CLIMATE EXTREMES IN THE GEORGIA BASIN

SUMMARY REPORT

PACIFIC CLIMATE IMPACTS CONSORTIUM

INTRODUCTION

The need for projections of changes to the climate of the Georgia Basin

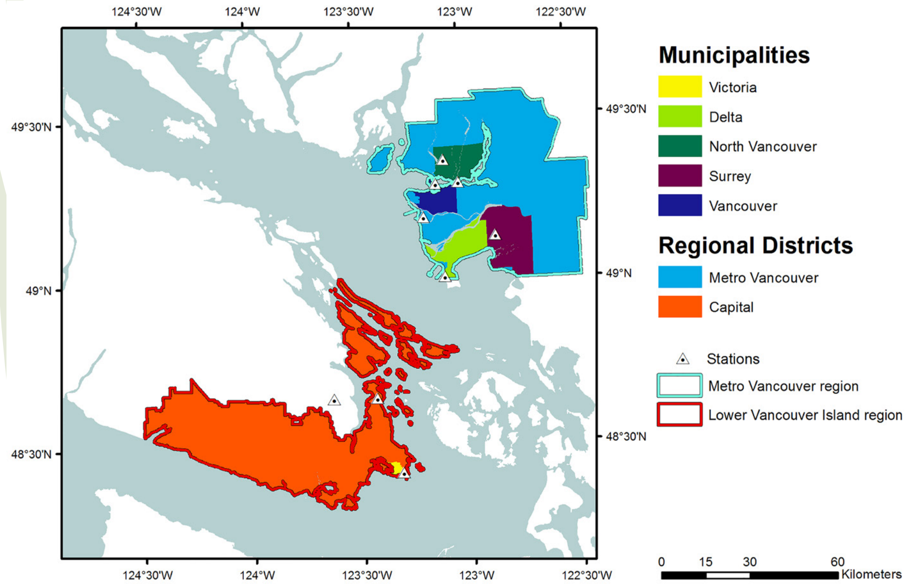
To plan for and adapt to the potential impacts of climate change, there is a need among communities in British Columbia for projections of future climate and climate extremes at a suitable, locally-relevant scale. This report summarizes work completed in 2012 by the Pacific Climate Impacts Consortium (PCIC) to this end. Commissioned by a group of municipalities and regional districts in the Georgia Basin (Figure 1), PCIC developed and analyzed a set of projections of future climate and climate extremes for the area. The full report, *Georgia Basin, Projected Climate Change, Extremes and Historical Analysis*, is available from PCIC's online publications library.

The study used a variety of data sets, with each chosen to be the best available for the type of analysis that it was used for. Broadly speaking, three types of data were used: observational data for the historical period and both Global Climate Model (GCM) output and downscaled Regional Climate Model (RCM) output for future projections. The observational data comes from an expert-guided, high-resolution climate tool known as PRISM[1] and from stations. The future projections use output from different sets of GCMs run under differing emissions scenarios and with different post-processing steps, depending on the information of interest. Because of this, the ranges shown may vary slightly by section and should not be taken as a complete representation of the range of possible changes. Though the ensemble of GCM output used to produce elevation-corrected maps was chosen to span a large range of the projected changes (Figure 2), the subset of GCMs used was small, so changes to climate that are greater and smaller than those presented here should be considered in risk assessments.

PROJECTIONS INDICATE THAT SOME TYPES OF CLIMATE EXTREMES WILL INCREASE IN THEIR INTENSITY AND FREQUENCY IN THE FUTURE

1. PRISM is the Parameter Regression on Independent Slopes Model, developed by the Oregon State University's PRISM Climate Group. See: Daly, C. et al., 1994: A statistical-topographic model for mapping climatological precipitation over mountainous terrain. *Journal of Applied Meteorology*, **33**, 140–158, doi: 10.1175/1520-0450(1994)033<0140:ASTMFM>2.0.CO;2. See also: Daly, C., et al., 1997: The PRISM approach to mapping precipitation and temperature. Preprints, *10th Conference on Applied Climatology*, Reno, NV, American Meteorological. Society, 10–12, doi:10.1.1.730.5725.

