PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE October 2024

PROJECT AND RESEARCH UPDATES

2023 and the Transition to 2024: A Record-Breaking Year Globally and for BC

The planet's average surface temperature in 2023 was the warmest on instrumental record (stretching back to the late 1800s) by a substantial margin, as determined by all major scientific organisations that gather and analyse such data, including the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration and the Hadley Centre. According to some of these records, the Earth reached 1.5°C above the average temperature of the preindustrial period (taken to be 1850-1900) for the year[1]. Globally, July 2023 was the warmest month ever recorded on Earth up until that point in time, and both Canada and British Columbia (BC) experienced their warmest summers since modern record keeping began. This record hot year was reflected in temperature anomalies across BC (Figure 1, left). PCIC scientists examined data from the European Centre for Medium-range Weather Forecasting (ECMWF) Atmospheric Reanalysis Product (ERA5) across the regions defined by the BC River Forecast Centre's 23 Snow Index Basins, from 1950 to the end of 2023. They found that annual average temperatures in all 23 basins ranked in the top five years since 1950, with 2023 being the warmest year in most basins. Long-term trends in mean daily temperature were found to be positive (increasing), and statistically significant both annually and in all seasons. As in 2021 and 2022, the summer was marked by extreme heat at multiple locations across the province, with the town of Lytton recording the hottest surface air temperature in Canada for 2023, at 42.2°C on August 15th.

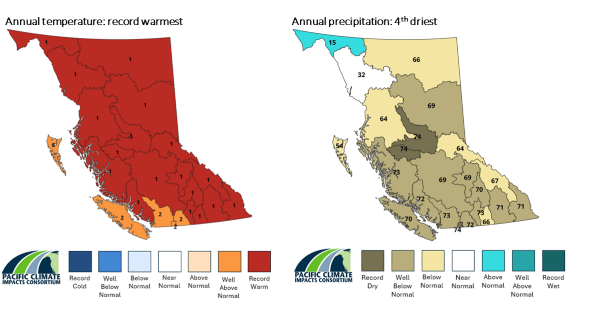

Figure 1: This figure helps to place the 2023 annual averages of daily mean temperature (left panel) and total precipitation (right panel) over BC into historical context. The colour scale is based on percentile ranges and the numbers in each basin refer to ranking by year over the 1950 – 2023 period, with 1 being the warmest/wettest year and 74 being the coldest/driest year.

PCIC's scientists also analyzed precipitation in 2023. The year was the fourth driest year ever recorded in BC, with the Upper Fraser West, Nechako, and Skagit basins all receiving their lowest annual precipitation since 1950 (Figure 1, right).

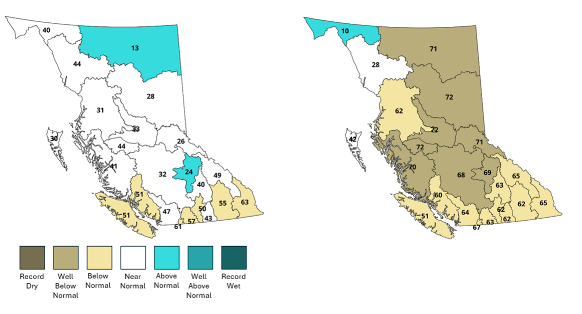

Figure 2: This figure shows the historical context for total precipitation in winter (December 2022 to February 2023, left), and fall (September to November 2023, right) over BC. The colour scale is based on percentile ranges and the numbers in each basin refer to ranking by year over the 1950 – 2023 period, with 1 being the wettest year and 74 the driest.

Across most of BC, conditions progressed over the year from near-normal precipitation and snowpack in the winter and spring to well below normal conditions in many areas by the fall (Figure 2). Winter snowpack at the beginning of 2023 was below normal, and this was followed by a warmer than usual spring and summer, leading to rapid snow depletion by summer. By the end of July 2023, 84% of BC was rated as either *Abnormally Dry* or in *Moderate* to *Exceptional Drought* and areas affected by drought encompassed 98% of BC's agricultural lands. Drought conditions persisted through the rest of 2023, with about half of the province still in moderate to exceptional drought by the end of the year, and similar conditions in the first half of 2024. During 2023, most of BC experienced extreme low streamflow, low soil moisture, and a record-breaking wildfire season.

