PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE JANUARY 2017

2016: ANOTHER RECORD WARM YEAR

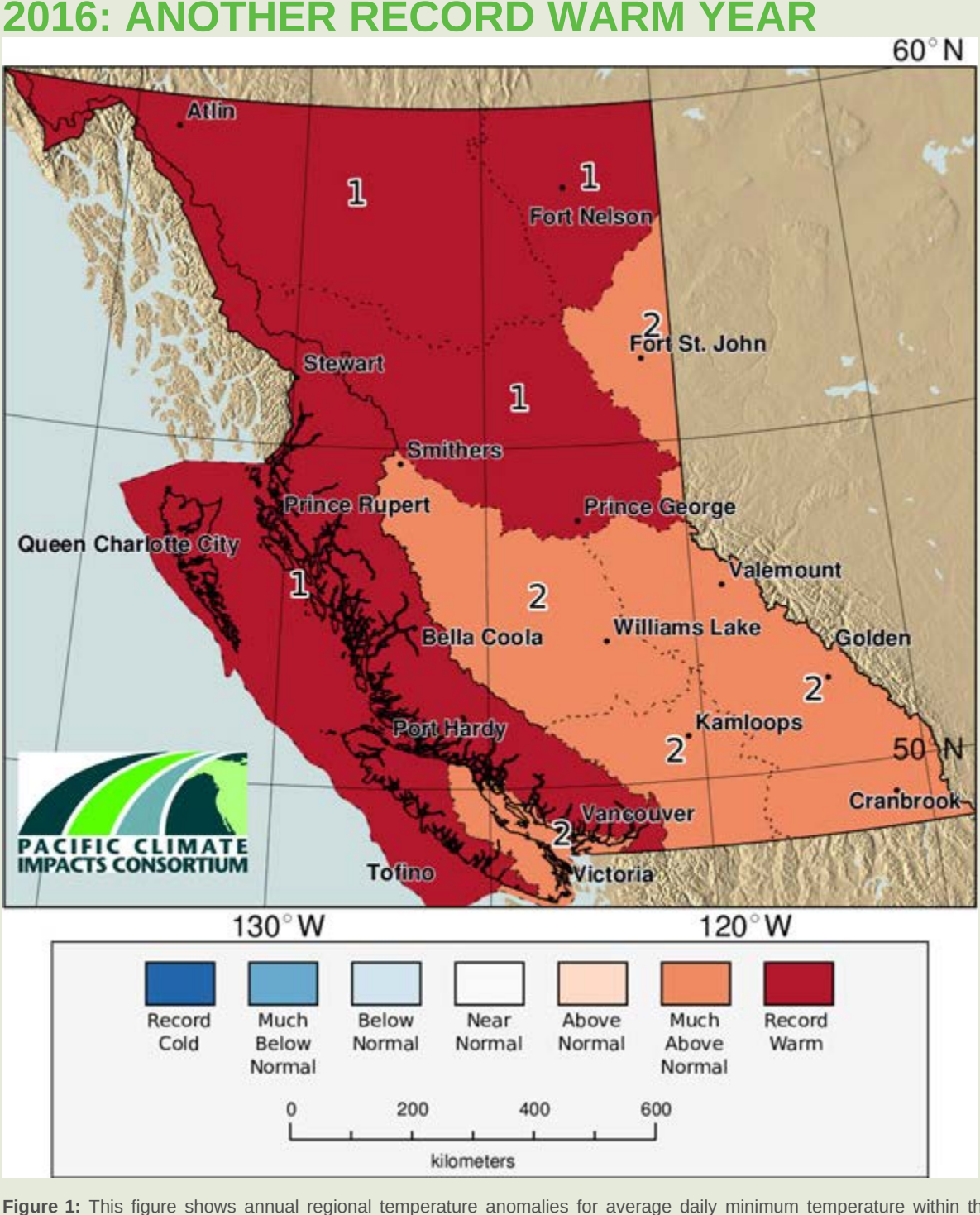


Figure 1: This figure shows annual regional temperature anomalies for average daily minimum temperature within the ecoprovinces of BC (outlined with dashed lines). Colours indicate whether the averages are near normal (within the central 1/3rd of the data), whether they are above or below normal (between the top and bottom 1/3rd and 1/10th), much above or below normal (between the top 1/10th and record setting) or record setting. Numbers printed within each ecoprovince indicate the rank of the current year within the 117 year record from record warmest (1) to record coldest (117). The dark red colours indicate records. In addition, while not record breaking for most of the province, daily maximum temperatures were much above normal.

