PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE October 2021

PROJECT AND RESEARCH UPDATES

Assessing Changing Flood Risk

One of the primary impacts to infrastructure from climate change is increased flood risk. In order to address the potential risks associated with flooding, the British Columbia Ministry of Transportation and Infrastructure (BCMoTI) supported the Pacific Climate Impacts Consortium (PCIC) in a pilot project to provide guidance on design flood values (2-, 20-, 50-, 100- and 200-year events). The guidance provides information for historical and future periods and makes the underlying data accessible as a gridded product via PCIC's Climate Explorer tool. This work focused on the Upper Fraser, a region in northern British Columbia covering 34,200 square kilometres (km^2) upstream of Prince George, BC, 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 grid cell (about 30 km^2), with design flood values for each grid cell based on streamflow routed from the area upstream of the selected cell.

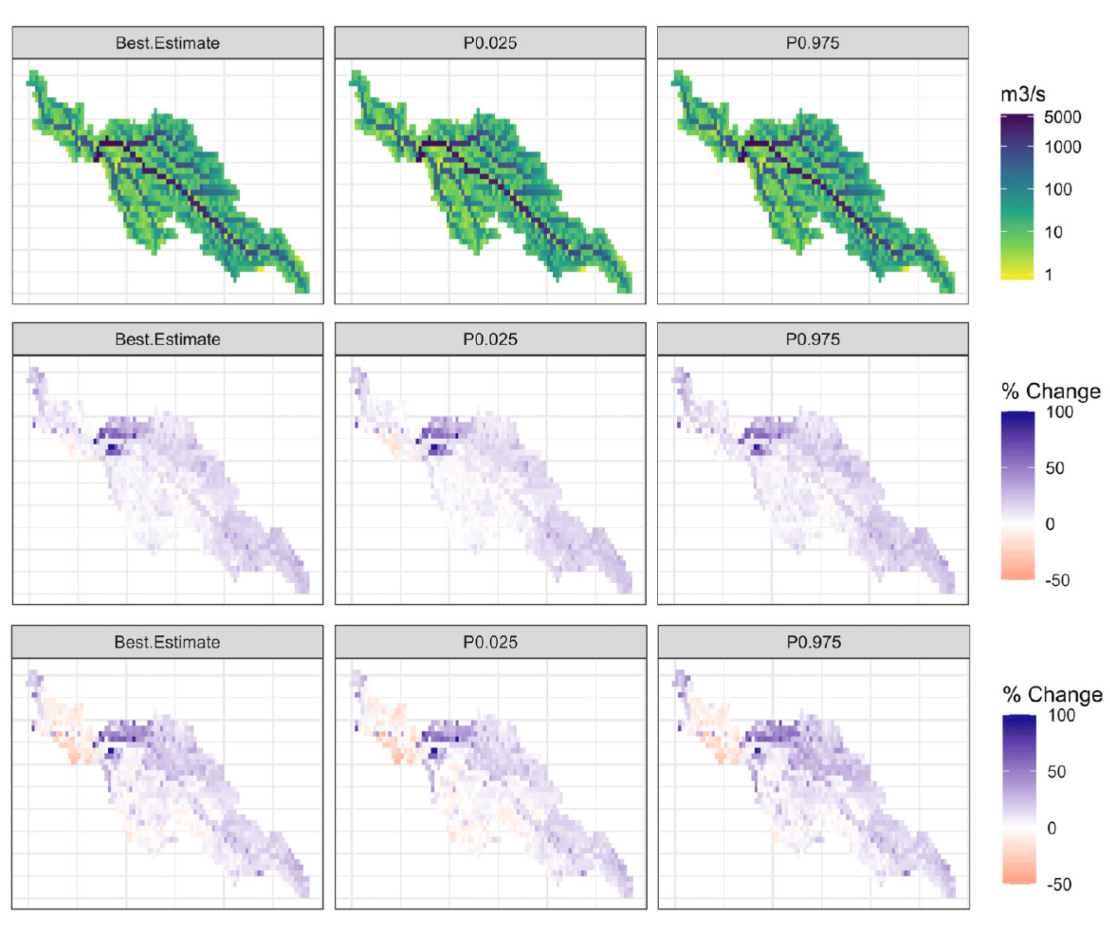

Figure 1: This figure shows the absolute (m^3/sec) 1961-1990 (top) and projected relative change (%) in annual peak flow magnitude for 100-yr return period events for 2040-2069 (middle) and 2070-2099 (bottom) as simulated by the VIC-GL hydrologic model when driven by the second version of the Canadian Earth System Model (CanESM2) under the RCP8.5 greenhouse gas emissions scenario. Results are shown for the 2.5th percentile (left), best estimate (middle) and 97.5th percentile (right). Note that the absolute values in the top panel are presented on a logarithmic scale.

