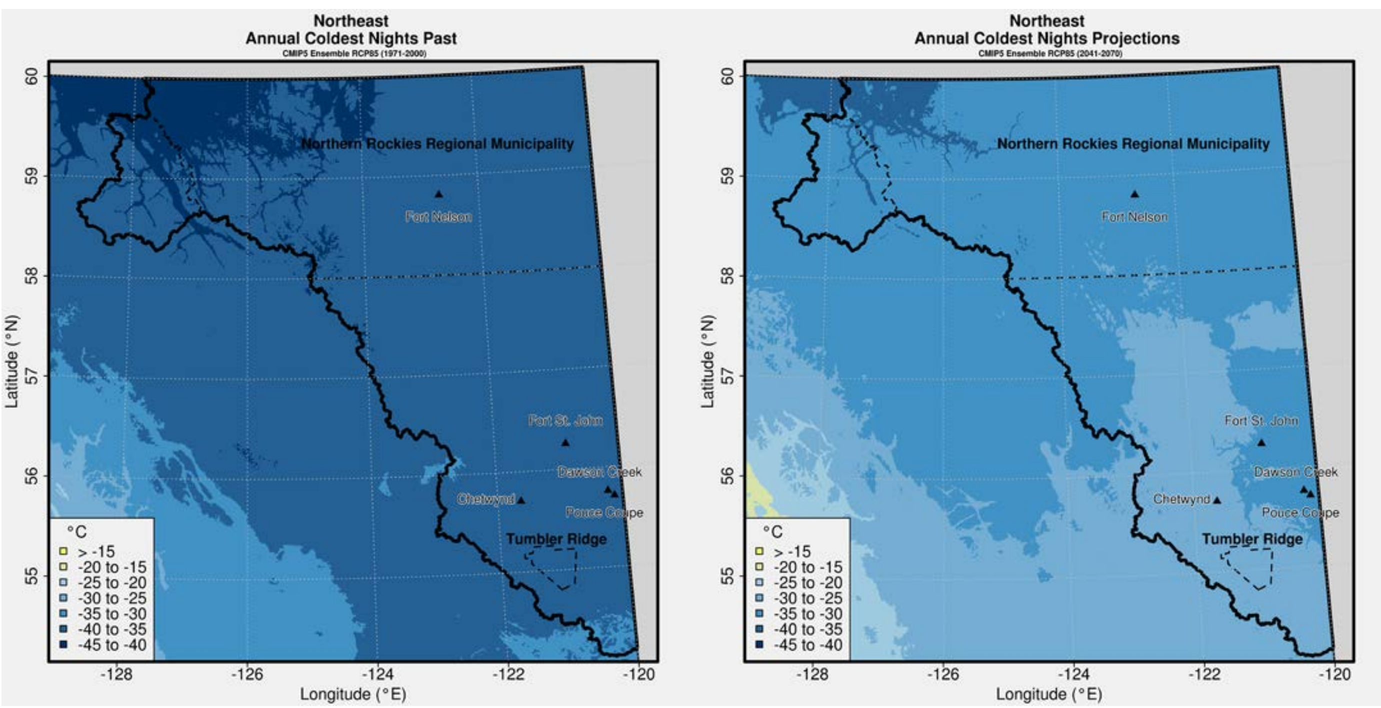


Table 11: Extreme Winter Temperature Indicators

	Past (°C)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Warmest Winter Day (TXx)	8.3	Average (°C) Range (°C)	0.7 (0 to 2)	1.5 (0 to 3)	2.5 (1 to 4)
Coldest Winter Night (TNn)	-38.1	Average (°C) Range (°C)	3.4 (2 to 5)	6.5 (5 to 8)	10.6 (9 to 12)
Coldest Winter Day (TXn)	-29.4	Average (°C) Range (°C)	3.1 (1 to 5)	6.2 (5 to 8)	9.8 (8 to 12)
1-in-20 Coldest Night (RP20 TASMIN)	-43.5	Average (°C) Range (°C)	2.4 (1 to 4)	5.5 (4 to 7)	9.6 (8 to 12)

Frost Days

About this Indicator

- *Frost days* is an annual count of days when the daily minimum temperature is less than 0°C, which may result in frost on the ground. This indicator is useful because changes in how often temperatures below freezing occur could affect native and agricultural species.

Projections

- In the past, the region has experienced, on average, 222 frost days. The region will experience 18% fewer frost days by the 2050s, and 28% fewer by the 2080s.
- Frost days will decrease at higher elevations slightly faster than at lower elevations. By the 2080s, the region can expect to see 31% less frost days at higher elevations, on average. (See Table 12).
- Fewer frost days have implications for invasive species, agriculture, and streamflow.

Table 12: Frost Days

	Past (days)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Regional	222	Average Range	-8% (-11 to -6)	-18% (-24 to 12)	-28% (-36 to -22)
Lowlands	212	Average Range	-8% (-10 to -5)	-17% (-23 to -11)	-26% (-34 to -20)
Highlands	237	Average Range	-9% (-11 to -7)	-19% (-25 to -14)	-31% (-39 to -25)

Ice Days

About this Indicator

Ice days are days when the daytime high temperature is less than 0°C. This measure offers insight into changes in the number of days when the temperature does not rise above freezing, which could affect ecosystems, species, and transportation in the region.

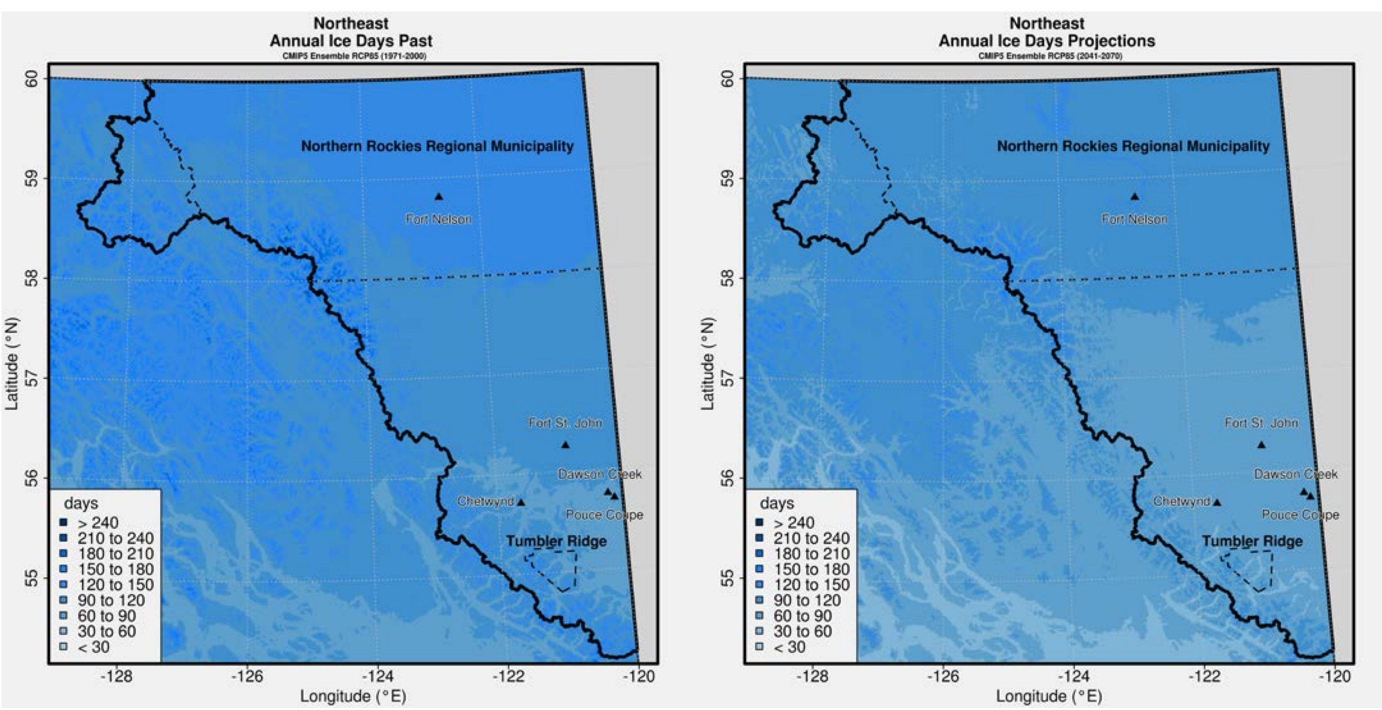
Projections

- In the past, the region had, on average, 119 ice days. The Northeast will experience fewer ice days by the 2050s, and even less by the 2080s.
- Highland ice days will reduce slightly more than the regional average (see Figure 8 maps below).
- Depending on annual variability, this could result in additional freeze-thaw cycles in some years, possibly leading to rain-on-snow events.

