PACIFIC CLIMATE IMPACTS CONSORTIUM
PCIC UPDATE
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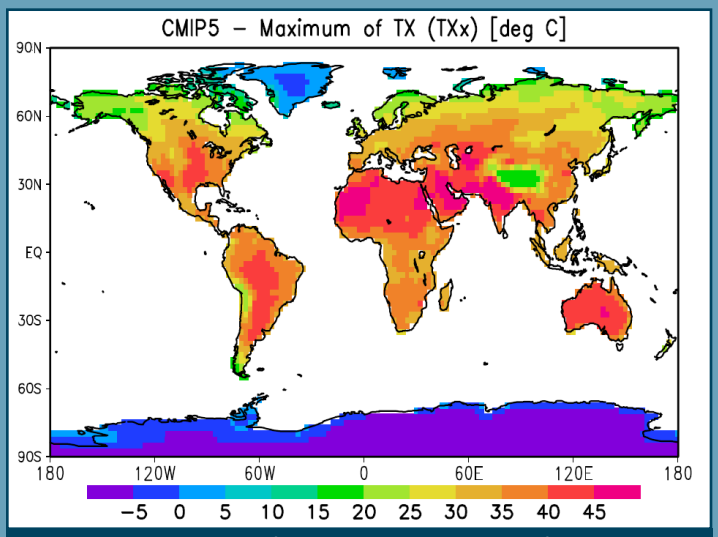
IMPROVED PCIC SOFTWARE FOR CLIMATE EXTREMES

The climate modelling community uses a standard suite of 27 indices, known as the "CLIMDEX indices," to describe and evaluate climate extremes. These were formulated by the Expert Team on Climate Change Detection and Indices. In 2011, PCIC's computational support team completed an independent implementation of the indices and evaluated an existing program used to compute the CLIMDEX indices. In 2012, David Bronaugh, PCIC Programmer/Analyst took the project to the next level, improving the implementation of the climdex.pcic software package and developing additional software to facilitate computing the indices in parallel, reducing the required computation time from months to days. The newly developed package will be released via the PCIC software library as open source software.

Climdex.pcic is written in the R programming language and has been made so that it can be used to calculate the indices from both climate model output and observations. It was written to be reused and automated, such that the requirements for human involvement in the calculation of the indices is minimized. Work continues on improving the implementation with the goal of full autonomation (automation with automatic quality control and defect correction).



The 1981-2000 mean of the annual maximum of the maximum daily temperature for each month (TXx), a ClimdEX index, in degrees Celsius. (Taken from Sillman et al., 2013.)

Using climdex.pcic software and output from 300 climate model runs from the fifth phase of the Coupled Model Intercomparison Project (CMIP5), PCIC computed a set of the CLIMDEX indices using Compute Canada's supercomputers.

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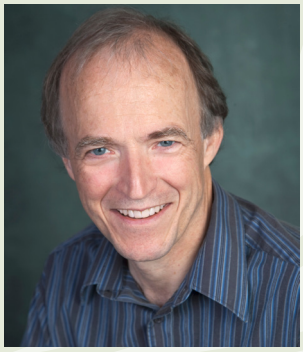


PERSPECTIVE:
MESSAGE FROM THE DIRECTOR

PCIC is abuzz with activity as we approach the end of another satisfying and productive fiscal year. Amongst other projects, we are in the midst of downscaling newly available climate change projections produced by climate modelling centres as part of the international CMIP5 climate model intercomparison project. We have also extracted a large suite of indicators of climate extremes from these simulations following a set of internationally recognized protocols and definitions for such indicators. Those indices are being made available to scientists and users the world over, and have been extensively documented in a pair of peer reviewed articles that are in press at the Journal of Geophysical Research. While a seemingly simple task , both the means to access CMIP5 climate change simulations and the actual process for calculating extremes indicators from such very large data sets, requires a great deal of ingenuity. The PCIC computing support group more than met the challenge, and have produced a sophisticated state-of-the art package of tools that PCIC is contributing back to the larger open-source software development community. This is consistent with our approach of relying on open-source software to the greatest extent possible, and in return, contributing to the further enhancement of those open source resources. This approach has allowed us to deliver state-of-the-science tools that go well beyond expectations relative to the size of the PCIC computational support group, and has allowed users to benefit from much more sophisticated and reliable tools.

