CORPORATE REPORT
2020–2021

ATHABASCA
LILLOOET DISTRICT
YALE DISTRICT
KOOTENAY DISTRICT
WESTMINSTER DISTRICT
EDMONTON
CALGARY
RED DEER
LACOMBE
INNISFALL

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MESSAGE FROM PCIC'S CORPORATE LEADERSHIP

The 2020-2021 year has been a challenging year for everyone due to the uncertainty and disruptions of the COVID-19 pandemic. PCIC nevertheless continued to respond to a consistent and growing need for comprehensive and authoritative climate information to support adaptation planning and decision making in BC and nationally.

PCIC has continued to maintain highly collaborative, user-driven relationships with partners even as these relationships have moved online. Our work continues to benefit from long-term partnerships and collaborations that strengthen our capacity to address climate change and variability, and provide scientific information to support policy development and decision making.

The body of climate information and applied research that PCIC provides has continued to grow. In 2020-2021, through its relationships with partners, PCIC has developed new information and online tools that will support partners and decision makers. For example, PCIC collaborated with the National Research Council to provide updated design values for buildings and infrastructure, provided a new online tool the share weather files for energy modelling in BC, continued to grow the Pacific Climate Data Set and developed to capability to deliver station data to users from a network of observing stations in Canada's Western Arctic. New research on extreme precipitation led by PCIC researchers contributed to the broader scientific discourse on climate extremes. PCIC continued to expand the regions within BC that are modelled by our hydrological tools, providing this information through its Data Portal, developing new hydrological modelling capacity and continuing work to develop a tool for assessing the risks faced by salmon under future climate change in their freshwater habitat. Every project that PCIC is involved with builds further capacity for current and future partners.

All of this was achieved despite the difficult circumstances, and none of it would have been possible without the strong support of our partners and the hard work and commitment of our staff, for which we are sincerely grateful.

PCIC GOVERNANCE

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Francis Zwiers, Director, Pacific Climate Impacts Consortium

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Bottom row, left to right: Stephen Sobie, Qiaohong Sun, Travis Tai, Kari Tyler, Yaqiong Wang, Francis Zwiers

Not pictured: Nicolaas Annau, Charlotte Ballantyne, Samah Larabi, Sangwon Lim, Nigus D. Melaku, Nikola Rados, Cairo Sanders, Shayna Thompson, Kai Tsuruta, Kathy Veldhoen, Eric Yvorchuk, Lee Zeman

PARTNERS

BC Knowledge and Development Fund

BC Housing

BC Hydro

BC Ministry of Agriculture, Food and Fisheries

BC Ministry of Environment and Climate Change Strategy

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BC Ministry of Transportation and Infrastructure

Canada Foundation for Innovation

Canadian Statistical Sciences Institute

Centre de Recherche Informatique de Montréal

Compute Canada

École de technologie supérieure

Environment and Climate Change Canada, Canadian Centre for Climate Services

Environment and Climate Change Canada, Canadian Centre for Climate Modelling and Analysis

Environment and Climate Change Canada, Climate Research Division

Environment and Climate Change Canada, Meteorological Service of Canada

Fisheries and Oceans Canada, BC Salmon Restoration and Innovation Fund

Fisheries and Oceans Canada, Pacific Biological Station

Financial Accountability Office of Ontario

FPInnovations

Government of the Northwest Territories, Department of Environment and Natural Resources

GHD Group Pty Ltd.

Global Water Futures

Institut national de la recherche scientifique

National Research Council Canada

Natural Resources Canada

Natural Sciences and Engineering Research Council

Ouranos Inc.

Oregon State University, PRISM Climate Group

Pacific Institute for Climate Solutions

Prairie Climate Centre

Rio Tinto

University of British Columbia

University of Manitoba

Université du Québec à Montréal

University of Northern British Columbia

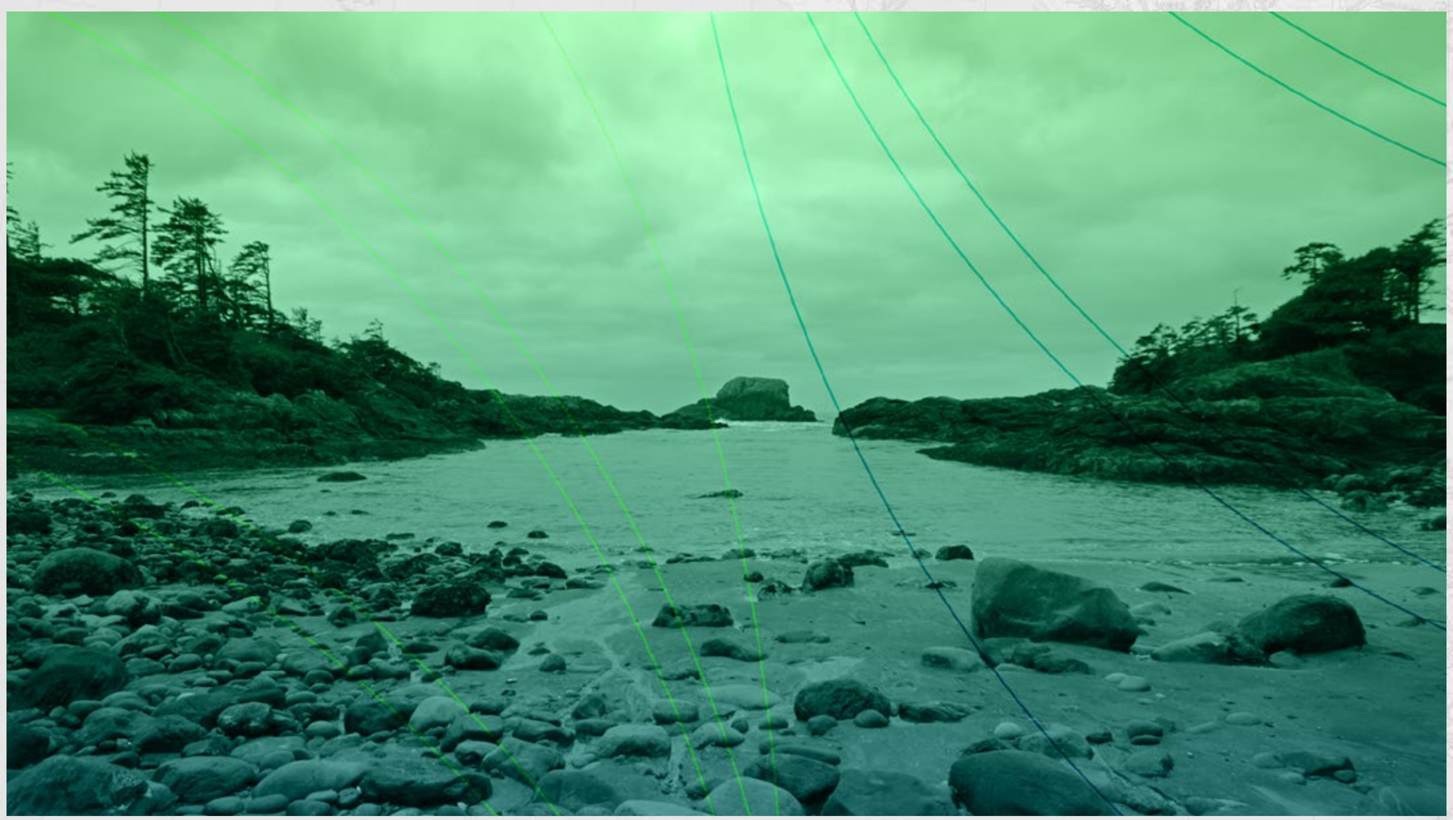
University of Saskatchewan

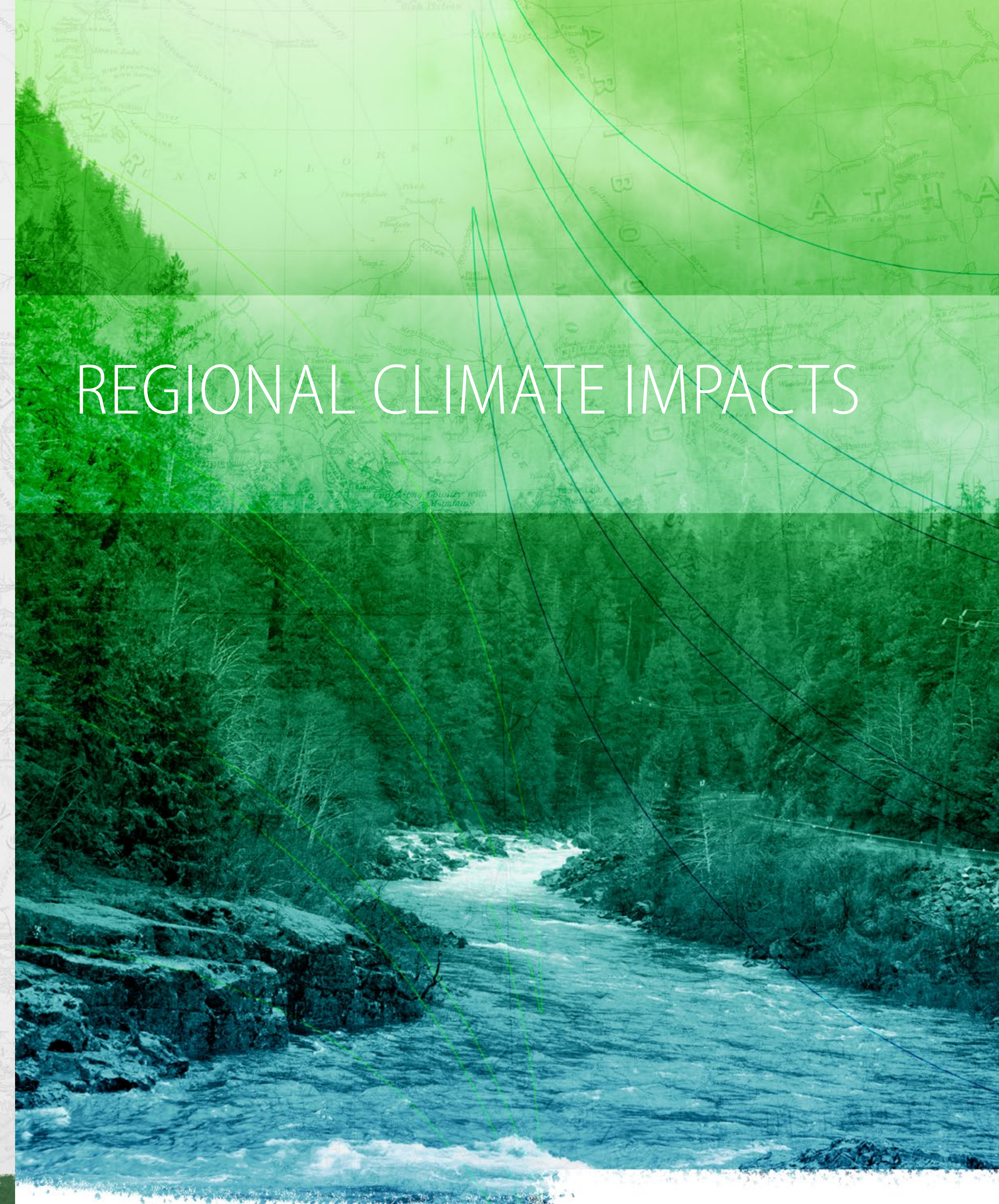
University of Toronto

University of Victoria

PCIC'S THEMES

PCIC's applied research program is organized around three interrelated themes: Regional Climate Impacts, Hydrologic Impacts, and Climate Analysis and Monitoring. The Regional Climate Impacts theme is concerned with determining the effects of global climate variability and change at the regional and community scales. The Hydrologic Impacts theme is concerned with estimating the effects of climate variability and change on water resources using hydrologic models. The Climate Analysis and Monitoring theme addresses the need for accurate historical and near real-time climate data. The work of these themes is supported and made available to PCIC's users by our Computational Support Group, who develop and maintain PCIC's analysis tools and Data Portal, develop software for scientific analysis, and maintain the computational capacity that enables PCIC's research.





REGIONAL CLIMATE IMPACTS

UPDATING CANADIAN CLIMATE DESIGN VALUES

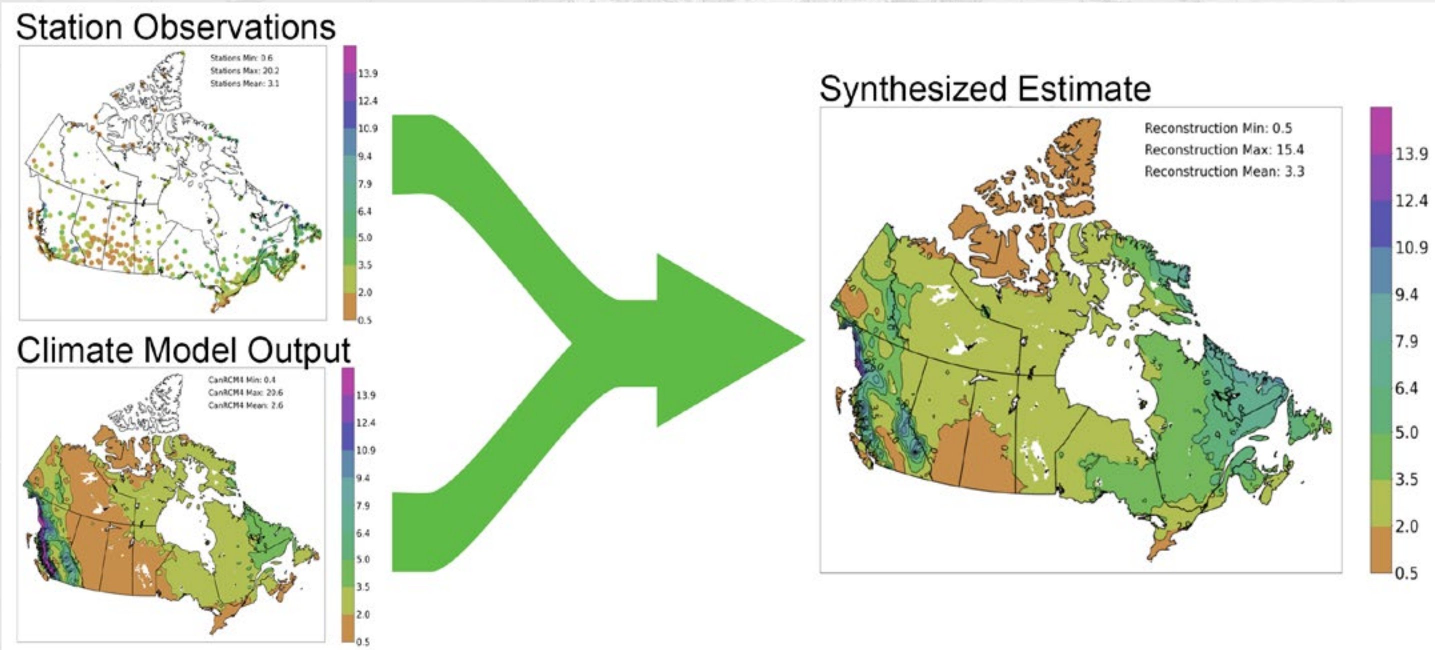


Figure 1: This figure illustrates the approach that PCIC used to produce design value estimates for every location in Canada. First, design values were estimated at individual observing stations using updated methods and carefully quality controlled observations extending as close to the present as possible. The upper left panel shows results that were obtained at stations for the 50-year snow-load design value. Secondly, corresponding design value estimates were obtained using climate model output for the 1986-2016 period (lower left). As a third step, station values (upper left) were spatially interpolated to all locations in Canada using a technique that guides the placement of contours using the results from the climate model (lower left) to produce the map of design values in the right-hand panel (labelled "synthesized estimate"). Values in kilopascals are as indicated by the colours in the legends. The 50-year snow load is the pressure exerted by the weight of the snow that has a one-in-fifty chance of being exceeded on any given year.

To account for environmental influences, building professionals and infrastructure engineers use a set of design values based on the historical climate in their planning and design work. Compiled in the National Building Code of Canada (NBCC), the last major update of these climatic parameters occurred in 2015, with the underlying data current to 2008. However, buildings and infrastructure being constructed today will be exposed to a future climate that may differ substantially from that of the recent historical period. With the support of Infrastructure Canada through the National Research Council of Canada, PCIC partnered with Environment and Climate Change Canada (ECCC) to update the majority of the climatic design values in the NBCC, develop a web portal to display these values in tabular and mapped format, and provide guidance to building and infrastructure engineers that accounts for the changing climate.

