PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE June 2025

PROJECT AND RESEARCH UPDATES

2024 – A Record-Breaking Year

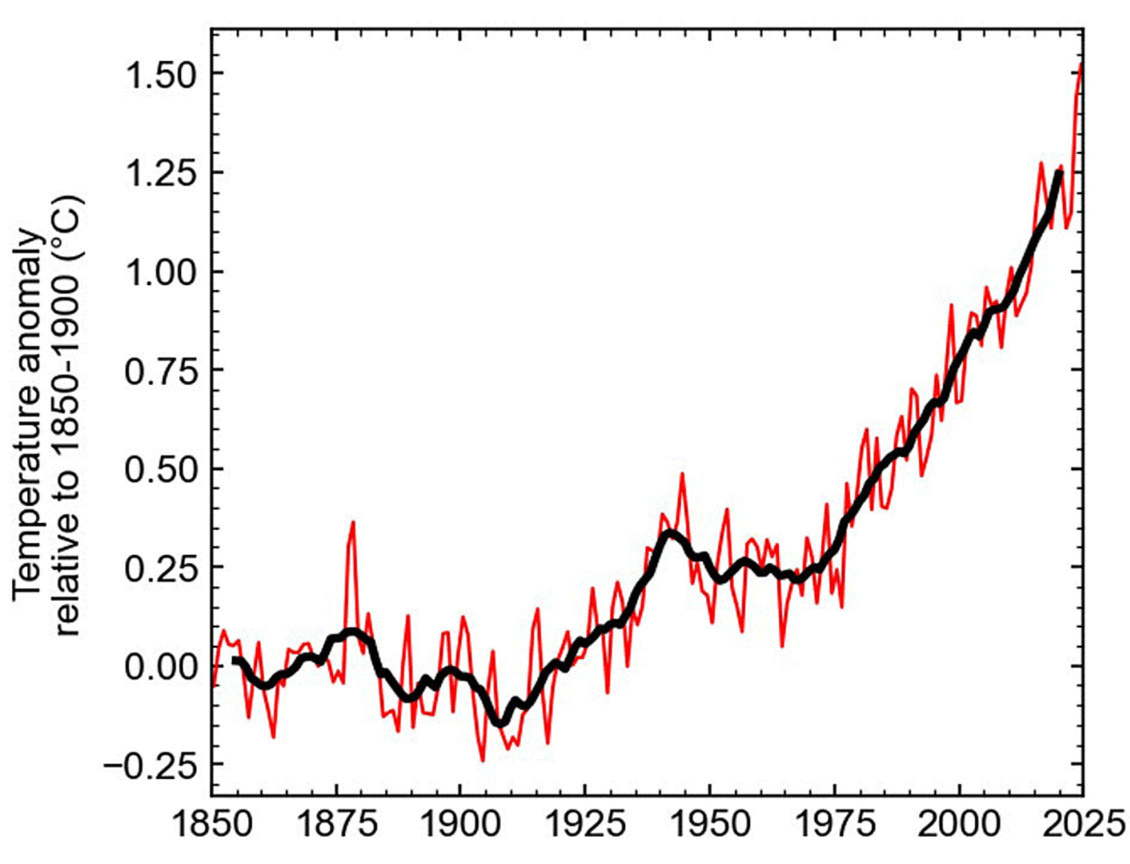

Figure 1: This figure shows the global annual mean surface temperature difference from the 1850-1900 preindustrial baseline period, based on four datasets, taken from Forster, P.M. et al (2025), under review.

According to organizations that monitor and analyse global surface temperatures, 2024 was the warmest year yet, with a best estimate of 1.52 °C above the preindustrial (1850-1900) level, eclipsing the previous record set in 2023. Of this, 1.36 °C is attributable to anthropogenic sources. In response to continuing anthropogenic greenhouse gas emissions, the last decade now contains the ten warmest years in the instrumental record, with an average warming of 1.24 °C above the preindustrial, of which 1.22 °C is anthropogenic in origin.

