FloodNet Annual General Meeting 2016 Scientific Program

NSERC Canadian FloodNet 2nd Annual General Meeting: DAY 1-19 September 2016 Agenda	
Registration and Breakfast D1: 8:00-8:30 AM	**Breakfast and Registration in Toscana A** • All participants register and enjoy breakfast
D1: 8:30-8:45 AM	**Welcome, Introduction and Network Update** Dr. Paulin Coulibaly, FloodNet Scientific Director
D1: 8:45-8:50 AM	**Welcome Words from FloodNet Board of Directors** Dr. Alain Pietroniro, Chair of FloodNet Board of Directors
SESSION 1: THEME 1 - FLOOD REGIMES IN CANADA: LEARNING FROM THE PAST AND PREPARING FOR THE FUTURE (Chairs: Dr. Wazneh & Ms. Scheepers)	
Project 1-1 D.H. Burn D1: 8:50-9:20 AM	**Update of Current Flood and Storm Quantiles** Project Update *D. H. Burn* Investigating Techniques for Flood Quantile Estimation in Canada *S. M. Zadeh & D. H. Burn*
Project 1-2 F. Ashkar D1: 9:20-9:50 AM	**Examination of Spatial and Temporal Variation of Extreme Events** Project Update *F. Ashkar & D.H. Burn* New Results on the Discrimination Between Statistical Distributions for Hydrological Frequency Analysis *I. Ba & F. Ashkar*
D1: 9:50-10:20 AM	**Coffee Break**
Project 1-3 A. Arain D1: 10:20-10:50 AM	**Analysis and Applicability of Future Extreme Events in Regional and Local Context** Spatial and Temporal Climate Trends in Canada *H. Wazneh, M.A. Arain & P. Coulibaly* Past and Future Evolution of Streamflow in Southern Ontario *O. Champagne, M.A. Arain & P. Coulibaly*
Project 1-4 V. Nguyen D1: 10:50-11:20 AM	**Development of New Methods for Updating IDF Curves in Canada** Summary of Research Progress and Further Works *V.T.V. Nguyen* SMExRain: A Decision Supports Tools for Construction of IDF Relations for Current Climate *T.H. Nguyen & V.T.V. Nguyen* SDExRain: A Decision Support Tool for Assessing the Climate Change Impacts on IDF Relations *M.H. Yeo & V.T.V. Nguyen*

	Overview of Stochastic Modeling of Extreme Rainfall Processes *S. El-Outayek & V.T.V. Nguyen*
Project 2-1[*] B. Tolson D1: 11:20-11:50 AM	**Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on a Single Model** Project Update *Bryan Tolson* Forecasting in Madawaska Watershed Considering Parameter Uncertainty *H. Liu & B. Tolson*
D1: 11:50-12:50 PM	**Lunch**
D1: 12:50-1:20 PM	**KEYNOTE ADDRESS** **Challenges of Forecasting the Red River of the North** ***Dr. Pedro Restrepo***
SESSION 2: THEME 2 – QUANTIFYING AND REDUCING THE PREDICTIVE UNCERTAINTY OF FLOODS (Chair: Dr. Tilmant)	
Project 1-5[†] A. Binns D1: 1:20-1:50 PM	**Spatial Changes to Flood Prone Areas in Urban Environments** Project Update *A. Binns & T. Kokas*
Project 2-2 F. Anctil D1: 1:50-2:20 PM	**Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on Multiple Models** Project Update *F. Anctil* Investigating Quality and Value of Dissimilar Streamflow Forecasting Systems *A. Thiboult, F. Anctil, & M.-H. Ramos* Hydrological evaluation of the Canadian meteorological ensemble reforecast product *M. Abaza & F. Anctil*
D1: 2:20-2:50 PM	**Coffee Break**
Project 2-4 F. Anctil D1: 2:50-3:20 PM	**Evaluation of Flood Warning Based on Hydraulic Model with Assimilation and Hydrological Ensemble Forecasts** Project Update *F. Anctil & A. Thiboult* Ensemble Forecasting of Water Levels in Rivers with Data Assimilation: Application to Chaudière River in Quebec *M. A. Bessar & F. Anctil*
Project 2-5 A. Tilmant D1: 3:20-3:35 PM	**Real-time Reservoir Operation Based on a Combination of Long-term and Short-term Optimization and Hydrological Ensemble Forecasts** Project Update *A. Tilmant*