Table 13: Ice Days

	Past (days)		2020 Change (days)	2050 Change (days)	2080 Change (days)
Regional	119	Average Range	-12 (-17 to -7)	-22 (-29 to -14)	-37 (-50 to -23)
Lowlands	118	Average Range	-10 (-15 to -6)	-20 (-28 to -13)	-34 (-49 to -20)
Highlands	121	Average Range	-14 (-19 to -9)	-26 (-34 to -16)	-42 (-53 to -27)

Figure 8: Ice Days – Past & Future (2050s)



Heating Degree Days

About this Indicator

Heating degree days is an indicator of the amount of energy that it takes to heat buildings to comfortable temperatures. It is a derived variable calculated by multiplying the number of days that the average daily temperature is below 18°C by the number of degrees below that threshold. For example, if a given day saw an average temperature of 14°C (4°C below the 18°C threshold), that day contributed 4 heating degree days to the total. If a month had 15 such days, and the rest of the days had average temperatures above the 18°C threshold, that month would result in 60 heating degree days.

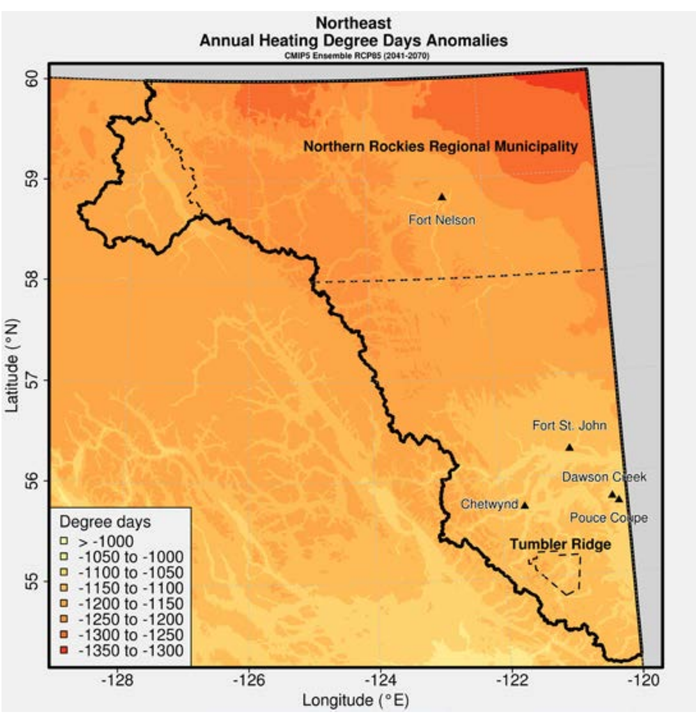
Projections

- The region currently experiences more heating degree days than cooling degree days.
- The past regional average heating degree days is 6640. This will decrease by 18% by the 2050s, and 28% by the 2080s. This percent change in degree days in similar across the region and marks a considerable difference from the past.
- The region will require less energy for heating in the future, more so in regions where heating loads were greatest. (Figure 9).

Table 14: Heating Degree Days

<table>
<tr><th></th><th>Past (degree days)</th><th></th><th>2020 Percent Change</th><th>2050 Percent Change</th><th>2080 Percent Change</th></tr>
<tr><td>Regional</td><td>6640</td><td rowspan="3">Average
Range</td><td rowspan="3">-9%
(-12 to -6)</td><td rowspan="3">-18%
(-24 to -12)</td><td rowspan="3">-28%
(-36 to -21)</td></tr>
<tr><td>Lowlands</td><td>6480</td></tr>
<tr><td>Highlands</td><td>6890</td></tr>
</table>

Figure 9: Heating Degree Days – Future Change (2050s)



Chapter 5 — Precipitation Indicators

As noted previously, precipitation increases can be expected year-round, with the largest increases during the spring and autumn months. On average, the region can expect 30% more precipitation during these seasons by the 2080s. The Northeast can also expect summer to remain the wettest season, but by a smaller margin. By the 2050s, on average, October and November precipitation is expected to be greater than the summer months of the past (Figure 5). Although the highlands and lowlands experienced a difference in precipitation levels in the past, the relative increases are similar across the region over time. The indicators below offer additional insight into future precipitation trends for the Northeast region. These indicators offer insight into future drought and storm intensity, and will be important for potable water, flood, and stormwater management.

Wettest Day

About this Indicator

Wettest day is the largest amount of rain that falls on any single day, on average.

Projections

- Precipitation volume on wet days will increase.
- In the past, the wettest day (averaged over the region) was a day with 27 mm of precipitation. This will increase by 18% by the 2050s, and 23% by the 2080s. This relative change is quite consistent across the region.

Wettest 5 Days

About this Indicator

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

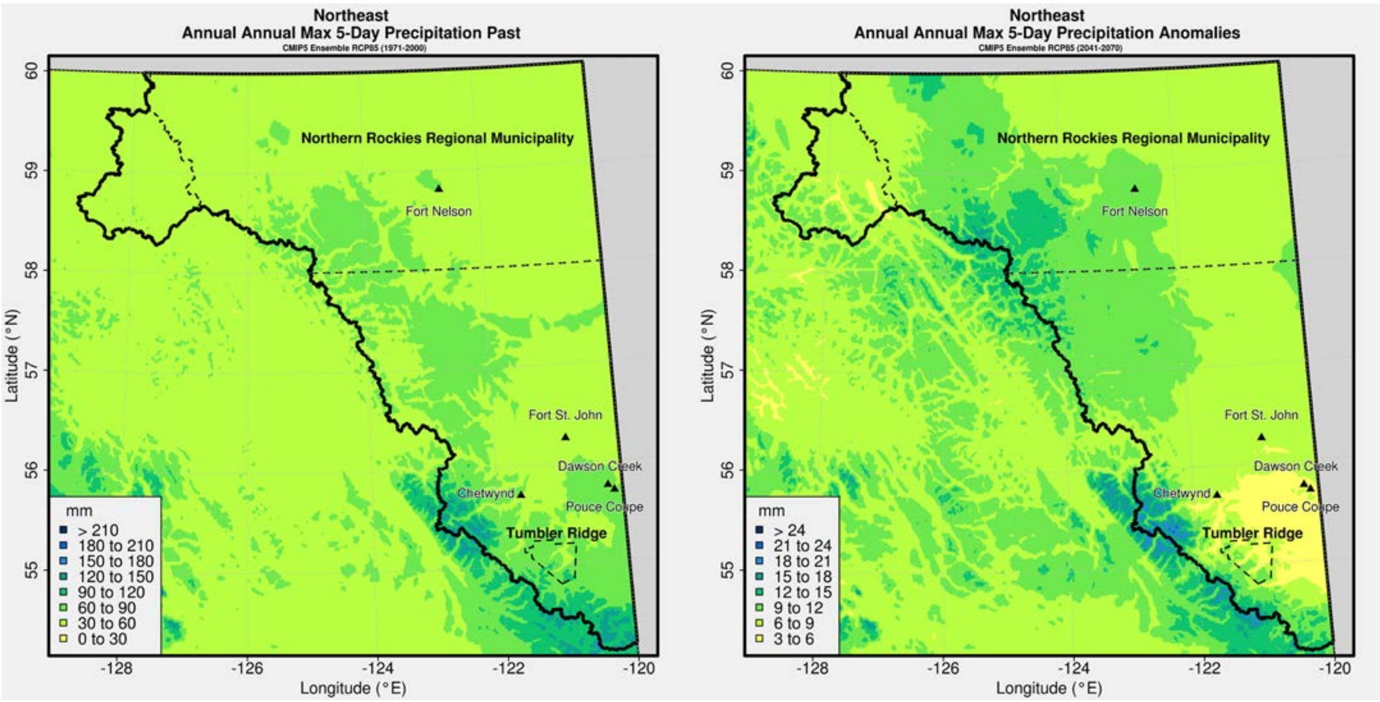
Projections

- In the past, the wettest 5 days received 53 mm of precipitation, on average. This will increase by 17% by the 2050s, and 21% by the 2080s.
- Similar relative increases are expected across the region, though westward mountainsides will see the largest increases in the wettest 5 days (see Figure 10 maps).