Figure 1: **Map of the study area.** Shown is the study area for this report, the Georgia Basin. The outlines show regional district boundaries and were used for computing regional averages.



THE RESULTS SHOW WARMER AVERAGE TEMPERATURES AND AN INCREASE IN WARM TEMPERATURE EXTREMES, AS WELL AS INCREASES IN AVERAGE PRECIPITATION AND EXTREME PRECIPITATION EVENTS

Summary of results

In the Georgia Basin, climate is expected to warm by about 2 °C by the 2050s[2] (2041-2070) relative to a baseline period of 1961-1990 (Figure 3) assuming emissions that are a combination of business as usual and roughly half of that. Other projections for this same time period include:

- Decreased summer precipitation on average (range of change from +5% to -30%) possibly with slightly more of a decrease in the CRD than in Metro Vancouver.
- Increased winter precipitation (range of change from about -5% to over +15%).
- Warmer extreme temperatures; extreme warmth that would have been exceeded on average only once every ten years (about 32 °C to 35 °C) in the past is projected to occur once every two to six years.
- Increased precipitation on very wet days (increases of about 20% to 25% heavier for the indices[3] R95p and R99p).
- Heavier extreme precipitation events; thresholds for extreme precipitation that have been exceeded on average only once every 10 years in the past are projected to be exceeded about three times as often in Metro Vancouver and possibly slightly more often in the CRD.

2. See Murdock et al., 2015: *Georgia Basin, Projected Climate Change, Extremes and Historical Analysis*. PCIC, 63 pp.

3. The indices R95p and R99p represent the precipitation that falls on those days that are so wet that they are in the 95th percentile and 99th percentile of wettest days for a given year. For more information, see: http://etccdi.pacificclimate.org/list_27_indices.shtml.

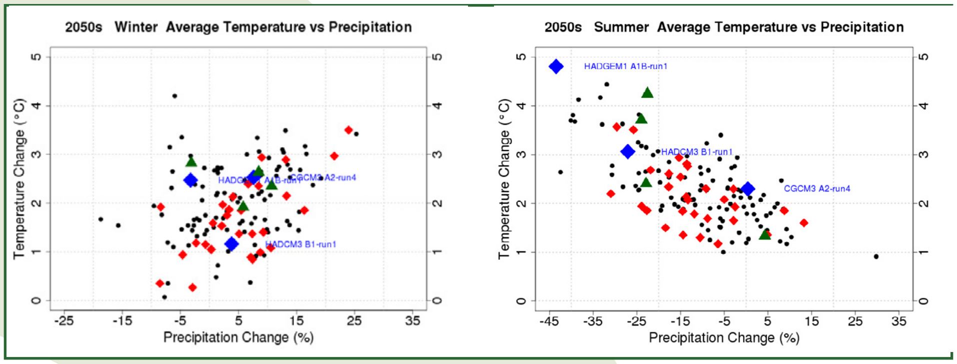


Figure 2: Comparison of different types of projections for the Lower Mainland and Vancouver Island.
This figure shows the range of different types of model output in terms of their projected changes in average temperature and precipitation for summers (June, July and August) and winters (December, January and February) in the 2050s (2040-2069), in the Lower Mainland and Southern Vancouver Island regions compared to the 1961-1990 period. The blue diamonds show the CMIP3 projections from global climate models that were used to make the high resolution maps in this report. These were chosen to span a large portion of the overall range of projected changes. The red diamonds indicate the ensemble used for PCIC's Plan2Adapt tool. The green triangles indicate the GCM output that was used to drive the regional climate models that were used for specific numbers quoted in this report. The black dots show the rest of the projections from GCMs and give a sense of the overall range of climate model projections.

ICLEI Canada, working with PCIC, summarized the concerns of local governments based on the projections provided by PCIC:

- Projected climate changes could impact physical systems by increasing the costs of maintenance, protection and replacement for infrastructure, such as bridges, buildings, dykes, culverts, roads and levees.
- Projected climate changes could impact social systems by affecting the health of individuals, causing incidences of environmental refugees, affecting the livelihoods of certain populations and increasing the need for up-to-date emergency response plans.
- Projected climate changes could impact economic systems, causing economic losses, affecting the production, price and demand for goods and services, increasing costs to public health and safety, change winter tourism as winter snow decreases and affect insurance costs.
- Projected climate changes could impact ecological systems and such impacts may include changes in species range, abundance and distribution, increases to habitat fragmentation and reductions in habitat diversity, changes to migration patterns, breeding and survival rates, and increases in insect infestation incidence.

