



**PACIFIC CLIMATE
IMPACTS CONSORTIUM**
CORPORATE REPORT | 2014-2015

OUR ROLE

As the Earth's climate continues to change, regional stakeholders from the public and private sectors require accessible, high-quality climate information in order to aid in planning. The mandate of the Pacific Climate Impacts Consortium is to meet this need by providing high-quality regional climate services, including data, analysis and interpretation, to our stakeholders in the Pacific and Yukon Region of Canada. PCIC directly performs applied, regional climate research, distils research from the broader climate science community and provides information ranging from raw data and model output suitable for scientific research, to high-level summaries and regional overviews suitable for regional planning, and policy research. PCIC's research activities are focused into three Themes: Regional Climate Impacts, Hydrologic Impacts and Climate Analysis and Monitoring. In order to provide the most robust and highest quality services possible, PCIC builds strong partnerships with stakeholders across the public and private sectors, collaborates closely with researchers in university and government labs and participates actively in the peer-reviewed literature, through publication and review.

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MESSAGE FROM THE CHAIR BOARD OF DIRECTORS DR. DAVID CASTLE

For the past decade, the Pacific Climate Impacts Consortium at the University of Victoria has consistently delivered high-quality climate information to government, industry and the public in BC and beyond. As the need to understand the impacts of climate change and variability continues to grow, PCIC's role as a regional climate service centre is increasingly relevant and its services more in demand. The high value UVic places on PCIC's role and services is reflected in the recent 5-year renewal of its financial commitment to PCIC. This investment will allow for the continued leveraging of strategic partnerships with the public and private sectors and ensure that practical information, analysis and interpretation continues to be made available to stakeholders to support planning, decision-making and inform adaptation strategies.

On behalf of the Board of Directors, I would like to thank PCIC's leadership, governing bodies, staff and partners for their dedication and commitment, and for another year of achievements and advancements in applied research and climate service delivery.

Board of Directors March 2015

- David Castle (Chair)**, University of Victoria
- Renata Kurschner (Vice-Chair)**, BC Hydro
- Don Barnhardt**, University of Victoria
- Alain Bourque**, Ouranos
- Paul Knowles**, BC Ministry of Forest, Lands and Natural Resources Operations
- Asit Mazumder**, University of Victoria
- Adam Monahan**, University of Victoria
- Tom Pederson**, Pacific Institute for Climate Solutions
- Carol Pendray**, University of Victoria
- Terry Prowse**, Environment Canada
- Francis Zwiers (Director, President and CEO)**, Pacific Climate Impacts Consortium
- Cassbrea Dewis (Treasurer)**, Pacific Climate Impacts Consortium
- Jamie Millin (Secretary)**, University of Victoria



MESSAGE FROM THE CHAIR PROGRAM ADVISORY COMMITTEE THOMAS WHITE

This past year, PCIC made significant progress advancing our understanding of climate impacts in a variety of sectoral and regional contexts, drawing on its ongoing partnerships with private and public partners and the strength of its applied research programs focused on the delivery of climate impacts data, the analysis of the impacts of climate variability and the interpretation of climate impacts data and information.

Highlights from the many achievements this past year include two new hydrologic data portals, updates to Seasonal Climate Maps, Plan2Adapt and the Regional Analysis Tool, enhanced capabilities for modelling glacial processes and improvements to downscaling methods. BC climate trends and climatologies were updated to 2013 using station data from both the public and private sectors and PCIC initiated work on robust "intensity-duration-frequency" curves for a changing climate. A project report has been prepared and a briefing note is due for release in fall of 2015. Several new regional climate assessments for different communities and sectors were completed, including climate projections for the Fraser Valley, peak flow projections for the Fraser River and contributions to assessments for the oil and gas sector in Northeastern BC and the Ministry of Transportation and Infrastructure, many of which are available online as indicated in their respective sections in this report.

The Committee also welcomed new members with expertise from agriculture, health, hydrology, local government and industry and was actively engaged with PCIC staff in the development of updated 5-year research plans for each of its three applied research programs. The plans are aligned with PCIC's new Strategic Plan and position the programs to maintain their broad and comprehensive suite of climate services, while also ensuring they stay relevant and forward-looking to emerging climate science questions. These plans are available online in PCIC's Publications Library.

Program Advisory Committee March 2015

- Thomas White (Chair)**, BC Ministry of Environment
- Yapo Alle-Ando**, Teck Resources Ltd
- David Campbell**, BC Ministry of Environment
- Greg Flato**, Environment Canada
- Brenda Goehring**, BC Hydro
- Cathy LeBlanc**, BC Ministry of Community, Sport and Cultural Development
- Kate Miller**, Cowichan Valley Regional District
- Dirk Nyland**, BC Ministry of Transportation and Infrastructure
- Lawrence Pitt**, Pacific Institute for Climate Solutions
- Stephanie Smith**, BC Hydro
- Dave Spittlehouse**, BC Ministry of Forests, Lands and Natural Resource Operations
- Tim Takaro**, Simon Fraser University
- Stephanie Tam**, BC Ministry of Agriculture and Lands
- Francis Zwiers**, Pacific Climate Impacts Consortium

On behalf of the program committee, I would like to congratulate PCIC's staff for another successful year. I look forward to working with PCIC in my ongoing role as Chair of the Committee.



MESSAGE FROM THE PCIC DIRECTOR DR. FRANCIS ZWIERS

PCIC's 2014-2015 year was one of review, planning, renewal and achievements. Following on our successful organizational review in

2014, UVic extended its funding commitment for an additional five years. We renewed our long-term agreement with BC Hydro, formed many new partnerships and continued to maintain over 40 active partnerships with the private and public sectors. Collaboration is a PCIC core value and we acknowledge and thank all our partners and governing bodies for their support which provides the long-term operational and financial stability required to deliver our services.

As our organization grows and evolves, we continue to add new services for our users. One such service is assisting others in their efforts to deliver information and data to their users. This has included providing projections for the Ministry of Agriculture, providing data for the development of a transboundary ecosystem assessment, providing both data and analysis for the development of an engineering Technical Circular and Climate Language Primer, and developing software for calculating climate extremes that has been used widely in research conducted all over the world.

Looking forward, we are excited to continue engaging with our users to advance projects, explore new opportunities and use the synergy of our collaborations to bridge the gap between climate science and applications.

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To set the stage for our renewed five-year mandate, we updated our strategic and research plans. The revised 2015-2019 plans are the result of extensive consultation involving input from users, our Board of Directors and Program Advisory Committee, as well as guidance from the UVic Board of Governors. Our new strategic plan enhances our focus on user engagement and reprioritizes our service objectives and supporting goals to ensure the production and delivery of useful and timely climate information, analysis and interpretation to regional stakeholders. Similarly, our new research plans were adjusted to align with the current needs of our users and to ensure PCIC has the scientific and information resources necessary to support our service delivery objectives.

Our research staff and affiliates continued to meet their objectives of quantifying, analyzing and interpreting the impacts of climate change, and our operational and computational teams ensured that the appropriate resources and processes were in place to support our research programs. Together, they fulfilled commitments of long-term agreements while remaining flexible and engaging in new opportunities. This report highlights PCIC's operational and research achievements and we celebrate these with our partners.

REGIONAL CLIMATE SERVICES

PCIC's delivery of regional climate services is organised around our three service objectives. These are:

1. To provide historical data and future climate projections specific to the PCIC study region
2. To provide analysis of the impacts of climate variability and change on the regional climate and water resources
3. To provide interpretation of regional climate information specific to user needs

Historical data and future climate projections form the foundation of the regional climate services we provide. They allow us to understand the climate of past decades and how the future may differ from it. We gather and generate climate observations and data, which we then provide to our users through intuitive map-based point and click interfaces on our Data Portal. We also use these data products, including high resolution downscaled information and hydrologic model output, to analyze potential impacts in the BC-Yukon region and share the results of this analysis with stakeholders in our region. Finally, we provide tailor-made interpretation of these results to fit our users' needs.