In the first phase of this work, PCIC's team created an extensive database of over two billion meteorological observations nationwide, sourced from both weather stations and manual snow surveys. The researchers quality-controlled the observations and conducted various types of analysis depending on the design variable of interest. In the second phase of the project, the researchers developed a novel spatial interpolation scheme based on both the observations and output from a 50-member large-ensemble of regional climate model simulations over Canada. This allows for design values to be made available anywhere across Canada, including the reference locations listed in the building code (Figure 1).

To provide on-demand access to these engineering design values, PCIC developed an online visualization tool, provisionally called the Design Value Explorer (Figure 2), that is currently undergoing beta-testing. The spatial interpolation scheme that PCIC researchers developed forms the backbone of this open-source software tool. The Design Value Explorer allows users to access the maps and tables of historical design values produced by PCIC, and also those published in the NBCC. In addition, the PCIC team incorporated future climate projections of the NBCC design values into the Design Value Explorer. It also provides projections of the impacts of future climate change on intensity-duration-frequency (IDF) curves for short-duration rainfall by incorporating a well-validated scaling relationship between rainfall and temperature into the Design Value Explorer.

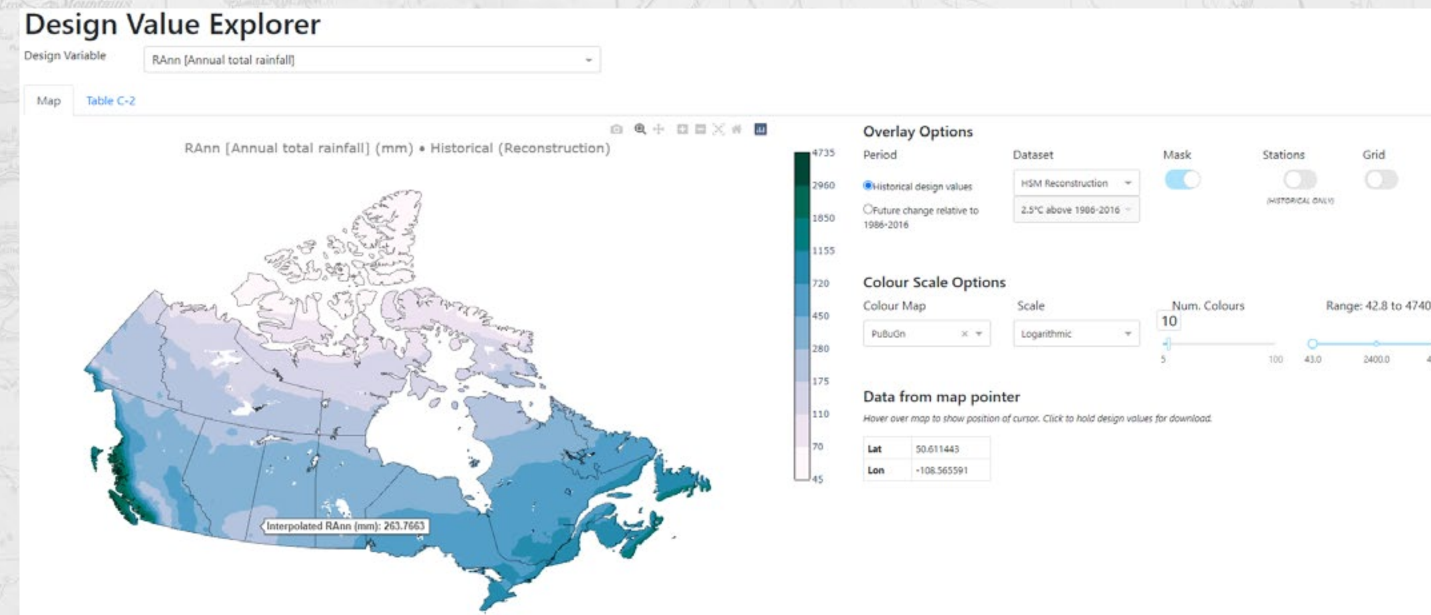


Figure 2: This figure shows the user interface of the current beta testing version of the Design Value Explorer.

PCIC scientists also played a role in the development of the ECCC report, *Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada*. This report provides projections of how climate change may affect engineering design values, for different levels of global warming and assesses the confidence that we can have in the science that supports these climate projections. In addition, it discusses observed changes in Canada's climate, considerations for the use of climate data, and future directions of climate change research that may lead to improved projections.

PROVIDING FUTURE-SHIFTED WEATHER FILES

One way in which PCIC supports building designers in accounting for climate change in their projects is by developing and providing future-shifted weather files that are used for building energy modelling. Buildings are long-lived structures and their energy requirements for heating and cooling are affected by climate change. Energy modellers and building designers recognize that historical weather files, based on past observations, may not be sufficient for the current climate, let alone the future climate. The future-shifted weather files that PCIC has developed, which are now available through PCIC's Data Portal, will allow engineers to include climate change in their planning.

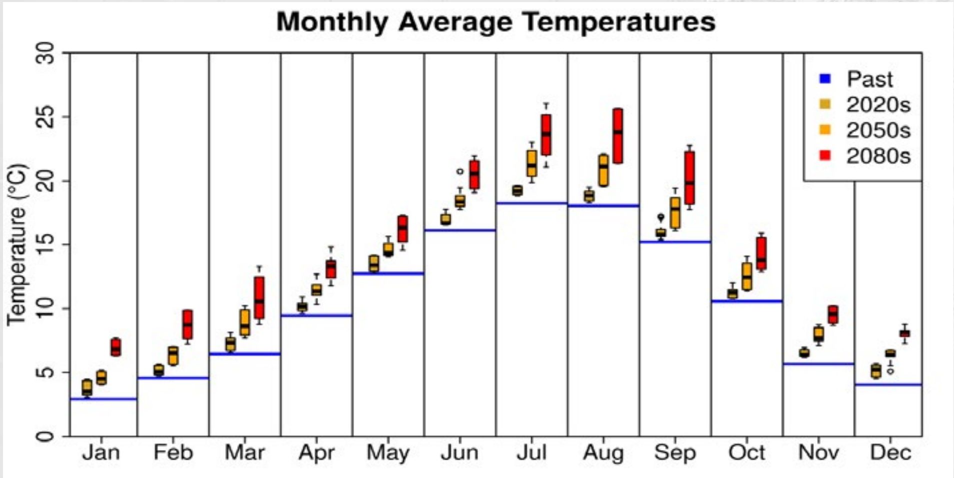


Figure 3: This figure shows the monthly average air temperatures at Abbottsford, BC, available in the summary files from the Future Shifted Weather Files Data Portal page. The horizontal lines show the 1998-2014 period mean values while the vertical boxes indicate the range of projected means for the 2020s, 2050s and 2080s obtained using global climate model output assuming a high-emissions scenario (RCP 8.5).

This project started as a collaboration between PCIC and researchers at the University of British Columbia. The objective was to test a method for creating weather files that are adjusted to be representative of future climate change. This method takes historical observations at a given site and adjusts them using projections from climate model output, while accounting for the characteristics of the weather at the downscaling site. The project continued with researchers from RDH Building Science and generated further interest, which led to presentations for BC Hydro, Engineers and Geoscientists BC, the Canadian Health Engineering Society, the BC Climate Action Secretariat and several other groups. The future-shifted weather files informed the development of the BC Housing Step Code Design Guide Supplement on Overheating and Air Quality. This also led to PCIC providing energy files for projects for BC Housing, Vancouver Coastal Health, Island Health and the construction of a new residence building at thhe University of Victoria (UVic).

PCIC has now released files for three future time periods via our Data Portal (Figure 3) to meet the expanding requirements for future-shifted weather files across BC. These are available on demand and can be accessed by city name, geographical coordinates or Canadian Weather Energy and Engineering Datasets (CWEEDS) location codes.

STRENGTHENING CANADIAN CLIMATE SERVICE DELIVERY

The Canadian federal government is working to implement the Pan-Canadian Framework on Clean Growth and Climate Change. This includes an effort by the Canadian Centre for Climate Services (CCCS) to bring together Canada's climate service providers, to train, support, build capacity and deliver climate services driven by user needs. PCIC is participating in this national collaboration via the CCCS's Climate Services Working Group (CSWG) Training sub-group and other collaborative activities. PCIC collaborated with the training leads from the network of climate service organizations to develop introductory training materials that address key concepts. Several batches of materials, both video and text, are complete and hosted on the Learning Zone of ClimateData.ca, with more under development.

With CCCS's support, PCIC has delivered engagement and training to stakeholders in BC, building regional capacity with a focus on mid-career professionals, particularly in building design and related engineering sectors. PCIC has given presentations to the Architectural Institute of BC, to buildings engineers at the New Horizons in Green Civil Engineering (NHICE) conference, and to engineers from the BC ministries of Transportation and Infrastructure, and Forestry, Lands, Natural Resource Operations and Rural Development, and others. PCIC also delivered training on their new future-shifted weather files in several webinars for buildings professionals.

PCIC's user engagement and training specialist delivered twenty-five presentations at online workshops and seminars over the past year. Three of those presentations occurred at Community Climate Preparedness workshops attended by the Métis Nation of BC, Coastal First Nations, Kitselas First Nation, Northern Shuswap First Nation , Tseshaht First Nation and K'ómoks First Nation . PCIC also continued to provide regional capacity building to engage public sector partners in understanding climate impacts to aid informed discussion about the development of BC's Climate Preparedness and Adaptation strategy.

PCIC continues to engage actively with our user base to coordinate and share lessons learned from our experience through the collaborative platforms and working groups with CCCS. PCIC staff participate in the Climate Services Support Desk working group, including responding to occasional inquiries forwarded from CCCS Support.

More information on the Pan-Canadian Framework on Clean Growth and Climate Change can be found at: https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html.

DOWNSCALING GLOBAL CLIMATE MODEL PROJECTIONS

PCIC has partnered with Environment and Climate Change Canada's (ECCC) Climate Research Division to develop a set of high-resolution downscaled climate change scenarios for all of Canada. The climate model output used was taken from the sixth phase of the Coupled Model Intercomparison Project (CMIP6), which was used in the most recent Working Group I Assessment process of the Intergovernmental Panel on Climate Change (IPCC).

The resulting downscaled data will be shared with other groups such as ClimateData.ca, and Canadian regional climate service providers, such as Ouranos and the Prairie Climate Centre, for use in their analyses. The project is being conducted in two stages. In the first stage, started during the 2020-2021 fiscal year, the same downscaling method and target data set as used previously by PCIC for the CMIP5 Global Climate Models (GCMs) is applied to the CMIP6 GCMs (Figure 4). In the second stage, a multivariate downscaling method that accounts for dependencies between climate variables will be applied, along with an improved target dataset. Upon completion, PCIC and ECCC will have multiple downscaled scenarios from the latest CMIP6 GCMs to share with users. PCIC will use these scenarios to inform its work and produce up-to-date analyses for distribution.

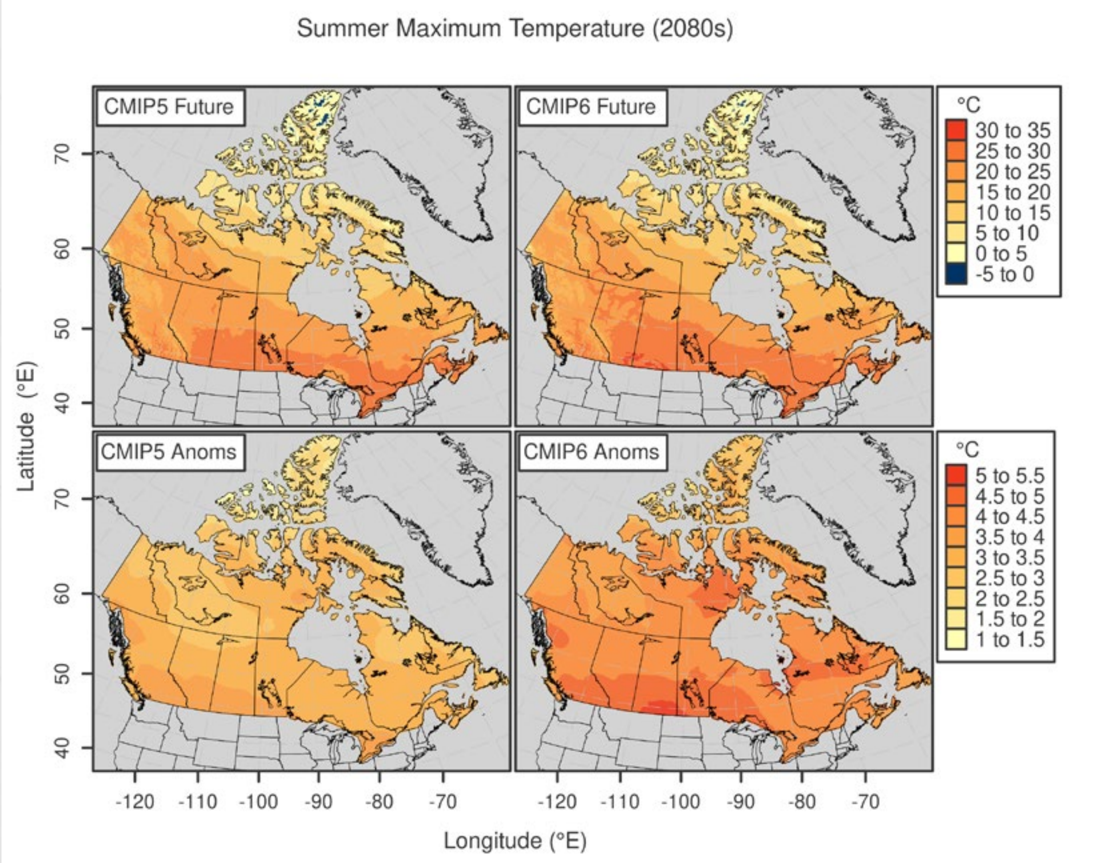


Figure 4: This figure shows ensemble median future values for summer maximum temperature in the 2080s (top row) and their changes relative to 1971-2000 (bottom row) values. Projections are made using the RCP 4.5 emissions scenarios for CMIP5 and the SSP2-4.5 emissions scenario for CMIP6. These are moderate emissions scenarios. Changes are as indicated in the legend.

MAKING TRAINING MATERIALS FOR DECISION MAKERS

The climate science community uses multiple emissions scenarios to drive the global climate models that provide projections of potential future climates. PCIC partnered with the Climate Action Secretariat (CAS) to develop two Primer documents for policymakers and planners that provide an overview of how to best understand and make use of the range of future climate scenarios.

The development of the Primers comes at a transitional point for the climate science community. With the release of the Intergovernmental Panel on Climate Change's Sixth Assessment Report, the climate science community is shifting to a new set of future emissions scenarios. At the same time, PCIC and other regional climate service providers are exploring a new framework that ties regional climate change and associated impacts to fixed changes in global average temperature, in parallel to the traditional approach of specifying fixed future time periods.

PCIC has also produced a guidance document for CAS that focuses on British Columbia specifically to support the use of future projections in planning. All of the Primers are being developed in a reader-friendly style for ease of use by a non-technical audience (Figure 5).

