UNIVERSITY OF BRITISH COLUMBIA

Local Governments for Sustainability CANADA

Climate Science Report

November 2023

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Glossary of Terms

Definitions have been taken from the Intergovernmental Panel on Climate Change (IPCC) (https://www.ipcc.ch/report/sr15/glossary/), Climatedata.ca, and the Climate Atlas of Canada (climateatlas.ca).

Baseline

A climatological baseline is a reference period, typically three decades (or 30 years), that is used to compare fluctuations of climate between one period and another. Baselines can also be called references or reference periods.

Climate Change

Climate change refers to changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the build-up of greenhouse gases which trap heat and reflect it back to the earth's surface.

Climate Projections

Climate projections are a projection of the response of the climate system to emissions or concentration scenarios of greenhouse gases and aerosols. These projections depend upon the climate change (or emission) scenario used, which are based on assumptions concerning future socioeconomic and technological developments that may or may not be realized and are therefore subject to uncertainty.

Climate Change Scenario

A climate change scenario is the difference between a future climate scenario and the current climate. It is a simplified representation of future climate based on comprehensive scientific analyses of the potential consequences of anthropogenic climate change. It is meant to be a plausible representation of the future emission amounts based on a coherent and consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships.

Computerized Tool for the Development of Intensity-Duration-Frequency Curves Under Climate Change (IDF_CC) Version 6.0

IDF_CC is a publicly available web-based intensity-duration-frequency tool to update and adapt local extreme rainfall statistics to climate change. The IDF_CC tool is pre-loaded with 898 Environment and Climate Change Canada rain stations. Users can select any rain station with 10 or more years of data and develop IDF curves based on historical data and curves adjusted to reflect climate change. The tool also allows the development of IDF curves for ungauged locations in Canada.

Ensemble Approach

An ensemble approach uses the average of all global climate models (GCMs) for temperature and precipitation. Research has shown that running many models provides the most realistic projection of annual and seasonal temperature and precipitation than using a single model.

Extreme Weather Event

A meteorological event that is beyond the normal range of activity at a place and time of year, such as an intense storm, tornado, hail storm, flood or heatwave. An extreme weather event would normally occur very rarely or fall into the tenth percentile of probability. Weather models predict shorter return periods of extreme weather events in the future.

General Climate Models (GCM)

Computer model that is a mathematical representation of the climate system, based on equations that drive the physical processes governing the climate, including the role of the atmosphere, hydrosphere, biosphere, etc. It represents a unique tool that helps reproduce a complex ensemble of processes relevant for climate evolution. Note the term Global (or General) Circulation Model is often used as a synonym.

Greenhouse Gas (GHG) Emissions

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation, emitted by the Earth's surface, the atmosphere itself, and by clouds. Water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs) are the six primary greenhouse gases in the Earth's atmosphere in order of abundance.

Heat Wave

The Climate Atlas of Canada defines a heat wave as three days in a row that reach or exceed 30°C and considers two variables for heat waves: the annual average length of heat waves, and the annual number of heat waves.

The Government of British Columbia's Provincial Heat and Response System (BC HARS): 2023 defines a heat event, or a 'heat alerting threshold' that would trigger an Environment and Climate Change Canada warning for the Vancouver area as two or more consecutive days of daytime maximum temperatures expected to reach 29°C or warmer and nighttime minimum temperatures are expected to remain at 16°C or warmer.

Intensity-Duration-Frequency curve

An Intensity-Duration-Frequency curve (IDF Curve) is a graphical representation of the probability that a given average rainfall intensity will occur. Rainfall Intensity (mm/hr), Rainfall Duration (how many hours it rained at that intensity) and Rainfall Frequency/Return Period (how often that rainstorm repeats itself) are the parameters that make up the axes of the graph of the IDF curve. An IDF curve is created with long term rainfall records collected at a rainfall monitoring station.

Radiative Forcing

The change in the value of the net radiative flux (i.e. the incoming flux minus the outgoing flux) at the top of the atmosphere in response to some perturbation, in this case, the presence of greenhouse gases.

Representative Concentration Pathways

Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. It supersedes Special Report on Emissions *Scenarios* (SRES) projections published in 2000.

Shared Socio-economic Pathways

Shared Socio-economic Pathways (SSPs) are five “families” of socio-economic characteristics that influence greenhouse gas emissions (and subsequently Radiative Forcing) based on the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6) used by the IPCC for its Sixth Assessment Report (AR6). SSP scenarios further refine previous greenhouse gas concentration scenarios known as Representative Concentration Pathways.

Climate Indices

The climate indices included in this study are listed and defined in Table 1 below. The indices represent a broad range of important climate variables that impact daily life at the University of British Columbia (UBC). Each indicator is discussed in more detail in their respective sections below.

Table 1: Climate Indices Definitions

Climatic Driver	Climate Indicator	Description	Units
Hot Temperature	Mean Temperature	The average temperature of the season (or annually).	ºC
	Mean Monthly Maximum Temperature	The average monthly maximum temperature.	ºC
	Mean Monthly Minimum Temperature	The average monthly minimum temperature.	ºC
	Hot Days (+30ºC)	A Hot Day is a day when the temperature rises to at least 30°C. This is the temperature where a Heat Alert is issued by Environment Canada.	Days
	Number of Heat Waves	The average number of heat waves per year. A heat wave occurs when at least two days in a row reach or exceed 29°C and does not go below 16°C.	Number of heat waves
	Average Length of Heat Waves	The average length of a heat wave. A heat wave occurs when at least two days in a row reach or exceed 29°C and there is a minimum temperature of 16°C.	Days
Cold Temperature	Freeze-Thaw Cycles	This is a simple count of days when the air temperature fluctuates between freezing and non-freezing temperatures.	Days

	Frost Days	A frost day is one on which the coldest temperature of the day is lower than 0°C.	Days
	Icing Days	An Icing Day is a day on which the air temperature does not go above 0°C.	Days
Growing Season	Last Spring Frost	The spring date after which there are no daily minimum temperatures during the growing season less than 0°C (Tmin > 0°C).	Date of Year
	First Spring Frost	The first date in the fall (or late summer) on which the daily minimum temperature is less than 0°C (Tmin < 0°C).	Date of Year
	Frost Free Season	The number of days between the date of the last spring frost and the date of the first fall frost, equivalent to the number of consecutive days during the 'summer' without any daily minimum temperatures below 0°C.	Days
Precipitation	Mean Precipitation	The average precipitation for a given season (or annually)	mm
	Heavy Precipitation Days (10mm)	A Heavy Precipitation Day (10mm) is a day on which at least a total of 10 mm of rain or frozen precipitation falls.	Days
	Heavy Precipitation Days (20mm)	A Heavy Precipitation Day (20mm) is a day on which at least a total of 20mm of rain or frozen precipitation falls.	Days
	Max. 1-day Precipitation (mm)	The amount the precipitation that falls on the wettest day of the year.	mm
	Max 5-day Precipitation (mm)	The wettest five-day period.	mm
Extreme Weather	Wildfires	General trends in Western Canada	event
	Rainfall IDF Curves	The annual maximum rainfall intensity for specific durations. Common durations for design applications are: 5-min, 10-min, 15-min, 30-min, 1-hr, 2-hr, 6-hr, 12-hr, and 24-hr.	Mm/h
	Hail	General trends in British Columbia	event

	Humidex	Days with Humidex > 30 (Hx>30°C) gives an indication of the number of hot and humid days.	event
Sea Level Rise	Relative Sea Level Change	The change in ocean level relative to land. Relative sea-level change is the combination of the effects from global sea-level change and the vertical motion of the land (i.e., subsidence and/or rebound).	cm

Location

In order to collect data from a consistent location, a single ~10km x 6 km grid cell was selected to represent the UBC Vancouver campus climate. For this purpose, the grid cell selected is labelled "Point Grey Beach, BC," unless otherwise indicated (e.g., Humidex variable is for the "Vancouver" grid cell). A note that the climate data for that location is representative of the UBC Vancouver campus location and that it does not necessarily reflect an exact point, particularly where there may be varying microclimates. Additional research should be conducted to retrieve more precise downscaled climate projections where appropriate.

Introduction

Climate change is an increasingly critical issue at the national and local level. Recent events in Canada, including flooding, heat domes, wildfires and other occurrences of extreme weather over the past several decades, have highlighted the need to be prepared for ongoing challenges. The goal of the Building Adaptive Resilient Communities (BARC) Program is to build capacity within municipalities and institutions to better understand impacts resulting from climate change, and develop localized climate change adaptation plans to address their community's priority risks.

British Columbia (BC) is no stranger to the impacts of extreme weather. Recent events ranging from extreme flooding, wildfire and heat events in the province have been some of the deadliest weather events in Canadian history. For example, the BC Coroners Service confirmed that there were 619 heat-related deaths during the heat dome, which took place from June 25 to July 1 2021.[1] That same year also included a devastating fire season, which destroyed the village of Lytton, and saw provincial firefighting costs hit $718.8 million.[2] This was then followed by severe flooding in the fall. The atmospheric river in mid-November led to floods and landslides that killed five people and cut off all road and rail routes between Metro Vancouver and the rest of Canada—the costliest natural disaster in the province's history.[3]

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[1] Government of Canada. https://science.gc.ca/site/science/en/blogs/science-health/surviving-heat-impacts-2021-western-heat-dome-canada. Published 2022-06-26

[2] Government of British Columbia. https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/wildfire-history/wildfire-season-summary

[3] Zwiers, Francis. "2021 BC floods and climate change." *University of Victoria*, 15 February 2022, https://www.uvic.ca/news/topics/2022+bc-floods-and-climate-change+news. Accessed 14 September 2023.

This report primarily focusses on changes in temperature and precipitation patterns which will affect the social, natural, built, and economic systems of UBC's Vancouver campus, including both the academic lands and residential neighbourhoods.