The numbers are in: 2016 was the warmest year on record in the observational data sets kept by both the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. It is also one of the two hottest on record in the data set produced by the Met Office and University of East Anglia's Hadley Centre, in which it pulled very slightly ahead of 2015, but by an amount that was smaller than the uncertainty in the temperatures. The story is similar for our province. In December, we reported that, owing to a combination of ongoing anthropogenic climate change and a strong El Nino, 2016 was on track to be one of the two warmest years on record for British Columbia. The observational data are now in and we can say that 2016 is one of the two warmest years on record. As with the Met Office and Hadley Centre's global figure, 2016 barely edged ahead of 2015 for the province, with both years being well ahead of the third warmest year, 1987. However, with a difference of only about a tenth of a degree separating 2015 and 2016, the difference between the two is smaller than the uncertainty in the temperature.

That 2016 was so warm here in BC might seem unusual because daytime high temperatures, while high, were not record breaking, the relatively wet spring and summer moderated the province's fire season and a surge of arctic air led to a relatively cool end to the year. However, the province experienced extremely warm daily minimum temperatures (Figure 1) during the nights throughout most of the year, and these were largely responsible for 2016's record. These warm nighttime temperatures were probably due in large part to cloudy conditions. During the day clouds reduce the amount of incoming sunlight and so serve to cool a region. However, at night, this is reversed, as the clouds reduce the Earth's ability to release heat, causing warmer temperatures. The increase in cloud cover was accompanied by increased precipitation in the form of rain and snow, with most of the province seeing increased precipitation over most seasons. Taken together, these conditions led to 2016 being wetter than normal and a record-breaker in terms of temperature.

For more information, read our updated analysis of 2016 by PCIC Climatologist Faron Anslow.

FRASER RIVER BASIN CLIMATE IMPACTS

With an area of just under 230,000 square kilometres, the Fraser River Basin spans roughly a quarter of British Columbia's area. It is an integral part of many of BC's ecosystems and is home to more than 60% of our province's population. Recently, PCIC Hydrologist Arelia Schoeneberg (née Werner) and the University of Northern British Columbia's Siraj ul Islam and Stephen Déry investigated how climate change may alter the contribution of snowmelt to runoff in the basin and subsequent changes to streamflow in the Fraser River.