It is worth noting that, while 2024 was a record-breaking year, its being 1.52 °C above preindustrial temperatures does not mean that the 1.5 °C Paris guardrail, meant to limit the destructive impacts of climate change, has been breached. The temperature limit for the Paris guardrail is determined by long-term global averages, not individual years. Nevertheless, according to a team of top climate scientists, the 1.5°C Paris guardrail might be reached or exceeded on a long-term basis in around five years if the world's nations don't act now to substantially reduce emissions.

While new global surface temperature records don't always imply records for smaller regions of the Earth, 2024 is tied with 2010 as Canada's warmest year since record-keeping began in 1948, according to Environment and Climate Change Canada.

British Columbia in 2024

According to a recent analysis by PCIC presented at the annual Department of Fisheries and Oceans "State of the Pacific Ocean" meeting, 2024 was the second-warmest year in British Columbia since 1940, with precipitation that was below normal to near-normal (Figure 2). This was slightly less hot and substantially less dry than 2023, although the drought persisted across the northeast part of the province throughout the year.

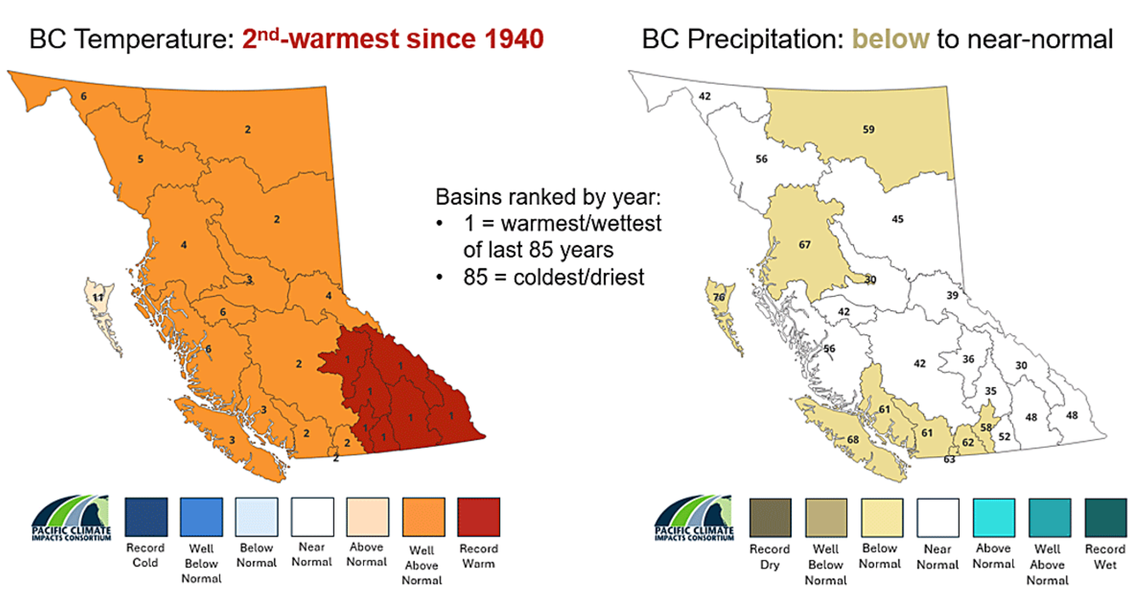

Figure 2: This figure shows annual temperature and precipitation rankings in BC, divided into 23 snow basins used by the River Forecast Centre. The rankings are determined over all years since 1940.

Compared to the average of all years since 1940, 2024 started with temperatures that were well above normal and, for the province as a whole, warmer than average conditions remained throughout the year. By the fall, temperatures in northern BC had returned to normal, but in the south, temperatures remained well above seasonal norms, with a heatwave gripping the southern part of the province in early September. The winter of 2023-2024 began with record-low snowpack levels across the province, a continuation of drought conditions tracing back to the fall of 2022. Drought conditions worsened throughout the spring with central BC seeing below-normal precipitation through the spring and into the growing season. Despite a return to near-normal precipitation by summer, hydrologic drought persisted until the arrival of regular Pacific storms in mid-September, easing drought conditions and bringing relief to much of BC. Well above normal precipitation through November and December continued to ease drought conditions up to the end of the year, with the exception of northern BC.

