flash FloodNet

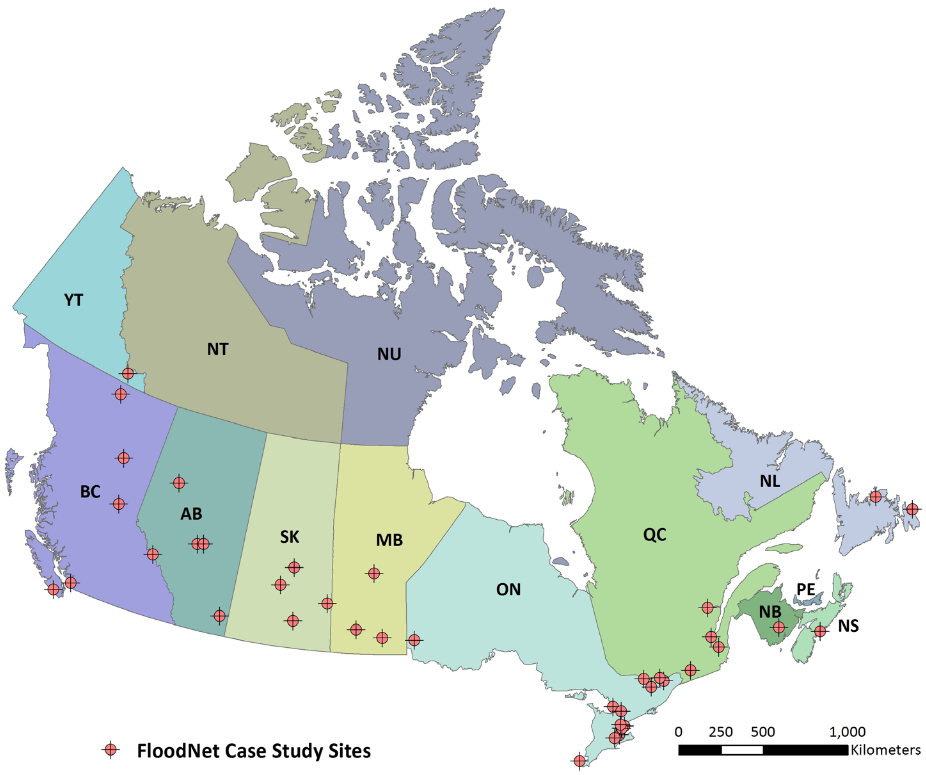
Volume 2 - June 2017

A vehicle for a concerted nation-wide effort to enhance flood forecasting and management capacity in Canada

Researchers and partners have been very active since the release of the last volume of *flash* **FloodNet**. Recent flooding in many parts of the country have reinforced the important need for the work being completed within this network all across Canada. The map below shows all of the FloodNet study sites and indicates just how far reaching the FloodNet research program really is. Some of this work is highlighted in this volume of *flash* **FloodNet**.

Highlights from this issue include a National Flood Risk Assessment Framework; recent findings related to the impacts of climate change on flood events; articles on model development; methods for frequency analysis and an assessment of the economic value of flood forecasting.

This year the FloodNet community also lost a dear friend and colleague with the passing of Professor Peter Rasmussen. On Page 11 we share the tributes presented on behalf of the FloodNet community at the celebration of his life.



Topography and Nightlight-Based National Flood Risk Assessment

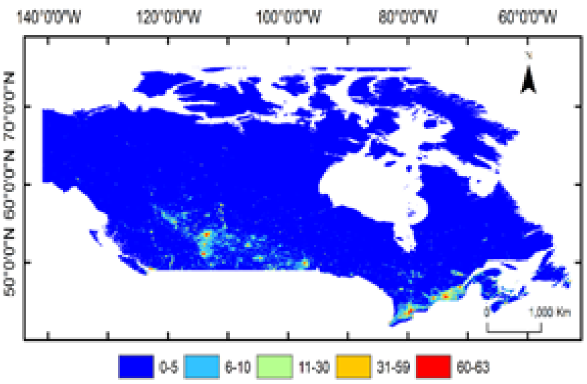
Bharath Raja & Amin Elshorbagy

Research Summary

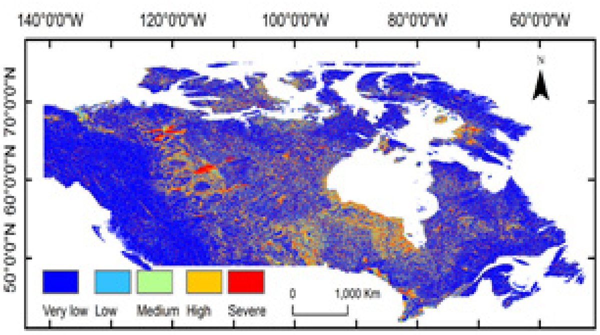
In Canada, floods are a costly natural hazard and have caused over $7 billion in damages over the recent five years (2010-2015). Flood analysis and water resource management in Canada are tasks conducted at the provincial level; therefore, unified national-scale approaches to water-related problems are uncommon. In one of our FloodNet research studies, a national-scale flood risk assessment approach for Canada is proposed and developed by integrating several and relevant sources of information to develop a flood risk assessment approach with affordable computational cost and data requirements. It leads to national flood hazard and risk maps that benefit from topographic information, remotely sensed nightlight data and, as an option, local information. For this purpose, parameters representing the concepts of hazard and exposure were identified and subsequently, a flood risk index was developed based on the integration of both hazard and exposure. Flood hazard was estimated using two parameters: elevation above the nearest drainage (EAND) and distance from the nearest drainage (DFND) that were derived from a digital elevation model (DEM). Flood exposure was estimated using Nightlight satellite imagery as a proxy for human activities, and a land-use map for Canada. The hazard and exposure parameters were reclassified into 5 classes based on their importance and finally, flood risk was calculated as the product of hazard and exposure.

The approach is practical and reliable for large scale flood risk analysis over Canada. The flood hazard map, when compared with existing flood extent map for the city of Calgary, was found to be in close agreement with flood maps produced using detailed hydraulic modeling. The nightlight data are useful proxy for exposure and risk mapping in Canada. It is also demonstrated that the flood risk map can be updated by incorporating local information (e.g. population density) to arrive at "socioeconomic" flood risk map. Such maps are useful products as they allow for evaluating the spatial distribution of the expected flood damage, and thus, can help in prioritizing government intervention and strategic resource allocation.

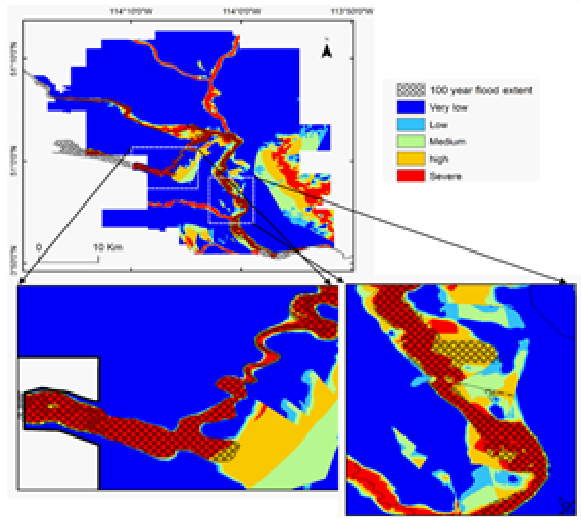
Classified Nightlight Luminosity



Flood Hazard Map



Calgary 100yr Flood Extent (Hatched) Compared to Present Flood Hazard Map



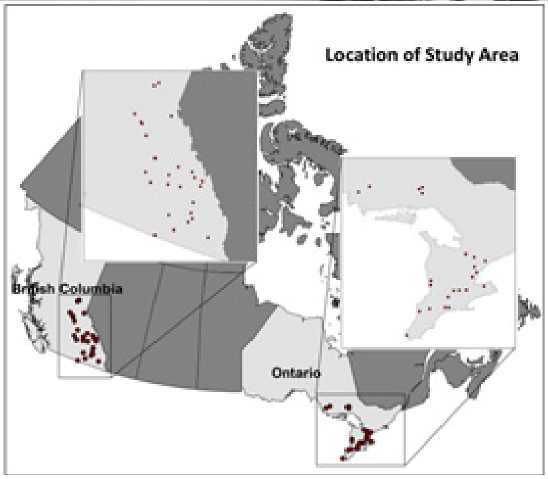
Elshorbagy, A., Lakhanpal, A., Raja, B., Ceola, S., Montanari, A., and Lindenschmidt, K.-E. (In Review) Topography-and nightlight-based national flood risk assessment in Canada. Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-524.