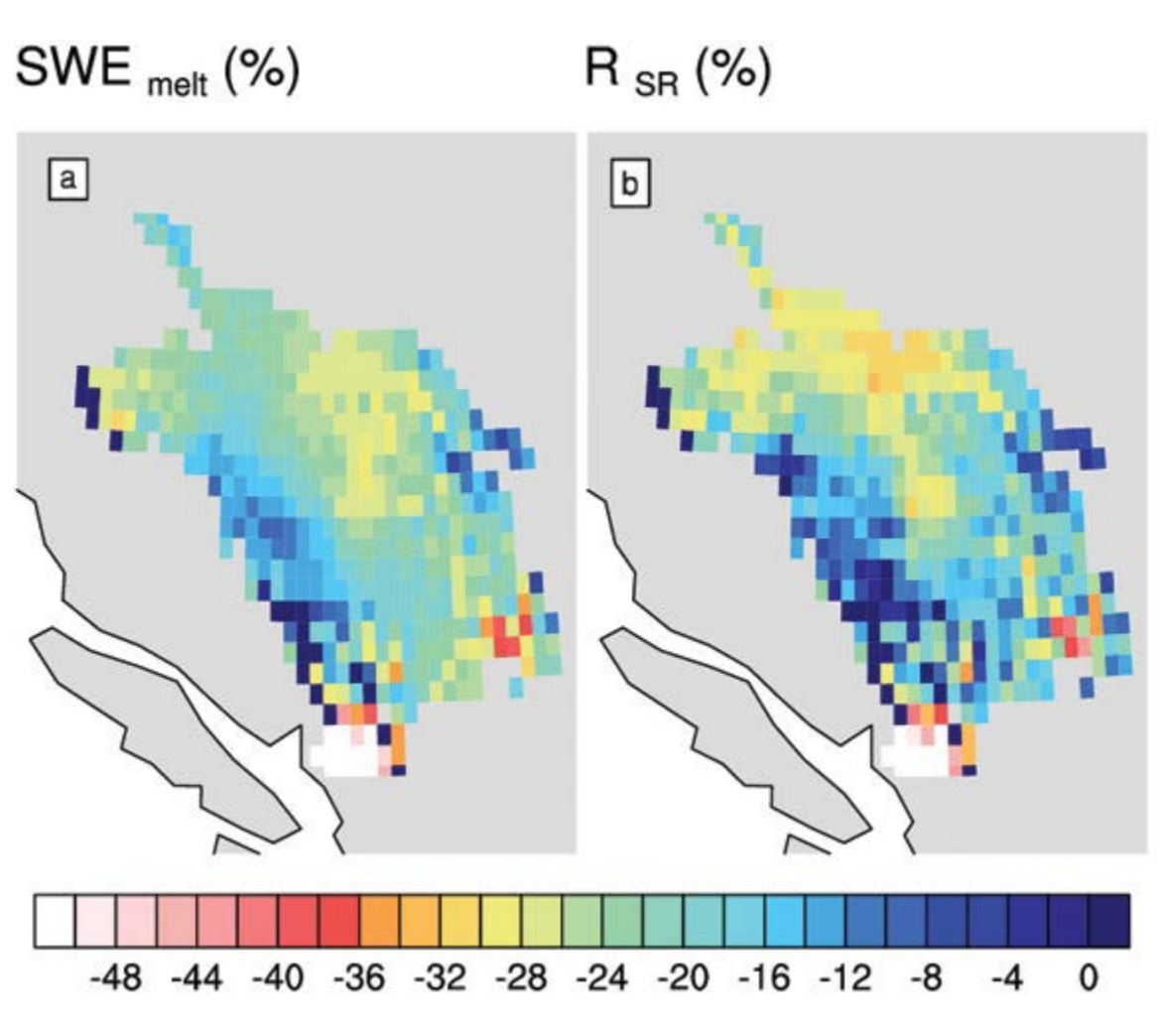


Figure 2: This figure shows the projected mean percent change of (a) snow melt and (b) the contribution of snow melt to runoff generation for each year. The projections are for the 2050s as compared to the 1980-2009 base period, assuming business-as-usual greenhouse gas emissions.

The researchers used global climate output following two emissions scenarios, one moderate and one business-as-usual, to drive the Variable Infiltration Capacity (VIC) hydrologic model. They found that by the 2050s, the basin sees a projected increase in annual average temperatures of between 2.0 to 2.4 °C relative to the reference period in the moderate scenario, and an increase of between 2.4 and 3.0 °C in the business as usual scenario. Precipitation is projected to decrease in summer, but increase in all other seasons and these changes are larger in magnitude in the higher-emissions scenario. As the area continues to warm, there is an almost 50% reduction in the projected amount of precipitation falling as snow by the 2050s, compared to the 1980-2009 reference period. The projections also show a pattern of decreasing snowpack over the Interior Plateau region, and the Rocky and Coast Mountains. This loss proceeds more quickly at lower elevations. Altogether about a third of the basin's snowpack is lost completely by the 2050s. Both snowmelt and the contribution of snow melt to runoff (Figure 2) decrease significantly across all of the major subbasins, owing to a decrease in snow accumulation and snow-covered areas. The projections also show spring melt comes earlier by about 25 days. This results in increased spring and decreased summer runoff, a longer dry season and decreased river flows during the summer and autumn months. This means a decrease in water availability when demand is greatest and an increase in availability when demand is at its lowest.

The researchers also tested the hydrologic model by driving it with observational data and checking its output against observations of the river's flow. The model was implemented with grid cells of about 25-kilometre resolution, each divided into 10 elevation bands of equal area, to better characterize future climate change impacts at different elevations. They found that simulated river flow matches observations very closely in six out of the seven main subbasins and reasonably well in the seventh, with the model capturing both the volume of the flows and the timing of runoff peaks.