The global mean temperature in 2023 was well above estimates from climate models and past observations. This spurred a dialogue in the scientific community about the contribution of different factors to the excessive warming. From one year to the next, changes in greenhouse gas emissions from human activity play only a limited role: other forcings (for example, recent declines in sulfate aerosol emissions over the world's oceans) and natural climate variability—particularly the transition from the previous La Niña climate pattern into what became a strong El Niño—may have been key contributors.

As temperature and precipitation in BC are sensitive to variations in Pacific ocean temperatures, the transition to a strong El Niño in 2023 is consistent with the warmer than normal conditions. However, early in 2024, the El Niño pattern gave way to neutral conditions, and one forecast from the Climate Prediction Center at the National Weather Service puts a transition to La Niña as likely (66% chance) during the September-November period.

- To track how monthly conditions in BC vary from the historical norm, see PCIC's Seasonal Anomaly Maps.

1. While some records show that global surface temperatures in 2023 surpassed 1.5°C above preindustrial levels, this does not mean that the 1.5°C limit from the Paris Agreement has been breached. This limit is defined in terms of the long-term mean (at least 30-year average) global surface temperature, rather than the annual temperature in a single year.

Salmon Climate Impacts Portal Released

PCIC is proud to share the release of the Salmon Climate Impacts Portal (SCIP), in June of this year. This online tool enables users to locate, visualize, summarise, and download summary data describing projected changes to salmon exposure in the freshwater environment within the BC Coastal domain. The data quantifies streamflow and water temperature conditions that are relevant for salmon populations over annual, monthly and daily time scales. The changing climate in British Columbia (BC) is expected to affect various hydrological factors pertinent to salmon growth, survival, and habitat interconnectivity, leading to changes in species distribution at broad spatial scales. This work was supported by the British Columbia Salmon Restoration and Innovation Fund.

- Go to the Salmon Climate Impacts Portal.
- Watch a seminar on the research behind the Portal and a demonstration of the tool.

Development of High-resolution Climate Change Freshwater Hazard Data for BC

With the support of the British Columbia Salmon Restoration and Innovation Fund, PCIC is engaged in research needed for the assessment of site- and population-specific salmon vulnerability to climate change. This will complement the broad-scale information that has recently been produced. Such information is essential for fisheries management, stock assessment, recovery planning, and habitat restoration activities.

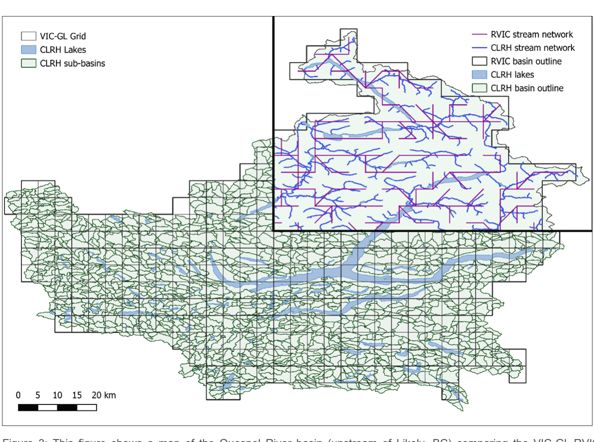

Figure 3: This figure shows a map of the Quesnel River basin (upstream of Likely, BC) comparing the VIC-GL-RVIC computational grid and CLRH sub-basins and lakes (primary map) with the RAVEN-CLRH streamflow networks (overlay at upper right).