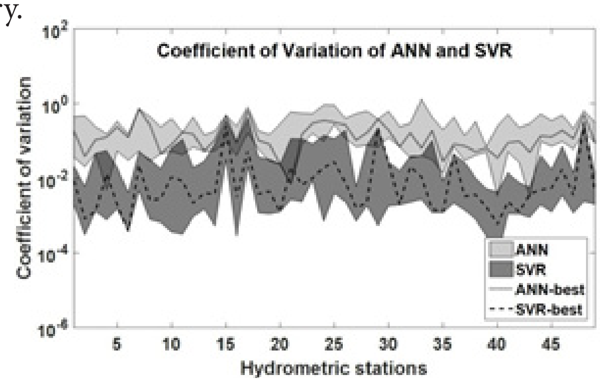
Possible Impact of Climate Change on Future Extreme Precipitation Events of Southern Alberta

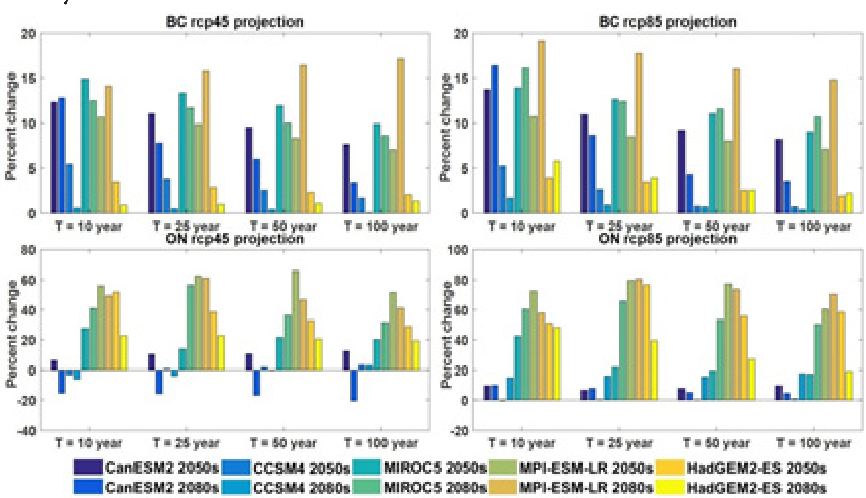
Mesgana Gizaw & Thian Yew Gan

Research Summary

Regional Flood Frequency Analysis (RFFA) are statistical methods that are widely used to estimate flood quantiles of catchments with limited streamflow data. In addition, sometimes only a limited number of stations with complete dataset are available from hydrologically similar, surrounding catchments to estimate the flood quantile of certain ungauged sites. Besides traditional regression based RFFA methods, recent applications of machine learning algorithms such as the artificial neural network (ANN) have shown encouraging results in regional flood quantile estimations. In this study, another novel machine learning technique, Support Vector Regression (SVR), was used to develop an RFFA model to estimate regional flood quantiles for two study areas, one with 26 catchments located in southeastern British Columbia (BC) and another with 23 catchments located in southern Ontario (ON), Canada. The SVR-RFFA model for both study sites was developed from 13 sets of physiographic and climatic predictors for the historical period. The Ef (Nash Sutcliffe coefficient) and R2 of the SVR-RFFA model was about 0.7 when estimating flood quantiles of 10, 25, 50 and 100 year return periods which indicate satisfactory model performance in both study areas. With a fairly limited amount of data available to train the RFFA models, the SVR-RFFA model was also found to perform better than an ANN based RFFA model, and with significantly lower median CV (coefficient of variation) of the estimated flood quantiles. The SVR-RFFA model was then used to project changes in flood quantiles over the two study areas under the impact of climate change using the RCP4.5 and RCP8.5 climate projections of five CMIP5 GCMs (Global Climate Models) for the 2041-2100 period. The results suggest that due to an increase in the mean annual precipitation, and rainfall of a given return period, the flood quantile is projected to increase by about 7% for the southeastern BC and 29% for southern ON region in the mid- and late 21st century.







Gizaw, M., & Gan, T.Y., 2016, Regional Flood Frequency Analysis using Support Vector Regression Under Historical and Future Climate, J. Hydrology, DOI: 10.1016/j.jhydrol.2016.04.041

Simulating Flood Hydrology with the Raven Modelling Framework

James R. Craig, Bryan Tolson, Hongli Liu, Juliane Mai, & Rob Chlumsky

Research Summary

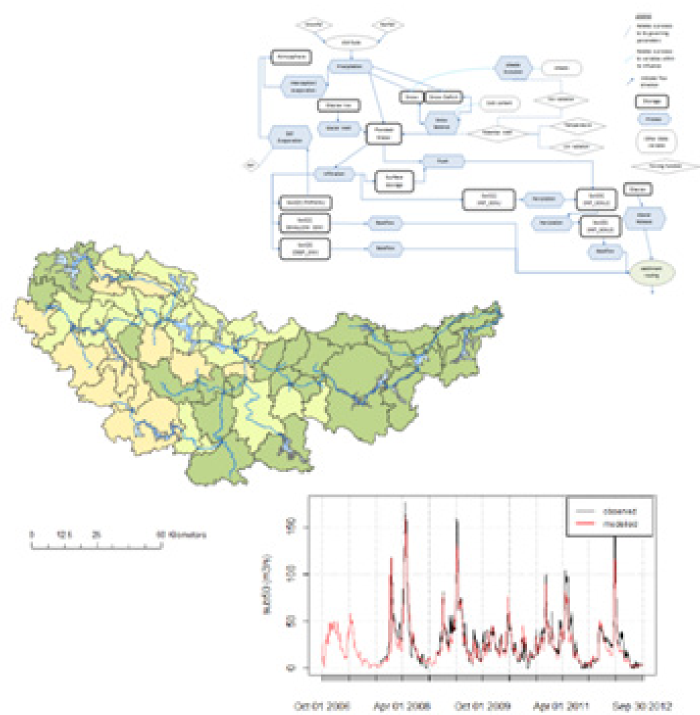
Researchers in the Department of Civil and Environmental Engineering at the University of Waterloo have been working for the past eight years on the development of the software tool Raven. Not just another hydrologic model, Raven is rather a robust and flexible hydrological modelling framework which enables a variety of different model configurations to be built and/or emulated. It was designed for application to challenging hydrological problems in academia and practice. This fully object-oriented and open source code provides complete flexibility in spatial discretization, interpolation, hydrological process representation, routing, and forcing function generation. Models built with Raven can be as simple as a single watershed lumped model (with only a handful of inputs required) to a full semi-distributed system model with physically-based treatment of infiltration, evapotranspiration, snowmelt, and routing. It also readily plugs into time series databases (including Kisters WISKI and Deltares FEWS), forecasting, and GIS applications and can emulate and augment a number of existing hydrologic models, including the UBC Watershed model, HBV-EC, and GR4J. Because of these traits, it is currently being used by (e.g.) BC Hydro and TransAlta for reservoir inflow forecasting, and by New Brunswick's Ministry of Environment for water resources planning. For FloodNet, it is being applied to watersheds managed by Ontario Power Generation and the Lake of the Woods control board.

