DAY ONE - JUNE 18, 2018	
8:00 - 8:30	**Breakfast & Registration – GRAND SALON**
Welcome 8:30 – 9:00	**Introduction & Network Update** *Dr. Coulibaly & Dr. Roy*
SESSION 1: THEME 3 - DEVELOPMENT OF CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) *CHAIRS: Dr. Coulibaly & Dr. Stadnyk*	
Project 3 – 1 9:00 - 9:30	Evaluation of Flood Forecasting and Warning Systems Across Canada. *T. Stadnyk & A. Muhammad*
Project 3 – 2 9:30 - 10:00	Real-time Spatial Information Evaluation and Processing *A. Berg & R. Pardo*
Project 3 – 3 10:00 - 10:30	Enhanced Information Communication Systems *W. Song & H. Moussa*
10:30 - 11:00	**COFFEE**
Project 3 – 4 11:00 - 11:30	Development of Canadian Flood Forecasting and Early Warning System (CAFFEWS) *P. Coulibaly, J. Leach & J. Keum*
SESSION 2: THEME 2 - QUANTIFYING AND REDUCING THE PREDICTIVE UNCERTAINTY OF FLOODS *CHAIRS: Dr. Anctil & Dr. Tolson*	
Project 2 – 1 11:30 - 12:00	Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on a Single Model *B. Tolson, J. Mai & H. Liu*
Project 2 – 2 12:00 - 12:30	Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on Multiple Model *F. Anctil, J. Xu & C. Poncelet*
12:30 - 1:30	**LUNCH – Espace Jardin**
Project 2 – 4 1:30 - 2:00	Evaluation of Flood Warning Based on Hydraulic Models with Assimilation and Hydrological Ensemble Forecasts *F. Anctil & A. Bessar*
Project 2 – 5 2:00 - 2:30	Real-time Reservoir Operation Based on a Combination of Long-term and Short-term Optimization and Hydrological Ensemble Forecasts *A. Tilmant & H. N. Ashouri*
SESSION 3A: THEME 4 - RISK ANALYSIS OF PHYSICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF FLOODS *CHAIRS: Dr. Xenopoulos & Dr. Elshorbagy*	
Project 4 – 1 2:30 - 3:00	Role of Floods on Aquatic Ecosystem Condition *M. Xenopoulos, C. Fasching & S. D'Amario*
Project 4 – 3 3:00 - 3:30	Modelling-based Integrated Assessment on Flood Impacts on Urban and Rural Water Resources Systems *A. Elshorbagy & M. Ahmed*
3:30 - 4:00	**COFFEE**
Keynote Address 4:00 - 5:00	*A Numerical Fully-Coupled Atmospheric-Hydrologic Model-Based Real-time Rainfall and Flood Forecasting System for Three River Basins in Malaysia* *Dr. M Levent Kavvas*

POSTER SESSION - Atrium *CHAIRS: F. Awol, H. Wazneh & D. Wijayarathne*	
5:00 - 5:45	Poster Pitch
5:45 - 6:30	Poster Session
6:30 - 8:00	**Welcome & Networking Dinner**

DAY TWO - JUNE 19, 2018	
8:30 - 9:00	**BREAKFAST– Saveurs Campus**
SESSION 3B: THEME 4 - RISK ANALYSIS OF PHYSICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF FLOODS *CHAIRS: Dr. Xenopoulos & Dr. Elshorbagy*	
Project 4 – 4 9:00 - 9:30	Flood Risk Analysis and its Utility for Management Decisions *A. Elshorbagy & B. Raja*
Project 4 – 5 9:30 - 10:00	Assessing and Planning for the Socio-Economic Effects of Floods *N. Yiannakoulias & J. Gordon*
SESSION 4: THEME 1 - FLOOD REGIMES IN CANADA: LEARNING FROM THE PAST AND PREPARING FOR THE FUTURE *CHAIRS: Dr. Burn & Dr. Nguyen*	
Project 1 – 1 10:00 - 10:30	Update of Current Flood and Storm Quantiles *D. Burn, S.M. Zadeh & Z. Yang*
10:30 - 11:00	**COFFEE**
Project 1 – 2 11:00 - 11:30	Examination of Spatial and Temporal Variation of Extreme Events *F. Ashkar, B.B. Dieng & D. Burn*
Project 1 – 3 11:30 - 12:00	Analysis and Applicability of Future Extreme Events in Regional and Local Context *A. Arain, O. Champagne & M. Zhao*
Project 1 – 4 12:00 - 12:30	Development of New Methods for Updating IDF Curves in Canada *V.T.V. Nguyen, T.H. Nguyen & S. El Outayek*
12:30 - 1:30	**LUNCH – Espace Jardin**
Project 1 – 5 1:30 - 2:00	Spatial Changes to Flood Prone Areas in Urban Environments *Y. Guo, P. De Boer & Z. Zhang*
Project 1 – 6 2:00 - 2:30	Development of a New Flood Estimation Manual *D. Burn, M. Durocher & A. Requena*
SESSION 5: WORKING GROUPS & PANEL MEETING	
2:30 - 3:30	Working Group 2 & 3 Panel Discussion *F. Anctil, P. Coulibaly, R. Turcotte, D. Campbell, E. Welles*
3:30 - 4:00	**COFFEE**
4:00 - 4:30	Working Group 4 & Panel Discussion *A. Elshorbagy, A. Arain, N. Yiannakoulias, J. Frain, D. Chekol*
4:30 - 5:00	Working Group 1 Panel Discussion *D. Burn, V.T.V. Nguyen, K. Kornelsen, W. Ho*
6:30 – 9:00	**NETWORKING DINNER & FloodNet 2 Meeting @ Pub Universitaire**

DAY THREE - JUNE 20, 2018	
8:30 - 9:00	**BREAKFAST – Saveurs Campus**
8:30 - 9:30	Board of Directors Meeting (BOD)/Partner Advisory Committee (PAC) Meeting
SESSION 5: PARTNER & COLLABORATOR INVITED PRESENTATIONS *CHAIRS: J. Keum & Z. Zahmatkesh*	
Partner Presentation 9:00- 9:20	High-flow warnings based on the Water Cycle Prediction System for the Great Lakes and St. Lawrence River *D. Durnford*
Partner Presentation 9:20- 9:40	Projected Changes to the Frequency of High-Flows in the Athabasca Watershed: Sensitivity of Results to Statistical Methods of Analysis *Y. Dibike*
Partner Presentation 9:40- 10:00	Recent development in applied hydrology in Quebec aiming to support flood mitigation *R. Turcotte*
10:00 - 10:20	**COFFEE**
10:20 - 10:40	ISAP Feedback
Wrap-Up 10:40 – 11:00	Closing Remarks *Dr. Coulibaly & Dr. Roy*
11:00	**End of AGM**

POSTER SESSION *CHAIRS: F. Awol, H. Wazneh & D. Wijayarathne*	
Theme 1 Posters	
Author & Affiliation	***Title***
Mounada Gbadamassi[1] 1. Université de Moncton, Moncton, NB	Confidence Interval for quantiles of the Gumbel Distribution
Babacar B. Dieng[1] *& Fahim Ashkar*[1] 1. Université de Moncton, Moncton, NB	Two problems related to frequency analysis of flood flows in hydrology
Hussein Wazneh[1]*, Altaf Arain*[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON	Interdependence between temperature and precipitation in southern Ontario, Canada
Ziyang Zhang[1]*, Donald H. Burn*[2] *& Tricia Stadnyk*[1] 1. University of Manitoba, Winnipeg, MB 2. University of Waterloo, Waterloo, ON	Identification of a preferred statistical distribution model for at-site flood frequency analysis in Canada
Tianshuo Zhou[1] *& Donald H. Burn*[1] 1. University of Waterloo, Waterloo, ON	Exploring problematic sites from current developed regional flood frequency analysis for Canada
Chun-Chao Kuo[1]*, Thian Yew Gan*[1] *& Siyuan Liu*[1] 1. University of Alberta, Edmonton, AB	Risk of exceeding extreme design storm events under possible impact of climate change.
Pavneet Brar[1]*, Yiping Guo*[1] 1. McMaster University, Hamilton, ON	Incorporating Resilience in Urban Flood Control Systems

Theme 2 Posters	
Philippe Richard[1] 1. Université Laval, Québec, PQ	The added value of human expertise with an automated hydrological forecasting system
Emixi Sthefany Valdez Medina[1] 1. Université Laval, Québec, PQ	Exploring a statistical post-processing technique of ensemble precipitation forecast for operational hydrologic forecasting
Hajar Ashouri[1]*, Michael Osina*[1]*, Amaury Tilmant*[1]*, François Anctil*[1]*, Emixi Valdex*[1] *& Jasson Pina*[1] 1. Université Laval, Québec, PQ	Short-term Optimization of Reservoir Operation using Ensemble Streamflow Forecasts
Theme 3 Posters	
Xi Tao[1] 1. University of New Brunswick, Fredericton, NB	Efficient Task Allocation for Mobile Crowdsensing Based on Evolutionary Computing
Jobanmeet Kaur[1] 1. University of New Brunswick, Fredericton, NB	System Requirements for an efficient flood warning system
Frezer S. Awol[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON	Model setup for improved reservoir inflow forecast into Shelmouth Reservoir
Zahra Zahmatkesh[1]*, Dominique Tapsoba*[2]*, James Leach*[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON 2. IREQ, Varennes, QC	Evaluation and bias-correction of SNODAS SWE estimates for Canadian watersheds
Jetal Agnihotri[1]*, Tara Razavi*[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON	Identification of snowmelt estimation techniques to enhance spring peak flow prediction
Dayal Wijayarathne[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON	Evaluation of radar assimilated quantitative precipitation estimates for enhanced calibration of flood forecasting models
Shasha Han[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON	Application of Bayesian processor with bias corrected ensemble weather forecasts to assess and reduce uncertainty in flood forecasting
Pedram Darbandsari[1] *& Paulin Coulibaly*[1] 1. McMaster University, Hamilton, ON	Inter-comparison of the performance of lumped hydrological models in data poor watersheds
Theme 4 Posters	
Connor Darlington[1] *& Niko Yiannakoulias*[1] 1. McMaster University, Hamilton, ON	Sociodemographic Vulnerability to Flooding in Calgary, Hamilton and Winnipeg
Jun Wang[1] *& Yiping Guo*[1] 1. McMaster University, Hamilton, ON	Impacts of Land Use and Climate Change on the Drainage of the Davis Creek Subwatershed
Michele Tsang[1] *& Darren Scott*[1] 1. McMaster University, Hamilton, ON	Quantifying land use change using supervised classification in Calgary, Hamilton and Winnipeg
Ceara J. Talbot[1]*, Michael J. Paterson*[2] *& Marguerite A. Xenopoulos*[1] 1. Trent University, Peterborough, ON 2. IISD-ELA, Winnipeg, MB	Nutrient Budgets calculated in floodwaters using a whole-ecosystem experimental manipulation