PROJECTIONS OF FUTURE CLIMATE: METRO VANCOUVER REGION

Projected regional changes in temperature and precipitation

The overall picture of projected future climate change in the Metro Vancouver region is one of warming (Figure 4). This is evident during all seasons, and is accompanied by slight increases to annual, spring, fall and winter precipitation, but decreases to summer precipitation.

4. Most of these projections follow a combination of the A2 and B1 emissions scenarios, developed by the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES). For more information on emissions scenarios, see: http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains3.html.

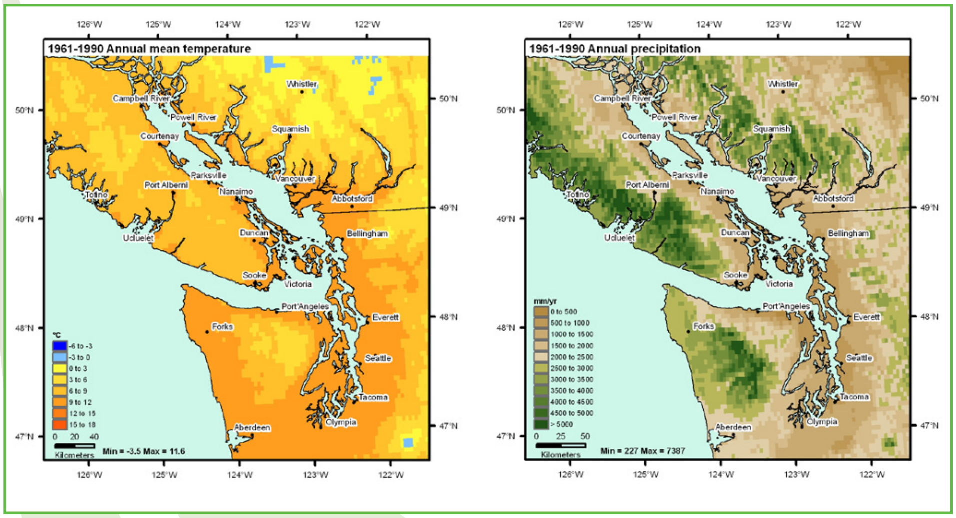


Figure 3: Georgia Basin annual temperature and precipitation, 1961-1990.
The high-resolution maps on the left show the 1961-1990 historical baseline climate for the Georgia Basin region, taken from the high-resolution PRISM data set.

An ensemble[4] of 30 projections from 15 GCMs running under two emissions scenarios used for PCIC's Plan2Adapt tool, shows a median annual warming in the Metro Vancouver region of +1.7 °C (with a range of +1.0 °C to +2.6 °C) by the 2050s. Seasonally, this translates to a warming of +2.1 °C (+1.4 °C to +2.8 °C) in the summer and +1.6°C (+0.8 °C to +2.7 °C) in the winter. By the 2080s, this warming increases to +2.7 °C (+1.5 °C to +4.2 °C) in the annual average, +3.2 °C (+2.0 °C to +5.0 °C) in the summer and +2.3 °C (+1.2 °C to +4.1 °C) in the winter.

These changes in the mean climate alter the frequency of extreme events. Days in the summer when the temperatures are warm enough (between 20 °C and 25 °C, depending on the area) that they would be above the 90th percentile for the 1971-2000 period occur twice as often in the 2050s. Extremely hot days (when the temperature reaches between 32 °C and 35 °C, depending on the area) that would only occur about once every ten years on average historically are projected to occur twice often.

The same ensemble finds an increase in annual precipitation of 7% (-2% to +11%) by the 2050s, with summer precipitation decreasing by 15% (-25% to +5%) and winter precipitation increasing by 6% (-5% to +16%). For the 2080s, annual precipitation is projected to increase by 8% (+1% to +18%), while summer precipitation is projected to decrease by 14% (-38% to -2%) and winter precipitation is projected to increase by 9% (+1% to +24%).