Raven is useful in FloodNet applications because it is fast enough to deploy for ensemble forecasting, rigorous sensitivity analysis or calibration, but also has a number of features that support forecasting in challenging environments. For instance, it allows for the specification of time-dependent reservoir operation rules, supports time-variable land use, handles daily and sub-daily time-stepping, and calculates and reports more than a dozen different model quality diagnostics for any observation data supplied.

Other useful features:

- A generic discretization approach which supports lumped or semi-distributed models on a regular grid or irregular basin network
- Over 80 hydrological process algorithms and 40 forcing function generators can be applied and easily swapped out as better data becomes available
- Ability to override any model state variable for data assimilation
- Complete control over generated output; able to produce spatially and temporally aggregated reports on any state variable, forcing function, or flux in the model
- Platform independent: runs on Windows/Linux/Mac and readily compiles on SharcNet

With partial support from FloodNet, we are currently working to improve Raven support for both gridded CaPa products developed by Environment Canada and any other netCDF-compatible model forcings. We are also deploying the tool in flood forecasting mode with improved data uncertainty handling in hydrologic model calibration and data assimilation.



Raven Download: www.civil.uwaterloo/jrcraig/Raven/Main.html

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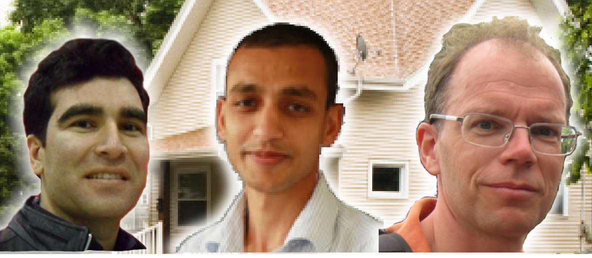
Challenges and Model Limitations in Predicting Streamflow in the Canadian Prairie Region

Ameer Muhammad, Sanjeev Jha, & Peter Rasmussen

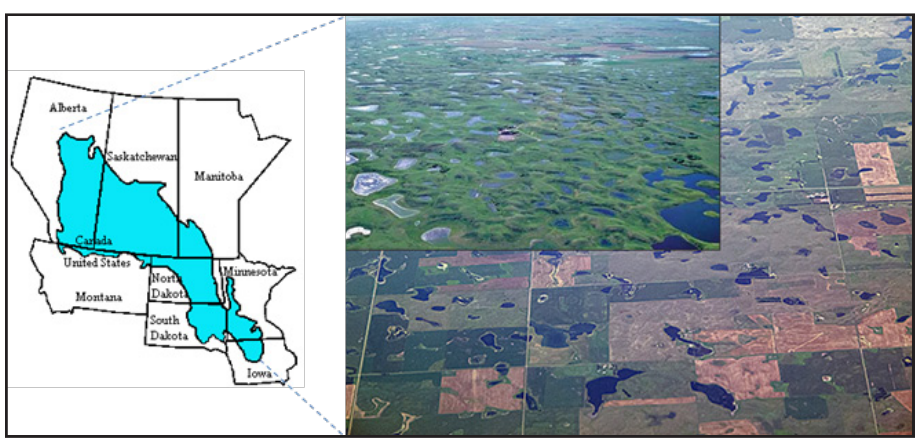


Research Summary

Under Project 3.1 an article discussing the current flood forecast systems across Canada was published in Vol. 1 of Flash FloodNet, where a number of challenges were highlighted. One challenge is to develop better hydrologic models for the prairie region. A common problem of Prairie hydrology is how to better include the impact of potholes in hydrologic models. Prairie hydrology (see Fig.) has been studied for many decades, so it is well established that surface runoff in prairie regions often drains into depressions, forming wetlands or potholes. These depressions are closed basins which retain water for longer periods and do not contribute flow to the stream under normal conditions. During times of high runoff, the storage capacity of many depressions can be exceeded, causing a fill-and-spill process to occur. Once the depressions are filled, the overflow water connects them and starts to flow to the stream. Consequently, temporary streams can form, resulting in a dynamic increase in the contributing area for runoff. At some point, the movement of water stops, causing a break in the interconnection of wetlands, and consequently reducing the contributing area. The dynamic nature of these isolated potholes makes hydrological processes of the prairie region difficult to quantify.

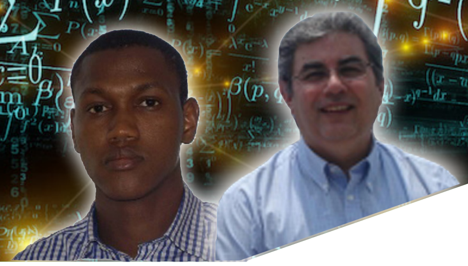
Relatively few studies have examined the impact of potholes on the hydrology of a watershed. The FFC of Manitoba has employed and tested a combination of hydrologic models to better depict the presence of potholes and the fill-and-spill process of potholes. However, in most cases, either a lumped concept of wetlands was adopted or the fill-and-spill of the potholes was missing.

The potential benefit of wetlands, their disappearance, and the limited number of catchment-scale studies on potholes have resulted in a pressing need for further research on the impact of potholes on the hydrology of the Prairie region. Partly due to the interest of FloodNet partners (Manitoba and Saskatchewan forecasting centres), this study aims to develop the SWAT model for the Upper Assiniboine River basin at Kamsack, a basin that is dominated by potholes. SWAT is a physically-based and semi-distributed model that has routines for wetland, pond, reservoir and potholes. We modified the potholes representation of the SWAT model at the Hydrologic Response Unit (HRU) level to attempt to capture the dynamics of the contributing and non-contributing areas caused by the fill-and-spill of potholes. We then calibrated the modified model at a daily time scale using the Sequential Uncertainty Fitting v.2 package. The performance of the model showed a maximum KGE of 0.78 and 0.80 in the calibration and verification process, with an acceptable range of uncertainty. We observed a significant improvement in replicating stream flow using this novel approach and foresee that it will effectively improve the predictive power of SWAT for this highly complex study. Hydrologic modelling of prairie potholes is a common problem both in Canada and the US. To bring expertise and to test various techniques on Canadian prairie watersheds, this project is undertaken in close collaboration with Dr. Grey Evenson (Environmental Protection Agency, US). The knowledge gained through our model development will not only help FFCs in Canada but would also help centres south of the border.



Discriminating Between Probability Distributions for Frequency Analsysis

Ismaila Ba & Fahim Ashkar



Research Summary

When hydrologists fit several candidate frequency models to a data set, the selection of a final fitting model often reduces to having to choose, or "discriminate", between a specific pair of competitive models (e.g., M1 and M2). In the peaks-over-threshold (POT) approach to the modeling of hydrological extremes, two-parameter probability distributions are typically very useful. One focus of our research is to evaluate and compare some widely used discrimination statistics (DS) in terms of their ability to correctly select between pairs of competitive 2-parameter distributions employed in a hydrological frequency modeling. Another research focus is attempting to classify frequency model pairs according to how difficult it is to discriminate between them.

Statistical research has shown some DS to have better capacity than others for the correct selection between competitive pairs of 2-parameter models. These discrimination statistics include:

1. the classical ratio of maximized likelihood (RML) statistic, which is closely associated with the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC);
2. the widely used Anderson-Darling (AD) goodness-of-fit (GoF) statistic;
3. a relatively new DS denoted by "TN.SW" that our team has introduced and studied, which is derived from the Shapiro-Wilk (SW) statistic used in GoF testing of the normal distribution;
4. another new DS denoted by "TN.PPCC" that is derived from the probability plot correlation coefficient (PPCC) GoF statistic.