FloodNet Annual General Meeting 2018 Book of Abstracts

Note: Asterisk indicates oral presentation

Keynote Presentation

A Numerical Fully-Coupled Atmospheric-Hydrologic Model-Based Real-time Rainfall and Flood Forecasting System for Three River Basins in Malaysia *

M.L. Kavvas[1], N. Ohara[2], Z.Q. Chen[3] & S. Jang[4]

1. University of California, Davis, USA
2. University of Wyoming, Laramie, USA
3. California Department of Water Resources, USA
4. Water Resour. Res. Ctr., K-Water Inst. Korea

By means of a numerical fully-coupled atmospheric-hydrologic model, an Atmospheric Model-Based Rainfall and Flood Forecasting (AMRFF) System has been developed for three river basins, Pahang, Johor and Kelantan, in Malaysia. The AMRFF system provides real-time three-day-ahead river flow forecasts in hourly increments, updated and issued at every 6 hours, based on the Global Forecasting System (GFS). GFS is an operational numerical global scale atmospheric model-based weather forecast system that is operated by U.S. National Center for Environmental Prediction (NCEP). The coarse-resolution weather forecasts from the GFS are dynamically downscaled to the three target watersheds by means of Weather Research and Forecasting (WRF) numerical atmospheric model with the dimensional data assimilation (FDDA) functionality which is employed to nudge the model's state variables to the upper air observations. The Quantitative Precipitation Forecasts (QPFs) that are then obtained from the nudged WRF model, are then further assimilated to the real-time rain gauge data, observed at the real-time telemetric stations. Then the rain gauge data-assimilated QPFs are input automatically to the physically-based Watershed Hydrology model WEHY to produce 72-hour-ahead river flow forecasts at hourly increments at all desired locations over the river network of a target basin. Finally, these streamflow forecasts are assimilated by a statistical filter every six hours to issue the actual 72-hours-ahead, hourly river flow forecasts over the target basin, along with their confidence bands.

This fully-integrated and fully-automated flood forecasting system that is based on numerical coupled atmospheric-hydrologic models with data assimilation filters at various levels, will be presented along with its numerical applications to the three target watersheds.

Theme 1: Flood Regimes in Canada: Learning from the Past and Preparing for the Future

Project 1-1: Update of Current Flood and Storm Quantiles

Project 1-1: Update of Current Flood and Storm Quantiles: Project Update*

Donald H. Burn[1]

1. University of Waterloo, Waterloo, ON

Project 1-1: Pooled Peaks-Over-Threshold and AMAX Frequency Analyses of Extreme Flood Events for Canada*

Shabnam Mostofi[1]***& Donald H. Burn***[1]

1. University of Waterloo, Waterloo, ON

Estimation of the probability of occurrence of extreme flood events is essential for hydrological planning purposes but rather difficult since these events are rare and the length of recorded data is often short. Pooled flood frequency analysis is an approach often used to reduce the uncertainty in the estimation of flood quantiles, assuming the pooling group is homogeneous. Two different models for analyzing extreme flow events are considered; annual maximum (AMAX) flood sampling, which remains the most popular approach to flood frequency analysis, with an alternative, peaks-over-threshold (POT). The POT approach is an interesting alternative since it provides the opportunity to take into consideration extreme events exceeding a threshold that would not be considered in the AMAX series. The POT approach remains under-employed primarily because of the complexities associated with its definition. The objective of this research is to develop a framework for the implementation of pooled frequency modeling based on POT series. Towards this objective, POT series are extracted for a large subset of Canadian catchments and used in constructing homogeneous pooling groups and estimating pooled flood quantiles. This study compares the performance of pooled flood estimation based on POT series with that obtained from pooled analysis using AMAX series. The performance is evaluated in terms of the accuracy and the uncertainty of T-year event estimators. POT pooling groups were concluded to be superior to AMAX pooling groups in respect to estimating flood quantiles, and the former have smaller uncertainty associated with the quantile estimates.

Project 1-1: Formation of Homogeneous Groups for regional IDF Estimation using the Region of Influence Approach*

Zhe Yang[1]***& Donald H. Burn***[1]

1. University of Waterloo, Waterloo, ON

In the regional context, the intensity-duration-frequency (IDF) curve at a target site is obtained by analyzing extreme rainfall observations from a homogenous group. The automatic feature selection and weighting algorithm in a three-layer design, which can distinguish the spatial differences of the similarity indicators for the homogeneous group formation at various regions and consider the possible impacts from urbanization on rainfall generation process, is conducted by using fuzzy c mean clustering. However, the ability of the selected optimal feature combinations to act as the rainfall pattern indicators for the target site can be undermined when the information from the input stations is limited or biased. This paper explores the application of a three-layer searching algorithm in a pooling environment by using the Region of Influence (ROI) approach. Compare to the previous approach, two modifications have been made: 1) feature extraction methods specifically Isometric feature Mapping (ISOMAP) instead of the feature weighting is used to reduce the impacts from feature correlation on the pooling groups. 2) Left-truncated AD test is used to speed the process of determining the balance point between station number and uncertainty in quantile estimates when expanding the number of stations in the pooling group. This modified three-layer search algorithm was used to form the homogenous groups for several stations with different rainfall characteristics in the target area and generates better quantile estimates compared to the previous version of the algorithm.

Project 1-2: Examination of Spatial and Temporal Variation of Extreme Events

Project 1-2: Examination of Spatial and Temporal Variation of Extreme Events: Project Update*

***Fahim Ashkar*[1]**

1. Université de Moncton, Moncton, NB

Project 1-2: Floods in Canada under climate change – not necessarily larger but definitely different*

***Don Burn*[1]**

1. University of Waterloo, Waterloo, ON

It has been hypothesized that changes to the hydrologic regime as a result of climate change will result in changes in flood events. This work explores the nature of changes that are occurring in flood events within Canada and adjacent areas in the United States. We examine data from 27 long term hydrometric reference streamflow gauging stations for changes that have occurred in flood regimes from natural watersheds. The stations considered have data records that span most of the past century; 18 reference sites are from the Canadian Reference Hydrometric Basin Network (RHBN) and nine sites are from the U.S. Geological Survey (USGS) Hydro-Climatic Data Network (HCDN). These reference networks were specifically developed to assist in the identification of the impacts of climate change; stations included are considered to have good quality data and were screened to avoid the influences of regulation, diversions, or land use change. We used Peaks over Threshold (POT) data to investigate changes in the magnitude, duration, volume and timing of flood events. Seasonality measures are used to explore changes in the nature of the flood regime based on changes in the timing and regularity of flood threshold exceedances. A variety of measures are used to infer flood regime shifts including from a nival regime to a mixed regime and a mixed regime to a more pluvial-dominated regime. The flood regime at many of the subject watersheds demonstrates a decreased prevalence of nival flood occurrences.

Project 1-2: Two problems related to flood frequency analysis in hydrology*

***Babacar Bachir Dieng*[1]**

1. Université de Moncton, Moncton, NB

The GEV frequency model is widely used to fit extremes in hydrology, particularly annual maximum flood flows. A key objective in fitting a model such as GEV to the data is to allow the estimation of distribution quantiles. The maximum likelihood (ML) method is a recommended method for fitting the GEV model to the data. To provide a measure of the statistical error involved in estimating design events, confidence intervals for quantiles (CIQ) must be calculated. Hydrologists have traditionally used large sample theory to construct these CIQs, but we show that this leads to inaccurate results for quantiles in the right tail of a GEV. An improvement is proposed for these CIQs obtained under a GEV model fitted by ML. Conventional and proposed approaches are compared by Monte Carlo simulation for small sample sizes.

In the peak-over-threshold (POT) approach for the analysis of hydrological extremes, an important problem is the identification of a frequency model to fit to the data. A way to reach this identification is to use statistical discrimination between models. To discriminate between the generalized Pareto, gamma, Kappa, Gumbel and logistic models, we will use the Anderson-Darling and a modified Shapiro-Wilk (SW) statistic. The ML method is used to fit the models to the data and to measure the differences between the empirical distribution function and the fitted distribution functions of each of the models given above. The results obtained show that the modified Shapiro-Wilk statistic gives better results.

Project 1-2: Confidence Interval for quantiles of the Gumbel Distribution

Mounada Gbadamassi[1]

1. Université de Moncton, Moncton, NB

La distribution de Gumbel est utilisée souvent en hydrologie pour décrire le comportement statistique des valeurs extrêmes. Cette distribution est un cas spécial de la loi des valeurs extrêmes généralisées (GEV). Nous allons nous focaliser sur l'estimation de l'intervalle de confiance des quantiles de la loi Gumbel. En effet, nous estimons les deux paramètres de cette loi par la méthode de maximum de vraisemblance et ensuite nous faisons une estimation du quantile à partir des paramètres estimés. Pour avoir une convergence plus rapide du quantile estimé vers la loi normale, nous proposons de faire une transformation Box-Cox à ce quantile estimé. Nous allons considérer les deux cas suivants: 1) la distribution est à deux paramètres à estimer (position et échelle); 2) la distribution est traitée comme un cas particulier de la distribution GEV, donc elle a trois paramètres à estimer (position, échelle et forme).

Project 1-3: Analysis and Applicability of Future Extreme Events in Regional and Local Context

Project 1-3: Analysis and applicability of future extreme events in regional and local context: Project Update*

M. Altaf Arain[1]

1. McMaster University, Hamilton, ON

Project 1-3: Increase of winter high-flow events in Southern Ontario since the 1980's driven by a shift in atmospheric circulation*

Olivier Champagne[1], Altaf Arain[1]

1. McMaster University, Hamilton, ON

Flooding is a major concern for Canadian society as it is the costliest natural disaster in Canada. Southern Ontario, which houses one-third of the Canadian population, is in an area of high vulnerability for floods. The most significant floods in the region generally occur in March and April due to snowmelt coupled with extreme rain events. However, there has been a shift during the last three decades with an increasing number and amplitude of floods occurring in winter in January and February. The 100-year return period flood in February 2018 in the Thames and Grand River is a good example of these significant winter floods that occurred recently due to the conjunction of warm weather and extreme rainfall events. The aim of this study was to understand the impact of atmospheric circulation on the shift of high flow events observed in southern Ontario. The evolution of the atmospheric circulation was assessed using a discretization of daily geopotential height at 500HpA level (Z500) in classes of recurrent meteorological situations over North America. The Precipitation Runoff Modeling System (PRMS), a rainfall-runoff semi distributed hydrological model, was also applied to four watersheds in southern Ontario. This model was used to analyze the sensitivity of streamflow to the temporal shift of precipitation and temperatures. The results show an increase of high flows in winter, not only driven by a warming and enhancement of snowmelt, but also by an increase in frequency of rainfall events. The investigation of ten weather regimes classes suggests that the increase in frequency of high pressure systems over the eastern coast of North America increased the frequency of these events due to more advection of wet and mild air masses. These results are important to improve the seasonal forecasting of high flows and to assess the uncertainty of the future evolution of streamflow in the region.

