NEWSLETTER

Changing Cold Regions Network

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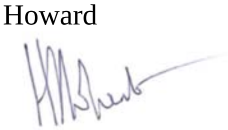
Message from the Principal Investigator

CCRN is now in year 3, and it's great to see progress being made on all fronts. The Special Observing and Analysis Period (SOAP) is well underway, a focused field campaign on precipitation in the Rockies is in full swing, papers are coming together for a special journal issue on the Calgary floods, and modelling work is producing new insights and improved modelling capability.

We would like to keep network members up to date with progress using this newsletter so please send any items to Chris DeBeer for the next edition. And having spent much time telling people what CCRN was planning to deliver, we now need to focus on getting our achievements out to the user community, so if you have a good news or information story that will be of relevance to any of our partners or stakeholders, please contact Graham Strickert.

I look forward to a productive summer field season and to catching up with you all in our upcoming Fall meetings.

Regards,
Howard



Upcoming Events

CCRN at the 2015 AGU-GAC-MAC-CGU Joint Assembly, Montreal, QC, 3–7 May, 2015

The CCRN community will have a large and active presence at the upcoming Joint Assembly of the American Geophysical Union, Geological Association of Canada, Canadian Mineralogical Society, and Canadian Geophysical Union in Montreal in early May. CCRN members are authors or co-authors on 72 papers being presented, and the Joint Assembly will also feature four oral sessions and one poster session entitled "*Changing Cold Regions: Climate, Cryosphere, Hydrology, Ecology*", that will include 53 papers on the observation, diagnosis, and/or prediction of components of the changing cold regions Earth system.

- The conference website is http://ja.agu.org/2015/
- A list of all papers by CCRN members is at www.ccrnetwork.ca/documents/JA2015/CCRN_JA2015.pdf
- An ICS file for these papers (for calendar application) can be downloaded at www.ccrnetwork.ca/documents/JA2015/CCRN_ja2015.ics

CCRN at the 49th CMOS Congress & 13th AMS Conference, Whistler, BC, 31 May–4 June, 2015

The Canadian Meteorological and Oceanographic Society's 49th Congress and the American Meteorological Society's 13th Conference on Polar Meteorology and Oceanography is being held at the Whistler Conference Centre in early June (http://congress.cmos.ca/). Watch for the following talks by CCRN members and collaborators of CCRN:

2 June, 2015			
Time	**Title**	**Presenter**	**Room**
10:30	Constraining the strength of the terrestrial CO2 fertilization effect in Earth system models	Vivek Arora	Fitzsimmons
10:30	Recent Earth system change in the interior of western Canada – recent results from the Changing Cold Regions Network	Chris DeBeer	Garibaldi
11:00	The June 2013 Alberta Catastrophic Flooding: Water vapor transport analysis by WRF simulation	Yanping Li	Garibaldi
14:00	The June 2013 Alberta Catastrophic Flooding Event	Ron Stewart	Wedgemont
14:15	Intercomparison of snow depth and snow water equivalent measurements during WMO SPICE	Craig Smith	Garibaldi
3 June, 2015			
14:00	Potential future carbon uptake may overcome losses from a large insect outbreak in British Columbia, Canada	Vivek Arora	Spearhead
4 June, 2015			
8:30	Twenty-first century warming and the deglaciation of Western Canada	Garry Clarke	Plenary
11:45	A comparison of surface energy balance and degree day models for mass balance of Arctic icefields and the Greenland Ice Sheet	Shawn Marshall	Rainbow

CCRN Modelling Workshop on the Diagnosis of Change, Saskatoon, SK, 28–30 September, 2015

We will be holding a modelling workshop to evaluate progress across our Themes, including fine-scale and large-scale hydrological, hydro-ecological and atmospheric modelling, and in particular, to address issues including the diagnosis and prediction of change. The workshop will be held 28–30 September at the National Hydrology Research Centre in Saskatoon. For further information, or if you would like to attend, contact Chris DeBeer (chris.debeer@usask.ca; 306-966-6224).