To choose between a pair of competing models M1 and M2 to fit a data set, the hydrologist obviously needs to employ the most powerful and least biased procedure possible. The "Probability of correct selection" (PCS) is a standard measure used to compare and choose between the different DS. Two distinct features characterize this PCS: (1) discrimination power (DP), and (2) discrimination absolute bias (DAB). Both of these features are analyzed in our research. We use extensive computer Monte Carlo (MC) techniques to compare the ability of the various DS for correct selection between competing models. While our focus is usually directed towards small to moderate sample sizes that are typically encountered in hydrology, some large-sample studies are also undertaken. Our studies have shown that TN.SW has some advantages that make it worth further consideration in future research.

A hypothetical example:

PCS results for various sample sizes. Discrimination is between a model M1 and two alternative models M2 and M3. Values of *PCS.mean*(a measure of discrimination power, DP) are outside the brackets; values of *PCS.abs.diff* (a measure of discrimination absolute bias, DAB) are within brackets. All reported values are in percentage, rounded to the nearest integer.

		Sample size *n*					
Alternative Distribution (ALT)	**Discrimination Statistic (DS)**	**10**	**20**	**40**	**60**	**80**	**100**
	RML	67(0)	77(0)	88(0)	93(0)	96(0)	97(0)
M2	TN.SW	67(2)	77.5(1)	88(0)	93(0)	96(0)	97(0)
	TN.PPCC	67(2)	77(2)	88(0)	93(0)	95.5(1)	97(0)
	RML	66.5(23)	76.5(15)	88(8)	93(4)	95.5(3)	97.5(1)
M3	TN.SW	67(4)	76.5(3)	87.5(1)	92.5(1)	95.5(1)	97.5(1)
	TN.PPCC	66.5(1)	76.5(1)	87(2)	92.5(3)	95(2)	97(2)

Ashkar, F. & Ba, I. (2016) Selection between the generalized Pareto and kappa distributions in peaks-over-threshold hydrologic frequency modeling. Hydrol. Sci. J. (in press)

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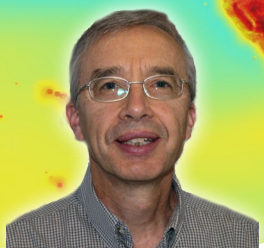
Identification of Changes in Flood Regimes in Canada Using a Peaks Over Threshold Approach

Don H. Burn



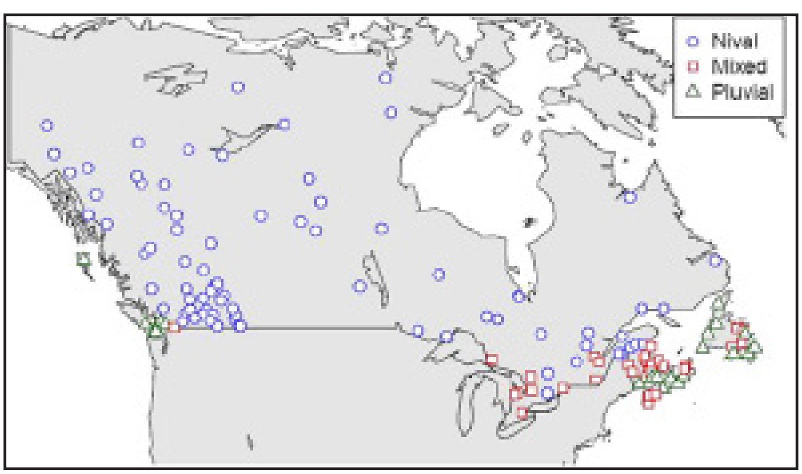
Research Summary

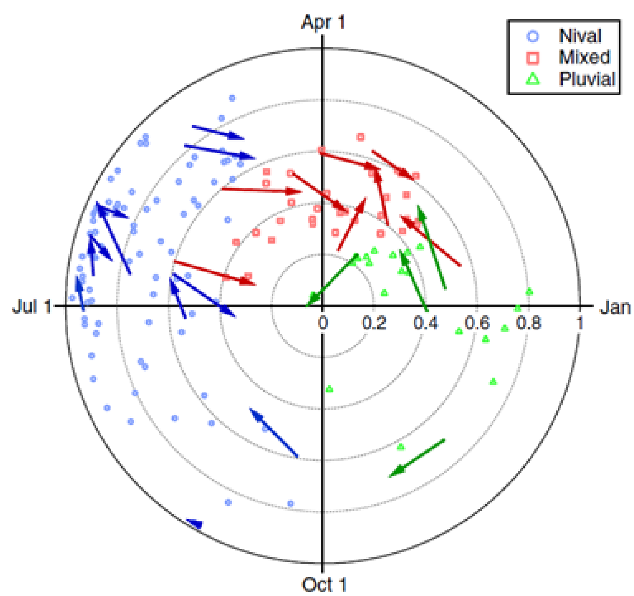
Recent flood events have led to speculation that changes in flood behaviour are occurring; these changes have often been attributed to climate change. This research, which is a part of Project 1-2, examines flood data for 132 gauging stations in Canada, all of which are part of the Canadian Reference Hydrometric Basin Network (RHBN). The RHBN stations are considered to have good quality data and were screened to avoid the influences of regulation, diversions, or land use change. Daily flow data for each watershed are used to derive a peaks over threshold (POT) dataset. Several measures of flood behaviour are examined based on the POT data. The changes in flood responses of the watersheds are summarized by grouping the watersheds by size (small, medium, and large) and also by hydrologic regime (nival, mixed and pluvial).

The results imply that changes have occurred to the flood regime in Canada, including:

1. smaller magnitude snowmelt events;
2. an increased number of over threshold events;
3. decreased importance of snowmelt events and increased importance of both rain on snow events and rainfall events;
4. a transition of nival catchments to a more mixed response; and
5. a transition of mixed flood regime to a more pluvial regime.

There are noticeable differences in trend response between the different hydrologic regimes (nival, mixed, or pluvial) but few differences related specifically to catchment size. There is also evidence of a shift in the flood regime in some catchments from nival to mixed to pluvial, reflecting a decreased importance of the spring freshet flood event. The observed changes in the flood regime, and changes expected to occur in the future, will require changes to flood management strategies in Canada.





Burn, D.H., Whitfield, P.H. & Sharif, M. (2016) Identification of changes in floods and flood regimes in Canada using a peaks over threshold approach, Hydrol. Process. DOI: 10.1002/hyp.10861.