REGIONAL CLIMATE SERVICES PROVIDING DATA: DATA PORTALS

In order to understand the past and ongoing changes to the climate of the BC-Yukon region and what the future may hold in store, we require both observational weather data and climate model output. Often the latter must be downscaled to be of use for the analysis of PCIC's study region. PCIC scientists, working closely with our computational support team both gather and generate data and model output, which are then used for our research and provided to our users through our data portal.

MULTIPLE AND EXPANDED DATA PORTALS

During 2014-2015, PCIC continued to maintain and enhance its excellent data delivery services by building upon the strong foundation laid in previous years. This year saw several further improvements, and a substantial effort into maintaining the product and supporting our users. We released two new data portal pages, continued to ingest near real-time station observations from our Provincial partners, added new features, answered users' questions and fixed software bugs. We developed and deployed 2 minor and 10 bugfix releases throughout the fiscal year. Additionally, we:

- › Serviced over 3000 users
- › Distributed 4.6 terabytes of gridded climate projections
- › Distributed 11 billion meteorological observations
- › Added 20 million past observations to the Provincial Climate Data Set
- › Created and released two new Hydrologic Projections portal pages:
 - » a page which provides access to gridded input to and output from the VIC Hydrologic Model
 - » a page which provides access to routed streamflow projections at gauged locations around the province.

HIGH RESOLUTION PRISM CLIMATOLOGIES

Working in collaboration with Oregon State University's PRISM group, PCIC has applied the PRISM climate mapping system to develop climate maps for BC. This system has been tested and verified throughout the United States and used across the world. It is well-suited for the BC-Yukon region's complex terrain and the mix of continental and ocean influences which affect the area's climate. PRISM was used to generate new monthly climatological precipitation and maximum and minimum temperature maps for the most recent 1981-2010 climate normal period. These maps were prioritised to meet the needs of British Columbians as well as two US agencies who are interested in the current climate of the Columbia River basin. These maps will be offered on the PCIC data portal in late 2015.

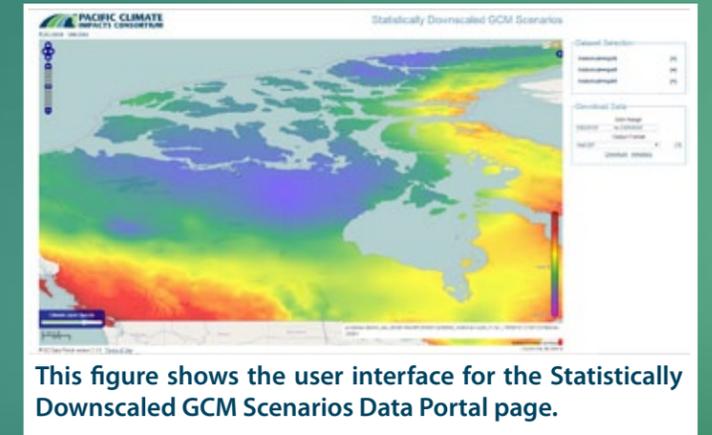
pacificclimate.org/data/high-resolution-prism-climatology

REGIONAL CLIMATE SERVICES PROVIDING DATA: DATA PORTALS

HIGH RESOLUTION CLIMATE CHANGE PROJECTIONS

Using Global Climate Model output from models participating in the fifth phase of the Coupled Model Inter-comparison Project (CMIP5), PCIC has downscaled and made available a number of climate variables for all of Canada on our Statistically Downscaled GCM Scenarios Data Portal page (see figure on right). Environment Canada also links to this portal as a service to its users. The downscaled scenarios are high resolution (10 kilometre, daily) and were produced with our newly developed Bias Correction/Constructed Analogues with Quantile mapping (BCCAQ) downscaling technique. This method was specifically designed to improve the representation of extreme precipitation, better represent spatial patterns and maintain the trend of the projections. We have also applied this method to the coterminous United States (i.e. the "Lower 48") and this product is available to researchers by request.

pacificclimate.org/data/statistically-downscaled-climate-scenarios



This figure shows the user interface for the Statistically Downscaled GCM Scenarios Data Portal page.

BC STATION DATA - PROVINCIAL CLIMATE DATA SET

Continually updated in near real-time, our Station Data Portal page draws observational climate data from over 6700 locations in the BC-Yukon region. These stations have records that extend back up to 140 years. PCIC researchers have gathered together a substantial amount of data from Environment Canada, several BC Ministries, BC Hydro, Rio Tinto Alcan and devoted efforts to backfilling missing data from the Ministry of Transportation and Infrastructure. Current work on this portal includes the updating of BC Hydro data through an initial attempt to remove non-climatic artefacts in the data (called "data homogenization").

pacificclimate.org/data/bc-station-data

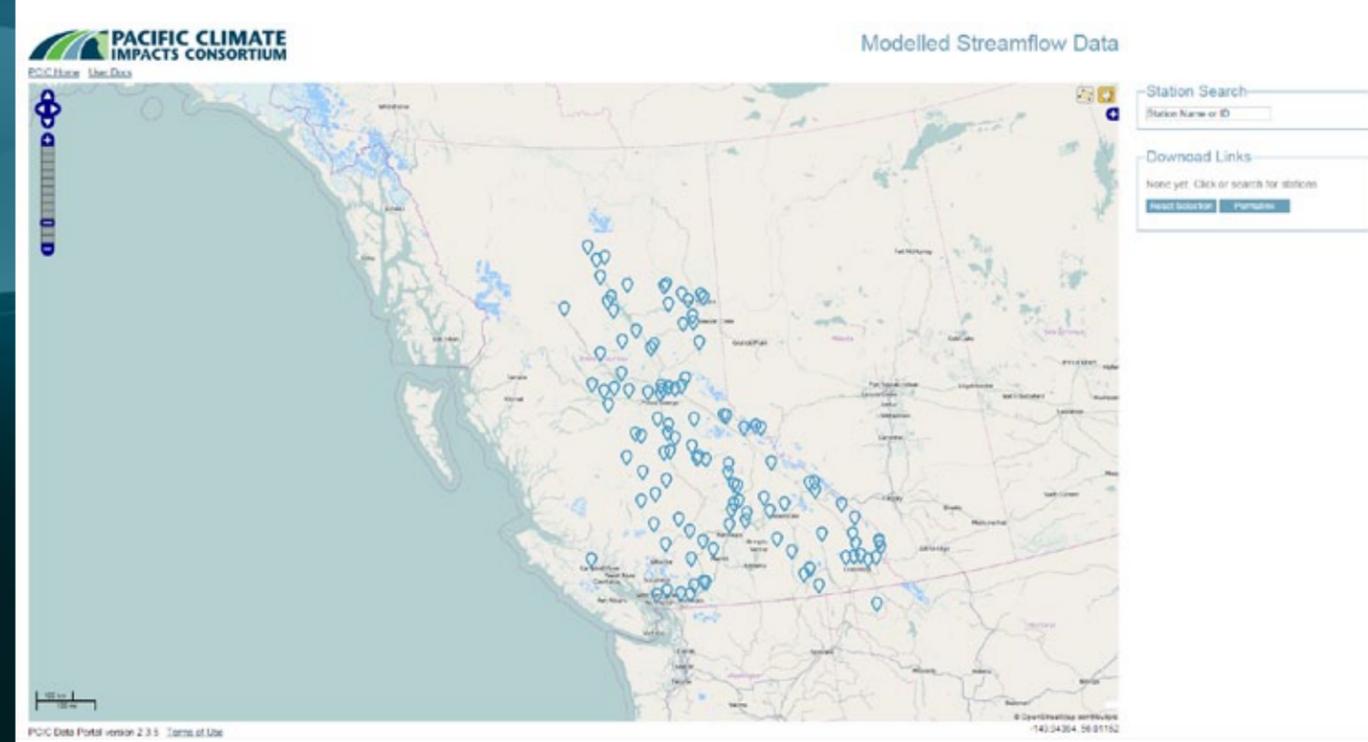
REGIONAL CLIMATE SERVICES PROVIDING DATA: DATA PORTALS

STATION HYDROLOGIC MODEL OUTPUT

Using data from climate observations as well as model output from the third phase of the Coupled Model Inter-comparison Project, statistical downscaling methods and the VIC hydrologic model, PCIC scientists have simulated streamflow data for more than 120 stations in BC. The locations include Water Survey of Canada gauge locations and BC Hydro project sites in the Peace, upper Columbia, Fraser and Campbell River watersheds. These location-specific projections are also available from our Station Hydrologic Output Data Portal (see figure, below).

pacificclimate.org/data/station-hydrologic-model-output

This figure shows the user interface for the Modelled Station Hydrologic Output Data Portal page.