One influence on the conditions of 2024 that bears mention is the El Niño-Southern Oscillation (ENSO), a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean that has implications for climate condition across the globe and in BC. ENSO began the year in an El Niño state, which tends to bring warmer, dryer conditions to our province, consistent with what was seen early in the year. This subsided to neutral conditions in June 2024 before briefly entering a weak La Niña state (which tends to have the opposite effects as El Niño on BC seasonal climate) by December 2024.

Applying Multivariate Downscaling to the Fraser River Basin

While climate models can simulate Earth system processes at coarse scales (i.e., at resolutions of a few hundred kilometres), they generally cannot resolve the small-scale details that are important for regional climate adaptation. One method of bridging this gap between spatial scales is statistical downscaling, which uses known relationships between large- and small-scale phenomena to translate climate model output into local-scale information. Often, this is done for individual climate variables, such as temperature or precipitation, independently, but this does not preserve the known dependence between variables. In a recent peer-reviewed study, PCIC researchers tested a multivariate downscaling approach, known as the n-dimensional Multivariate Bias Correction (MBCn) scheme, that is designed to preserve these relationships. They found that it produced accurate daily, seasonal and annual downscaled results for nine climate variables in the Fraser River Basin, while preserving the interdependencies among the variables. This is important because many climatic phenomena arise from the compounding effect of more than one variable, for example, when hot and dry conditions result in heightened drought and wildfire risk.