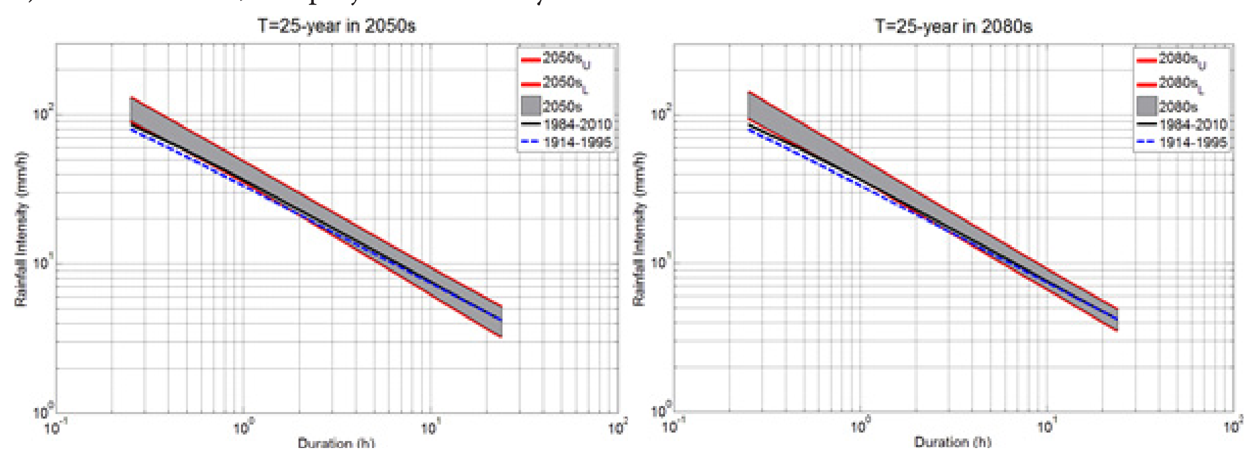
FloodNet NSERC

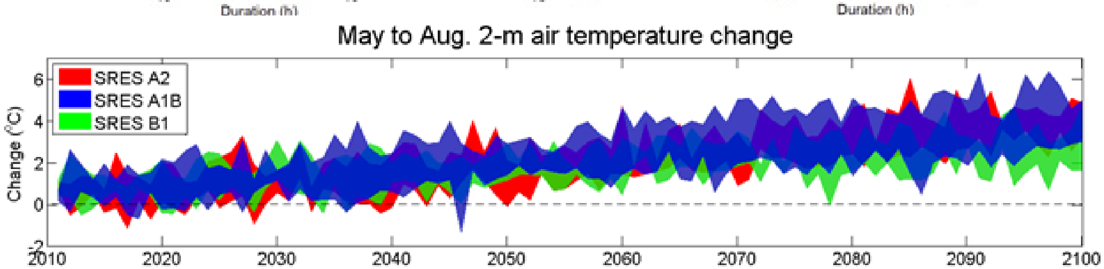
Potential Impact of Climate Change on Intensity Duration Frequency Curves of Central Alberta

Chun-Chao Kuo, Thian Yew Gan & Mesgana Gizaw

Research Summary

Under the effect of climate change, warming likely leads to more water vapour in the atmosphere and extreme storms are expected to occur more frequently and with greater severity, resulting in Intensity-Duration-Frequency (IDF) curves with higher intensities and shorter return periods. A regional climate model, MM5 (the Pennsylvania State University / National Center for Atmospheric Research numerical model), was set up in a one-way, three-domain nested framework to simulate future summer (May to August) precipitation of central Alberta. MM5 is forced with climate data of four Global Climate Models of CMIP3, for the baseline 1971–2000 and 2011–2100 based on the Special Report on Emissions Scenarios (SRES) A2, A1B, and B1 of Intergovernmental Panel on Climate Change. Based on projected IDF curves, it seems that future storms of central Alberta will gradually become more intensive, especially storms of short durations (≤1 hour). In some cases, the projected intensity for storms of short durations could increase up to 84.9 % in the 2080s. Further, for storms of low return periods (2 and 5-years), the projected intensities are consistently higher for all storm durations considered, and the projected increase ranges from 12.2 to 38.5 %. Return periods of short duration storms are projected to decrease in 2011–2100. However, return periods of future storms of moderate durations, e.g., 4-h, could either increase or decrease while that of long duration storms, e.g., 24-h, tends to increase. Overall, future IDF curves of central Alberta are expected to shift upward with a wide range of increased intensities because of increased air temperature and precipitable water which are projected to be about 2.9 °C and 29 % in average by 2071–2100, respectively. Our results imply that the impact of climate change could increase the future risk of flooding due to more frequent occurrences of more intensive storms of short durations in central Alberta.



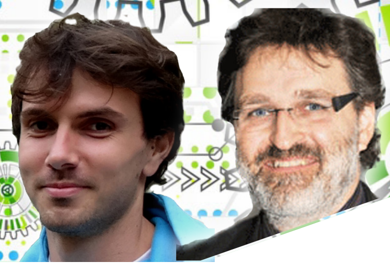


Kuo, C.C., Gan, T.Y., & Gizaw, M. (2015) Potential impact of climate change on Intensity-Duration-Frequency curves of Central Alberta, Climate Change, DOI:10.1007/s10584-015-1347-9.

FloodNet NSERC

Quantifying Uncertainties to Improve the Quality and Value of Flood Early Warning Systems

Antoine Thiboult & François Anctil



Research Summary

Floods are one of the most devastating natural disasters. Related socio-economic impacts are considerable and require adequate prevention measures. Traditionally, risk reduction is preferred over relief for economic and human considerations. Skillful Early Warning Systems (EWS) have the capability to offer flood prevention by issuing warnings up to several days before the flood event. Unfortunately, EWS are imperfect and will remain imperfect mainly because of the different sources of uncertainty that lies in the hydrometeorological modeling chain. A better quantification of uncertainties should improve the quality of the forecast and therefore should provide better decisions.

A comparison of six Early Warning Systems (EWS) based on contrasted hydrometeorological forecasting systems is performed to investigate how the quantification of uncertainties affects the quality of a decision. These hydrometeorological forecasting systems differ by the location of the sources of uncertainty, and the total amount of uncertainty they take into account. Generally, three sources of uncertainty are regarded as dominant: the hydrological initial conditions, the hydrological model structure and its parameters, and the meteorological forcing. These uncertainties have different natures and affect the quality of the hydrometeorological forecast in different ways and lead times. Therefore, one needs to resort to distinct methods to quantify and reduce them specifically. Three hydrometeorological tools are identified to improve forecast qualities: the Ensemble Kalman Filter (EnKF), a hydrological multimodel, and a meteorological ensemble forcing. The contribution of each tool to the overall forecast quality and value, and the way they complement each other is investigated.

The six systems are assessed with the Relative Economic Value (REV), which is a flexible measure to quantify the potential economic benefits of an EWS. The REV is computed for a wide range of cost-loss ratios, i.e. for various costs of mitigation and avoidable losses due to an adverse event. Therefore, numerous potential cases can be built upon this synthetic assessment.

Results show that all systems provide a gain over the case where no EWS is used up to 9 days ahead for most cost-loss ratios. The most complex systems, i.e. those that consider more sources of uncertainty in the forecasting process, are those that showed the most reduced expected damages. Each hydrometeorological tool contributes to improving the REV. Data assimilation acts mostly on shorter lead times, meteorological ensemble forcing on longer lead times, while the contribution of the hydrological multimodel approach appears constant throughout all horizons. The tools are complementary and should be used jointly to maximize the REV.

Like for the economic value, the use of hydrometeorological tools improves both forecast accuracy and reliability. Also, a preliminary investigation of a relationship between the quality and the value of a forecasting system revealed that, in general, better accuracy and reliability translate into higher economic values as measured by the REV. However, while the link was more clearly defined for the forecast accuracy attribute, the same was not observed for reliability. Our results showed that the relationship between the REV and reliability strongly depends on the system and on how reliability and ensemble spread vary with lead time.

Overall, these results suggest that a suitable quantification and reduction of uncertainties carried out by a set of appropriate hydrometeorological tools can contribute to mitigating flood losses and increase the economic value of a forecast system.