CCRN 3rd Annual General Meeting, Saskatoon, SK, 1–4 November, 2015

CCRN will be holding its 3rd Annual General Meeting in Saskatoon on 2–4 November, with an extra day set for the early career researchers on 1 November. The location will be the Park Town Hotel, in the Cedar Room:

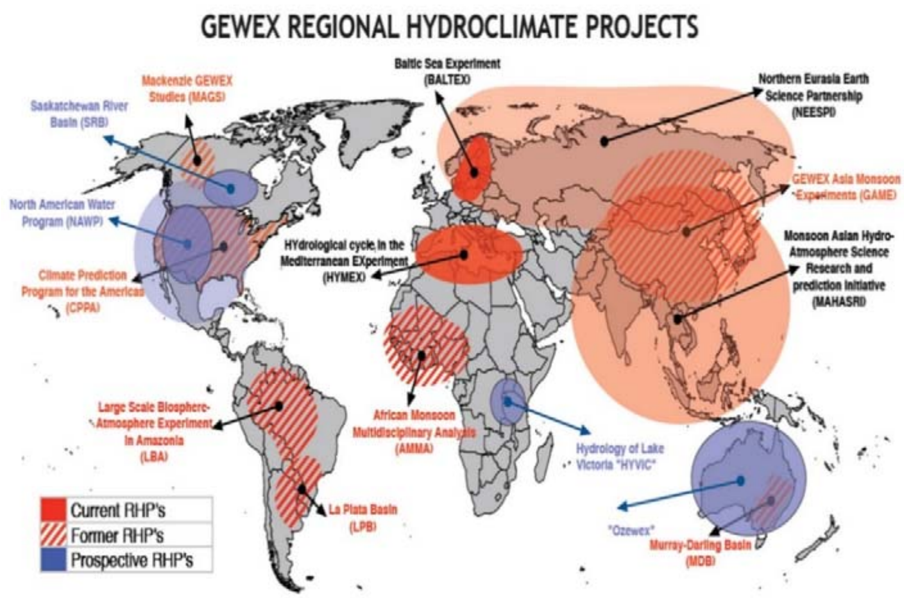
Park Town Hotel
924 Spadina Crescent East
Saskatoon, SK S7K 3H5
Toll Free: 1 (800) 667-3999
Phone: (306) 244-5564
Fax: (306) 665-8698
http://www.parktownhotel.com

There is a block of guestrooms reserved for us ($155/night, standard queen) that will be held until 1 October. For further information, or if you would like to attend, contact Chris DeBeer (chris.debeer@usask.ca; 306-966-6224).

Announcements and Recent Publications

The Mackenzie and Saskatchewan River Basins—CCRN as a GEWEX Regional Hydroclimate Project

In December 2012, the Global Energy and Water Exchanges (GEWEX) Hydroclimate Panel approved the Saskatchewan River Basin (SaskRB) Project as a Regional Hydroclimate Project (RHP), designed to support the GEWEX mission, imperatives and science questions. Subsequently, at the 7th International Scientific Conference on the Global Water and Energy Cycle held in The Hague in July 2014 it was suggested that there could be significant benefits from a broader RHP in western Canada that mirrored CCRN (SaskRB and Mackenzie River Basin (MackRB)). Given its geographical focus (from the Canadian Rocky Mountains in the West to Lake Winnipeg in the East, and from the Canada–U.S. border in the South to the Arctic Ocean in the North), this project would complement well current proposals for a U.S. RHP focused on the Colorado River Basin. A proposal focusing on the GEWEX themes of Global Water Resource Systems, Observations and Predictions of Precipitation, Changes in Extremes and Water and Energy Cycles and Processes was approved at the GEWEX Hydroclimate Panel meeting in Pasadena, CA in mid-December 2014. This extension will place CCRN in a position to more broadly engage the international scientific community and to contribute our results to this important global forum.



Recent Publications by CCRN Members

We are pleased to share some recently published papers by our members, describing various aspects of CCRN research and related activities. A complete listing of journal publications by CCRN members can be found at www.ccrnetwork.ca/outputs/publications, and links to these papers are available there.

- Elvis Asong, a PhD student of Naveed Khaliq and Howard Wheater at the Global Institute for Water Security, University of Saskatchewan, has been working on statistical downscaling of climate model outputs over the Prairie region. See a summary on page 7 of this newsletter.
  - Asong, Z.E., Khaliq, M.N., and Wheater, H.S., 2015. Regionalization of precipitation characteristics in the Canadian Prairie Provinces using large-scale atmospheric covariates and geophysical attributes. *Stochastic Environmental Research and Risk Assessment*, **29**, 875–892, http://link.springer.com/article/10.1007/s00477-014-0918-z