The Fraser River is an essential ecosystem. In particular, it is the world's most productive river for salmon, serves as a part of the Pacific Flyway for migratory birds and is an important area for breeding waterfowl. It supplies water to a large number of fisheries, mining operations and farmland. It is also susceptible to change due to anthropogenic factors, including urbanization, forestry and climate change. Changes to its flow could affect flood risk, hydroelectric power generation and river temperatures, which have consequences for salmon survival.

SURVEY ON OUR ONLINE TOOLS

Online tools are an important way that Pacific Climate Impacts Consortium delivers climate information to our users. To ensure effectiveness and relevance, we rely on your feedback.

If you can spare a few minutes to fill out our short online survey at https://www.surveymonkey.com/r/9H26RPM, it will help us improve the services we provide.

We are also conducting personal interviews to dig a little deeper into how people use our online climate tools. Interviews can be done by phone, Skype or in person. For more information please contact Noemie Bechtet at nbechtet@uvic.ca.

DATA PORTAL UPDATES

PCIC's Data Portal has seen upgrades that will make our portal more useful to our users as well as easier to develop and maintain for our computational support team. Most immediately obvious, on the front end, we have added a point tool that allows users of gridded data products to easily download data for single boxes. Users also now have the option to download an entire time series with one click. Two bugs with the colour bar have also been addressed, fixing issues where the colour bar was overly precise in the labels for its divisions and displayed incorrect colours.

Changes to the back end of the data portal have been more extensive. These changes will make it easier to continue development of the data portal into the future. The changes include a new software suite to test code, and guides for deployment and development.

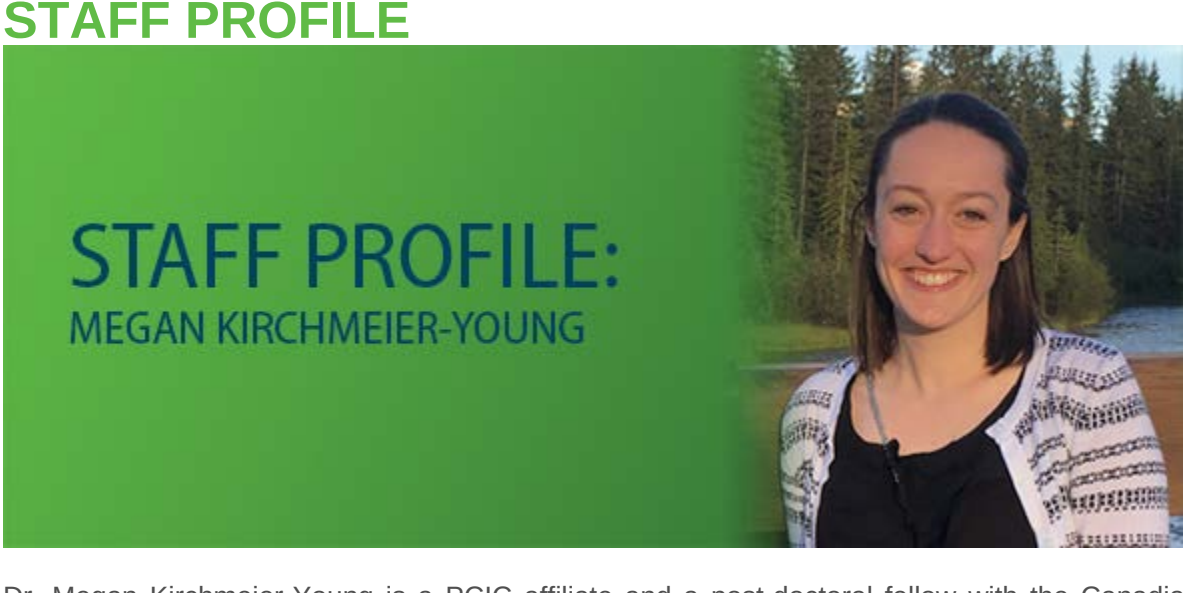
Go to our Data Portal.