This work takes advantage of hydrologic projections produced by PCIC using the Variable Infiltration Capacity model with Glaciers (VIC-GL) hydrologic model driven using output from a large ensemble of runs from a global climate model. This large ensemble, which is based on the Representative Concentration Pathway 8.5 (RCP 8.5) high-emissions scenario, provides enough samples of peak flow to allow the statistically robust estimation of long return-period events that occur very infrequently.

The design of roads, bridges, culverts and other structures often requires estimates of peak-flow quantiles. These are values of peak flow that have defined probabilities of being exceeded, or equivalently, specified return periods. In this project, these return periods varied from 2-years up to 200-years. When we rely on small sample sizes, as is typically the case when using observational data, quantiles often correspond to return periods that are substantially longer than the observational data that we have to work with. It can be difficult to estimate, for example, the intensity of events that are expected to occur only once every 200 years on average, from only 30 years of data. The benefit of using a large ensemble of hydrologic simulations is that it provides enough samples that even the quantiles corresponding to very rare 200-year events can be estimated directly. For example, for a given 30-year period such as 1961-1990, the large ensemble simulation of the Fraser provides 1500 years of simulated streamflow data, and thus 1500 realizations of annual maximum streamflow, that is representative of that period.

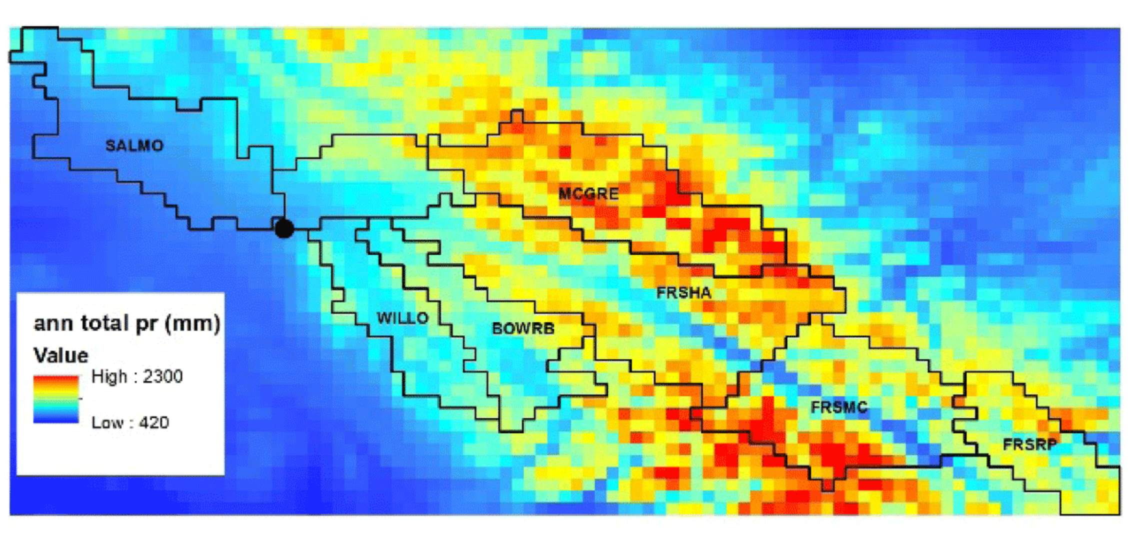

Figure 2: Mean annual precipitation for the Upper Fraser study region with sub-basin outlines over the 1961-1990 period. The sub-basins are as follows: Bowron River (labelled BOWRB), Fraser River at Hansard (FRSHA), Fraser River at McBride (FRSMC), Fraser River at Red Pass (FRSRP), McGregor River MCGRE), Salmon River (SALMO) and Willow River (WILLO). The outlet of the entire study area is indicated by the black dot.