HIGH RESOLUTION HYDROLOGIC PROJECTIONS

Using output from the Variable Infiltration Capacity (VIC) hydrologic model, PCIC researchers have analyzed and provided gridded projections of several hydroclimatic variables for four basins in British Columbia: the Peace, upper Columbia, Fraser and Campbell River. This output, including runoff, snow water equivalent, soil moisture and streamflow following three different future emissions scenarios is available from our Data Portal at a resolution of 1/16 degrees (about five to six kilometres, depending on latitude).

pacificclimate.org/data/gridded-hydrologic-model-output

REGIONAL CLIMATE SERVICES PROVIDING ANALYSIS: ANALYSIS TOOLS

Using both data and model output, PCIC scientists undertake research that serves to improve our understanding of our region's climate and further the fields of regional climate analysis and hydrology more generally. Our researchers examine past, present and projected future changes to the climate of the BC-Yukon region, including climate extremes and provide their findings in usable forms for our users and the scientific community. These include web-based analysis tools and full regional and sectoral analyses of changes to climate and hydrology that are suitable for planners, engineers and policymakers.

UPDATED ANALYSIS TOOLS

» **Plan2Adapt:** Plan2Adapt.ca

Because the effects of climate change will be different in each region of BC, PCIC has developed the Plan2Adapt tool in order to allow users to see climate projections and impacts for their areas, climate variables and sectors of interest. The Plan2Adapt tool generates regional maps, plots and data, and has summaries of potential impacts for projected climate change in BC. Over the 2012-2013 fiscal year, the tool was updated with new functionality and regions. Over the 2014-2015 fiscal year, PCIC researchers and the computational support team worked on processing climate model output from the fifth phase of the Coupled Model Intercomparison Project (CMIP5), reconfiguring tools to handle the new base data and adding a health impacts tab. The updated tool is scheduled for release in spring of 2016.

» **Regional Analysis Tool:** pacificclimate.org/analysis-tools/regional-analysis-tool

As with the Plan2Adapt tool, the Regional Analysis Tool was created to help users access information relevant to their areas of interest by generating regional maps, plots and data for projected changes to the climate of the BC-Yukon region. It differs from the Plan2Adapt tool in that it has more configurable options, more variables and the ability to analyze individual global climate model runs. PCIC researchers and the computational support team have recently performed similar data processing and tool reconfiguration for the Regional Analysis Tool as they performed for Plan2Adapt. The development version of this tool has been completed and we look forward to the release of the production version in spring of 2016.

» **Seasonal Maps:** pacificclimate.org/analysis-tools/seasonal-maps

In addition to serving the PRISM climate maps through the PCIC data portal and the results of trends analysis for the province, PCIC also continues to update the seasonal anomaly maps on a monthly and seasonal summary basis. These maps show temperature and rainfall departures from the 30-year mean climate from weather station observations throughout BC. The maps start in 1972 and were recently updated to 2015.

» **Open Source Software Library:** pacificclimate.org/resources/software-library

In the course of their research, PCIC scientists and our computational support team have developed a number of software packages in the R programming language for use with climate data. This software ranges in use from simple tasks like unit conversion and conversion between calendars, to our world-leading software package for calculating indices of climate extremes, `climindex.pci`. This software, recently updated, is the only package in the world that can scalably compute the 27 core climate extremes indices of the international Expert Team on Climate Change Detection. It has been used as model software for the calculation of indices all over the world. It has also been utilized for numerous scholarly articles, including several to which PCIC has contributed. Results produced with the package have helped to further our understanding of projected future changes to climate extremes along different emissions trajectories and how some mitigation methods, such as geoengineering may affect climate extremes.

REGIONAL CLIMATE SERVICES PROVIDING ANALYSIS: DOWNSCALED PROJECTIONS

A core service offered by PCIC is the development and use of downscaled projections to assess the potential regional impacts of climate change. These are used in sectoral analyses in areas such as transportation, health and outdoor recreation, but also in more fundamental assessments of changes to the local features of the Earth system, such as changes in storminess and ecosystem connectivity. The focus of each assessment is determined in co-operation with users. Over the pasts fiscal year, ongoing progress in these assessments has been made in a number of regions. Some of these are discussed elsewhere in this report, including projections in Northeast BC for the Oil and Gas Commission, in the Fraser Valley for the BC Ministry of Agriculture, the BC Agriculture and the Food Climate Action Initiative, and climate summaries for the Ministry of Forestry, Lands and Natural Resource Operations. In addition, PCIC engaged in an assessment of potential impacts to agriculture in BC and a project on transboundary ecosystems.

AGRICULTURAL ASSESSMENT

As the climate continues to change, farmers and their communities in BC will have to deal with changing conditions and make decisions about the costs and benefits of undertaking adaptation measures. To aid in this, climate projections provided by PCIC were used to assess potential impacts to BC's agricultural sector. The Ministry of Agriculture's Innovation and Adaptation Services Branch used these projections and collaborative discussions with industry experts, agronomists, and PCIC researchers, to develop four scenarios to examine potential economic impacts to agriculture in four regions of BC. These scenarios were also used to investigate the extent to which adaptation may be able to offset these impacts. Though the exact figures varied with the scenario, the estimated total economic benefits of taking adaptation measures range between \$105 million to \$270 million in a year over all four regions. A report from this work was released through the BC Ministry of Agriculture.

pics.uvic.ca/sites/default/files/Climate%20Stressor%20Scenarios-%20Final%20Report%20pdf.pdf

TRANSBOUNDARY ECOSYSTEM ASSESSMENT

While adaptation efforts centred on the retention and restoration of ecosystem connectivity are recommended for maintaining ecosystem biodiversity, there is relatively little in the way of guidance for these activities. Because of this, a broad group of partners including PCIC and the Great Northern Landscape Conservation Council have convened to develop science-based plans for conserving ecosystem connectivity in the BC-Washington transboundary region. Over the 2014-2015 fiscal year, five meetings and two workshops were held in order to identify climate impacts and goals, develop and review conceptual models, determine adaptation strategies and orient partners to the projects. PCIC scientists participated in this through the provision and analysis of climate data sets. The final results of this analysis are to be released in fall 2015, in the form of datasets, conceptual connectivity models, adaptation strategies and reports, as well as associated workshops, training sessions and webinars. A peer-reviewed paper on this work is to be completed for spring 2016.

REGIONAL CLIMATE SERVICES PROVIDING ANALYSIS: SUMMARIES AND TREND ANALYSIS

REGIONAL CLIMATE SUMMARIES

In order to help regional stakeholders plan for projected climate change, in 2013 we prepared a set of high-level summaries for BC's eight resource regions with the support of the BC Ministry of Forestry, Lands and Natural Resource Operations. These summaries place climate change projections into a historical context and discuss how this relates to the overall picture for the province as a whole. Using output from PCIC's Plan2Adapt tool, and the CANGRID and PRISM data sets, as well as information on the climate influences, terrain, economies and local ecosystems, the summaries give an overview of projected climate change and its associated impacts for each region. This year we have updated these summaries to include hydrologic information, including both past trends and future projections.

