2017 2018

PACIFIC CLIMATE IMPACTS CONSORTIUM

A MESSAGE FROM PCIC'S CORPORATE LEADERSHIP

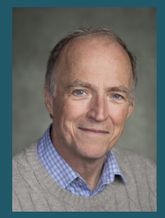
The challenges presented by climate change continue to drive demand for the wide range of services that PCIC offers, and consequently this fiscal year saw steady growth in research partnerships and projects from multiple sectors, both within British Columbia and beyond.

Our partnerships are based on a highly collaborative, user-needs driven process, with common goals to build and strengthen capacity to address climate change and variability, and provide a scientific basis for policy development and decision-making. Our work benefits from long-term partnerships that have continued to strengthen and grow in their depth and richness, and also from many new partnerships developed over the past year.

The successful service delivery and outcomes highlighted in this report represent the opportunity side of the challenges we face, and it is thanks to the support and commitment of all our partners that we continue to grow in our ability to meet the needs of our users and address important questions in regional climate science and hydrology.

Dr. David Castle
Chair, Board of Directors

Thomas White
Chair, Program Advisory Committee

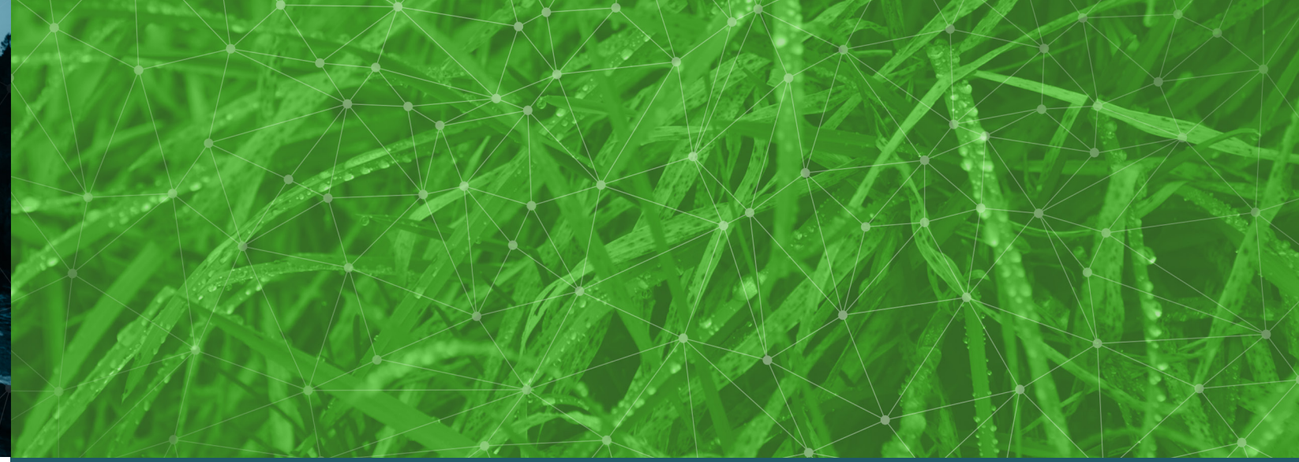


Dr. Francis Zwiers
PCIC Director

GOVERNANCE

BOARD OF DIRECTORS, FISCAL YEAR 2017-2018

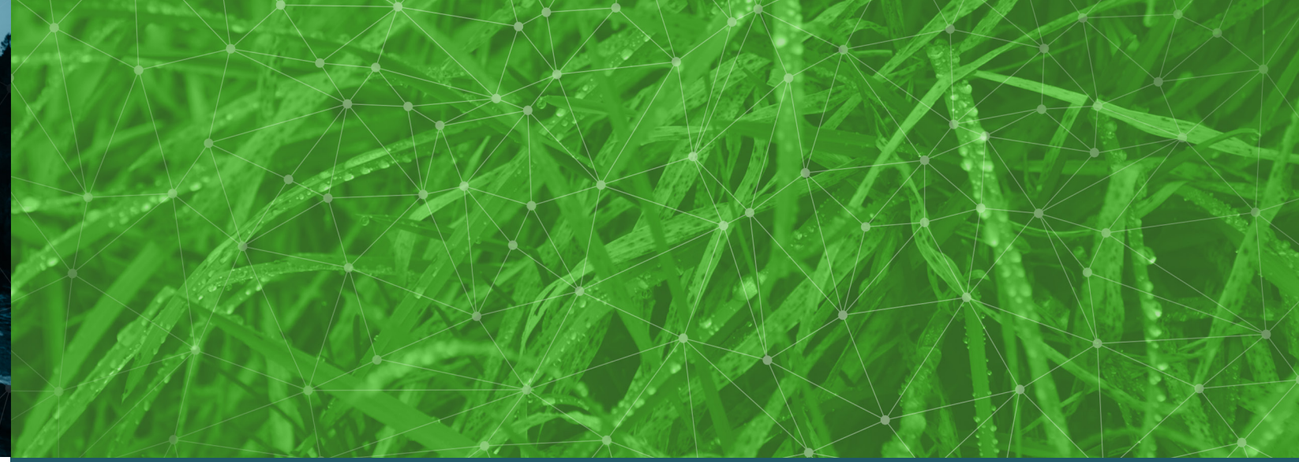
- David Castle (Chair), Vice President Research, University of Victoria
- James Barnes, Manager, Corporate Engineering Initiatives, BC Ministry of Transportation & Infrastructure
- Don Barnhardt, General Counsel, University of Victoria
- Alain Bourque, Directeur Général, Ouranos
- Charles A. Lin, Director General, Atmospheric Science and Technology Directorate, Environment and Climate Change Canada
- Johannes Feddema, Professor and Chair, Department of Geography, University of Victoria
- Heather Matthews, Director, Generation Resource Management, BC Hydro
- Adam H. Monahan, Professor, School of Earth and Ocean Sciences, University of Victoria
- Tom Pedersen, Professor, School of Earth and Ocean Sciences, University of Victoria
- Terry Prowse, Professor, Department of Geography, University of Victoria
- Sybil Seitzinger, Executive Director, Pacific Institute for Climate Solutions, University of Victoria
- Laird Shutt, Director General, Atmospheric Science and Technology Directorate, Environment and Climate Change Canada
- Francis Zwiers, Director, President & CEO, Pacific Climate Impacts Consortium, University of Victoria



PROGRAM ADVISORY COMMITTEE, FISCAL YEAR 2017-2018

- Thomas White (Chair), Manager, Science and Adaptation, Climate Action Secretariat, BC Ministry of Environment
- Yapo Allé-Ando, Water Resources Engineer, Teck Resources Ltd.
- David Campbell, Section Head, River Forecast Centre, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Nathan Gillett, Manager and Research Scientist, Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada
- Adelana Gilpin-Jackson, Specialist Engineer, BC Hydro
- Cathy LeBlanc, Senior Planner, BC Ministry of Community, Sport and Cultural Development
- Kate Miller, Manager, Environmental Initiatives, Cowichan Valley Regional District
- Dirk Nyland, Chief Engineer, BC Ministry of Transportation and Infrastructure
- Leigh Phillips, Science Writer, Pacific Institute for Climate Solutions, University of Victoria
- Stephanie Smith, Manager, Hydrology and Technical Services, BC Hydro
- Dave Spittlehouse, Research Climatologist, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Tim Takaro, Professor, Faculty of Health Sciences, Simon Fraser University
- Stephanie Tam, Water Management Engineer, BC Ministry of Agriculture
- Francis Zwiers, Director, Pacific Climate Impacts Consortium

PCIC'S PARTNERS



OUR PARTNERS

PCIC provides a broad set of climate services that are made possible by its network of partners that extends through the public and private sectors. Maintaining these partnerships allows PCIC to better understand the needs of its users and better share the research and data that it produces. PCIC collaborates with partner organizations, sharing climate data and working toward overlapping research goals, in order to piece together a more complete picture of British Columbia's changing climate.

- BC Agriculture and Food Climate Action Initiative
- BC Agricultural Climate Adaptation Research Network
- BC Blueberry Council
- BC Hydro
- BC Ministry of Agriculture
- BC Ministry of Health
- BC Ministry of Municipal Affairs and Housing
- BC Ministry of Community, Sport and Cultural Development
- 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
- Capital Regional District
- Canadian Centre for Climate Modelling and Analysis
- Canadian Meteorological and Oceanographic Society
- Canadian Network for Regional Climate and Weather Processes
- Canadian Sea Ice and Snow Evolution Network
- Canadian Statistical Sciences Institute
- City of Vancouver
- City of Victoria
- Columbia Basin Trust
- Compute Canada
- Comox Valley Regional District
- Cowichan First Nation
- Engineers and Geoscientists BC
- Engineers Canada
- Environment and Climate Change Canada
- FPInnovations
- Fraser Basin Council
- Fraser Health
- Global Water Futures
- Government of Northwest Territories Environment and Natural Resources
- Indigenous and Northern Affairs Canada
- Island Health
- Metro Vancouver
- Marine Environmental Observation Prediction and Response Network
- National Oceanic and Atmospheric Administration
- National Research Council
- Natural Resources Canada
- Oregon State University, PRISM Climate Group
- Ouranos Inc.
- Pacific Institute for Climate Solutions
- Rio Tinto
- Splatsin First Nation
- Statistical and Applied Sciences Institute
- Toquaht First Nation
- Université du Québec à Montréal
- University of British Columbia
- University of Northern British Columbia
- University of Saskatchewan
- University of Washington, Climate Impacts Group
- University of Victoria
- Vancouver Coastal Health

PROGRAMS AND SERVICES

The Pacific Climate Impacts Consortium, (PCIC) is a regional climate services provider serving British Columbia and surrounding areas. PCIC's applied research program is comprised of three interrelated themes that deal with different aspects of climate change as it affects this region: Hydrologic Impacts, Climate Analysis and Monitoring, and Regional Climate Impacts. These themes perform applied research that includes hydrologic modelling, statistical analysis and the downscaling of global climate model data. They provide data, analysis and interpretation to PCIC's users. The themes are supported in their work by the Computational Support Group and an Administration and Communications team. The Computational Support Group manage and develop the computational resources that enable PCIC's work, and develop the web-based tools that allow wide access to climate data and analysis. These web-based tools and PCIC's Data Portal serve up large amounts of data to researchers, planners and contractors. The Administration and Communications team keep PCIC running smoothly, ensure PCIC's results are communicated to the users that would be served by them and perform some interpretation of important results from the broader field of climate science. PCIC works directly with its users to develop materials suited to their needs, a process that facilitates two-way learning that helps users to work with climate data and PCIC to better understand the needs of the stakeholders it serves.