PCIC DIRECTOR PRESENTS KEYNOTE AT WILDLAND FIRE CANADA MEETING

The Wildland Canada Conference Series is a biannual series that serves as an opportunity for scientists and planners in forest management to share their research, best practices and network. In 2016 the Wildland Canada Conference was held in Kelowna, from October 24th to the 28th. Wildfire risk is tied to climate and climate extremes events. Whenever a large wildfire breaks out, such as the Fort McMurray wildfire of 2016, one of the questions that people have is, "was this fire caused or made more likely to occur by climate change?" To help address the answers that climate science can provide for these sorts of questions, PCIC Director Francis Zwiers was invited to deliver a keynote lecture, *The Emerging Science of Attributing Causes to Extreme Events*. In it, he shared the current state of the art in detection and attribution analysis for climate extreme events and how these are relevant to wildfires, including recent work conducted at PCIC on the Fort McMurray wildfire of 2016. He also discussed how the type of question asked affects the answer. Differing event definitions and research focus points—for example, focusing on intensity of events as opposed to frequency—can yield substantially different answers in terms of the extent to which events can be attributed to human influence. Dr. Zwiers presented a public talk in Kelowna on the same subject, on October 27th.

Download Francis Zwiers's presentation.

STAFF PROFILE



Dr. Megan Kirchmeier-Young is a PCIC affiliate and a post-doctoral fellow with the Canadian Sea Ice and Snow Evolution (CanSISE) Network. Working between PCIC and the Canadian Centre for Climate Modelling and Analysis, she uses her experience in statistical downscaling and extreme event analysis to add to PCIC's capacity for studying extreme climate and weather events.

"One thing I find interesting about studying extremes is that it depends greatly on the frame of reference," she explains. "We can have standard definitions of what constitutes an 'extreme' event from a climate perspective, but on a practical level, an extreme event varies by application, user, location, etc. It is a fun challenge to provide a reasonable amount of results, but that are general enough to be useful for a variety of interests."

Dr. Kirchmeier-Young's current research focuses on quantifying the influence of human greenhouse gas emissions on the occurrence of extreme events. This is known as event attribution and it involves comparing climate model simulations that include observed emissions with simulations of the world as it would have been without any human influence. "We calculate the probability of a specific event's occurrence in each scenario and compare these to assess changes in risk," says Kirchmeier-Young. She adds, "it is similar to what we often hear from the medical field: just like how smoking increases the risk of a person getting lung cancer, anthropogenic emissions can increase the risk of a particular extreme event occurring. This information is useful to policy makers and those concerned with the impacts of such events, but also, I think, can help improve the general understanding of climate change and its impacts."

Dr. Kirchmeier-Young and colleagues have recently published an event attribution paper examining extreme minimums in Arctic sea ice extent. Their work shows that events like the current record minimum of 2012 would not have occurred in a world without human emissions. "I am currently working on an event attribution analysis for extreme wildfire risk in western Canada. This work was inspired by the fire in Fort McMurray earlier this year and our results so far suggests that the risk of general metrics of extreme fire potential in this area has increased by 1.5 to 5 times due to the influence of human emissions." Though these cases in particular do not deal with extreme events in BC, the methods of statistical analysis underlying them are broadly applicable and valuable tools for the attribution of climate change in BC and abroad.

Read Dr. Kirchmeier-Young's recent paper on Arctic sea ice extent.

THE PACIFIC CLIMATE SEMINAR SERIES CONTINUES

Figure 3: The figure above shows Dr. Hebda delivering his talk on November 30th (main panel) and PCIC's Dr. Ben Alaya delivering his talk on October 19th (inset).

Following the kick-off talk by Dr. Rod Davis in September, the 2016-2017 Pacific Climate Seminar Series continued with talks by with PCIC Research Fellow, Dr. Mohamed Ali Ben Alaya on October 19 and Dr. Richard J Hebda on November 30th (Figure above). Dr. Ben Alaya's talk titled, *Probabilistic hybrid modular structure for multisite and multivariable statistical downscaling*. covered the use of probabilistic regression approaches for downscaling multiple variables from global climate model output. Dr. Hebda's talk *Dispersed adaptation to climate change: the heritage potato crop-climate project* covered using a dispersed adaptation approach to improve food security in which multiple varieties of heritage potatoes were grown in different climates across Canada in order to determine which varieties work where.

The first talk of 2017 was delivered on Wednesday, January 18th by Dr. Werner A. Kurz of the Canadian Forest Service and PICS Forest Carbon Management Project. His talk, titled, *The potential contribution of the BC forest sector to climate change mitigation* covered recent work by the Forest Carbon Management Project in quantifying the potential contribution of British Columbia's forest sector to climate change mitigation.