The changing climate in BC is expected to affect various hydrological factors (flow levels, timing, and water temperature) pertinent to salmon growth, survival, and habitat interconnectivity, potentially leading to changes in species distribution at broad spatial scales. Therefore, improving information on salmon vulnerability to the impacts of climate change is essential for fisheries management, stock assessment, recovery planning, and habitat restoration activities. Recent PCIC research has focused on improving our understanding of potential threats to Pacific salmonids across a large geographic range. These are well-suited for domain-wide broad-scale strategic hazard assessments. However, the response of salmon to climate change can be affected by local conditions or unique population characteristics that can outweigh larger, regional scale drivers. Therefore, more detailed local- or site-scale information is still required.

PCIC is currently developing high-resolution data to understand the impact of climate change on the freshwater environment at the level of individual stream channels and lakes. To accomplish this, researchers are using broad-scale hydrologic projections from the Variable Infiltration Capacity model with glaciers (VIC-GL) to force a vector-based routing and water quality sub-module that will be deployed at a very fine spatial resolution. The streamflow routing and water quality simulations will be based on the Raven Hydrologic Modelling Framework.

The Quesnel basin, a major tributary of the Fraser River, can serve as an example to contrast regional-scale modelling with smaller, local-scale approaches. Traditionally, a routing model (part of the larger Variable Infiltration Capacity Model, VIC) has been used to simulate streamflow through and across a landscape at the regional scale. This model is driven by output from a hydrologic model coupled to a glacier model (VIC-GL). Using this approach, streamflow can only be derived for areas larger than a single grid cell in the hydrologic model, about 25 km^2 (Figure 3). In this case the Quesnel watershed is represented by this method using 202 computational grids. Stream connections are defined by assigning each grid cell a single flow direction, resulting in a very coarsely resolved streamflow network that poorly represents small drainage areas and areas with narrow water bodies (Figure 3). Also, lakes are not explicitly resolved in the VIC-GL routing model.

In contrast, river networks can be modelled using the shape of their catchments and information about elevation to form catchment areas over which a single stream channel is defined, in an approach known as "vector-based routing." To achieve this, PCIC scientists are using the Raven model, a product developed by the University of Waterloo[2].

Raven leverages high-resolution topological information from the Canadian Lake and River Hydro fabric v1.0 (CLRHv1.0), improving the spatial resolution by more than five-fold compared to the VIC-GL method above (Figure 3). At this higher resolution, the Quesnel at Likely watershed (5970 km^2) is composed of 935 sub-basins and 129 lakes, for a total of 1064 discretely modelled areas, known as 'hydrologic response units.' As a result, the CLRH-based product represents a more physically realistic routing network (Figure 3).

Vector-based routing will provide a much more accurate representation of the river networks in BC, leading to more faithful representation of streamflow and water quality at the scale of individual channel segments and lakes. This will allow climate impact assessments to distinguish between different habitats relevant to the various salmonid life-history stages (e.g., spawning, egg incubation and emergence, and fry and parr rearing). PCIC scientists have already tested Raven's ability to simulate streamflow within the Fraser watershed, including the Quesnel Basin, used as an example here. They found that Raven performed at least as well as VIC-GL (in terms of flow volume and timing) in this area, while providing streamflow at a higher resolution. They are now deploying it across a roughly 400,000 km^2 domain of watersheds along the BC Coast that drain to the Pacific Ocean.

This initiative is part of a larger project that PCIC's scientific team is working on, with four parts: expanding VIC-GL hydrologic projections to ungauged basins, improving lake temperature modelling, implementing oxygen saturation into their modelling, and creating an ensemble of streamflow and water quality projections downscaled to a very high-resolution stream and lake network. This work will ultimately provide very high-resolution projections of changes in streamflow, water temperature and dissolved oxygen at a substantially enhanced level of detail over a spatial domain that includes most BC drainage areas that flow into the Pacific Ocean. These will be developed and shared alongside a suite of streamflow and water temperature indicators, at the scale of individual reaches and lakes, all delivered via a web-based data portal. The knowledge, understanding, and data resulting from this work will directly support site- and population-specific climate change vulnerability assessments.