HYDROLOGIC IMPACTS

PCIC's Hydrologic Impacts theme seeks to understand how the changing climate will affect water resources in British Columbia and the surrounding area. This includes investigating potential changes to the availability of water for power generation and agriculture, understanding the timing of river flows, the amount of water traveling through the province's many basins and the temperature of water in rivers and lakes. In order to do this, the theme uses observational data, downscaled climate model output and a physics-based hydrologic model, which allows for the simulation of individual river basins in the province. Their work is greatly benefitted by collaborating with BC Hydro, the Global Water Futures program, and various research groups, who together are bringing together an understanding of the changing hydrology of the region. The theme's work also leads to the advancement of regional hydrologic modelling more generally, as they update the model that they use, share their findings and methods with the broader research community, and develop new high-resolution data sets suitable for hydrologic modelling and other purposes. The data sets used to drive the hydrologic model and its output are available via PCIC's Data Portal.

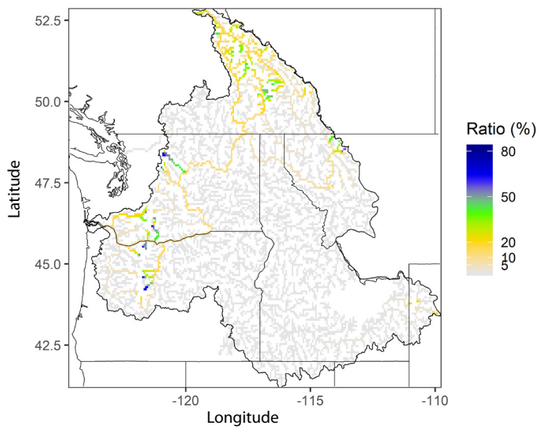
HYDROLOGIC IMPACTS

SIMULATING BASINS AND RIVERS IN BC USING THE UPDATED VIC-GL MODEL

Globally, glaciers are shrinking as a result of climate change. Owing to their roles in hydrologic systems, glaciers are incredibly important to ecosystems and communities in BC. Through their influence on streamflow, changes to glaciers can affect the timing and availability of fresh water, sediments, nutrients and organic materials to lakes, rivers and the coast. BC has a large number of glaciers and thus it is important to include changes to glaciers in future hydrologic projections for the province. Because of this, PCIC's Hydrologic Impacts theme has updated the hydrologic model that they use to explicitly model glacier processes.

The updated VIC-GL model, PCIC's version of the Variable Infiltration Capacity (VIC) model, simulates the accumulation and ablation of snow and ice directly and includes a coupled regional glacier dynamics model. Model development also benefitted from a variety of new data sources, including the development of a new meteorological data set. Much of this was a collaborative effort between PCIC, the University of British Columbia, the University of Northern British Columbia and BC Hydro.

The model is now being applied over northwestern North America, including the major drainage basins of the Columbia, Fraser and Peace, and several smaller watersheds on Vancouver Island. It is being used to study future changes in flood hazard, and testing is underway to also add an integrated water temperature model to VIC-GL.

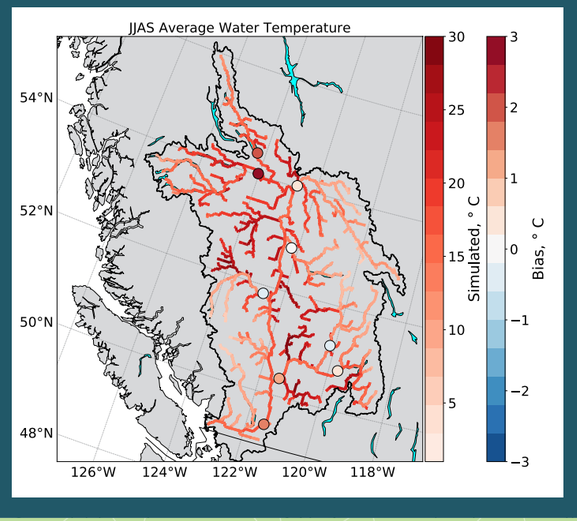


This figure shows the influence of glacier runoff in the Columba during the historical period (1945 to 2012). It shows the estimated proportion of August runoff in the Columbia basin that is composed of glacier outflow (glacier melt, snowmelt and rainfall that occurs on glaciers) throughout the drainage network. The ratios are based glacier outflow and total runoff averaged over the period 1945 to 2012 based on VIC-GL simulations driven by observed climate data and represents the glacier contribution throughout the network for an unregulated basin (what it would be predicted to be without dams and regulation).

FRASER RIVER WATER TEMPERATURE

The temperature of the water in a river is important for the ecosystems that rely on it. For example, increased water temperatures can increase the mortality rate of sockeye salmon that spawn in the Fraser River, reducing salmon populations. To better understand the evolution of water temperatures, PCIC's Hydrologic Impacts theme is working on coupling a water temperature model to the hydrologic model that they use, VIC-GL. This will allow them to analyze the past and projected future thermal regimes of rivers in BC.

Current work includes using the coupled hydrologic/water temperature model to develop a reconstruction of Fraser River water temperatures (see figure below) from 1945 to the present day, in order to better understand past water temperature variability and the possible role that climate change may have played in changing Fraser River temperatures. The model's performance is also being evaluated. It shows relatively small bias at upstream stations, but larger bias at the Nechako River, where water is regulated by dams. At Hope, the model underperforms statistical models, but is comparable with process-based models for the region. In general, the model biases are smaller than interannual variability. Developing the capability for water temperature modelling with VIC-GL will also allow for the analysis of projected future changes in water temperatures.

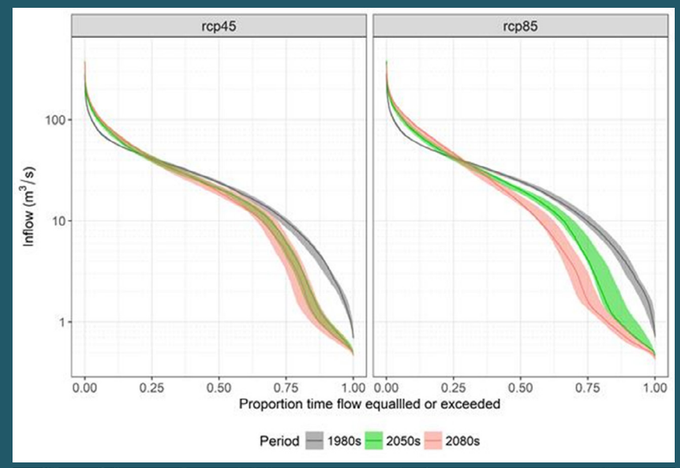


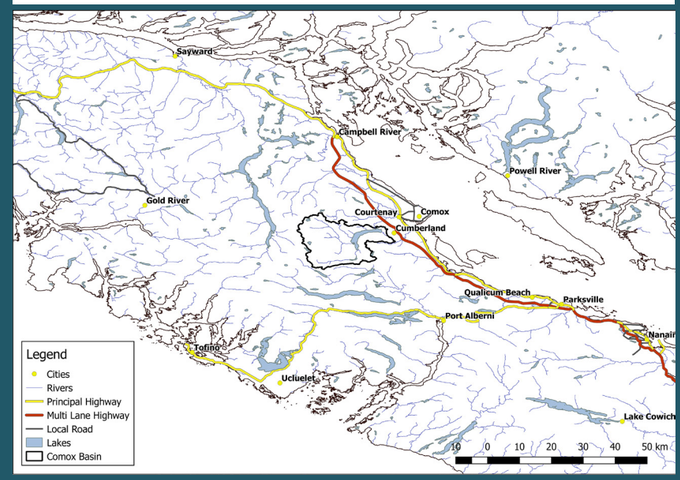
This figure shows the simulated average summer (here, June, July, August and September) temperature of water in the Fraser River Basin for the 1950-2012 period. The dots on the map represent the bias of the simulated temperatures relative to observed temperatures.