Table 15: Wettest Day & Wettest Days

	Past (mm)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Wettest day of the year precipitation	27	Average Range	11% (2 to 24)	18% (9 to 33)	23% (11 to 38)
Wettest 5 days of the year precipitation	53	Average Range	10% (2 to 17)	17% (7 to 30)	21% (10 to 30)

Figure 10: Wettest Five Days – Past & Future Change (2050s)



95th & 99th Percentile Wettest Days

About this Indicator

The 95th percentile wettest days precipitation indicator (R95P) is an indicator of extreme precipitation. It is the total amount of rain that falls on the wettest days of the year, specifically on days when precipitation exceeds a threshold set by the annual 95th percentile during the baseline period (1971–2000). The ***99th percentile wettest days*** (R99P) is the total amount of rain that falls on the wettest days of the year, specifically when precipitation exceeds a threshold set by the annual 99th percentile of wet days during the baseline period.[1] This indicator measures total annual precipitation during heavy events, which is a combination of both how often these events occur (frequency) and the size of these events (magnitude).

Projections

- In the past, the precipitation on days above the 95th percentile wettest day was, on average, 121 mm. This will increase by 19% by the 2050s, and by 60% by the 2080s. This is a remarkable change, especially by the latter half of the century.
- Increases will be somewhat higher in the highlands (43% by the 2050s; 70% by the 2080s) than in the lowlands (35% by the 2050s; 51% by the 2080s).
- In the past, the precipitation on days above the 99th percentile wettest day was, on average, 38 mm. By the 2050s, this amount is expected to increase by 64%, and to nearly double by the 2080s.
- The region can expect both more frequent large precipitation events and an increased intensity of precipitation that falls during these events.

[1] More information about percentiles can be found in Appendix 1 – Methodology and Interpretation.

Table 16: 95th Percentile Wettest Days

	Past (mm)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Regional	121	Average Range	19% (5 to 29)	39% (23 to 58)	60% (39 to 84)
Lowlands	108	Average Range	19% (0 to 35)	35% (12 to 57)	51% (27 to 77)
Highlands	142	Average Range	19% (7 to 30)	43% (31 to 65)	70% (45 to 96)

Table 17: 99th Percentile Wettest Days

	Past (mm)		2020 Percent Change	2050 Percent Change	2080 Percent Change
Regional	38	Average Range	33% (7 to 57)	64% (21 to 86)	93% (54 to 136)
Lowlands	35	Average Range	34% (4 to 69)	59% (16 to 100)	78% (29 to 117)
Highlands	44	Average Range	32% (11 to 48)	71% (50 to 99)	113% (76 to 159)

1-in-20 Wettest Day

About this Indicator

The 1-in-20 wettest day is and indicator of extreme weather. It is a day so wet that it has only a 1-in-20 chance of occurring in a given year. That is, there is a 5% chance in any year that a 1-day rainfall event of this magnitude will occur.

Projections

- In the past, the 1-in-20 wettest day was a day with 47 mm of precipitation, on average. This is expected to increase by 25% by the 2050s and 29% by the 2080s. Similar relative increases are expected quite consistently across the region.

Table 18: 1-in-20 Wettest Day

	Indicator Code	Past (mm)		2020 Percent Change	2050 Percent Change	2080 Percent Change
1-in-20 Wettest Day	RP20 PR	47	Average Range	14% (3 to 33)	25% (14 to 33)	29% (11 to 44)

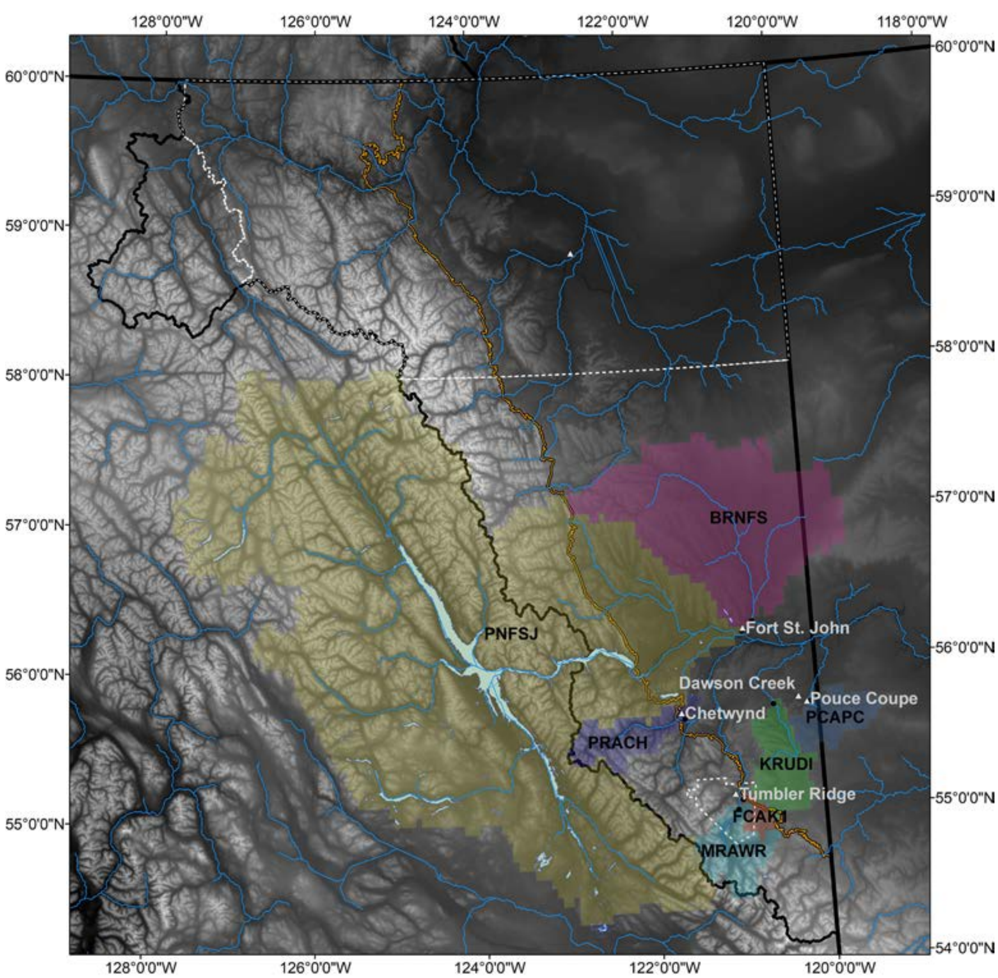
Chapter 6 — Hydrology

Participating communities selected seven locations (see Figure 11) on regional waterways close to communities for analysis to gain insight into future regional water resource management.[2] Analysis was conducted to determine changes in annual and seasonal low and high flows to reflect future water availability, occurrence of droughts and floods, and impacts on extraction and discharge practices. Additionally, snowpack in these watersheds was analyzed to better understand causes for future streamflow changes.

Results demonstrate that hydrology in the region is shifting. In the future, warmer temperatures will cause a larger proportion of precipitation to fall as rain versus snow than occurred in the past. This will result in a smaller snowpack, an earlier freshet with slightly higher peak flows, and less snowmelt contributing to summer flows. These factors, combined with small relative increases in precipitation and increased evaporation, result in considerably less streamflow in summer: -27% on average (-9% to -46%).

Overall, even though there will be precipitation falling as rain, and more runoff in the winter period, the basins identified by the communities will remain snowmelt dominated.

Figure 11: Selected Watersheds



[2] Results were provided for all watersheds of interest to the Northeast assessment communities for which the Pacific Climate Impacts Consortium (PCIC) have model results. PCIC applied the Variable Infiltration Capacity model (VIC-GL) on the Peace River Basin, which lies south of the Northern Rockies Regional Municipality (NRRM). The Liard is the major watershed draining the NRRM and PCIC does not have model results for that watershed at this time.

Table 19: Watershed Elevations

Abbrev.	Name	Min (m)	Max (m)	Mean (m)
Highlands				
MRAWR	Murray River (above Wolverine River)	759	2333	1325
PRACH	Pine River (at Chetwynd)	578	1812	1121
PNFSJ	Peace River (near Fort St. John)	415	2625	1243
Mixed				
FCAK1	Flatbed Creek (at Heritage Highway km 110)	836	1905	1140
Lowlands				
BRNFS	Beatton River (near Fort St. John)	473	1612	808
KRUDI	Kiskatinaw (upstream of intake)	703	1454	952
PCAPC	Pouce Coupe River (at Pouce Coupe)	627	958	821

Streamflow

About this Indicator

Seasonal change in ***streamflow*** presents projected average flow of water through a specific point in the river by season. The unit used in this indicator is daily average cubic meters per second (m3/s), and results are presented as future percent change (in the 2050s) from the past (1980s).