2. The CLRH v1.0 product is topographically corrected to match the Water Survey of Canada (WSC) stream gauge locations. It is constrained using a hydrologically corrected DEM developed by Environment Climate Change Canada (ECCC). Because of this topographical correction, CLRH flow networks and sub-basin boundaries lie closer to gauge locations and more accurately reproduce water features from the BC Freshwater Atlas.

Updates to Plan2Adapt and PCIC Climate Explorer

PCIC recently updated the Plan2Adapt and PCIC Climate Explorer analysis tools with downscaled climate data from the latest phase of the Coupled Model Intercomparison Project, CMIP6. Both tools now present the most up-to-date climate modelling available.

PCIC Climate Explorer includes CMIP6 data from 26 climate models downscaled using a multivariate technique known as N-dimensional Multivariate Downscaling (MBCn). While MBCn has excellent performance in downscaling single variables, it also strives to preserve observed relationships between variables in the final downscaled product. Climate Explorer continues to provide downscaled climate model output from CMIP5 using the previous, univariate, method (BCCAQv2). For Plan2Adapt, a subset of 12 models was selected that best represent the overall range of model output available from CMIP6 for Canada. Plan2Adapt now shows projected changes under high emissions scenario SSP5-8.5, replacing the RCP8.5 scenario used in CMIP5. In addition, historical baseline values (1981-2010) were added to the summary tables so that users can put the projected changes in each variable in the context of recent climatology. Seasonal data have been added for temperature, precipitation, and precipitation as snow. In addition, a new regional delineation was added showing a representation of First Nations language families and Indigenous territories in BC. This new delineation is intended to support the accessibility of future climate data for Indigenous communities and other users across the province. PCIC is grateful for contributions to this project from Environment and Climate Change Canada and the support of The BC Ministry of Emergency Management and Climate Readiness.

- Access Plan2Adapt
- Access PCIC Climate Explorer
- Access univariate and multivariate downscaled CMIP6 data

The Pacific Climate Data Set Surpasses One Billion Observations

After collecting data for nearly 13 years, the Pacific Climate Data Set (PCDS) recently surpassed one billion observations for British Columbia. The PCDS holds observations from over 7000 stations across the province, with the oldest records going back to 1870. Observations continue to be automatically ingested, with resolutions from 15 minutes to semi-daily and for a wide range of variables, from surface temperature and precipitation to upwelling radiation and soil moisture. These data are made available to users via PCIC's BC Station Data portal. The PCDS is a frequently accessed and continually updated resource for a wide range of our users. The data it holds are also used at PCIC for a wide range of applications, including creating climate maps using the Parameter Regression on Independent Slopes Method (PRISM) and for analysis of climate trends and variability in all areas of the province.

PCIC is one partner among several under an agreement coordinated and managed by the Climate Related Monitoring Program, who work together to make this project possible. PCIC extends its gratitude to the other partners in this project: the British Columbia Ministry of Environment and Climate Change Strategy, the British Columbia Ministry of Agriculture and Food, the British Columbia Ministry of Forests, the British Columbia Ministry of Transportation and Infrastructure, the British Columbia Ministry of Emergency Management and Climate Readiness, Rio Tinto, BC Hydro, Environment and Climate Change Canada / Environnement et Changement climatique Canada, Government of Northwest Territories, Metro Vancouver and The Capital Regional District.

- Access the Pacific Climate Data Set.

STAFF PROFILE: QUINTIN SPARKS

Quintin Sparks is a Programmer/Analyst in PCIC's Computational Support Group, where he develops and maintains tools for climate analysis, combining his interests in technology and environmental stewardship. He explains, "I was drawn to geomatics during my undergraduate studies. I found it fascinating how this field combines social and natural sciences with technological innovation." Providing some examples, he continues, "these include precise resource mapping capabilities enabled by hyperspectral satellites and machine learning—and the democratization of data which has allowed us to address problems across vast spatial scales."