Flows at any point are a result of water from precipitation, melting snow and ice, and subsurface flows that entered the drainage system of a river basin upstream of that point. Thus, larger peak-flow values occur where the flow of water concentrates in the main valley-bottom channels. Consequently, the largest peak streamflow values in the domain occur along the mainstem of the Fraser River (Figure 1, top panels). The relative changes in peak-flow magnitude that are projected to occur at each grid cell are influenced by a number of factors, with the relative importance of each factor varying as a function of spatial scale. For cells draining very small areas, individual grid cell changes will be affected more by local elevation, relief (the amount of variation in elevation), and changes to the local climate, whereas peak-flow changes in cells draining larger areas are likely to be influenced by changes occurring in distant (potentially wetter) upstream locations. Consequently, 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. For example, for the 100-year event there is no clear relationship to either topography, climate, or the spatial arrangement or structure of the river network for either the middle or end of the century (Figure 1, middle and bottom panels, respectively). Nevertheless, when spatially integrated, the influence of climate (represented by precipitation in Figure 2) can be seen at the sub-basin scale (Figure 3).

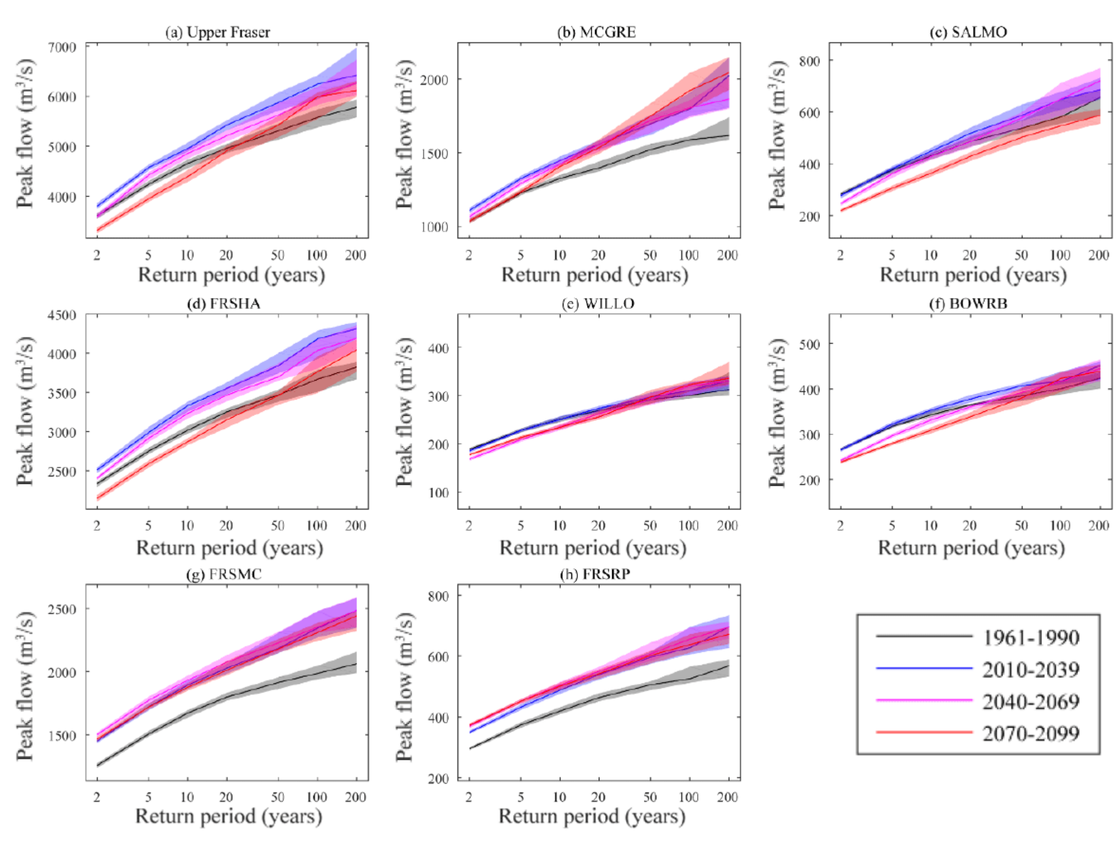

Figure 3: Flood frequency plot of annual maximum daily streamflow for the outlets of seven sub-basins and four 30-year periods as estimated from the VIC-GL large ensemble hydrologic simulation driven by the CanESM2 global climate model using the RCP8.5 emissions scenario. Drainage basins are defined and labelled as in Figure 2. The upper left panel (labelled Upper Fraser) shows results for the outlet of the entire study region. Best estimates are given by the solid lines and the ribbons show 95% confidence intervals.

For the wetter sub-basins (McGregor River, Fraser River at Red Pass and Fraser River at McBride), which are located in the Rocky Mountains, there is a clear signal of increasing design flow magnitude for all return periods and all three future periods. In the drier regions (Bowron River, Willow River and Salmon River sub-basins) results show little change or decreasing magnitudes in the early- and mid-century, but there is a clear trend of declining design values for all but the largest return periods by end of the century (Figure 3). For the larger Fraser River at Hansard sub-basin, and for the outlet of the entire study domain (Upper Fraser in Figure 3), the projections are more mixed. In these cases, design flow values are projected to increase in early- and mid-century. By the end of the century, however, projections suggest that small events with return periods shorter than about 20-50 years will decrease in magnitude, whereas large events with return periods longer than 100 years may still increase in magnitude.