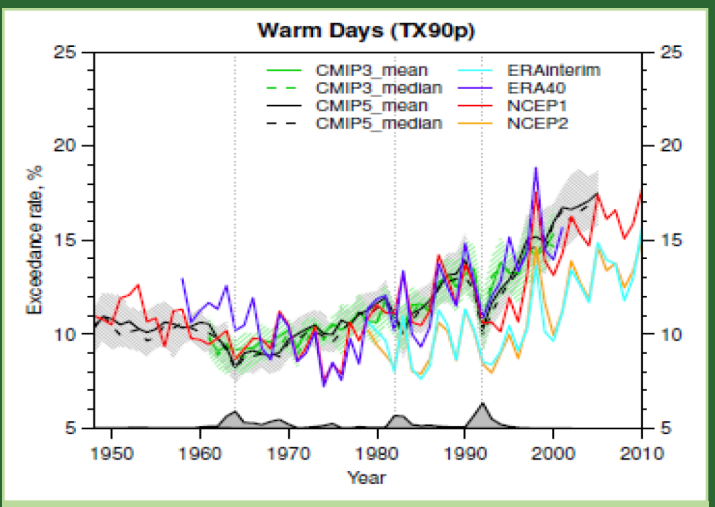
In addition to being in the midst of a beehive of scientific and production activity in-house, we have also just organized and hosted a successful workshop to assess the state of knowledge in the region on "Atmospheric Rivers" (or if you, prefer, the "Pineapple Express"). Atmospheric rivers are narrow concentrated flows of moist tropical air that periodically stream across the Pacific and cause intense and often damaging amounts of precipitation when they reach our coast. They can also have substantial effects inland. Consisting of a day and an evening with a mixture of speakers, panel discussion and group discussion sessions that were designed to maximize information exchange and participant engagement, the workshop was co-organized by PCIC, the BC Ministry of the Environment, and PICS with financial support from Natural Resources Canada. Roughly forty participants representing emergency preparedness organizations, planners and policy makers, monitoring and forecasting organizations, and researchers from the region and US, were present. The workshop findings will be presented to the Ministry of Environment and NRCan in a report, and will form the basis for the further articulation of regional needs for additional science and improved monitoring, forecasting and planning related to extreme precipitation and its impacts.

These were then checked to ensure quality and sent to the Canadian Centre for Climate Modelling and Analysis, where they are being hosted for use by the research community.

Research utilizing these CLIMDEX indices calculated by PCIC has recently been published. Sillman et al. (2013) examined the ability of global climate models to simulate climate extremes and explored projected changes in climate extremes. Two of PCIC's researchers serve as co-authors on the papers, the first of which compares models from the third and fifth phases of the Coupled Model Intercomparison Project with observational data. This first paper examines a number of climate extremes indices (see figures on this page and page 1), notes improvements, such as the closer correspondence of modelled and observed precipitation extremes, discusses general features, such as the reduced spread in modelled temperature extremes and points out areas where discrepancies between the models and observations remain substantial. The second paper goes on to analyze projected changes to climate extremes, on global and regional scales, over the 21st Century, discussing general trends and spatial patterns of change. Climdex.pcic is available in PCIC's new Software Library, which contains software packages written at PCIC for use with climate data.

http://pacificclimate.org/resources/software-library

Sillman, J., V.V. Kharin, X. Zhang, F.W. Zwiers (PCIC) and D. Bronaugh (PCIC) 2013: Climate extreme indices in the CMIP5 multi-model ensemble. Part 1: Model evaluation in the present climate. *Journal of Geophysical Research: Atmospheres*, **118**, doi:10.1002/jgrd.50203.



The global spatial mean over land of the warm day index (days for which the maximum temperature exceeds the 90th percentile of warm days relative to the 1961-1990 base period). Shown above are the ensemble means (solid) and medians (dashed) of 31 CMIP5 models (black) and 18 CMIP3 models (green), with shading representing the spread from the 25th to the 75th percentiles—along with four reanalysis products: NCEP1 (red), NCEP2 (orange), ERA40 (blue) and ERA-Interim (cyan). Note that NCEP2 and ERA-Interim use a base period of 1979-2008. (Taken from Sillman et al., 2013.)