Project 1-3: Moisture sources and pathways associated with the spatial variability of seasonal extreme precipitation over Canada*

Thian Yew Gan[1], Xuezhi Tan[1]& Menglong Zhao[1]

1. University of Alberta, Edmonton, AB

Flooding is a major concern for Canadian society as it is the costliest natural disaster in Canada. Southern Ontario, which houses one-third of the Canadian population, is in an area of high vulnerability for floods. The most significant floods in the region generally occur in March and April due to snowmelt coupled with extreme rain events. However, there has been a shift during

the last three decades with an increasing number and amplitude of floods occurring in winter in January and February. The 100-year return period flood in February 2018 in the Thames and Grand River is a good example of these significant winter floods that occurred recently due to the conjunction of warm weather and extreme rainfall events. The aim of this study was to understand the impact of atmospheric circulation on the shift of high flow events observed in southern Ontario. The evolution of the atmospheric circulation was assessed using a discretization of daily geopotential height at 500HpA level (Z500) in classes of recurrent meteorological situations over North America. The Precipitation Runoff Modeling System (PRMS), a rainfall-runoff semi distributed hydrological model, was also applied to four watersheds in southern Ontario. This model was used to analyze the sensitivity of streamflow to the temporal shift of precipitation and temperatures. The results show an increase of high flows in winter, not only driven by a warming and enhancement of snowmelt, but also by an increase in frequency of rainfall events. The investigation of ten weather regimes classes suggests that the increase in frequency of high pressure systems over the eastern coast of North America increased the frequency of these events due to more advection of wet and mild air masses. These results are important to improve the seasonal forecasting of high flows and to assess the uncertainty of the future evolution of streamflow in the region.

Project 1-3: Interdependence between temperature and precipitation in southern Ontario, Canada

Hussein Wazneh[1], Altaf Arain[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Analysis and simulation of the joint distribution of precipitation and temperature are important to better capture extreme events and for agriculture production. However, accurate simulation is difficult due to possible interdependence between these two climatic variables. In this paper, the concept of copulas was used to model the seasonal interdependence between precipitation and temperature in Southern Ontario, Canada. Five family of copula was fitted for 1960-2013 period and then theoretical and empirical copulas are compared to select the most appropriate family for this region. Results show that no one copula is selected as a best for the entire region. Gumbel is founded as best copula for winter and Clayton for summer. Also more variability in terms of best copula was founded in spring and fall. By extracting the multivariate and the univariate quantiles related to a preselected risk we found that ignoring the joint distribution of precipitation and temperature lead to underestimates the risk of an extreme event which can also lead to a wrong conclusion/decision in terms of return periods.

Project 1-4: Development of New Methods for Updated IDF Curves in Canada

Project 1-4: Development of new methods for updating IDF curves in Canada: Project Update*

Van-Thanh-Van Nguyen[1], Truong-Huy Nguyen[1] & Sarah El Outayek[1]

1. McGill University, Montreal, PQ

Project 1-4: Stochastic modeling of daily rainfall process in the context of non-stationarity*

Sarah El Outayek[1] & Van-Thanh-Van Nguyen[1]

1. McGill University, Montreal, PQ

Information on the variations of extreme rainfall events in space and time is essential for the design and management of different water resources systems. However, it is difficult in practice to obtain this information simply based on the available historical precipitation records due to the random behavior of these phenomena, especially in the context of climate change. Therefore, the use of a statistical or stochastic approach is more appropriate for describing more accurately the spatio-temporal variability of precipitation characteristics. The main objective of the present study is therefore to develop an original stochastic model to represent the daily precipitation process in the context of non-stationarity. The proposed model (referred herein as MCME) consists of two components: (i) the first component representing the occurrences of daily rainfalls based on the first-order Markov Chain; and (ii) the second component describing the daily rainfall intensities using the Mixed Exponential distribution. A comparative study was carried out to assess the performance of the MCME as compared to the popular LARSWG model using NCEP re-analysis data and observed daily precipitation data available in the province of Quebec. Results of this assessment will indicate the accuracy and robustness of each model using a set of common graphical and numerical performance criteria.

Project 1-4: Linking climate change to urban storm drainage system design: An innovative approach to modeling of extreme rainfall processes over different spatial and temporal scales*

Truong-Huy Nguyen[1] & Van-Thanh-Van Nguyen[1]

1. McGill University, Montreal, PQ

Climate change has been recognized as having a profound impact on extreme hydrologic processes. Consequently, there is an urgent need to assess this climate change impact on the estimation of extreme storm rainfalls for the design of urban drainage systems. However, the main challenge in current engineering practices is how to establish the linkages between the climate projections given by Global Climate Models (GCMs) at the global scale and the observed extreme rainfalls (ERs) at a given local site. Therefore, in the present study, an innovative statistical downscaling (SD) approach was proposed for establishing these linkages in the modeling of ER processes over a wide range of temporal and spatial scales. An illustrative application has been carried out to assess the feasibility and accuracy of this SD method. Results of this application have indicated that the proposed SD approach can be used for describing accurately the linkages between climate projections provided by GCMs under different climate change scenarios and daily

and sub-daily annual maximum rainfalls at a given local site. Finally, it has been shown that these linkages can be used to provide a robust and accurate assessment of the climate change impacts on the estimation of ERs for urban drainage system design.

Project 1-5: Spatial Changes to Flood Prone Areas in Urban Environments

Project 1-5: Spatial Changes to Flood Prone Areas in Urban Environments: 2018 Update*

Yiping Guo[1], Andrew Binns[2], Zihao Zhang[1] & Philip De Boer[2]

1. McMaster University, Hamilton, ON
2. University of Guelph, Guelph, ON

Expansion of urban town centers have created watershed wide-land-use changes resulting in excess runoff. The research in Project 1-5 is aimed at assessing the effect of intensifying urban development on spatial changes to flood prone lands and flood hazard in urban environments. Previous work in Project 1-5 has applied modeling techniques to examine land-use changes and strategies to mitigate stormwater in the Davis Creek Watershed in Hamilton and Black Creek Watershed in Toronto as case studies. Current research seeks to further verify the conclusions from the previous case studies, specifically the role of low impact development (LID) measures in reducing stormwater runoff from higher magnitude storm events. Current research will also look into the impact of an individual flood control pond on the flood peaks at locations further and further downstream of the pond. The goal of the research is to obtain generalized conclusions by testing groups of subcatchments with similar and different properties through simulation with PCSWMM. The conclusions will be verified further by creating synthetic subcatchments with extreme conditions (low permeability, small width, etc.) in PCSWMM. The analytical probabilistic modeling approach will also be used to ensure that the conclusions obtained by using the design storm approach are indeed correct.

Project 1-5: Assessing the Impact of LIDs on Higher Magnitude Peak Flow Events Using Real World and Synthetic Catchments*

Philip De Boer[1], Yiping Guo[1], Andrew Binns[1]

1. University of Guelph, Guelph, ON
2. McMaster University, Hamilton, ON

In his previous work for Floodnet, Kokas (2017) completed a low impact development (LID) analysis on the Black Creek Watershed in Vaughn, Ontario using a calibrated PCSWMM model. His results showed that LIDs were unable to significantly reduce high magnitude peak flows (25 year to 100 year storm events). This presentation will continue to explore the results of Kokas (2017) with a focus on obtaining general results. The spatial extent of the analysis will expand to include over 700 subwatersheds in a calibrated PCSWMM model. The subwatersheds will be grouped according to similar imperviousness area, width, slope, and area. Each subwatershed in a given group will have a percentage of area converted to LIDs. Using PCSWMM, a higher magnitude peak flow event will be run on each subwatershed before and after a percentage of area is converted to LID. The results from each group will be compared to results from other groups in an attempt to draw general conclusions and recommendations. The conclusions will be verified using synthetic catchments and APSWMM. PCSWMM will be used to create subwatersheds with extreme conditions (low permeability, small width etc.) to test if the conclusions drawn from the real world model are still applicable in these circumstances. The results will be further verified by constructing models for the same catchments using a probability distribution based model called

APSWMM to test if the simplifying probability assumptions in PCSWMM are valid for our conclusions.

Project 1-5: Spatial Changes to Flood Prone Areas in Urban Environments: A Case Study in The East River Watershed*

Zihao Zhang[1] Yiping Guo[2], Andrew Binns[1]

1. University of Guelph, Guelph, ON
2. McMaster University, Hamilton, ON

The number of flooding events in Canadian urban environments continue to increase, causing major environmental, economic and social consequences. Project 1-5 is aimed at assessing the impacts of intensifying urban development on spatial changes to flood prone lands and reducing the flood hazard in urban environments. This part of project 1-5 is based on the East River Watershed located in the Southwest part of the City of Edmonton and storm water management (SWM) facilities such as detention ponds are the major measurements for flood control in this case study. Because of the impervious area caused by urbanization, it is necessary to improve the performance of existing ponds and determine the best locations on main trunk where the retrofitted ponds can effectively reduce the flood hazard. Thus, SWMM models were built to investigate the impacts of changing distance from the pond to the watershed outfall on peak discharge reduction.

Moreover, previous work has proved that Low-Impact Development (LID) practices can be effective in reducing peak runoff for frequent small storm events but has little attenuation effect on peak runoff for extreme storm events. Current research continues to evaluate the effectiveness of various LIDs at decreasing the duration of high flows for extreme events. Major flood events such as 100-year Huff design storms were used in the simulations to more accurately reflect real storm conditions.

Project 1-5: Incorporating Resilience in Urban Flood Control Systems

Pavneet Brar[1] & Yiping Guo[1]

1. McMaster University, Hamilton, ON

With the rise of extreme events, there will inevitably be conditions that will exceed infrastructure system design capacities. Resilience strategies that aim at minimizing flood impacts and enhancing recovery are required for a realistic management of urban communities. Many promising conceptual frameworks and preliminary mathematical approaches have been developed in the past; however, further investigations on quantifying resilience are necessary for the development of effective decision-making tools. A review of literature regarding urban storm water management is conducted with the focus being on understanding the flood control capabilities of natural conveyance- and storage-prone areas and man-made infrastructure.