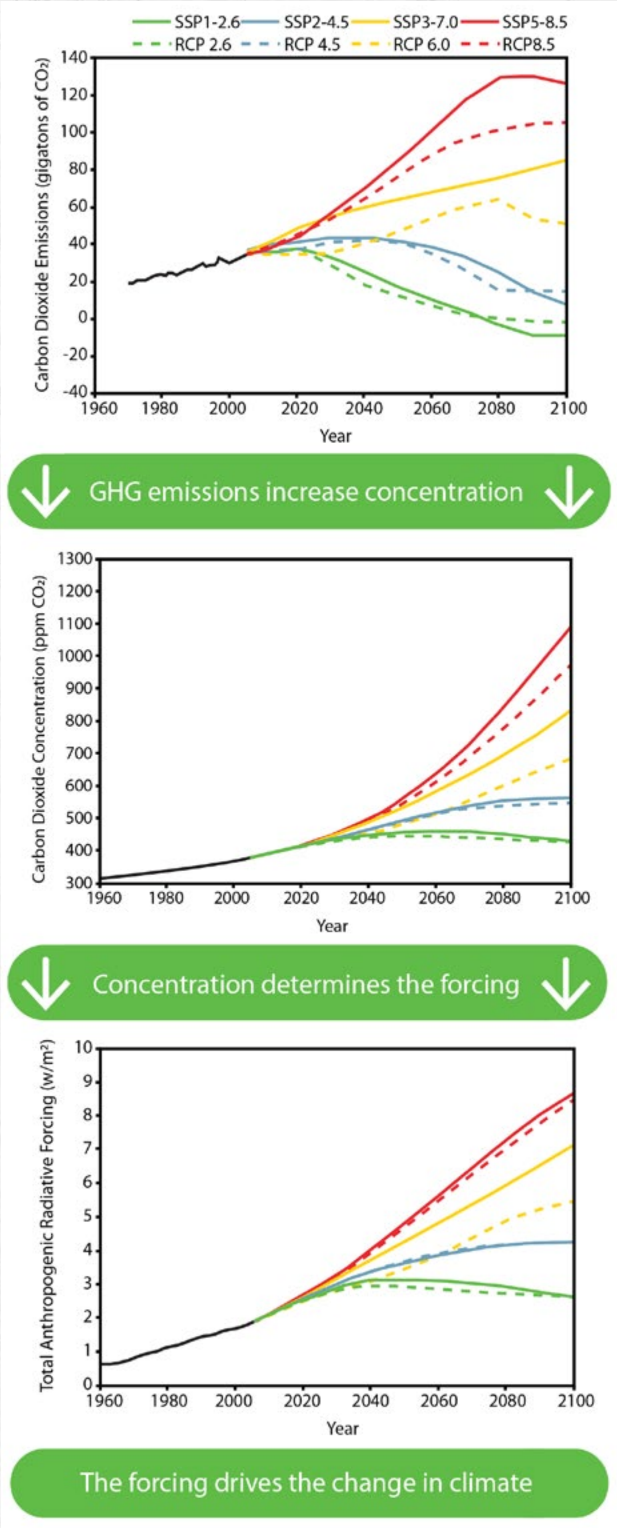


Figure 5. This figure shows one of the infographics being used in the first Primer. The figure guides the reader through the chain of causal factors leading to climate change: the emission of greenhouse gases such as carbon dioxide (CO_2) into the atmosphere (top) alters their atmospheric concentrations (centre), which results in a net radiative forcing (bottom). The magnitude of the radiative forcing, along with various feedback processes, determines how much the climate will change. This figure shows results for the Representative Concentration Pathways (RCPs, solid lines) of CMIP5 and the Shared Socioeconomic Pathways (SSPs, dashed lines) of CMIP6 and was developed after the work of O'Neill et al. (2016). Note that negative emissions are required to reduce greenhouse gas concentrations.

ANALYZING THE PROPERTIES OF EXTREME PRECIPITATION

Extreme precipitation can have many impacts, including severe economic damage due to flooding. Because of this, it is vital to know how anthropogenic climate change may affect the intensity, duration and frequency of extreme precipitation events. In order to better understand this, with the support of Global Water Futures (GWF), PCIC researchers have been studying how extreme precipitation varies with temperature, which is sometimes called temperature "scaling". This work, divided into multiple projects, helps PCIC in the development of user guidance concerning projected changes in extreme precipitation, and is of interest to the broader scientific community studying climate extremes.

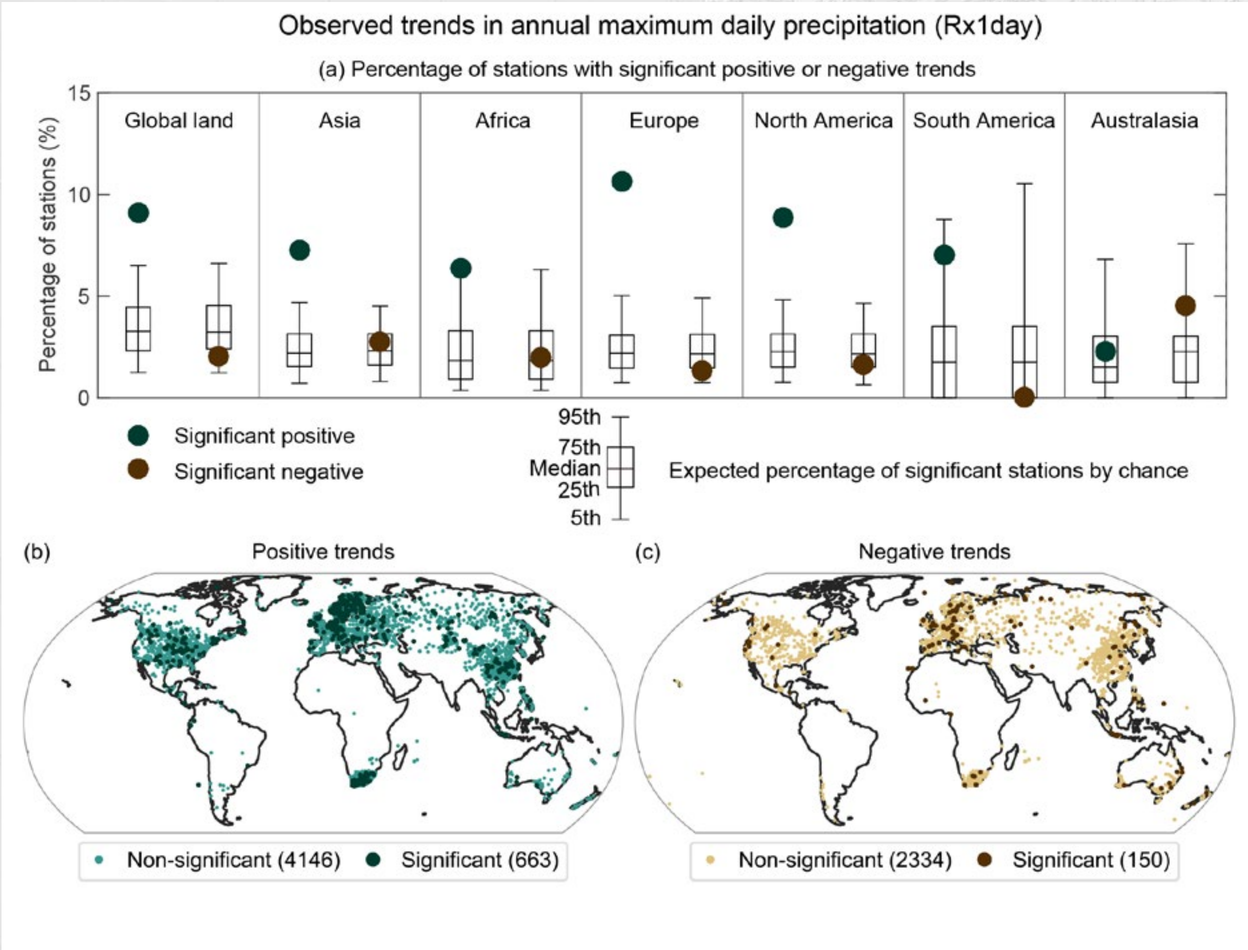


Figure 6: This figure, taken from Sun et al. (2021) and used as Figure 11.13 in Chapter 11 of the IPCC's sixth assessment report (AR6) shows the signs and significance of the observed trends in annual maximum daily precipitation (Rx1day) during 1950–2018 at 8345 stations with sufficient data. The top panel, (a), shows the percentage of stations with statistically significant trends in Rx1day. Green dots indicate positive trends and brown dots indicate negative trends. The box-and-whisker plots indicate the expected percentage of stations with significant trends due to chance. Note that globally, and for Asia, Europe and North America, the positive trends exceed those expected by chance. The boxes mark the medians, and the 25th and 75th percentiles. The upper and lower whiskers show the 97.5th and 2.5th percentiles, respectively. The lower panels show maps of stations with positive (b) and negative (c) trends. Light colours indicate stations with non-significant trends and dark colours indicate stations with significant trends. (Caption modified from AR6.)

In the first project, PCIC researchers led the study of the scaling relationship between temperature and precipitation extremes in high-quality station data up to 2018 and in a large ensemble of regional climate model simulations. In the observational data, they found that extreme precipitation has increased at about two-thirds of the stations they tested and that this signal of increased extreme precipitation intensity was clear at the global scale, as well as for several continents and smaller regions. They also estimated the rate at which observed extreme precipitation intensifies with observed warming. Using regional climate model output, they compared two methods for calculating this rate of intensification and their results suggest that one of the methods, which is frequently used, may not be a reliable indicator for future changes in precipitation with temperature. Some of this work was included in the IPCC's Sixth Assessment Report (Figure 6) and was also the focus of an article in UVic's KnowlEDGE, a public outreach publication of the university that highlights research being done at UVic.

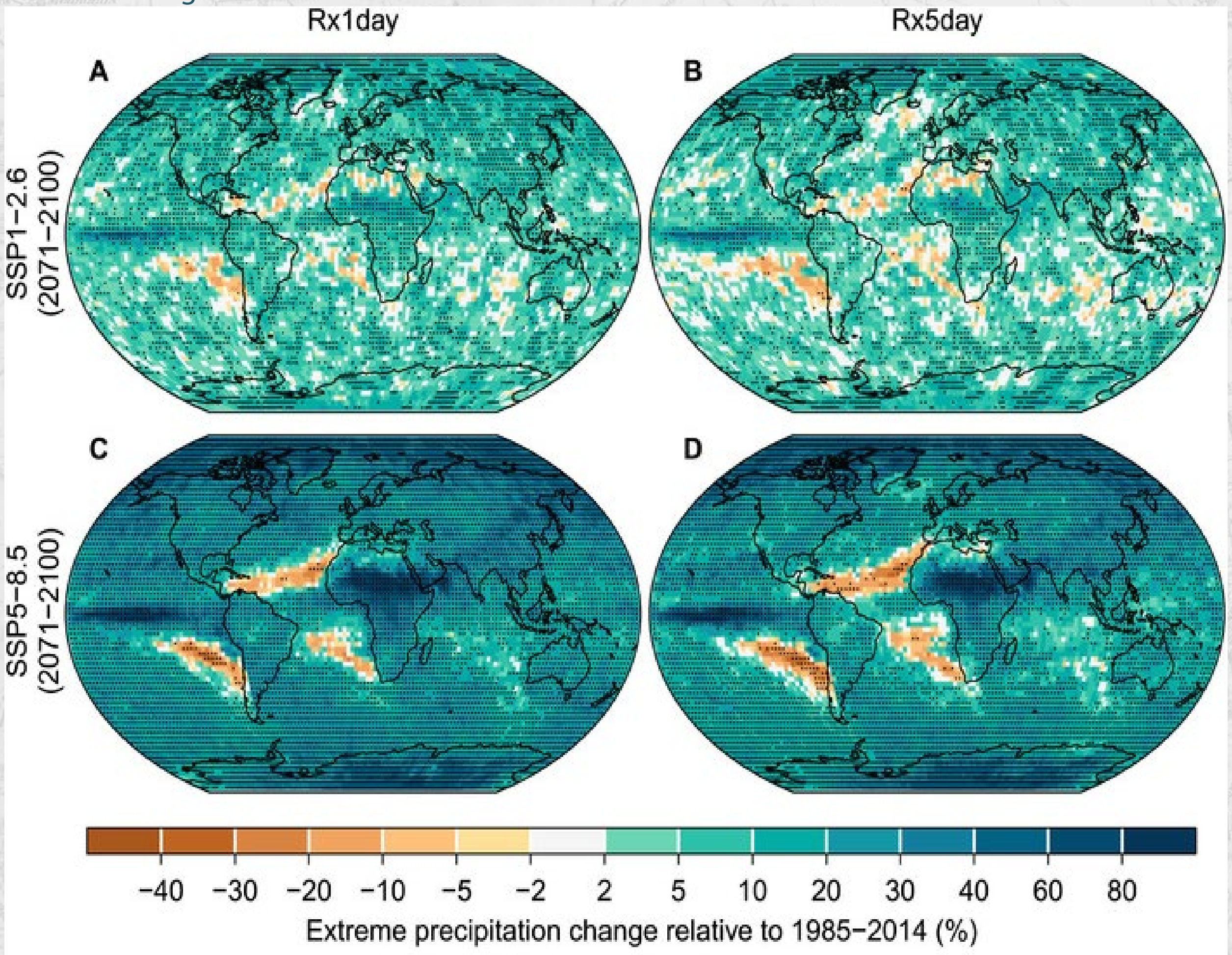


Figure 7: This figure shows the projected changes in annual maximum one- and five-day precipitation, Rx1day and Rx5day, expressed in percentages, taken from CMIP6 ensemble medians. The projections are for 2071–2100 under the SSP1–2.6 low-emissions scenario (A, B) and the SSP5–8.5 high-emissions scenario (C, D), relative to the 1985–2014 period. Stippling indicates regions where at least 80% of the available models or warming level windows agree on the sign of the corresponding ensemble median changes. (From Li et al. 2021.)

In the second project, PCIC researchers participated in work examining the relationship between warming and the intensification of extreme precipitation in climate model output from CMIP6. They found that the CMIP6 models were able to simulate the observed relationship over the historical period and that globally, the intensity and frequency of both temperature and precipitation extremes increased with the warming climate in future projections (Figure 7).

The third project examined whether precipitation extremes with long return-periods can be well-estimated using standard approaches based on extreme value theory. In this work, the researchers found that one of the assumptions required to apply the theory may not hold, which could lead to bias in the results. In a subsequent study, the use of a different extreme value analysis approach that is based on an extension of the theory and starts by decomposing precipitation into physically distinct components was found to reduce the uncertainty and biases in making these estimates, even when there is only a modest amount of data available to work with.

PCIC researchers also examined another type of scaling, called simple scaling, which refers to the relationship between extreme precipitation extremes with long return periods and different durations, such as the relationship between extreme one-hour events and extreme one-day events. The motivation for this was to test the potential for this sort of scaling for the improvement of intensity, duration and frequency estimates which are used by engineers in the design of infrastructure, such as roads, buildings and bridges. The results of this testing showed that simple scaling would not be effective in improving such estimates.

In looking at the distribution of the extremes of precipitation there are events with an exceptionally large amount of precipitation and events characterized by extreme periods of dryness and drought. To explore this latter facet of extremes in the hydrologic cycle, researchers have been developing and applying statistical approaches over the last fiscal year to study the potential impacts of changes in drought-related extremes. This has been possible with support from GWF, the Canadian Statistical Sciences Institute (CANSSI), and PCIC.

FURTHER UPDATES TO CLIMATEDATA.CA

There is a widespread need for credible, detailed climate information that policy and decision makers can use to inform their planning. To address this, PCIC has joined in a collaboration with Canada's other regional climate service providers, the Canadian Centre for Climate Services and the Computer Research Institute of Montréal (CRIM) to contribute to a national climate information portal for all of Canada, ClimateData.ca. The portal allows users to access, visualize and analyse a wide variety of temperature and precipitation-based climate projections at both local and national scales. All partners participate in multiple working groups, overseeing the projects, data, sector-specific modules and outreach for ClimateData.ca. PCIC is involved in many elements of the development of the portal, from the data that supports it to the written text on the site.

PCIC coordinates the content for the transportation and buildings modules of ClimateData.ca, with staff members chairing the corresponding working groups. Both of these working groups were informed by user needs as assessed by a survey, to gather information for the development of the site and related training materials. The working groups also developed case studies to illustrate how climate information was used to inform planning in specific contexts to help users incorporate climate information into their planning. These two modules will soon be available on ClimateData.ca.

WEBINARS FOR STREAM-CROSSING DESIGNERS

In partnership with FPInnovations, PCIC has participated in a series of webinars for engineers who design stream crossings, such as culverts that channel water under roads. These webinars were part of a series to help the forest industry and the Ministry of Forests, Lands, Natural Resource Operations and Rural Development with adaptation planning for forest service roads. The PCIC Climate Explorer tool, introduced in one webinar, can help decision makers and infrastructure managers in many sectors to increase the climate resilience of their designed structures in the face of climate change impacts. In addition, a second webinar introduced the Gridded and Station Hydrologic Model Output pages on PCIC's Data Portal, which provide hydrologic data to aid in decision making.