These summaries are available at:

pacificclimate.org/sites/default/files/Climate_Summaries.zip



TREND ANALYSIS OF OBSERVATIONAL DATA IN BC

Our users need access not only to observational climate data, but also analyses of the trends in these data, which indicate how the climate has changed in the past and continues to change through the present day. In collaboration with the Climate Action Secretariat and Environmental Reporting BC, PCIC was able to update trend analyses for temperature and precipitation for BC from 1900 to present. Additional analyses investigated trends in growing degree days, heating degree days, and cooling degree days. The results of these analyses are used in an updated report on climate trends and indicators for BC and are presented on the web through Environmental Reporting BC.

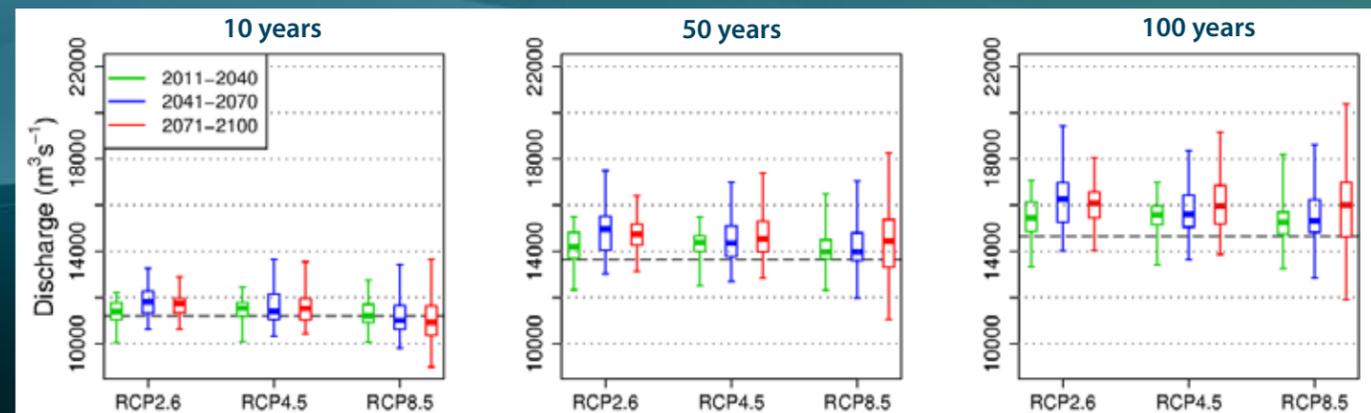
<http://www2.gov.bc.ca/assets/gov/environment/climate-change/policy-legislation-and-responses/adaptation/climatechangeindicators-2015update.pdf>

REGIONAL CLIMATE SERVICES PROVIDING INTERPRETATION: SECTORAL ANALYSIS

Providing regional climate services to our users means more than supplying data and analysis. In order to meet the needs of our regional stakeholders we also translate the results of basic scientific research and analysis for a variety of levels. The resulting interpretations include technical reports, some of which are user-commissioned, tailored to our users' needs. They also include plain language summaries, guidance documents, presentations and in-depth user consultations.

MODELLING HYDROLOGIC IMPACTS OF CLIMATE CHANGE

PCIC scientists have recently examined the effects of climate change on Fraser River flooding scenarios and modelled annual maximum peak flow on the Fraser River from climate projections. This project was undertaken on behalf of the BC Ministry of Forests, Lands and Natural Resource Operations. The intended outcome was to better understand potential changes to the peak flow of the Fraser River at Hope, using output from climate models from both CMIP3 and CMIP5. Our researchers employed a statistical approach to estimate peak flow change using the model output as large scale climatic drivers of seasonal temperature and precipitation.



This figure shows projected changes in three peak flow return levels for the Fraser River at Hope for three periods (2011-2040, 2041-2070 and 2071-2100) and three RCP emissions scenarios. Projected flows are given as box-plots summarizing the results for an ensemble of CMIP5 projections, with ensemble sizes of 45, 56, and 56, for RCP 2.6, 4,5 and 8.5, respectively. The dashed line indicates the flows for the 1961-1990 baseline period.

CLIMATE CHANGE AND BC'S HIGHWAYS

Large scale infrastructure projects, such as BC's highways, tend to have long lifespans and as a result, planning for such projects is necessarily long-term. In order to help the BC Ministry of Highways and Transportation Infrastructure with long-term planning that takes climate change into account, PCIC scientists performed an analysis of historical gridded observations and climate projections using model output from CMIP5. This was used for the Highway Vulnerability Assessments for the Stewart, Bella Coola and Pine Pass. In addition, PCIC scientists aided in the development of a Climate Language Primer and a Technical Circular for engineers, which were completed in spring of 2015.

The Technical Circular is available at:

<http://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/technical-circulars/2015/t06-15.pdf>

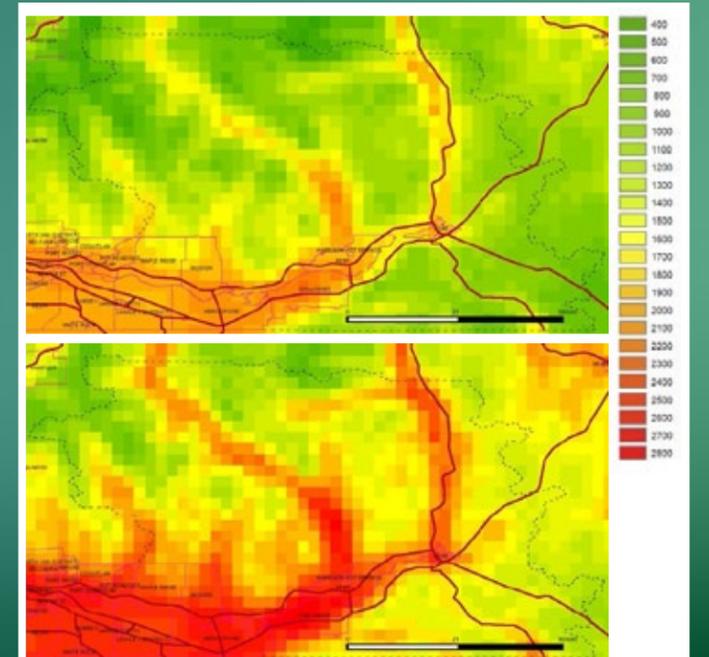
The Climate Language Primer is available at:

http://www.th.gov.bc.ca/climate_action/documents/Climate_Data_Discussion_Primer.pdf

REGIONAL CLIMATE SERVICES PROVIDING INTERPRETATION: SECTORAL ANALYSIS

CLIMATE PROJECTIONS FOR THE FRASER VALLEY

In order to support planning with climate change in mind for British Columbia's agricultural sector, PCIC scientists provided climate data for a volume of the BC Agriculture & Food Climate Action Initiative's BC Agriculture and Climate Change Regional Adaptation Strategies series. The projections provided were for the Fraser Valley in the 2020s and 2050s and showed a number of changes to variables of interest, including a warming of 1.8°C, increases of 7% in annual precipitation, 26 additional frost-free days and 353 additional growing degree days (see figure on right) by the 2050s. These projections are intended to help agricultural producers prepare for potential changes to their region's climate and form the foundation for the agricultural impacts analysis in the report.



This figure shows growing degree days, a measure of heat accumulation used for crop growth in agriculture, over the 1961-1990 baseline period (top) and from model projections for the 2050s for the Fraser Valley.

OIL AND GAS SECTOR

Northeastern BC has recently seen strong growth in several sectors, including forestry, tourism, mining, oil and natural gas. The oil and gas sector is dependent on other sectors such as transportation, and resources such as water. In addition, oil and gas projects involve long-term planning and work in remote locations with long supply chains, and sensitive infrastructure such as pipelines and drilling pads. Because of this, there is an interest in the sector for projections of the region's future climate and potential associated climate impacts. The Fraser Basin Council, Natural Resources Canada and the BC Ministry of Environment therefore undertook a sectoral risk assessment using climate data from PCIC. In addition, they released a climate Backgrounder, discussing climate change in the region, with the participation of PCIC's Regional Climate Impacts Theme.

