PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE JUNE 2017

THE VIC-GL MODEL NOW OPERATIONAL

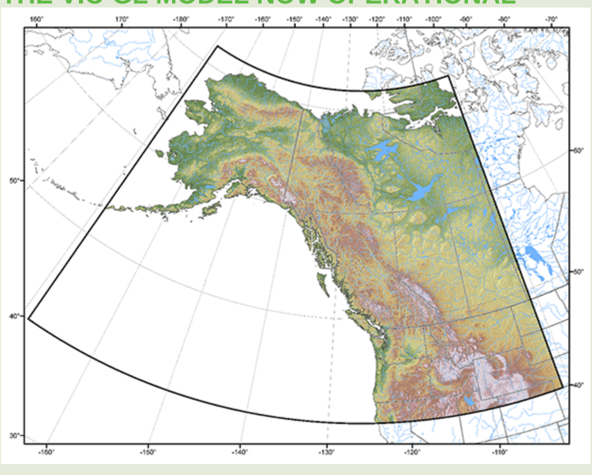


Figure 1: This figure shows the VIC-GL model domain.

The hydrologic Impacts theme at PCIC is pleased to announce that the VIC-GL model, PCIC's version of the Variable Infiltration Capacity (VIC) hydrology model, is now operational. This version of the model has been upgraded to more accurately simulate relevant hydrological processes in British Columbia and neighbouring areas. The new model has also been substantially re-engineered to improve computational efficiency. It offers the Hydrologic Impacts theme a vastly improved tool with which to assess the effects of climate change and variability on the water resources of British Columbia.

The major upgrade introduced to VIC-GL is the ability to explicitly model glacier processes. Glacier mass balance, which is the accumulation and ablation of snow and ice, is modelled directly in VIC-GL using an energy balance approach while changes in glacier area are then modelled by coupling VIC-GL with a Regional Glaciation Model (RGM). The RGM is a glacier dynamics model developed by researchers at the University of British Columbia (Clarke et al. 2015; Jarosch et al. 2013). Model development and testing has been a collaborative effort between researchers at PCIC, the University of British Columbia, the University of Northern British Columbia and BC Hydro.

VIC-GL has been set-up at a 1/16-degree spatial resolution (about five-to-six kilometres, depending on the latitude) over a domain spanning northwestern North America (see Figure 1). As part of the set-up HI staff dedicated considerable effort to improving the parameterization of VIC-GL with updated elevation, land cover, soil and climatological data. The calibration of VIC-GL, in which the parameters of the model are tuned so that the model's output best matches observations, has also benefited from the availability of new and novel data sources. As well as using traditional streamflow data, model calibration will incorporate evapotranspiration data, satellite-based snow cover data and glacier mass balance data.

Application of the VIC-GL model over northwestern North America also required the development of a new gridded historical meteorological data set, which is required for calibrating the model and simulating past environments. This new data set spans the same domain as the hydrology model, is gridded at 1/16-degree spatial resolution, and provides daily values of maximum and minimum temperature, precipitation and wind speed for the period 1945 to 2012. This data set utilizes long-term quality-controlled station data from Canada and the United States and PRISM climatological data, which includes the latest version for BC produced by the Climate Analysis and Monitoring theme at PCIC.

References:

Clarke, G. K. C., A. H. Jarosch, **F. S. Anslow**, V. Radić, and B. Menounos, 2015: Projected deglaciation of western Canada in the twenty-first century. *Nature Geoscience*, **8**, 372–377, doi:10.1038/ngeo2407.

Jarosch, A. H., C. G. Schoof, and **F. S. Anslow**, 2013: Restoring mass conservation to shallow ice flow models over complex terrain. *The Cryosphere*, **7**, 229–240, doi:10.5194/tc-7-229-2013.