ANALYZING PROJECTED CHANGES TO BC LANDSLIDES

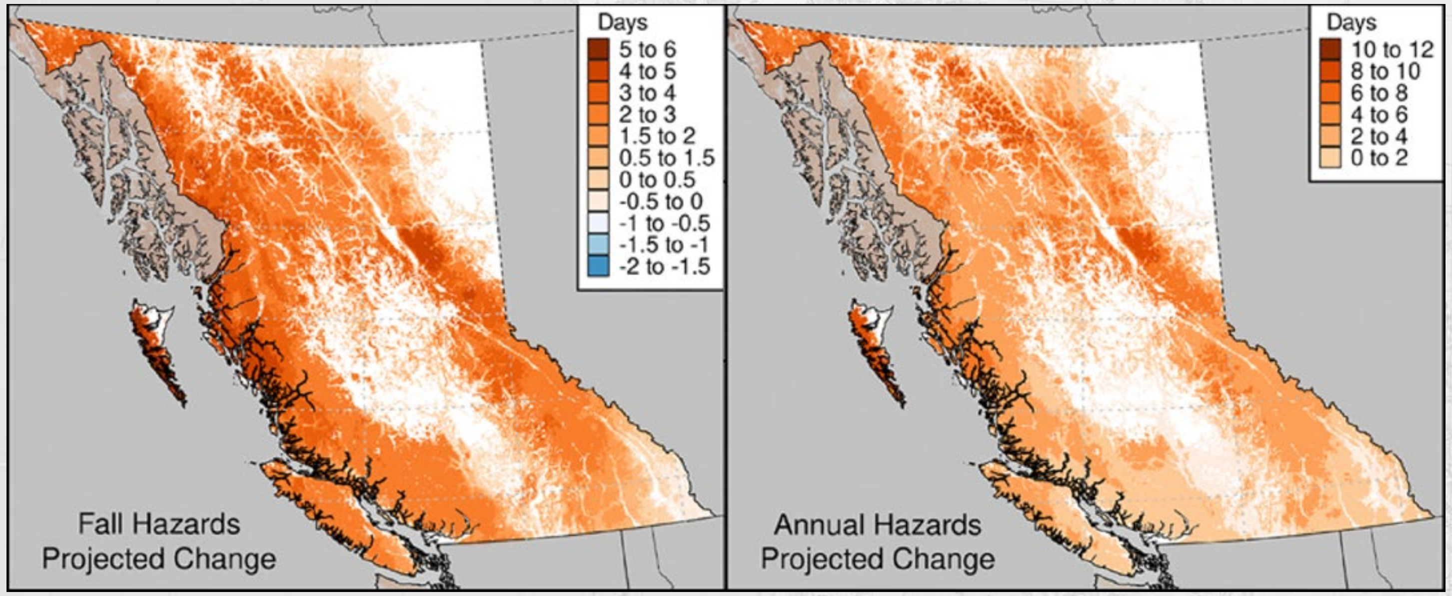


Figure 8: This figure shows the projected change in the average number of days with moderate and high landslide hazards for British Columbia during the fall (left) and annually (right), for the 2041–2070 period as compared to the 1951–2012 period. The results are from an ensemble average of downscaled CMIP5 climate model projections that were driven using the RCP 8.5 emissions scenario.

Landslides are a significant hazard in British Columbia, which experiences more landslides than any other Canadian province, causing 75-200 million dollars in damage, annually. PCIC studied how climate change may affect landslides in BC using a landslide hazard model, along with landslide observations, precipitation data and GCM output. This research showed that the hazard model performed well at classifying observed landslide dates and locations when driven by gridded observational data in BC. Future projections under a high-emissions scenario suggest that landslide hazards may increase (Figure 8) from about 16 days per year in the past (1951-2012) to 21 days per year by the 2050s, a growth of about 32%. The projected increase is greater in those regions that already see the most landslides, such as the west coast and the northern Rocky Mountains, where hazardous days are projected to increase by 50% to 60%.

EXAMINING STATISTICAL DOWNSCALING PROCEDURES

While climate change is a global phenomenon, the impacts are felt regionally and PCIC’s users need information about how the areas they live in may be affected. The coarse resolution of the global climate models used to make climate projections means that their output must be “downscaled” to finer resolutions to determine what the resulting regional effects and impacts will be. In Canada, one of the primary sources of downscaled climate information comes from a statistical method developed at PCIC, the second version of the Bias Correction with Constructed Analogues and Quantile mapping reordering (BCCAQv2) method. PCIC researchers recently tested the ability of BCCAQv2 to represent future precipitation extremes and also have substantially improved its computational efficiency.

As with any statistical downscaling method, BCCAQv2 creates “transfer” functions that capture the empirical relationship between large-scale variables from climate models and fine-scale surface variables, such as temperature and rainfall. One of the key questions is, will the relationships represented by the transfer function that were found to hold for the historical climate still hold in a warmer future climate?

To address this question, PCIC researchers used projections of 21st century climate from a regional climate model and two sets of output from a very high resolution weather forecast model. They first tested the transfer function on simulations of extreme precipitation over the historical period to measure the bias that arises when the function is used on model output that it is not calibrated on and found that, overall, only a very small amount of bias was introduced in this way. Larger biases arose when the trained downscaling scheme was applied to projections of extreme precipitation at the end of the century, raising some possible concerns about the performance of the transfer function under a changing climate. Work continues to understand the origins of these biases and to determine whether they are of concern.

PCIC also evaluated BCCAQv2 and implemented changes to the code that runs the downscaling method that has improved its computational efficiency. PCIC’s programmers and computer scientists found ways to improve one of the four main processes used in BCCAQv2, speeding it up by about 30%. This process represents about one-third of the computational cost of running BCCAQv2, and thus this efficiency gain produced a 10% reduction in the overall time required to run BCCAQv2.

SUPPORTING PROVINCIAL AND MUNICIPAL GOVERNMENT DECISION MAKING

In order to support the use of climate information in decision making, PCIC has, on occasion, been contracted as an independent reviewer for the work of private sector consultants and others who provide climate-related advice. PCIC has performed this service twice over the last fiscal year. This provides an opportunity for PCIC to share our research expertise and to improve the quality of climate services being offered, while also staying connected to the landscape of consultants and climate service providers as we work together to meet the needs of decision makers.

SUPPORTING METRO VANCOUVER DECISION MAKERS

As part of ongoing efforts to share information to support planning, PCIC worked with the Climate Action Secretariat to analyze two types of downscaled data being used by XDI, a consulting firm that offers, as one of their services, support for community risk analysis and municipal planning. Their platform provides an estimate of the economic costs of climate impacts. PCIC compared results from the dynamical downscaling of output from a global climate model, which is performed using a regional climate model, with those from statistical downscaling, so that these can be used for comparison with the results from XDI for a broader understanding of potential impacts. PCIC researchers found that the higher spatial resolution of the statistically downscaled climate output allowed for a more detailed representation of the landscape and that future trends in threshold-based indices such as freeze-thaw days are most sensitive to spatial resolution.

SUPPORTING THE CANADIAN FORESTRY SECTOR

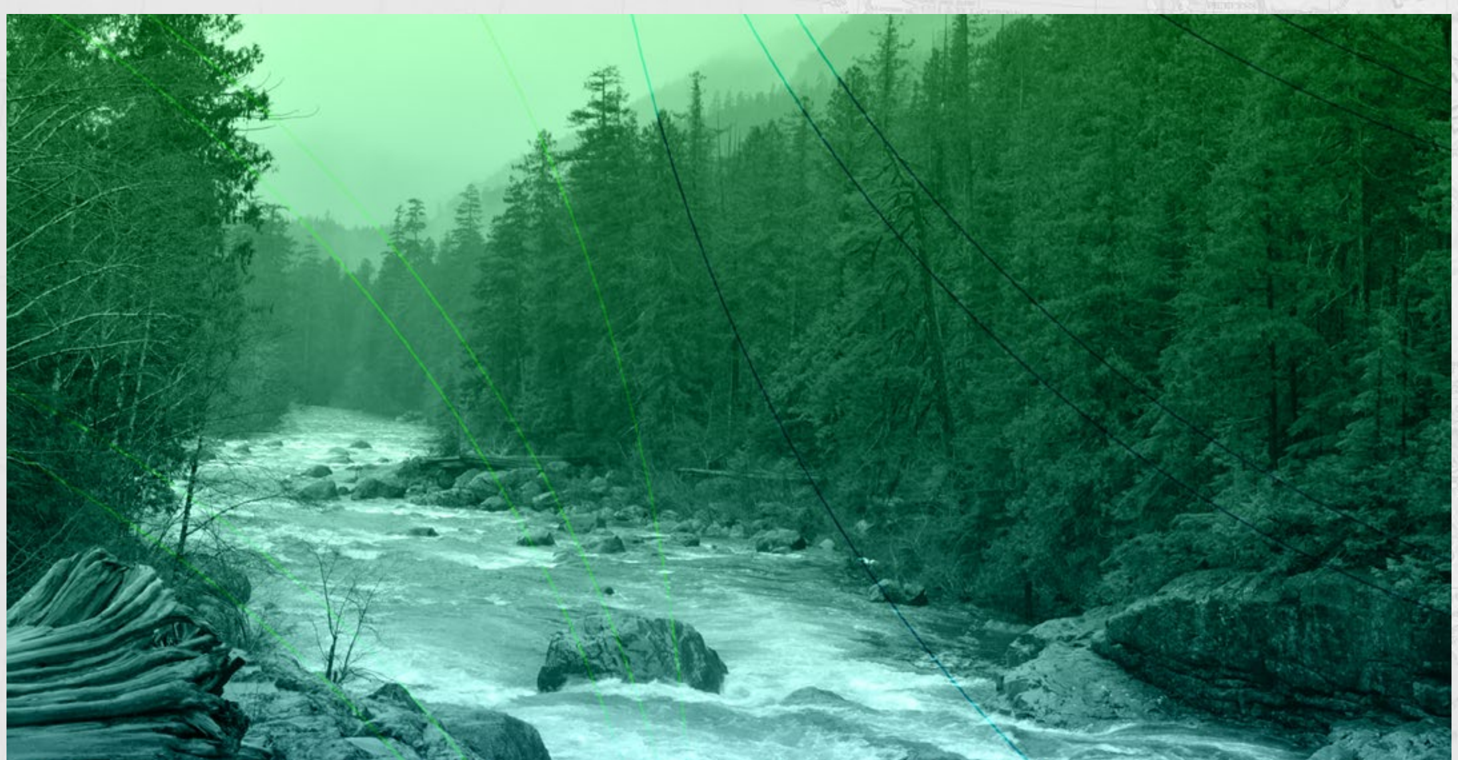
Anthropogenic climate change may affect the Canadian forestry sector by changing fire activity and by altering the distribution of pests, disturbance patterns and tree species. It may also affect tree growth and mortality rates. To support planning in the Canadian forestry sector, PCIC partnered with FPInnovations to provide a set of temperature and precipitation extreme-based indices across Canada, and also indices describing dry and freezing weather for BC's resource regions. This work was subsequently used by FPInnovations to support regional vulnerability assessments.

HYDROLOGIC IMPACTS

PARTNER FOCUS: BC HYDRO

The relationship between PCIC and BC Hydro, which is now in its 16th year, continues to enable a substantial volume of work, resulting in a greater understanding of the climate and hydrology of the province at ever more detailed scales, actionable climate information that can support planning, and tools to make this information widely available. We describe below how BC Hydro's support has enabled the development of the hydrologic model projections that form the core of multiple projects at PCIC and the development of the Raven hydrological modelling framework for application by our team. In addition, BC Hydro's support also contributes to updates to the Provincial Climate Data Set that are discussed in the Climate Analysis and Monitoring theme's section and the development of the PCIC Climate Explorer as discussed in the Regional Climate Impacts theme's and Computational Support Group's sections of this report.

In addition, BC Hydro's support was key to a project undertaken by PCIC examining the relationship between surface wind speeds and power outages in BC. High winds, primarily during the winter and spring, are the main cause of tree- and weather-related power outages in BC. The detailed power outage data covering the period 2005-2017 that were provided by BC Hydro clearly show the relationship between outage frequency and wind speed, with outages occurring much more frequently when wind speeds exceed 50 kilometres per hour. The analysis suggests that there may be a link between large-scale atmospheric circulation over the North Pacific ocean and outage frequency, and that this connection may provide some useful information for predicting sub-seasonal to seasonal variations in power outage frequency. This work was also supported by the Marine Environmental Observation, Prediction and Response Network and the Canadian Sea Ice and Snow Evolution Network.



EXPANDING THE HYDROLOGIC PROJECTIONS OFFERED BY PCIC

Given the vital importance of water resources, it is important to know how the hydrology of the province will be affected by climate change. Over the 2020-2021 fiscal year, with support from BC Hydro, and the BC Ministries of Environment and Climate Change Strategy (ENV), and Forestry, Lands, Natural Resource Operations and Rural Development (FLNRORD), PCIC's Hydrologic Impacts theme completed hydrologic projections for the Peace, Fraser and Columbia River basins, a region that encompasses roughly two-thirds of the province. These hydrologic projections form the foundation of multiple projects at PCIC. They provide data and information to inform planning so that decision makers in the province can plan for changes in timing, volume, and temperature of surface water in British Columbia, including changes in extremes such as floods and droughts. For example, hydrologic projections for the Columbia River basin were used to provide BC Hydro with projections for the amount of water flowing through 62 hydropower and regulation sites in the portion of the Columbia River Basin in the United States.

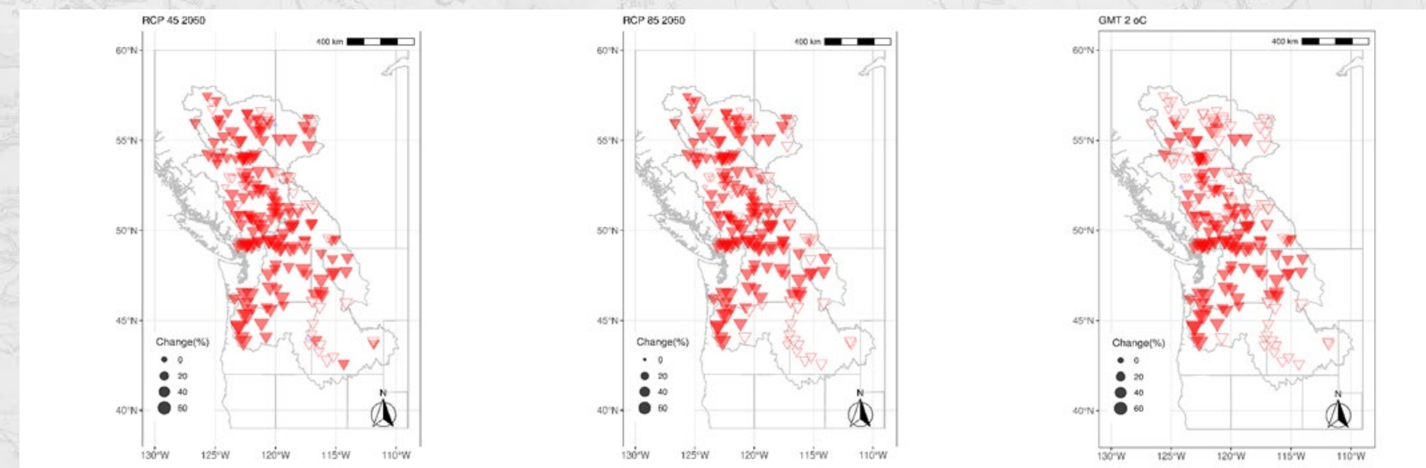


Figure 9: This figure shows the change in summer (June, July and August) streamflow in the 2050s (2041-2070) versus a historical baseline period (1971-2000) for six global climate models (GCMs) run under the Representative Concentration Pathway (RCP) 4.5 (a) and RCP 8.5 (b) emissions scenarios, and for the same six GCMs run under two RCPs (making 12 ensemble members) at 2°C global mean temperature above the pre-industrial (1861-1880) period (c) for 187 hydrometric sites that were used to calibrate (158 sites) and evaluate (29 sites) the VIC-GL model in the Peace, Fraser and Columbia River basins. The direction of change of the ensemble median is denoted with red, downward-pointing triangles indicating decreases and blue, upward-pointing triangles indicating increases. Filled triangles indicate locations where all ensemble members agree in the direction of change. The size of the triangles corresponds to the magnitude of the change.

PCIC also developed a report on future changes in streamflow for the Chilliwack and Seymour Rivers, three sub-basins of the Fraser River, and Cayoosh Creek. These areas were selected to represent different regions and streamflow regimes of the province. In addition to results from the physical modelling, the dialogue between PCIC, ENV and FLNRORD during the writing of the report was instrumental in gaining mutual understanding, helping PCIC researchers to understand what sorts of further modelling would be of most use for water planners, and drafting a document that is useful for a wider audience.