Projections

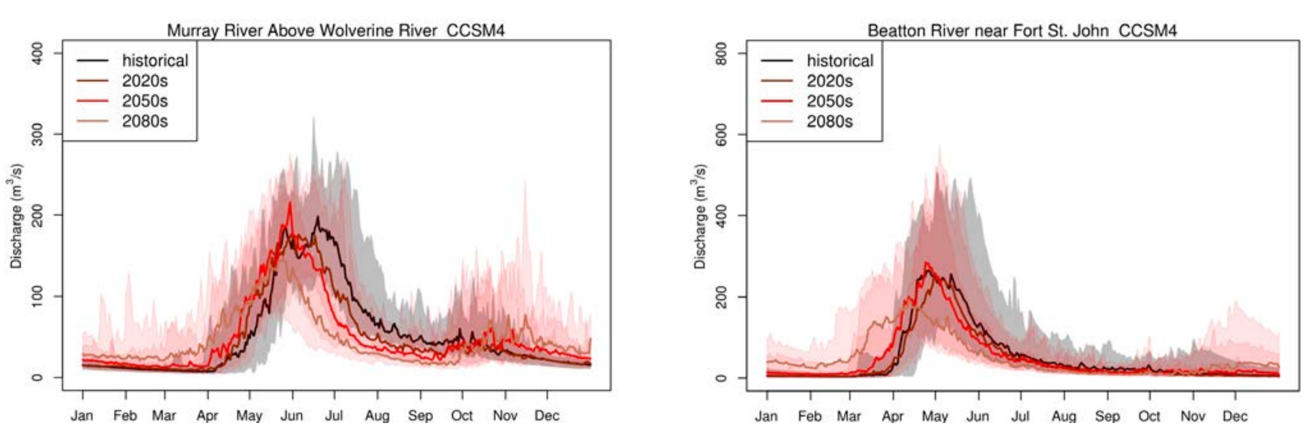
- Annual streamflow across the region is projected to increase (Table 20).
- Spring streamflow is expected to increase in all basins, due to increased precipitation and earlier snowmelt (resulting in an earlier freshet).
- Summer streamflow is projected to decrease in all basins due to minimal or even zero precipitation increases, increased evaporation, and earlier snowmelt.
- Autumn streamflow is projected to increase as a result of seasonal precipitation.
- Warmer temperatures will cause an increasing amount of precipitation to fall as rain rather than snow, causing immediate runoff during winter warm spells and decreased snowpack.

The streamflow changes noted above will become more pronounced over time. (See Figure 12)

Table 20: Seasonal & Annual Streamflow Change in the 2050s and 2080s

	Spring			Summer			Autumn			Winter			Annual		
Water Shed	Past (m3/s)	2050% Change	2080% Change	Past (m3/s)	2050% Change	2080% Change	Past (m3/s)	2050% Change	2080% Change	Past (m3/s)	2050% Change	2080% Change	Past (m3/s)	2050% Change	2080% Change
Murray	54	51 (34 to 68)	80 (48 to 125)	122	-24 (-33 to -8)	-49 (-63 to -33)	44	18 (1 to 33)	39 (23 to 66)	16	82 (67 to 108)	184 (132 to 224)	59	8 (0 to 24)	13 (-3 to 30)
Pine	53	72 (48 to 95)	93 (64 to 136)	76	-46 (-57 to -30)	-75 (-85 to -61)	14	49 (16 to 82)	99 (63 to 135)	6	74 (49 to 111)	259 (137 to 412)	37	10 (2 to 24)	15 (-3 to 32)
Peace	1141	69 (43 to 97)	108 (71 to 148)	2726	-23 (-32 to -8)	-44 (-62 to -23)	736	22 (-6 to 37)	38 (18 to 61)	308	47 (24 to 67)	126 (83 to 167)	1232	10 (-3 to 20)	14 (-1 to 34)
Flatbed	5	31 (15 to 70)	33 (-9 to 72)	5	-42 (-54 to -19)	-63 (-71 to -46)	2	-6 (-22 to 7)	0 (-22 to 44)	2	75 (51 to 105)	156 (101 to 240)	3	5 (-7 to 34)	9 (-20 to 38)
Beatton	150	24 (8 to 56)	21 (3 to 59)	81	-18 (-32 to 11)	-37 (-52 to -18)	27	34 (-14 to 80)	64 (-16 to 122)	11	222 (102 to 309)	557 (209 to 774)	67	20 (4 to 47)	27 (4 to 56)
Kiskati-naw	19	10 (-4 to 42)	5 (-22 to 39)	9	-27 (-43 to 4)	-44 (-59 to -17)	4	42 (14 to 67)	80 (33 to 164)	4	191 (138 to 257)	350 (280 to 473)	9	26 (11 to 54)	41 (6 to 69)
Pouce Coupe	11	6 (-8 to 45)	1 (-26 to 39)	2	-9 (-35 to 54)	-25 (-49 to 19)	2	47 (-8 to 88)	87 (13 to 177)	2	173 (119 to 262)	337 (236 to 493)	4	30 (13 to 62)	48 (8 to 80)

Figure 11: Average Daily Historical & Future Streamflow in the Murray & Beatton



Snowpack

About this Indicator

Snow water equivalent (SWE) is the measurement of how much water is present within a **snowpack**. April 1 SWE and May 1 SWE refer to the amount of water contained in the snowpack on that specific date in millimetres. The snowpack indicator can assist in determining how much snowmelt will be available during the spring freshet.

Projections

- Snowpack is projected to decrease in all basins, with greater percentage decreases in the lowlands than in the highlands (Table 21).
- May 1 SWE is projected to decrease more than April 1st SWE, which is consistent with the streamflow analysis (above).

Table 21: Snowpack in the Watersheds: April 1 & May 1 SWE (Change 1971-2000)

		Watershed	Past (mm)	2050 Percent Change	2080 Percent Change
April 1	Highlands	Murray	426	-21 (-30 to -14)	-40 (-48 to -33)
		Pine	296	-19 (-32 to -12)	-38 (-50 to -28)
		Peace	383	-11 (-18 to -5)	-25 (-30 to -18)
	Mixed	Flatbed	166	-41 (-63 to -26)	-70 (-80 to -64)
	Lowlands	Beatton	86	-30 (-58 to -11)	-52 (-78 to -41)
		Kiskatinaw	55	-52 (-79 to -26)	-79 (-92 to -66)
		Pouce Coupe	25	-52 (-84 to -12)	-76 (-94 to -49)
May 1	Highlands	Murray	412	-35 (-51 to -25)	-58 (-64 to -51)
		Pine	269	-32 (-46 to -19)	-53 (-64 to -41)
		Peace	350	-38 (-57 to -26)	-62 (-74 to -52)
	Mixed	Flatbed	97	-69 (-87 to -56)	-88 (-96 to -80)
	Lowlands	Beatton	28	-62 (-87 to -25)	-81 (-98 to -62)
		Kiskatinaw	15	-84 (-93 to -74)	-92 (-100 to -81)
		Pouce Coupe	1	-87 (-100 to -54)	-84 (-100 to -81)

Low and High Flow Extremes

About this Indicator

The *low and high flow extremes* indicator provides changes to summer low and annual peak streamflow extremes. The former reflects potential drought conditions and the latter potential flood. It offers insight into two hydrologic events that can put communities at risk.

Projections

In this report, the Murray River above Wolverine River is used as an example of a highlands basin, and the Beatton River near Fort St. John is used as an example of a lowlands basin. The Murray River is fed by snow and glacier melt at high elevations. The Beatton River is in the Boreal Plains, which has less elevation gain. Melt events can occur throughout the year in watersheds in this region.

Murray (Highlands)

- A summer low-flow event that historically had a 10% chance of happening per year will have more than an 80% chance of happening per year by the 2050s (Table 22).
- The daily volume during a future 1-in-10 summer low-flow event will reduce by roughly 40%, on average, compared to the past.
- The peak-flow event that historically had a 5% chance of happening per year will have more than a 10% chance of happening per year, by the 2050s.
- The daily volume of the future 1-in-20 annual peak-flow event will be approximately 20% greater, on average, than it was in the past.