Wavelet Analysis of Precipitation Extremes Over Canadian Ecoregions and Teleconnections to Large-Scale Climate Anomalies

Xeuzhi Tan, Thian Yew Gan and D. Shao

Research Summary

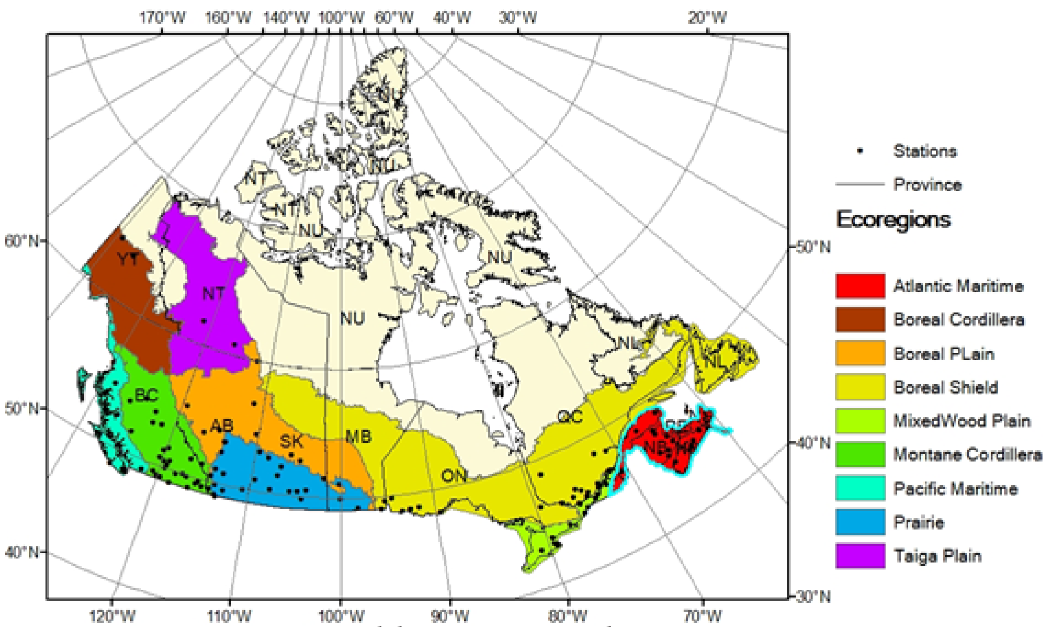


Fig. 1 131 precipitation stations and divisions over Canada

To detect significant interannual and interdecadal oscillations and their teleconnections to large-scale climate anomalies such as El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO) and the North Atlantic Oscillation (NAO), monthly and seasonal maximum daily precipitation (MMDP and SMDP) from 131 stations across Canada were analyzed using variants of wavelet analysis. Interannual (1-8 years) oscillations were found to be more significant than interdecadal (8-30 years) oscillations for all selected stations, and the oscillations are both spatial and time-dependent. Similarly, the significant wavelet coherence and the phase difference between leading principal components (PCs) of monthly precipitation extremes and climate indices were highly variable in time and in periodicity, and a single climate index explains less than 40% of the total variability. Partial wavelet coherence analysis shows that both ENSO and PDO modulated the interannual variability, and PDO modulated the interdecadal variability, of MMDP over Canada.

NAO is correlated with the western MMDP at interdecadal, and the eastern MMDP at interannual scales. Composite analysis shows that precipitation extremes at about 3/4 of the stations have been significantly influenced by ENSO and PDO patterns, while about 1/2 of the stations by the NAO patterns. The magnitude of SMDP in extreme El Niño years, and extreme PDO event of positive phase, was mostly lower (higher) over the CP region in summer and winter (spring and autumn) than in extreme La Niña years. Overall, the degree of influence of large-scale climate patterns on Canadian precipitation extremes varies by season and by region.

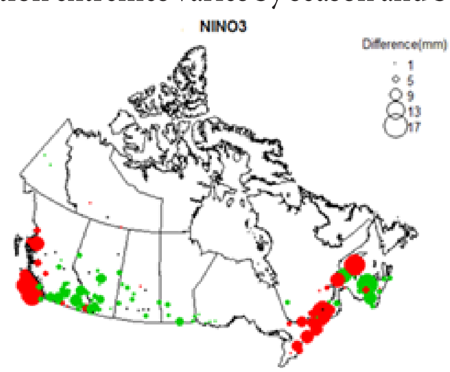


Fig. 2 Composite differences in winter maximum daily precipitation (WMDP) averaged over 5 years with the lowest and the highest NINO3 values, respectively. Red and green dots indicate stations whose WMDP is statistically significantly influenced by NINO3 positively and negatively, respectively

Tan, X., Gan, T.Y., & Shao, D. (2016) Wavelet analysis of precipitation extremes over Canadian ecoregions and teleconnections to large-scale climate anomalies, Journal of Geophysical Research-Atmospheres (doi:10.1002/2016JD025533)

State-of-the-Art in Bayesian Flood Forecasting

Shasha Han & Paulin Coulibaly

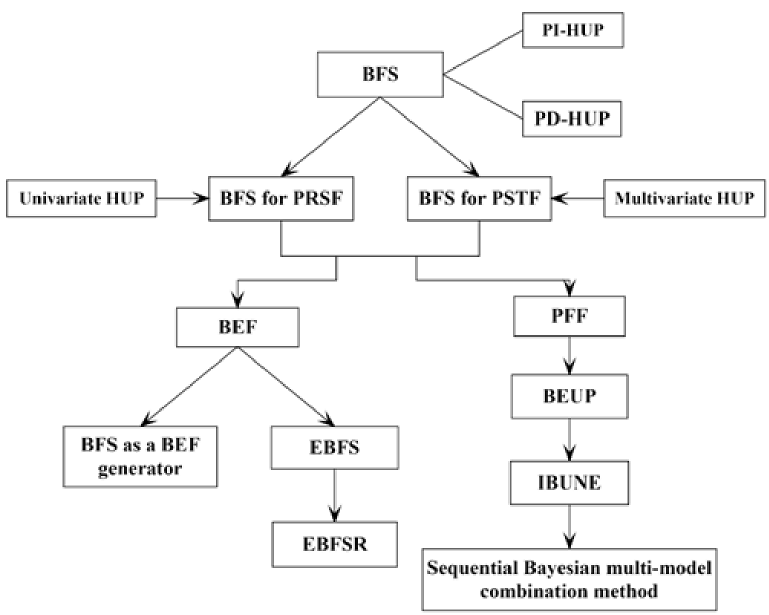
Research Summary

It is widely believed that accurate uncertainty estimation associated with flood forecast is of great importance for rational decision making. Among the predictive uncertainty quantification approaches suited for flood forecasting, Bayesian Forecasting System (BFS) provides an ideal theoretic framework that could be used for probabilistic flood forecast through any deterministic hydrologic model. Since the BFS method was first introduced in 1999, it has been developed into various advanced versions to meet different requirements (see Fig. 1). A comprehensive literature review on Bayesian flood forecasting approaches and comparison between all the predictive uncertainty assessment methods in flood forecasting were performed.

Results show that Bayesian flood forecasting approaches are effective and robust for flood forecast with uncertainty estimation, they consider all sources of uncertainties, including precipitation input uncertainty, model parameter uncertainty, model structure uncertainty, and so on. Given all the available information, the prior distribution is updated to posterior distribution which is more close to the real value. Instead of giving just a single value of estimate, they produce predictive distribution which contains information about uncertainty. It was found that by incorporating Bayesian method with ensemble technique or multi-model combination, it can overcome limitations of single model and fixed model weight, and sometimes could reduce predictive uncertainty. In addition to the Bayesian forecasting methods, there are other uncertainty assessment approaches in flood forecasting application, from the theoretical base, all the approaches can be classified into 5 categories: (1) model error analytical methods; (2) ensemble based techniques; (3) Bayesian methods; (4) data assimilation methods; (5) machine learning techniques. Each of them has pros and cons, the choice of a method depends on the available data and the research purpose.

Although the Bayesian flood forecasting approaches have shown some promising potential, significant work is still needed to provide a BFS that can be applicable to various watersheds and with more complex hydrologic models including the use of ensemble weather forecasts.

Abbreviation	Expansion
BFS	Bayesian forecasting system
PI-HUP	precip-independent hydrologic uncertainty processor
PD-HUP	precip-dependent hydrologic uncertainty processor
PRSF	probabilistic river stage forecast
PSTF	probabilistic stage transition forecast
BEF	Bayesian ensemble forecast
EBFS	ensemble Bayesian forecasting system
EBFSR	EBFS with randomization
PFF	probabilistic flood forecast
BEUP	Bayesian ensemble uncertainty processor
IBUNE	integrated Bayesian uncertainty estimator



Han, S. & Coulibaly, P. (2017) Bayesian Flood Forecasting Methods: A Review, Journal of Hydrology. doi: 10.1016/j.jhydrol.2017.06.004.