- Several papers have recently been published by John Pomeroy and colleagues and students in the Centre for Hydrology, University of Saskatchewan, Environment Canada, University of Idaho and Universidad de Chile. These describe important CCRN-relevant research on snowmelt energetics in disturbed forested areas with implications for modelling, the use of meteorological model reanalysis data for physically based mountain hydrological prediction in data sparse regions, spatial variation of Canadian Prairie evapotranspiration as a function of drought and its parameterization for land surface schemes, and the transformations in temporal frequency distributions moving from those of snowfall, to snow on the ground, snowmelt runoff, depressional storage, and finally streamflow.
  - Musselman, K.N., Pomeroy, J.W., and Link, T.E., 2015. Variability in shortwave irradiance caused by forest gaps: Measurements, modelling, and implications for snow energetics. *Agricultural and Forest Meteorology*, **207**, 69–82, http://dx.doi.org/10.1016/j.agrformet.2015.03.014
  - Krogh, S.A., Pomeroy, J.W. and McPhee, J., 2015. Physically based mountain hydrological modelling using reanalysis data in Patagonia. *Journal of Hydrometeorology*, **16**, 172–193, http://journals.ametsoc.org/doi/abs/10.1175/JHM-D-13-0178.1
  - Armstrong, R.N., Pomeroy, J.W., and Martz, L.W., 2015. Variability in evaporation across the Canadian Prairie region during drought and non-drought periods. *Journal of Hydrology*, **521**, 182–195, http://dx.doi.org/10.1016/j.jhydrol.2014.11.070
  - Shook, K., Pomeroy, J., and van der Kamp, G., 2015. The transformation of frequency distributions of winter precipitation to spring streamflow probabilities in cold regions; case studies from the Canadian Prairies. *Journal of Hydrology*, **521**, 395–409, http://dx.doi.org/10.1016/j.jhydrol.2014.12.014

- Daqing Yang is part of the Mountain Research Initiative, Elevation-dependent Warming (EDW) Working Group, which recently published a paper on climate warming in the mountain regions of the world. The paper provides a good approach for what could also be done over the northern regions, particularly the impact of warming to hydrology and water resources.
  - Pepin et al., 2015. Elevation-dependent warming in mountain regions of the world. *Nature Climate Change*, **5**, 424–430, http://www.nature.com/nclimate/journal/v5/n5/full/nclimate2563.html

Field Research Highlights—Spring 2015

Hoarfrost Episodes at BERMS in Winter 2014–2015

The eddy-covariance flux measurements at the Old Black Spruce and Old Aspen flux towers were briefly confounded during the winter of 2014–2015 by the appearance and prolonged presence of hoarfrost on the sonic anemometers (Figure 1) at both sites beginning early in the morning on December 8, 2014 when the air temperature (T_{air}) was around –10 °C. Hoarfrost results when the T_{air} drops below the frost point temperature—the value of T_{air} at which the partial pressure of ambient atmospheric water vapour reaches the saturation point over an ice-surface (referred to as the dew point when T_{air} is above 0 °C)—and ice is deposited directly on frozen surfaces from the vapour phase (desublimation).

Figure 1: Hoarfrost on Gill R3 sonic anemometer, January 5, 2015. (photo credit: Greg Neufeld).

The first appearance of hoarfrost caused the Gill R3 sonic anemometer to malfunction. Another potential hoarfrost episode occurred in mid-December. T_{air} remained at about –10 °C between December 16 and 26 and it is possible that snowfall that fell (Dec 23) during that interval also contributed to the increasingly poor quality data, as the hoarfrost would have given the falling snow purchase on the sonic arms and the chance to accumulate. The sonic anemometer began outputting good data on January 5, 2015 when Greg Neufeld, the site research technician caused most of the hoarfrost to fall off the sonic as the simple consequence of his movements when climbing the tower. Also seen in Figure 2 is hoarfrost on the tamarack trees at the Old Black Spruce site in mid-December.