The purpose of this report is to summarize localized projections. These climate projections, specific to the UBC Point Grey campus, will be used to help determine the impacts of what vulnerabilities and risks the UBC community faces as a result of climate change. This process is one of the first steps to inform and understand how the University institution, Neighbourhoods and the community can prepare for projected climate impacts to increase resilience to them.

Data Collection

Data for this report was collected through several platforms. Primarily, localized climate change data was collected from three online, publicly available tools. These include:

- Climate Change Data and Scenarios Tool - Climatedata.ca
- The Climate Atlas of Canada was used to collect data relating to CMIP5 climate projections where CMIP6 data was unavailable from climatedata.ca
- Computerized Tool for the Development of Intensity-Duration-Frequency Curves under Climate Change Version 6.0 - http://www.idf-cc-uwo.ca/home

More information concerning these online tools are provided in the Glossary. Other information pertaining to expected climatic changes in BC were taken from various academic or government reports. These are identified and cited where applicable.

Climate Change Modelling and Downscaling

Wherever possible, the data presented in this report is based on global climate models (GCMs) and emission scenarios defined by the Intergovernmental Panel on Climate Change (IPCC), drawing from the Sixth Assessment Reports. Data projecting temperature and precipitation changes have been constructed using Coupled Model Intercomparison Project (CMIP6) data as they are the most current global climate model data available. CMIP6 improves upon CMIP5 by including 49 climate modelling groups running 100 climate models.

Many different methods exist to construct climate change scenarios, however GCMs are the most conclusive tools available for simulating responses to increasing greenhouse gas concentrations, as they are based on mathematical representations of atmosphere, ocean, ice cap, and land surface processes.[4]

Wherever possible, this report uses an ensemble approach, which refers to a system that runs multiple climate models at once. Research has shown that this provides a more accurate projection of annual and seasonal temperatures and precipitation than a single model would on its own.[5]

[4] Government of Canada. Multi-model ensemble scenarios (canada.ca). Published 2022-07-22

[5] Government of Canada. Multi-model ensemble scenarios (canada.ca). Published 2022-07-22

Greenhouse Gas Emissions Scenarios

Climate change scenarios are based on models developed by a series of international climate modeling centers. They are socioeconomic storylines used by analysts to make projections about future greenhouse gas emissions and to assess future vulnerability to climate change. Producing global model scenarios requires estimates of future population levels, economic activity, the structure of governance, social values, and patterns of technological change. In this report, climate change scenarios from the Fifth and Sixth IPCC Assessments are considered.

SSP Scenarios - IPCC Sixth Assessment Report (AR6)

Shared Socio-economic Pathways (SSPs) are the newest set of climate change scenarios that provide the basis for IPCC's Sixth Assessment report (AR6). While the Representative Concentration Pathways (RCPs) used in the IPCC's Fifth Assessment Report (AR5) focuses on mitigation targets to address physical climate change, the SSPs focus on the underlying socioeconomic contexts which may present challenges to mitigation and adaptation policies. The SSPs incorporate socioeconomic characteristics and other human-caused climate drivers (e.g., population growth, education levels, GDP growth, income inequality, use of technology, energy use, political contexts, land-use change) to derive scenarios that describe differing influences on greenhouse gas emissions. AR6 assesses and compares the RCP and SSP scenarios and incorporates new data, new models, and updated climate research from around the world to allow for a standardized comparison of society's choices and their resulting levels of climate change. The premise is that every radiative forcing pathway (see Glossary) can result from a diverse range of socioeconomic and technological development scenarios. SSP-based scenarios are categorized by their relationship to both adaptation and mitigation, and their approximate total radiative forcing in the year 2100 relative to pre-industrial levels, and are labeled as SSP1-SSP5.

These five pathways range from SSP1, where challenges to mitigation and adaptation are low, to SSP3 where challenges to mitigation and adaptation are both high, and the remaining SSPs are representative of the spectrum of possible societal futures.

For this report, where possible, projections will use both SSP2-4.5, and SSP5-8.5, as they represent a carbon reduced future with support of adaptation actions, and a 'fossil-fueled development' scenario with high challenges to mitigation and low challenges to adaptation. These scenarios were chosen because they represent a wide-range of possible future climates, have associated projections available from many different climate models, and correspond with Representative Concentration Pathways (RCP) 4.5 and 8.5 utilized in the IPCC's AR5 Report. Additionally, it is important that municipalities are aware of some of the most potentially dramatic effects of climate change should global emissions persist. Table 2 provides a description of SSP scenarios 1, 2, and 5, while Figure 1 illustrates the projected global warming associated with the three scenarios.

Table 2: IPCC Sixth Assessment Report Climate Change Scenario Characteristics[6]

Scenario	Description
SSP1-2.6 – Sustainability ***Taking the Green Road***	• Low challenges to both mitigation and adaptation • Policy focused on sustainable development • Effective international cooperation • Reduced inequality within and across countries • Low consumption

[6] Riahi , K., et al. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Science Direct*, *42*, 153-168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

	● Low population growth
SSP2-4.5 ***Middle of the Road***	● Medium challenges to both mitigation and adaptation ● Current development and consumption patterns continue ● National and global institutions are slow to achieve sustainable development goals ● Environmental systems decline ● Slow improvements to inequality ● Moderate population growth
SSP5-8.5 – Fossil-fueled Development ***Taking the Highway***	● High challenges to mitigation, low challenges to adaptation ● Policy focused on free markets ● High consumption ● Effective international cooperation ● Reduced inequality ● High economic growth ● Low population growth

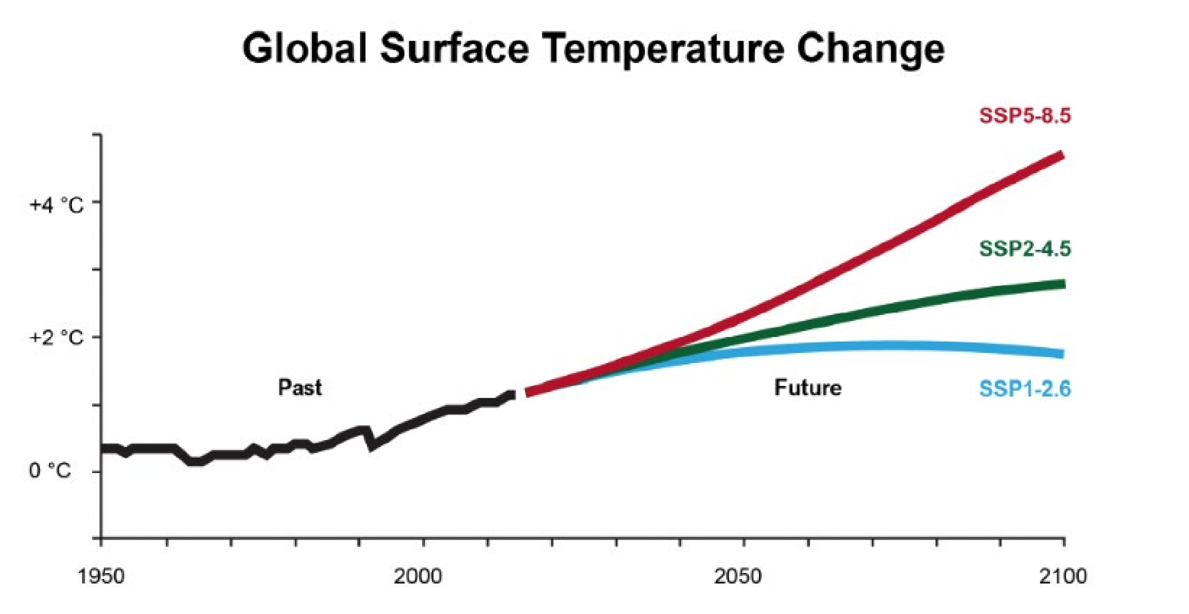

Figure 1: Global Surface Temperature Change

Time Periods

Climatic projections are typically provided within time periods of 20-30 years. Additionally, a consistent baseline period is established so that projections can be accurately compared with historical trends. In this report, the time periods of 2021-2050 (immediate future) and 2051-2080 (near future) are used most frequently. Many climate indices are also divided into seasonal periods, defined below.

Table 3: Seasonal Timeframes

Season	Months
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Fall	September, October, November

Uncertainty

It is important to note that uncertainty is an integral part of the study of climate change. Uncertainty is factored into climate change scenarios, models, and data, and reflects the complex reality of environmental change and the evolving relationship between humans and the planet. Climate change cannot be predicted with absolute certainty in any given case, and all data must be considered with this in mind. While it is not possible to anticipate future climatic changes with absolute certainty, climate change scenarios help to create plausible representations of future climate conditions. These conditions are based on assumptions of future atmospheric composition and on an understanding of the effects of increased atmospheric concentrations of greenhouse gases, particulates, and other pollutants.

The ensemble models do not represent a 'best' model as there is not one and therefore, as mentioned under climate change modelling, an ensemble model is used. For this report the 50th percentile (median) was used in order to present where the majority of results fall.[7]

Temperature

Annual and Seasonal Temperatures

Broader Context

Over the last six decades, Canada has become warmer, with average temperatures over land increasing by 1.5°C between 1950 and 2010.[8] This rate of warming is almost double the global average reported over the same period.[9] The average temperature for the year 2022 in Canada was 1.2 °C above the baseline, making it the 16th warmest year since 1948[10].

Assuming emissions continue at the current rate of global output, BC is projected to experience an increase in annual average temperature of 4.9°C by the end of the century from a historical baseline of 1.0°C. Table 4 displays the expected seasonal temperature change in BC based on the IPCC Fifth

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[7] "Uncertainty in Climate Projections — Climate Data Canada." *Climate Data Canada*, https://climatedata.ca/resource/uncertainty-in-climate-projections/. Accessed 14 September 2023.
[8] Douglas, A.G. and Pearson, D. (2022). Ontario; Chapter 4 *in* Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham, D.L. Dupuis and D.S. Lemmen; Government of Canada, Ottawa, Ontario.
[9] Douglas, A.G. and Pearson, D. (2022). Ontario; Chapter 4 *in* Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham, D.L. Dupuis and D.S. Lemmen; Government of Canada, Ottawa, Ontario.
[10] "Temperature change in Canada." *Canada.ca*, 10 July 2023, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/temperature-change.html. Accessed 14 September 2023.