CLIMATE VARIABILITY: THE HOT COLD WINTER OF '16-'17

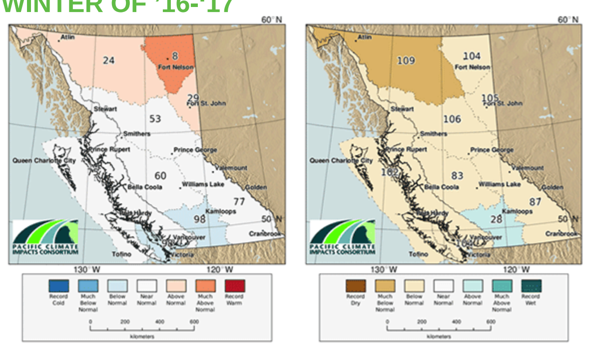


Figure 2: Maps showing how warm or cold (left panel) and wet or dry (right panel) regions of BC were in winter 2016/2017 compared with a long-term record from 1900 through 2017. In the left panel, colors represent cooler (blues) or warmer (reds) than normal conditions for daily maximum temperature. In the right panel, colors represent wetter (greens) or drier (browns) than normal conditions for seasonal precipitation totals. Numbers indicate percentile ranking of the temperature (left panel) or precipitation amount (right panel) with large numbers indicating colder (left panel) or drier (right panel) conditions. For example, a figure of 98 on the left panel indicates that of the 118 years of record, 97 were warmer and 20 were colder and a figure of 104 on the right panel indicates that of 118 years of record, 103 were wetter and 15 were drier.

The winter of 2016-2017 in British Columbia was both notable and certainly noted by many. It started early throughout the province and continued well past its astronomical expiration date. The rains came, they stuck around, they were replaced by snow and then the rains took over once again. As of mid-May the rains were ongoing and flooding in the southern interior of BC became a major concern. But, the cold and wet winter is only part of the story, one that only unfolded in southern British Columbia (Figure 2). The picture in northern British Columbia was the very opposite – warmth and low precipitation. All of this falls on the heels of an El Niño-fuelled, and exceptionally warm, 2014 and 2015 which transitioned into an ongoing warm 2016. What is going on? In a recent article on our website, PCIC scientists Faron Anslow and Trevor Murdock attempt to untangle the unusual weather and place it in climatological context. Read it now.

NATURE GEOSCIENCE PAPER ON SHORT-DURATION EXTREME RAINFALL EVENTS

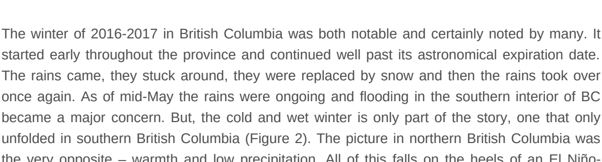
PCIC Director Francis Zwiers is the co-author of a paper recently published in *Nature Geoscience* that examines our understanding of how short-duration extreme rainfall relates to temperature. In the paper, the authors argue that observed relationships between day-to-day temperature variations and extreme precipitation are not suitable for making projections of future precipitation extremes.

Using data from different parts of the world, several studies have reported an interesting apparent relationship between temperature and intense, hourly precipitation by linking extreme rainfall events to day-to-day temperature variations. They report that, over a wide temperature range, sub-daily precipitation extremes appear to increase with temperature at a greater rate than would be expected from a consideration of thermodynamics alone. Some in the research community have suggested that this "super Clausius-Clapeyron" relationship could be used to make projections of future sub-daily precipitation extremes, which would imply that subdaily precipitation extremes would intensify very rapidly with warming, at a rate faster than the ~7% per °C of warming suggested by thermodynamic theory via the Clausius-Clayeron relation.