THE OVERALL PICTURE OF PROJECTED FUTURE CLIMATE CHANGE IN THE METRO VANCOUVER REGION IS ONE OF WARMING DURING ALL SEASONS

The changing climate will also alter the frequency of extreme precipitation events. By the 2050s, the amount of precipitation falling on days that are so wet that they are in the 95th and 99th percentile of wettest days increases by about 20% and 30% respectively when compared to the 1971-2000 period. Extreme rainfall events that are so intense they would only occur about once every ten years on average are expected to occur about three times as often.

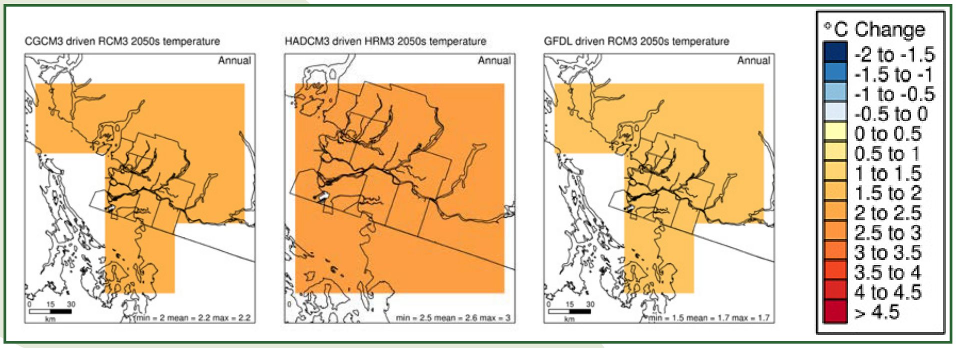


Figure 4: Regional climate model projections of annual temperature in the 2050s for the Metro Vancouver Regional District.
These panels show temperature projections from three of the eight RCMs used for the projections of climate extremes in this region.

High-resolution climate maps

While overall regional trends are useful, they lack the detailed spatial information that is often required for climate adaptation planning. To help with this, PCIC created high-resolution maps of future climate projections for seven variables: temperature, precipitation, precipitation as snow[5], growing degree days, heating degree days, cooling degree days, night-time low temperature, daytime high temperature and frost free period. To do this, the output from GCMs, which have a relatively coarse resolution (here about 200 kilometres), must be translated to a finer resolution. The maps were created using GCM output that is augmented by high-resolution historical climatologies from PRISM. This method accounts for some features down to the scale of roughly four kilometres, such as complex topography, that are of a much finer scale than GCMs can capture. However, fine-scale feedbacks, such as the interaction between temperature and snow cover (e.g. rising temperatures decrease reflective snow-cover, causing more warming as less solar radiation is reflected) are not included at this fine scale. All changes are compared to the average for the historical period of 1961-1990.

EXTREME RAINFALL EVENTS THAT ARE SO INTENSE THEY WOULD ONLY OCCUR ABOUT ONCE EVERY TEN YEARS ON AVERAGE ARE EXPECTED TO OCCUR ABOUT THREE TIMES AS OFTEN

Maps of projected changes for this region show two general features: (1) they are quite similar to each other in terms of the type of change that is seen in each area, and (2) while the projected changes for the 2050s yield a climate that is different from the 1961-1990 baseline period, by the 2080s the projected climate is almost unrecognizable.

The Metro Vancouver Regional District is projected to warm during all seasons, and the changes to variables of interest all reflect this. The amount of precipitation that falls as snow[5] is projected to decrease (Figure 5) by about 30% to 60% by the 2050s, and about 40% to 80% by the 2080s. Average summer daytime high temperatures are expected to increase (Figure 6) from 20 °C to between 23 °C and 26 °C by the 2050s and between 25 °C and 27 °C by the 2050s. Similarly, January nighttime

5. 'Precipitation as Snow' is a derived variable to estimate snow water equivalent, calculated from GCM projected total precipitation (rain and snow) as well as temperature. For more information, see:

Wang, T.L., Hamann, A., Spittlehouse, D.L. and Aitken, S.N., 2006: Development of scale-free climate data for Western Canada for use in resource management, *International Journal of Climatology*, **26**, 383-397.