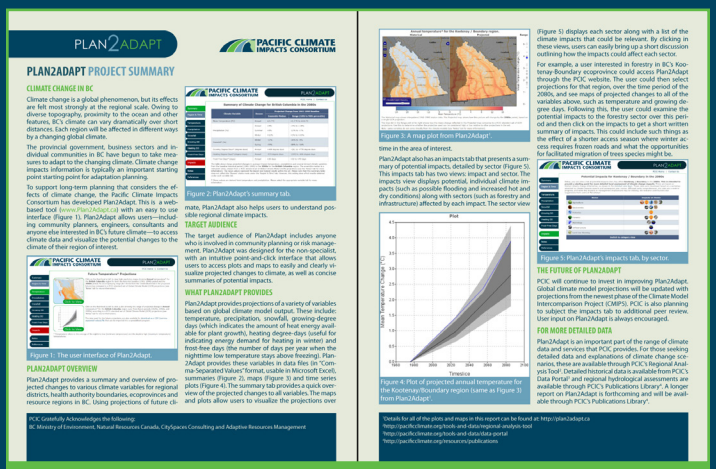
Sillmann, J., V. V. Kharin, F. W. Zwiers (PCIC), X. Zhang, and D. Bronaugh (PCIC), 2013b: *Climate extremes indices in the CMIP5 multi-model ensemble. Part 2: Future projections*. Journal of Geophysical Research: Atmospheres, doi:10.1002/jgrd.50188, in press.

PLAN2ADAPT SUMMARY

Global climate change's effects are felt at the regional scale and a variety of stakeholders in BC are starting to take measures to adapt. In order to adapt, these stakeholders need information on the potential effects of the changing climate on their regions of interest. To respond to this need, PCIC developed Plan2Adapt, a web-based tool that provides users with easy access to regional climate projections through an intuitive interface.

We have recently updated Plan2Adapt and have published a summary of our Plan2Adapt update project. The summary gives a brief overview of Plan2Adapt and its functions. The summary also discusses the project's target audience and how PCIC intends to continue updating the tool in the future, as well as where users can access more detailed data.

Plan2Adapt is intended to be a starting point for more in-depth local assessments of the impacts of climate change. It provides maps of projections and time-series plots for a variety of variables, brief summaries of these variables in tables, as well as short summaries of potential impacts which are broken down both by impact and by sector.



Plan2Adapt map interface, showing the temperature for June, July and August, for all of British Columbia.

The report is available from our Publications Library:

http://pacificclimate.org/resources/publications

The Plan2Adapt tool is available at:

http://plan2adapt.ca

PEER-REVIEWED PUBLICATION: EFFECTS OF CLIMATE CHANGE ON BC FORESTS

British Columbia is already showing signs of climate change and related ecological change. BC's forests are likely to face multiple stresses as the climate continues to change. These stresses may cause changes to the spatial distribution of plants and the timing of their life cycles.

In a recent article (Flower et al., 2012) in the journal *Environmental Science & Policy* (26), a group of researchers from PCIC, including Aquila Flower, Trevor Murdock and Francis Zwiers, with a colleague from the Canadian Forest Service, examined how the impacts of climate change stresses on BC spruce and Douglas Fir forests could affect tree species suitability. Spruce and Douglas Fir forests were chosen because of their susceptibility to bark beetles and budworms, respectively. This research contributes to our understanding of the effects of cumulative climate change impacts.

The authors used historical records, observational data, global climate models using three different possible greenhouse gas emissions scenarios, downscaling techniques and a statistical model that grouped together climate variables and related them to the growing conditions for each species.

The researchers found that the projections indicate a rapid shift in suitability for all of the trees to higher elevations and latitudes. Flower et al. suggested that this loss of habitat could potentially be reduced by the assisted migration of trees. Both forest types seemed to be more sensitive to changes in temperature than to changes in precipitation. The authors also found that the projections are subject to large uncertainties that are reflected by significant differences between projections in terms of the speed, extent and details of the changes. They then quantified the uncertainty due to differences in climate models and emissions scenarios chosen, as well as the uncertainty due to the resolution of the climate data used.

This work was done as part of a project that was funded by the Forestry Science Program.

For more information, see PCIC's Publications Library:

http://pacificclimate.org/resources/publications

Projected changes to the climatic suitability for spruce in the 2050s, relative to the baseline period of 1961-1990, modified from Flower et al., 2013.

Flower, A., **T. Q. Murdock**, S. W. Taylor and **F. W. Zwiers,** 2013: Using an ensemble of downscaled climate model projections to assess impacts of climate change on the potential distribution of spruce and Douglas-fir forests in British Columbia. *Environmental Science & Policy*, **26**, 63–74, doi:10.1016/j.envsci.2012.07.024.