HYDROLOGIC IMPACTS

COMOX VALLEY REGIONAL DISTRICT

In many communities throughout British Columbia, domestic water is supplied from surface sources, which may be vulnerable to climate change. Comox Lake is the drinking water source for around 45,000 people in the Comox Valley and the Comox Valley Regional District (CVRD) holds a license for the withdrawal of water for domestic use. The CVRD currently withdraws water from the BC Hydro penstock in the Puntledge River, but plans to begin withdrawing water directly from Comox Lake in the next three years. Water supply is affected by both high and low extreme flow events. High-flow events can adversely affect water quality via increased turbidity levels, which often require boil water advisories. Periods of extreme low inflows can result in water shortages, requiring the implementation of water use restrictions. There is also growing concern that dropping lake levels may result in the complete cessation of flows in the Puntledge River. Consequently, PCIC engaged in a project to provide a quantitative assessment of changes in the quantity of inflow into Comox Lake, including potential changes to summer season low flows, and the range of extreme flows possible under different greenhouse gas emissions scenarios. Model analysis shows that climate change will result in a change in the overall distribution of daily inflow in the 2050s and 2080s. Large flows (those which are exceeded during less than 25% of the baseline period) are projected to increase in magnitude whereas moderate to low flows (below levels corresponding to the lowest 25% of those during the baseline period) are projected to decrease in magnitude, with a robust signal of decreasing summer flow under a warming climate (see figure on right).





This figure shows the historical and projected flow duration of daily Comox Lake inflow (upper panels) and a map of the area containing the study region (lower panels). The daily inflow for RCP4.5 (a moderate emissions scenario, left panel) and RCP8.5 (a business as usual emissions scenario, right panel) for the baseline period (1980s), mid-century (2050s) and end of the century (2080s). are shown. The solid line in the upper panels indicates the ensemble median flow duration curve, and colored ribbons show ensemble minimum and maximum range. In the lower panel, cities, highways, streams, lakes, glaciers and the study region are as indicated in the map legend.

REGIONAL CLIMATE IMPACTS

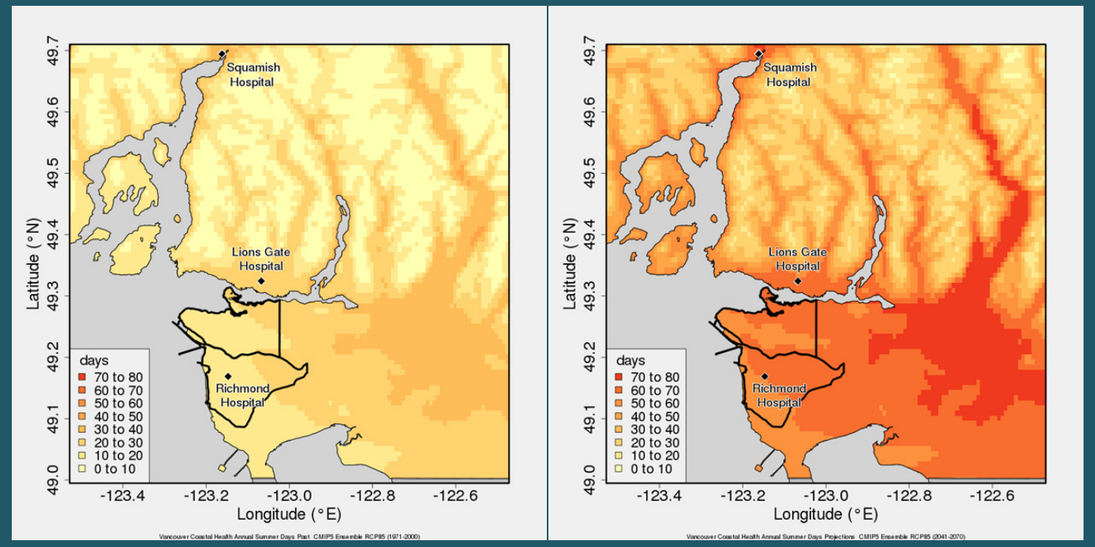
PCIC's Regional Climate Impacts theme examines how global climate change and variability will affect British Columbia and the surrounding area local to regional scales, to help stakeholders in the province adapt. The theme uses statistical downscaling methods to interpret the output of global climate models at the scale of communities. The theme also develops reports, often written collaboratively with users, that are tailored directly to user needs. Because the impacts of climate change are broad, the theme works with a diverse set of users. The work that the Regional Climate Impacts theme performs also benefits the broader scientific community, through the development and application of statistical downscaling techniques, and the climate services community, through the sharing of general methods that the theme uses when working with users to integrate the findings of climate science into planning. The statistically downscaled global climate model data that the theme develops and uses is available through PCIC's Data Portal.

CLIMATE PROJECTIONS AND DESIGN VALUES FOR ENGINEERS AND HEALTH CARE

The changing climate could potentially have significant effects on engineering projects, from the impacts of changing flood frequency on infrastructure to changing needs for heating and cooling buildings. PCIC researchers provide site-specific analysis and data to assist engineers.

Recently, PCIC researchers have worked on four projects to assist engineers with building design. This has included providing extremes indices, weather files and guidance on using future climate information for building energy modelling. While climate projections indicate that BC will warm in the future, neither tables of design conditions in the building code nor energy files used for energy modelling yet account for this. Not considering the future climate can result in over-designing for heating and under-designing for cooling. This may result in cooling needs being unmet, while capital is invested in infrastructure for heating that will not be fully utilized. In addition, very efficient buildings, such as the "passive house" or those buildings that qualify as net-zero by the BC Energy Step Code, that also have high internal heat gains or do not adequately address solar shading, will have increased cooling requirements over the shoulder seasons. This means that only designing for today's climate may require a retrofit in the future climate.

The first project was with Island Health, for construction and renovation projects at the Nanaimo Regional General Hospital. PCIC provided building code parameters, projections of climate extremes indices and guidance on data use. This led to significant interest in the project, which was presented at meetings for Engineers and Geoscientists BC, BC Hydro, the Canadian Health Engineering Society, and others. Since then, PCIC has worked with Vancouver Coastal Health (see figure on right) to help produce a regional climate



This figure shows the number of days Above 25°C in the past (1971-2000, left) and in the future (2050s, right) taken from the average of 12 global climate models following a business-as-usual emissions scenario (RCP8.5) and downscaled with using the BCCAQv2 statistical downcaling method.

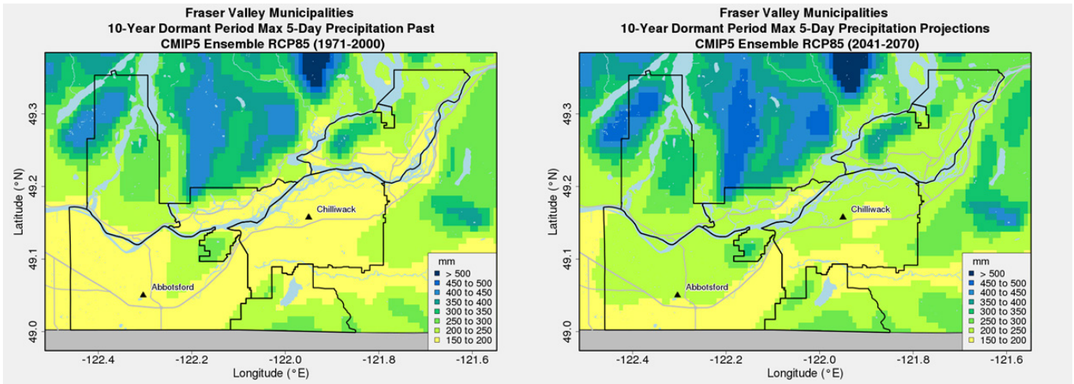
impacts report that will inform several health care infrastructure projects in the region. PCIC researchers have also worked with UBC and consulting engineers to develop an online interface for providing "future-shifted" weather files that incorporate future climate projections into weather files that are widely used in the energy modelling that is carried out to inform building design. Finally, PCIC is providing interpretation and support to a BC Housing-led project that is seeking to develop training materials to inform engineers and other buildings professionals on how to incorporate future conditions into design.

REGIONAL CLIMATE IMPACTS

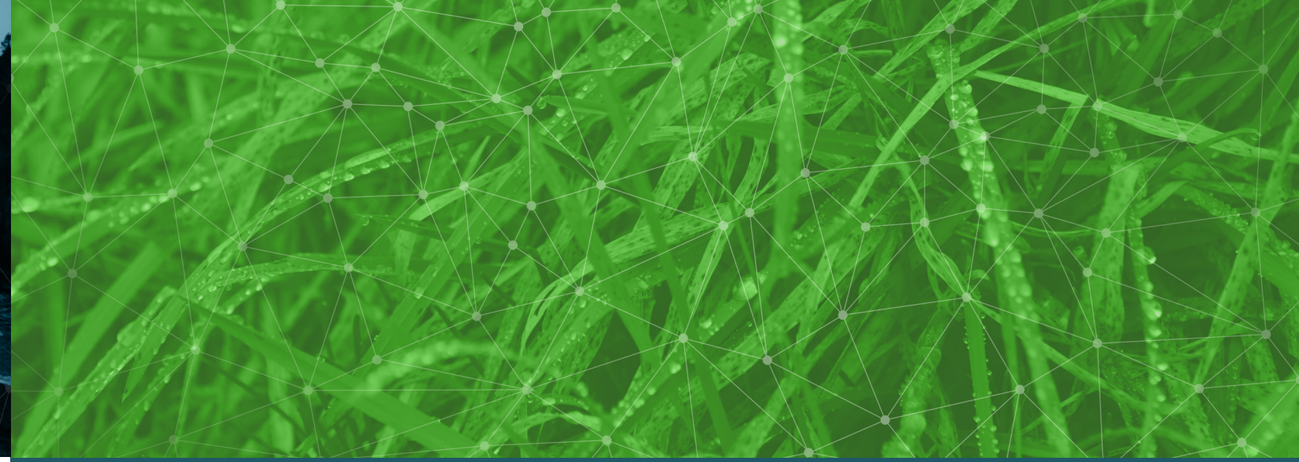
SUPPORTING AGRICULTURE IN THE FRASER VALLEY

Following from a series of regional climate assessments co-produced for the agricultural sector by PCIC and the BC Agriculture and Food Climate Initiative, PCIC partnered on a project with the BC Agriculture and Food Climate Action Initiative, the BC Blueberry Council and other groups in the Fraser Valley. Projections including potential future changes in precipitation (see figure, below) and river inflow were generated and shared through the Fraser Valley Climate Adaptive Drainage Management Forum. This was an event which brought together researchers, agricultural producers and local and provincial and government staff to discuss agricultural drainage challenges and potential solutions.