PCIC researchers continue their work to turn raw hydrologic projections into actionable information that can inform decision making. One part of this is improving model performance and analysing output, such as performing further model validation and evaluating changes to summer streamflow conditions across the modelling region, to look for patterns of change and agreement between the climate models used to drive the hydrologic models (see Figure 9). Another part of this is looking at how to present projected changes. For instance, results presented by different emissions scenarios are contrasted (Figure 9) with those organized by global mean temperature (GMT) change, such as a level that is 2°C above preindustrial (1861-1880) levels. These projections show decreasing summer streamflow and little difference in the magnitude of the change between the different emissions scenarios by 2050. Substantial differences between emissions scenarios become apparent by the end of the 21st century, both in terms of the level of warming that results and in the impact on streamflow.

These projections are also the basis for some of the work discussed elsewhere in this section: the prototype risk assessment methodology (see Supporting the Management of BC Salmon Habitats) and the work on assessing changing flood risk (see Assessing Changing Flood Risk), which draws on a large ensemble of runs from the second generation Canadian Earth System Model (CanESM2-LE).

NEW ADDITIONS TO THE DATA PORTAL AND PCIC CLIMATE EXPLORER

PCIC has released its latest hydrologic modelling results through the PCIC Data Portal. These results were obtained using VIC-GL, which is an upgraded version of the Variable Infiltration Capacity (VIC) model that was coupled to a glacier dynamics model. The model output available includes a historical run that was driven by PCIC's gridded meteorological data for northwest North America (PNWNAmet), which covers the 1945 to 2012 period. In addition, twelve hydrologic scenarios run under two Representative Concentration Pathways (RCPs), 4.5 and 8.5, are available for the 1945 to 2099 period. The model output, which is available for the Peace, Fraser and entire Columbia (US and Canada) river basins, is presented in two ways. There are 120 routing sites with results for each site on the Station Hydrologic Model Output Data Portal page. Gridded data are also available for several variables, including Snow Water Equivalent, Evaporation and Glacier Mass Balance, all of which can be selected both spatially and by time period on the Gridded Hydrologic Model Output Data Portal page.

SUPPORTING BC SALMON HABITAT MANAGEMENT

Pacific salmon hold a position of key importance in BC's marine and freshwater ecosystems. Anthropogenic climate change will affect both freshwater and marine habitats, impacting the different stages of the salmon life cycle. In partnership with researchers from Fisheries and Oceans Canada (DFO) and with the support of the British Columbia Salmon Restoration and Innovation Fund (BCSRIF), PCIC is developing risk assessment tools that will support the regional management and planning of freshwater salmon habitat that takes climate change into consideration.

The changing climate in BC is expected to affect various hydrological properties important to salmon development such as the temperature, timing and volume of streamflow. This may lead to changes in species number and distribution across the province.

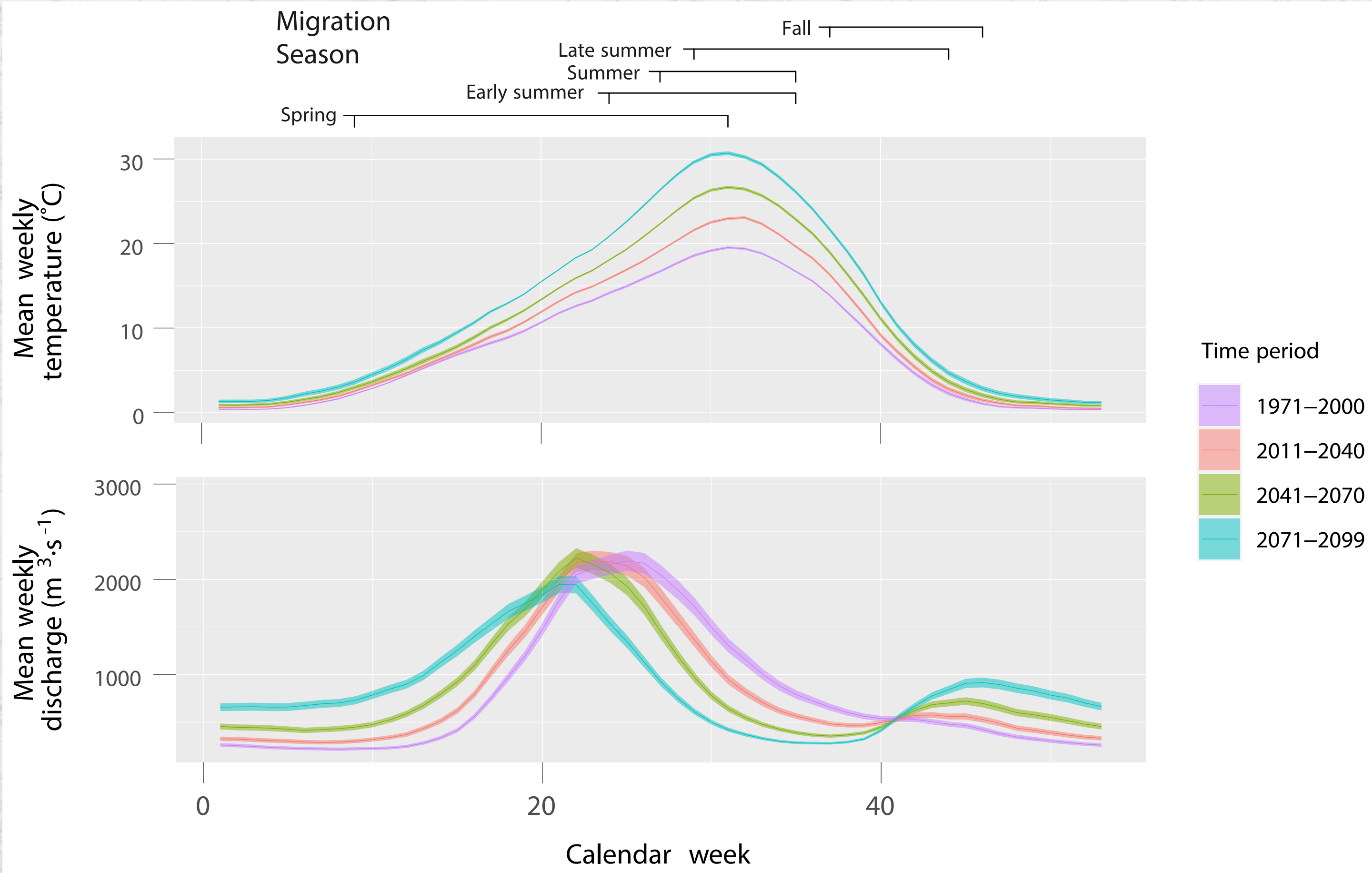


Figure 10: Mean weekly temperature and flow rates across the 62 Fraser River salmon conservation units. Results are presented for historical (1971-2000), current (2011-2040), mid-century (2041-2070), and end-of-century (2071-2099) time periods under climate change scenario RCP8.5. Weekly temperature and flow rates were averaged across the migration corridor for each salmon conservation unit, then averaged across all conservation units. The migration corridors vary in length, with corridors for some conservation units being localized to the lower Fraser valley, while others reach into the upper headwaters of the Fraser basin. Timing of migration shown above the graphs is based on the conservation unit migration season categories. A description of the conservation units can be found at: https://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2007/2007_070-eng.htm.

PCIC researchers are applying two hydrologic models to explore the potential effects of climate change in BC's fresh water salmon habitats. Using VIC-GL, they are simulating streamflow and water temperature in drainage areas along coastal BC, representing an area of 426,543 square kilometres. These simulations will be used to inform large-scale salmon risk-assessment (Figure 10). To support small-scale salmon risk-assessment, the Raven model is being deployed to eight sub-basins: the Auke, Tahltan, Babine, Chilko, Quesnel, Stuart-Takla, Somass and Meziadin. PCIC researchers have also developed a prototype risk assessment framework for salmon conservation units in the Fraser River basin, which takes advantage of streamflow and water temperature simulations previously conducted in the Fraser with VIC-GL. The methods and indicators for this framework will be used for a BC-wide risk assessment for all wild salmon species by conservation unit. The results of this work will be delivered to fisheries managers and others via an online tool that PCIC will develop as part of this project.

MAKING THE HYDROLOGIC MODELLING OF LARGE AREAS MORE EFFICIENT

The hydrologic models that PCIC runs are used to simulate hydrologic processes over large domains, including river basins that span large portions of the province. The models account for variations in the characteristics of the landscape, its soil, and the snow and vegetation covering it in part by using mathematical representations of land surface processes that include a number of adjustable parameters. To run a hydrologic model on a new domain, the model must be calibrated with these parameters adjusted to suit the domain. This is usually the most computationally expensive part of the hydrologic modelling process. With the support of the Global Water Futures program and in partnership with the University of Waterloo, PCIC researchers are looking at ways to reduce that cost by determining which parameters have a strong effect on model performance so that calibration efforts may be focused on these "sensitive" parameters. This will allow them to perform the sensitivity analysis in a general way in the future, so that it does not need to be repeated on each new domain to be modelled.

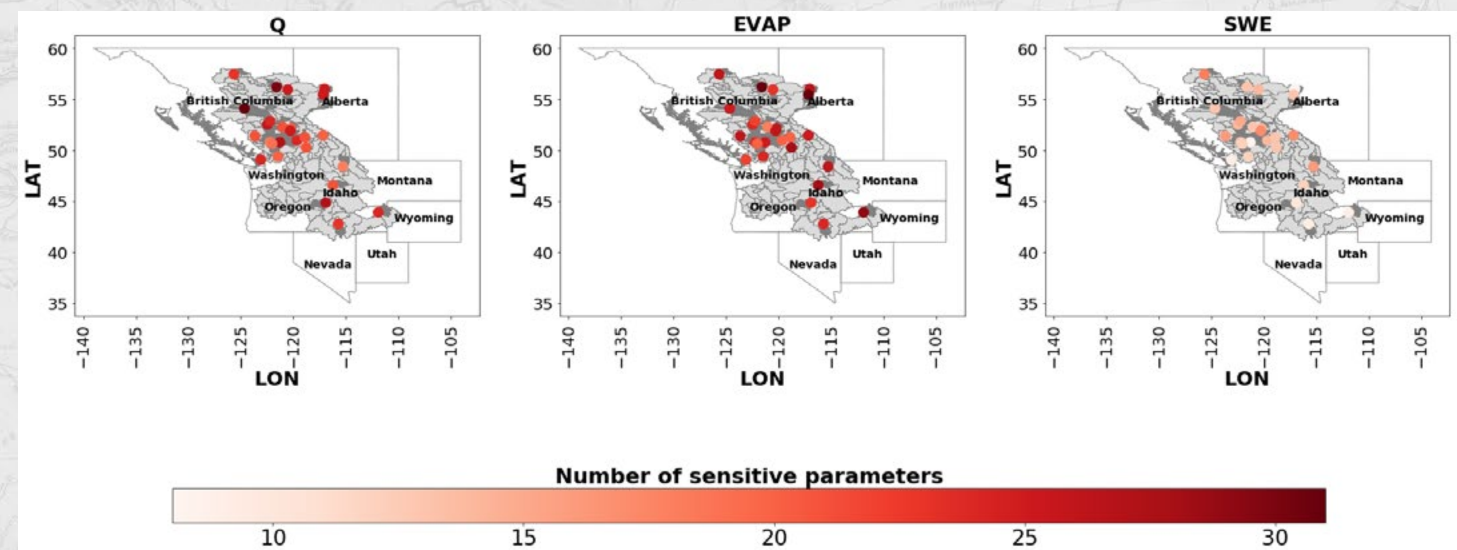


Figure 11: This figure shows the number of sensitive parameters (as coded by colour in the legends) for each variable, over the selected basins, marked in grey. The variables are, from left to right: streamflow (Q), evaporation (EVAP) and the snow cover in terms of snow-water equivalent (SWE). A total of 45 parameters were tested, including parameters describing soil and vegetation properties, as well as snow and glacier processes.

As part of the parameter sensitivity analysis, PCIC's team used a screening method to identify these sensitive parameters using sub-basins across the Pacific Northwest region that are representative of different hydrologic regimes. Figure 11 shows the number of parameters that can be considered sensitive for each sampled sub-basin and each process. After screening the parameters, the researchers then assessed whether parameter sensitivity can be inferred from the climate and terrain characteristics of the basins, which would allow suitable parameters to be chosen without having to calibrate all of the parameters in each basin. Preliminary results from this work suggest that aridity, snow index and glacier coverage are the best indicators of model sensitivity for streamflow, evaporation and snow cover.

ADAPTING NECHAKO RIVER FISH HABITAT

The Nechako River supports multiple species of fish, including trout, sturgeon and several salmon species. Over the last fiscal year, PCIC has contributed to work to better understand the effect of climate change on water temperature in the Nechako River. The focus of this work is on water released from the Nechako Reservoir via the Skins Lake Spillway into the lower reaches of the Nechako River. Water is released during the salmon migration period so that salmon migrating up the Nechako River are not exposed to excessively warm water. The changing climate could increase the impact of reservoir operations on fish habitat in several ways.

In order to anticipate and better understand the potential impacts of climate change on the temperature and water flow regimes of the Nechako Reservoir, PCIC researchers have coupled their streamflow model, VIC-GL, with a model of the Nechako Reservoir that simulates fluid flow and water temperature.

The first step, in which historical (1987-2016) streamflow was simulated, has been completed. The combined modelling system does a good job in simulating the volume and temperature of reservoir inflow and in modelling the changes in reservoir volume, water level and water temperature, closely matching observed values. For example, Figure 12 demonstrates that the model does well in representing the variability of the vertical temperature profile over time at Kenney Dam. Figure 13 shows the annual cycle of water temperature at various depths at the same location. The shaded region in Figure 13 indicates the period during which the Summer Temperature Management Program, or STMP, operates annually in order to regulate water temperature in the Nechako during sockeye migration. The next step in this work will be to repeat the

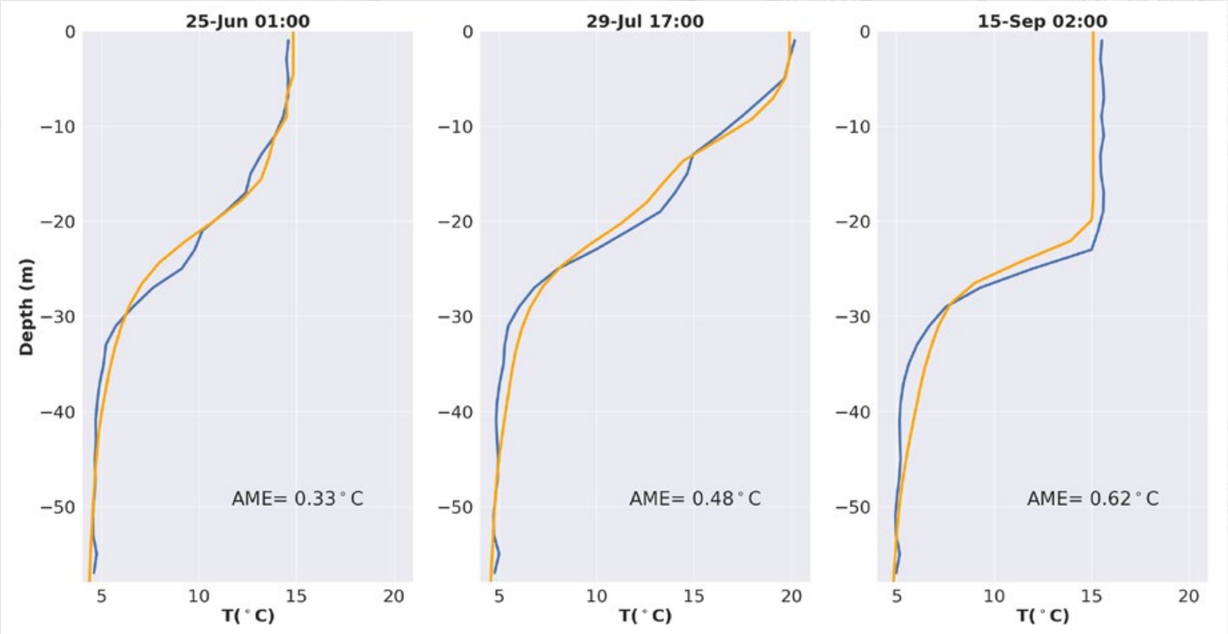


Figure 12: This figure shows the observed (blue) and simulated (yellow) water temperature profiles (temperatures at depth) for three days and times, at Kenney Dam over the 1987-2016 period. Depth is indicated by the vertical axis and temperatures are indicated by the horizontal axis.