LAUNCH OF THE PCIC SCIENCE BRIEFS

In November 2012, PCIC released the first in what is now a regular series of short reports on articles from the climate science literature. These Science Briefs explain the results of studies that are important and relevant to regions within BC and Yukon, placing them in context and discussing their potential implications.

Three Science Briefs have been released so far, with more in the works, to be released monthly. The first three discuss: ice core data from the Yukon as an indicator of the historic climate variability in the region, recent increases to the upper bounds of sea level rise projections due to new findings regarding the ocean's thermal expansion, and how dynamical models have recently surpassed statistical models in El Niño prediction.

These PCIC Science Briefs are available from PCIC's publications library:

http://pacificclimate.org/resources/publications

TALKS & LECTURES

PCIC is active in the evolving scientific discussion surrounding climate extremes and impacts. In addition to our reports and peer reviewed research, our experts deliver presentations to the broader scientific community. Also, as part of our ongoing science communication service, PCIC delivers and hosts a number of public seminars.

The joint PCIC-PICS fall seminar series continued with Adam Kamp discussing bio-energy from lumber mill residues in his talk, "Bio-energy Production in the BC Forest Industry" on November 7th. Following that, former Republican Congressman Bob Ingliss gave a talk titled, "Prospects for a Revenue-Neutral Tax Swap in America," in which he surveyed the centre-right political landscape in America and discussed the prospects for conservative support for a revenue-neutral carbon tax.

In 2013, the first talk in the series was given by Dr. Howard Wheater, the Director of the Global Institute for Water Security. His talk was titled, "Water Security in the Canadian Prairies: Science and Management Issues." In this talk Dr. Wheater discussed water security in the Saskatchewan River Basin. He outlined a research agenda to develop the interdisciplinary scientific understanding of water futures under continuing social and environmental change. He also argued that water resource vulnerability analysis was a useful approach for analyzing water security.

In 2012, PCIC participated in the American Meteorological Society's (AMS) 2012 Annual Meeting. At the AMS Meeting, PCIC climate scientist Dr. Alex Cannon delivered a talk titled, "Objective Selection of Representative CMIP5 GCM Simulations for Regional Climate Change Impacts Research: Cluster Initialization and the ETCCDI Climate Extreme Indices." In this talk Dr. Cannon presented on the challenges in visualizing and selecting representative climate scenarios when looking over a large number of variables and discussed the benefits of an automated procedure that grouped model output together into clusters, which are easier to analyze.

In addition to these, PCIC Director, Dr. Francis Zwiers was invited to attend a data assimilation and detection and attribution workshop in Buenos Aires, in October, giving two talks while there. In the first, "Data Assimilation-based Detection: Paleoclimate reconstruction," Dr. Zwiers discussed different paleoclimate reconstruction techniques and their evaluation, how "climate field" reconstruction techniques perform well, but do not appear to be consistently better than "composite plus scale" reconstruction techniques, and how reconstructions are probably affected more by the choice of proxy than the choice of reconstruction method. In his second talk, "Detection and Attribution: Methods, Concepts and Challenges," he outlined the approaches in use for detection and attribution analysis and some key questions that have yet to be answered, such as how to make objective choices about how to filter data prior to analyzing it and how best to estimate internal variability.

Dr. Zwiers also spoke about the mounting evidence that human influence has affected both long-term climatic averages and the odds of some kinds of extreme events, at the Annual Conference and AGM of the Association of Professional Engineers & Geoscientists of BC. This talk was titled, "Our Evolving Climate." On November 28th, 2012, Dr. Zwiers gave an invited talk at Stanford University's Department of Environmental Earth System Science's Fall Seminar Series, titled, "How and Why are Precipitation Extremes Changing?" In this talk, he surveyed recent research on precipitation extremes, including the improved precipitation data sets that are being produced—in part with PCIC's help, see the CLIMDEX story in this issue—the observed intensification of precipitation extremes and how the ability of climate models to simulate precipitation extremes compares with observations.

The PCIC/PICS joint Pacific Climate Seminar Series will continue into April; check our calendar for upcoming events:

http://pacificclimate.org/calendar

EMPLOYMENT & RESEARCH OPPORTUNITIES AT PCIC

Four new employment and research opportunities have become available at PCIC!