Zwiers and co-authors examine sub-hourly observations from the Netherlands; as do others, they find warming and a super-Clausius–Clapeyron relationship between day-to-day temperature variations and extreme hourly precipitation, but no evidence that the most extreme sub-daily rainfall amounts annually have increased at the super Clausius–Clapeyron rate over the period (1957-2015) covered by the data. They also cite recent studies with very high-resolution convection-permitting atmospheric models that come to similar conclusions. The authors suggest that the apparent discrepancy occurs because the calculation that produces the "super Clausius-Clapeyron" scaling relationship uses data from different parts of the annual cycle, and therefore confounds the effect of temperature change from one point in the annual cycle to another with circulation change between different points in the annual cycle. By comparison, the authors expect that circulation change will play a much weaker role in long term changes in the most extreme events annually. Because of these issues, the authors argue that such curves are unsuitable for making projections of the effects of long-term warming on precipitation extremes.

Zhang, X., **F.W. Zwiers**, G. Li, H. Wan and A.J. Cannon, 2017: Complexity in estimating past and future extreme short-duration rainfall. *Nature Geoscience*, **10**, 255–259, doi:10.1038/ngeo2911.

STAFF PROFILE: MOHAMED ALI BEN ALAYA



Dr. Mohamed Ali Ben Alaya is a Research Fellow at PCIC and a post-doctoral fellow with the Canadian Network for Regional Climate and Weather Processes (CNRCWP). His background includes a PhD and MSc in Water Sciences from the INRS-ETE in Quebec and an engineering degree in Hydro-meteorology from the National School of Engineering in Tunis, Tunisia. Dr. Ben Alaya uses his skills to enhance PCIC's ability to study extreme precipitation events, which has immediate practical relevance for areas such as engineering, water resource management, ecological systems management and public health.

In civil engineering practice, an index known as "probable maximum precipitation" (PMP) is used to approximate the largest amount of rainfall that can be expected to fall in a given area over a given period of time. Determined from meteorological principles, PMP is one of the key parameters used in civil engineering to determine the maximum flooding that an area may expect. This finds several important applications, among them, in designing dams. "In civil engineering practice, high-risk dams must be able to withstand floods caused by extreme precipitation events," Dr. Ben Alaya explains. So, developing the most reliable, robust, accurate figures possible for these events taking into account how they may change in the future, is a key research goal.

Dr. Ben Alaya's current work aims to produce an improved procedure for calculating the PMP for a given area: "our proposed approach attempts to take advantage of recent developments in probabilistic extreme value analysis to explore uncertainty and to provide ranges of PMP values." "What I find interesting about PMP is the attractive idea of treating precipitation as a compound event," he explains. Extreme rainfall events are compound events because they arise as a result of many individual factors interacting in complex ways. The topography of the landscape, large-scale weather patterns and small-scale weather events with strong updrafts are some of the factors that can work together to create intense downpours. Dr. Alaya continues, "a probabilistic model, by analysing the precipitation process as a compound event, corresponds more directly to nature, and can tell us more about the given phenomenon than analysing the observations themselves as a univariate process. This offers some measure of credibility when used to estimate a high, unobserved magnitude of precipitation."

Dam managers have begun using the data produced by regional climate models to estimate future changes in PMP. These regional climate models (RCMs) have a finer resolution than global climate models, allowing them to resolve smaller-scale environmental processes. However, before these regional models can be used for this purpose, their ability to project future changes in PMP must be assessed. Dr. Ben Alaya is currently conducting an assessment of the ability of two Canadian RCMs, CanRCM4 and CRCM5, to provide projections of PMP over North American. Sharing his findings so far he says, "overall, our main results show that the ability of the two RCMs to reproduce the major characteristics of the different components involved to calculate PMP is good, making them a possible tool to derive PMP estimates that could serve as a basis for flood studies at the basin scale."

PCIC IN THE NEWS

PCIC scientists are often drawn upon to share their expertise to make sense of various aspects of climate science, as well to discuss their research and its potential implications. Earlier this year,Trevor Murdock, the Lead of our Regional Climate Impacts theme was interviewed by The Weather Network regarding a report on projections to Metro Vancouver, and then again by several organizations, including CFAX 1070, Sirius XM channel 167 satellite radio, CBC News Vancouver at 6 (at the 37-minute mark) and a CBC Vancouver regarding projections for the Capital Regional District released in a recent report to which PCIC contributed. Research Climatologist Dr. Christian Seiler was also interviewed on CBC's Central Morning with Leigh Anne Power, regarding his work on storms in the Atlantic Ocean.