Assessment Report (AR5). Climate modelling suggests that these changes will continue and the climate change associated risks will increase in the future.

Table 4: Annual and Seasonal Temperature Change in BC for RCP8.5*

Emissions Scenarios	T Mean (°C)	Baseline (1976-2005)	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
RCP8.5	Spring	0.8	0.6	2.8	5.1	1.9	4.6	7.3
	Summer	11.7	12.2	13.8	15.3	13.9	15.9	18.0
	Fall	1.4	1.3	3.1	4.8	3.1	5.1	7.0
	Winter	-10.1	-11.3	-8.0	-5.0	-9.4	-6.0	-2.9
	Annual	**1.0**	**1.6**	**3.0**	**4.4**	**3.1**	**4.9**	**6.7**

*Province wide data not available for SSP5-8.5 – see Data Collection section above for more information

UBC Vancouver Campus

Temperatures at UBC are expected to rise in congruence with the provincial changes observed in the data above. The climatedata.ca tool was used to collect downscaled climate projections, using a baseline of 1971-2000.

At UBC there is a projected annual temperature increase from the baseline mean of 10.4°C between 12.3°C in the immediate future and 13.7°C by 2080 under scenario SSP5-8.5. Table 5 and Figure 2 depict the projected temperatures using an ensemble of global climate models applying the SSP2-4.5 and SSP5-8.5 scenarios.

Table 5: Projected Mean Temperatures for UBC Vancouver Campus (°C) by Season – SSP2-4.5 and SSP5-8.5

Emissions Scenarios	T Mean (°C)	Baseline (1971-2000)	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
SSP2-4.5	Spring	9.6	10.5	10.9	12.3	11.3	12.0	13.7
	Summer	17.0	18.3	19.0	20.2	19.2	19.7	21.8
	Fall	10.6	11.7	12.2	13.3	12.6	13.2	14.9
	Winter	4.4	5.4	5.8	6.2	6.1	6.9	7.7
	Annual	**10.4**	**11.6**	**12.0**	**12.9**	**12.4**	**12.8**	**14.5**
SSP5-8.5	Spring	9.6	10.9	11.3	12.5	11.9	12.5	15.1
	Summer	17.0	18.7	19.3	20.8	20.3	20.9	23.5

	Fall	10.6	12.1	12.4	13.8	13.4	14.1	16.3
	Winter	4.4	5.3	6.3	6.8	6.9	7.6	9.3
	Annual	**10.4**	**11.8**	**12.3**	**13.5**	**13.3**	**13.7**	**15.9**

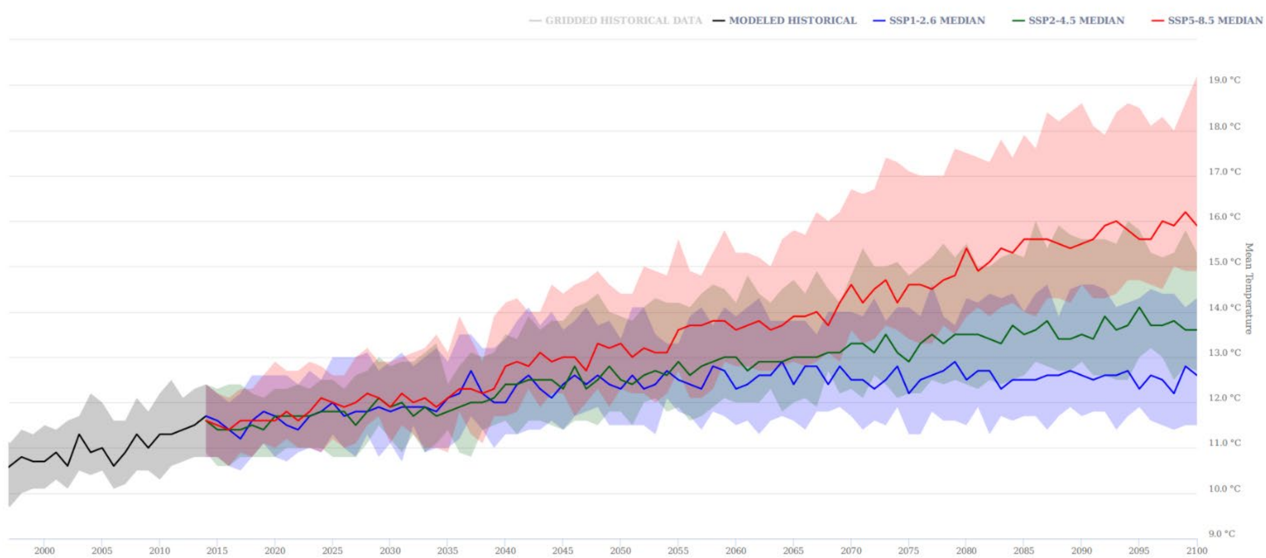

Figure 2: Projected Mean Temperature Change for UBC Vancouver Campus SSP1-2.6, SSP2-4.5, SSP5-8.5

Hot and Cold Days

Maximum and minimum temperature trends show the average high temperatures and the average low temperatures for a given season.

Minimum Temperatures

In terms of minimum temperatures, the baseline mean minimum temperatures across each season were 5.7, 12.7, 7.3, and 1.8°C for spring, summer, fall and winter respectively. Minimum seasonal temperatures under an SSP5-8.5 scenario are projected to increase substantially, with an increase of 2.8°C in spring, 3.8°C in summer, 3.3°C in fall and 3.4°C in winter from 2051-2080.

Table 6: Projected Average Seasonal Minimum Temperatures for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenario	**T Mean (°C)**	**Baseline (1971-2000)**	**2021-2050**			**2051-2080**		
			Low	Mean	High	Low	Mean	High
SSP2-4.8	Spring	5.7	6.7	7.0	8.4	7.4	7.9	9.8
	Summer	12.7	14.0	14.3	15.5	14.7	15.3	17.0

	Fall	7.3	8.4	8.7	10.0	9.2	9.9	11.8
	Winter	1.8	2.9	3.4	3.9	3.6	4.4	5.7
	Annual	**6.9**	**8.1**	**8.4**	**9.4**	**8.9**	**9.2**	**11.0**
SSP5-8.5	Spring	5.7	6.9	7.3	8.6	8.0	8.5	11.0
	Summer	12.7	14.3	14.6	15.9	16.0	16.5	18.8
	Fall	7.3	8.8	9.1	10.5	10.1	10.6	13.0
	Winter	1.8	2.9	3.9	4.7	4.4	5.2	7.3
	Annual	**6.9**	**8.3**	**8.7**	**9.8**	**9.8**	**10.1**	**12.5**

Maximum Temperatures

In terms of Average Seasonal Maximum Temperatures, seasonal average baseline temperatures for UBC Vancouver Campus were 13.4, 21.3, 13.9, and 6.9˚C for spring, summer, fall and winter respectively. UBC is expected to experience an increase in all seasonal maximum temperatures, with Average Summer Maximum Temperatures reaching 25.6˚C in the years 2051-2080 under SSP5-8.5.

Table 7: Projected Average Seasonal Maximum Temperatures for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenarios	**T Mean (°C)**	**Baseline (1971-2000)**	**2021-2050**			**2051-2080**		
			Low	Mean	High	Low	Mean	High
SSP2-4.5	Spring	13.4	14.5	14.9	16.1	15.1	15.8	17.7
	Summer	21.3	22.6	23.5	24.9	23.6	24.3	26.6
	Fall	13.9	15.0	15.6	16.6	15.9	16.6	18.2
	Winter	6.9	7.8	8.2	8.6	8.5	9.2	9.9
	Annual	**13.9**	**15.1**	**15.6**	**16.6**	**15.9**	**16.3**	**18.0**
SSP5-8.5	Spring	13.4	14.7	15.2	16.4	15.6	16.5	19.2
	Summer	21.3	23.0	23.9	25.6	24.7	25.6	28.6
	Fall	13.9	15.5	15.8	17.1	16.6	17.5	19.7
	Winter	6.9	7.8	8.5	9.1	9.3	10.0	11.4
	Annual	**13.9**	**15.3**	**15.9**	**17.0**	**16.7**	**17.3**	**19.6**

Average Winter Maximum Temperatures will increase 3.1˚C by 2051-2080 according to SSP5-8.5, while the Average Summer Maximum Temperature is expected to increase by 2.6˚C to 23.9˚C in the near future (2021-2050). These temperatures do not factor in additional warming due to the humidex which could make it feel 5 to 10˚C warmer. These extreme temperatures can cause heat-related illnesses in not only vulnerable populations but also healthy, young adults.

Extreme Heat

Extreme heat is the best-documented natural hazards associated with health consequences and increased all-cause mortality, but the thresholds and duration of extreme heat days and events vary across the country.[11] The Government of BC defines an extreme heat emergency as "Daytime and overnight temperatures are higher than seasonal norms and getting hotter every day.[12]"

Examples of the health risks associated with extreme heat include heat cramps, heat edema, heat exhaustion, or heat stroke. Specific groups, such as those who work outside, infants and young children, older adults (over the age of 65), those with chronic medical conditions, people experiencing homelessness, people playing outdoor sports or activities, and those with limited mobility may be more adversely affected.[13] Moreover, while higher summer temperatures increase electricity demand for cooling, at the same time, these temperatures can lower the ability of transmission lines to carry power, possibly leading to electricity reliability issues during heat waves.[14]

The baseline average number of days when the maximum temperature (TMax) was greater than or equal to 30°C was 1 day for UBC. This is expected to increase to an average of 11 days, with a possible range in any given year of 6 to 39 days in the 2051-2080 period under the SSP5-8.5 scenario.