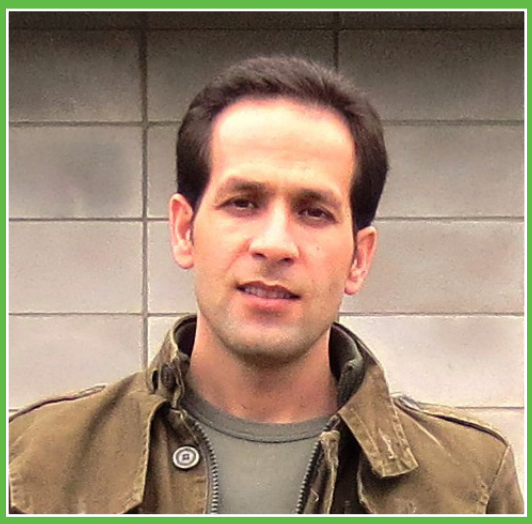
For more information on these opportunities, see the Careers section of our website:

http://pacificclimate.org/about-pcic/careers

VISITING RESEARCHER: RUHOLLAH OJI

PCIC is pleased to welcome visiting researcher Ruhollah Oji. Ruhollah has completed the third year of his doctoral studies at Tarbiat Modares University in Iran. His dissertation is on "The Uncertainty Analysis of Single-site and Multi-site Methods on Temperature and Precipitation Downscaling." Prior to undertaking his Ph.D., Ruhollah completed a M.S. in climatology on synoptic map-patterns, storm tracks, and cyclone frequencies associated with wet spells in the midwest of Iran. In addition to his background in climatology, Ruhollah has worked extensively with GIS and has spent the last six years at the National Cartographic Center of Iran.

At PCIC, Ruhollah will be applying expanded downscaling (XDS) to stations in western North America. Station outputs from XDS will be interpolated to a fine-scale grid, ultimately leading to a product that will complement those based on BCSD and related gridded downscaling algorithms.



SHARING KNOWLEDGE: NEW PCIC PUBLICATIONS

Below are a few recent, selected PCIC publications. For more information on our publications, please visit our Publications Library: **http://pacificclimate.org/resources/publications**

Flower, A., **T.Q. Murdock**, S.W. Taylor and **F.W. Zwiers**, 2013: Using an ensemble of downscaled climate model projections to assess impacts of climate change on the potential distribution of spruce and Douglas-fir forests in British Columbia. *Journal of Environmental Science and Policy*, **26**, 63-74, doi:10.1016/j.envsci.2012.07.024.

Murdock, T.Q., S.W. Taylor, **A. Flower**, A. Mehlenbacher, A. Montenegro, **F.W. Zwiers** and R. Alfaro, 2013: Pest outbreak distribution and forest management impacts in a changing climate in British Columbia. *Journal of Environmental Science and Policy*, **26**, 75-89, doi:10.1016/j.envsci.2012.07.026.

Pacific Climate Impacts Consortium, 2013: Plan2Adapt Summary Report. Pacific Climate Impacts Consortium, 2 pp.

Schnorbus, M., **A. Werner** and K. Bennet, 2012: Impacts of cliamte change in three hydrologic regimes in British Columbia, Canada. Hydrological Processes, doi: 10.1002/hyp.9661.

Sillmann, J., V.V. Kharin, X. Zhang, **F.W. Zwiers** and **D. Bronaugh**, 2013: Climate extreme indices in the CMIP5 multi-model ensemble. Part 1: Model evaluation in the present climate. *Journal of Geophysical Research: Atmospheres*, **118**, 1-18, doi:10.1002/jgrd.50203.

Sillmann, J., V.V. Kharin, **F.W. Zwiers**, X. Zhan and **D. Bronaugh**, 2013: Climate extreme indices in the CMIP5 multi-model ensemble. Part 2: Future climate projections. *Journal of Geophysical Research: Atmospheres*, in press.

Wan, H., X. Zhang, **F.W. Zwiers**, H. Shiogama, 2013: Effect of data coverage on the estimation of mean and variability of precipitation at global and regional scales. *Journal of Geophysical Research: Atmospheres*, **118**, 2, 534-546, doi:10.1002/jgrd.50118.

Zwiers, F.W., L.V. Alexander, G.C. Hegerl, T.R. Knutson, J. Kossin, P. Naveau, N. Nicholls, C. Schär, S.I. Seneviratne and X. Zhang, 2013: Challenges in Estimating and Understanding Recent Changes in the Frequency and Intensity of Extreme Climate and Weather Events. In (*Climate Science for Serving Society: Research, Modelling and Prediction Priorities*, G. Asrar and J. Hurrell, eds.), in press.