The hydrologic model output generated for this research is available under the Extreme Streamflow tab on the PCIC Climate Explorer. The associated report, *Future Design Flood Values in the Upper Fraser River Basin Using the CanESM2-LE*, is available from PCIC's Publications Library.

- Access the PCIC Climate Explorer.
- Read the the report.

Congratulations to the Recipients of the 2021 Nobel Prize in Physics

The Nobel Prize in Physics was recently awarded to three scientists whose work increased humanity's understanding of complex systems: Drs. Syukuro Manabe of Princeton University, Klaus Hasselmann of the Max Planck Institute for Meteorology and Giorgo Parisi of Sapienza University. The inclusion of Drs. Manabe and Hasselmann marks the first time that the Nobel Prize in Physics has been awarded to researchers whose primary work is within climate science.

PCIC extends its heartfelt congratulations to all of the recipients of the 2021 Nobel Prize in Physics, for their work in understanding the complex systems that make up our world.

- Read more about this year's laureates.

2020-2021 PCIC Corporate Report Released

The PCIC 2020-2021 Corporate Report is now out. Over the 2020-2021 fiscal year, PCIC continued to push at the boundaries of knowledge in climate science. The year also saw an expansion of the climate services that PCIC offers. Some of the highlights of PCIC's work this year include expanding PCIC's hydrologic projections, supporting the management of several fish habitats in BC, the analysis of statistical downscaling methods and their application across Canada, supporting decision makers in the public and private sectors, the analysis of the properties of extreme precipitation and leading the development of modules for ClimateData.ca.

PCIC also added to the data and analysis tools we offer, adding data to the Pacific Climate Data Set, adding features to the PCIC Climate Explorer, rewriting the Plan2Adapt tool, adding new features and hydrologic projections to the PCIC Climate Explorer, and continuing to develop a new data portal for Canada's western Arctic region.

- Read about these stories and more in the 2020-2021 Corporate Report.

Supporting the Management of BC Salmon Habitats

Pacific salmon are culturally and economically important in British Columbia, and occupy a central position in food webs and nutrient cycling in BC's freshwater and marine ecosystems. Anthropogenic climate change is expected to affect freshwater and marine salmon habitats, impacting the different stages of the salmon life cycle. In partnership with researchers from the 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 habitats that takes climate change into consideration.