SESSION 3a: DEVELOPMENT OF CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) (Chairs: Dr. Keum & Dr. Razavi)	
Project 3-1 P. Rasmussen D1: 3:35-4:05 PM	**Evaluation of Flood Forecasting and Warning Systems Across Canada** Overview of River Flood Forecasting Practices in Canada *S. Jha, Z. Z. Aliabadi & P. Rasmussen*
Project 3-2 A. Berg D1: 4:05-4:35 AM	**Real-time Spatial Information Evaluation and Processing** Project Update *A. Berg* A Relationship Between Satellite Derived Soil Moisture Anomalies and Watershed Runoff Ratios over Canadian Watersheds *E. Ueckermann & A. Berg*
SNEI K. Kornelsen D1: 4:35-5:00 PM	**NSERC FloodNet Strategic Network Enhancement Initiative** *K. C. Kornelsen & V. Smakhtin*
SESSION P1: NSERC CANADIAN FLOODNET POSTERS (Chairs: Dr. Jha & Mr. Leach)	
D1: 5:00-6:30 PM	**Poster Session P1 And Networking**
D1: 6:30-9:00 PM	**Networking Dinner**

* Project 2-1 is part of Theme 2. Presentation timing is due to a scheduling conflict.

† Project 1-5 is part of Theme 1. Presentation timing is due to a scheduling conflict.

NSERC Canadian FloodNet 2nd Annual General Meeting: DAY 2 – 20 September 2016 Agenda	
Breakfast D2: 8:00-9:00 AM	**Breakfast (All Participants)** **Board of Directors Meeting (York Room)** **Partner Advisory Committee Meeting (MacKenzie Room)**
SESSION 3b: DEVELOPMENT OF CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) (Chairs: Dr. Keum & Dr. Razavi)	
Project 3-3 W. Zhuang D2: 9:00-9:30 AM	**Enhanced Information Communication Systems** Project Update *W. Song* Joint Scheduling and Transmission Power Control in Wireless Ad Hoc Networks *K. R. Malekshan & W. Zhuang*
Project 3-4 P. Coulibaly D2: 9:30-10:00 AM	**Development of Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS)** Project Update *P. Coulibaly* Uncertainty Estimation through Bayesian Forecasting System (BFS): An Application to Humber River Watershed in Southern Ontario, Canada *S. Han & P. Coulibaly*

D2: 10:00-10:30 AM	**Coffee Break**
SESSION 4: THEME 4 – RISK ANALYSIS OF PHYSICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF FLOODS (Chairs: Dr. Jha & Ms. D'Amario)	
Project 4-1 M. Xenopoulos D2: 10:30-11:00 AM	**Role of Floods on Aquatic Ecosystem Condition** Environmental Effects of Flooding *M. Xenopoulos* Factors Influencing Stream Nutrient Concentration-Discharge Relationships in Ontario and Manitoba Streams *S.C. D'Amario, H. F. Wilson, R. Metcalfe, M.A. Xenopoulos*
Project 4-3 A. Elshorbagy D2: 11:00-11:30 AM	**Modelling-based Integrated Assessment on Flood Impacts on Urban and Rural Water Resources Systems** Project Update *A. Elshorbagy* Development of a Suitable Hydrological Model for Streamflow Simulation in Canadian Prairie Watershed *M.K. Hussein & A. Elshorbagy*
Project 4-4 A. Elshorbagy D2: 11:30-12:00 AM	**Flood Risk Analysis and its Utility for Management Decisions** Framework for National Flood Risk Assessment for Canada *A. Elshorbagy* Hydraulic Modeling of Moose Jaw River for Flood Risk Assessment *R. Bharath & A. Elshorbagy*
Project 4-5 N. Yiannakoulias D2: 12:00-12:15 PM	**Assessing and Planning for the Socio-Economic Effects of Floods** Using Experimental Games to Understand Flood Decision Making *J. Gordon & N. Yiannakoulias*
D2: 12:15-1:15 PM	**Lunch**
Working Group Meetings D2: 1:15-2:30 PM	**Working Group Meetings** Working Group 2 & 3 (Themes 2 & 3) Working Group 1 (Theme 1) Working Group 4 (Theme 4)
D2: 2:30-3:00 PM	**Coffee Break**
D2: 3:00-3:45 PM	**ISAP & PAC Feedback** (Chairs: Dr. Singh & Dr. Fortin)
D2: 3:45-4:00 PM	**Closing Remarks** (Dr. Pietroniro & Dr. Coulibaly)