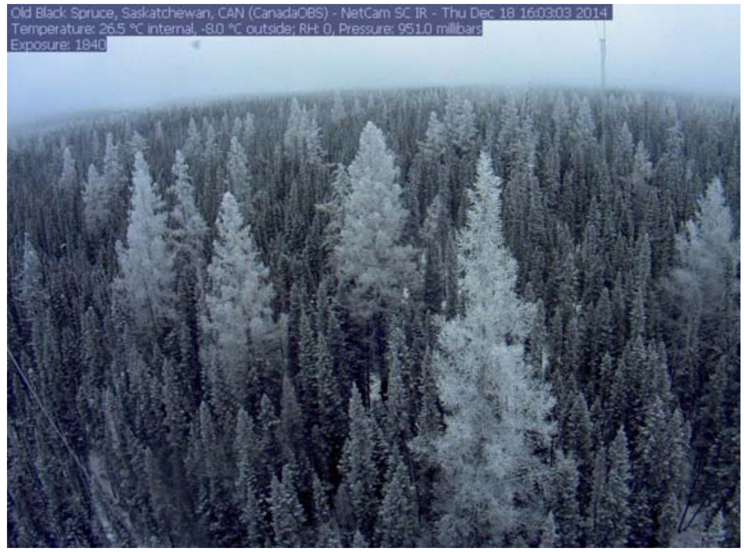


Figure 2: Hoarfrost on tamarack at Old Black Spruce, December 18, 2014 (photo credit: PHENOCAM, Andrew Richardson).

Athabasca Glacier Katabatic Wind and Lapse Rate Campaign

Understanding how a glacier interacts with the atmosphere above it is one of the key uncertainties in modelling climate–glacier interactions. This summer, an intensive glacio-meteorological campaign is planned for the Athabasca Glacier, to investigate the interaction of katabatic and valley wind systems and the impact of these winds on the melt rate across the glacier. SODAR (SOnic Detection And Ranging) and kite profiling systems will be used to capture the characteristic wind and temperature profiles within the valley, while meteorological and eddy-covariance measurements at two sites on glacier will enable the effect of katabatic winds on turbulent and radiative transfer to be examined in detail. Transects of air temperature and humidity sensors will also be installed from the summit of the Columbia Icefield down both the Athabasca and Saskatchewan Glaciers to understand how local and regional atmospheric circulation patterns influence lapse rates, a process that is still poorly represented in current glacier mass balance modelling efforts. The study is being led by a team from the University of Saskatchewan (Dr. Jonathan Conway, Dr. Warren Helgason and Dr. John Pomeroy) along with collaborators from L'Institut de recherché pour le développement, France (Dr. Jean-Emmanuel Sicart), the Geological Survey of Canada (Michael Demuth) and University of Victoria (Dr. David E. Atkinson).

Above: (from left) Dr. Jonathan Conway, May Guan and Dhiraj Pradhananga at the Athabasca Glacier Meteor-ological station after its installation in September 2014.

Left: Athabasca Glacier in January 2015, viewed from the last glacial maximum lateral moraine.

Precipitation Formation in Kananaskis

Major precipitation events occur in the Banff/Calgary area of Alberta that are a critical aspect of the region's water cycle and can lead to major disasters such as the June 2013 flooding. To begin to examine atmospheric factors leading to precipitation in this region, a small March–April 2015 field project is underway in the Kananaskis area.

Instrument setup at the Kananaskis Emergency Services site.

A number of instruments have been deployed, mainly at the Kananaskis Emergency Site (KES) near Kananaskis Village, and weather observations have also been collected at Fortress Mountain and the Nakiska Ski Area. These instruments include a vertically-pointing Microwave Rain Radar (MRR), a portable sounding system, OTT Parsivel precipitation counter equipment, precipitation micro-photography, and a Geonor precipitation gauge. As appropriate, measurements are also being made using equipment strapped to skiers at Nakiska or out of the windows of cars passing through precipitation regions, especially up to Fortress Mountain. The study is being led by Julie Thériault along with Ronald Stewart with essential linkages with John Pomeroy and his group at the Cold Water Laboratory. Much of the effort is being carried out by graduate students including (UQAM) Émilie Bresson, Mélissa Cholette, Dominic Matte, Émilie Poirier, Housseyni Sankare and Paul Vaquer, (University of Manitoba) Juris Almonte, Stephen Berg and Ida Hung, and (University of Saskatchewan) Lucia Scaff.

Clockwise from top left: Juris Almonte and Ida Hung conducting a snow density sample, Émilie Poirier collecting snowflakes for micro-photography at Fortress Mountain, Paul Vaquer releasing a weather balloon, Mélissa Cholette keeping the kestrels well ventilated for accurate measurements, photograph of a bullet rosette taken March 15.