Beatton (Lowlands)

- By the 2050s, a summer low-flow event that historically had a 10% chance of happening per year will have a slightly increased chance of occurring, on average.
- The daily volume during a future 1-in-10 summer low-flow event will be 7% less than in the past, on average.
- The peak-flow event that historically had a 5% change of happening per year will have a slightly increased chance of occurring in the future, on average.
- The daily volume of the future 1-in-20 annual peak-flow event will be roughly 10% greater than it was in the past, on average.

In both basins, the trend towards decreased volumes and more frequent low-flow events continues in the 2080s. Annual peak flows are not as predictable in their response. A majority of models show an increased peak in the 2050s and then a decreased peak volume in the 2080s, but not all. More analysis that makes use of additional global climate models (GCMs), and especially considers the effects of non-stationarity, would be required to better understand these differences.

Table 22: Change in Return Period Volume & Frequency, 2050s

Murray (Highlands)	Units	ACCESS1.r1	CanESM2.r1	CNRM.CM5.r1	CCSM4.r2	HadGEM2.ES.r1	MPI.ESM.LR.r3	med	mean	min	max
1-in-10 year summer 7-day low-flow volume	%	-48	-32	-37	-50	-49	-33	-43	-42	-50	-32
1-in-20 year annual peak-flow volume	%	12	24	25	18	23	6	20	18	6	25
1-in-10 year summer 7-day low-flow return period	Years	1.1	1.9	1.9	1.2	1.2	1.9	1.6	1.5	1.1	1.9
1-in-20 year annual peak-flow return period	Years	9.0	5.0	8.0	8.0	8.0	13.0	8.0	8.5	5.0	13.0
Beatton (Lowlands)	**Units**	**ACCESS1.r1**	**ACCESS1.r1**	**CNRM.CM5.r1**	**CCSM4.r2**	**HadGEM2.ES.r1**	**MPI.ESM.LR.r3**	**med**	**mean**	**min**	**max**
1-in-10 year summer 7-day low-flow volume	%	9	13	0	-16	-20	-30	-8	-7	-30	13
1-in-20 year annual peak-flow volume	%	1	16	-19	-3	17	51	9	11	-19	51
1-in-10 year summer 7-day low-flow return period	Years	NA	21.0	10.0	5.0	5.0	3.0	5.0	8.8	3.0	21.0
1-in-20 year annual peak-flow return period	Years	19	11	NA	24	9	7	11.0	14.0	7.0	24.0

Chapter 7 — Regional Impacts

Rising temperatures and increases in precipitation, in concert with increased variability throughout the year, are expected to alter flows in rivers, causing water shortages and floods, increased incidence of low-flow periods and drought, and a host of downstream impacts. They will likely also cause more intense storms, meaning stronger winds, larger hail, and more lightning strikes, resulting in, among other damages, increased incidence of wildfire and health impacts due to smoke and poor air quality.

Proactive efforts to increase resiliency to climate change will prepare communities to withstand these climate events without enacting emergency management protocols and plans. In addition to ongoing, aggressive mitigation activities to curb global climate change at the 2050s projections offered in this report, investment in physical and social infrastructure, coupled with efforts to protect and diversify our economy will be the best line of defense again rising global temperatures.

The tables below present the results of the discussion from a regional workshop of municipal representatives and offer preliminary thoughts on how future climate can be expected to have an impact on our physical and social infrastructure, natural systems, and economy.

Table 23: Preliminary Impacts of Concern to Physical Infrastructure

Physical Infrastructure	
	Preliminary Impacts of Concern
Road Maintenance	• The freeze-thaw cycle may happen more commonly in the shoulder seasons, leading to road, runway and bridge damage (cracks and potholes). • Increased ice on surfaces will cause winter transportation safety to become a growing concern, requiring enhanced planning and operational capacity to ensure human safety and environmental integrity of adjacent lands. • Increases in maximum flows are likely to overburden exiting culverts, and may threaten bridges, and can be expected to cause debris and water to pool on and near existing transportation infrastructure. • During dry spells, gravel surfaces will require more water for dust control. • Increased precipitation, meaning that snow events are larger and more frequent, will require snow management. • An increase in rain-on-snow events can be expected, causing treacherous road and bridge conditions, ice scouring in ditches, and ditches and culverts to become covered in ice.
Buildings	• Increased precipitation in the spring months, summer, and autumn, with increasing storm intensity could compromise the build season, causing issues with the tendering and execution of capital projects. • The floodplain is expected to shift, and buildings and infrastructure in the floodplain can expect to be inundated with increasing frequency over time, causing policy implications. • Buildings may experience damage during future severe storm events due to intense winds, heavy rains and snows, and large hail events. Heavy snow loads in winter, and heavy wet snow in spring, may challenge the structural integrity of roofing systems. • During years with wildfires, indoor air quality will be compromised from ambient smoke entering through conventional ventilation systems. In buildings with mechanical air purification systems, costs to run and maintain this infrastructure will increase. • As temperatures rise, heating demand in buildings will likely decrease, while increasing cooling demand and smoke days may trigger a need for air conditioning. • Incorporating future temperature projections into building design and operational planning will inform new thresholds for building and HVAC design. • Increases in the duration, frequency, and intensity of maximum flows will challenge sewerage and drainage systems, and will require major stormwater upgrading to avoid overland flooding. • Replacement of damaged infrastructure after flood events creates an opportunity to upgrade systems, though flood damage funding will not be enough to meet the higher costs associated with improved systems. • Increases in the peak volume of stormwater will further challenge aging municipal and regional infrastructure. • Heavy rainfall will cause erosion and flooding in waterways (e.g., through downtown Chetwynd).
Stormwater & Flooding	• Increases in the duration, frequency, and intensity of maximum flows will challenge sewerage and drainage systems, and will require major stormwater upgrading to avoid overland flooding. • Replacement of damaged infrastructure after flood events creates an opportunity to upgrade systems, though flood damage funding will not be enough to meet the higher costs associated with improved systems. • Increases in the peak volume of stormwater will further challenge aging municipal and regional infrastructure. • Heavy rainfall will cause erosion and flooding in waterways (e.g., through downtown Chetwynd).

Physical Infrastructure	
	Preliminary Impacts of Concern
Water Security	• High turbidity from storms and flooding can lead to increased costs for water withdrawal, pumping, and water treatment. • Lengthened periods of low flows may stress adequate raw water storage and negatively impact water supply. • Warmer summers will increase water demand in communities and cities. Competition for limited water resources will become an increasingly important issue. • Water constraints in summer months may also trigger conflicts between tourism, communities, and industry. • Earlier spring melt and reduced snowpack volumes will stress water supply. • Rain-on-snow events cause winter rains and snowmelt to run off into watercourses, reducing water storage of winter precipitation, resulting in a loss of water supply.
Waste Water	• Decreasing summer streamflow may impact the ability for a community to discharge effluent due to low dilution rates. • Extreme precipitation events may increase infiltration and inflow into sanitary sewers resulting in effluent volumes that exceed allowable limits.
Energy Systems	• Energy systems including transmission lines will be more vulnerable to damage from wildfire, hail and ice storms in the future. Critical energy infrastructure located in the floodplain will be at increased risk of flooding. • Warmer winter temperatures will require less heating during the winter months. Warmer summer temperatures and an increase in smoke days may require increased cooling and air purification in the summer months. • Increased heat waves may cause problems for Passive Housing in the summer, and southern-facing windows and concrete floor slabs designed to take advantage of passive thermal gain may overheat. • Solar energy systems could require increased maintenance in the winter to clear additional snow loads in some years, though may offer additional opportunity for solar generation during summer months.

Table 24: Preliminary Impacts of Concern to Social Infrastructure

Social Infrastructure	
	Preliminary Impacts of Concern
Public Health (Physical)	• Air quality can be expected to decline with increasing summer temperatures. An increase in wildfires will contribute particulate matter into the air, which is a known human carcinogen, and aggravator of respiratory illness. This may trigger asthma, reduce lung function, and cause lung disease, particularly in children, older adults, and people who are active outdoors. • Extreme heat can cause heat exhaustion and death in vulnerable populations, including the elderly. • Increasing temperature and increases in summer rains can lead to an increase in vector-borne disease and invasive species, such as ticks. • Increases in extreme weather and flood events may pose increased risk to public safety. • With increased threats to public health, hospitals may struggle to provide effective care during future patient-surge events.
Public Health (Social)	• Some communities may experience isolation during future events when transportation and communication infrastructure is down. This can prevent access to health services and other critical services. • Future projections can cause public anxiety, which may either lead to a sense of urgency in support of mitigation and adaptation, or to helplessness. • Stress is caused by a changing climate when cultural traditions and practices cannot be performed, such as fishing, hunting, recreating, etc., or when communities need to be relocated out of a floodplain.
Recreation and Tourism	• Severe weather, including summer drought, wildfire and associated smoke, along with increased summer rains in some years, will likely reduce recreational activities in summer, limiting travel and tourism. • Larger annual peak flows may cause flooding and washout of recreational access roads, preventing access to popular recreation zones. • Threat of extreme weather increases risk of outdoor recreation, as the likelihood of being caught in severe weather increases. • Changes in winter precipitation may bring more snow in some years, which would benefit recreational skiing and sledding activities; however, increases in rain-on-snow events could have adverse effects, create safety hazards, and limit winter recreation activities. • As water supply and quality changes, fish health and populations may suffer, curtailing fishing opportunities.
Food Security	• Severe events may compromise our transportation system, which may make transportation of food into the region more challenging (e.g., Pine Pass, Grande Prairie). The same will be true during dry years, when wildfires will challenge community resupply of essential foodstuff. • Future competition for water resources and increased variability in climate may dissuade small-scale local producers from growing for local consumption.