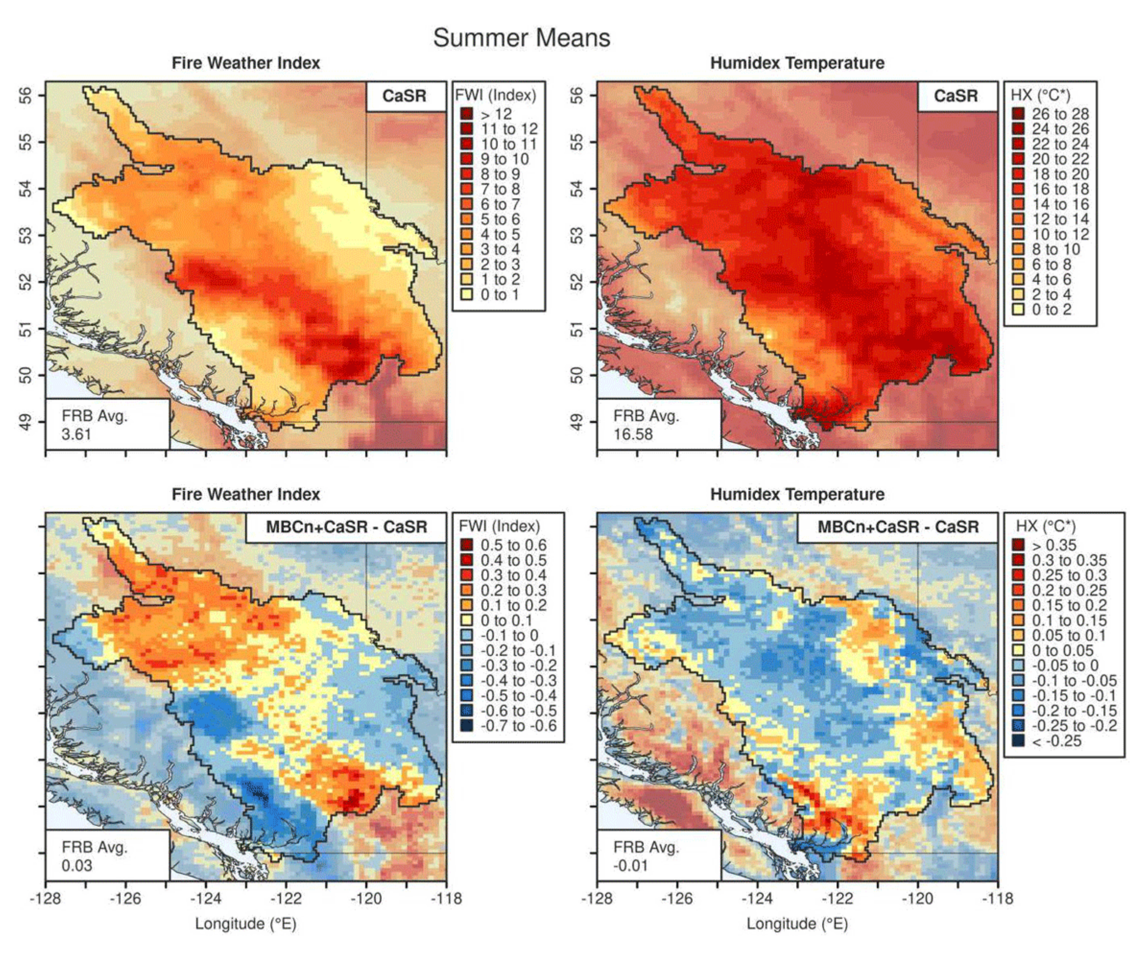

Figure 3: This figure shows the comparison of summer mean values from the perfect model test for Fire Weather Index (left panels) and Humidex (right panels). The top panels show the mean values from CaSR over 1980-2018, and the bottom panels display the differences between downscaled results from MBCn and the original data from CaSR. Note the difference in the scale used in the two panels, which show that the differences between MBCn-downscaled CaSR and CaSR itself are small compared to the target data values. (Figure taken from Sobie, Curry and Ben Alaya, 2025.)

PCIC's team performed two tests of the multivariate downscaling method. The first employed a so-called "perfect model" approach, wherein a high-resolution (10 km by 10 km) dataset for the 1980-2018 period called the Canadian Surface Reanalysis Version 2.1 (CaSR) was coarsened to mimic global climate model output (280 km by 280 km) and then downscaled back to the original resolution using MBCn. The researchers found that MBCn reproduced most of the CaSR variables well, except for certain climate extremes and indices over the more mountainous areas of the Fraser basin. As shown in Figure 3, the summertime Humidex index (which uses temperature and humidity to describe how hot it feels outside) is modestly overestimated by MBCn in the narrow valleys in the southern part of the basin, and in the Rocky Mountains in the east, and underestimated in the interior of the basin. A more complex variable, the Fire Weather Index (a rating of fire-favourable conditions that included temperature, precipitation, humidity and wind), displays a more nuanced pattern of difference, although in relative terms, the downscaling errors are still modest.

In another, less idealized, test, the researchers used multiple simulations from the Canadian Earth System Model Version 5 (CanESM5; 280 km x 280 km) as downscaling inputs, again with CaSR as the target data. This time, both MBCn and a simpler, univariate method were used to downscale the same set of variables, to determine whether MBCn produced superior results. By comparing correlations between all possible pairs of the nine downscaled variables to the same relationships in the original CaSR variable pairs, PCIC's team demonstrated that MBCn outperformed the univariate approach for nearly all variables. Since the Fraser basin is a challenging region to simulate, due to the complex topography and oceanic influences that make the climate highly spatially variable, there is good reason to expect that MBCn will perform as well or better over other domains. Moreover, the larger set of downscaled variables and the fact that their mutual dependences are preserved makes these MBCn-downscaled outputs valuable for hydrologic modelling and other applications across Canada. PCIC is grateful for the financial support of Environment and Climate Change Canada which made this project possible.

- Read the paper.