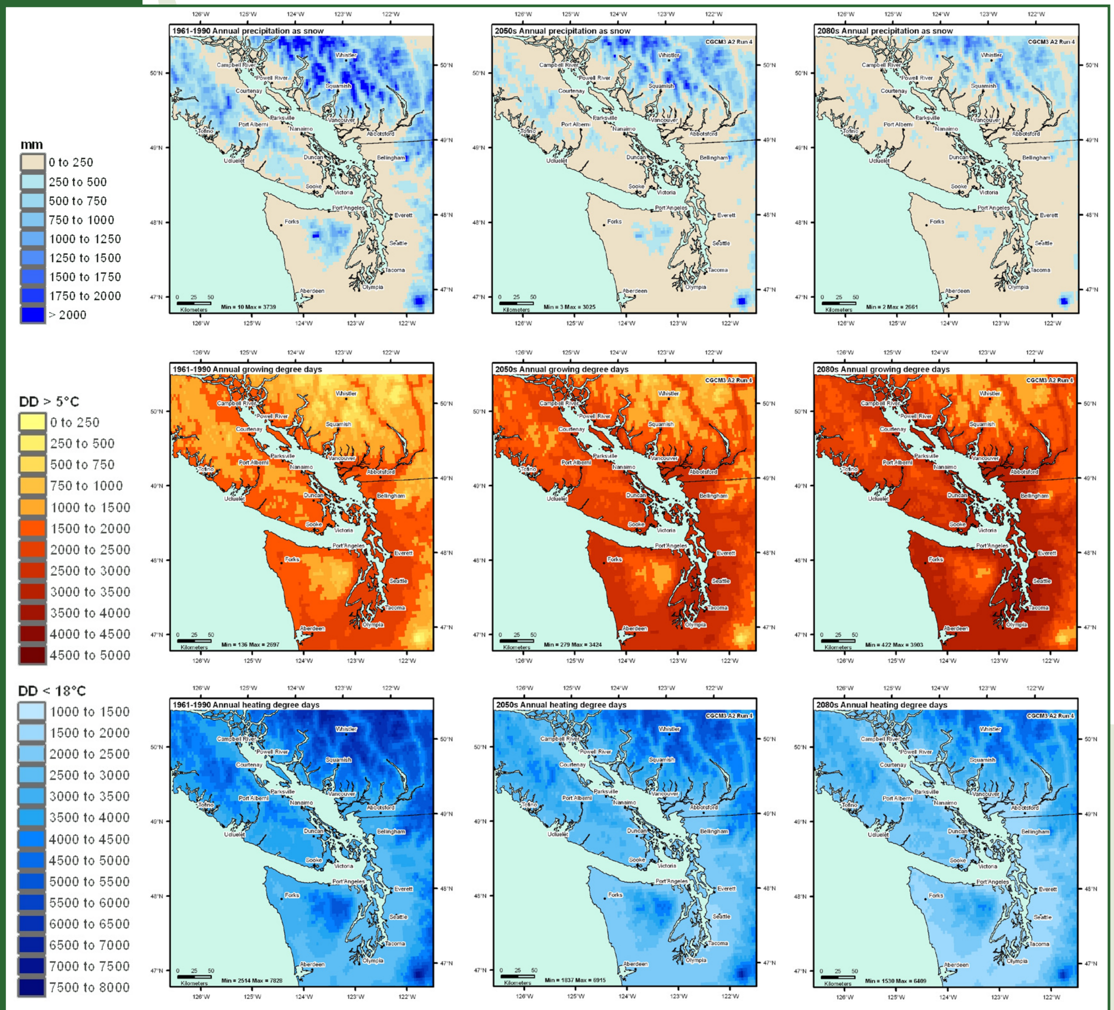


Figure 5: **Precipitation as snow, growing degree days and heating degree days for the baseline period, 2050s and 2080s.** These panels show (left to right) the 1961-1990 baseline and projections for the 2050s and 2080s for (top to bottom) annual precipitation as snow[5], annual growing degree days and annual heating degree days. Projections are for the CGCM3 GCM and follow the A2 emissions pathway

low temperatures are projected to increase (Figure 6), from -1 °C to up to 3 °C by the 2050s and up to 4 °C by the 2050s.