Table 25: Preliminary Impacts of Concern to Natural Systems

Natural Systems	
	Preliminary Impacts of Concern
Public Health (Physical)	• As the climate changes, the distribution of many fish and wildlife species will change as maladapted populations decline, migrate, or adapt over time, and as generalists spread to take advantage of higher rates of disturbance. (E.g., warmer temperatures and shorter winters may cause moose-borne ticks to proliferate, threatening moose in the region and causing rippling effects throughout ecosystems.) • Warmer winter temperatures and increasing length of the growing season will continue to attract prey (e.g., whitetail deer) and their predators (e.g., cougars and wolves) to the Northeast. Caribou populations, who are more susceptible to predator attack than other prey species, will be at increased risk of predation. • The earlier snowmelt, longer periods of low flows, and more storm events will cause changes in temperature and turbidity of water, increase debris in watercourses, and will have a negative impact on the health of fish and other aquatic organisms. • Ecosystems will likely undergo ecological damage. (E.g., flooding could cause degradation of waterways and terrestrial ecosystems; increasing temperatures are likely to attract invasive species into our forests; as current tree species struggle to thrive, deadwood increases, and lightning strikes increase, leading to an increased risk of wildfires.) • A secondary stress to ecosystems will be the distribution of pollutants into natural areas during storm events (e.g., overflow events, winter road maintenance).

[3] (https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/adaptationclimate20change20vulnerability20of20bcs20fish20and20wildlife20final20june6.pdf)

[4] IBID

Table 26: Preliminary Impacts of Concern to Economic Infrastructure

Economic Infrastructure	Preliminary Impacts of Concern
General	• Economic activities across sectors will suffer, as operations may need to stop more frequently as extreme events (flood, fire, snow) become more frequent. • Damages from floods, snow loads, and fire may cause increased cost of business, including increased insurance rates over time, and future loss of insurance protection in vulnerable areas, and loss of business and/or closure during extreme events. • Due to earlier spring melt and rain-on-snow events, road restrictions will begin earlier and stay in place longer. • In addition to protecting the economic sector from climate change, the region must reflect on the impacts of long-term growth, including impacts on First Nations rights and title, and impacts on the natural environment (e.g., wildlife and ecosystems).
Oil and Gas	• The oil and gas sector is vulnerable to increased flooding, which would cause work stoppages. • Lengthened periods of low flows may challenge the oil and gas sector, causing more frequent suspensions of short-term water licenses by the Oil and Gas Commission.
Timber Harvesting	• Hot, dry summers and rising temperature will result in increased pests in northern forests, resulting in decreased forest productivity for timber harvesters. • Changing temperatures will influence changes in tree species. • Increasing temperatures and precipitation are likely to attract invasive species into our forests. • As current species struggle to thrive and deadwood increases, risk of wildfires will increase.
Agriculture	• Water supply for agricultural uses will likely become more costly, requiring new points of access, pumping, and purification for increasing irrigation needs. In years experiencing drought, agricultural producers may be challenged to access water over the growing season. • Warmer temperatures combined with increases in summer precipitation in some years may increase the region's ability to grow new crops in the future, while new conditions may cause heat stress to other, more traditional crops. This opportunity will require increased irrigation during dry years, further stressing limited water resources. • Warmer temperatures will cause heat stress in livestock animals, and increases in summer rain will cause hay farmers to suffer increasing episodes of crop loss. • Strong storm events may damage soil and plants, while warmer temperatures will encourage invasive species and pests to thrive. Together, these threats may reduce agricultural production in some years. • As spring temperatures warm more quickly, pollinators may emerge before crops are ready for pollination, resulting in reduced agricultural productivity. Additionally, warmer temperatures may cause stress to bee populations and reduce their ability to pollinate crops.

Emergency Management

Notwithstanding this action to adapt our communities to the changes ahead, emergencies are bound to occur. Without significant investment, the region can expect emergency situations to become more frequent and severe, requiring more resources, planning, and preparation to deal with emergencies. Increased fatigue (burnout) of human resources can be expected, along with increased budgets, as a result of larger-scale events that come with greater frequency.

- More intense rainfall puts an increased pressure on flood response planning throughout the region (see sidebar).
- Specific issues of concern to emergency managers responding to climate events include:
- Managing populations, livestock, and pets during emergencies.
- Reducing negative impacts on reception communities.
- Supporting community connection to critical infrastructure (roads, electricity, communication, etc.).
- Maintaining communication with community partners in advance of and during emergency events (schools, hospitals, employers).

Planning for extreme events and securing proper resources and systems in advance of future emergencies will be critical to successfully responding to future climate emergencies.

2016 Flood

On June 16 and 17, 2016, 162 mm of rain fell on the City of Dawson Creek (City) and the Village of Pouce Coupe, causing a large flooding event that resulted in many social and economic impacts.

As the creek swelled, four bridges washed away, leaving the city divided with only one uninterrupted transportation route left intact. This division isolated emergency services: RCMP, ambulance, and fire protection services in the north, and the hospital and airport in the south end. Homes flooded, neighbourhoods lost power, and residents were unable to access businesses, workplaces, and schools. Bridge and culvert replacements added unexpected costs to the municipality and the Ministry of Transportation and Infrastructure.

The annual exceedance probability for the 2016 flood is ~10% (Ebbwater Consulting, 2018), meaning that this size of flood event has a 10% chance of occurring in any year. The likelihood of events like this occurring in the future will increase as the climate continues to change. The City is taking steps to update floodplain mapping and understand how changes to our climate will increase flood risk in order to shift from reactionary responses to planned investments that support resiliency.

Chapter 8 — Preliminary Observations

Municipal representatives from participating communities met to discuss the climate projections during a regional workshop in 2018. The following key messages summarize the outcomes of this workshop, and offer preliminary observations on how future climate can be expected to have an impact on physical and social infrastructure, natural systems, and economy. This section represents the high-level observations from the first phase of the Northeast Climate Risk Project.

1. Current and future climate needs to be considered when designing and maintaining buildings and infrastructure by:

- Giving more thought to long-term investments in the flood plain, as these may be increasingly threatened over time, and pose risks to local governments and the public.
- Updating to Intensity-Design-Frequency curves and using them to improve stormwater management infrastructure.
- Planning to use on-site renewables during future extreme events to maintain reliable low-carbon power.
- Developing policy to require new buildings to assist residents with resiliency (e.g., better ventilation to manage indoor air quality during smoke events).

2. Industry, community, and local governments will need to work together to resolve potential climate conflicts by:

- Taking a regionally and provincially coordinated approach to offer the best opportunity to increase resilience.
- Developing a cross-sectorial plan for long-term water usage (drinking water, recreation, agriculture, industry).
- Creating opportunities to resolve challenges between tourism, road maintenance, and fire protection to protect environmentally sensitive areas, and to enhance mitigation efforts.

3. Mitigation is a key adaptation strategy, and all sectors will need to engage to build personal and community resiliency by:

- Working together as a region towards sustainable use and development of resources to lower the footprint of industry.
- Sharing and discussing known risks and pathways towards community resiliency with businesses, industry, and the public.

4. Ongoing measurement and monitoring of our health and natural ecosystems will be important to inform and support mitigation and adaptation efforts by:

- Supporting wildlife ecosystem planning at the regional and provincial level.
- Exploring adaptive vegetation that will thrive in future climate conditions.
- Working with the Pacific Climate Impacts Consortium (PCIC) to develop new indicators for smoke and wind intensity.