Project 1-6: Development of New Flood Estimation Manual for Canada

Project 1-6: Towards a Flood Estimation Manual for Canada: Project Update*

Donald H. Burn[1] and Fahim Ashkar[2]

1. University of Waterloo, Waterloo, ON
2. Université de Moncton, Moncton, NB

Project 1-6: Techniques for estimating flood quantile at ungauged locations and automated extraction of POT data*

Martin Durocher[1], Shabnam Mostofi Zadeh[1], Donald H. Burn[1] and Fahim Ashkar[2]

1. University of Waterloo, Waterloo, ON
2. Université de Moncton, Moncton, NB

The estimation of flood quantiles at ungauged locations is an important part of FloodNet Theme 1-6. Indeed, as hydrometric stations are not always available at a site of interest, the run-off properties must be derived from catchment descriptors. For this task, multiple regression inside pooling groups is an approach frequently recommended by national agencies in countries such as the United Kingdom and Australia. However, various other techniques have also been proposed with success in different parts of the world. A comparative analysis of these techniques was carried out at the national and provincial level. Our results show that more accurate estimates were obtained by combining Generalized Additive Model (GAM) and spatial interpolation method.

Two widely known approaches for estimating flood quantile in the context of an ungauged analysis are the index-flood model and the regression of at-site flood quantiles. For ungauged frequency analysis, both methods require the prediction of a variable that is not directly observed. For multiple regression, using Generalized Least Squares (GLS) is recognized as good practice to account for the uncertainty associated with both sampling and model errors. In particular, ignoring intersite correlation in the samples leads to underestimating the true model variability. However, for techniques other than multiple regression, GLS is not always possible. Therefore, we present a bootstrap sampling scheme that can evaluate the total uncertainty of all methods previously compared and characterize inter-site correlation by a proper copula model.

For univariate frequency analysis, two common modelling approaches are the modelling of annual maximums or peaks over threshold (POT) data. Contrary to annual maximums, POT can consider, on average, more than one observation per year, which provides more information and thus reduces the uncertainty. However, POT requires the specification of a threshold where graphical methods are often employed. For a large network of stations, manually performing these graphical methods can be very time consuming. Our research proposed a semi-automatic method based on the Anderson-Darling test. The procedure was performed on several Canadian sites and compared to thresholds manually obtained from previous study. Our results showed that the proposed selection method is able to reproduce correctly the outcomes of graphical methods and to decrease modelling uncertainty.

Project 1-6: Regional Intensity-Duration-Frequency (IDF) Curves for Canada*

Ana Requena[1], Donald H. Burn[1] and Paulin Coulibaly[2]

1. University of Waterloo, Waterloo, ON
2. McMaster University, Hamilton, ON

Intensity-duration-frequency (IDF) curves are used for estimating the magnitude of rainfall events needed to design urban infrastructure. Efforts towards improving their estimation are hence essential to reduce potential damage from extreme rainfall. IDFs for a given location are usually obtained from rainfall series recorded at a nearby gauged station, yet available records may not be long enough to allow accurate extreme event estimation. Regional (pooled) IDFs for Canada are proposed in this study to obtain more reliable IDFs by using rainfall information from a number of similar gauged stations. The approach is based on the index-event method with group formation according to the region of influence approach. Geographical distance is used as the similarity measure. Several types of macro regions are also considered during the pooling group formation to account for the existence of different physiographic/climatic characteristics across the country. The initial dataset consists of 565 stations used by Environment and Climate Change Canada for at-site IDF estimation. A trend analysis is performed on all extreme rainfall series with at least 20 years of data to identify nonstationary stations to be removed. Stations north of 65˚ latitude are not considered in the pooled analysis due to being remote stations with a very low station density. The generalized extreme value distribution is found to be the most suitable distribution for pooling growth curve estimation across Canada. The performance of several approaches based on different criteria for pooling group formation is compared through a framework where error and uncertainty measures are evaluated. Recommendations for pooled IDF estimation across Canada will be provided based on the obtained results, which are currently in progress. Further research will consist of updating the pooled IDFs under climate change through a pooled-grid-based approach for which an overview is presented.

Project 1-6: Identification of a preferred statistical distribution model for at-site flood frequency analysis in Canada

Ziyang Zhang[1] & Donald H. Burn[1]

1. University of Waterloo, Waterloo, ON

At-site flood frequency analysis is commonly used to estimate design flood quantiles for a site of interest. The selection of a statistical distribution is of fundamental importance for accurately estimating design flood quantiles. As part of the development of the Canadian flood estimation manual, this study investigates a preferred statistical distribution in the national context based on annual maximum flow series and instantaneous peak flow series at 186 Reference Hydrometric Basin Network stations. Four three-parameter distributions: Generalized Logistic, Generalized Extreme Value (GEV), Pearson Type III, and Log Pearson Type III are compared both quantitatively and qualitatively using two goodness-of-fit measures (i.e., Modified Anderson-Darling test and L-Moment Z test). Results show the GEV distribution is the preferred distribution amongst the four considered distributions. In addition, goodness-of-fit results are displayed on a national map to explore for potential spatial patterns. No noticeable spatial pattern is found;

however, a relatively weak performance of distribution fit is observed in the southern Prairie region.

Project 1-6: Exploring problematic sites from current developed regional flood frequency analysis for Canada

Tianshuo Zhou[1], Donald H. Burn[2] & Tricia Stadnyk[1]

1. University of Manitoba, Winnipeg, MB
2. University of Waterloo, Waterloo, ON

Regional frequency analysis is widely accepted as a powerful method to provide more accurate flood quantile estimates. The proposed regional method for FloodNet uses the idea of super regions to group together stations with similar drainage area and basin average precipitation. The region of influence method is used within each super region to form groups for regional analysis based on measures of the timing of peak discharge. This procedure provides good results in terms of forming homogeneous regions with only 118 out of 1115 stations possibly heterogenous and 12 heterogenous. Success or failure for each station is defined by comparing confidence intervals between regional method and at site method with a successful station having narrower confidence intervals from the regional method. In analysis of a weighted confidence interval by averaging 20-year flood, 50-year flood and 100-year flood, 204 stations failed. From GIS study, three regions are highlighted: Rocky Mountain, Prairie and Northern Canada. In the next phase of the research, detailed analysis will be conducted for each failure station, exploring other important factors influencing floods, such as watershed lake effect, average watershed slope and limitations of the current super region approach. Recommendations should come after systematic study to improve current regional method, such as creating alternate super region or other method for some specific geographic regions.

Theme 2: Quantifying and Reducing the Predictive Uncertainty of Floods

Project 2-1: Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on a Single Model

Project 2-1: Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on a Single Model: Project Update*

Bryan Tolson[1]

1. University of Waterloo, Waterloo, ON

Project 2-1: Five Reasons Why You Should Know the Canadian Surface Prediction Archive CaSPAr*

Juliane Mai[1], Bryan Tolson[1], Kurt Kornelsen[2], David Schäfer[3], Noclas Gasset[4], Vincent Fortin[4], Michael Leahy[5], & Paulin Coulibaly [2]

1. University of Waterloo, Waterloo, ON
2. McMaster University, Hamilton, ON
3. Helmholtz Centre for Environmental Research UFZ, Leipzig, Germany
4. Environment and Climate Change Canada, Montreal, QC
5. Esri Canada, Toronto, ON

Environmental models are tools for a wide range of applications such as flood and drought monitoring, carbon storage and release estimates, predictions of power generation amounts, or reservoir management amongst others. Environmental models differ in the types of processes they incorporate, where land surface models focus on the energy, water, and carbon cycle of the land and hydrological models concentrate mainly on the water cycle. All these models, however, have in common that they rely on environmental input data from ground observations such as temperature, precipitation and/or radiation to force the model. If the same model is run in forecast mode, numerical weather predictions (NWPs) are needed to replace these ground observations. Therefore, it is critical that NWP data be available to develop models and validate forecast performance. These data are provided by the Meteorological Service of Canada (MSC) on a daily basis. MSC provides multiple products ranging from large scale models (~50km) to high resolution pan-Canadian models (~2.5km). Operational products providing forecasts in real-time are made publicly available only at the time of issue through various means with new forecasts issued 2-4 times per day. Unfortunately, long term storage of these data are offline and effectively inaccessible to the research and operational communities. The new Canadian Surface Prediction Archive (CaSPAr; www.caspar-data.ca; developed under NSERC Canadian FloodNet Research Program) platform is an accessible archive of 10 of MSCs NWP products. We will present the user-friendly frontend of CaSPAr as well as five reasons why you might want to use this archive. These reasons range from (1) the ability to drastically reduce the amount of data to download (2) personalized user requests to (3) standardized file formats that allows (4) for easy comparison of NWP products or (5) downloaded data already formatted to immediately enable either forecast or hindcast model runs.

Project 2-1: Accounting for climate uncertainty in hydrological model calibration and ensemble Kalman filter based on an existing historical climate ensemble dataset *

Hongli Liu[1] & Bryan Tolson[1]

1. University of Waterloo, Waterloo, ON

Our research demonstrates using the Gridded Ensemble Precipitation and Temperature Estimates dataset (Newman et al., 2015), covering the contiguous United States, northern Mexico, and southern Canada, to represent the precipitation and temperature uncertainty in model calibration and the ensemble Kalman filter. First, an ensemble climate based model calibration framework is proposed to explicitly account for climate data uncertainty in model calibration. The framework performance is verified with 30 synthetic experiments and 20 Québec catchments real case studies. Results show that the framework effectively reduces the inaccurate flow predictions caused by poor quality climate measurements and improves the overall performance of ensemble flow predictions. Second, we propose the direct use of the Newman et al. (2015) dataset in the ensemble Kalman filter application. Our research for the first time compares the Newman et al. (2015) dataset based climate ensemble with the carefully tuned hyper-parameters based climate ensemble in real ensemble flow forecasting. The forecast performance comparison of 20 Québec catchments shows that the Newman et al. (2015) ensemble yields improved or similar deterministic and probabilistic flow forecasts relative to the tuned hyper-parameters based climate ensemble, especially for short lead times (i.e., 1-3 days) when the influence of data assimilation dominates. However, the analyst and experimental time required to use the Newman et al. (2015) dataset is much less compared to the fastidious hyper-parameter tuning.

Project 2-2: Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on Multiple Models

Project 2-2: Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on Multiple Models: Project Update*

***François Anctil*[1]**

1. Université Laval, Québec, PQ

The presentation will provide an overview of the work that was performed, within FloodNet Theme 2-2, on improving hydrological ensemble prediction systems, notably through the use of multiple models and probabilistic data assimilation methods.