Dual-Entropy Multi-Objective Optimization (DEMO): An Introduction

Kurt C. Kornelsen, Jongho Keum, James Leach, Connor Werstuck & Paulin Coulibaly

Research Summary

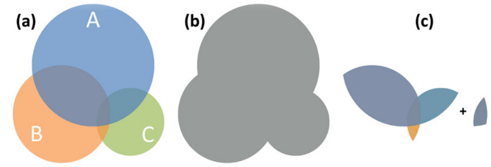


Figure 1

The design of hydrometric monitoring networks is a challenging and critical task for water resource managers. In practice the location of many hydrometric monitoring stations are placed based on ad-hoc approaches or assessments. The goal of Dual-Entropy Multi-Objective Optimization (DEMO) is to provide managers scientifically sound support for locating new monitoring stations that will optimally compliment the existing network. The key advantages of DEMO are:

1) it takes into consideration the information provided by the entire network, or proposed network, rather than considering stations individually;

2) it explicitly considers non-linear interactions.

DEMO accomplishes these two goals using an Information Theory or Entropy approach to the optimization problem. Figure 1 shows a hypothetical network with three stations (A, B, C). The information content from each of the three individual monitoring stations is represented in the Venn diagram in a) and is considered to the entropy or information content of the station. The stations are in a similar study area and so capture some similar information, represented by the overlap in a). The total information (joint entropy) of all three stations is shown in b) and in selecting stations we should seek to maximize this total amount of information. However, there is also a degree of overlap between all of these stations and this information can be considered a redundant and not beneficial to a monitoring network. The redundant information or total correlation can be seen in c). These information measures (as well as other metrics) are combined with the ε-hBOA genetic algorithm (GA) to create DEMO.

The method works by providing DEMO data for every currently existing and potential station in a hydrometric network. The GA is then used to select a series of potential network designs (population) that containt the maximum amount of information (joint entropy) while simulatneously minimizing the overlap in information (total correlation). The 'heat-map' in Fig. 2 shows locations that were most likely to be selected in an optimum network in an application in the Columbia River basin. DEMO has been applied to design streamflow, precipitation, snow and soil moisture networks in several basins across Canada using data from models, observation stations and satellites.

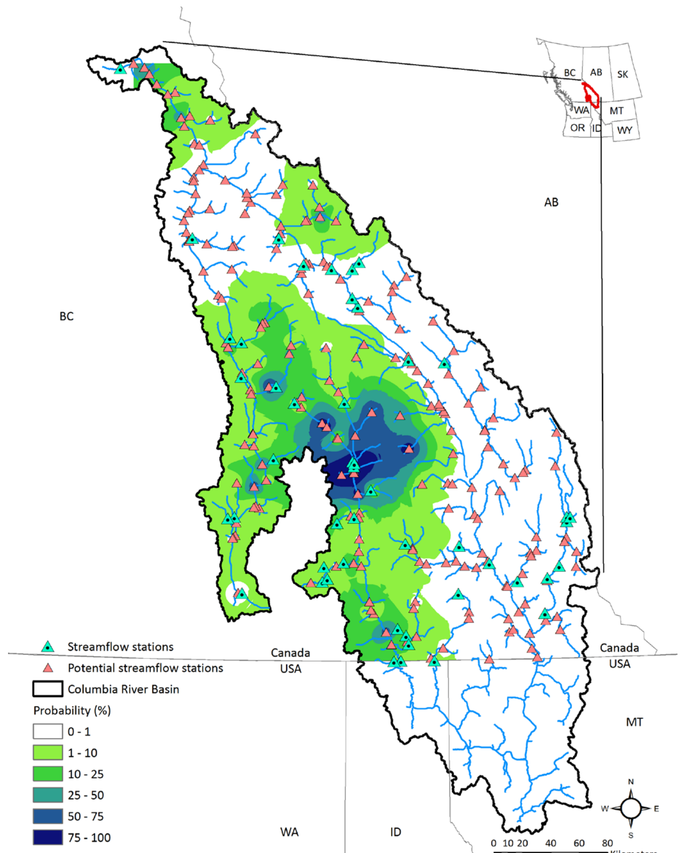
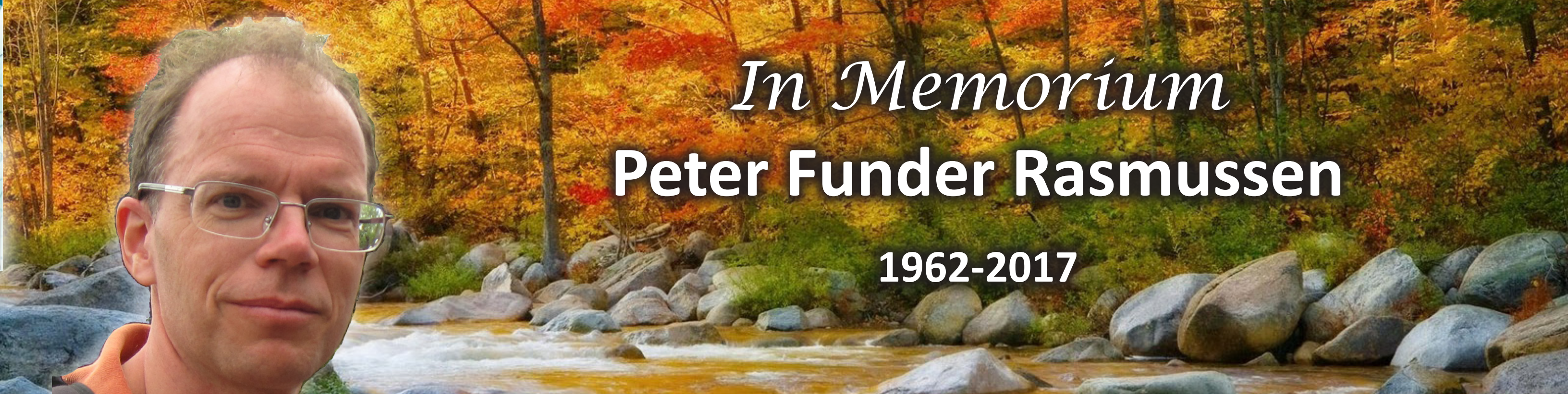


Figure 2: Heat-map from DEMO design of a streamflow newtwork in theColumbia River Basin

Details and references to various peer-reviewed journal articles that explore and make use of DEMO can be found at www.hydrology.mcmaster.ca



In Memorium

Peter Funder Rasmussen

1962-2017

It was a unique opportunity for us to have Peter on the FloodNet team from its inception to the actual research work. This was an amazing and memorable journey! His deep and high level of thinking about what we should focus on, why and how, was critical to the success of the FloodNet proposal.

Working with Peter was a unique privilege but a costly privilege! Why? You have to be prepared for tidiness, precision, deep thinking… then ask yourself, is this sound enough? If not, start over again with a good smile!

Some of us who attended the 2015 Hydrotechnical Conference in Montreal, still very much vividly remember Peter's talk on the State of Flood Forecasting in Canada. He was really trying to make a funny point that forecasting is not a job that you want because no one is ever happy with your projections and you better not miss the big one! This led him into the importance of improving our flood forecasting models.

Another colleague's anecdote with Peter is worth mentioning. He always remembers Peter whenever he hears these two words "Bayesian forecasting". In a presentation where our colleague spent fifteen minutes explaining why he wants to investigate Bayesian forecasting, the first question came from Peter. I quote "Nice presentation, but why are you investigating this Bayesian forecasting? The room was full of laughs and our colleague was totally confused. Peter was not convinced by his rationale, he needed more.

Peter always pushed the frontiers in his research and helped us to do so! Simply knowing that Peter is in the room, makes you think twice about what to say.

High quality work in relaxing and joyful atmosphere was the wonderful experience we enjoyed with Peter!

He will be missed by all of us in this research network.