The Book of Abstracts is available online at
http://tinyurl.com/hqlkrry

FloodNet NSERC

FloodNet Annual General Meeting 2016 Book of Abstracts

Note: Asterisk indicates oral presentation

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*

***Donald H. Burn*[1]**

1. University of Waterloo, Waterloo, ON

Floods are arguably the most common natural disaster with considerable social, economic and environmental consequences. Damages from floods can include property loss, destruction of infrastructure, loss of life, social and economic disruption from evacuations, and environmental degradation. This FloodNet project explores ways to better estimate the probability of occurrence of extreme events. The research is providing updated estimates for flood and extreme rainfall quantiles for many locations across Canada and is working towards a unified procedure for applying frequency analysis that reflects the diversity of hydrologic and meteorological conditions in Canada. The research adopts a regional (pooled) approach to frequency analysis. Important aspects of the pooled approach will be presented and future plans will be discussed.

Project 1-1: Investigating Techniques for Flood Quantile Estimation in Canada*

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

1. University of Waterloo, Waterloo, ON

As one of the most destructive natural hazards, floods have a devastating influence on various aspects of human society and the environment. Understanding of the frequency of floods is essential for effective flood mitigation. Estimation of these frequencies is difficult since extreme events are by definition rare and the length of the recorded data is often short. This component of FloodNet research aims to explore different methodologies in flood frequency analysis and will provide updated flood quantile estimation for many locations across Canada, as well as developing a standardized approach to estimate these quantiles in Canada. This research will explore ways to better estimate the probability of occurrence of flood events based on a pooling (regionalization) approach. In the context of pooled flood frequency analysis, this work considers annual maximum flow series, partial duration flow series, and also nonstationary flow series. Among different regionalization approaches, the region of influence (ROI) approach was employed in a case study to identify homogeneous regions for annual maximum flow series. This study employs the seasonality (timing) of the flood events as the basis for a similarity measure for grouping catchments. The method was applied to a set of catchments in Atlantic Canada. The results demonstrate the effectiveness of the regionalization technique based on flood seasonality for estimating extreme flow quantiles for the catchments under study.

Project 1-1: Automatic Feature Selection and Weighting for the Formation of Homogenous Groups for IDF Estimation

Zhe (Emma) Yang[1] & Donald H. Burn[1]

1. University of Waterloo, Waterloo, ON

The IDF curve has been widely accepted as an effective tool to provide the essential hydrological information for urban planning. However, the impacts from recent climate change and urbanization have caused the traditional IDF estimates to become increasingly inaccurate. Under the non-stationary environment, an approach for automatic feature selection and weighting for the homogeneous group formation at a specific region is proposed in this research to improve the current IDF estimation. According to the vertical structure of the planetary boundary, the time series of multiple features in three successive sub-layers will be selected to consider the impacts of urbanization and climate change on the rainfall climatology. Then, the hybrid searching algorithm of Tabu search and clustering will be applied sequentially at different layers to obtain the optimal subsets of attributes and their corresponding weights. The three-layer hierarchical searching is designed to save the computational time and accommodate the need of separating possible stationary and nonstationary features during clustering. The results demonstrate the effectiveness of the approach for extreme rainfall quantiles estimation in the catchments under study. This approach fills in the gap of including the urbanization impacts in the pooling group formation; furthermore, it challenges the traditional assumption that the same set of features can be equally effective in generating the optimal homogeneous group for the regions with different geographic and meteorological characteristics.

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

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

***Fahim Ashkar*[1]**

1. Université de Moncton, Moncton, NB

We will outline research results obtained during the past year, as well as planned short-term research, by team members working in Project 1-2 on the following themes:1)Assessing whether and how changes in flood events are occurring over time in various regions of Canada. Changes have been studied at hydrometric stations across Canada, and significant regional or local increasing or decreasing trends have been identified. Rates of change during the period of record have been quantified.2)Identifying regions where seasonal variations in floods need to be incorporated into flood modelling due to the presence of distinct flood sub-populations. In the coming year, we will attempt to identify geographical regions with distinct flood sub-populations. When necessary, seasonal models will be developed that would be more appropriate than non-seasonal ones. We will attempt to identify/develop homogeneity tests capable of statistically confirming whether or not seasonal modelling is needed at a specific hydrological site.