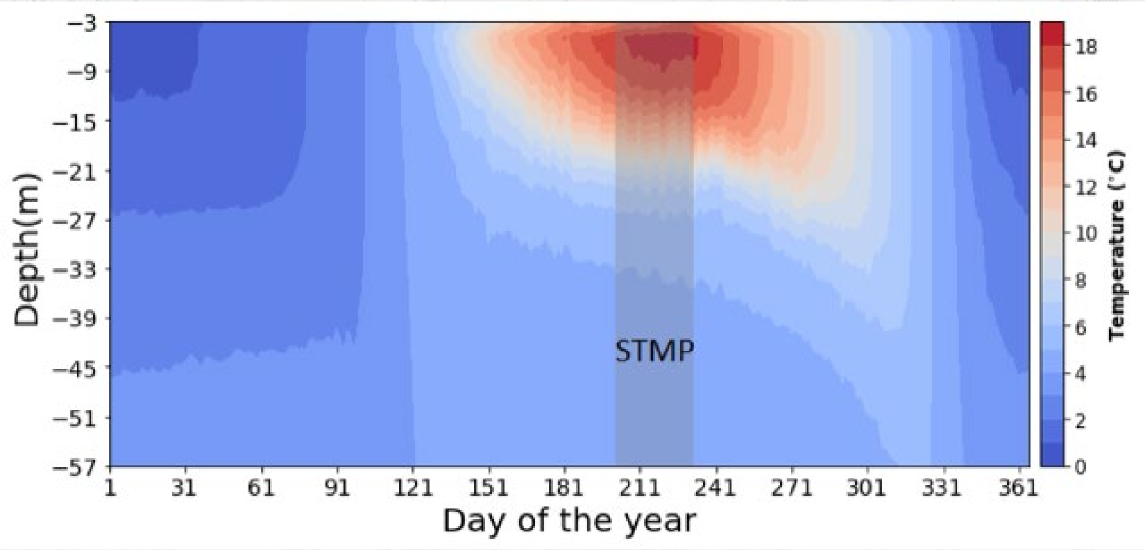


Figure13: This figure shows the simulated mean daily water temperature at depth for the Kenney Dam from 1987-2016. The depth is indicated by the vertical axis and the day of the year is indicated by the horizontal axis. Temperatures are as indicated by the colours in the legend. 'STMP' stands for the Summer Temperature Management Program and the dates covered by this program are indicated by shading.

modelling under future climate conditions, which will then provide information that will help to determine how the STMP should be altered in the future to best protect salmon from the impacts of a warming climate.

This work is supported by Rio Tinto, PCIC and a Collaborative Research and Development grant from the Natural Sciences and Engineering Council of Canada (NSERC). This grant involves researchers from: L'Institut national de la recherche scientifique in Quebec, the École de technologie supérieure in Montreal, the University of British Columbia, Rio Tinto and PCIC.

RAVEN DEVELOPMENT

Glaciers are an important source of water for many rivers in BC. The likelihood that BC's glaciers will shrink due to global warming raises questions about how this will affect streamflow in these rivers. With support from BC Hydro and the BC Salmon and Restoration Innovation Fund, PCIC researchers are using these questions as an opportunity to deploy and test the flexible hydrologic-modelling framework known as Raven. PCIC is adopting Raven because it is computationally efficient and because its modular structure allows for easy updating and the ability to represent physical processes with different levels of complexity as necessary.

This work has progressed in two phases. PCIC researchers first deployed a version of Raven model that included output from a separately run regional glacier model over the Mica basin to simulate changes to stream discharge and runoff. For the second phase, PCIC's research team examined the hydrologic impacts of glacier recession in the Cheakamus Basin, which contains the Daisy Lake reservoir that stores and diverts water to the Cheakamus Generating Station. Rather than the one-way approach used in the first phase for the Mica basin, a two-way coupling strategy was used to connect the hydrologic and glacier models. At any given time, Raven determines the glacier surface mass balance, which is the amount of ice that melts from the glacier and the amount of snow that accumulates on its surface. Given the glacier mass balance, the dynamics model updates the footprint and surface elevation of the glacier. This information is then fed back to Raven, which starts the coupling cycle anew by again melting ice and accumulating snow over the next coupling interval. This two-way coupling allows for a more internally consistent representation of the water budget in the landscape. The Cheakamus work also focussed on the different ways that the glacier dynamics component could be calibrated to match observations, and the implications for future summer streamflow projections. The broad findings are that summer streamflow will be reduced as the glaciers feeding the Cheakamus become depleted of ice, which is an impact on streamflow that will occur in addition to summer streamflow reductions that are the direct result of changing climatic conditions. The details of how this is projected to occur are, however, sensitive to the coupling and glacier dynamics calibration approaches.

ASSESSING CHANGING FLOOD RISK

Flooding is one of the largest risks that infrastructure and asset managers have to plan for and the changing climate may affect the frequency and magnitude of flooding events. With the support of the BC Ministry of Transportation and Infrastructure (MoTI), PCIC undertook a pilot project to provide guidance on design flood values for historical and future periods, and to make these design flood value estimates accessible on demand, as a gridded product via PCIC's Climate Explorer tool. This will aid engineers in their efforts to design climate-resilient infrastructure. The work focused on the Upper Fraser River, a 34,200 km^2 region upstream of Prince George, BC. This is a primarily snow-dominated watershed, in which the annual variation in streamflow is strongly affected by snowpack buildup and melting. Results from this work have been provided throughout this domain at the scale of a hydrologic model's grid cell, each with an area of about 30 square kilometers, with design flood values for each grid cell based on the streamflow coming into the cell from the area upstream of it.

This work makes use of hydrologic projections produced by PCIC using VIC-GL, which are based on the Representative Concentration Pathway 8.5 (RCP8.5) high-emissions scenario and spans 7,500 simulation years in total, providing enough samples of annual maximum peak flow to allow the statistically robust estimation of long return-period events that occur very infrequently.

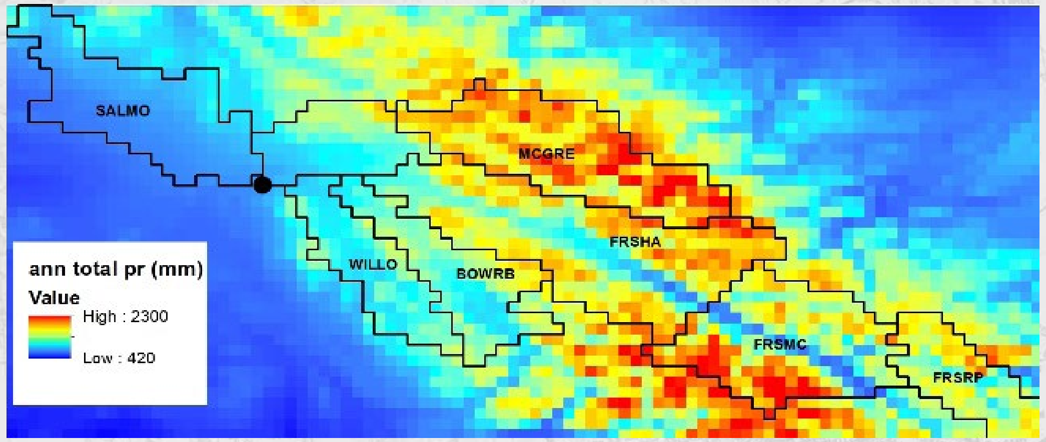


Figure 14. This figure shows the mean annual precipitation over 1960-1991 for the Upper Fraser study region with each of the sub-basins outlined. The sub-basins in the region are as follows: BOWRB stands for the Bowron River, FRSHA stands for the Fraser River at Hansard, FRSRP stands for the Fraser River at Red Pass, MCGRE stands for the McGregor River, SALMO stands for the Salmon River and WILLO stands for the Willow River. The outlet of the entire study area is indicated by the black dot.

The design of infrastructure such as roads, bridges and culverts often requires estimates of peak-flow quantiles. These are values that have defined probabilities of exceedance, or equivalently, specified return periods, which in this project varied from 2-years up to 200-years. When reliant on small sample sizes, as is typically the case when using observed data, quantiles often correspond to return periods that are substantially longer than the observational data that is available. It can be difficult to estimate the intensity of events that occur, say, only once every 200 years, from 30 years of data. The benefit of using a large ensemble of hydrologic simulations, as was done here, is that it provides enough samples that even the quantiles corresponding to very rare 200-year events can be estimated directly from the hydrologic model output. For example, for a given 30-year period, the large ensemble simulation of the Fraser provides 1500 years of streamflow data, and thus 1500 realizations of annual maximum streamflow representative of that period, from which the statistics of the streamflow, including peak flow, can be explored.

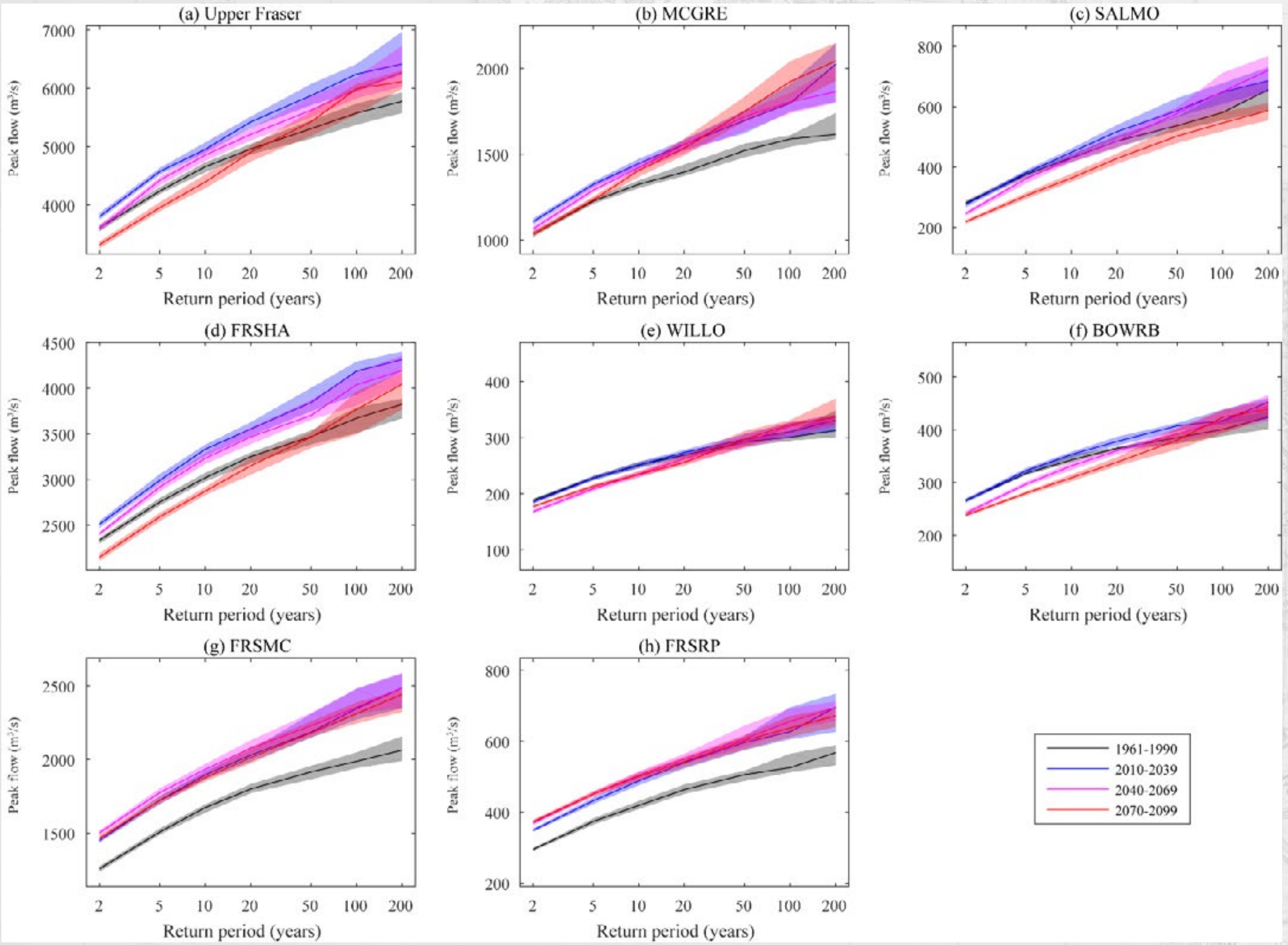
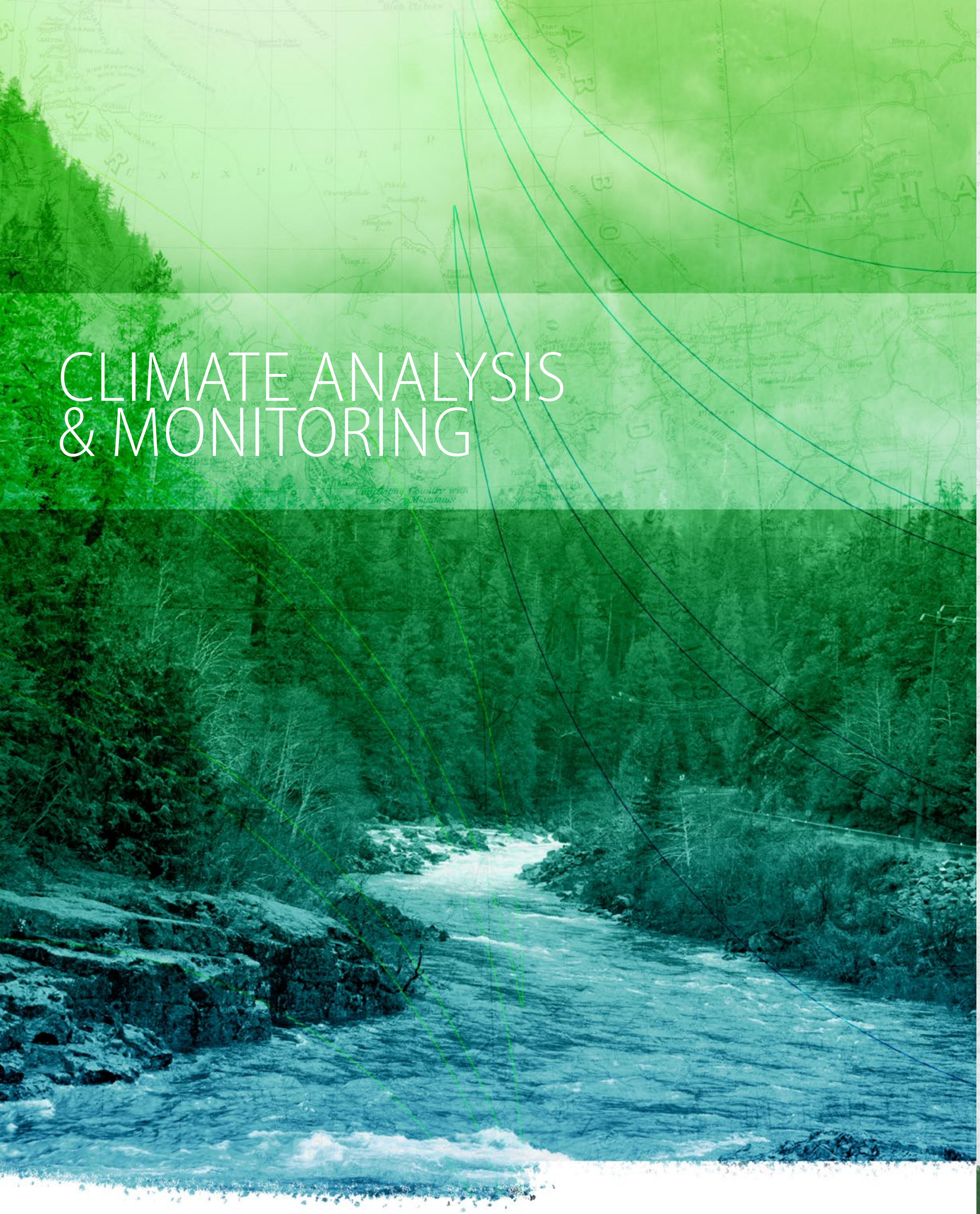


Figure 15. This figure shows plots of the flood frequency, in terms of the annual maximum daily streamflow and return period, for each of the outlets of the seven sub-basins in the study region, and for the whole upper Fraser (top left panel), as labeled. These are shown for the four time periods, as indicated by the colours in the legend. Note that the Upper Fraser panel shows results for the outlet of the entire study region which corresponds to the black dot in Figure 1. Best estimates are given by the solid lines and the shading around them indicates 95% confidence intervals.