Delivered by Amin Elshorbagy at Peter's Celebration of Life on behalf of FloodNet Researchers.

My name is Zara, one of Peter's post-doctoral fellows under FloodNet.

I am here today on behalf of the FloodNet students and post-docs and myself, to provide a hint of our work and life experience with Peter. It is unrealistic to pretend to provide even a simple picture in such few minutes!

In very few words, what we will never forget in our lives, is the unique character of Peter in his person to person relationship! He was a deeply carrying, generous, excellent supervisor. Always there to help, to guide, to encourage, to share his knowledge, all with such a smooth and relaxing attitude.

Meeting and chatting with Peter, learning from him, are pleasant moments that will be part of our lives' memories.

In a personal note, I still vividly remember what he once said at one of our meetings, I quote:

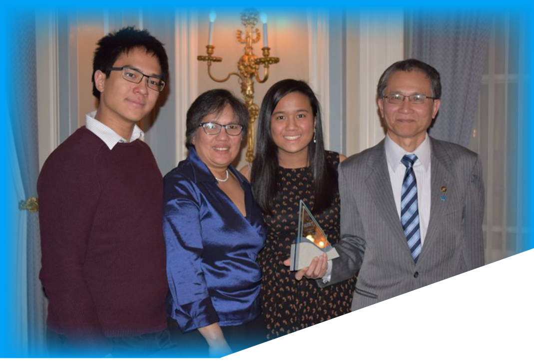
"The good things of life don't come to you, you have to seek them, go enjoy the beautiful fall in Canada, with the maple trees turning bright red".

All the students and post-docs who had the opportunity to work with Peter, are impressed by the depth and extend of his technical knowledge and skills, his unique character.

He was an excellent mentor, a guide, a friend. Peter will be remembered in all lives touched by him over the years!

Delivered by Zahra Zahmatkesh Aliabadi at Peter's Celebration of Life on behalf of FloodNet students and post-docs.

The Peter Funder Rasmussen Fellowship in Civil Engineering has been setup in Peter's Honour. Please consider donating to the fellowship at https://tinyurl.com/ya683xme.



Publications & Recent Events

Congratulations!

Congratulations to Dr. Thian Yew Gan of the University of Alberta who on March 31 was awarded the Association of Science and Engineering Technology Professionals of Alberta (ASET) Technical Excellence Award.

The FloodNet Administration Office endeavours to keep an accurate and up to date record of all recent publications, conferences and events. We want to promote your work and help you share your successes but we can't do it without you. Whenever you present at a conference please send a copy of your slides/poster (in pdf format) to us to post on our website. Similarly we are archiving any publications that arise from FloodNet research and will link to the publishers website. Lastly, we want to share your success with the network, so please inform us of any promotions, successful defences, awards or whatever else deserves celebrating. All information can be sent to floodnet @ mcmaster.ca.

Recent Publications

Liu, H., Tolson, B. A., Craig, J. R. and Shafii, M. (2016). A priori discretization error metrics for distributed hydrologic modeling applications. Journal of Hydrology (Accepted), doi:10.1016/j.jhydrol.2016.11.008.

Nguyen, V-T-V. & Nguyen, T-H. (2016). Statistical modeling of extreme rainfall processes (SMExRain): A decision support tool for extreme rainfall frequency analyses. Procedia Engineering, DOI:10.1016/j.proeng.2016.07.561, Vol. 154: 624-630.

Pina J., Tilmant, A. & Anctil, F. (2016). Horizontal approach to assess the impact of climate change on water resources systems. Journal of Water Resources Planning and Management 10.1061/(ASCE)WR.1943-5452.0000737 , 04016081.

Rahimi Malekshan, K., Zhuang, W. & Lostanlen, Y. (2016). Coordination-based medium access control with space-reservation for wireless ad hoc network. IEEE Transactions on Wireless Communications. 15(2), 1617-1628.

Razavi, T., Switzman, H., Arain, A., Coulibaly, P. (2016). Regional Climate Change Trends and Uncertainty Analysis Using Extreme Indices: A Case Study of Hamilton, Canada. Climate Risk Management, doi : 10.1016/j.crm.2016.06.002.

Song, W. & Zhuang, W. (2016). Packet assignment under resource constraints with D2D communications. IEEE Network, 30(5), 54-60.

Tan, X., Gan, T. Y., & Shao, D. (2016) Wavelet analysis of precipitation extremes over Canadian ecoregions and teleconnections to large-scale climate anomalies. Journal of Geophysical Research-Atmosphere, 121, doi:10.1002/2016JD025533.

Thiboult A., Anctil F. & Boucher M.A. (2016). Accounting for three sources of uncertainty in ensemble hydrological forecasting. Hydrology and Earth System Sciences 20, 1809-1825.

Wazneh, H., Arain, A. & Coulibaly, P. (2016). Historical spatial and temporal climate trends in southern Ontario. Journal of Applied Meteorology and Climatology (Accepted).

Werstuck, C.A., Coulibaly, P. (2016). Hydrometric Network Design Using Dual Entropy Multi-Objective Optimization in the Ottawa River Basin. Hydrology Research, DOI: 10.2166/nh.2016.344. (In Press).

Ye, Q. & Zhuang W. (2016). Distributed and adaptive medium access control for Internet-of-Things-enabled mobile networks. IEEE Internet of Things Journal, DOI: 10.1109/JIOT.2016.2566659

Zhou, Y. & Zhuang, W. (2016) Performance analysis of cooperative communication in decentralized wireless networks with unsaturated traffic. IEEE Transactions on Wireless Communications. 15(15), 3518–3530.

Please consider contributing to a future issue of
flash **FloodNet**.

We encourage submissions from both researchers and partners on a variety of topics including research summaries, recent advances or methodologies, sharing of best practices in the community or commentaries.

FloodNet NSERC

CaSPAr

Canadian Surface Prediction Archive

Users submit data requests to CaSPAr via the Portal for ArcGIS web-interface or RESTful API.

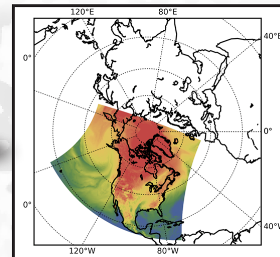
The Portal submits a request to the Compute Canada cluster selects, sub-sets and processes the user requested NWP dataset. The portal notifies the user their data is ready for pickup!

User Community

Front End Portal

esri Portal for ArcGIS

Back-End-Server



globus

GitHub

A common data format allows users to interact and share CaSPAr related codes via the GitHub community to greatly expand the utility of CaSPAr.

Users download their requested data using the cloud-based Globus big-data transfer service web-interface or API.

PRODUCTS

- Global Deterministic and Ensemble Weather Predictions
- Regional (North American) Deterministic and Ensemble Weather Predictions
- High Resolution (Canada) Deterministic Weather Predictions
- Canadian Land Data Assimilation System Analyses
- Canadian Precipitation Analysis

University of Waterloo

McMaster University

Université Laval

Environment and Climate Change Canada

esri Canada

compute canada | calcul canada

School of Geography and Earth Sciences

NSERC CRSNG

CaSPAr

Canadian Surface Prediction Archive

Providing foundational knowledge and data infrastructure to link numerical weather prediction to environmental applications!

Coming Soon!

Development primarily supported through the NSERC Canadian FloodNet. CaSPAr is a community supported accessible web-platform to archive, process and make available Canadian numerical weather prediction model data to the end-user community.

FloodNet
NSERC

CaSPAr TEAM

Bryan Tolson
Juliane Mai
Kurt C. Kornelsen
Vincent Fortin
François Anctil
Paulin Coulibaly
Michael Leahy
Brent Hall

University of Waterloo
McMaster University
Université Laval
Environment and Climate Change Canada
esri Canada
compute canada | calcul canada
School of Geography and Earth Sciences
NSERC CRSNG