PCIC DIRECTOR GIVES INVITED PUBLIC LECTURE ON EXTREME WEATHER AT CMOS

PCIC Director Francis Zwiers was recently invited to deliver a public lecture at the Canadian Meterological and Oceanographic Society's Annual Congress. The conference, which drew in just over 600 ocean and atmospheric scientists, is the largest annual conference of its type in Canada. Dr. Zwiers's talk focused on how climate change is affecting extreme weather events, discussing long-term trends in such events, individual examples and how we can detect and attribute human influences in these events. He was also interviewed for a podcast related to the event, in which he discussed a number of topics, including the detection and attribution of extreme events, climate change risks, adaptation and mitigation, and some of the downscaling work being done at PCIC.

For more information, read the full story on our site.

SPRING TALKS

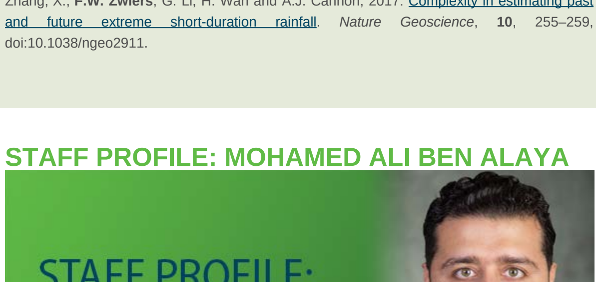


Figure 3: The figure above shows Dr. John Scinocca delivering his talk on March 29th.

The 2016-2017 Pacific Climate Seminar Series has continued with talks delivered by Dr. Kristie Ebi on February 2nd and Dr. John Scinocca on March 29th.

Dr. Ebi's talk, *Implications of future development pathways for the risks of climate change*, covered five potential pathways of future socioeconomic development. These ranged from relatively isolated regional blocks with poverty and wealth inequality to a world achieving sustainable development goals, each scenario having implications for the climate system and humankind's ability to deal with the impacts of changing climate.

Dr. Scinocca's talk, *Coordinated Global and Regional Climate Modelling*, discussed recent work conducted at the Canadian Centre for Climate Modelling and Analysis on developing a regional climate model to downscale the output of a parent global climate model. This allows for the regional model to have all of the variables it uses available from the global model and to more closely track the evolution of the climate over time in the larger scale model.

NEWSWORTHY SCIENCE

The response of vegetation to the changing climate and the changing concentration of carbon dioxide is important because it can impact ecosystems and agricultural production. PCIC's latest Science Brief covers two recent papers by Obermeier et al. (2017) and Schauberger et al. (2017) that examine how these changes may affect temperate grasslands and three types of crops in the United States. Obermeier et al. (2017) find that the fertilization effect of increased carbon dioxide in the atmosphere on C3 grasslands is reduced when conditions are wetter, dryer or hotter than the conditions to which the grasses are adapted. Schauberger et al. (2017) find that yields for wheat, soy and corn decline at temperatures greater than 30°C, with reductions in yield of 22% for wheat, 40% for soy and 49% for corn. They also find that Irrigation has a much larger preventative effect on yield loss than increased carbon dioxide, suggesting that water stress at higher temperatures may be largely responsible for losses.

Read the latest Science Brief.

PCIC STAFF CHANGES

Owing to the nature of the Pacific Climate Impacts Consortium as a centre of climate service delivery and applied research, with many collaborating partners and institutions, we are often welcoming new scientists and support personnel to work with us. Working with these organizations and researchers brings our research community closer together, helps our researchers to remain at the forefront of their fields and allows us to provide training for the next generation of scientists. In this exchange of knowledge and talent, PCIC's scientists also move to other research institutions, where they continue their research to further refine our understanding of the Earth's climate.