Heating degree days[6] and cooling degree days[7] are derived variables that can be useful for indicating energy demand (i.e. the need to heat homes, for heating degree days, or the need to use air conditioning for cooling degree days, etc.). As the climate warms in future projections, heating degree days decrease (Figure 5) from their baseline value of about 3500, with a reduction of about 15% to 30% by the 2050s and 20% to 40% by the 2080s. Cooling degree days increase (Figure 6) from their baseline value of 55 by about 200% to 600% by the 2050s and 300% to 1000% by the 2080s.

6. Heating degree days are 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.

7. Cooling degree days are similar to heating degree days, except that they are calculated based on the days that the average daily temperature is above 18 °C and the number of degrees above that threshold.

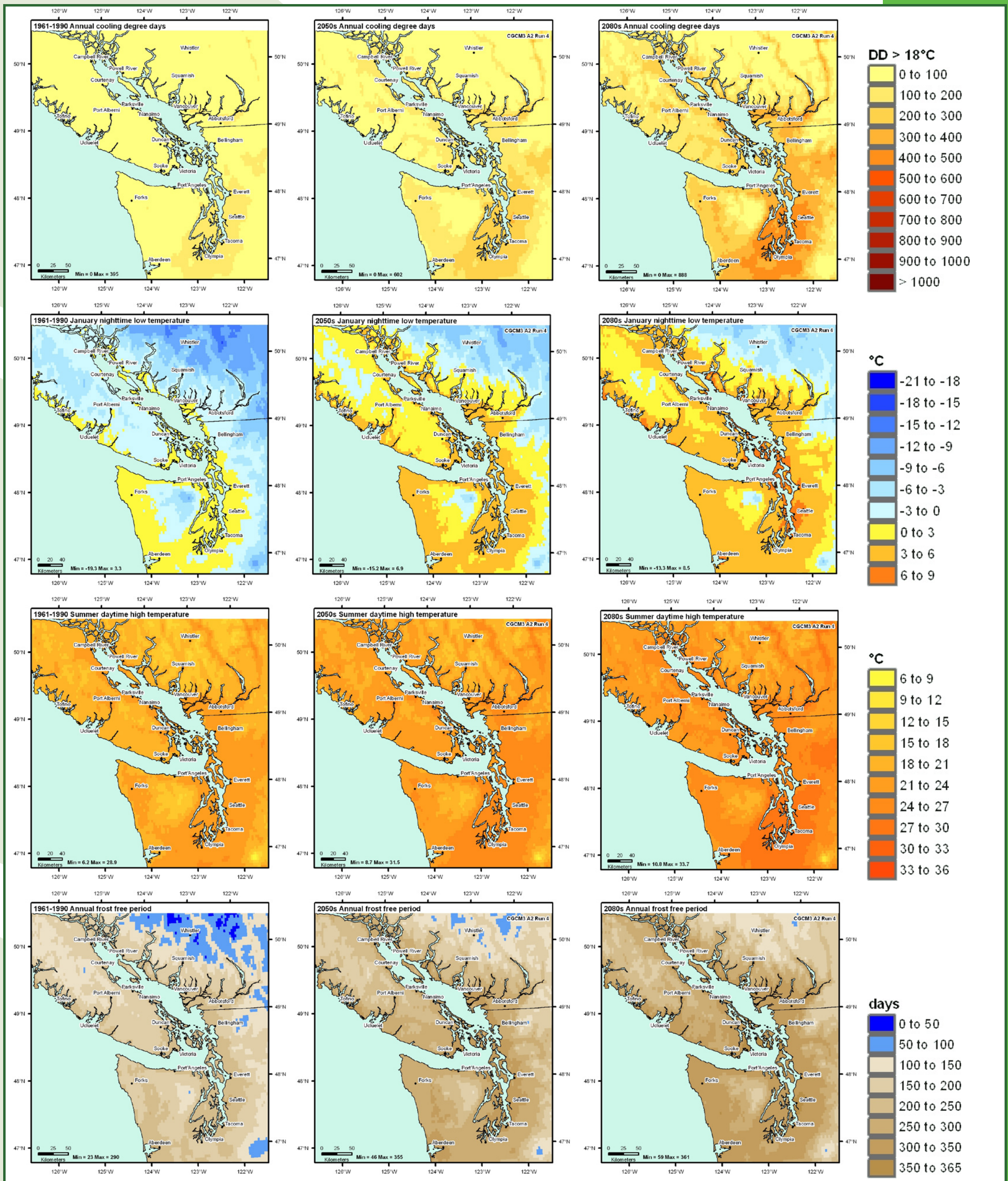


Figure 6: **Annual cooling degree days, January nighttime low, summer daytime high and annual frost free period for the baseline period, 2050s and 2080s.**

These panels show (left to right) the 1961-1990 baseline and projections for the 2050s and 2080s for (top to bottom) annual cooling degree days, January nighttime low temperatures, summer daytime high temperatures and annual frost-free period. Projections are for the CGCM3 GCM and follow the A2 emissions pathway

Turning to variables that are of use for agriculture, growing degree days are similar to heating and cooling degree days, in that they are an accumulation of degrees over 5 °C each day. They are projected to increase (Figure 5) from their baseline value of about 1700 growing degree