Table 8: Hot Days (Tmax ≥30°C) for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenario	Tmax (days)	Baseline (1971-2000)	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
SSP2-4.5	30°C or more	1	2	3	6	2	5	14
SSP5-8.5	30°C or more	1	2	4	9	6	11	39

[11] Gosselin, P., Campagna, C., Demers-Bouffard, D., Qutob, S., & Flannigan, M. (2022). Natural Hazards. In P. Berry & R. Schnitter (Eds.), Health of Canadians in a Changing Climate: Advancing our Knowledge for Action. Ottawa, ON: Government of Canada.
[12] Government of British Columbia. https://www2.gov.bc.ca/gov/content/safety/emergency-management/preparedbc/know-your-hazards/severe-weather/extreme-heat
[13] Health Canada. (2011). Adapting to Extreme Heat Events: Guidelines for Assessing Health Vulnerability. Ottawa, ON. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/pubs/climat/adapt/index-eng.php
[14] Centre for Climate and Energy Solutions (n.d.). Heat Waves and Climate Change. C2ES. Retrieved from https://www.c2es.org/content/heat-waves-and-climate-change/

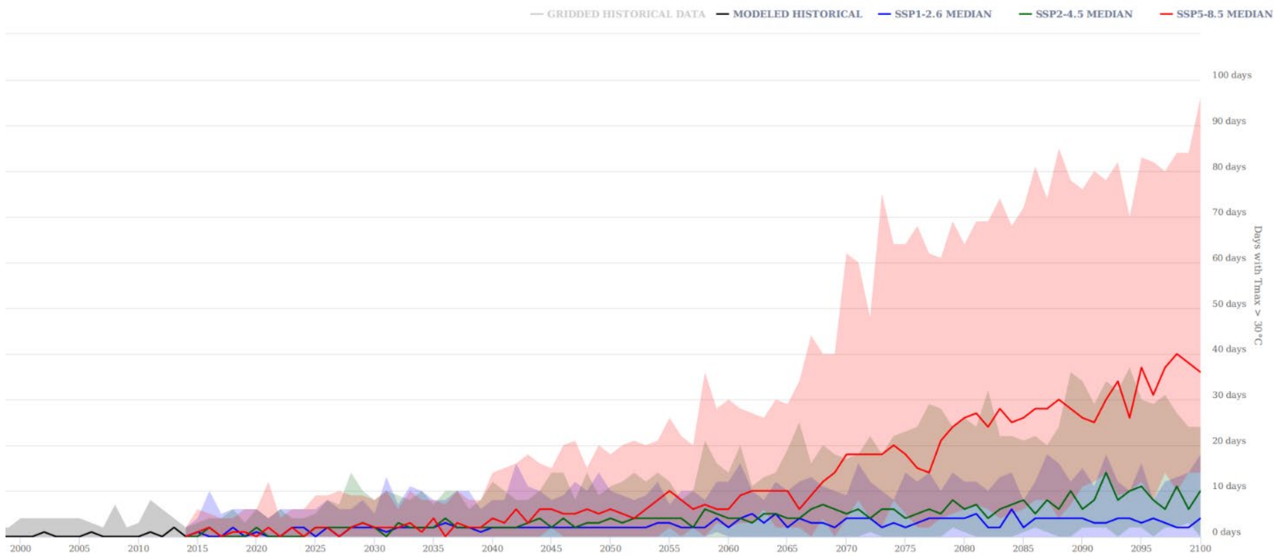

Figure 3: Hot Days (Tmax ≥30°C) for UBC Vancouver Campus SSP1-2.6, SSP2-4.5, SSP5-8.5

Heat Waves

BC's Provincial Heat Alert and Response System:2023 from the BC Center for Disease Control defines a heat wave within the Vancouver Coastal Health region as two days in a row that reach or exceed 29°C and does not go below 16°C. The baseline number of heat waves for UBC Vancouver Campus is 0.03 as presented in Table 9. In the 2051-2080 period according to RCP8.5, UBC can expect to experience over 15.6 heat wave events per year.

Table 9: Number of Annual Heat Waves for UBC Vancouver Campus – RCP4.5 and 8.5*

Emissions Scenarios	Baseline (1971-2000)	2021-2050			2051-2080		
		Low	Mean	High	Low	Mean	High
RCP4.5	0	0	2.1	5	2	5.1	11
RCP8.5	0	0	3.1	8	4	15.6	34

With regards to the average length of heat waves (in days), where a heat wave event is when the daily minimum temperature is 16°C and the daily maximum temperature is 29°C for a minimum of 2 consecutive days[15]. UBC experienced an average of 0.1 days of heat wave conditions in the baseline period as displayed in Table 10. In the 2051-2080 period, according to RCP8.5, UBC can expect to see an average heat wave event occurring for 17.1 days.

[15] "BC Provincial Heat Alert and Response System (BC HARS): 2023." *BC Centre for Disease Control*, http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/Provincial-Heat-Alerting-Response-System.pdf .

Table 10: Average Annual Length of Heat Waves for UBC Vancouver Campus – RCP4.5 and 8.5*

Emissions Scenarios	Baseline (1971-2000)	2021-2050			2051-2080		
		Low	Mean	High	Low	Mean	High
RCP4.5	0	0	2.3	5	2	6.4	11
RCP8.5	0	0	3.4	9	6	17.1	34

Overall, heat waves are projected to occur more frequently and for longer periods of time, leading to greater occurrences of extreme heat events at UBC. These changes become more pronounced over time, and in response to higher emissions scenarios (Figure 3). High, persistent temperatures also increase the risk of drought, which can severely impact food production and increases the risk of wildfire. High temperatures can also lead to more storms, which means increased risks of flash flooding, lightning, hail and even tornadoes.[16] More frequent and extended heat waves will impact those that currently don't have access to cooling.

Humidex

The humidex measurement provides the number of days where the humidex is greater than 30°C (Hx>30°C) has been recently released through Climatedata.ca. However, the measurements for humidex days >30°C has not been calculated for the area on which the UBC Vancouver Campus is situated (Point Grey Beach, BC grid cell), therefore data has been derived from the Vancouver grid cell.

The humidex index was developed by the Meteorological Service of Canada to describe how hot and humid the weather feels to the average person. In Canada, it is recommended that outdoor activities be moderated when the humidex exceeds 30, and that all unnecessary activities cease when it passes 40.[17]

The number of hot and humid days in Vancouver will increase from an Hx>30°C baseline average of 8 days for Vancouver to 24 days in the 2021-2050 period, and 48 days in the 2051-2080 period under the SSP5-8.5 scenario.

Table 11: Number of Humidex days >30°C for Vancouver – SSP2-4.5 and SSP5-8.5

Emissions Scenario	Humidex (days)	Baseline (1971-2000)	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
SSP2-4.5	>30°C	8	16	22	30	25	30	49
SSP5-8.5	>30°C	8	21	24	34	39	48	71

[16] Sauchyn, D., Davidson, D., and Johnston, M. (2020): Prairie Provinces; Chapter 4 in Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham and D.S. Lemmen; Government of Canada, Ottawa, Ontario.

[17] Mekis, Éva & Vincent, Lucie & Zhang, Xuebin & Shephard, Mark. (2015). Observed Trends in Severe Weather Conditions Based on Humidex, Wind Chill, and Heavy Rainfall Events in Canada for 1953–2012. Atmosphere-ocean. 53. 383-397. 10.1080/07055900.2015.1086970.

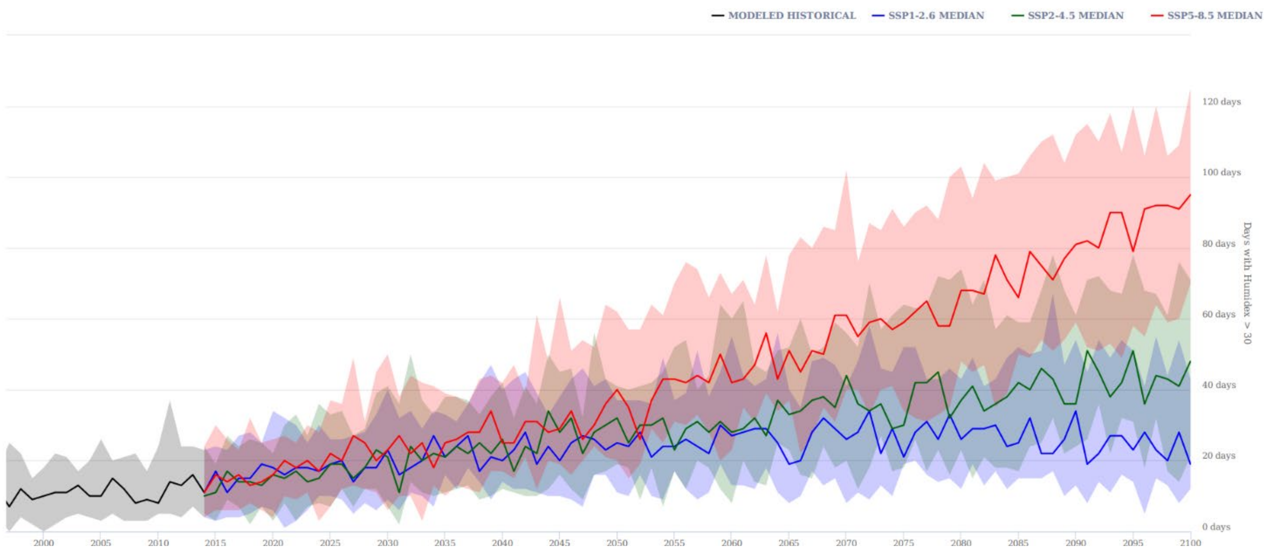

Figure 4: Days with Humidex >30°C for Vancouver SSP1-2.6, SSP2-4.5, SSP5-8.5

Cold Weather

Overall, the frequency and severity of cold days are decreasing across Canada, and it is important to know how our winters will change in the future, because cold temperatures affect health and safety, where and how plants and animals survive, limit or enable outdoor activities, define how we design our buildings and vehicles, and shape our transportation and energy use.