This spring, PCIC has been happy to welcome five new people: Dr. Gildas Dayon, Dr. Dhouha Ouali, Lee Zeman, Matthew Benstead and Anthony Constantin. We also welcome back Shelley Ma, who has returned from maternity leave. Dr. Dayon has joined our Hydrologic Impacts theme from Paul Sabatier University in Toulouse, France. Joining our team as a Hydroclimate Scientist, he will be helping PCIC with streamflow temperature modelling and to work out the impacts of internal variability on the hydrologic cycle. Dr. Ouali joins PCIC as a Research Associate with the Marine Environmental Observation Prediction and Response Network. Dr. Ouali's research at PCIC is focused on the possible impacts of extratropical cyclones on the power transmission grid and is part of a collaborative project with BC Hydro. Lee joins PCIC as a Programmer and Analyst from the Evergreen State College in Olympia. He is an expert in computer graphics, database development and software engineering who brings significant experience in data visualization to PCIC's Computational Support Team. Matthew joins our Computational Support Group as System Administrator, where he supports and maintains the computer, storage and network infrastructure we use. Anthony, a 4th year student in Water Science and Technology at Polytech Montpellier in France, has joined the Hydrologic Impacts theme for two months this summer as a volunteer intern. During his time with PCIC, Anthony will be investigating changes in temperature and precipitation extremes using the HI theme's downscaled gridded climate projections. Shelley Ma, who has been an Administrative Assistant with PCIC since 2011, was away for the last year on maternity leave. Welcome new members to our team and welcome back, Shelley!

The spring also sees us saying farewell to Dr. Norman Shippee, Valerie Acosta and Noémie Bechtet. Dr. Shippee was a Research Associate with the Marine Environmental Observation Prediction and Response Network. His work analyzing the ability of seasonal forecasting systems to simulate extra-tropical cyclones was invaluable. Valerie served as our Administrative Assistant for the last year and was instrumental in keeping PCIC's operations running smoothly. Noémie served PCIC as a Research Intern whose work on how PCIC's web tools are used will assist us in serving our users in the future. Noemie will be returning to her studies at the Toulouse Business School and the Toulouse Institute of Political Studies. We wish Dr. Shippee, Valerie and Noémie the best of luck in their future endeavours!

RECENT PAPERS AUTHORED BY PCIC STAFF AND AFFILIATES

Najafi, M.R. and **F. Zwiers**, 2017: Attribution of the Observed Spring Snowpack Decline in British Columbia to Anthropogenic Climate Change *Journal of Climate*, **30**, 11, 4113–4130, doi:10.1175/JCLI-D-16-0189.1.

Pebesma, E., T. Mailund and **J. Hiebert**, 2016: Measurement units in R. *The R Journal*, **8**, 2, 486–494.

Seiler C., **F.W. Zwiers**, K.I. Hodges and J. Scinocca, 2017: How does dynamical downscaling affect model biases and future projections of explosive extratropical cyclones along North America's Atlantic coast? *Climate Dynamics*, 1-16, doi:10.1007/s00382-017-3634-9.

Sobie, S.R. and **T.Q. Murdock**, 2017: High-Resolution Statistical Downscaling in Southwestern British Columbia. *Journal of Applied Meteorology and Climatology*, **56**, 6, 1625–1641, doi:10.1175/JAMC-D-16-0287.1.

Zhang, X., **F.W. Zwiers**, G. Li, H. Wan and A.J. Cannon, 2017: Complexity in estimating past and future extreme short-duration rainfall. *Nature Geoscience* **10**, 255–259, doi:10.1038/ngeo2911.

Our address is:
Pacific Climate Impacts Consortium
University House 1
2489 Sinclair Road
University of Victoria
Victoria, British Columbia
Canada V8N 6M2