The project identified a number of possible actions that would help to mitigate the impacts of climate change and improve adaptive capacity. Suggestions include the piloting of drainage area management planning, and enhancing professional and informational/technical resources that are available to producers to support drainage improvements.

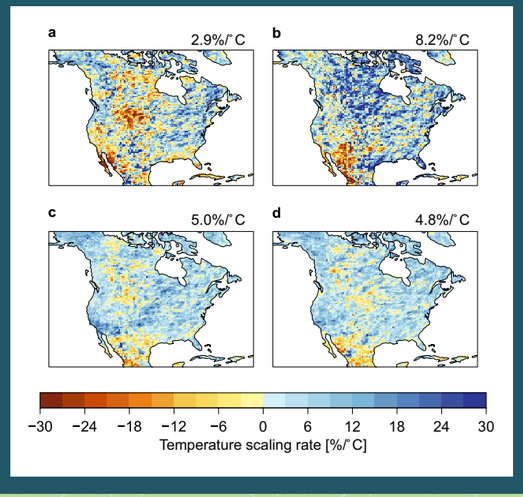


This figure shows the simulated historical (1971-2000, left) and projected (2041-2070, right) maximum precipitation that falls over a five-day period for those precipitation events that are so intense that they only occur once every ten years. An overall median increase in precipitation of 14% (6 to 27%) during such extreme events in the annual average can be seen in the future projections. This can be compared to the more modest annual total precipitation increase of 5% (-1% to 10%).



CONSTRAINING ESTIMATES OF FUTURE LOCAL PRECIPITATION EXTREMES

Global warming is expected to increase the amount of moisture in the atmosphere, resulting in heavier extreme precipitation. This leads, for instance, to concerns in the engineering community that it may be necessary to adjust building codes and engineering practices to account for the increasing precipitation intensity. Various studies have attempted to use the historical relationship between extreme precipitation and temperature (a method known as “temperature scaling”) to provide guidance about precipitation extremes in a future, warmer climate. Recent research at PCIC that was supported by a Grants and Contributions agreement with Environment and Climate Change Canada, suggests that available records of precipitation and temperature observations likely do not contain enough information to reliably estimate local temperature scaling relationships. The limited historical observations are therefore unlikely to be able to provide reliable guidance for future adaptation planning at local spatial scales. Using climate models, the study shows that much more information is needed to characterize temperature scaling relationships well, but that large ensemble simulations with high-resolution climate models provide a path forward for developing such relationships and that well-constrained temperature scaling does provide a feasible basis for projecting future precipitation extremes over most parts of North America.

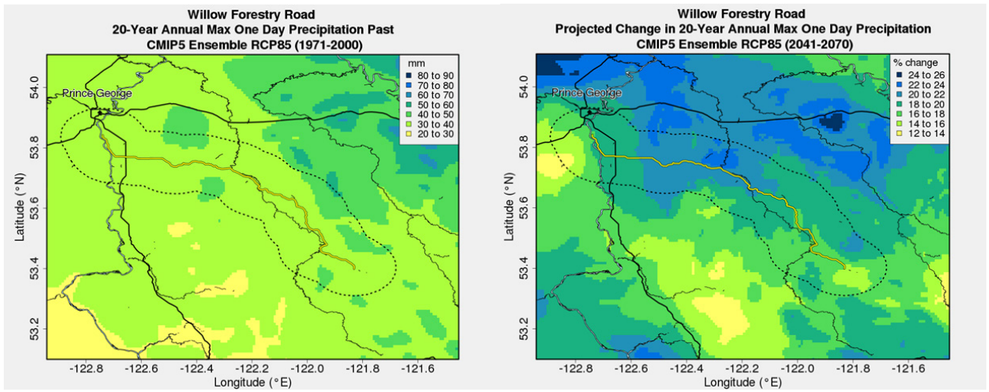


This figure shows the temperature scaling rate, the percent change in precipitation for each degree of temperature change from climate model simulations. Panels a) and b) show the scaling rates for the 50th percentile of the annual maximum precipitation for the 1951-2015 period from two model runs selected because they have the smallest and largest scaling rates, respectively. Panels c) and d) show the same, but for the 2036-2100 period. Differences between these runs are only due to the model simulating different realizations of natural "internal" variability or weather, in the two simulations, since external forcing from greenhouse gas emissions and other sources is the same for both simulations. The numbers above each panel show the spatial average scaling rate estimates for that particular panel. The noisy spatial patterns indicate that the estimated temperature scaling rates are highly uncertain.

REGIONAL CLIMATE IMPACTS

PROJECTIONS FOR FORESTRY SERVICE ROADS

As the climate changes, long-lived infrastructure such as roads will be exposed to changing conditions that may lead to more frequent extreme events, such as flooding, that go beyond their design capacity. To help address this, PCIC has been working on an ongoing series of case studies for forestry service roads, for which it has completed three thus far. For the first two of these, PCIC partnered with the BC Ministry of Forestry, Lands, Natural Resource Operations and Rural Development (FLNR) to examine how climate change may affect such roads. For the most recent work, PCIC partnered with FLNR, the BC Ministry of Transportation and Infrastructure (MOTI) and FP Innovations to determine how climate change may affect forestry service roads in Prince George in the future. This work included both observational data and high-resolution downscaled projections from global climate models. As in earlier work, PCIC scientists found that heat and precipitation extremes are projected to increase in their frequency, as all seasons warm and summers get drier, while winters get wetter. Increases in extreme precipitation events and increased snowmelt present challenges to drainage systems. Changes to temperature may affect road conditions during the summer, due to wildfire risk, and during the winter, due to reduced snowfall, and more frequent freezing and thawing. Research is ongoing to generalize these results to the rest of the province.



The above figure shows both historical (1971-2000, left) and projected future (2041-2070, right) maximum one-day precipitation that falls during events that are so extreme that they only occur at most once every twenty years, for the Willow Forestry Road in Prince George. These figures use model output from an ensemble of global climate models that participated in the fifth phase of the Coupled Model Intercomparison Project. Future projections assume a business-as-usual emissions scenario.

UPDATED GUIDANCE FOR THE ENGINEERING COMMUNITY

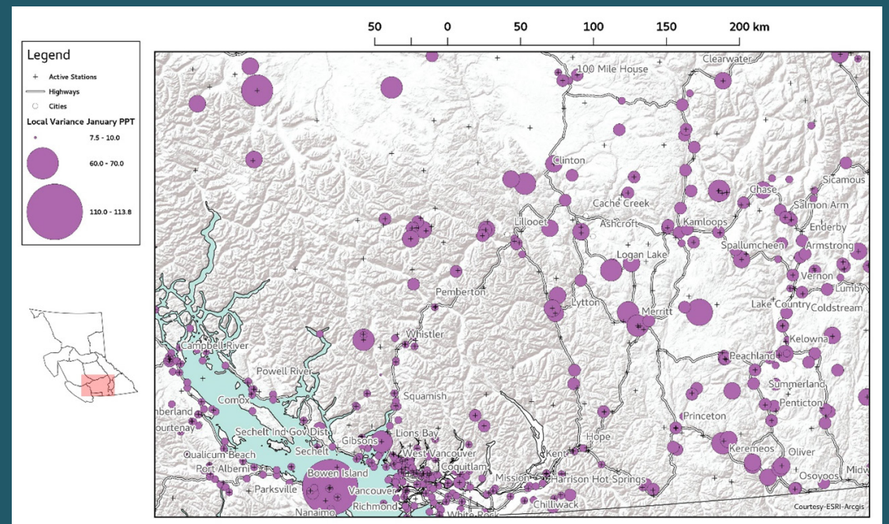
Canada's changing climate will affect the nation's buildings and public infrastructure. The National Research Council of Canada (NRC) is supporting PCIC in a collaboration with Environment and Climate Change Canada (ECCC) that will contribute to the development of updated guidance to the engineering community for infrastructure design that takes recent climate observations and projected climate change into account. The NRC is the federal agency that supports the development of the National Building Code of Canada and is a lead contributor to the Canadian Highway Bridge Code (CSA S6). PCIC is very pleased to be able to collaborate with both the NRC and ECCC on this important project.

CLIMATE ANALYSIS AND MONITORING

PCIC's Climate Analysis and Monitoring theme gathers and examines historical data to better understand how the climate of British Columbia and the surrounding regions has changed in the past and continues to change in the present. In order to do this, the theme gathers data from partners in the public and private sectors, applies quality control methods to the data and conducts analyses using it. This data and analysis is used in the reports of PCIC and PCIC's partners. The theme also examines the data from existing weather networks to identify areas where user needs are not being met. The results of the theme's data gathering, quality control and analysis are shared with a broad variety of users in the form of maps and data, available through PCIC's Data Portal. Key among these is the Provincial Climate Data Set, which contains 34 climate variables, ranging from mean temperature and precipitation to cloud cover and sea level, comprising more than 600 million observations and growing, made possible through the Climate Related Monitoring Program.