Frost Days and Ice Days

Cold weather indicators, such as Frost Days and Ice Days, can help to understand freeze and thaw patterns throughout the region and document risks relating to morbidity and mortality from traffic accidents, damage to roads and infrastructure, facility closures and more.

A Frost Day is a day with frost potential, meaning the **minimum** temperature is below 0°C. Frost Days are predicted to decrease an average of nearly 26 days by the 2080s in SSP5-8.5 from baseline.

Table 12: Projected Frost Days for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenarios	Baseline (1971-2000)	2021-2050			2051-2080		
		Low	Mean	High	Low	Mean	High
SSP2-4.5	30	10	15	21	3	7	14
SSP5-8.5	30	6	11	19	2	4	11

Similarly, the number of Ice Days are projected to decrease. Ice Days are the total number of days when daily **maximum** temperature is at or below 0°C. A reduction in days below 0°C could have an impact on the survival and spread of ticks and Lyme disease, as ticks can be active in temperatures above 4°C.[18] While deer ticks are most active in spring and fall, warmer winters could extend their window of activity. Ice Days are expected to decrease by nearly 3 days by the 2080s in SSP5-8.5.

Table 13: Projected Ice Days for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenarios	Baseline 1971-2000	2021-2050			2051-2080		
		Low	Mean	High	Low	Mean	High
SSP2-4.5	3	1	2	3	0	1	2
SSP5-8.5	3	1	1	3	0	0	1

Freeze-Thaw

A freeze-thaw cycle is any day where the minimum temperature is below 0˚C and the maximum temperature is above 0˚C. The SSP5-8.5 ensembles project that freeze-thaw cycles will decrease due to overall warmer temperatures. This is likely a result in the overall increase in projected warmer days, and UBC Vancouver Campus is likely to experience a decrease in the number of days that reach a minimum temperature below 0°C.

Under these conditions, it is likely that some water at the surface was both liquid and ice at some point during the 24-hour period. Freeze-thaw cycles can have major impacts on infrastructure. Water expands when it freezes, so the freezing, melting, and re-freezing of water can over time cause significant damage to roadways, sidewalks, and other outdoor structures. Potholes that form during the spring, or during mid-winter melts, are good examples of the damage caused by this process.

Table 14: Average Annual Freeze-Thaw Cycles for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenarios	Baseline (1971-2000)	2021-2050			2051-2080		
		Low	Mean	High	Low	Mean	High
SSP2-4.5	17	6	8	12	2	4	8
SSP5-8.5	17	3	7	11	1	2	6

Growing Season

Growing Season Start Date, End Date, and Length

Changes in seasonal temperatures, precipitation events, the length of growing seasons, and the timing of extreme heat and cold days all determine the types of vegetation and crops that can be grown now

[18] Alberta Health. (2019). Lyme disease tick surveillance. Retrieved from https://www.alberta.ca/lyme-disease-tick-surveillance.aspx

and in the future.[19] While increased temperatures will extend the growing season of some plants, other climate change projections are expected to result in a series of deleterious factors which may negate any benefit. For instance, increased temperatures may also increase the likelihood of drought conditions, reduce the water supply for irrigation, improve conditions for some pests, and disrupt pollination patterns.[20]

The growing season is defined by the last and first frosts and also the median frost-free days. The SSP5-8.5 ensembles project earlier start dates and later end dates to the growing season of UBC Vancouver Campus as shown in Table 15. The baseline start date is typically around March 9, while the end date is typically November 21, resulting in a growing season of approximately 257 days. According to the SSP5-8.5 ensemble, by the end of the 21st century, the growing season is projected to occur approximately 26 days earlier, while the end date will likely occur approximately 12 days later. This means, on average, the growing season will likely increase by approximately 11.5 weeks a year, following the high emissions scenario.

Table 15: Growing Season Length for UBC Vancouver Campus– SSP5-8.5

	SSP5-8.5		
	Median Start date (Date of Last Spring Frost)	**Median End date (Date of First Fall Frost)**	**Median frost-free days**
1971-2000 (Baseline)	March 9	November 21	257
2021-2050	February 15	December 2	309
2051-2080	February 12	December 3	338

Precipitation

Annual and Seasonal Precipitation

Broader Context

Canada has, on average, become wetter during the past half century, with average precipitation across the country increasing by approximately 20%.[21] Other parts of the country can expect to see a significant percentage increase in precipitation, particularly Northern Canada.

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[19] Capital Regional District. (2017, July 17). *Climate Projections for the Capital Region.* Retrieved from www.crd.bc.ca: https://www.crd.bc.ca/docs/default-source/climate-action-pdf/reports/2017-07-17_climateprojectionsforthecapitalregion_final.pdf

[20] Capital Regional District. (2017, July 17). *Climate Projections for the Capital Region.* Retrieved from www.crd.bc.ca: https://www.crd.bc.ca/docs/default-source/climate-action-pdf/reports/2017-07-17_climateprojectionsforthecapitalregion_final.pdf

[21] Natural Resources Canada. (2019) Canada in a Changing Climate. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR_FULLREPORT-EN-FINAL.pdf Government of Canada, Ottawa, ON. p.156.

Projections for BC show less dramatic changes to precipitation patterns, noting that the increase in precipitation is not spread equally over the seasons. Table 16 below details the projected precipitation changes for the province of BC under the RCP8.5 scenario.

Table 16: Projected Annual Precipitation (mm) by Season for BC – RCP8.5*

Emissions Scenario	Total Precipitation (mm)	Baseline 1976-2005	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
RCP8.5	Spring	155	122	164	206	131	174	221
	Summer	192	148	198	248	144	198	255
	Fall	243	200	261	324	216	282	349
	Winter	247	191	263	339	205	283	360
	Annual	**837**	**768**	**886**	**1002**	**803**	**938**	**1063**

*Province wide data not available for SSP5-8.5 – see Data Collection section above for more information

UBC Vancouver Campus

On a seasonal basis, spring, winter and autumn precipitation accumulations are projected to increase marginally by the end of the century for UBC Vancouver campus, while summer precipitation will decrease. Table 17 presents the precipitation accumulation projections for UBC according to seasons under SSP2-4.5 and SSP5-8.5. Figure 5 presents the precipitation accumulation projections for UBC out to 2080.

For UBC, the baseline average annual precipitation is 1420 millimetres. In a high-emission scenario, UBC can expect to experience an average annual precipitation increase of 51 millimetres during 2021-2050 and 95 millimetres during 2051-2080.

Table 17: Projected Annual Precipitation (mm) by Season for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Emissions Scenario	Total Precipitation (mm)	Baseline (1971-2000)	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
SSP2-4.5	Spring	299	290	307	330	299	311	333
	Summer	151	113	134	155	107	133	157
	Fall	429	422	454	478	449	472	498
	Winter	564	546	583	610	559	590	634
	Annual	**1420**	**1417**	**1454**	**1503**	**1460**	**1498**	**1551**

SSP5-8.5	Spring	299	287	306	329	302	316	345
	Summer	151	107	130	156	89	117	147
	Fall	429	435	451	486	437	477	528
	Winter	564	541	596	622	547	602	675
	Annual	**1420**	**1411**	**1471**	**1497**	**1407**	**1515**	**1623**

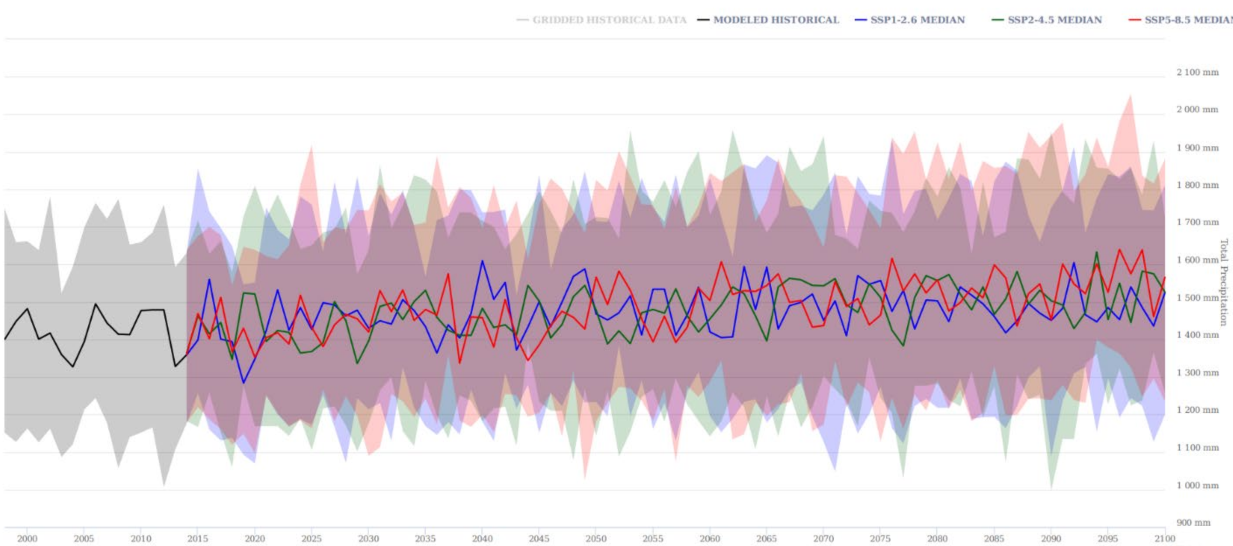

Figure 5: Projected Annual Precipitation for UBC Vancouver Campus – SSP1-2.6, SSP2-4.5, and SSP5-8.5

Extreme Weather Events

Canada has seen more frequent and intense extreme events over the last 50-60 years than ever before. These events come in the form of extreme heat days, more instances of extreme precipitation and flooding, windstorms, wildfires, and snow or ice storms. Over the last forty years, extreme weather events have resulted in damages of $31 billion in Canada alone, with global costs estimated at nearly $5 trillion (2019 dollars).[22]

Extreme weather events are having significant impacts on BC's economy and on the health and well-being of its population[23]. The likelihood and the severity of these events are increasing with climate change.[24] Extreme weather events will affect communities across Canada, from damage to

[22] Boyd, R. and Markandya, A. (2021): Costs and Benefits of Climate Change Impacts and Adaptation; Chapter 6 in Canada in a Changing Climate: National Issues Report, (Eds.) F.J. Warren and N. Lulham; Government of Canada, Ottawa, Ontario.