Quintin has recently completed enhancements to the Plan2Adapt tool, providing localized climate projections across British Columbia for community planners assessing regional climate impacts. A part of this included integrating a new, multivariate downscaled climate projections dataset into Plan2Adapt, as described in the story above. Quintin says, "this provides users, including indigenous communities, with insights into regional climate projections, and future improvements are planned for how we assess climate impacts." These enhancements, which are now live on PCIC's site, will benefit PCIC's stakeholders by providing up-to-date climate data that is now more accessible for a wider range of users.

In Quintin's present work, he is exploring the feasibility of developing vector tile base-maps for our web applications. Whereas raster maps are made of mosaics of static images, vector maps use mathematical representations of a region (such as polygons), that can be dynamically updated and styled at any time. Quintin explains, "By using a single data source, we can create custom-styled and projected base-maps that emphasize relevant features and exclude unnecessary map elements. Vector tiles also support interactivity, such as feature highlighting, which enhances user engagement." They can reduce storage costs in multiple ways: they are smaller and require less storage compared to raster tiles, and a single dataset in vector format can serve multiple thematic layers and styles, reducing data redundancy and further reducing storage needs.

THE PACIFIC CLIMATE SEMINAR SERIES

The Pacific Climate Seminar series will resume on October 23rd, with a presentation by Dr. Mike Flannigan from Thompson Rivers University entitled, *Climate change and wildfires in BC–a hot and smoky future?* This will be followed by a seminar by Dr. Duo Chan from the University of Southhampton, who will speak on global climate data development on November 27th. This year's seminar series will close with a talk by Dr. Alex Cannon (ECCC) on December 11th, on the topic of using machine learning to make projections of future thunderstorms in Canada. More information on these talks will be provided through our site and mailing list in the coming weeks.

- Visit our site for more information on Dr. Flannigan's talk and to register.

PCIC STAFF NEWS

Several staff changes have occurred at PCIC recently. We have said goodbye to Regional Climate Impacts Theme Lead, Trevor Murdock, Research Associate, Dr. Dhouha Ouali, Programmer/Analyst, Eric Yvorchuk, Co-op Hydrologic Impacts Data Analyst, Narges Sayah and Data Intern, Forood Azargoshasbi. We have also welcomed Loni Feffer into our user engagement and training team.

Trevor was one of PCIC's first staff members, sitting at the table when the concept of a regional climate services centre was first being developed and articulated. From those early days, Trevor was instrumental in the development of the Regional Climate Impacts Theme and its major projects, including PCIC's downscaling efforts, regional impacts assessments, and tools such as Plan2Adapt and the PCIC Climate Explorer. Trevor brought his passion for climate science and deep concern for climate impacts to all of the projects he worked on, and it is with our utmost gratitude that we wish him the best as he moves to his new role as Manager at the Data and Products Office at the Canadian Centre for Climate Services.

While at PCIC, Dhouha's research spanned multiple projects, most recently including the development of gridded high-intensity rainfall data and the derivation of engineering design variables from climate model projections data. We wish Dhouha well in her new role as Environmental Programs Coordinator at the Canadian Centre for Climate Services. Eric assisted broadly in the development and maintenance of PCIC's various climate analysis tools, including the development of a prototype on-demand downscaling service. Narges's research was focused on analyzing the impacts of future climate change on extreme stream flows and droughts, and developing streamflow and water temperature hazard exposure indicators. And finally, Forood's short but productive stint at PCIC focused on the analysis of heavy precipitation simulated by high-resolution climate models over North America. We are grateful to all of the above for their contributions to PCIC, and wish them success in all of their future endeavours.

PUBLICATIONS

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Dunn, R. J. H. and 27 co-authors including **X. Zhang**, 2024: Observed global changes in sector-relevant climate extremes indices - an extension to HadEX3. *Earth and Space Science*, **11**, 4, e2023EA003279 doi:10.1029/2023EA003279.

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Sobie, S., D. Ouali, C. Curry, F. Zwiers, 2024: Multivariate Canadian Downscaled Climate Scenarios for CMIP6 (CanDCS-M6). *Geoscience Data Journal*, early view, doi:10.1002/gdj3.257.

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