The final report is available at:

http://www.retooling.ca/cgi/page.cgi/Northeastern_BC_Climate_Risk_Assessment_for_the_Oil_Gas_Sector-r372?_id=105

The Climate Backgrounder is available at:

http://www.retooling.ca/cgi/page.cgi/Backgrounder_Future_Climate_in_Northeastern_British_Columbia-r369?_id=105

REGIONAL CLIMATE SERVICES PROVIDING INTERPRETATION: USER-SPECIFIC REPORTS

Our regional stakeholders have a variety of individual needs. In order to best meet these needs, PCIC meets and works closely with users and stakeholders in order to produce reports and summary information that are developed specifically to meet their requirements.

REPORTS FROM WORKSHOPS

One of the best ways to determine what our users are looking for is to meet with them. Over the 2014-2015 fiscal year, PCIC released three reports on workshops held both to improve the services that we offer and to bring together members from various sectors for dialogue. Two of these reports were from workshops focused on PCIC's Hydrologic Impact and Regional Climate Impact Themes and the third focused on atmospheric river events. In the former two workshops PCIC scientists discussed the methodology of PCIC's research teams, recent research findings, and the data and services that PCIC makes available. PCIC users also delivered talks on their needs and experiences. The meetings concluded with open discussion groups including all members, focused on how these PCIC Themes can best serve the public. The third report summarized a joint workshop on atmospheric rivers that was held by PCIC, the Pacific Institute for Climate Solutions and Environment Canada. This report discusses the workshop itself, summarizes our current best understanding of these events and how they are expected to change in the future, as well as covering current efforts to identify key areas of vulnerability and actions to offset expected impacts.



SUMMARIES AND USER-COMMISSIONED REPORTS

As part of our ongoing engagement with our users, PCIC has spent the last year developing a large volume of summary information and user-commissioned reports. PCIC researchers have worked with users to analyse downscaling methods and develop guidance documents for the use of downscaled model projections from CMIP5. These include an analysis of the robustness of the downscaling techniques themselves and have resulted in five research papers. This project was ongoing through the 2014-2015 fiscal year, as PCIC researchers continued to test the best methods on a much larger group of climate models. A guidance document from this work is scheduled for release in late spring, 2016. The report and guidance document developed for the BC Ministry of Transportation mentioned in the Sectoral Analysis of Climate Change Impacts section above is also an example of the type of user-specific report that PCIC delivers to our community.

REGIONAL CLIMATE SERVICES PROVIDING INTERPRETATION: SCIENCE COMMUNICATION

While data, technical analysis, low-level technical reports and guidance documents are useful for our technical and scientific users, our regional stakeholders also require high-level summaries and presentations, describing both research results and PCIC's activities. These summaries and presentations are provided in plain language, in order to help our users to stay abreast of the most recent, relevant findings in the scientific literature as well as advances in regional climate services and analysis that may be of interest to them.

PLAIN LANGUAGE SUMMARIES

There is a clear need for the translation of scientific results into plain language, high-level summaries that explain the most important results of a particular vein of research but do not rely on the user having previous knowledge of the specific area. In order to address this need, PCIC publishes summary reports of research projects and workshops, as well as Science Briefs, short discussions of articles from the peer-reviewed literature chosen for their relevance to the needs of our regional stakeholders. In addition to the workshop summary reports discussed in the User-Specific Reports section, PCIC released a summary report on research on the suitability of the monthly drought code as a metric for fire weather. The code is a means of describing the moisture content of deep soils and the researchers found it to be a simple but effective metric for simulating wildfire severity.

This year's Science Briefs covered eleven papers from the peer-reviewed literature. The Science Briefs examined topics ranging from the projected biomass changes in North America and the role that utilizing bioenergy could play in mitigation efforts, to the response of the Earth's climate to carbon emissions, how mean and extreme snowfall may respond to climate change and the so-called "hiatus" in surface warming, among others.

These Science Briefs are available from our Publications Library:

pacificclimate.org/resources/publications



REGIONAL CLIMATE SERVICES PROVIDING INTERPRETATION: SCIENCE COMMUNICATION

ELECTRONIC COMMUNICATION

In order to share our services widely and keep our users up-to-date with our latest projects, PCIC maintains a strong web presence and regularly sends out PCIC Updates, our newsletter. As discussed above, our website includes a data portal and a number of cutting-edge tools and software packages for different types of technical analysis. In addition, we use our site to share our publications, PCIC-related news and events, as well as links to other sources of climate information for our users. Our website's Publication Library was recently upgraded to make it easier to search by publication type. Our site also saw a restructuring, including the creation of an Analysis Tools section. Our newsletters serve as another method to share what we're up to, including summaries of projects that we're working on and commentary from PCIC researchers on recent weather and climate events. Over the 2014-2015 fiscal year these included a discussion of our hydrologic model's ability to simulate streamflow indicators, expansions to our Data Portal, commentary on the release of the IPCC's reports and some discussion of our work downscaling climate projections across North America.



The updated PCIC Publications Library, with increased search functionality.

BC CWRA WORKSHOP

On November 18th 2014 PCIC Hydrologists held a workshop for the BC Branch of the Canadian Water Resources Association's at the Creekside Community Centre, in Vancouver. The researchers began by detailing the methodology behind PCIC's hydrologic projections. This included a discussion of the global climate model output and the downscaling methods used, as well as how the VIC hydrologic model works and the decision-making process of PCIC's Hydrologic Impacts team. The researchers also discussed some of the results for the Fraser, Peace, Columbia and Campbell Rivers and how hydrologic data could be accessed from PCIC's Data Portal. In addition, they explained the uncertainty in the projections that arises from a number of sources including the climate models themselves, the emissions scenarios used to run them and the downscaling process, before concluding with a discussion of future research directions.

SCIENTIFIC & INFORMATION RESOURCES

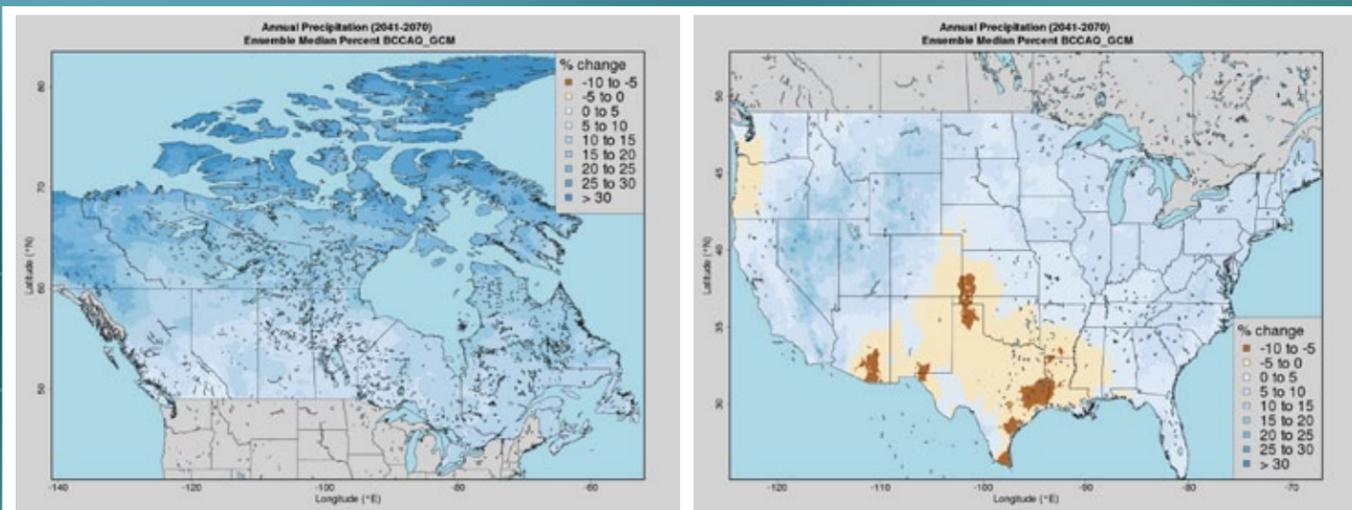
PCIC leverages its research partnerships and the skill of its scientific personnel to provide cutting-edge regional climate services to its regional stakeholders. These services include applied research that is focused directly on supporting our service objectives. This research improves our understanding of the underlying physical processes that affect regional climate and the performance of the scientific toolkit we use in our analysis.