[23] Sauchyn, D., Davidson, D., and Johnston, M. (2020): Prairie Provinces; Chapter 4 in Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham and D.S. Lemmen; Government of Canada, Ottawa, Ontario.

[24] Feltmate, B. and M. Moudrak. 2021. Climate Change and the Preparedness of 16 Major Canadian Cities to Limit Flood Risk. Intact Centre on Climate Adaptation, University of Waterloo

infrastructure and critical services, to economic and industry productivity, and the health of vulnerable populations.[25]

Wildfires

Wildfires are caused by three main factors: fuel (type, structure, amount, and moisture), ignition (natural or human-caused), and fire-conductive weather (hot, dry, and windy).[26] Seasonal trends, including relatively unchanged summer rainfall amounts paired with the projected increases in temperatures and heatwave lengths, may lead to increased instances of dry weather and extended drought periods resulting in conditions ripe for wildfires throughout the spring, summer, and fall seasons.

Research shows that extreme wildfire risk in western Canada has increased by a factor of 1.5 to 6 due to climate change. Warmer temperatures lengthen the fire season and are associated with increased lightning strikes. More large and high-intensity wildfires, such as that experienced in Kelowna in 2023, are expected under current climate change projections.[27]

Wildfire emissions contain a number of different air pollutants and are dependent on many factors that include fuel type, combustion, and weather conditions, and can travel over 1,000 km depending on atmospheric and wind conditions. Recent literature has identified that wildfire smoke is associated with an increase in all-cause mortality, especially respiratory issues such as asthma as well as increased respiratory infections.[28] Additionally, studies have shown that wildfire smoke results in significant increases hospitalizations, emergency room visits, and the use of medication for those who suffer from respiratory conditions associated with the increased presence of wildfire smoke.[29]

Heavy or Extreme Precipitation

The projections of several extreme precipitation indices are presented in this section. Heavy Precipitation Days (both 10mm and 20mm) are days on which at least a total of 10mm (or 20mm) of rain or frozen precipitation falls. Frozen precipitation is measured according to its liquid equivalent: 10 cm of snow is usually about 10 mm of precipitation.[30]

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[25] Feltmate, B. and M. Moudrak. 2021. Climate Change and the Preparedness of 16 Major Canadian Cities to Limit Flood Risk. Intact Centre on Climate Adaptation, University of Waterloo

[26] Sauchyn, D., Davidson, D., and Johnston, M. (2020): Prairie Provinces; Chapter 4 in Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham and D.S. Lemmen; Government of Canada, Ottawa, Ontario.

[27] Sauchyn, D., Davidson, D., and Johnston, M. (2020): Prairie Provinces; Chapter 4 in Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham and D.S. Lemmen; Government of Canada, Ottawa, Ontario.

[28] Egyed, M., Blagden, P., Plummer, D., Makar, P., Matz, C., Flannigan, M., MacNeill, M., Lavigne, E., Ling, B., Lopez, D. V., Edwards, B., Pavlovic, R., Racine, J., Raymond, P., Rittmaster, R., Wilson, A., & Xi, G. (2022). Air Quality. In P. Berry & R. Schnitter (Eds.), Health of Canadians in a Changing Climate: Advancing our Knowledge for Action. Ottawa, ON: Government of Canada.

[29] Egyed, M., Blagden, P., Plummer, D., Makar, P., Matz, C., Flannigan, M., MacNeill, M., Lavigne, E., Ling, B., Lopez, D. V., Edwards, B., Pavlovic, R., Racine, J., Raymond, P., Rittmaster, R., Wilson, A., & Xi, G. (2022). Air Quality. In P. Berry & R. Schnitter (Eds.), Health of Canadians in a Changing Climate: Advancing our Knowledge for Action. Ottawa, ON: Government of Canada.

[30] Prairie Climate Centre (2020). *Climate Variables*. Climate Atlas of Canada. Retrieved from https://climateatlas.ca/variables

Max 1-Day precipitation and Max-5 Day precipitation indicate the amount of precipitation that falls on the wettest day of the year, and the five wettest days of the year respectively. The Max 1-Day precipitation amount could be the result of a short but intense precipitation event such as a storm or because a moderate amount of snow/rain falls continuously all day, rather than all at once.

Table 18 shows the projected Heavy Precipitation Days (both 10mm and 20mm), as well as the Max 1-Day and 5-Day Precipitation for UBC.

Table 18: Extreme Precipitation Indices for UBC Vancouver Campus – SSP2-4.5 and SSP5-8.5

Variable	Emissions Scenario	Baseline 1971-2000	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
Wet Days (>=10mm)*	**RCP4.5**	18.1	16.5	20.0	23.9	17.6	21.1	24.9
	RCP8.5	18.1	16.5	20.1	23.8	18.1	22.4	26.5
Wet Days (>=20mm)	**SSP2-4.5**	16	16	17	19	17	18	20
	SSP5-8.5	16	17	18	18	17	19	21
Max 1-Day Precipitation (mm)	**SSP2-4.5**	53	53	57	62	57	59	64
	SSP5-8.5	53	54	58	61	56	62	65
Max 5-Day Precipitation (mm)	**SSP2-4.5**	126	124	132	141	129	137	150
	SSP5-8.5	126	125	134	142	131	142	151

*CMIP6 data not available for Wet Days (>=10mm) – see Data Collection section above for more information

Heavy Precipitation Days at UBC are expected to increase marginally for 10mm days and 20mm days according to SSP5-8.5 by 2051-2080. Maximum 1-Day and 5-Day events are also expected to increase marginally, with the greatest increase in 5-day events. For example, Max 5-Day events are projected to increase from a baseline of 126mm to 142mm by 2051-2080 for SSP5-8.5.

Intensity-Duration-Frequency

Intensity-duration-frequency (IDF) curves represent one way to analyze and predict heavy precipitation under a changing climate. They provide a graphical representation of the probability that a given average rainfall intensity will occur. Rainfall Intensity (mm/hr), Rainfall Duration (how many hours it rained at that intensity) and Rainfall Frequency/Return Period (how often that rainstorm repeats itself) are the parameters that make up the axes of the graph of IDF curve.[31]

The Institute for Catastrophic Loss Reduction (ICLR) and the University Waterloo’s Facility for Intelligent Decision Support has developed a tool that assists users in developing and updating IDF curves using precipitation data from existing Environment Canada hydro-meteorological stations. Available precipitation data is integrated with predictions obtained from Global Climate Models to assess the

[31] IDF Curve. The Climate Workspace. Accessed from: http://www.glisaclimate.org/node/2341

impacts of climate change on IDF curves. Global climate models and scenarios developed for the IPCC Sixth Assessment Report (AR6) are used to provide future climate projections.

The station selected to produce localized IDF curves for UBC Vancouver Campus was the Vancouver UBC Station. For the Vancouver UBC Station, this baseline was calculated between 1958 and 1990. Projections are based on increases from the precipitation rate baseline, which is the average amount of precipitation in the years the station was active. Table 19 and Figure 6 depict baseline precipitation intensity for UBC.

Table 19: Baseline Precipitation Intensity Rates for UBC Vancouver Campus (mm/h) (1958-1990)

T (years)	2	5	10	20	25	50	100
5 min	34.09	49.27	59.32	68.96	72.01	81.43	90.79
10 min	25.16	35.14	41.74	48.07	50.08	56.27	62.41
15 min	20.72	28.65	33.89	38.93	40.52	45.44	50.32
30 min	14.16	18.80	21.87	24.82	25.76	28.64	31.50
1 h	9.76	12.65	14.57	16.41	17.00	18.80	20.58
2 h	6.82	8.18	9.08	9.94	10.22	11.06	11.90
6 h	4.40	5.19	5.72	6.22	6.38	6.87	7.36
12 h	3.36	4.16	4.68	5.19	5.35	5.84	6.33
24 h	2.32	2.96	3.38	3.79	3.92	4.31	4.71