More information about Dr. Ben Alaya's talk or Dr. Hebda's talk or any talk hosted by PCIC can be found on the seminars section of our site. More information on Dr. Kurz's talk can be found on the event's page.

PCIC DIRECTOR RECOGNIZED AS HIGHLY CITED RESEARCHER

PCIC Director Francis Zwiers is one of three UVic academics who were recently recognized by Thomson Reuters in their annual list of top-cited researchers. This rare distinction is reserved for those who are in the top 1% of the most cited researchers in their fields. For more on this, see the article in UVic News.

NEWSWORTHY SCIENCE

PCIC's latest Science Brief highlights a recent paper by Mao et al. (2016) that examines the recent greening of the northern extratropical land surface. Using satellite observations and global climate model output, the authors find that the increase in leaf area that has been observed in this area over the 1982-2011 period is largely due to anthropogenic greenhouse gas emissions.

Read the latest Science Brief.

PCIC AT THE AMERICAN GEOPHYSICAL UNION'S 2016 FALL MEETING

Figure 4: This figure shows a slide from Dr. Parkinson's presentation at the 2016 AGU Fall Meeting. On screen is one of the first images ever taken of Arctic sea ice extent. It dates to 1975.

Each year, PCIC researchers are among the tens of thousands of Earth and space scientists who attend the AGU's Fall Meeting. This is the largest such meeting of scientists in these disciplines in the world and it is a chance both to share our most recent findings and to talk with other researchers whose work is at the cutting edge of their fields.

PCIC Director Francis Zwiers was invited as a speaker for the session, *Determining matured science: utility, cases and formats*. This session focused on how best to identify and distill those knowledge claims that are mature and relatively settled, as opposed to those more contentious claims that lie nearer to the boundaries of scientific knowledge. In her talk, titled, *Assessment of Climate Change Impact on Streamflow Extremes in Mountainous Regions using a Coupled Hydrology-Glacier Model* Hydrologist Arelia Schoeneberg (née Werner) presented results from the PCIC Hydrologic Impacts Theme's research on assessing their newly updated Variable Infiltration Capacity (VIC) hydrologic model that is coupled to a dynamic glacial model for its ability to represent extreme streamflow events. Katherine Pingree-Shippee's presentation, *Seasonal Extratropical Storm Activity Potential Predictability and its Origins during the Cold Seasons*, focused on the extent to which extratropical cyclone storm activity can be predicted on a seasonal timescale using several large teleconnection patterns. Affiliate Research Associate Charles Curry and Regional Climate Impacts Analyst Stephen Sobie each presented posters. Dr. Curry's poster, *Predictors of High Streamflow Events in the Fraser River Basin of British Columbia, Canada* focused on work done at PCIC using the VIC model driven to determine the causes of annual peak daily streamflow events in the Fraser River basin. Stephen Sobie's poster, *Experiences with collaborative climate impacts assessments for regional governments in southwestern British Columbia* shared lessons learned in developing collaborative reports with regional and local governments in BC.

This is only a small sampling of work from one of the largest scientific conferences on Earth. The research presented was incredibly broad in breadth and varied from the technical details of approaches for representing convection in climate models to virtual reality "tours" of Mars presented by NASA. To watch recorded presentations from the conference online for free, go to AGU On Demand.

Download Arelia Schoeneberg's presentation, Katherine Pingree-Shippee's presentation, Stephen Sobie's poster or Charles Curry's poster through our Publications Library.