ANALYZING THE PACIFIC CLIMATE DATA SET FOR AGRICULTURAL APPLICATIONS

Agricultural productivity is dependent to a large degree upon weather conditions, and thus, having access to high-quality weather data is very useful for agricultural planning. Over the last year, PCIC has partnered with the BC Agricultural Climate Adaptation Research Network and the Ministry of Agriculture to find out if the needs of farmers for weather data are being met. This work included making an inventory of the data that is being collected and studying the Provincial Climate Data Set to determine how far apart weather stations may be while still allowing proper analysis of climate and weather data. The results of this work show that the need for daily and sub-daily observations is probably not being met in many areas, that the need for increased precipitation monitoring is greater than the need for increased temperature monitoring and that BC's variable topography requires increased station density where terrain is most complex. PCIC will continue to assist the agricultural sector as needed and is engaging with the Ministry of Environment to assist in assessing the observational network for understanding BC's changing climate over the entire province.

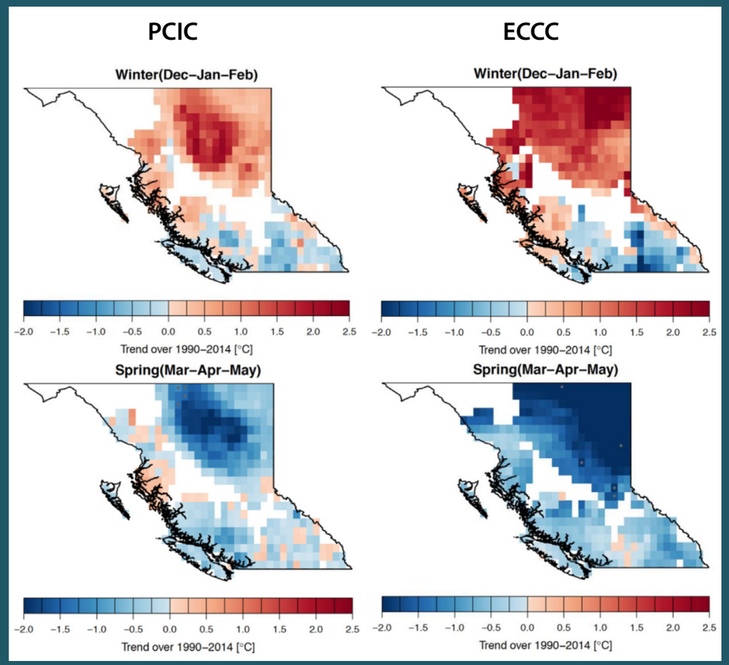


The figure above shows the currently active precipitation observing network in the Pacific Climate Data Set in a region containing part of the south coast and southern interior of British Columbia. The size of the purple dots indicate the variance in precipitation in January, with larger dots implying greater spatial variability. The analysis was conducted using data from 1950 to 2017 and stations with more than 30 years of record.

CLIMATE ANALYSIS AND MONITORING

QUALITY CONTROL AND HOMOGENIZATION

Having high-quality data available improves the ability of researchers and planners to understand the climate of British Columbia. In order to provide this, PCIC's CAM theme undertook a data homogenization project, funded by Environment and Climate Change Canada (ECCC), applying quality control and homogenization methods to climate data in BC. This work includes making corrections for biases and errors that can occur when stations are moved or equipment changed. The final stages of this project were to perform homogenization on daily temperature data and to explore the application to monthly precipitation data. The data have initially been used to look at short-term trends in BC in comparison with those calculated from an ECCC product. Results are favourable and show the value of the Climate Related Monitoring Program's data for representing the climate of BC. The figure on the right is of trends from PCIC data and ECCC data, on the left and right, respectively. The figure shows that patterns in the two products are comparable and that recent trends show strong winter warming in northeast BC and cooling in the spring almost province-wide. Although the monthly anomaly values are similar in the figure at right, the homogenized data product that PCIC produced has many more stations in BC and therefore enables a more detailed spatial characterization of the intricacies of daily weather in the province since ~1990. Continued homogenization efforts in the future will expand the areas for which carefully quality-controlled and adjusted observational data are available in BC, thereby increasing the value of PCIC's station data holdings. This effort will be expanded to variables other than temperature as resources allow.



This figure shows seasonal temperature trends in the final homogenized and quality-controlled data for BC, over the 1990-2014 period. PCIC data is shown on the left panels and ECCC data is shown on the right panels.

RENEWED AND EXPANDED CLIMATE RELATED MONITORING PROGRAM AGREEMENT

In April 2018, the BC ministries that collect weather data, BC Hydro, Rio Tinto and PCIC renewed a pledge first made in 2010 to share climate-related observational data within the province of British Columbia. In doing so, they were joined by three new partners, Environment and Climate Change Canada (ECCC), Metro Vancouver and the Capital Regional District (CRD). PCIC participates in this agreement by aggregating, applying quality control measures to, and disseminating this data though its Data Portal. The new agreement enables outside parties to participate in data sharing and membership. It introduces observational networks from the newest partners, ECCC, Metro Vancouver and the CRD. It also establishes new committees focused on data collection and observational network administration, and does so for the coming eight years. BC continues down a firm path for climate monitoring in the province and the open exchange of climate data, which are key components of regional climate service delivery.

Visit the Climate Related Monitoring Program's page at the Province of BC for more information:

https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/climate-related-monitoring.

CLIMATE DATA FOR THE NORTHWEST TERRITORIES AND YUKON

Over the last fiscal year, PCIC has entered into an agreement with the Government of the Northwest Territories to make weather and climate data more easily accessible in the region. PCIC will characterize climate observations for use in climate mapping in the Northwest Territories and Yukon, forming a database of weather data with a data portal to deliver it. PCIC will also report on climate data interpolation methods for the area, and provide an assessment of the data available for climate mapping.

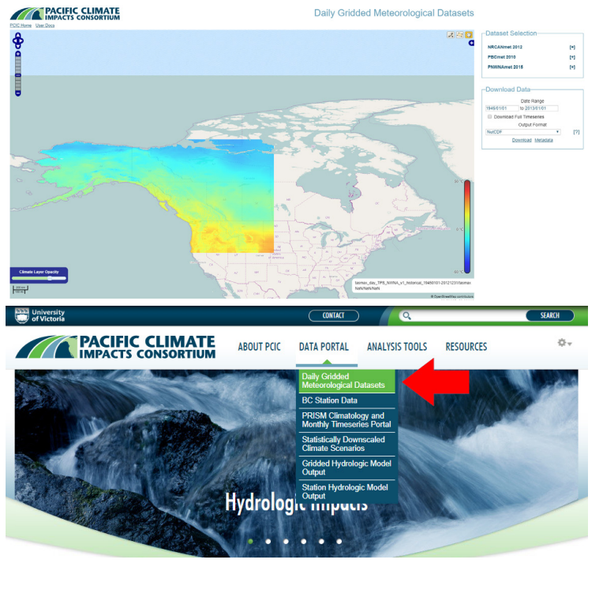
DATA AND INFORMATION DELIVERY

All of the data, model output and analysis that PCIC develops, as well as its communications materials, the output of its scientists in the peer-reviewed literature and most of the reports that it develops with users are available through a variety of channels on PCIC's website. These include interactive tools that can help to inform planning, visualize and access data, as well as maps, journal articles, summaries, presentations and project reports. PCIC is also constantly adding to these, releasing the results of its applied research program and developing new tools and materials to better serve the needs of its users.

DATA AND INFORMATION DELIVERY

NEW ADDITION TO THE DATA PORTAL: GRIDDED METEOROLOGICAL DATASET

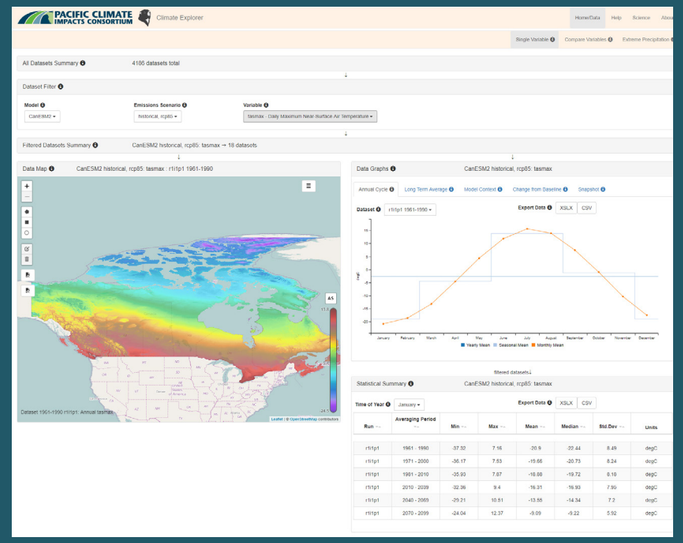
The PCIC Data Portal continued to expand this year, offering three new Daily Gridded Meteorological Datasets. These datasets have been developed over the last decade and have been used to drive PCIC's hydrologic model. The earliest of these is the PCIC meteorology for BC (PBCmet) data set, developed in 2007, followed by the NRCANmet observational data set, developed by Natural Resources Canada (NRCan) over the 2011-2013 period, and finally, the PCIC NorthWest North America meteorological dataset (PNWNAmet), developed at PCIC in 2017. Each of these are high-resolution, ranging from about six kilometres to about ten kilometres, depending on the data set and latitude. They cover varying portions of the Pacific Northwest, with the latest dataset covering a region that spans from Northern California to the Arctic and from the west coast to partway through Manitoba. The data sets start in 1950 (PBCmet and NRCANmet) or 1945 (PNWNAmet) and extend through to 2004 (PBCmet) or 2012 (NRCANmet and PNWNAmet).