days by about 30% and 70% by the 2050s, and 45% and 100% by the 2080s. Another variable of interest for agriculture is the frost-free period, which is the length of time between the last winter or spring frost and the first fall and winter frost. These are projected to increase (Figure 6) in length as temperatures rise, growing in length about 20% to 45% from their baseline of 200 days by the 2050s and 25% to 60% by the 2080s.

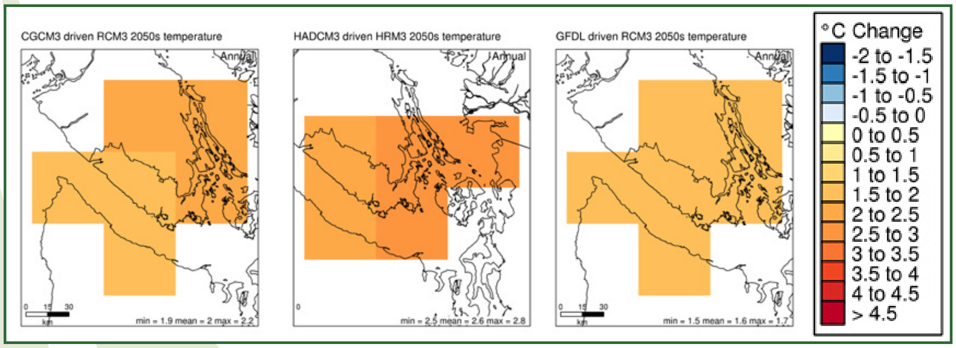


Figure 7: Regional climate model projections of annual temperature in the 2050s for the Capital Regional District. These panels show three of the eight RCM projections used for the projections of climate extremes in this region.

THE PROJECTIONS SHOW SUMMERS IN VANCOUVER TO BE AS WARM IN THE 2080S AS THEY ARE IN SAN DIEGO IN THE 1961-1990 BASELINE PERIOD

PROJECTIONS OF FUTURE CLIMATE: CAPITAL REGIONAL DISTRICT

Projected regional changes in temperature and precipitation

The projected changes in climate in the Capital Regional District mirror those of the Metro Vancouver Region, for both temperature (Figure 7) and precipitation (slight increases in spring, fall and winter, but decreases in summer).

Projections from the Plan2Adapt tool show a median annual warming in the Capital Regional District of +1.6 °C (with a range of +1.0 °C to +2.3 °C) by the 2050s. The summer warms by about +2.0 °C (+1.4 °C to +2.6 °C) and the winter warms by about +1.5 °C (+0.8 °C to +2.4 °C). This warming increases by the 2080s, to +2.5 °C (+1.4 °C to +3.9 °C) in the annual average, which translates to a summer warming of +3.0 °C (+1.8 °C to +4.6 °C) and a winter warming of +2.2 °C (+1.0 °C to +3.7 °C).