5. New communication protocols between community, agency, and industry partners are required for use during future extreme events.

- To avoid fatigue while adaptive capacity is being built, additional human resources and training will be required in advance of and during extreme events.
- To mobilize resources, senior government officials will need to recognize and be in support of additional emergency planning work between all levels of government.

Appendix 1 — Methodology & Interpretation

Climate Scenario Selection

The amount our climate will change depends on the intensity of greenhouse gas (GHG) emitted into our atmosphere over the coming years. This report presents a recognized roughly "business as usual" GHG emissions scenario for the remainder of the century, known as Representative Concentration Pathway 8.5 (RCP8.5).

Additional information from lower emissions scenarios (RCP4.5 and 2.6) is available from the Fraser Basin Council and each community for sensitivity analysis, and to illustrate the relationship between adapwtation and GHG emissions reductions or mitigation. The RCP4.5 "medium stabilization" scenario represents mitigation efforts that result in about half of the emissions compared to the RCP8.5 scenario. Substantial and sustained reductions in GHG emissions—for example, extensive adoption of biofuels and sustainable agriculture, along with carbon capture and storage—would be required to achieve RCP2.6, which is the only pathway predicted to keep global warming below 2°C above pre-industrial temperatures. The projected global temperature change for each pathway (this figure only shows 2 of the 4) is illustrated below.

Representative Concentration Pathways (RCP)

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

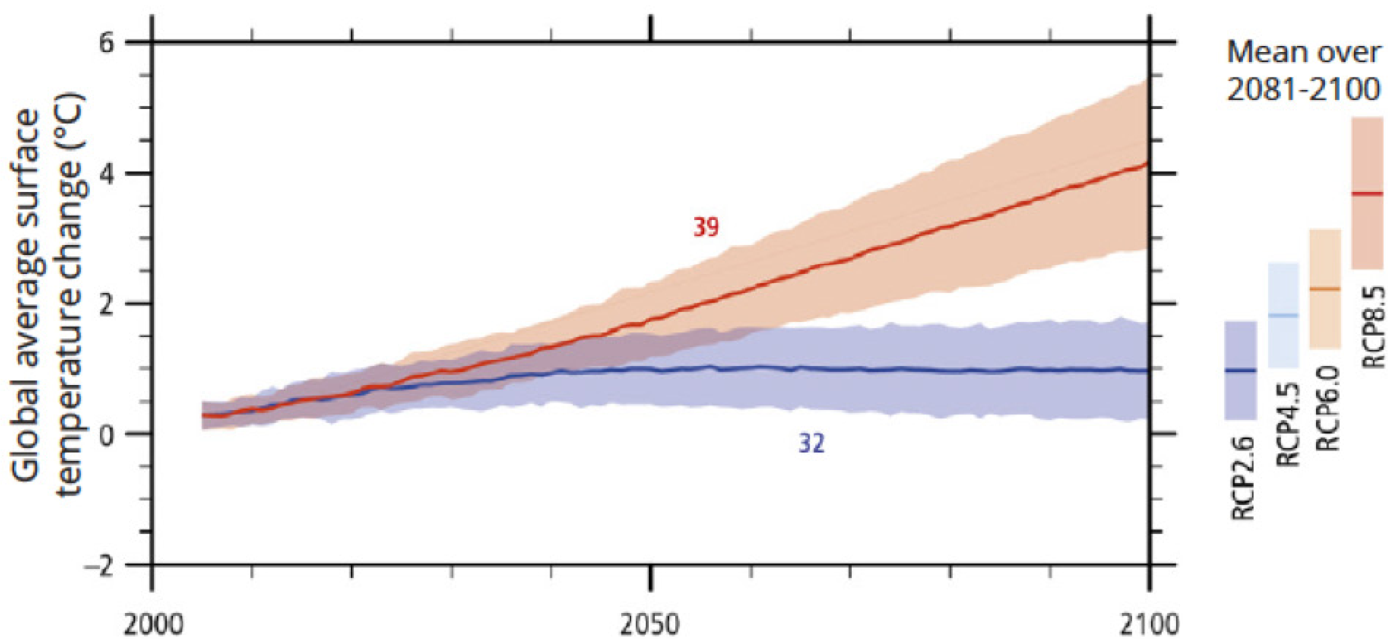


Figure SPM.6(a) from IPCC's Climate Change 2014: Synthesis Report shows modeled global average surface temperature change relative to 1986-2005. The mean of the projections (lines) and a measure of uncertainty (shading) are shown for RCP8.5 (red) and RCP2.6 (blue). The number of climate models used to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

Climate Model Selection

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

The results in this report are based on a subset of climate models selected by PCIC from the Coupled Model Intercomparison Project 5 (CMIP5). The CMIP5 climate models were first screened to remove those that least accurately represented historical data. From the remainder, an ensemble of 12 models was chosen to provide the widest range of projected change for a set of climate parameters.

Information from the large-scale global climate models was translated into projections at local scales using a procedure called downscaling. The model projections were downscaled to a 10-km grid using a historical daily time series of temperature and precipitation (ANUSPLIN) in conjunction with the climate model projections.

BCCAQ statistical downscaling was used, which is a hybrid climate analogue/quantile mapping method. These daily observations and future projections at 10-km resolution were then draped over an 800-m grid (PRISM) of 1971–2000 average temperature or precipitation to generate high-resolution maps of projected changes in the region.

About Climate Models

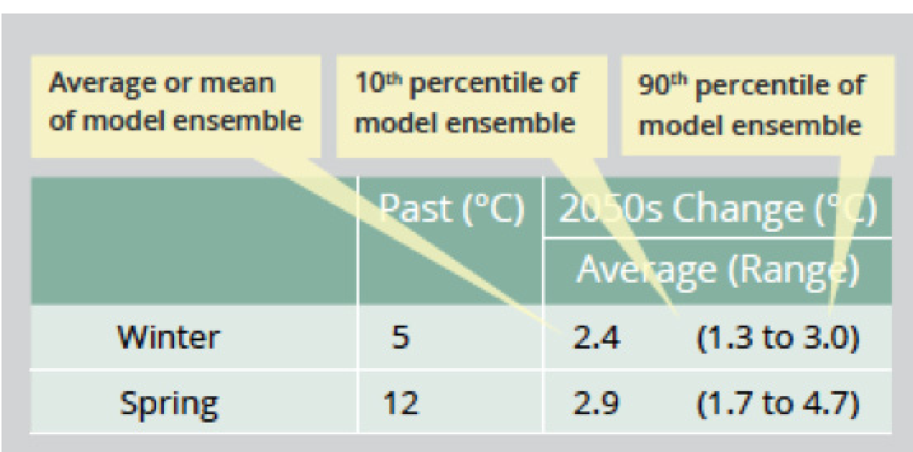
More information about climate models is available from the Pacific Institute for Climate Solutions' Climate Insights 101 course.

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

Indicator Derivation

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

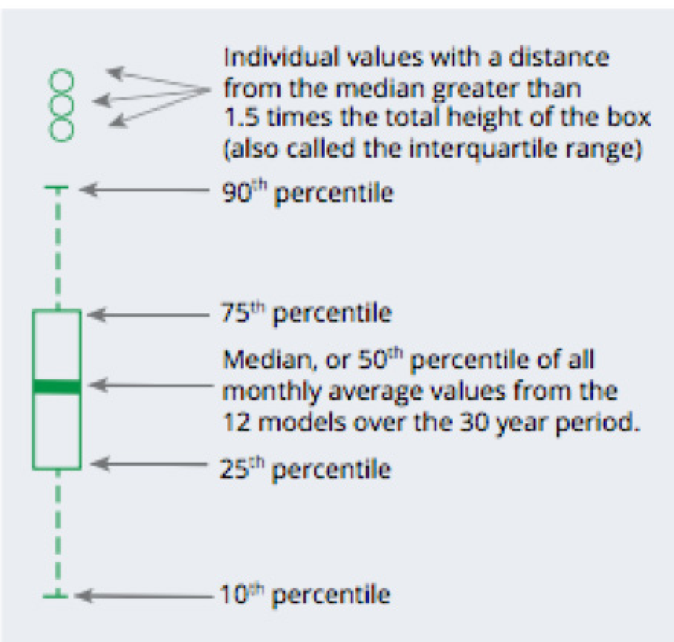
Many of the indicators of extreme events used in this report are derived using the definitions recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI), known as the CLIMDEX indices. The indicator names in this report have been translated into plain language, with the original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