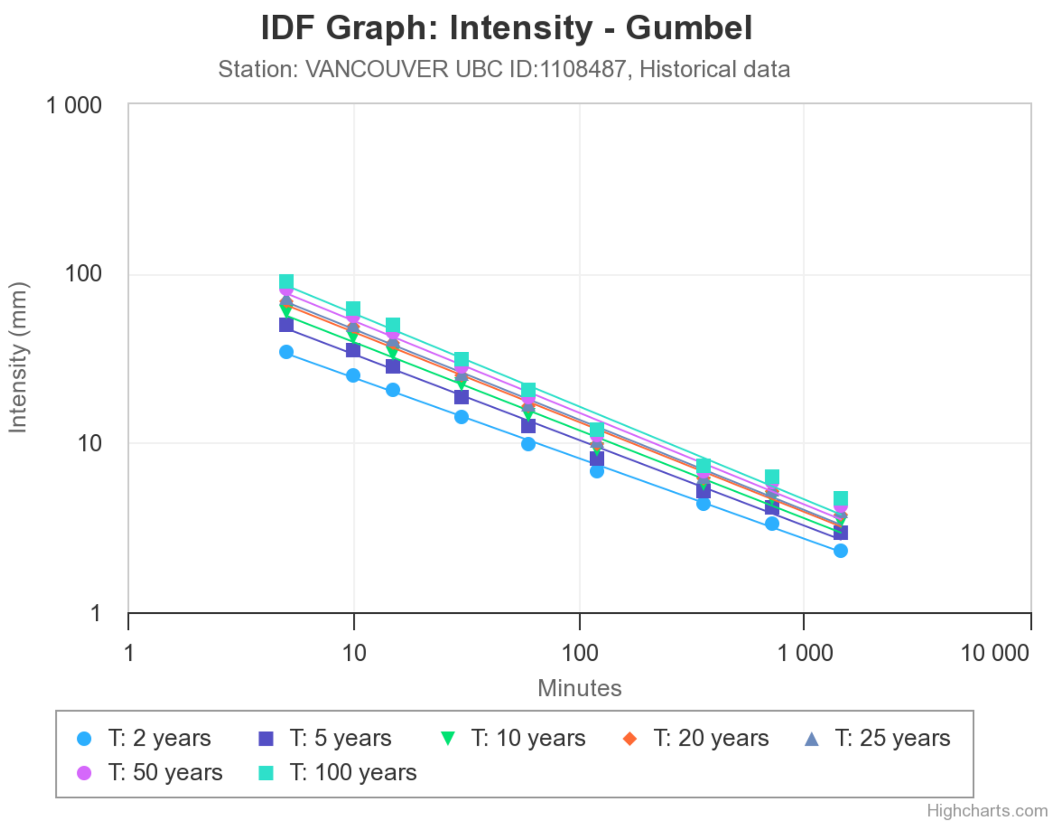

Figure 6: Baseline Precipitation Intensity for UBC Vancouver Campus

Table 20 and Table 21, and Figure 7 and Figure 8 below represent the change in IDF curves under a high emissions scenario. The projections cover a 30-year frame from 2021-2050, and 2051-2080. As seen in the graphs, the intensity of rainfall is projected to increase slightly from 2021-2050, and regress towards the baseline from 2051-2080. While longer, more frequent rainfall events will bring slightly higher amounts of rain, the intensity of rainfall during more infrequent, extreme storms (i.e. 1 in 20, 25, 50, 100-year storms, and atmospheric rivers) is projected to increase.

Table 20: Projected Precipitation Intensity Rates (mm/h) for UBC Vancouver Campus 2021-2050 – SSP5-8.5

T (years)	2	5	10	20	25	50	100
5 min	36.39	52.47	62.89	72.97	76.30	86.33	96.19
10 min	26.87	37.42	44.23	50.99	53.07	59.62	66.19
15 min	22.13	30.50	35.91	41.29	42.95	48.14	53.41
30 min	15.13	20.02	23.22	26.32	27.30	30.48	33.60
1 h	10.42	13.47	15.47	17.40	18.02	20.01	21.96
2 h	7.28	8.72	9.63	10.53	10.84	11.80	12.69
6 h	4.70	5.54	6.07	6.59	6.77	7.33	7.83

12 h	3.59	4.43	4.96	5.49	5.67	6.22	6.76
24 h	2.47	3.15	3.59	4.01	4.15	4.59	5.03

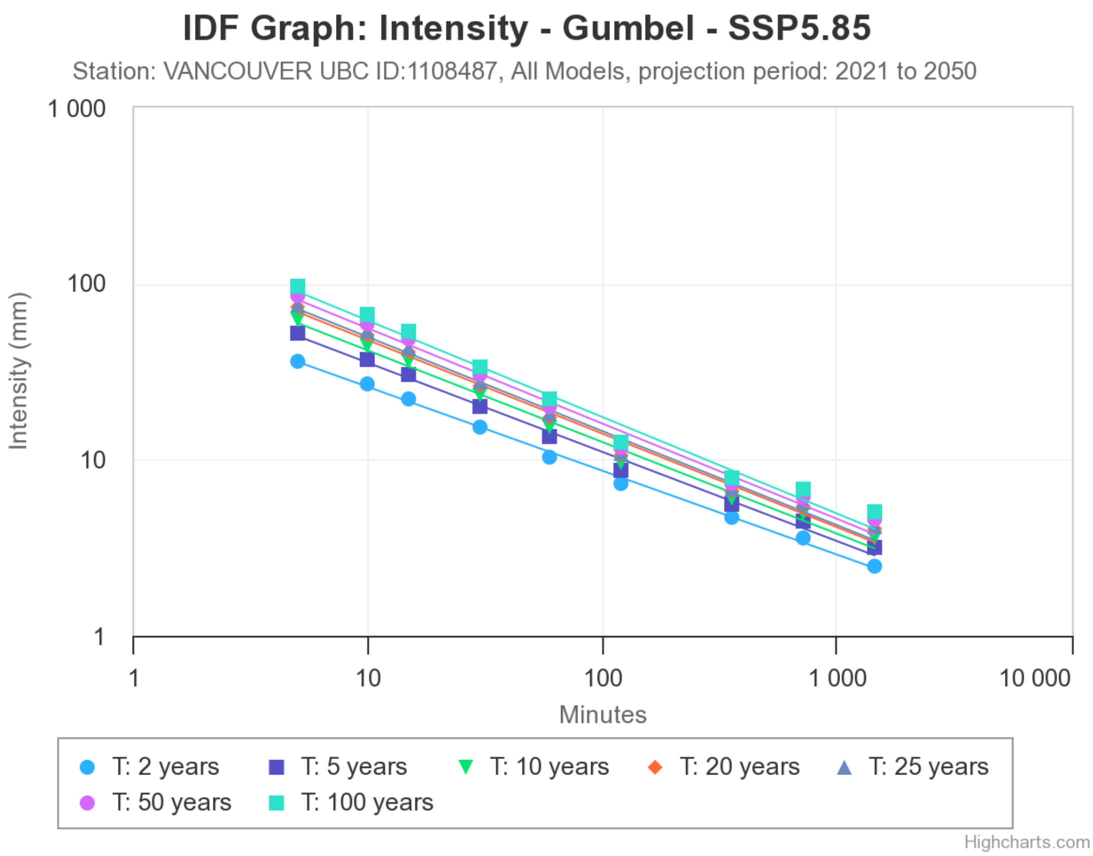

Figure 7: IDF Graph: Intensity for UBC Vancouver Campus SSP5.85

Table 21: Projected Precipitation Intensity Rates (mm/h) for UBC Vancouver Campus 2051-2080 – SSP5-8.5

T (years)	2	5	10	20	25	50	100
5 min	40.13	58.10	69.47	80.76	84.34	95.38	106.33
10 min	29.51	41.43	48.88	56.30	58.65	65.90	73.10
15 min	24.31	33.78	39.83	45.62	47.46	53.22	58.94
30 min	16.65	22.17	25.68	29.07	30.17	33.54	36.89
1 h	11.48	14.92	17.10	19.22	19.91	22.01	24.11
2 h	8.02	9.65	10.64	11.65	11.97	12.95	13.94
6 h	5.15	6.13	6.75	7.34	7.53	8.11	8.69
12 h	3.96	4.90	5.48	6.07	6.26	6.84	7.41
24 h	2.73	3.49	3.97	4.44	4.59	5.05	5.51

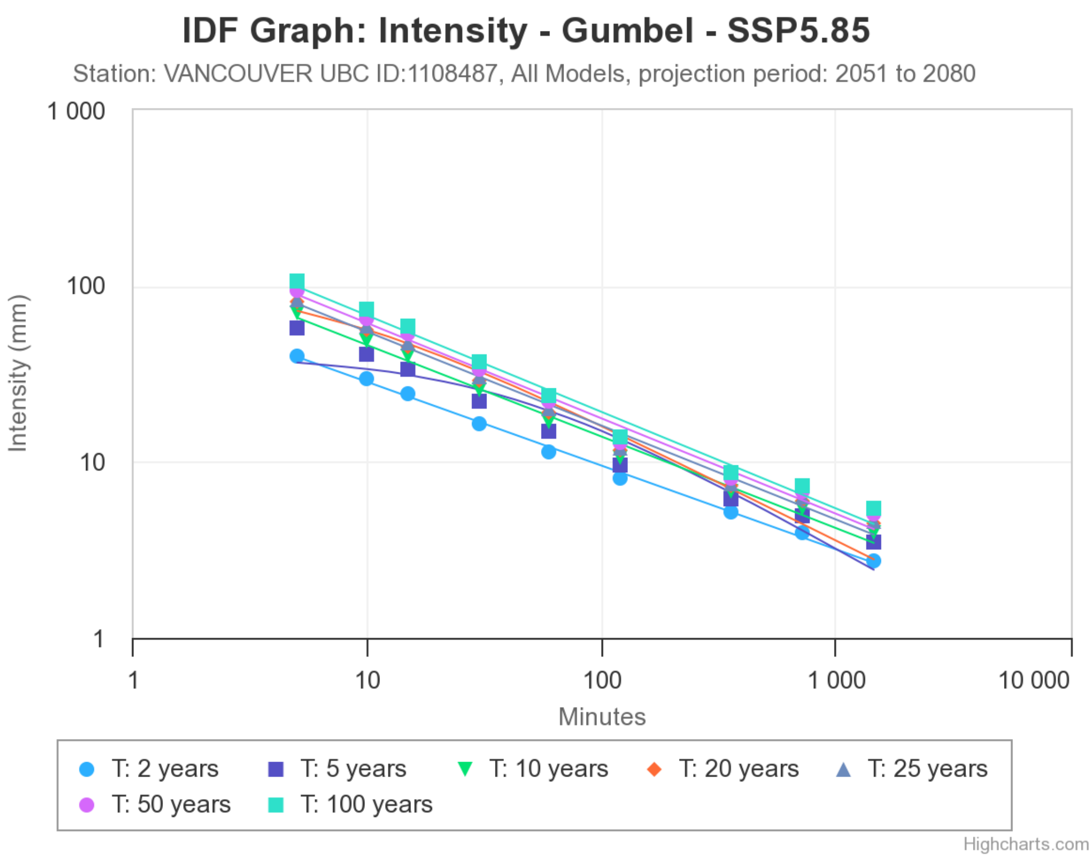

Figure 8: Projected Precipitation Intensity Rates (mm/h) for UBC Vancouver Campus 2051-2080 – SSP5-8.5

The projected IDF curves above demonstrate that the intensity (mm/h) of rainfall will increase, with more rain falling in shorter time periods. Storms that occur less frequently (e.g. 100-year storms) are projected to see a greater increase in intensity. Furthermore, such heavy precipitation events are projected to become more common than they once were impacting stormwater systems and increasing the risk of overland flooding.