Project 1-2: New Results on the Discrimination Between Statistical Distributions for Hydrological Frequency Analysis*

***Ismaila Ba*[1] *& Fahim Ashkar*[1]**

1. Université de Moncton, Moncton, NB

We will present some new results on the discrimination (choice) between statistical distributions for hydrological frequency analysis. We had presented in 2015 some results on discrimination tests aimed at correctly choosing between the generalized Pareto distribution and other competitive two-parameter models used in peaks-over threshold (POT) modeling. We will update these results by including new research on the Gumbel distribution. Our updated results will show more clearly the advantages of the (modified) Shapiro-Wilk statistic as a model discrimination tool.

Project 1-2: Seasonal Frequency Analysis of Floods in Canada

***Bakary Simpara*[1] *& Fahim Ashkar*[1]**

1. Université de Moncton, Moncton, NB

We will focus on the analysis of flood frequencies in Canada and their temporal distribution during the year. The peaks over threshold method will be used to get a seasonal portioning of the year for each hydrometric station. We will group stations that are similar in their seasonal flood distribution and attempt to group similar stations into geographical regions.

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*

***M. Altaf Arain*[1]**

1. McMaster University, Hamilton, ON

Project 1.3 focuses on to investigate the limitations and applicability of various indices to describe and characterize extreme weather events, in particular precipitation events at local scales. It also strives to explore the applicability of extreme weather indices for predicted future climatic conditions at local scales in selected regions across Canada.

Project 1-3: Spatial and Temporal Climate Trends in Canada*

***Hussein Wazneh*[1]*, M. Altaf Arain*[1]*& Paulin Coulibaly*[1]**

1. McMaster University, Hamilton, ON

Extreme events may have serious impacts on communities and vulnerable populations. In recent years many indices have been developed to describe and characterize extreme weather events. However, the limitations and the applicability of these indices have not been evaluated at regional and local scales and/or using observed and simulated historical climate data. This study provides a regional picture and a deeper understanding of the variability of extreme climate indices across Canada. A suite of climate indices derived from daily observed and simulated precipitation and temperature data, has been computed and analyzed for different regions across Canada. The observed data were obtained from weather station data archives of Environment Canada (EC) and the Canadian Gridded data (CanGrid, 8 km resolution) from the Natural Resources Canada. The simulated data were obtained from the Canadian Regional Climate Model (CanRCM4, 40 km resolution) and some global climate models (GCMs) of the fifth phase of coupled model Inter-comparison Project (CMIP5, 100 km resolution). Annual indices were gridded to explore the spatial and temporal variability of climate trends. Trends in the gridded fields were computed and tested for their statistical significance. Results showed a decline in the frequency of cold temperature extremes, and increase in the frequency of warm extremes. Smaller increase in maximum temperature and larger increase in minimum temperature were observed. Regarding precipitation, the annual total precipitation and the frequency of extreme precipitation experienced an increase. In terms of comparison between observed and simulated data, results showed a mismatch for both temperature and precipitation indices. The historical observed trends in the climate indices were best simulated by the CanRCM4, while the climate indices themselves were better simulated by CCSM4 model developed by the National Center for Atmospheric Research (NCAR) and the CanESM2 of the Canadian Center for Climate Modeling and Analysis. It was found that the use of statistical bias-correction method to downscale climate model data improved the simulated indices trends when compared to observation.