This figure shows a screenshot of the new Daily Gridded Meteorological Datasets page on PCIC's Data Portal (upper panel) and where the new Daily Gridded Meteorological Datasets page can be found on the main menu of PCIC's website, as indicated by the red arrow (lower panel).

CLIMATE TOOL FOR ENGINEERS

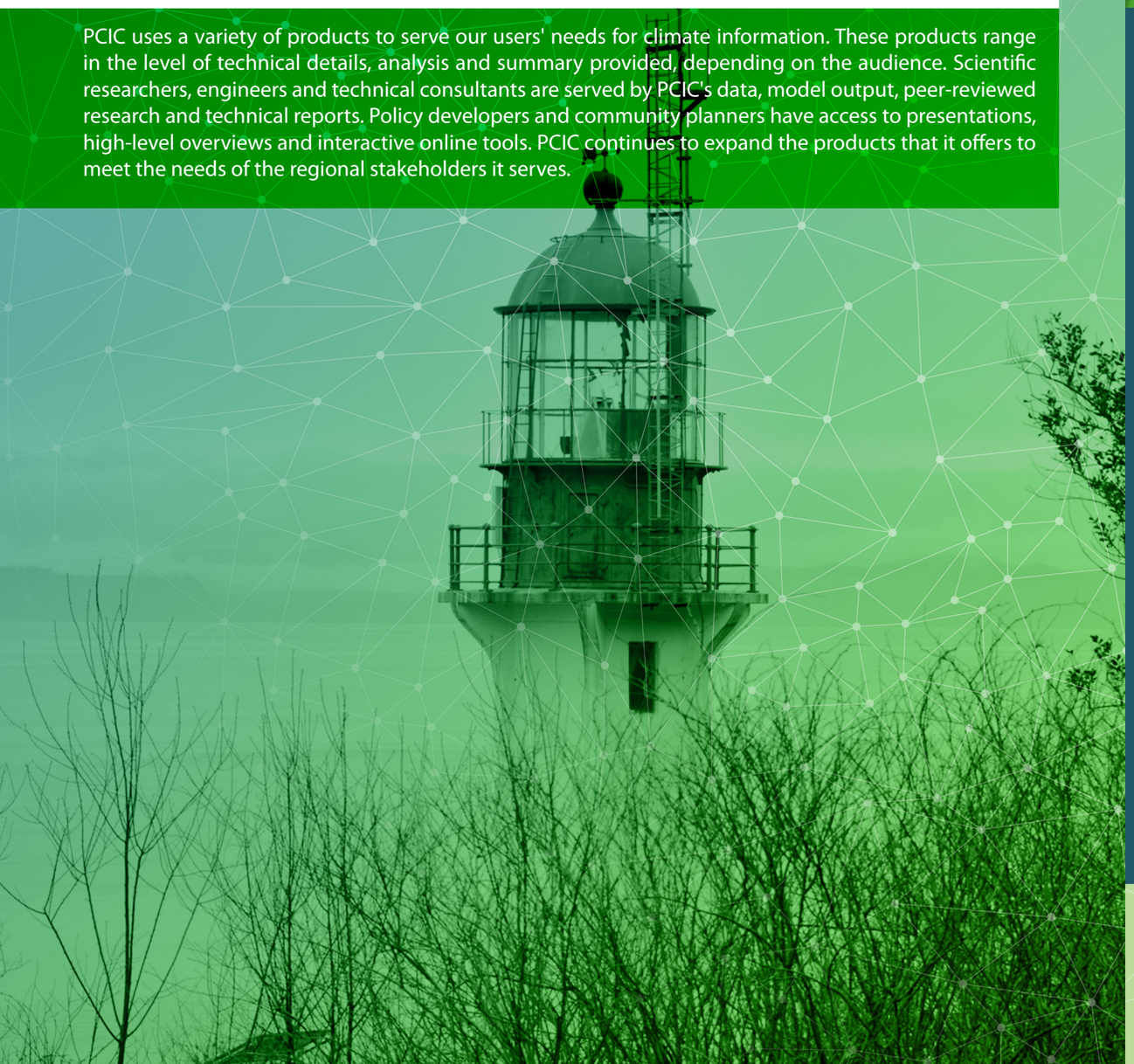
Engineers require climate data for many types of projects, including infrastructure and buildings. In order to help engineers access and explore this data, PCIC has been applying its expertise in climate data analysis and online tool development to create a climate tool for engineers (see figure below). This tool has an easy to use web interface that will both display climate information in the form of maps and timeseries, and allow users to select and download data for their regions. It is being developed in tandem with a second version of the tool for a broader audience. The data provided by the tool will include output from the global climate models that participated in the fifth phase of the Coupled Model Intercomparison Project (CMIP5), BCCAQ downscaled data with a ten-kilometre resolution and indices of climate extremes (CLIMDEX). The development of this tool has benefitted from a partnership with the BC Ministry of Transportation and Infrastructure. Fall 2018 saw the beta release of this tool, while full release is scheduled for 2019. A series of instructional videos to assist engineers in using the tool for extracting climate data for engineering projects are also in development.



This figure shows a screenshot of the beta release of the climate tool for engineers that is in development.

COMMUNICATION

PCIC uses a variety of products to serve our users' needs for climate information. These products range in the level of technical details, analysis and summary provided, depending on the audience. Scientific researchers, engineers and technical consultants are served by PCIC's data, model output, peer-reviewed research and technical reports. Policy developers and community planners have access to presentations, high-level overviews and interactive online tools. PCIC continues to expand the products that it offers to meet the needs of the regional stakeholders it serves.



COMMUNICATION

SCIENCE BRIEFS AND NEWSLETTERS

In order to serve its users's need for plain-language summaries of current, relevant research, provided with the context necessary to understand it, PCIC provides Science Briefs. This year, PCIC released four Science Briefs on nine papers in the peer-reviewed literature. The topics covered include the projected changes to grasslands and three US crops, how snowmelt and drought are changing, sea level rise observations and the acceleration of sea level rise, and climate impacts on fruit and grazing in the Pacific Northwest.

PCIC also uses its newsletter, the PCIC Update, to keep users informed about the ongoing projects and happenings at PCIC, as well as to provide commentary on climate-related issues. PCIC released three newsletters this year. The topics covered in these newsletters included: updates on the VIC-GL model and its application to new regions, an discussion of the weather events of 2017 in a climatological context, findings from papers by PCIC researchers regarding changes to short duration extreme precipitation events, summer wet bulb temperatures and extreme wildfire risk in the Fort McMurray area.


PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE OCTOBER 2018

IN THE NEWS: IPCC SPECIAL REPORT ON GLOBAL WARMING OF 1.5°C

PCIC SCIENCE BRIEF: ON PARIS CLIMATE ACCORD EMISSIONS AND TEMPERATURE LIMITS

PCIC SCIENCE BRIEF: WAVES AND COASTAL SEA LEVEL AND THE HUMAN INFLUENCE ON CANADIAN TEMPERATURES

The three panels above show the first sections of the October 2018 PCIC Update (left), two PCIC Science Briefs: On Paris Climate Accord Emissions and Temperature Limits (centre), and, Waves and Coastal Sea Level and the Human Influence on Canadian Temperatures (right).

COMMUNICATION

PLACING 2017 INTO CLIMATOLOGICAL CONTEXT

Having access to plain language discussions of how current weather records and events fit into the broader climatic context can help to inform users about how climate change is affecting the region that PCIC serves, and provide a basis from which to understand how it is projected to change in the future. To this end, PCIC periodically releases short overviews of recent weather and climate events. In March of 2018, PCIC's Climate Analysis and Monitoring theme released a discussion of the weather of 2017 regionally and globally. They pointed out how 2017 was one of the top-three warmest years in the instrumental record globally and in the top-20 for BC. This was despite the largely cool conditions, due partially to a La Niña event that prevailed through the province for most of the year. It was an especially hot summer with extreme daily maximum temperatures that raised the overall average temperatures into the top-20 for the province.

PEER-REVIEWED PUBLICATIONS

PCIC researchers actively participate in the peer-reviewed scientific literature, publishing and reviewing a number of articles each year, as well as sitting on editorial boards for major journals. This allows PCIC's team to keep on top of the frontiers of knowledge in their fields, and share their findings with the broader research community. It also ensures that PCIC's methods are subject to rigorous peer review, updating and constructive criticism from the most knowledgeable researchers in their fields. PCIC then distills and applies the findings of the global climate research community to the challenges faced by PCIC's users.

OUTREACH

In order to share their findings and understanding of the climate system, and learn from the findings and experiences of others, PCIC scientists devote a portion of their time to outreach activities. These outreach activities include presentations that PCIC scientists deliver to widely varying audiences, from researchers at conferences to community planners and the general public. Through the Pacific Climate Seminar Series, hosted jointly with the Pacific Institute for Climate Solutions, PCIC also holds talks by both local and visiting researchers from a variety of fields, which is an opportunity for sharing findings and also for networking and sparking conversations.