The frequency of extreme events also changes, with the Capital Regional District experiencing a greater increase in extreme temperature events. Summer days (between 20 °C to 25 °C, depending on the area) warm enough that they would have temperatures above the 90th percentile for the 1971-2000 period occur over two-and-a-half times as often in the 2050s. Those extremely hot summer days (when the temperature reaches between 32 °C to 35 °C, depending on the area) that would only occur about once in ten years on average are expected to occur about four times as often.

Annual precipitation is projected to increase by 6% (-2% to +12%) by the 2050s, with summer precipitation decreasing by 18% (-30% to +1%) and winter precipitation increasing by 5% (-5% to +17%). Annual precipitation is projected to increase by 8% (+1% to +18%) by the 2080s, with summer precipitation decreasing by 20% (-46% to -1%) and winter precipitation is increasing by 9% (-2% to +23%).

The pattern of changes in the frequency of extreme precipitation events in the Capital Regional District is very similar to that of Metro Vancouver. By the 2050s, the amount of precipitation falling on days that are so wet that they are in the 95th and 99th percentile of wettest days increases by 20% and 25% respectively when compared to the 1971-2000 period. Extreme rainfall events that are so intense they would only occur about once every ten years on average are expected to about 2.5 times as often.

High-resolution climate maps

As with the Metro Vancouver Regional District, the Capital Regional District is expected to warm during all seasons. As the region warms, projections show a reduction in the amount of precipitation that falls as snow[5] (Figure 5) by about 35% to 65% by the 2050s, and 40% to 80% by the 2080s from the ~150 mm per year in the baseline period. Similarly, average summer daytime high temperatures warm (Figure 6) from 20 °C in the baseline period, to between 22 °C and 24 °C by the 2050s and between 24 °C and 26 °C by the 2080s. January nighttime low temperatures also increase (Figure 6), from 0 °C to up to 3 °C by the 2050s and up to 5 °C by the 2050s.

Heating degree days decrease in the projections (Figure 5) from their baseline value of ~3400, by about 15% to 30% by the 2050s and 25% to 45% by the 2080s. Cooling degree days increase (Figure 6) from their baseline value of ~40 by about 200% to 650% by the 2050s and 500% and 1100% by the 2080s.

The same general story applies to growing degree days and frost-free days. Growing degree days are projected to increase (Figure 5) from their baseline value of ~1700 growing degree days by about 30% to 60% by the 2050s, and 45% to 100% by the 2080s. The annual frost-free period is projected to increase (Figure 6) in length by about 20% to 40% from its baseline of ~200 days by the 2050s and 25% to 55% by the 2080s.

EXTREME RAINFALL EVENTS THAT ARE SO INTENSE THEY WOULD ONLY OCCUR ABOUT ONCE EVERY TEN YEARS ON AVERAGE IN THE CAPITAL REGIONAL DISTRICT ARE EXPECTED TO OCCUR ABOUT TWO-AND-A-HALF TIMES AS OFTEN.

SUMMARY

Projected changes to the Georgia Basin

Climate model projections available from three different types of sources in 2012 show similar changes for the Metro Vancouver Regional District and the Capital Regional District. This is true for both the 2050s and the 2080s. The overall picture is one of warming during all seasons, dry summers with slight increases to precipitation during all other seasons and increases to the frequency of extreme precipitation events, with projected changes becoming more extreme as time goes on. The warming brings with it increases to the frequency of extreme heat events, which may increase heat stress, especially in urban centres, with implications for medical resources. The warming may also usher in a potentially large shift in energy demands, as more energy is required for cooling in the summer and less is required for heating in the winter. The projected warming may also increase the number of growing degree days and the annual frost-free period, potentially increasing the growing season. This may allow for new crops to be grown in the province, but could be accompanied by changes in pest outbreak patterns and water shortages. The warming also decreases the amount of precipitation falling as snow, which may decrease the number of days suitable for skiing and cause water shortages for communities that depend on snow pack for their water supplies.

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