SCIENTIFIC & INFORMATION RESOURCES APPLIED RESEARCH

In order to ensure that we have a wealth of scientific and information resources of the highest possible quality to support our service delivery objectives, PCIC researchers undertake a variety of applied research projects each year. Over 2014-2015, these included two projects for the VIC hydrologic model, broadening the spatial domain over which it has been applied and adding glacier dynamics to better understand the hydrology of regions with meltwater. PCIC researchers also expanded the areas to which they have applied downscaling and continued to examine downscaling methods. In addition, our researchers updated the PRISM maps that we offer and began examining future projections of the intensity, duration and frequency of rainfall events.

DOWNSCALED CLIMATE INFORMATION FOR NORTH AMERICA

In order to better understand how global climate change will affect regions in North America, PCIC researchers used the BCCAQ statistical downscaling method that has been developed in-house to develop a 10-kilometre daily time series of projected changes in temperature and precipitation using model output available from CMIP and NARC-CAP, for all of North America. The daily 10-km resolution projections for Canada are available from the PCIC data portal, while those for the United States are available to users upon request.



The panels above show the projected percent change in annual precipitation from the 1971-2000 climate baseline period for the 2050s, over Canada (left) and the coterminous United States (right). Median values from an ensemble of 12 runs from GCMs participating in CMIP5 are shown. The models were driven with the RCP 8.5 (high) emissions scenario.

SCIENTIFIC & INFORMATION RESOURCES APPLIED RESEARCH

HYDROLOGIC MODEL OVER LARGER SPATIAL DOMAIN

PCIC has been continuously increasing the scope of hydrologic analysis within the BC-Yukon region. For the upcoming CMIP5-based hydrologic projections, PCIC hydrologists will apply the VIC hydrologic model to a to river basins within a much larger spatial domain than previous work. This has required reworking the parameterizations that are used within the model from scratch. These parameterizations account for processes that happen on a finer scale than what the model can resolve and this reworking has also opened up the opportunity to make sure that they are up-to-date with the latest data that is available on soil, vegetation, topography, climate and hydrometric features. Models must be calibrated to known observational data and our hydrologists have also revisited and modernized the model calibration scheme. In addition, they have incorporated updated tools for dealing with how streamflow reacts at different points in a river channel.

The VIC model's code has been substantially reengineered to produce a more realistic description of the land surface, to run more efficiently, and to better handle data input and output.



This figure shows the old (yellow) and new (green) study domains for the hydrologic projections. The extent of glaciated terrain is shown in light blue.

DOWNSCALING METHOD INTER-COMPARISON

Our users require regional climate projections on a scale that is often below the resolution of global climate models. In order to provide this information some form of downscaling must be applied to the output of global climate models. Statistical downscaling works by determining if there is a statistical relationship between observations and climate model simulations of past climate states and, if there is such a relationship, applying it to climate model simulations of future climate states. Since 2011, PCIC has been testing various statistical downscaling methods for their ability to simulate regional climates and extreme climate events.

In addition, PCIC researchers have expanded their work in testing and comparing statistical downscaling approaches for their ability to drive a hydrologic model to accurately simulate hydrologic extremes. Using seven statistical downscaling methods to drive the VIC hydrologic model over the Peace River Basin, the researchers evaluated the model for peak flows, as well as 26 indices of climate extremes. Their findings were published in the journal *Hydrology and Earth Systems Sciences*.

SCIENTIFIC & INFORMATION RESOURCES APPLIED RESEARCH

UPDATED PRISM CLIMATE MAPS

Over the last fiscal year PCIC's Climate Analysis and Monitoring Theme worked extensively on updating the PRISM Climate Maps that we offer for our users. We updated these maps to the new 1981-2010 climate normal period and expanded the domain partly into Alberta and to a region that overlaps with the Canadian-US border specifically to support the needs of contributors to the project. These updates included updated precipitation estimates from glacier and snow survey data, the use of the North American Regional Reanalysis upper air data and the incorporation of additional archival BC Hydro data. Our computational support team helped to rapidly develop a PRISM map review tool capable of allowing users to query gridded data values, view surrounding stations and terrain, and post comments on the maps. This product was critical for accomplishing the review of the new maps in early spring 2015. The new maps were made available in early October 2015 on PCIC's data portal.

EXTERNALLY FUNDED RESEARCH PROJECTS

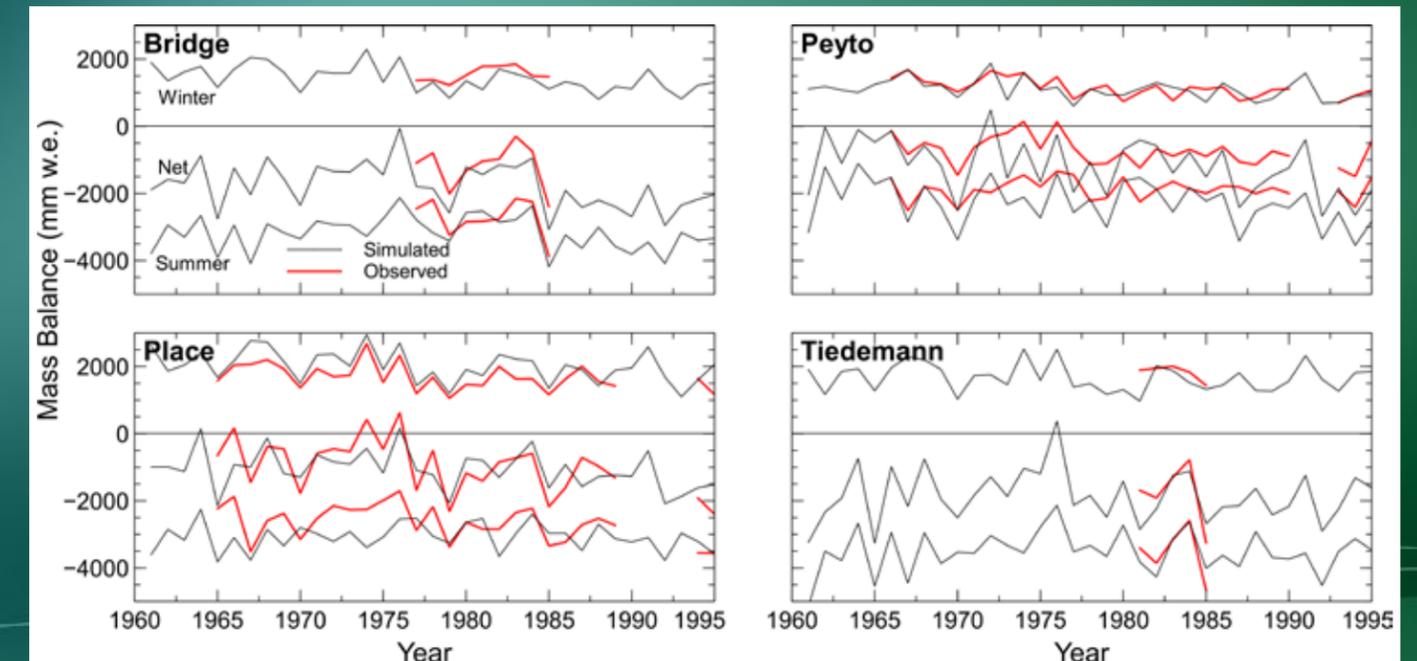
There is substantial overlap between the objectives of PCIC and other scientific research networks. As a result, PCIC has formed several research partnerships that have benefitted our respective user bases and the scientific community as a whole. Over the last year, externally-funded research with three research networks has allowed for a large volume of scientific output. These research networks are: the Marine Environmental Observation, Prediction and Response Network (MEOPAR); the Canadian Sea Ice and Snow Evolution Network (CanSISE); and The Canadian Network for Regional Climate and Weather Processes (CNRCWP). Altogether, PCIC has hosted eight young scientists who have conducted research at PCIC as a part of these collaborations, six over the 2014-2015 fiscal year.