Extreme Streamflow on the PCIC Climate Explorer Tool

PCIC's Climate Explorer (PCEX) now allows users to view streamflow design values for the Fraser and Peace River basins based on the CanESM2 large ensemble. PCEX is a powerful tool that allows users to locate, visualise and download data describing projected future climate conditions anywhere in Canada. With the new feature, users can access streamflow design values as a gridded product (for 2-, 20-, 50-, 100- and 200-year events), for historical and future periods, over a region including the Peace, Fraser and Upper Columbia basins, using a map-based point-and-click interface.

The design flood values were developed by PCIC researchers with the support of the BC Ministry of Transportation and Transit (MOTT), using the Variable Infiltration Capacity model with glaciers (VIC-GL), driven by a 50-member large ensemble of runs from the second version of the Canadian Earth System Model (CanESM2-LE). This large ensemble approach makes it easier to catch and count rare events, from which changing return periods can be estimated. Design flood values for each high-resolution grid cell (an area of approximately 30 km2) are based on streamflow that enters from the area upstream of the selected cell. This means the size of areas ranges from one grid cell to the full 665,000 km2 of the catchment. These flood design values were provided for discrete 30-year windows from 2015 to 2085. This builds on previous work supported by MOTT, beginning with a pilot project where the Pacific Climate Impacts Consortium estimated historical and future design flow values for the upper Fraser watershed. This work is intended to support engineers as they incorporate climate change considerations into their infrastructure design process.

- Access the streamflow design values on the PCIC Climate Explorer.

PCIC at Indigenous Climate Events

PCIC is committed to advancing reconciliation by collaborating with First Nations, Indigenous communities, and organizations across BC to support community-led climate planning and knowledge sharing. PCIC participated in two Indigenous climate events this Spring, beginning with the 4th annual Indigenous Climate Resilience Forum hosted by the BC Ministry of Energy and Climate Solutions, Climate Action Secretariat. This year's forum focused on *Today, Tomorrow & Beyond, Climate Resilience One Step at a Time*, with three days of speakers and discussions connecting Indigenous communities, government, and climate organizations to discuss the impacts of climate change and fostering resilience. Ed Beard and Loni Feffer from PCIC's regional climate impacts team presented an introduction to climate projections and how climate data tools can support Indigenous resilience work.

In addition, PCIC was invited to give multiple presentations at the BC First Nations Climate Gathering hosted in Musqueam by the First Nations Summit. The two-day in-person event featured a wide range of presentations about climate change impacts and projections that will affect future generations. First Nations council members, Indigenous organizations, scientists, youth, and activists from across the province gathered to attend diverse sessions on climate change and to learn from one another. PCIC Director Dr. Xuebin Zhang and Regional Climate Impacts Lead Dr. Charles Curry gave multiple presentations, starting with a plenary presentation on past and future climate, followed by sessions on regional climate impacts, wildfire and sea level rise. At our booth, staffed by Loni Feffer (PCIC's Indigenous Communities Climate Knowledge Translator), we had many engaging conversations and connected with local First Nations and other participants regarding their ongoing climate-related work. We are grateful for the invitation to participate in these discussions, and for the opportunity to meet around our shared interests in increasing community climate resilience.

STAFF PROFILE: DR. TONG LI

Dr. Tong Li is a Post-doctoral Scientist at PCIC, where her research focuses on studying how the climate has changed in the past and how it will evolve in the future. Currently, she is developing and applying observational constraint techniques that use physically-based empirical relationships between aspects of the climate system to refine our estimates of how our climate responds to external forcing, such as increasing atmospheric greenhouse gas concentrations, on global and regional scales. Dr. Li is currently working on understanding the source of skill from the constraints—the physical mechanisms that underlie the observed relationships—as well as treating historical climate change and future projection problems within a unified statistical framework. An example of this work, has recently been published in the journal *Science Advances*.