OUTREACH

PCIC DIRECTOR INVITED TO SPEAK AT THE CANADIAN METEOROLOGICAL AND OCEANOGRAPHIC SOCIETY'S ANNUAL CONGRESS

Drawing more than 600 scientists in 2017, the Canadian Meterological and Oceanographic Society's Annual Congress is the largest annual conference for oceanic and atmospheric scientists in Canada. This year, PCIC Director Francis Zwiers was invited to deliver a public lecture at the Congress. Dr. Zwiers's talk discussed the relationship between climate change and extreme weather events, long-term trends in extreme events, and the application of detection and attribution analysis for such events. In addition, he was interviewed for a podcast related to the event, in which he discussed the topics above, as well as climate change risks, adaptation, mitigation, and some of PCIC's statistical downscaling work.

The podcast is available at: www.hipcast.com/podcast/HxqXsBVQ.

PARTICIPATING IN CLIMATE CHANGE ADAPTATION DIALOGUES WITH FIRST NATIONS

Over the past year, PCIC has had the opportunity to work with three First Nations communities. PCIC participated in the development of a report for the Cowichan First Nation, provided future climate projections and participated in a climate adaptation workshop with Splatsin First Nation and participated in a project with the Toquaht First Nation. PCIC jointly presented a webinar with Indigenous and Northern Affairs Canada's (INAC) First Nation Adapt Program, to share the types of climate change information and services PCIC can offer to communities preparing to adapt, and helped promoted funding opportunities for First Nation communities to assess, prepare and plan for climate change impacts.

THE PACIFIC CLIMATE SEMINAR SERIES

In partnership with its sister organization, the Pacific Institute for Climate Solutions, PCIC jointly hosts the Pacific Climate Seminar Series, an opportunity for local and visiting researchers to share their findings and connect with PCIC's users and the general public. The series leverages the large networks that PICS and PCIC have, that extend across diverse research communities and stakeholder groups, to bring people together.

2017-2018 SEMINARS:

Regional frequency analysis of hydro-meteorological extremes—non-standard aspects

Dr. Dhouha Ouali, PCIC Research Associate

October 25th, 2017

Climate change: legal risk and opportunities for professionals

Deborah Carlson, staff lawyer, West Coast Environmental Law

November 22nd, 2017

A climatology of mechanisms that generate intense extratropical cyclones in the Northern Hemisphere

Dr. Christian Seiler, PCIC Research Climatologist

January 31st, 2018

AWESome potential: Airborne wind energy's opportunities and challenges

Markus Sommerfeld, PhD candidate, UVic Department of Mechanical Engineering and PICS Fellow

March 1st, 2018

Coupling ice sheets into climate models for self consistent sea level projections: progress and challenges

Dr. Jeremy Fyke, Climate Scientist, Associated Environmental

March 28th, 2018

Some selected presentations from these seminars are available from PCIC's Publications Library:

http://pacificclimate.org/resources/publications

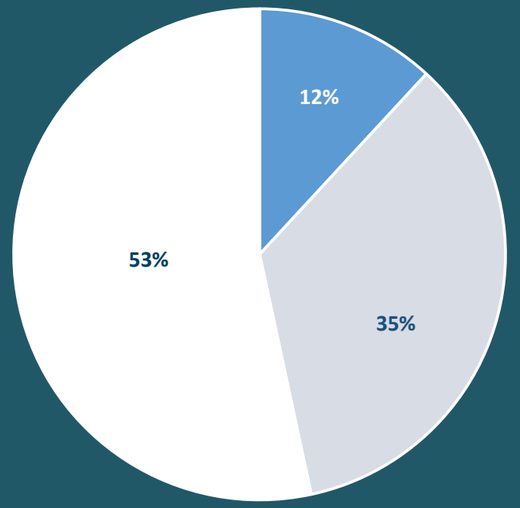
OPERATIONS AND FINANCE

OPERATIONS AND FINANCE

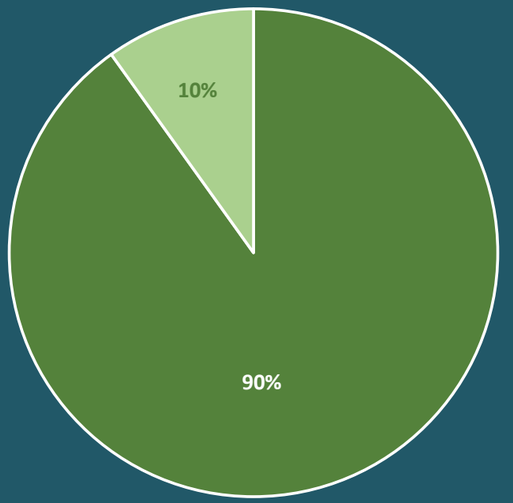
SUMMARY OF THE YEAR

As a not-for-profit corporation, and as a service organization, all of PCIC's activities are dependent on having a talented team and maintaining financial stability. The 2017-2018 fiscal year saw growth in revenue from long-term agreements and short-term contracts alike, with users and stakeholders much more than doubling the value of funding PCIC receives from an endowment that was placed at UVic by the BC Government in 2008, through both cash and in-kind contributions. This has provided us with the opportunity to invest in additional staff and computational hardware to meet the rising demand for our services.

2017-2018 REVENUE

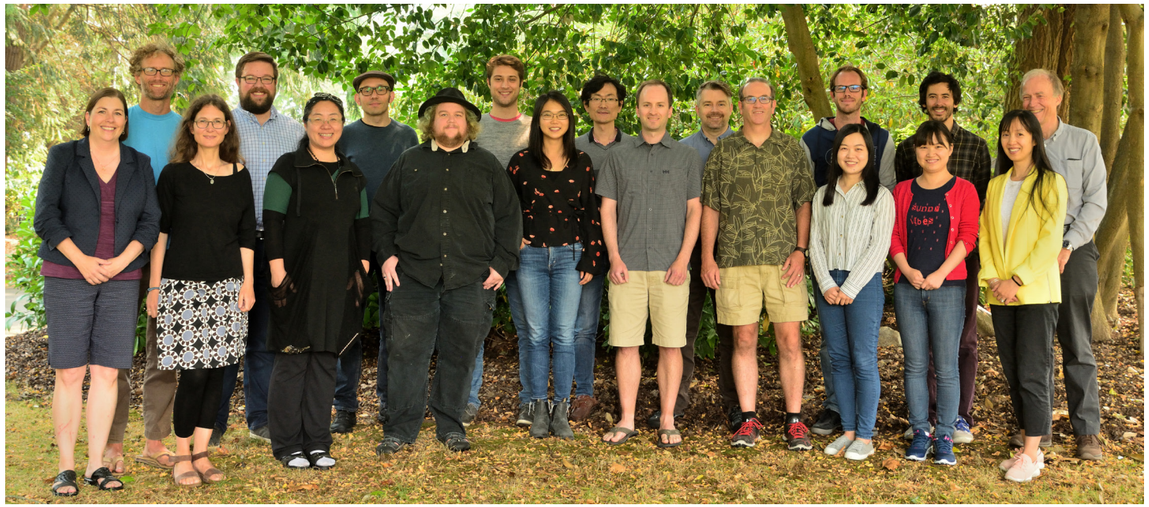


2017-2018 EXPENSES



OPERATIONS AND FINANCE

STAFF AND ASSOCIATES



PCIC staff and associates, left to right: Kathy Veldhoen, Faron Anslow, visiting researcher Jana Sillmann, Matthew Benstead, Yanping He, Michael Shumlich, Lee Zeman, Nikola Rados, Yaqiong Wang, Chao Li, Stephen Sobie, Trevor Murdock, Charles Curry, Gildas Dayon, Yaheng Tan, Qiaohong Sun, Kai Tsuruta, Shelley Ma, Francis Zwiers. Not pictured: Mohamed Ali Ben Alaya, Rod Glover, James Hiebert, Dhouha Ouali, Christian Seiler and Arelia Shoeneberg.

PUBLICATIONS

PUBLICATIONS

PCIC PUBLICATIONS & CO-PRODUCED PUBLICATIONS

The Capital Regional District, **the Pacific Climate Impacts Consortium** and Pinna Sustainability, 2017: *Climate Projections for the Capital Region*. The Capital Regional District, 66 pp.

Chandler, P.C., S.A. King and J. Boldt, 2018: *S*tate of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2017. *Canadian Technical Report of Fisheries and Aquatic Sciences*, **3266**, 245 pp.

The Cowichan Valley Regional District and **the Pacific Climate Impacts Consortium**, 2017: *Climate Projections for the Cowichan Valley Regional District*. The Cowichan Valley Regional District, 52 pp.

The Pacific Climate Impacts Consortium, 2017: *Climate Extremes in the Georgia Basin: Summary Report*. The Pacific Climate Impacts Consortium, 12 pp.

The Pacific Climate Impacts Consortium, 2018: Climate Change Scenario Modelling for the Fraser River *Watershed Phase 1. Final Report*, The Pacific Climate Impacts Consortium, 37pp.

The Pacific Climate Impacts Consortium, 2018: *PCIC Science Brief: Climate Impacts on Specialty Fruit and Grazing in the Pacific Northwest*. The Pacific Climate Impacts Consortium, 4 pp.

The Pacific Climate Impacts Consortium, 2017: *PCIC Science Brief: The Evolution of Snowmelt and Drought*. The Pacific Climate Impacts Consortium, 4 pp.

The Pacific Climate Impacts Consortium, 2017: *PCIC Science Brief: Projected Changes to Grasslands and Three US Crops*. The Pacific Climate Impacts Consortium, 4 pp.

The Pacific Climate Impacts Consortium, 2018: *PCIC Science Brief: Sea Level Rise Observations and Acceleration*. The Pacific Climate Impacts Consortium, 5 pp.