PCIC researchers have are applying two hydrologic models to explore the potential effects of climate change in BC's freshwater salmon habitats. Using VIC-GL, they are simulating streamflow and water temperature under present and future climate conditions in virtually all of BC's river basins that drain to tide water, representing an area of ~427,000 square kilometres. These simulations will in turn inform large-scale salmon risk-assessment. To support small-scale salmon risk-assessment in a selected set of sub-basins, the Raven model has recently been deployed to eight sub-basins: the Auke, Babine, Chilko, Quesnel, Somass, Stuart-Takla, Tahltan 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 region 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 the hydrologic modelling and risk assessment work will be delivered to fisheries managers and the public via a collection of online tools that will inform science-based policies and decisions in support of wild salmon conservation.

Talks at the Pacific Climate Seminar Series

The Pacific Climate Seminar Series started again for the fall on Wednesday, Sept. 29th at one p.m., with a talk given by Dr. Xuebin Zhang, Senior Research Scientist at the Climate Research Division of Environment and Climate Change Canada. He spoke on, *Weather and climate extremes in a changing climate: main findings from the IPCC AR6 WG1 assessment*.

The next talk in the series will be delivered by PCIC Post-Doctoral Scientist Dr. Qiaohong Sun on Wednesday October 27th at 3 p.m. She will be talking on, *Observed changes in precipitation extremes and their attribution at the global, continental, and regional scales*.

- Read more about Dr. Zhang's talk.
- Read more about, and register for, Dr. Sun's talk.

STAFF PROFILE: DR. DHOUHA OUALI

Dr. Dhouha Ouali joined PCIC as a research associate in the spring of 2017, following an early research career spent studying the regional frequency of hydro-meteorological extremes. Her initial research was focused on studying the impacts of high wind-speed resulting from extratropical cyclones on the power transmission grid across British Columbia. During the last two years, her work has been focused on producing updated engineering design values that account for projected changes in Canada's climate. This involves estimating return levels of several climate variables using models, and estimating the change factors that relate design values for the current climate to those in the future for different amounts of global warming.

Dr. Ouali is currently implementing and testing the performance of a downscaling and bias correction method to better account for the interdependence between temperature and precipitation. She is also working on generating an improved version of a dataset of daily maximum and minimum temperature and daily precipitation observations on which to train the downscaling method. Dr. Ouali explains that what fuels her interest in this work is the sense of progress she experiences with each new phase of research, working with a variety of datasets and methods, and different types of analysis, and how this allows her to continually learn something new and provide others with useful information on climate issues. "What I find interesting about statistical downscaling and climate science in general, is that it involves several components, ranging from sophisticated statistical methods to the manipulation of large sets of output from climate models, and computational tasks to provide stakeholders and users with reliable information about current and future climate conditions." She explains that, from the operational side, "it is always exciting for me to produce a climatology at high resolution with the smallest possible bias. This can serve as an important tool for a number of sectors to gain insights on the plausible impacts of climate change in the future."

PCIC STAFF NEWS

PCIC bids a fond farewell to Dr. Nigus Demelash Melaku, Nikola Rados, and Eric Yvorchuck. Dr. Melaku was a post-doctoral research hydrologist at PCIC whose research was focused on quantifying future climate-driven changes in river discharge and temperature in BC. Nikola and Eric were both a part of PCIC's Computational Support Group, Nikola as a DevOps Specialist and Eric as an Assistant Programmer (Co-op). They worked on the Data Analytics for Canadian Climate Services project. We thank Nigus, Nikola and Eric for the important contributions that they made helping PCIC achieve its objectives to serve its users and wish them all the best for the continued development of their careers.

We are happy to welcome back Shelley Ma as our Administrative Coordinator who provides executive support to the Director and the Lead Planning and Operations to facilitate day-to-day operations. In addition, we extend our congratulations to PCIC Programmer/Analyst Lee Zeman, who is moving to a position as the new Hydrologic Programmer/Analyst. He will be developing the information infrastructure and web-based tools to support fisheries planning and management with the support of the BC Salmon Restoration and Innovation Fund (BCSRIF). We are also happy to welcome Dr. Pei-Ling Wang, who has joined the Climate Analysis and Monitoring Theme as a Post-Doctoral Researcher. Her work at PCIC will be focused on developing uncertainty estimates to accompany high-resolution climate data, integrating remote sensing data into PCIC's climate maps, creation of high-resolution time-series maps of BC's climate, characterizing climate extremes in BC and developing data sets to drive hydrologic models.

PUBLICATIONS

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