Last year, the efforts of these researchers resulted in a contribution of nine articles to the peer-reviewed literature, exploring a range of topics. These included an analysis of statistical downscaling techniques as applied in Iran, an examination of the usefulness of ensemble averages of seasonal forecasts from a climate forecast system and projected future changes to water availability. The researchers also performed an analysis of extreme runoff using regional climate models, examined a statistical method for the impact of climate change on runoff extremes and successfully attributed and quantified the individual effects of greenhouse gas and aerosol emissions on changes to Arctic temperatures. In addition, these scientists examined the sensitivity of Bolivia's tropical forests to climate change, investigated the impacts that soil moisture had on maximum temperatures in Europe and examined methods of constructing ensembles of seasonal streamflow forecasts for the Western United States. Though some of these techniques were tested and analyzed over areas outside of PCIC's region of focus, the advancement of knowledge about the regional climate phenomena that were examined and the continued development of the tools and techniques that were used are of broad benefit to PCIC researchers as well as scientists whose work focuses on other locations.

SCIENTIFIC & INFORMATION RESOURCES APPLIED RESEARCH

GLACIER DYNAMICS AND MASS BALANCE ADDED TO THE VIC HYDROLOGIC MODEL

Future hydrologic changes within some parts of the BC-Yukon region will be affected by changes in our glaciers. Thus, PCIC scientists have added code to represent glacier dynamics within the VIC hydrologic model. The glacier mass balance code has been tested at four sites in western Canada and is now operational. The next step, which is ongoing, is coupling the VIC model to this glacier dynamics code. This work is nearing completion and these features are anticipated for fall 2015.



This figure compares modelled (red lines) to observed (black lines) glacier mass balance, broken into winter, summer and net (i.e. summer + winter) for four glaciers in western Canada.

PROJECTIONS OF INTENSITY, DURATION & FREQUENCY (IDF)

Given the link between extreme rainfall events and flooding, there is strong interest in the planning and engineering communities in how such events may change as the Earth's climate changes. Because of this, PCIC scientists are investigating extreme precipitation, including regional intensity-duration-frequency (IDF) extreme rainfall relationships, in the context of climate change projections. The next stage of investigation into approaches that could be used to produce future projections of IDF curves has been initiated with funding from Environment Canada and the Pacific Institute for Climate Solutions. A project report for Environment Canada has been written and a briefing note that elaborates the issues associated with producing robust IDF curve estimates in the context of a changing climate will be released in fall 2015.

SCIENTIFIC & INFORMATION RESOURCES PARTNERS

In order to provide the data, tools and research that regional stakeholders in BC-Yukon require, PCIC collaborates and partners with a variety of public and private sector organisations. These include academic, governmental and industry research groups who extend PCIC's research capabilities, as well as users who help us to understand their needs so that we can better tailor our climate services to meet them.

PARTNERSHIP FOCUS: BC HYDRO

Effective April 1st 2015, PCIC and BC Hydro signed a new 4-year partnership agreement. This new agreement ensures the continuation of a strong, ongoing and productive eight-year relationship between BC Hydro and PCIC. As a result of this valuable partnership, PCIC has been able to provide projected changes in hydrology and reservoir inflows over the 21st century for operations in the Peace, Columbia and Campbell River basins, which are being used to assess the potential effects of climate change on hydro-power generation. BC Hydro support has also been instrumental in several major projects of great value to our regional stakeholders, such as the upgrading of the VIC model and the development of the data portal, including the recent addition of both gridded and station hydrologic model output. The new agreement includes continuing assessment of hydrologic impacts (including the expansion of the hydrologic modelling to additional basins), as well as climate services on a broader range of topics, such as power generation, energy demand, integrated resource planning, and transmission and distribution.

RESEARCH PERFORMED WITH AND FOR OTHER PARTNERS

PCIC performed and assisted in the analysis of climate change impacts as part of research agreements for a number of other groups. These include the Columbia Basin Trust, for whom PCIC offered technical advising following the development of our report, *Climate Extremes in the Canadian Columbia Basin*. PCIC also provided a gridded climate data set for use with the Agriculture Water Demand Model, for the Partnership for Water Sustainability in BC. As part of our ongoing research relationship with the Pacific Institute for Climate Solutions we evaluated the ability of climate models to capture future changes in the intensity, duration and frequency of short-term precipitation events. This work has led to an extended research partnership with Environment Canada, examining the scaling properties of short-duration rainfall.

SCIENTIFIC & INFORMATION RESOURCES PARTNERS

2014-2015 PCIC PARTNERS

- Adaptive Resource Management Ltd.
- Agriculture and Agri-Food Canada
- Alberta Rural Development Ministry
- BC Hydro
- BC Ministry of Agriculture
- BC Ministry of Health
- BC Ministry of Community Development
- BC Agriculture & Food Climate Action Initiative Capital Regional District
- BC Agricultural Research & Development Corporation
- BC Ministry of Environment, Climate Action Secretariat
- BC Ministry of Forests Lands and Natural Resource Operations
- BC Ministry of Transportation and Infrastructure
- Bonneville Power Administration
- Capital Regional District
- Canadian Centre for Climate Modelling and Analysis
- Canadian Network for Regional Climate and Weather Processes (CNRCWP)
- Canadian Sea Ice and Snow Evolution Network (CanSISE)
- City of North Vancouver
- City of Vancouver
- City of Victoria
- Columbia Basin Trust
- Corporation of Delta
- Environment Canada
- Fraser Basin Council
- Great Northern Landscape Conservation Council
- Metro Vancouver
- Marine Environmental Observation Prediction and Response Network (MEOPAR)
- Municipality of Whistler
- National Oceanic and Atmospheric Administration (NOAA)
- Natural Resources Canada
- North Pacific Landscape Conservation Council
- Oregon State University, PRISM Climate Group
- Ouranos Inc.
- Pacific Institute for Climate Solutions
- Partnership for Water Sustainability in BC
- Simon Fraser University
- Teck Resources Limited
- University of British Columbia
- University of New Hampshire
- University of Northern British Columbia
- University of Washington, Climate Impacts Group
- University of Victoria

OPERATIONS & FINANCE

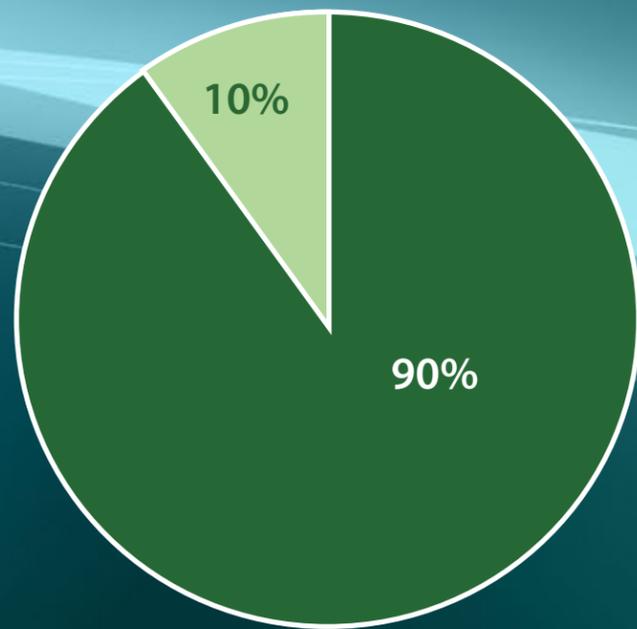
PCIC's most valuable asset is our team of highly talented experts, spanning fields from climate science and hydrology to computer science, communication and management. As they continue to innovate and create high-quality, cutting-edge tools and research, this team is supported by the operational and financial oversight afforded by PCIC's operations and management team.