So far, 15 events have been examined, although none can be deemed a huge event. The events have produced snow or rain in either upslope or downslope conditions. During precipitation, the lower atmosphere and surface have consequently been either near-saturated or quite dry (30–85% surface relative humidity values). In dry cases, there must be considerable loss due to sublimation or evaporation as the particles fell towards the surface, and solid precipitation was sometimes still occurring at the surface with temperatures approaching 8°C. The snow was often composed of dendritic crystals (but many other types also occurred), normally aggregated, and accretion was common.

Analysis of field project information is critical to the research of several of the participating graduate students.

- Link to the project blog: http://albertafieldproject.weebly.com/

Ongoing Research

Statistical downscaling of Atmosphere-Ocean General Circulation Model outputs to catchment-scale hydro-meteorological variables over the Canadian Prairie Provinces

Atmosphere-Ocean General Circulation Models (AOGCMs) are an important tool for estimating future climates that might result from further anthropogenic modification of the atmospheric system. However, outputs from these models cannot reliably be applied directly in many environmental and water resources studies because of coarse spatial resolution and limitations in representing sub-grid scale processes. To bridge this gap, downscaling methods (i.e. statistical and dynamical downscaling methods) have been widely utilized to transform AOGCM information to local- and regional-scale resolution. In this study, a multisite multivariate stochastic modelling approach is developed based on the generalized linear model (GLM) framework, using daily observations of precipitation and minimum and maximum temperatures from 120 sites (Fig.1) located across the Canadian Prairie Provinces: Alberta, Saskatchewan and Manitoba. Large-scale atmospheric covariates from the National Center for Environmental Prediction (NCEP) Reanalysis-I, teleconnection indices, and geographical site attributes are used as predictors.

Given the vast nature of the study area and the paucity of data, we started by proposing a new approach for identifying homogeneous regions for regionalization of precipitation characteristics for the Canadian Prairie Provinces. This approach incorporates information about large-scale atmospheric covariates, teleconnection indices and geographical site attributes that impact spatial patterns of precipitation in order to delineate homogeneous precipitation regions through combined use of multivariate approaches. This resulted in the delimitation of five homogeneous climatic regions (Asong et al., 2015). Subsequently, station observations from each region are used to calibrate GLMs for the 1971–2000. Validation of the developed models is performed on both pre- and post-calibration period data. Results of the study indicate that the developed models are able to capture spatiotemporal characteristics of observed precipitation and temperature fields, such as inter-site and inter-variable correlation structure, and systematic regional variations present in observed sequences. A number of simulated weather statistics, ranging from seasonal means to characteristics of temperature and precipitation extremes and some of the commonly used climate indices, are also found to be in close agreement with those derived from observed data (Asong et al., 2015, *submitted*).

The calibrated GLMs are used to generate daily sequences of the selected weather variables for the historical (conditioned on NCEP predictors), and two non-overlapping future periods (i.e., 2011–2054 and 2055–2098) using outputs from six CMIP5 (Coupled Model Intercomparison Project Phase 5) AOGCMs corresponding to RCP2.6 (mitigation), RCP4.5 (stabilization), and RCP8.5 (high emissions) scenarios. Future changes in the mean and tail characteristics of precipitation and temperature variables are analyzed relative to the 1962–2005 reference period. The results show that mean precipitation is projected to increase in summer, autumn, and spring, and to decrease in winter, while minimum temperature will likely warm faster than maximum temperature. Projected climate extremes will probably intensify with global warming and generally exceed changes in mean conditions (Asong et al., 2015, *in preparation*). The results of this analysis provide important information for decision making. The study concludes that the GLM framework can reliably be used for multisite multivariate downscaling of AOGCM outputs in this region of Canada. Also, from the downscaled daily data, we have computed >20 climate extremes indices at each site. Single- and multi-day climate extremes are also available for each site. The data are available for each season of the year. Lastly, any index of interest can be computed from the downscaled data and used as input to, for example, hydrological models.

Here we downscaled only the first run from six AOGCMs although multi-ensembles and more than 30 other CMIP5 climate models are available. Also, only one statistical downscaling model is tested in this study. Therefore, conclusions based only on one downscaling model, one Reanalysis dataset used to build the downscaling model, and predictors from six AOGCMs are not in any way optimal and may change with inclusion of other AOGCM outputs as well as downscaling models. This kind of uncertainty is a major limitation of this study, and it is inherent in any statistical downscaling investigation.