Hail

Hail damage events have resulted in significant damage and losses across the province of BC, with a major hail event in April of 2023 in Vancouver.[32] While localized data related to hail projections are largely unavailable and year-to-year variability of hail events can be high, recent studies suggest that the frequency of hailstorms is linked to the increased frequency of severe thunderstorms under future climate projections.[33] Additionally, the damage to the built environment associated with these events is projected to increase as density increases.[34]

Sea Level Rise

Sea levels vary widely depending on many temporal, atmospheric, and oceanographic factors. Climate variabilities such as El Niño/La Niña Southern Oscillation contribute to extreme water levels, temperatures, and storm surge flooding. Climate change impacts such as melting glaciers, warmer temperatures (thermal expansion), changes in salinity, and land water storage changes have also contributed to changing sea levels. Between 1901-1990, the trend of global mean sea-level rise (GMSL) was on average 1.4mm/year, and increased to 3.6mm/year from 2006-2015.[35] This is expected to rapidly increase. The IPCC projects a range of global sea-level rise of 0.61-1.10m by the year 2100, based on RCP8.5 emissions scenarios.[36]

On the BC coast, the projected amount of sea level rise is not uniform. The most drastic sea level rise is projected to occur on the Fraser Lowland, southern Vancouver Island, and the north coast[37]. Guidance from the province is to plan for 0.5m of SLR by 2050, 1m of SLR by 2100 and 2m of SLR by 2200 (see Figure 9). This direction was first drafted in 2011 and updated in the Flood Hazard Area Land Use

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[32] News article: https://www.vancouverisawesome.com/local-news/vancouver-weather-hail-snow-rain-sun-2023-6800815 Published: 2023-04-03

[33] IDF Curve. The Climate Workspace. Accessed from: http://www.glisaclimate.org/node/2341

[34] IDF Curve. The Climate Workspace. Accessed from: http://www.glisaclimate.org/node/2341

[35] Global Sea level rise: Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes- Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].

[36] Global Sea level rise: Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes- Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)].

[37] Government of British Columbia. Flood Hazard Land Use Management - Province of British Columbia (gov.bc.ca). Published 2018-01-01

Management Guidelines (S.3.5 and 3.6) that came into effect in January 2018, along with two options on methodologies for setting flood construction levels (FCL)[38].

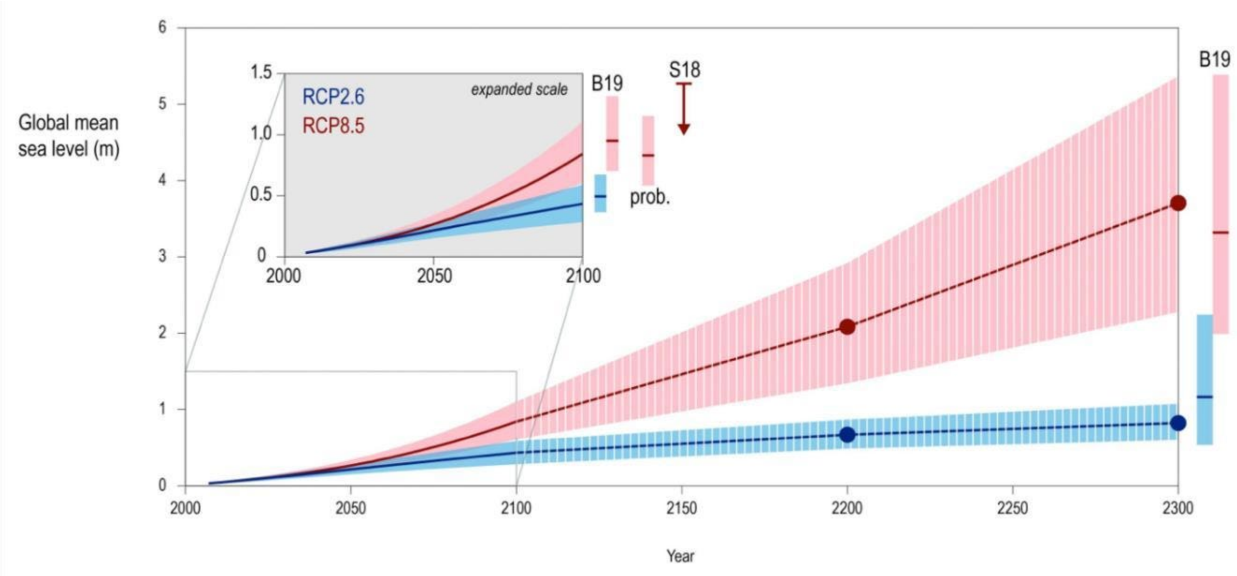

Figure 9: Projected Sea level rise (SLR) until 2080.

In addition to GMSL, extreme sea level (ESL) events; caused by tides, surges, and waves, that are rare today will become more frequent in the future[39]. The combination of GMSL and ESL will increase what were historically 100-year events into potentially yearly events by the middle of the century, including low-lying coasts that experience surges infrequently[40].

The projected sea level rise for the 'Wreck Beach, BC' grid cell data that encompasses most of the UBC Vancouver Campus is predicted to increase by an average of 38cm by 2080 in an RCP–8.5 median scenario and an average of 31cm by 2080 in an RCP-4.5 median scenario.

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[38] Government of British Columbia. Flood Hazard Land Use Management - Province of British Columbia (gov.bc.ca). Published 2018-01-01

[39] Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 321-445. https://doi.org/10.1017/9781009157964.006.

[40] Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 321-445. https://doi.org/10.1017/9781009157964.006.

Table 22: Projected Relative Sea Level Rise at UBC Vancouver Campus – RCP8.5, RCP-4.5

Variable	Emissions Scenario	Baseline 2006	2050			2080		
			Low	Mean	High	Low	Mean	High
Relative sea level rise change (cm)	RCP4.5 median	2	8	17	27	15	31	47
	RCP8.5 median	2	8	18	29	21	38	57

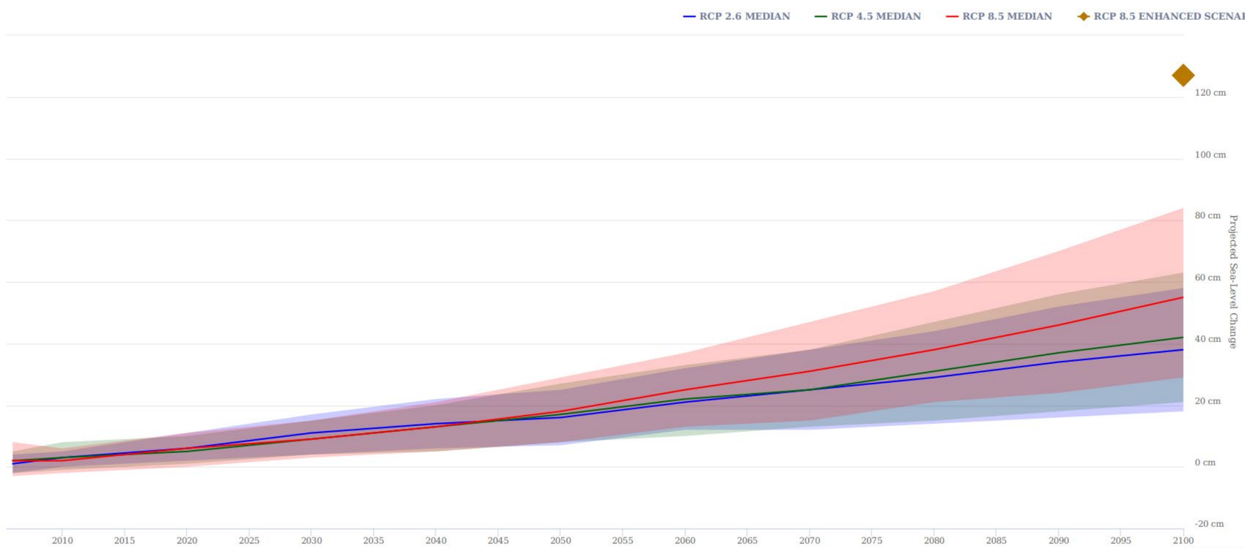

Figure 10: Projected Sea Level Rise Change for UBC Vancouver Campus in cm (2021-2080)

Conclusion

The information provided in this report provides a clear indication that climate models project climate changes in Canada, British Columbia, and specifically UBC Vancouver Campus. Rising temperatures, changes in precipitation, and increases in extreme events are major climate impacts that can have tremendous ecological, infrastructural, economic, and sociological effects for the community.

We will see significant warming both annually and across seasons with the annual baseline of 10.4°C increasing to 13.7°C by the 2080s. Each season is also projected to increase by a 3°C average. The number of heatwaves will increase from 1 to 9 annually and number of days over 30°C increasing to 11 days annually. The number of days that do not go above 0°C will decrease from 3 to 0 days by 2080.

We will see an annual increase of precipitation from 1420 to 1515mm by the 2080s on average. While this change is a modest increase, the timing of when that precipitation falls is significant. Winter and Fall will see the greatest increases of 38mm and 48 mm respectively per each season, while Spring will see a more moderate increase of only 17 mm. Summers will actually see a decrease of 34 mm by 2080.

Precipitation is also predicted to fall at a faster rate, with more falling in a shorter amount of time. Heavy precipitation days, rain days with over 10mm and over 20 mm are both projected to increase.

The projected amount of sea level rise varies based on location and temporal, atmospheric and oceanographic factors, and is projected to be 38cm higher by 2080 with guidance from the BC province suggesting planning for a minimum of 50 cm rise.

This report is meant to act as a background to inform identifying the impacts on the community. Additional research should be conducted to retrieve more precise downscaled climate projections where appropriate.

This report summarizes the modelled projections for UBC Vancouver Campus, but actual events will vary from these projections. Events will occur, and have already occurred, outside of the range of projections. This is a limitation of climate change projection models, and UBC will need to consider and prepare for extreme events that may fall outside of these projections.