Project 2-2: Hydrological post-processing of streamflow forecasts issued from multimodel ensemble prediction systems*

***Jing Xu*[1]*, François Anctil*[1] *& Marie-Amélie Boucher*[2]**

1. Université Laval, Québec, QC
2. Université de Sherbrooke, Québec, QC

Hydrological simulations and forecasts are subject to various sources of uncertainties. For instance, Thiboult et al., (2016) constructed 50000-member great ensemble that ultimately accounts for meteorological forcing uncertainty, initial condition uncertainty, and structural uncertainty. This large 50000-member ensemble can also be separated into sub-components to untangle the three main sources of uncertainties mentioned above. However, in Thiboult et al., (2016) model outputs were simply pooled together, considering equiprobable members. This paper studies the use of Bayesian model averaging (BMA) to post-process multimodel hydrological forecasts. BMA assigns multiple sets of weights on different models and then generates more skillful and reliable probabilistic forecasts. BMA explicitly deciphers the structural uncertainties corresponding to each candidate hydrological model and then produces the predictive probabilistic density function (PDF) containing those informations about uncertainty. The BMA scheme displays a large contribution to the ensemble dispersion and compensates the reliability and skill of the systems that only include two sources of uncertainties, as the 50000-member great ensemble using all forecasting tools (i.e., multimodel, EnKF, and Meteorological ensemble forcing) could predict jointly. Furthermore, previous research revealed that the meteorological forecasts were somehow biased and unreliable on some catchments that were rejected. The BMA scheme is capable to improve the accuracy and reliability of the hydrological forecasts for those sites as well.

Project 2-2: Importance of the hydrological (multi)model in an ensemble prediction system*

***Carine Poncelet*[1]*, François Anctil*[1]*, Antoine Thiboult*[1] *& Gregory Seiller*[2]**

1. Université Laval, Québec, QC
2. Danish Hydraulic Institute, France

The value of hydrological forecasts largely relies on the correct estimation of uncertainties (Thiboult et al. 2017). The three main sources of uncertainties (Thiboult et al. 2016) are: (i) the meteorological forecasts, (ii) the initial conditions and (iii) the hydrological model structure. The first source of uncertainty can be estimated by using ensemble meteorological forecasts, the second by including a probabilistic data assimilation procedure, and the third one by using several dissimilar hydrological models. The data assimilation step is found to be quite important, strongly modifying model behaviours to improve both accuracy and reliability of the forecast. However, it is still unknown to what extent the initial properties of the hydrological (multi)model impact the overall quality of the forecast system. This raises the question of how to choose the hydrological model(s) to maximize the EPS performance. The recently developed Empirical Multistructure Framework (Seiller et al. 2017) provides a tool to create a large quantity of diverse lumped hydrological models. It consists in identifying functional components in existing ("parent") models and combining them to produce new ("child") models. Applying the EMF to twelve parent models, Seiller et al. (2017) produced some 108 800 new hydrological models and showed the ability of this framework to build accurate, sharp, and reliable hydrological ensembles for streamflow simulations. The EMF opens the door to the building and testing of many models and multimodels. In this study, we aim at transposing the EMF to an ensemble prediction system. In particular, we aim at understanding how probabilistic data assimilation techniques modify the properties of a single or an ensemble of hydrological models.

Project 2-2: Short-term optimization of reservoir operation using Ensemble stream flow forecast

Michael Osina[1]

1. Université Laval, Québec, QC

Project 2-4: Evaluation of Flood Warning Based on Hydraulic Models with Assimilation and Hydrological Ensemble Forecasts: Project Update*

François Anctil[1]

1. Université Laval, Québec, PQ

Project 2-4: Ensemble water level forecasting with hydrological ensemble forecasts *

Mohammed Amine Bessar[1]

1. Université Laval, Québec, PQ

In this presentation we will present an evaluation of coupling a hydraulic model to the hydrological ensemble forecasting chain for water level forecasting purpose. The analysis was made for a recent event where we assessed near real time coupled hydrological and water level forecasting.

Project 2-4: The added value of human expertise with an automated hydrological forecasting system

Philippe Richard[1]

1. Université Laval, Québec, PQ

With the diversity of hydrological forecasting sources and ever more complex and autonomous systems, the role of the hydrological forecaster in these systems is becoming a topical issue for operators and designers of hydrological forecasting systems. This research project, which is part of the St. Lawrence Action Plan under the Environmental Prediction tab, has as its, primary motivation, the improvement of the tools available to carry out hydrological forecasts in the Saint-Laurent watershed, while giving free space for the expertise and knowledge of hydrologist forecasters. This thesis will study both the human-machine interactions side and the performances and perceptions that flow from them.

Project 2-4: Exploring a statistical post-processing technique of ensemble precipitation forecast for operational hydrologic forecasting

Emixi Sthefany Valdez Medina[1]

1. Université Laval, Québec, PQ

The aim of this project is to investigate the use of a parametric statistical correction technique in meteorological ensemble prediction and to investigate whether this improves streamflow forecasts. The raw and post-processed ensemble precipitation forecasts from the ECMWF are used as forcing variables to 20 rainfall-runoff models to produce ensemble streamflow forecasts. To consider the uncertainty arising from the initial conditions, data assimilation is performed with the EnKF. The correction of precipitation forecast is assessed over Gatineau's sub-basins in Quebec using common metrics such as Brier skill scores, reliability diagrams, MCRPS and skill-spread plot. The statistical post-processing by Fitting Censored Shifted Gamma Distribution

(CSGD) yields probabilistic precipitation forecast that is reliable and skillful. However, improvements in bias and skill of the forcing ensembles vary with forecast amount, lead time, season and catchment. The results also show that an improvement of the forcing variable does not always translate into improved streamflow forecast, especially in the sub-basins where large reservoirs and anthropogenic activities are present.

Project 2-5: Real-time Reservoir Operation Based on a Combination of Long-Term and Short-Term Optimization and Hydrological Ensemble Forecasts

Project 2-5: Real-time reservoir operation based on a combination of long-term and short-term optimization and hydrological ensemble forecasts: Project Update*

***Amaury Tilmant*[1]**

1. Université Laval, Québec, PQ

Project 2-5: Short-Term Optimization of Reservoir Operation using Ensemble Streamflow Forecasts*

***Hajar Nikghalb Ashouri*[1]**

1. Université Laval, Québec, PQ

The optimal operation of a system of reservoirs is a complex decision-making problem involving, among others, the identification of a temporal trade-off regarding the use of water. Should the last unit of water be kept in storage or rather be released for use downstream? The variability of natural inflows further complicates this decision-making problem: at any given point in space and time, the trade-off between the immediate and future uses of water must be made without a perfect knowledge of future reservoir inflows. Generally speaking, the optimal balance between immediate and future uses of water requires the integration of short- and long-term policies. If short-term policies lead to shortsighted decisions, long-term operational strategies are not appropriate to handle short-term events such as floods. Another challenge is the integration of short-term and mid/long-term hydrologic forecasts. We propose a modelling framework based in the time decomposition (TD) approach: mid/long-term policies are determined first and then used as boundary conditions for the optimization of short-term policies. The mid-term optimization model processes seasonal flow forecasts whereas Ensemble Streamflow Predictions (ESP) are used to drive the short-term model on a daily time step. More specifically, a Stochastic Dual Dynamic Programming with exogenous hydrologic variables (SDDPX) generates the weekly benefit-to-go functions that are then imposed to a non-linear programming model implemented on each 9-days member of the ESP. This modelling framework is implemented in a rolling-horizon model on a cascade of power stations in the Gatineau River basin, Quebec, Canada. This framework makes it possible to analyze the economic value of alternative sets of hydrologic information (ESP, snow water equivalent, soil moisture, seasonal forecasts, sea surface temperature, etc.)

Theme 3: Development of the Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS)

Project 3-1: Evaluation of Flood Forecasting and Warning Systems Across Canada

Project 3-1: Evaluation of Flood Forecasting and warning systems across Canada: Project Update*

***Tricia Stadnyk*[1]**

1. University of Manitoba, Winnipeg, MB

Project 3-1: A multimodel framework coupled with various statistical post-processing techniques for improving seasonal ensemble streamflow prediction in the Canadian Prairie Region*

***Ameer Muhammad*[1]**

1. University of Manitoba, Winnipeg, MB

Hydrologic models are only approximation of the reality and thus are not able to perfectly simulate observed streamflow due to various sources of uncertainty. On the other hand, skillful operational hydrologic forecast is vital in water resources management and preparedness against extreme events. Consequently, multimodel techniques are developed, which have proven useful in improving forecast and quantify uncertainty. In this paper, we assess the performance of Multimodel Ensemble Streamflow Prediction (MESP) scheme coupled with various statistical post-processing techniques. The ESP from WatFlood, HEC-HMS, and SWAT models, coupled with four statistical post-processing [simple model averaging (SMA), linear regression (LR), quantile model averaging (QMA), and Bayesian model averaging (BMA)] techniques are examined. The quality of MESP is investigated for seasonal streamflow forecast with lead time of 6 months over the Upper Assiniboine River Basin at Kamsack (UARB). The framework, once developed, is envisaged to be a valuable input to enhance decision-making capacity of the Hydrologic Forecast Centre (HFCs) in Canada.

Project 3-2: Real-time Spatial Information Evaluation and Processing*

***Aaron Berg*[1]**

1. University of Guelph, Guelph, ON

Project 3-2: Identification of soil freeze/thaw (F/T) thresholds for model validation*

***Renato Pardo Lara*[1]*, Aaron Berg*[1] *& Jon Warland*[1]**

1. University of Guelph, Guelph, ON

Approximately 50% of soils in the Northern Hemisphere experience seasonal freezing and thawing. This transition influences physical, chemical, and biological processes in the vadose zone. Hydrologically speaking, the most important effect of frozen soil is the limiting of rainfall and snowmelt infiltration, increasing the potential for overland flow and flooding. The hydraulic conductivity of frozen soil decreases sharply as ice formation preferentially occurs in large pores, forcing liquid water to flow in smaller pores and thin films, strongly influencing the amount and timing of winter and spring runoff in cold regions. The importance of ground F/T state in weather and climate models has been demonstrated, particularly in flood forecasting applications. In most studies, the freezing temperature of liquid water (0°C) is considered the threshold between frozen and thawed states. However, in soil pores the effects of capillary and adsorptive forces combine with the presence of dissolved salts combine to depress the freezing point. Thus, the 0°C threshold is only an approximation of the soil F/T transition point which is a function of soil texture, liquid water content, ice pressure, and contaminant concentration. For more accurate modeling and prediction of land surface hydrological and biospheric processes, a good representation of the soil F/T state – and thus the F/T threshold – is needed in land surface schemes.