Relative changes in the volume of peak flow passing through each grid cell will be influenced by numerous factors, and as a result, at the spatial scale of an individual hydrologic model grid cell, it can be difficult to determine the causes for the spatial patterns of peak flow quantile change. However, when spatially integrated, the influence of climate (represented by precipitation in Figure 1) can be seen at the sub-basin scale (Figure 2). For the wetter sub-basins of the McGregor River, and the Upper Fraser River at Red Pass and McBride, which are located in the Rocky Mountains, PCIC researchers found that there is a clear signal of increasing design flow magnitude for all return periods and all three future periods. In the drier regions encompassed by the Bowron River, Willow River and Salmon River sub-basins, a clear trend of declining design values emerges for all but the largest return periods by end-century (Figure 2). For the larger sub-basin of the Upper Fraser River at Hansard, and for the outlet of the entire study domain (Upper Fraser in Figure 3), the projections are more mixed. Design flow values are projected to increase in early- and mid-century, however, by end-century one expects that small events with return periods shorter than 20-50 years will decrease in magnitude whereas large events with return periods longer than 100 years may still increase in magnitude.

These design peak flow values are now available online, through a tab on the PCIC Climate Explorer (PCEX) tool. This allows engineers and planners to access the results of this work as needed to inform their design and planning decisions.



CLIMATE ANALYSIS & MONITORING

UPDATING PCIC'S PRISM MAPS

Having high-quality climate data presented in a manner that makes it easy to see regional changes is important for decision making. One way in which PCIC provides this is in the form of maps of 30-year climate normals and monthly time-series maps developed using the Parameter Regression on Independent Slopes Method (PRISM). With the support of the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, PCIC researchers are working to update the 30-year climate normal PRISM maps to the new 1991-2020 climate normal period, as well as to expand and improve the quality of the data that is used to make them. This collaboration is aimed at bringing in information about climate from ecologists who are familiar with vegetation on the ground and the climate needed to support those ecosystems. Where disagreement exists between the ecological data and the PRISM climate data, the mapped climate will be adjusted to reflect what is observed on the ground. These kinds of data, external to the PRISM climate mapping expert-system, are critical to accurately mapping climate in remote regions with few weather observations.

PCIC is also working to improve the monthly time-series of PRISM maps of temperature and precipitation. Observational monthly mean temperature and total precipitation data are assembled regularly for the purpose of assessing seasonal anomalies as well as producing interpolated monthly data using PRISM software. This year, PCIC expanded the PRISM monthly dataset to include weather data that has been homogenized—meaning data for which non-climatic shifts and trends in data are removed for improved trend analysis. Previous maps have used non-homogenized data that allows for a denser network of observing sites while sacrificing the ability to accurately analyze the maps for climatic trends. An example of the difference between these is shown in Figure 16. The goal of this work is to provide two monthly mapping streams: (1) an automated system that regularly updates monthly maps for near real-time analysis of monthly and seasonal weather anomalies and (2) a homogenized set of maps that are useful for trend analysis, which will enable the assessment of rates of climatic change at a high spatial resolution for planning purposes.

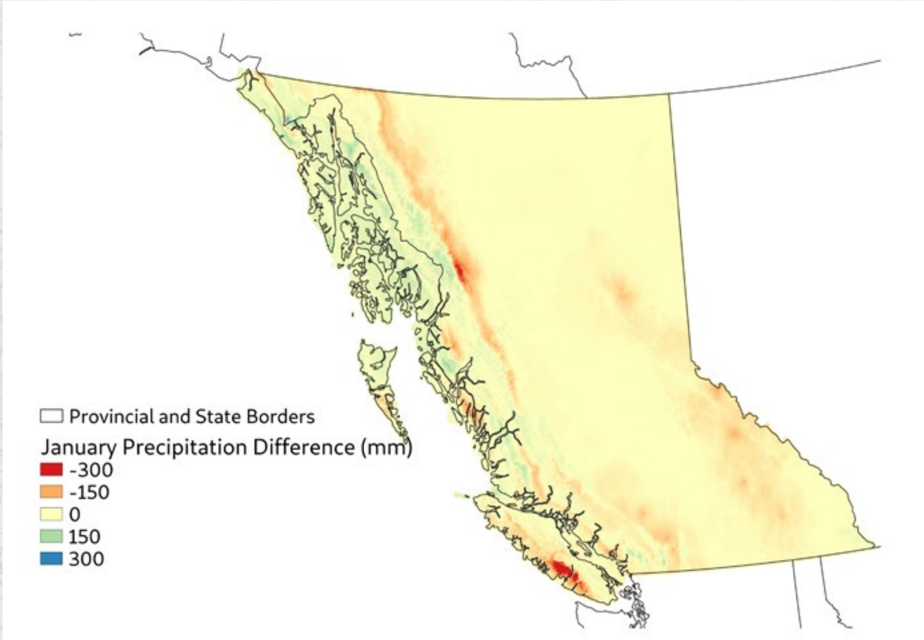


Figure 16: This figure shows the difference between the long-term average of monthly precipitation for January using non-homogenized data and that using only homogenized data.

UPDATING THE PROVINCIAL CLIMATE DATA SET

The Pacific Climate Data Set (PCDS) continues to grow, with more than 169 million observations added this year (Figure 17). The PCDS is a collaborative effort between multiple BC ministries, Rio Tinto, BC Hydro, ECCC, Metro Vancouver and the Capital Regional District. The PCDS is used to create PRISM climate maps, the annual State of the Ocean Report published by Fisheries and Oceans Canada, and much of PCIC's seasonal analysis. It is also served to the public via PCIC's BC Station Data portal as a one-stop source of weather station data gathered in BC. The portal currently makes available data from 6,964 stations in BC, drawing from our holdings of about 7,200 stations.

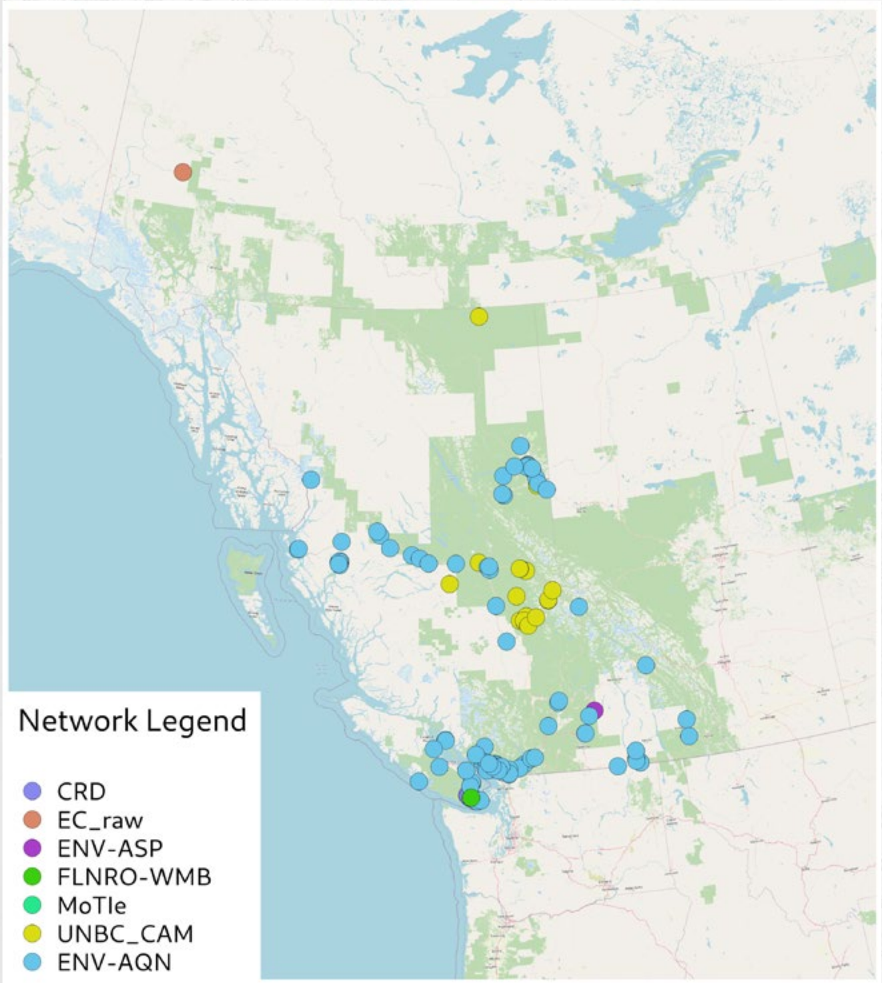


Figure 17: This figure shows the locations of new data sources added to the PCDS over the 2020-2021 fiscal year, by network. The networks are as follows: CRD is the Capital Regional District, EC_raw are the raw observations from ECCC,, ENV-ASP are from ECCC's automated snow pillow network, ENV-AQN are from ECCC's air quality network, FLNRO-WNB are from the Wildfire Management Branch of the BC Ministry of Forestry, Lands, Natural Resource Operations and Rural Development, MoTIe is from the BC Ministry of Transportation and Infrastructure and UNBC_CAM is the University of Northern BC's Cariboo Alpine Mesonet.

Renewed in 2018 following eight years of growth, the data sharing agreement between the partners involved in the PCDS promises ongoing support for data availability for PCIC's users. The more than 169 million observations added this year is a substantial increase over the previous year's addition of 144 million observations, and this comes in addition to a new data feed from the Capital Regional District that will allow the automated collection of data in Victoria's watershed. At the same time, changes to BC's observation network have occurred that change the number of observing sites that include the closing of some stations and the addition of new ones as part of regular operations of Climate Related Monitoring Program (CRMP) partners. Ongoing work with ECCC has been aimed at ensuring the alignment of metadata (information about the meteorological data, such the location of the station where it was collected and methods used for doing so) among the networks and PCIC. PCIC has also continued to support CRMP's efforts to centralize climate data in BC and streamline the collection of such data, moving toward greater automation to provide data to our users in near real-time.

UPDATING SERVICES FOR CANADA'S WESTERN ARCTIC

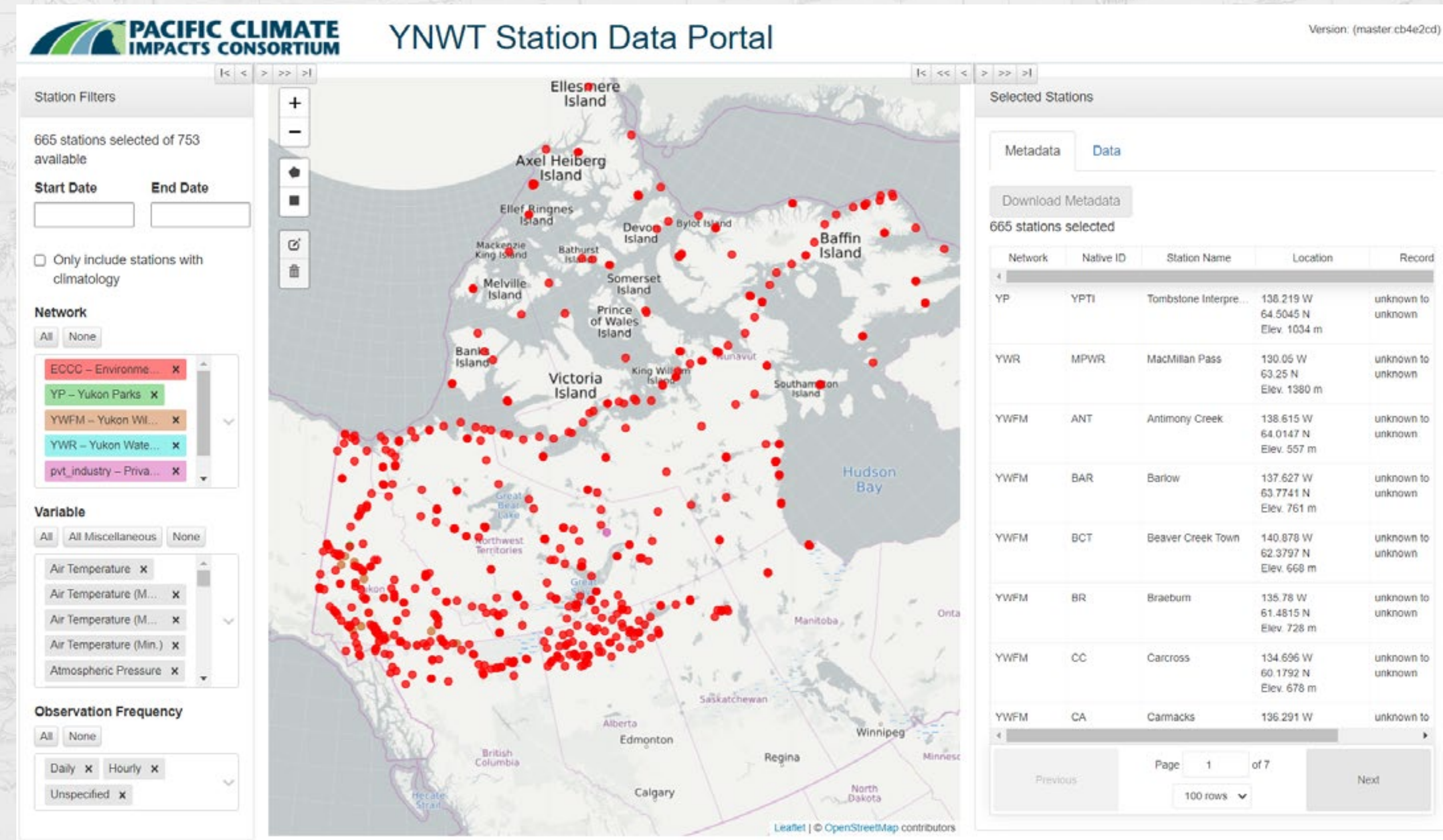


Figure 18: This figure is a screenshot of the interface of one of the current working versions of the Data Portal for Canada's Western Arctic that is currently in review and development.

As PCIC continues to expand our data and services, this year we released a beta version of a station data portal for Canada's western Arctic (Figure 18) to the Government of Northwest Territories for their internal assessment. This tool will allow PCIC users to access data from this region and is a further step in ongoing work to serve PRISM climate maps and observational data portals to support research and planning for these communities. Part of this project involved the development of new map tiles to improve the quality of the presentation for users, and a re-write of the station data portal front end in a more contemporary web framework. This portal represents a modernization of the station data portal technology and aesthetics that has served PCIC since 2012. A similar modernization will also be undertaken for the BC station data portal.

With partnerships in place and quality control protocols for station data established, PCIC has continued with the next steps in producing PRISM climate maps for the region. This includes expanding the database of station data that the maps will draw upon, and completing the assessment of digital elevation models (DEMs) for Northwest Territories and Yukon. The PRISM mapping process requires a DEM to provide detailed information about surface elevation and aspect, and thus it is important to understand the uncertainties in the available DEMs before beginning the mapping process.

COMPUTATIONAL SUPPORT GROUP

NEW FEATURES ADDED TO THE PCIC CLIMATE EXPLORER

PCIC has added extreme streamflow to the PCIC Climate Explorer (PCEX) tool and added a new application programming interface (API) which allows other organizations to access data from PCEX using their own computer programs and scripts. This expands the functionality of PCEX, making it a novel product that allows users to locate climate data for an arbitrary region—giving greater flexibility to the user—and then visualize it with maps and plots, and download data for their area of interest.