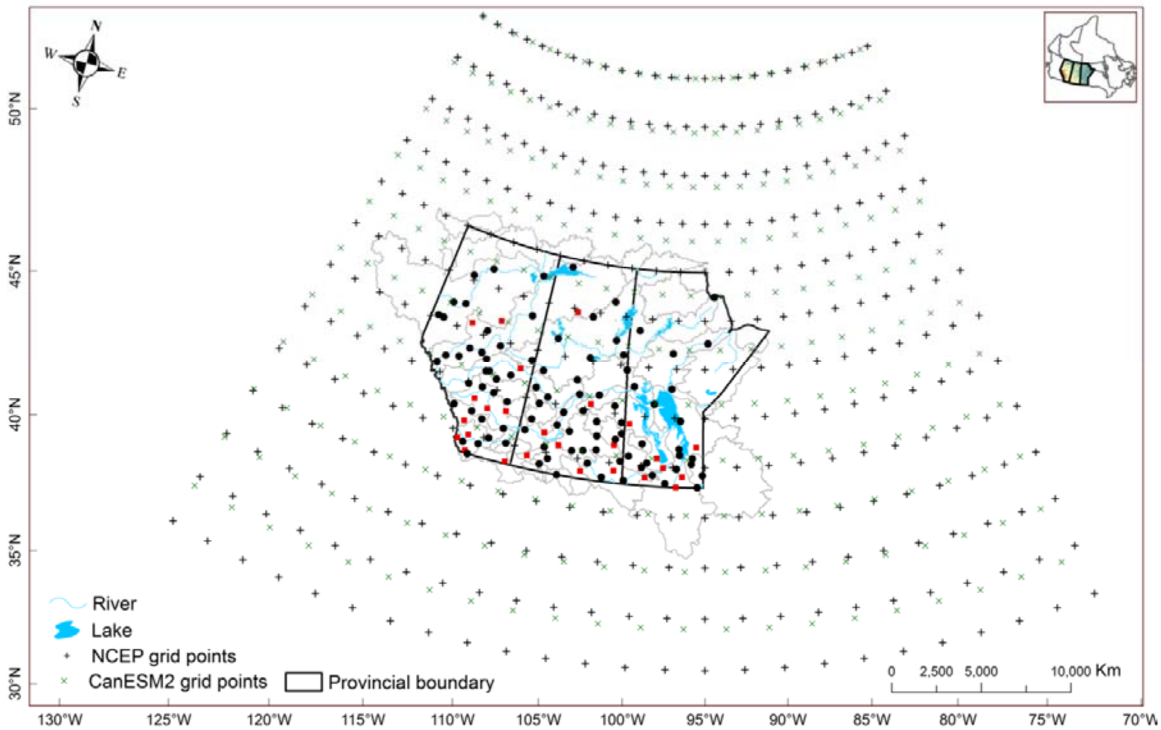


Figure 1: Study area and location of observation stations (black and red dots) considered in the study. Precipitation is observed at all stations, while temperature is recorded only at stations shown in black. Using the calibrated framework, we also simulated temperatures at ungauged stations (red dots). 47 watersheds spanning the study area are also shown. The inset shows location of the study area in Canada. The spatial domain for predictor selection is shown, as well as the NCEP versus example AOGCM grid points (CanESM2 grid points are shown)

*Elvis Asong is a PhD student at the Global Institute for Water Security, University of Saskatchewan, who is working on statistical downscaling of climate model outputs under the supervision of Professor Howard Wheater. If you would like more information on this project or to access data, contact Elvis by email at aez849@mail.usask.ca.

References

Asong Z.E., Khaliq, M.N., and Wheater, H.S., 2015. Regionalization of precipitation characteristics in the Canadian Prairie Provinces using large-scale atmospheric covariates and geophysical attributes. *Stochastic Environmental Research and Risk Assessment,* 29 (3), 875-892.

Asong Z.E., Khaliq, M.N., and Wheater, H.S., 2015. Multisite multivariate modeling of daily precipitation and temperature in the Canadian Prairie Provinces using Generalized Linear Models. Submitted to *Journal of Climate Dynamics* on 09/11/2014, CLDY-D-14-00659, under review.

Asong Z.E., Khaliq, M.N., and Wheater, H.S., 2015. Projected changes in precipitation and temperature characteristics over the Canadian Prairie Provinces using the Generalized Linear Model based multisite multivariate statistical downscaling approach, *in preparation*.

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For more information or to contribute material for the next issue, please contact the network manager, Chris DeBeer, at: chris.debeer@usask.ca (306) 966-6224; www.ccrnetwork.ca