PCIC AT THE 7TH ANNUAL NORTHWEST CLIMATE CONFERENCE

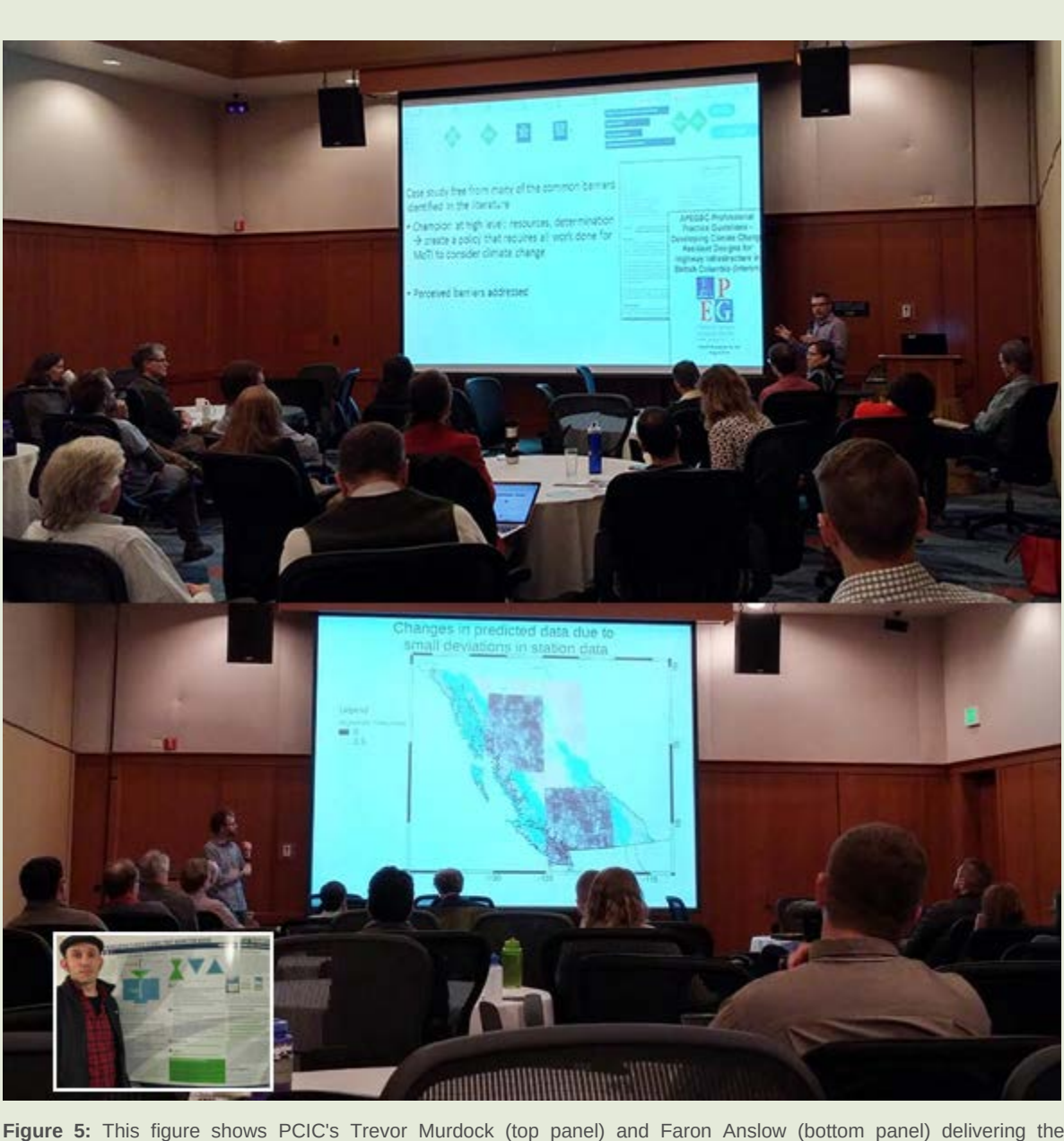


Figure 5: This figure shows PCIC's Trevor Murdock (top panel) and Faron Anslow (bottom panel) delivering their presentations at the 7th Annual Northwest Climate Conference and Michael Shumlich (bottom left inset) with his poster.

Each year the Northwest Climate Conference attracts policymakers, scientists, resource managers, decision-makers and science communicators from across the Pacific Northwest. They gather to share and catch up on the most recent research findings that are relevant to their regions, discuss the needs and experiences of their communities, network and participate in discussions about how those living in the northwest can best adapt to the changing climate. This year, the conference fell just days after the United States presidential election. In light of that fact, the public keynote and several of the panels included discussions about the election and how it may impact climate research and adaptation in the US. A large portion of these comments focused on the momentum that has been growing for mitigation and adaptation initiatives on the state level as well as the need to frame issues in terms of their impacts and what can be done at the local level. The individual presentations were divided by theme and covered a wide range of topics including the proposed development of a drought early warning system for the Pacific Northwest, climate vulnerability assessments, classifying landscapes in hydrologic models and characterizing uncertainty in regional climate models to projections of extreme precipitation events in the region.