OPERATIONS & FINANCE REPORT AND OUTLOOK

CONTINUED GROWTH IN REGIONAL CLIMATE SERVICES

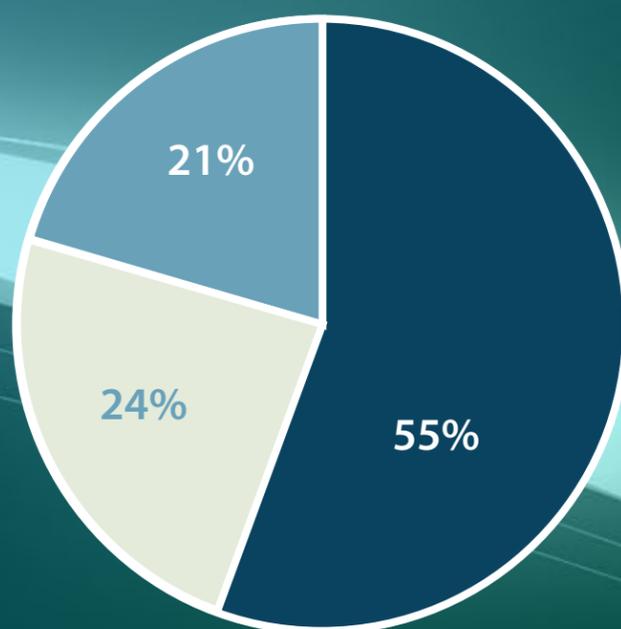
In 2014-2015, PCIC sustained a strong financial condition, with an increase in the annual funding envelope. In the past year, our organization continued to produce new products and services and the cumulative impact of these services expanded to outside of Canada. The new agreements that were implemented this year include user groups from the government agencies of the United States. All 17 projects, both long-term and short-term, supported the diversification of PCIC's funding envelope and spoke to PCIC's growing reputation as a reliable source for practical climate information. Growing partnerships with large research centres, stakeholder groups and government agencies has allowed us to leverage our funding. Our management maintained modest expenditures, and our largest expense continued to be our investment in human resources. We have been maintaining a long-term budgetary outlook, which includes the endowment, financial engagement by major stakeholders, strategic partnerships with other climate research organizations and climate information providers, and institutional support from UVic. Looking forward, PCIC will continue to sustain its financial strength, seek strong strategic partnerships and engage in new opportunities, and maintain low operating costs while providing users with high quality climate data and information.

2014-2015 EXPENSES



■ Personnel
■ Operating Expenses

2014-2015 REVENUE



■ Endowment
■ Long-Term Contracts (2 years+)
■ Short-Term Contracts

OPERATIONS & FINANCE PCIC STAFF

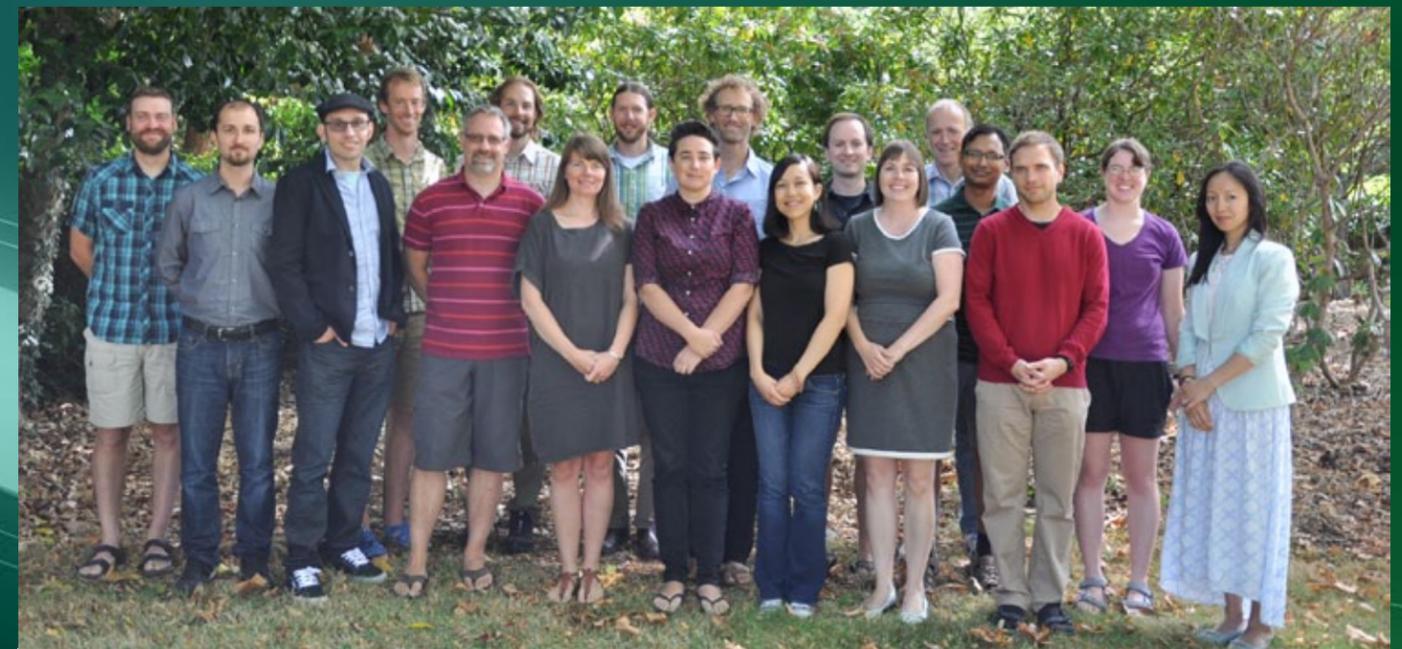
OUR TEAM

Staff:

Francis Zwiers, Director, President and CEO
Faron Anslow, Climatologist
Michael Fischer, Programmer/Analyst
Alex Cannon, Research Climatologist
Steve Dainard, Programmer/Analyst
Cassbreea Dewis, Treasurer and Outgoing Lead, Planning and Operations
James Hiebert, Lead, Computational Support
Shelley Ma, Administrative Assistant
Peggy Minaker, Administrative Assistant
Trevor Murdock, Lead, Regional Climate Impacts
Markus Schnorbus, Lead, Hydrologic Impacts
Raj Shrestha, Hydrologist
Michael Shumlich, Scientific Information Specialist
Stephen Sobie, Regional Climate Impacts Analyst
Basil Veerman, Geospatial Programmer/Analyst
Kathy Veldhoen, Incoming Lead, Planning & Operations
Arelia Werner, Hydrologist

Associates:

Megan Kirchmeier-Young, Post-doctoral Fellow (CanSISE)
Sanjiv Kumar, Research Associate (CanSISE)
Mohammad Reza Najafi, Post-Doctoral Researcher (CanSISE)
Katherine Pingree-Shippee, PhD Student, Geography, UVic (MEOPAR)
Christian Seiler, Post-Doctoral Researcher (MEOPAR)
Yaqiong Wang, MSc Student, Geography, UVic (PCIC)
Kirien Whan, Post-Doctoral Researcher (CNRCWP)



PCIC Staff (left to right): Steve Dainard, Mohammad Reza Najafi, Michael Shumlich, Basil Veerman, Markus Schnorbus, Michael Fischer, Arelia Werner, James Hiebert, Kirian Whan, Faron Anslow, Peggy Minaker, Steve Sobie, Kathy Veldhoen, Francis Zwiers, Rajesh Shrestha, Christian Seiler, Katherine Pingree-Shippee and Shelley Ma.

PUBLICATIONS

PCIC researchers are constantly working to improve our understanding of regional climate science and hydrology, including both statistical and physics-based modelling. They make use of the most current findings in the peer-reviewed literature and, in turn, their research creates a large volume of data and results that are of interest to the broader scientific communities in these areas. In addition to the mutual benefits that sharing results through the peer-reviewed literature provides to the participating researchers, it also serves as a method of quality assurance. The comprehensive peer-review by outside experts in the field helps to ensure that the basic research upon which PCIC's tools, data services and reports are built is robust and reflects our best current understanding of the science.

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