Coaxial impedance sensors, like Steven's HydraProbeII (HP), are the most widely used soil sensor in water supply forecast and climatological networks. These soil moisture probes have recently been used to validate remote sensing F/T products, however, this is still relatively uncommon. The ability of these instruments to accurately partition the total water content into frozen and unfrozen components remains questionable. An experiment was conducted to identify the correlation between the phase state of the soil moisture and the probe measurements. Six soil cores were subjected to F/T transitions in an environmental chamber. For each core, at a depth of 2.5 cm, the temperature and permittivity were measured every minute using HPs while two heat pulse probes captured the apparent heat capacity 24 minutes apart. Preliminary results show the phase transition of water is bounded by inflection points in the soil temperature, attributed to latent heat. The soil permittivity appears to be highly sensitive to the phase change of unbound soil moisture. This opens the possibility of estimating a relationship between the soil temperature and frozen water content in the sensing volume, yielding dynamic F/T thresholds.

Project 3-3: Enhanced Information Communication Systems

Project 3-3: Enhanced Information Communication Systems: Project Update*

***Wei Song*[1]**

1. University of New Brunswick, Fredericton, NB

Project 3-3: Channel access management for flood warning systems*

***Hesham Moussa*[1] *& Weihua Zhuang*[1]**

1. University of Waterloo, Waterloo, ON

Floods are devastating natural disasters that have been constantly endangering the lives of many human beings. Perhaps, the most devastating of them are river floods due to their brutality and the fact that they usually come unannounced. Therefore, it is of utmost importance to design a new flood warning mechanism by which people can be warned with ample time for them to evacuate their homes safely in the case of floods. A critical part of a successful warning system lies in the information collection and dissemination. Rivers, being massive water bodies, are expected to be covered with a large number of wireless sensors and monitoring devices used to collect vital indicative information from which floods can be predicted. Cellular networks are seen as the most suitable access technologies capable of providing the necessary coverage thanks to their wide coverage area and availability. Sensors transmit their data periodically; however, in the case of a flood, they transmit their data instantly where a large number of the sensors becomes active and attempt to access the cellular network simultaneously, leading to extensive delays and energy wastage. This problem is often referred to as the massive access problem. Many have attempt to solve this problem; nonetheless, available solutions have often relied on time spreading means which ignores the delay requirements of the underlying data.

Therefore, in this work, we aim at developing a new delay aware channel access mechanism capable of handling the massive access scenario. This work is divided into two parts. In the first part, we attempt to evaluate the performance of the current random channel access procedure of the cellular network when supporting a massive flood warning system. We use stochastic geometry to derive a novel mathematical framework to evaluate the channel access success probability and test it under massive simultaneous access situation. The results highlight the main trade-offs and emphasize the shortcomings of this access technology. Accordingly, in the second part, we aim at developing a new access mechanism that is better suited for flood warning systems based on the drawn conclusions from the first part. A potential solution is to use clustering where data from the sensors are aggregated into a larger data packet by the cluster head which will then relay the data to the cellular base stations. We will design the clustering scenario such that energy efficiency and delay constraints are taken into account.

Project 3-3: Efficient Task Allocation for Mobile Crowdsensing Based on Evolutionary Computing

Xi Tao[1]

1. University of New Brunswick, Fredericton, NB

Mobile crowdsensing (MCS) offers a promising paradigm for big data collection in a large scale. It leverages the power of mobile smart devices, and shows various advantages over traditional sensing networks, such as high energy efficiency, cost-effectiveness, and flexibility. A key problem in MCS is to efficiently allocate distributed tasks to mobile users (MUs) while addressing various constraints, e.g., in terms of the quality of sensed data and collection cost. We take into account the clustering effect of sensing tasks and propose an efficient approach to solve the NP-hard task allocation problem. In our solution, a variant genetic algorithm (GA) is utilized to maximize the task complete ratio and balance the sensed data among tasks while respecting the MUs' constraints. The simulation results show that the proposed GA-based solution significantly outperforms the baseline solution in terms of task complete ratio and data balance.

Project 3-3: System Requirements for an efficient flood warning system.

Jobanmeet Kaur[1]

1. University of New Brunswick, Fredericton, NB

Majority of the flooding events in Canada are the river floods, which, though easier to detect, have been causing great damages. Floods are five times as recurrent as wildfires, which are the second most common natural disaster in Canada. The bottom line is that a sound flood mitigation system is required to diminish the unprecedented losses caused. Since floods cannot be eliminated, numerous structural and non-structural measures are to be taken to reduce their development. FloodNet is a collaborative project for better flood management and forecasting. This part of the project aims at inspecting the system requirements for Floodnet warning signals dissemination and the challenges being faced at various levels of the FloodNet design. It targets the assimilation of appropriate heterogenous short and long range wireless networking strategies. These networks need to efficiently transmit the real time spatially distributed sensor data to the processing center and dispense the information from the processing center to the general public. The results from this study will help recognize the key performance metrics based upon what the suitable technology be chosen for various communication requirements. The available technologies for the key objectives are compared so as to reach the most fitting solution based on the studied research issues

Project 3-4: Development of the Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS)

Project 3-4: Development of the Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS)*

Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Project 3-4: Data Assimilation within the Canadian Adaptive Flood Forecasting and Early Warning System*

James Leach[1], Tara Razavi[1], Jongho Keum[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

We proposed an approach to assimilate observation data into the Community Hydrologic Prediction System (CHPS) within the Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS). Here we will present how this method was implemented in CHPS as a benchmark. To illustrate its performance, the assimilation was then tested in two basins (Upper Assiniboine River basin in Manitoba and Don River basin in Ontario). The results of assimilating streamflow observations into CHPS using the Ensemble Kalman Filter (EnKF) are also presented.

Project 3-4: Multi-Model Configurations of CAFFEWS*

Jongho Keum[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

The development of the Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS) demands many processes including adapting the selected watersheds, having appropriate hydrologic models and data assimilation modules, building adapters to connect the models with FEWS platform, and configuring forecast/hindcast simulation. Canadian water resources managers, such as forecasting centres and conservation authorities, have used various hydrologic models to meet their operational needs while controlling multiple watersheds. Therefore, it is essential that CAFFEWS offers the ability to run multiple models for a set of watersheds in a single platform, and the possibility of extended analysis, such as through data assimilation and/or Bayesian forecasting system. In the preliminary version of CAFFEWS, the Community Hydrologic Prediction System (CHPS) of US National Weather Service which includes the semi-distributed SAC-SMA model with SNOW17 as a snowmelt estimation component, WatFlood hydrologic model and Raven model are being configured for Don and Humber River watersheds in Southern Ontario. Preliminary test results are presented.

Project 3-4: Model setup for improved reservoir inflow forecast into Shelmouth Reservoir

Frezer S. Awol[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

The main objective of this particular study is to setup a macroscopic land surface distributed model to assist in reservoir inflow forecasting during spring and summer flood periods in Upper

Assiniboine river basin. The study investigates how the wetland, land cover and soil properties of the upper prairie areas could be well represented by the Variable Infiltration Capacity (VIC) model so that the flood and runoff simulation to the Shelmouth reservoir can be improved. The runoff from the land surface VIC model was routed to the river network using RVIC streamflow routing model. The default parameters of VIC model were further refined to improve the calibration output. The dynamic wetland module with in VIC model was activated and the associated wetland parameters were refined based on the vegetation type in the catchment. In addition, the soil parameters were sub-categorized into different soil groups based on the dominant and associated soil types of the basin. The output shows that the calibration was significantly improved by refining the wetland and soil parameters of the VIC model. Prominently, the model was able to simulate and predict floods induced entirely by a significant rainfall and wet antecedent conditions. This can be observed well by the model when it reproduced the 2014 Upper Assiniboine River Flood which was caused by a significant rainfall. Although the model can simulate such summer floods, the equivalent one-in-300-year flood event of 2011 Flood in the area which was caused by winter snow pack and spring melt was slightly underestimated by the model. The model will be further investigated to better represent spring melt induced floods.

Project 3-4: Evaluation and bias-correction of SNODAS SWE estimates for Canadian watersheds

Zahra Zahmatkesh[1], Dominique Tapsoba[2], James Leach[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON
2. Institut de recherche d'Hydro-Québec, Varennes, QC

The National Weather Service's SNOw Data Assimilation System (SNODAS) provides daily, gridded estimates of snow water equivalent (SWE), at a 1-km2 resolution. These products are useful to support hydrologic modelling for simulating spring runoff from snowmelt. To investigate the accuracy of SNODAS snow products for Canadian basins, this study developed a method to compare gridded SNODAS SWE estimates with the ground-measured snow. An interpolation method was utilized to spatially distribute snow observations over the basin onto a 1x1 km grid. Three study areas across Canada were selected including the Columbia River Basin, the Ottawa River Basin, and the La Grande River Basin. A bias-correction method based on cumulative distribution function matching as well as cluster analysis was used to correct the SNODAS SWE based on the interpolated SWE. To evaluate the bias-corrected SNODAS SWE for modeling purposes, the data was used in two hydrologic models, i.e., McMaster University-Hydrologiska Byråns Vattenbalansavdelning (MAC-HBV) and SACramento Soil Moisture Accounting (SAC-SMC), for streamflow simulation. Comparing the corrected SWE with the measured observed SWE indicates that the bias-correction method can significantly improve the accuracy of SNODAS data. Moreover, the results show that utilizing the corrected SWE in hydrologic modeling can noticeably improve the performance of streamflow and peak flow simulation. Although uncertainty of SNODAS products is high for Canadian basins, these data could be of great value for hydrologic modeling where snowmelt is an important component of the water cycle, specifically for regions with few number of ground-based snow stations

Project 3-4: Identification of snowmelt estimation techniques to enhance spring peak flow prediction

Jetal Agnihotri[1], Tara Razavi[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

In cold and snowy countries, accurate spring flood forecasting requires adequate snowmelt estimation technique especially in snow-dominated watersheds. The potential of two snow estimation models, a simple Degree-day method and comparatively sophisticated SNOW-17 model are investigated to capture spring flows at La-Grande River Basin (LGRB), Quebec and Upper Assiniboine river basin (UARB) at Shellmouth Reservoir, Manitoba in Canada. To facilitate the reservoir inflow forecasting, McMaster University Hydrologiska Byrans Vattenbalansavdelning (MAC-HBV) and Sacramento Soil Moisture Accounting (SAC-SMA) rainfall-runoff models are used. An experiment on parameter optimization for the above model configurations, based on annual and seasonal (spring) calibration is also presented. The model validation results indicate that, Degree-day method significantly improves the spring flow simulations as compared to SNOW-17 model at UARB. While the model performance at LGRB reveals that SNOW-17 model is slight better than degree-day method (~5 % model improvement). Moreover, the experiment suggests that for majority of the model combinations, the model performance is better (not significantly) with seasonally optimized models than with annually calibrated models at both the study areas. Conclusively, the results imply that employing simple yet computationally less demanding degree day method and seasonally calibrated models to produce better peak flow predictions than the SNOW-17 model and annually optimized models.