This year, PCIC sent three staff members to the conference. Theme Leads Faron Anslow and Trevor Murdock delivered and co-delivered a talk, respectively, and science communicator Michael Shumlich presented a poster. Faron's talk, *Developing and Delivering PRISM Uncertainty Estimates for BC* covered the work that PCIC has been doing on determining what the uncertainties in PRISM observational data are and in delivering this data to our users via our Raster Data Portal. Trevor and Johanna Wolf co-delivered their talk, *An engineer, a climate scientist and an adaptation researcher walk into a coffee shop…* which covered some of the relationships between information about future climate states and adaptation planning, as well as discussing lessons learned from, and barriers to, adaptation planning in BC. Michael's poster, *Approaches for Communicating Climate Science That Work for Users*, discussed three approaches that PCIC has used to develop plain language summary reports.

Download Trevor Murdock's presentation, Faron Anslow's presentation or Michael Shumlich's poster through our Publications Library.

PCIC STAFF CHANGES

The Pacific Climate Impacts Consortium is a hub of climate science service delivery and our team is involved in collaborations with partners from many other scientific institutions. Because of this, we are often welcoming new scientists and support personnel to work with us. Collaborating with these researchers and organizations strengthen our ties with them and ensures that our team is constantly abreast of new knowledge in their fields. It is also an opportunity to help early career scientists flourish and sharpen their skills. Inevitably, as a part of this exchange of knowledge, members of our scientific team also move to other research institutions, where they continue their research to expand the boundaries of knowledge..

Over the fall, PCIC has welcomed two new faces into University House 1, Rod Glover and Noemie Bechtet. Rod Glover is a Web Front-End Developer who joins to help our Computational Support Team develop web applications and online tools for visualizing and delivering climate data. Rod has a diverse background which has seen him working for a Silicon Valley web start-up, an engineering company that manufactures remote environmental monitoring systems, a medical devices and software company, and two federal scientific research institutions. Noemie Bechtet joins us as a research intern who is studying how PCIC's web tools are used so that we can better serve our users with them. Noemie is currently a student at the Toulouse Business School and the Toulouse Institute of Political Studies.

It is with gratitude and appreciation that PCIC says farewell to Dr. Mohammed Reza Najafi, Steve Dainard, Michael Fischer and Carl Masri, who have moved on to further pursue their career goals. Dr. Najafi joined PCIC in 2013 as a postdoctoral fellow before taking on a role as a Hydroclimate Variability Scientist at PCIC in 2015. His wide expertise expertise in watershed hydrology, hydroclimatic extreme events, and detection and attribution added greatly to our Hydrologic Impacts Theme. Steve Dainard had been with PCIC since 2014 and was one of the computational support group's key staff, supporting PCIC's storage, computation, and virtualization infrastructure, which are the backbone upon which the rest of PCIC's research relies. Michael Fischer joined PCIC in 2014, also as a member of the computational support group. As a member of this team, he used his expertise in software development to help in coupling the Variable Infiltration Capacity (VIC) hydrology model to the Regional Glacier Model (RGM) for improved glacier dynamics and long-term streamflow evolution studies. Carl Masri is a fourth-year UVic Computer Science student who helped our computational support group update the data portal and the tools they use for its development. We wish them all the best in their future pursuits.

RECENT PAPERS AUTHORED BY PCIC STAFF AND AFFILIATES

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Myhre, G., P.M. Forster, B.H. Samset, O. Hodnebrog, J. Sillmann, O. Boucher, G. Faluvegi, D. Flaschner, T. Iversen, M. Kasoar, V. Kharin, A. Kirkevag, J.-F. Lamarque, D. Olivie, T. Richardson, D. Shindell, K.P. Shine, C. Weum Stiern, T. Takemura, A. Voulgarakis and **F.W. Zwiers**, 2016: PDRMIP: A precipitation driver and response model intercomparison project, protocol and preliminary results. *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-16-0019.1.

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Williamson, S.N., D.S. Hik, J.A. Gamon, A.H. Jarosch, **F.S. Anslow**, G.K.C. Clarke and T.S. Rupp, 2017: Spring and summer monthly MODIS LST is inherently biased compared to air temperature in snow covered sub-Arctic mountains. *Remote Sensing of Environment*, **189**, 14-24, doi:10.1016/j.rse.2016.11.009.

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