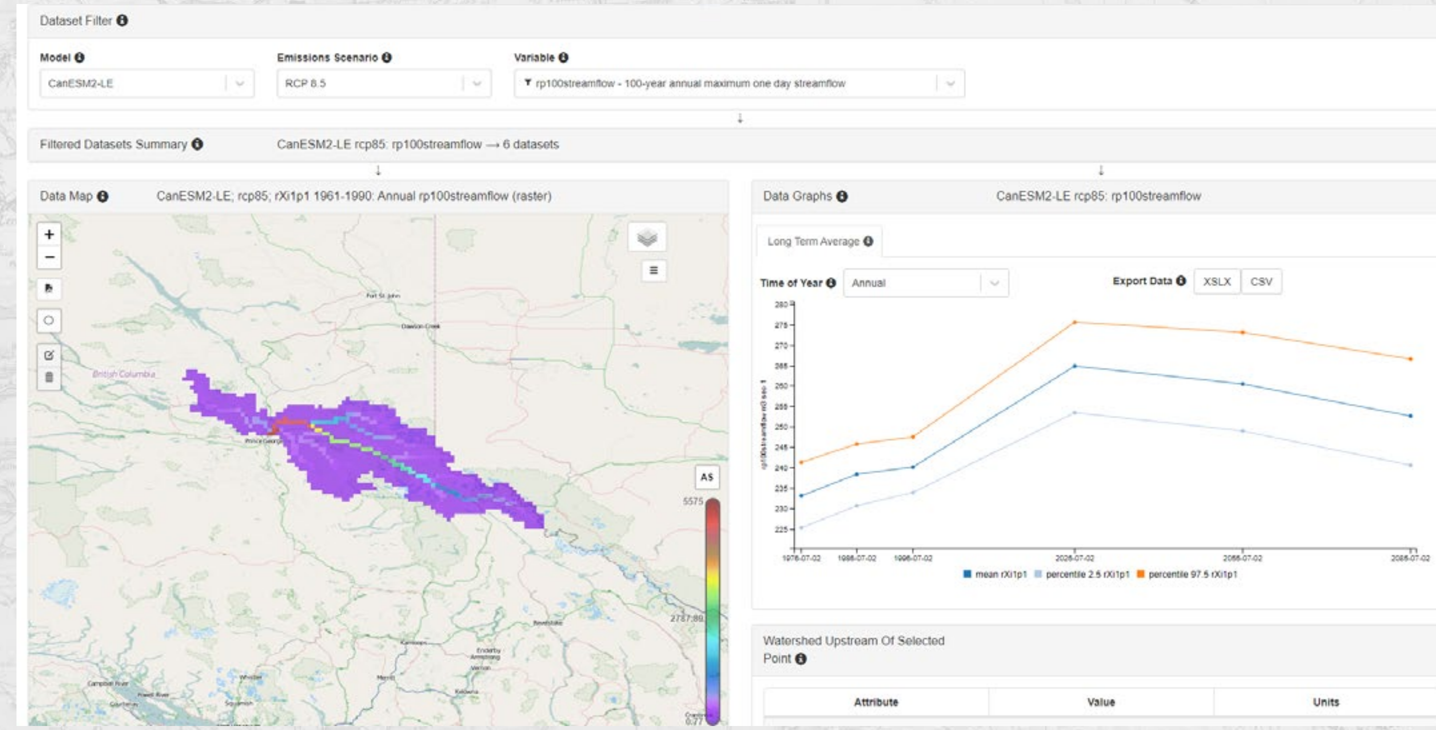


Figure 19: This screenshot shows the extreme streamflow output that is now available on PCEX.

The new API, which allows users to access multi-model percentiles from GCMs, started as a pilot project last year and this year was incorporated into the normal feature set of PCEX. This was made possible through the support of the Ministry of Transportation and Infrastructure (MoTI), who now use this API to access climate information for one of their internal tools.

In addition, and also with the support of MoTI, PCIC has added extreme streamflow output for the Upper Fraser Basin to PCEX (Figure 19). This makes streamflow output and statistics available for places where they weren't available before, with streamflow available for every place in the watershed. This information is of particular interest to engineers who are interested in extreme streamflow for projects such as bridges and culverts. In addition, because PCIC performed the river routing calculation to determine the flow at each point ahead of time, the tool can very quickly answer and fill requests for streamflow data.

NEW PLAN2ADAPT TOOL

PCIC offers a number of tools that present climate information at differing levels to meet our users' needs. PCIC's Plan2Adapt tool provides users with a high-level overview of projected climate change and impacts in BC (Figure 20). This year, Plan2Adapt was completely rewritten, improving the user interface and making it easier to maintain and update. The new tool will be easy to update to CMIP6 data and will still provide maps, graphs and information on climate change and impacts by sector, throughout the province.

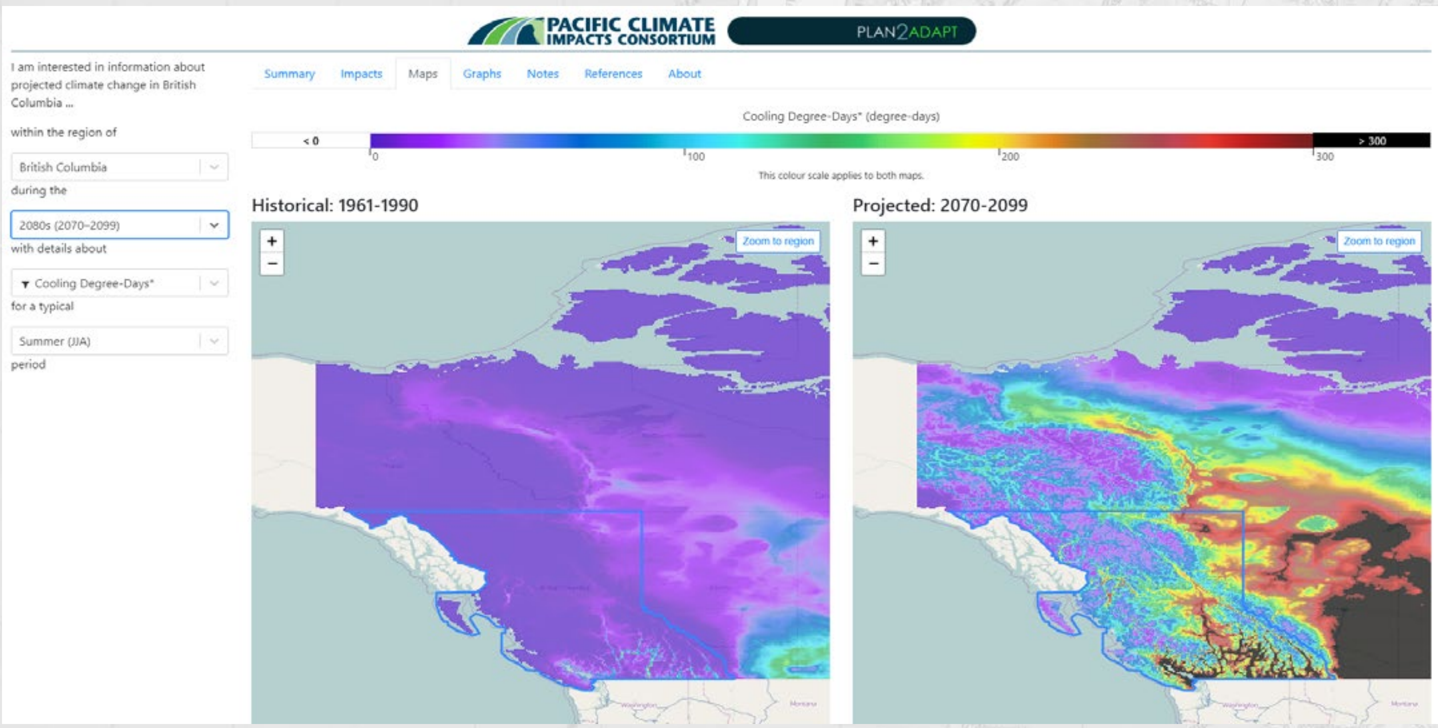


Figure 20: This figure is a screenshot of the new Plan2Adapt tool. In this case, the maps panel shows summer cooling degree-days (an index representing energy consumption required for cooling) for the historical baseline period (1961-1990, left) and 2080s projections (2070-2099) under a high-emissions scenario.

UPDATING WEB PROCESSING TOOLS

PCIC has added two new web processing tools to its contribution to the Data Analytics for Canadian Climate Services (DACCS) project. This project aims to make climate analytics more efficient by bringing analysis tools to the data itself. This involves developing DACCS nodes that can handle analytics requests and which reside near the data storage systems, making climate analytics more accessible and resulting in less duplicated work between research teams.

The new web processing tools added this year are named Sandpiper and Osprey. Sandpiper can perform all of the operations of the impacts engine that is the backbone of PCIC's Plan2Adapt tool. Using this web processing service, a user can supply a region and a decade, and get output for the different impacts that may be projected to occur in that region. Osprey can perform all of the operations of the RVIC streamflow routing model. Hydrologic models like VIC-GL determine how much runoff is produced in each grid cell, but a routing model, which runs separately, is used to gather runoff into streams and rivers and thus determine the streamflow at specific points in a drainage basin. With Osprey, a user can select a point and hydrologic simulation driven by a specific climate model input and emissions scenario to obtain streamflow for that point at a daily resolution. This is especially useful for engineers who are designing a bridge or culvert at a specific point. They may be interested in knowing what climate projections suggest the flow at that point will be as a design consideration. With Osprey, they can easily acquire this information. PCIC's Station Hydrologic Model Output Data Portal page provides precomputed streamflow at a limited number of locations, but with Osprey we can provide this information at any grid box in the regions that we have modelled with VIC-GL. Osprey and Sandpiper join three other pieces of web processing software that has been developed by PCIC.

Considerable work has also been done to ensure that these "birds" and related software can be maintained and deployed efficiently. The system is currently operating on PCIC's cloud computing resources, and PCIC staff have been invited to test their workflows on the new system. The hardware that will be needed to implement a dedicated DACCS server at PCIC has been acquired and work to commission the hardware has begun.

Work on DACCS is led by the University of Toronto and is being done collaboratively with our partners, Ouranos and the Computer Research Institute of Montréal (CRIM), with the support of the Canadian Cyber Infrastructure fund of the Canadian Foundation for Innovation and the BC Knowledge Development Fund.

UPDATING CLIMDOWN

PCIC's ClimDown package, which performs statistical downscaling has been improved this year. Climate downscaling translates climate information from low-resolution sources, such as the output available from global climate models, to the high-resolution information needed to study climate impacts at local and regional scales. Because so much regional analysis and impacts work relies on downscaled model output, and because downscaling is a computationally expensive task, improvements in the speed and efficiency of downscaling code are very beneficial. The improved ClimDown package runs 10% faster overall, which will save PCIC and others who use the package days-to-weeks of computation time. The package is freely available as Open Source code under the GNU GPL 3 license.

MAINTAINING PCIC'S SOFTWARE PACKAGES

PCIC is committed to a broad range of climate services, including software services, and making sure that everyone has access to the code that we produce. A part of this commitment is reflected in the work that we do to keep the software that we offer up-to-date. This fiscal year we continued to maintain all of the packages that we offer for the R statistical programming language. This ensures that our software maintains compatibility with other software packages and ensures that our packages are easily installed by a wide range of users from standard and default software package repositories. It also ensures that our software is stable. We will continue to maintain the software that we offer so that our users will have the best possible, up-to-date tools for their work.

COMMUNICATIONS & OUTREACH

RELEASING SCIENCE BRIEFS AND NEWSLETTERS

PCIC's Science Briefs and newsletters keep our users informed about selected research in the scientific literature and PCIC operations. PCIC Science Briefs are plain-language summaries of recent research papers from the scientific literature, selected for their relevance to PCIC's stakeholders and presented with context so that the findings can be easily understood. This year PCIC produced two Science Briefs: *The Human Climate Niche: Past, Present and Future* and *On the Loss of CO_2 in the Winter Observed Across the Northern Permafrost Region*. Over the year PCIC also produced five newsletters. These focused on many of the same stories that are covered in this report, along with talks given as part of the Pacific Climate Seminar Series, articles putting seasonal weather events into climatological context, staff profiles, lists of PCIC publications and notes on changes to PCIC staff.

Figure 21: This figure shows a sampling from PCIC's Science Briefs and PCIC Update newsletter.

PACIFIC CLIMATE SEMINAR SERIES

The Pacific Climate Seminar Series is an opportunity to share the work of PCIC researchers and other researchers whose findings are relevant to our community of users, as well as for community members from different sectors to network. Owing to the COVID-19 pandemic, the Pacific Climate Seminar Series was placed on hiatus for much of 2020. The series was started again, virtually, with two talks in the winter and spring of 2021. The first, *Imagining the unprecedented: developing climate risk storylines* was delivered by Dr. Liese Coulter on February 24th, 2021. The second, *Leveraging expert knowledge of weather extremes, climate models, and future change to inform infrastructure design standards in Canada*, was delivered by PCIC Acting Lead of the RCI theme, Dr. Charles Curry, on March 31st 2021 and the series continued into the next fiscal year.

PRESENTATIONS AND OUTREACH

As part of our commitment to share results with our users, listen to their needs and use this to inform our planning and services, PCIC staff are active in their outreach efforts. Over the pandemic, PCIC has continued to do virtual outreach, delivering presentations, running webinars and participating in workshops and conferences.

Collectively, PCIC staff delivered 90 presentations over the 2020-2021 fiscal year, all of which were made virtually.

OPERATIONS AND FINANCE

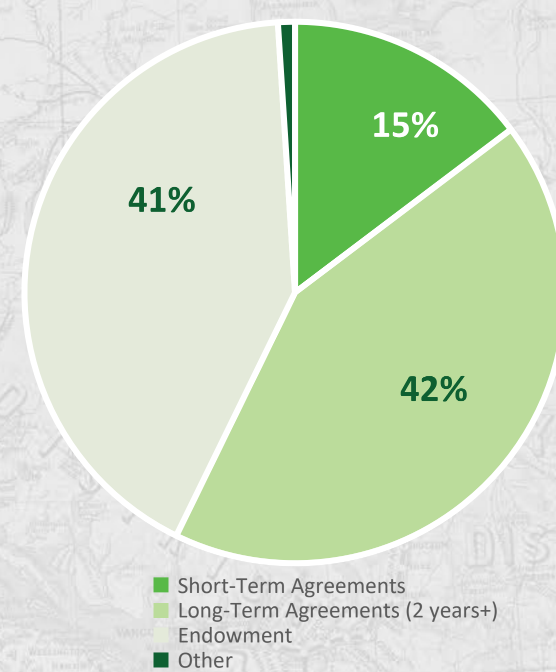
Despite the challenges caused by the COVID-19 pandemic, PCIC maintained a strong financial position with an increase in its annual funding envelope. PCIC managed 27 active agreements related to user-commissioned projects, research grant programs and other projects. Ten new contracts were signed with local governments, BC ministries and federal agencies. Short-term and long-term contracts with our users provided 56% of our revenue. The financial security provided by the endowment and our strategic partnerships allows PCIC to maintain a long-term budgetary outlook.

PCIC's most important asset, and our largest expense, continues to be our investment in human resources. In 2020-2021, 96% of PCIC's spending supported staff salaries. The remaining expenses supported operational expenses such as financial accounting and auditing services, computing resources, and staff professional development. The decrease in operational expenses over prior years was mainly due to the cut in business/conference travel caused by the pandemic and its associated world-wide travel restrictions.

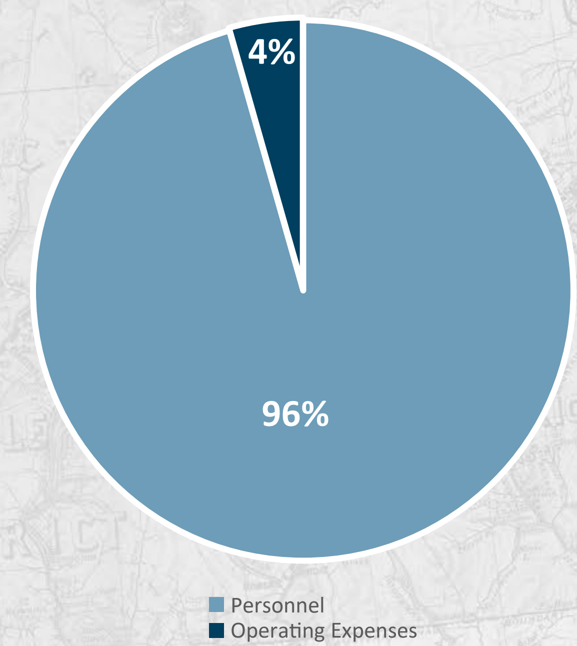
Our staff worked remotely throughout the year due to the pandemic, and did so productively and collaboratively within PCIC and with our partners. We express our sincere appreciation for the dedication, hard work and excellent teamwork of our very talented staff, UVic's excellent supporting infrastructure and the ongoing commitment of our partners.

The transition to a post-pandemic environment will, no doubt, bring us into further uncharted territory and create further uncertainty. As we have this year, we are confident that PCIC will be able to navigate those challenges successfully while providing high quality services, using the resources entrusted to us efficiently and ensuring long-term financial sustainability.

2020-2021 REVENUE



2020-2021 EXPENSES



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MAP
OF THE PROVINCE OF
BRITISH COLUMBIA.
COMPILED BY
J.H.BROWNLEE, D.L.S.
FROM THE LATEST MAPS AND SURVEYS
AND ALL RELIABLE SOURCES OF INFORMATION TO DATE.
THE HONOURABLE F.G.VERNON
CHIEF COMMISSIONER OF LANDS AND WORKS.

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