How to Read Figures

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

- **Values for each time period (past, 2050s, and 2080s) are averaged over each 30-year period. The 30-year period used to calculate past values is 1971–2000; the 2050s refer to 2041–2070, and the 2080s refer to 2071–2100.**
- Winters in the Northeast generally last from October until April, though for the purposes of this report, seasons are presented as winter (December-January-February), spring (March-April-May), summer (June-July-August), and fall (September-October-November).
- In tables throughout the document, projected change is given for the mean of the model ensemble along with the range (10th to 90th percentile) of the model ensemble. The 10th to 90th percentile range describes the uncertainty among the models and natural climate variability.
- Values in tables are averaged over the entire region (within the regional boundary shown on the maps), unless labelled as lowlands, referring to the plateau and agricultural areas, and highlands, defined as the mountainous area.
- For the 1-in-20 events described in this report, the “5% chance of occurrence” is based on an average over each 30-year period. To be precise, since climate change will occur throughout that time, there is slightly less than a 5% chance of such an event occurring at the beginning of the period and more than 5% chance at the end of the period, with an average 5% chance over the period.
- Maps show only the mean values of the model ensemble. Maps are provided in the body of the report when they add meaning to data interpretation, with additional maps for remaining indicators presented in Appendix 2.
- This report provides several box-and-whisker plots to illustrate year-to-year and model-to-model variability over time. The diagram below illustrates how these plots are to be interpreted.



Interpretation

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

- The 10th to 90th percentile values projected by the ensemble are important for adaptation planning, as they take into account the range of uncertainty when projecting future climate change. Risk managers may find it appropriate to consider 90th percentile values when planning critical infrastructure investments.

For some indicators, values for specific geographic areas may be more appropriate than the regional averages presented in the tables.

Appendix 2 — Indicator List

Indicator Name	Short Code	Definition
Hottest Day	TXx	The hottest daytime high temperature of the year, on average.
Hottest Night	TNx	The hottest nighttime low temperature of the year, on average.
Total Precipitation	PR	All precipitation summed over a month, season, or year, including rain and snow water equivalent.
Days above 25°C	SU	The number of days in a year that reach temperatures over 25°C in any one year.
Days above 30°C	SU30	The number of days in a year that reach temperatures over 30°C in any one year.
Nights Above 20°C	TR	The number of days in a year when the nighttime low temperature is greater than 20°C.
1-in-20 Hottest Day	RP20 TASMAX	The day so hot that it has only a 1-in-20 chance of occurring in a given year.
Growing Season Length	GSL	The annual measure that counts the number of days between the first span of at least 6 days with a daily average temperature greater than 5°C and the first span after July 1 of 6 days with temperature less than 5°C.
Growing Degree Days	GDD	A measure of heat accumulation that is useful for agriculture and horticulture.
Cooling Degree Days	CDD	The number of degrees that a day's average temperature is above 18°C.
Warmest Winter Day	TXx [DJF]	The highest temperature recorded during the winter months.
Coldest Days	TXn	The lowest daytime temperatures, on average. This is usually experienced during winter months.
Coldest Nights	TNn	The lowest nighttime temperatures, on average. This is usually experienced during winter months.
1-in-20 Coldest Night	RP20 TASMIN	The nighttime low temperature so cold that it has only a 1-in-20 chance of occurring in a given year.
Frost Days	FD	An annual count of days when the daily minimum temperature is less than 0°C, which may result in frost on the ground.
Ice Days	ID	Days when daytime high temperature is less than 0°C.

Indicator Name	Short Code	Definition
Heating Degree Days	HDD	This is a derived variable that can be useful for indicating energy demand (i.e., the need to heat homes, etc.). It is calculated by multiplying the number of days that the average daily temperature is below 18°C by the number of degrees below that threshold.
Dry Spells	CDD – CLIMDEX	A measure of the number of consecutive days where daily precipitation is less than 1 mm. The value denotes the longest stretch of dry days in a year, typically in summer.
Wettest Day	Rx1Day	The largest amount of rain that falls on any single day in the year, on average.
Wettest 5 Days	Rx5Days	The largest amount of precipitation that falls over a period of 5 consecutive days in the year.
95th Percentile Wettest Days	R95P	The total amount of rain that falls on the wettest days of the year, specifically on days when precipitation exceeds a threshold set by the annual 95th percentile during the baseline period (1971–2000).
99th Percentile Wettest Days	R99P	Days when precipitation exceeds a threshold set by the annual 99th percentile of wet days during the baseline period.
1-in-20 Wettest Day	RP20 PR	The day so wet that it has only a 1-in-20 chance of occurring in a given year. That is, there is a 5% chance in any year

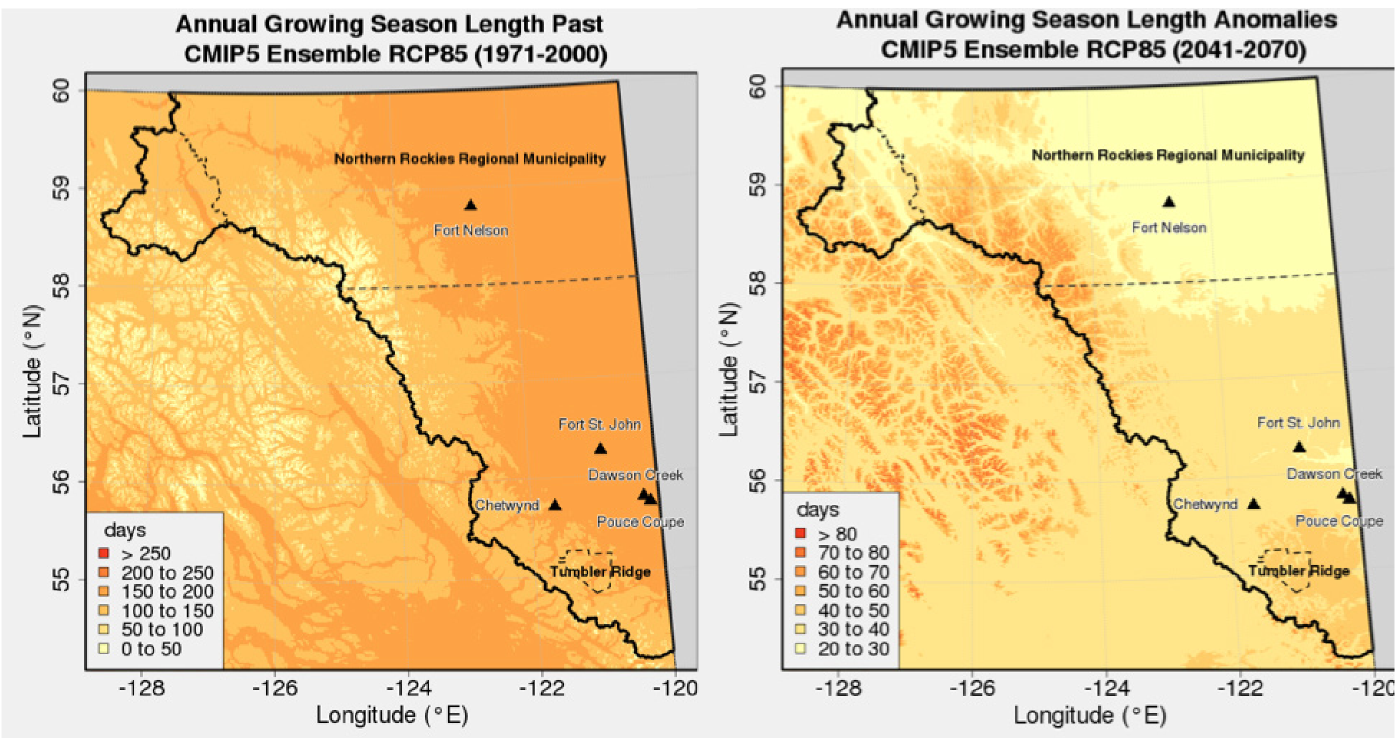
Growing Season Length further data

While the largest number of growing season days will occur in the lowlands, the largest increase will occur in the highlands, potentially stressing ecosystems (see table data below).

In the past, the region experienced an average of 160 days in the growing season at lower elevations where farming occurs. Across the Northeast, the region can expect this to increase to an average of 178 growing season days a year by the 2050s, and 198 by the 2080s (see figure below).

Growing Season Length (GSL)	Past (days)		2020 Change	2050 Change	2080 Change
Highlands	12	Average (days) Range (days)	18 (10 to 25)	39 (27 to 54)	65 (47 to 84)

Figure 13: Growing Season Length – Past & Future



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