Project 3-4: Evaluation of radar assimilated quantitative precipitation estimates for enhanced calibration of flood forecasting models

Dayal Wijayarathne[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Today, different quantitative precipitation estimates (QPEs) are produced by merging multiple QPEs with radar to improve the accuracy of the precipitation estimates. Integration of multiple QPEs can alleviate deficiencies in the single radar and provides more accurate detection of physical processes and quantitative precipitation estimates. Those products provide a fixed Cartesian grid with rainfall accumulation data summarized over a particular time. In this study, two-step validation process; 1. Point-to-point (P2P) & 2. Map-to-Map (M2M) is used to evaluate Canadian Precipitation Analysis (CaPA), National Mosaic and Multi-Sensor (NMQ), and Multi-Radar Multi-sensor (MRMS) to assess their ability to capture the spatial distribution of precipitation especially for extreme events. Inter-comparison between precipitation surfaces generated by different Geo-statistical interpolation techniques are also used as a part of QPE validation. Validation is performed assuming gauges as ground truth, and the standard forcing for the hydrologic models. Validation will be followed by event-based modeling tests using lumped, semi-distributed and distributed hydrologic models to verify the reliability and accuracy of QPEs as an additional data source for model calibration. The poster presents an outline of the study plan and some of the preliminary results.

Project 3-4: Inter-comparison of the performance of lumped hydrological models in data poor watersheds

Pedram Darbandsari[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

In watersheds with low data availability where the discharge at the catchment outlet is one of the main interest, using simple lumped hydrological models could be a good choice for streamflow prediction. The main goal of this research is to adapt, apply and evaluate the performance of various lumped hydrological models in data poor watersheds in Ontario. The Sacramento soil moisture accounting (SAC-SMA), the McMaster University Hydrologiska Byrans Vattenbalansavdelning (MAC-HBV) and modified version of the Soil moisture and accounting routing (SMARG) conceptual lumped rainfall runoff models as well as three different lumped models being developed based on the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) are compared for daily stream flow prediction. These six lumped hydrologic models are compared based on selected model performance criteria. The results suggest that although some of the HEC-HMS based models showed some good potential in reproducing the observed streamflow, the three other conceptual models (i.e. SAC-SMA, MAC-HBV and SMARG) provide more accurate results. Moreover, the best performing model is the MAC-HBV which also simulates high flows (more than 75 percentile) more accurately in comparison to the other aforementioned models.

Theme 4: Risk Analysis of Physical, Socio-Economic and Environmental Impacts of Floods

Project 4-1: Role of Floods on Aquatic Ecosystem Condition

Project 4-1: Environmental Effects of Flooding: Project Update*

***Marguerite Xenopoulos*[1]**

1. Trent University, Peterborough, ON

Project 4-1: Natural land cover in agricultural catchments alters flood effects on DOM composition and decreases nutrient levels in streams*

***Christina Fasching*[1] *& Marguerite Xenopoulos*[1]**

1. Trent University, Peterborough, ON

Streams and rivers play a major role in carbon cycling at the reach to global scale, controlling the input, transport and transformation of both terrestrial and autochthonous organic matter. Flooding events are expected to significantly alter the inputs and the ability of streams to effectively process received nutrients and dissolved organic matter (DOM). In light of increasing extreme events in the Anthropocene, a better understanding of agriculture and managed system is required so that we are prepared for a possible change in their ecological resilience. Here we analyzed spatio-temporal event-based data from 21 predominantly agricultural catchments with varying contributions of natural land cover like wetlands in Manitoba, Ontario. We studied the effect of extreme hydrological events on stream dissolved phosphorus (TDP) and nitrogen (TDN) concentrations and DOM composition and bioavailability, monitoring streamwater dissolved organic carbon (DOC) and a suite of DOM characteristics across varying hydrological and climatic conditions over four years. Our results suggest the flow regime to control stream DOM dynamics, modulated by seasonal processes and catchment characteristics, like soil organic matter (SOC) content. General additive models revealed the nonlinear interaction between catchments characteristics and discharge to control nutrient and DOM dynamics as well as its bioavailability. While high flow event generally led to an increase of DOM and nutrients, this increase was much more pronounced in predominately agricultural catchments with little or no natural land cover. In these catchments DOC concentration was generally elevated but characterized by a more microbial-like fluorescence signal (as characterized by EEMs and absorbance measurements). The combined occurrence of elevated autochthonous DOM and higher levels of nutrients at higher flows likely supported the increased microbial degradation (BDOC). In contrast, catchments with natural land cover, such as wetlands and grassland, led to more variable DOC concentrations and a greater proportion of terrestrial-like DOM, with high flow events having a less pronounced effect on the export of nutrients from the catchments. Our study highlights the relevance of natural land cover and catchment characteristics in determining how the flow regime controls the composition and dynamics of DOM and nutrients in streams.

Project 4-1: Hydrological and Flooding Effects on Stream Nutrient Levels*

Sarah D'Amario[1] & Marguerite Xenopoulos[1]

1. Trent University, Peterborough, ON

Stream solutes are strongly linked to hydrology, and as such, we sought to better understand how hydrology, particularly flooding, influences nitrogen (N) and phosphorus (P) levels. We used a long-term dataset of monthly water quality samples for many Ontario, Canada, catchments to assess the effects of landscape variables, such as land use and physiography, on the export of nutrients during floods, and to characterize overall concentration-discharge patterns. In general, we found that landscape variables could partially explain the export variation in flood waters, but that the importance of specific variables depended on flood characteristics. We also found that overall concentration-discharge relationships for N and P C were positive, but non-linear, with greater concentrations on the rising limb of the hydrograph depending on the nutrient. With these results, we have identified general patterns between nutrients and hydrology, which will be helpful for managing the ecological effects of flooding.

Project 4-3: Modelling-based Integrated Assessment on Flood Impacts on Urban and Rural Water Resources Systems

Project 4-3: Modelling-based Integrated Assessment on Flood Impacts on Urban and Rural Water Resources Systems: Project Update*

***Amin Elshorbagy*[1]**

1. University of Saskatchewan, Saskatoon, SK

Project 4-3: Improving Peak Flow Prediction under Complex Reservoir System in the Canadian Prairies*

***Mohamed Ahmed*[1]*, Amin Elshorbagy*[1] *& Alain Pietroniro*[2]**

1. University of Saskatchewan, Saskatoon, SK
2. Water Survey of Canada, Environment and Climate Change Canada, Saskatoon, SK

Prairies are characterized by cold and sub-humid climate where the majority of streamflow, especially peak flows during floods, is driven by snowmelt over frozen soil. The Qu'Appelle River Basin (QRB) in Saskatchewan has numerous land depressions and a complex lake system with operating rules and demands that pose additional challenges to large-scale watershed modelling and flood prediction in the prairies. Although considerable efforts were made to model the runoff process under the complexity of numerous land depressions in the prairies, efforts are still needed to improve flood prediction under the complexities associated with the existence of managed lakes (reservoirs), variable demand, and backflows from the river to upstream lakes. There is a need to increase focus in this direction by establishing appropriate methodologies for modelling both prairie floods and reservoir complexities. This study aims at improving prairie flood prediction capabilities of existing hydrological models, and modelling the complex hydrological system associated with managed lake system of the QRB. In this study, a hybrid modelling approach is developed for the QRB. In the hybrid approach, a watershed model handles the runoff generation from the headwater sub-basins, then, the resulting outflows are fed into a separate reservoir model that handles the dynamics of a series of lakes and backflow effects to arrive at the streamflow format the outlet of the QRB. The watershed modeling of the Qu'Appelle river sub-basins is handled by two different models, representing two watershed modeling alternatives. The first model is Modelisation Environmentale Communautaire (MEC)—Surface and Hydrology (MESH), which is a physically based model that is being used for runoff prediction in Canada. The second model is HBV_PRAIRIE, which is a conceptual bucket model that is modified in this study to handle the pothole storage complexities and to better simulate the prairie streamflow. In both MESH and HBV_PRAIRIE, the regular calibration techniques that aim at preserving the overall hydrograph are replaced with ones that focus on peak flow prediction to reduce error propagation in peak flow to the reservoir model for accurate prediction of the QRB peak outflow. For the selected sub-basins, results show that the HBV_PRAIRIE model shows potential in predicting peak flows when compared to the MESH model. In addition, results indicate an improvement in the prediction of peak flows for both models, when using peak calibration techniques. However, the accuracy of simulating low flows is affected, and this can be accepted when high flows prediction is more important than low flows. For the complex lake system of the QRB, the reservoir model shows potential in simulating the QRB outflow and lake dynamics, which suggests that the hybridization approach is convenient to the complex system of the QRB. Further effort is needed for better simulation of the QRB lake levels.

Project 4-3: Impacts of Land Use and Climate Change on the Drainage of the Davis Creek Subwatershed

Jun Wang[1] & Yiping Guo[1]

1. McMaster University, Hamilton, ON

Climate and land use changes have significant impacts on the hydrological behaviors of urban catchments. Hydrological modelling is useful to numerically simulate and evaluate the hydrological responses of urban catchments to land use and climate changes. In this study, the Storm Water Management Model (SWMM) is chosen to simulate the changes of hydrological responses in the Davis Creek subwatershed, which is a representative flood-prone urbanizing catchment located in the west part of the City of Hamilton. After calibration, the effectiveness of existing stormwater detention ponds on flood control is evaluated. Under the scenario representing future land uses, changes of peak flows at specific junction nodes of the stream are evaluated and a new detention pond is proposed for peak flow control with a specified storage-discharge relationship obtained from the modelling of the response of the catchment under a set of design storms of different return periods. Considering the impact of future climate change, different design storms based on updated future IDF curves are used in the simulation. Future climate change would generate an increase of up to 134.8% in peak flows despite of proposed control ponds. In order to mitigate the impacts of future land use and climate changes on flood control, stormwater management strategies including increasing storage of detention ponds and expansion of urban drainage pipe sizes are both suggested after simulations and analyses. Specifically, new control ponds with an average of 160 m3/ha storage to control the design storm of 100-year return period are required to be installed downstream of the subcatchments directly discharging into some of the junction nodes. For the existing detention ponds, an average 12.4-times increase in their storage is required to mitigate the impacts of climate change. Average increasing rates of 9.64% and 7.46% of sewer pipe diameters are required for conveying peak flows from design storms of 5 and 50-year return periods, respectively.