The Pacific Climate Impacts Consortium, 2017: *PCIC Update: December 2017*. The Pacific Climate Impacts Consortium, 1 pp.

The Pacific Climate Impacts Consortium, 2017: *PCIC Update: June 2017*. The Pacific Climate Impacts Consortium, 1 pp.

The Pacific Climate Impacts Consortium, 2018: *PCIC Update: March 2018*. The Pacific Climate Impacts Consortium, 1 pp.

RDH Building Science, 2018: *NRGH Climate Change Vulnerability Assessment Report*. RDH Building Science, 108 pp.

Vancouver Coastal Health, 2018: *Moving Towards Climate Resilient Health Facilities for Vancouver Coastal Health*. Vancouver Coastal Health, 68 pp.

Wilson, T. and Eco-Logical Resolutions, 2018: *Enhancing Runoff and Drainage Management in the Fraser Valley Agricultural Sector*. BC Agriculture and Food Climate Action Initiative, 47pp.

PEER-REVIEWED PUBLICATIONS

Ben Alaya, M.A., **F.W. Zwiers** and X. Zhang, 2018: Probable maximum precipitation: its estimation and uncertainty quantification using bivariate extreme value analysis. *Journal of Hydrometeorology*, doi: 10.1175/JHM-D-17-0110.1.

Bonnet, R., J. Boé, **G. Dayon** and E. Martin, 2017: Twentieth-century hydrometeorological reconstructions to study the multidecadal variations of the water cycle over France. *Water Resources Research*, **53**, 8366–8382. https://doi.org/10.1002/2017WR020596.

Curry, C.L. and **F.W. Zwiers**, 2018: Examining controls on peak annual streamflow and floods in the Fraser River Basin of British Columbia. **Hydrology and Earth System Science**, doi:10.5194/hess-2017-531.

Dayon G., J. Boe, E. Martin and J. Gailhard, 2017: Impacts of climate change on the hydrological cycle over France and associated uncertainties. *Comptes Rendus Geoscience*, **350**, 4, 41-153, https://doi.org/10.1016/j.crte.2018.03.001.

Gagné, M.-È., **M. C. Kirchmeier-Young**, N. P. Gillett, and J. C. Fyfe, 2017: Arctic sea ice response to the eruptions of Agung, El Chichón, and Pinatubo. *Journal of Geophysical Research: Atmospheres*, **122**, doi:10.1002/2017JD027038.

Hiebert, J., A. Cannon, **A. Schoeneberg**, **S. Sobie** and **T. Murdock**, 2018: ClimDown: Climate Downscaling in R. *Journal of Open Source Software*, **3**, 22, 360, doi:10.21105/joss.00360.

Kharin, V.V., GM. Flato, X. Zhang, N.P. Gillett, **F.W. Zwiers** and K. Anderson, 2018: Risks from climate extremes change differently from 1.5C to 2.0C depending on rarity. *Earth's Future*, **6**, 5, 704-715, doi:10.1002/2018EF000813.

Kirchmeier-Young, M., **F.W. Zwiers**, N.P. Gillett and A.J. Cannon, 2017: Attributing Extreme Fire Risk in Western Canada to Human Influences. *Climatic Change*, doi:10.1007/s10584-017-2030-0.

Kushner, P.J., L. Mudryk, W. Merryfield, J.T. Ambadan, A. Berg, A. Bichet, R. Brown, C.P. Dersken, S.J. Dery, A. Dirkson, G. Flato, C. Fletcher, J. Fyfe, N. Gillett, C. Haas, S. Howell, F. Laliberte, K. McCusker, M. Sigmond, R. Sospedra-Alfonso, N. Tandon, C. Thackeray, B. Tremblay and **F.W. Zwiers**, 2017: Canadian Snow and Sea Ice: Assessment of Snow, Sea Ice, and Related Climate Processes in Canada's Earth System Model and Climate Prediction System. *The Cryosphere*, doi:10.5194/tc-2017-157.

PUBLICATIONS

Li, C., Y. Fang, K. Calderia, X. Zhang, N.S. Diffenbaugh and A.M. Michalak, 2018: Widespread persistent changes to temperature extremes occurred earlier than predicted. *Nature Scientific Reports*, **8**, 1007, doi:10.1038/s41598-018-19288-z.

Li, C., X. Zhang, **F.W. Zwiers**, Y. Fang and A.M. Michalak, 2017: Recent very hot summers in northern hemispheric land areas measured by wet bulb globe temperature will be the norm within 20 years. *Earth's Future*, doi:10.1002/2017EF000639.

Mueller, B.L., N.P. Gillett, A. Monahan and **F.W. Zwiers**, 2017: Attribution of Arctic sea ice decline from 1953 to 2012 to influences from natural, greenhouse-gas and anthropogenic aerosol forcing. *Journal of Climate*, **31**, 19, 7771-7787, doi:10.1175/JCLI-D-17-0552.1.

Ouali, D., F. Chebana and T.B.M.J. Ouarda, 2017: Fully nonlinear statistical and machine-learning approaches for hydrological frequency estimation at ungauged sites. Journal of Advances in Modeling Earth Systems, 9, 2, 1292-1306, doi:10.1002/2016MS000830.

Najafi, M.R., **F.W. Zwiers** and N.P. Gillett, 2017: Attribution of the Observed Spring Snowpack Decline in British Columbia to Anthropogenic Climate Change. *Journal of Climate*, **30**, 4113-4130, doi:10.1175/JCLI-D-16-0189.1

Najafi, M.R., **F.W. Zwiers** and N.P. Gillett, 2017: Attribution of Observed Streamflow Changes in key British Columbia Drainage Basins. *Geophysical Research Letters*, **44**, 21, 11012-11020, doi:10.1002/2017GL075016.

Naveau, P., A. Ribes, **F.W. Zwiers**, A. Hannart, A. Tuel and P. Yiou, 2017: Revising return periods for record events in the climate event attribution context. *Journal of Climate*, **31**, 3411-3422, doi:101175/JCLI-D-16-0752.1.

Pingree-Shippee, K., **F.W. Zwiers** and D. Atkinson, 2017: Representation of Canadian Coastal Storm Activity by Six Global Reanalyses. *International Journal of Climatology*, **38**, 2, 1041-1059, doi:10.1002/joc.5235.

Seiler, C., **F.W. Zwiers**, K.I. Hodges and J.F. Scinocca, 2017. How does dynamical downscaling affect model biases and future projections of explosive extratropical cyclones along North America's Atlantic coast? *Climate Dynamics*, doi:10.1007/s00382-017-3634-9.

Sgubin, G. D. Swingedouw, **G. Dayon**, I.G. de Cortázar-Atauri, N. Ollat, C. Pagé and C. van Leeuwen, 2018: The risk of tardive frost damage in French vineyards in a changing climate. *Agricultural and Forest Meteorology*, **250-251**, 226-242, ISSN 0168-1923, https://doi.org/10.1016/j.agrformet.2017.12.253.

Shrestha, R., A.J. Cannon, **M.A. Schnorbus** and **F.W. Zwiers**, 2017: Projecting future nonstationary extreme streamflow for the Fraser River, Canada. *Climatic Change*, **145**, 289303, doi:10.1007/s10584-017-2098-6.

Sillmann, J., T.L. Thoranisdottir, N. Schaller, L. Alexander, G.C. Hegerl, S.I. Seneviratne, R. Vautard, X. Zhang and **F.W. Zwiers**, 2017: Understanding, modeling and predicting weather and climate extremes: Challenges and opportunities. *Weather and Climate Extremes*, **18**, 65-74,doi:10.1016/j.wace.2017.10.003.

Snauffer, A., W. Hsieh, A. J. Cannon, and **M. A. Schnorbus**, 2018: Improving gridded snow water equivalent products in British Columbia, Canada: multi-source data fusion by neural network models. *The Cryosphere*, **12**, 891-905, doi:10.5194/tc-2017-56.

Sobie, S.R. and **T.Q. Murdock**, 2017: High-resolution statistical downscaling in southwestern British Columbia. *Journal of Applied Meteorology and Climatology*, **56**, 1625-1641, doi:10.1175/JAMC-D-16-0287.1.

Stott, P.A., D.J. Karoly and **F.W. Zwiers**, 2017: Is the choice of statistical paradigm critical in extreme event attribution studies? *Climatic Change*, **144**, 143-150, doi:10.1007/s10584-017-2049-2.

Teufel, B., L. Sushama, O. Huzly, G.T. Diro, D.I. Jeong, K. Winger, C. Garnaud, R. de Elia, **F.W. Zwiers**, J.R. Gyakum, D. Matthews and V.-T.-V. Nguyen, 2017: Investigation of the mechanisms leading to the 2017 Montreal flood. *Climate Dynamics*, doi:10.1007/s00382-018-4375-0.

Wan, H., X. Zhang and **F.W. Zwiers**, 2018: Human influence on Canadian temperatures. *Climate Dynamics*, doi:10.1007/s00382-018-4145-z.

Zhang, X., G. Li, A. Cannon, **T. Murdock**, **S. Sobie**, **F.W. Zwiers**, K. Anderson and B. Qian, 2018: Indices of Canada's future climate for general and agricultural adaptation applications. *Climatic Change*, **148**, 1-2, 249-263 doi: 10.1007/s10584-018-2199-x.

PACIFIC CLIMATE IMPACTS CONSORTIUM

University House 1
PO Box 1700 STN CSC
University of Victoria
Victoria, British Columbia,
Canada

Phone: 250.721.6263
Fax: 250.721.7212

pacificclimate.org