Reflecting on what draws her to the work, she says, "One of the most exciting and interesting things is that I find several concepts, statistical methods, and ideas can be connected. Techniques used in different studies can be unified under the same statistical framework—what differs is simply the way they are implemented." This means that the same method can be applied across different areas of research to solve different but interconnected problems. Dr. Li continues, "This perspective allows me to approach problems from a broader viewpoint and deepens my understanding. Even while working on a single project, I find that many concepts can be applied interactively across different contexts—but, of course, a correct understanding of these concepts is essential."

Dr. Li is grateful to be able to add to the body of research that will ultimately inform climate adaptation. Discussing how her research supports decision makers, she explains, "estimating the contribution of human activities to past warming and reliably projecting future warming in Canada, with as small an uncertainty as possible, is key. Our research supports local and regional adaptation efforts by providing scientifically grounded insights that help stakeholders prepare for and respond to climate-related challenges."

THE PACIFIC CLIMATE SEMINAR SERIES

As reported in our last newsletter, the Pacific Climate Seminar Series opened this semester with a talk by Dr. Alex Cannon from Environment and Climate Change Canada on January 29th, titled, *Towards thunderstorm projections for Canada using machine learning and HighResMIP climate model simulations*. This was followed by a talk on February 26th by PCIC's Dr. Tong Li, who shared her research on the topic of constrained projections in her presentation, *Novel implementations of observational constraints for understanding past and future climate change in Canada and the world*. On March 26th, Dr. Nathan Lenssen from the Colorado School of Mines delivered a presentation titled, *Strong El Niño events lead to robust multi-year ENSO predictability*.

This semester's talks closed with a presentation on May 21st by Dr. Stephan Gruber from Carleton University, titled, *What keeps us from generating actionable permafrost information.* Information about talks in the fall semester will be released once it becomes available.

- Read more about Dr. Cannon's talk and watch it, here.
- Read more about Dr. Li's talk and watch it online.
- Read more about Dr. Lenssen's talk and watch a recording of it.
- Read more about Dr. Gruber's talk.

PCIC STAFF NEWS

We are pleased to be hosting PCIC alumna Dr. Qiaohong Sun as a Visiting Professor. Dr. Sun is currently a Professor at Nanjing University of Information Science & Technology in Nanjing, Jiangsu, China. She arrived at PCIC on May 1st and will be working with us until the end of July. While at PCIC, Dr. Sun will be conducting collaborative research with PCIC's team on historical changes in extreme precipitation in different parts of the world, as well as projected future changes in peak streamflow in BC.

PUBLICATIONS

Chai, Y., C. Miao, P. Gentine, L. Mudryk, C.W. Thackeray, W.R. Berghuijs, Y. Wu, X. Fan, L. Slater, Q. Sun, and **F.W. Zwiers**, 2025: Overcoming the Northern Hemisphere snow water resources paradox. Accepted, *Nature Climate Change*.

Li, C. **F.W. Zwiers**, **X. Zhang**, E.M. Fischer, F. Du, J. Liu, J. Wang, Y. Liang and L. Yuan, 2025: Constraining the entire Earth system projections for more reliable climate change adaptation planning. *Science Advances*, **11**, 9, doi: 10.1126/sciadv.adr5346.

Li, T., **F.W. Zwiers** and **X. Zhang**, 2025: Should we think of observationally constrained multi-decade climate projections as predictions? *Science Advances*, **11**, 20, doi:10.1126/sciadv.adt6485.

Li, Y., T. Wang, J. Yan and **X. Zhang**, 2025: Improved Optimal Fingerprinting Based on Estimating Equations Reaffirms Anthropogenic Effect on Global Warming. *The Journal of Climate*, **38**, 8, 1779-1790, doi: 10.1175/JCLI-D-24-0193.1.

Sobie, S.R., **C.L. Curry** and **M.A. Ben Alaya**, 2025: Evaluation of a Multivariate Statistical Downscaling Method over Canada's Largest Pacific Basin. *Atmosphere-Ocean*, **63:1**, 1-20, doi:10.1080/07055900.2025.2478829.

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