Project 4-4: Flood Risk Analysis and its Utility for Management Decisions

Project 4-4: Framework for National Flood Risk Assessment for Canada*

Amin Elshorbagy[1]

1. University of Saskatchewan, Saskatoon, SK

Project 4-4: Flood hazard assessment at different spatial scales in Canada*

Bharath Raja[1] & Amin Elshorbagy[1]

1. University of Saskatchewan, Saskatoon, SK

Developing a systematic approach for food risk analysis to quantify the risk under uncertainty and utilize its quantification for management and planning purposes are the main objectives of project 4-4. We extend a few of the approaches presented in the previous Floodnet meetings and also present the results related to new approaches being developed. In the first part, we present the results of a probabilistic flood hazard mapping technique in the prairies. The parameters of a hydrodynamic model and inflow hydrographs are perturbed within a plausible range to determine the probability of flooding of a location for a river reach in the Qu'Appelle River basin in Saskatchewan. Results indicate that the influence of the channel and floodplain roughness parameters on the flooding extents is higher in the steeper stretches of the river, compared to the flatter stretches. Our earlier development of a topography-based hazard mapping for Canada is evaluated against the detailed probabilistic hazard maps obtained in this study and a good level of agreement between both maps was observed.

The second part of the study focusses on quantifying the flood extents along the 440 km long Qu'Appelle River that is influenced by the presence of eight controlled and uncontrolled lakes of varying capacities. A two-dimensional hydraulic model is developed for the entire river reach and the flooding extents along the river are determined during high flows. The operation of the lakes during high flow years has an effect on the flooding along the river and it is simulated in the hydraulic model and hence, the initial lake levels are perturbed within the operational range to determine the effect of the lake levels on flooding along the river. Results are presented as flood extents maps and the flow at the Qu'Appelle River Basin outlet (at Welby) for different scenarios.

In the third part, flood hazard maps corresponding to different return periods are developed for multiple river basins using a combination of frequency analysis and geographical information systems. Frequency analysis of streamflow is carried out at multiple stream gauges in Canada to determine flows associated with different return periods, and water surface elevations corresponding to these flows are determined using stage-discharge relationships at those locations. Subsequently, the flood water levels are translated into flooding extents along the river reach. This approach can be used to arrive at a preliminary assessment of flooding extents for different return periods without the use of hydraulic modelling and can also be used along with the classified hazard map for Canada to obtain flooding extents at ungauged locations.

Project 4-5: Assessing and Planning for the Socio-Economic Effects of Floods*

Niko Yiannakoulias[1], J. Connor Darlington[1] & Julien N. Gordon[1]

1. McMaster University, Hamilton, ON

Project 4-5: Serious Games as a Research Tool: Using a Digital Role-Play Experiment to Model Flood Risk Mitigation Decisions*

Julien N. Gordon[1] & Niko Yiannakoulias[1]

1. McMaster University, Hamilton, ON

Private flood risk mitigation measures, including flood insurance, are important components to integrated flood risk management. Household decisions about whether or not to mitigate can directly and indirectly influence vulnerability to the flooding of a community. Gathering quality data about these household decisions could improve uptake of protective measures against floods by addressing social barriers to implementation. Alternative data gathering approaches such as Serious Games (SGs) may augment conventional stated preference surveys used to study environmental decision making. SGs can be useful in situations where it may be too costly, time-consuming, or unsafe to gather other types of data. Additionally, the immersive experience of the narrative involved in playing a game may assist in collecting richer data about decision-making, over the potentially abstract experience of a survey.

This project involves building a website-based research tool called Decision Game, a role-play exercise designed to collect data around flood risk mitigation and insurance decisions. In this game, participants make decisions about where to live and how to distribute limited income, given geographical information, including flood risk, about the city. Results showed that factors which predicted mitigation behaviour in the game were relatively consistent with the literature, which suggests that there is potential in the role play game approach for studying mitigation decisions. The in-game flood event was a major predictor of mitigation decisions. In-game income was a predictor of whether or not a person mitigated, but real-life income was not. Risk perception showed a relationship with risk mitigation. The results of this study illustrate the potential of SGs as a tool to collect data on risk mitigation behavior that could augment other data collection strategies, and improve our ability to predict and understand risk mitigation behavior.

Project 4-5: Sociodemographic Vulnerability to Flooding in Calgary, Hamilton and Winnipeg

Connor Darlington[1] & Niko Yiannakoulias[1]

1. McMaster University, Hamilton, ON

This study examines sociodemographic and socioeconomic vulnerability to flooding in Calgary, Hamilton and Winnipeg (Canada). Dissemination level financial, demographic and housing characteristics were analysed using a multiple linear regression to distinguish the effect of flood hazard on vulnerability between 1991 and 2016 using each Canadian census year. Modelled predictions of this data were graphed for each variable per city to display the relationship of each vulnerability measure by flood risk. This study shows that increasing flood hazard levels are associated with the lowest sociodemographic and socioeconomic vulnerability in each of the city's highest flood hazard areas. Flood hazard has a positive association with average family income, average dwelling value, and post-secondary education and a negative association with unemployment. Average dwelling values have been increasing faster in higher flood hazard areas within each city than in lower flood hazard areas. Demographically, flood hazard has a negative association with vulnerable populations including self-identified visible minorities, Aboriginal and immigrant populations. High flood hazard areas are more likely to have a higher proportion of migrants, indicating a higher influx of residents from different census subdivisions. These findings indicate that the highest risk flood hazard areas in Calgary, Hamilton and Winnipeg are composed lower vulnerability populations, suggesting that the greatest at-risk populations in these cities may also have the greatest coping capacity in the event of a flood event. This has implications into flood protective measures, the future of any risk-sharing amongst high-risk communities, and the affordability of flood insurance.

Project 4-5: Quantifying land use change using supervised classification in Calgary, Hamilton and Winnipeg

Michele Tsang[1] & Darren Scott[1]

1. McMaster University, Hamilton, ON

Historically, some of the most disastrous floods in Canada have occurred in Winnipeg and Calgary, due to the presence of nearby rivers. The high frequency of flooding events in recent decades has been linked to rapid urban expansion, increasing the rate of runoff due to the removal of vegetation and soil. Using remote sensing techniques, we quantify land use change to determine the potential areas at risk and identify the population that will be most vulnerable during flooding events. The study was carried out in three census metropolitan areas in Canada: Calgary, Hamilton and Winnipeg for the years 1991, 1996, 2001, 2006, 2011 and 2016. Supervised classification was used to classify 30-meter resolution rasters into 4 land cover types: developed, barren, vegetated and water. Over time, all three cities experienced a significant increase in developed area. From 1991 to 2016, Calgary had the greatest increase of developed area, while Hamilton had the highest proportion of the city convert to developed area, as it is the smallest city of the three. These regions are of concern as they will experience flooding more frequently, even for low intensity or short duration rainfall events. In order for cities to meet the increasing demand of residential and commercial infrastructure, appropriate land management policies must be employed to minimize the number of people effected from future flooding disasters.

Partner and Collaborator Invited Presentations

High-flow warnings based on the Water Cycle Prediction System for the Great Lakes and St. Lawrence River*

D. Durnford[1], V. Fortin[1], H. Wazneh[2], P. Coulibaly[2]

1. Meteorological Research Division, Environment and Climate Change Canada, Dorval, QC
2. McMaster University, Hamilton, ON

The Water Cycle Prediction System for the Great Lakes and St. Lawrence River is a regional scale Earth system model which is used to forecast water supplies to the Great Lakes for the next 3.5 days (Durnford et al., 2018). In order to do so, it is required to forecast flows for all tributaries of the Great Lakes watershed. For the period of May 2016 - September 2017, simulated and forecast flow for 252 stream gauges monitored by Environment and Climate Change Canada (ECCC) and having watershed areas larger than 100 km2 were compared to observed flow in order to evaluate the skill of the model at predicting high flows (Wazneh et al., in preparation). For the vast majority of rivers, the Nash-Sutcliffe criterion is positive and the true positive rate is higher than the false alarm rate when it comes to predicting seasonal flows of return period 1.25 year. Based on these encouraging results, a high flow warning product has been developed. It provides information on the number of hours left before daily mean flow is expected to exceed flow corresponding to various return periods. The product is displayed on a map, with each gauge being shown in a colour that reflects the time remaining before the threshold is crossed.The maps can be used internally to help maximize the efficiency and safety of flow monitoring operations but could also provide useful information for flood forecasting applications. This simple way of communicating high flow forecasts is illustrated for a recent rain-on-snow event in Southern Ontario and extension of the methodology to ungauged locations is discussed.

Projected Changes to the Frequency of High-Flows in the Athabasca Watershed: Sensitivity of Results to Statistical Methods of Analysis*

Y. Dibike[1], H-I. Eum[2] & P. Coulibaly[3]

1. Environment and Climate Change Canada, Victoria, BC
2. Alberta Environment and Parks, Calgary, AB
3. McMaster University, Hamilton ON

Observed and projected changes in global and regional climate are having some implications on the various components of the hydrologic-cycle, such as snow accumulation and melt, soil moisture and runoff affecting local hydrological regimes including the frequency and severity of high-flow events. Flood frequency analysis has generally been used to model extreme flows under the stationary assumption; however, with a changing climate, the assumption of stationarity is being challenged and non-stationary analysis is becoming more prominent. This study examines projected changes in the frequency and magnitude of high-flow events in the Athabasca watershed in Alberta, using the Variable Infiltration Capacity (VIC) hydrological model driven by a select-set of statistically downscaled climate change scenarios from the latest Coupled Model Inter-comparison Project (CMIP5). Analysis of the streamflow projections at different locations along the Athabasca River indicates projected increases in streamflow during the winter and spring and decreases during the summer and early fall seasons, with overall increases in high-flows, especially for low frequency events. The non-stationary analyses show relatively larger projected increases in the magnitudes of high-flows compared to that of the stationary methods, especially for the downstream stations. The study also revealed that the projected changes vary over a wide range, especially for low frequency events, depending on the driving climate model and the statistical method of flood frequency analysis and the inter-model variabilities generally increased with increases in the return periods. Nevertheless, the range of projected changes in high-flow events resulting from the multiple statistical methods of analysis is found to be relatively smaller than that from the multiple climate models used to drive the model.

Recent development in applied hydrology in Quebec aiming to support flood mitigation*

***R. Turcotte*[1]**

1. Centre d'Expert. Hydrique du Québec, Québec, QC

Major development activities realised by the Quebec government in the field of flood forecasting and impact of climate change on floods will be presented. Covered topics will be : the new version of the large scale application of the Hydrotel model over the entire southern Quebec, the implementation of the Deltares-FEWS for flood forecasting, the features of 2018 Hydroclimatic Atlas presenting historical and projected streamflows for gauged and ungauged rivers, and the newly announced Info-Crue service that implies large scale implementation of hydraulic models. The collaboration with the Ouranos consortium aiming to develop applied R&D for moving toward adaptation to climate change in flood mitigation will also be described.