Project 1-3: Past and Future Evolution of Streamflow in Southern Ontario*

Olivier Champagne[1], Altaf Arain[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Major flooding events have occurred in Canada in recent years as a consequence of global warming. Floods disaster occurrences have increased in Canada in the last few decades. Southern Ontario, which houses 1/3 of Canadian population, is an area of high vulnerability for floods. This region is important for agricultural and industrials production in Canada and the Greater Toronto Area is the largest urbanized zone in Canada. Understanding floods and their relationships with climate variability is very relevant in this region. The aim of this research is to understand the hydrological processes in southern Ontario and to assess the future evolution of streamflow and flooding. In this work we are using GS FLOW hydrological model, a coupled soil and subsoil conceptual semi-distributed model, in 3 watersheds across southern Ontario; urban dominated Credit river, the agricultural Bigcreek river watershed and the Thames river a semi-urban watershed. Past observed and Future climate data, simulated by different GCMs for two IPCC greenhouse gases emissions scenarios (RCP4.5 and 8.5), are used as input in the model. Initial results from the Thames river watershed show an increase in runoff in winter due to more rainfall events but a decrease in early spring as a consequence of early snowmelt in the last decades. Future runoff projections for both climate scenarios indicate also an increase in winter and a decrease in early spring which may have serious implications for this region.

Project 1-3: Non-Stationary Analysis of the Frequency and Intensity of Heavy Precipitation over Canada and their Relations to Large-Scale Climate Patterns

Yang Yang[1] & Thian Yew Gan[1]

1. University of Alberta, Edmonton, AB

In recent years, because the frequency and severity of floods have increased across Canada, it is important to understand the characteristics of Canadian heavy precipitation. Long-term precipitation data of 463 gauging stations of Canada were analyzed using non-stationary generalized extreme value distribution (GEV), Poisson distribution and generalized Pareto (GP) distribution. Time-varying covariates that represent large-scale climate patterns such as El Niño Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific decadal oscillation (PDO) and North Pacific Oscillation (NP) were incorporated to parameters of GEV, Poisson and GP distributions. Results show that GEV distributions tend to under-estimate annual maximum daily precipitation (AMP) of western and eastern coastal regions of Canada, compared to GP distributions. Poisson regressions show that temporal clusters of heavy precipitation events in Canada are related to large-scale climate patterns. By modeling AMP time series with non-stationary GEV and heavy precipitation with non-stationary GP distributions, it is evident that AMP and heavy precipitation of Canada show strong non-stationarities (abrupt and slowly varying changes) likely because of the influence of large-scale climate patterns. AMP in southwestern coastal regions, southern Canadian Prairies and the Great Lakes tend to be higher in El Niño than in La Niña years, while AMP of other regions of Canada tends to be lower in El

Niño than in La Niña years. The influence of ENSO on heavy precipitation was spatially consistent but stronger than on AMP. The effect of PDO, NAO and NP on extreme precipitation is also statistically significant at some stations across Canada.

Project 1-3: Regional Flood Frequency Analysis using Support Vector Regression under Historical and Future Climate

Mesgana Gizaw[1] & Thian Yew Gan[1]

1. University of Alberta, Edmonton, AB

Regional Flood Frequency Analysis (RFFA) are statistical methods that are widely used to estimate flood quantiles of catchments with limited streamflow data. In addition, sometimes only a limited number of stations with complete dataset are available from hydrologically similar, surrounding catchments to estimate the flood quantile of certain ungauged sites. Besides traditional regression based RFFA methods, recent applications of machine learning algorithms such as the artificial neural network (ANN) have shown encouraging results in regional flood quantile estimations. Another novel machine learning technique that is becoming widely applicable in the hydrologic community is the Support Vector Regression (SVR). In this study, an RFFA model based on SVR was developed to estimate regional flood quantiles for two study areas, one with 26 catchments located in southeastern British Columbia (BC) and another with 23 catchments located in southern Ontario (ON), Canada. The SVR-RFFA model for both study sites was developed from 13 sets of physiographic and climatic predictors for the historical period. The Ef (Nash Sutcliffe coefficient) and R^2 of the SVR-RFFA model was about 0.7 when estimating flood quantiles of 10, 25, 50 and 100 year return periods which indicate satisfactory model performance in both study areas. In addition, the SVR-RFFA model also performed well based on other goodness-of-fit statistics such as, BIAS (mean bias) and BIASr (relative BIAS). With a fairly limited amount of data available to train the RFFA models, the SVR-RFFA model was also found to perform better than an ANN based RFFA model, and with significantly lower median CV (coefficient of variation) of the estimated flood quantiles. The SVR-RFFA model was then used to project changes in flood quantiles over the two study areas under the impact of climate change using the RCP4.5 and RCP8.5 climate projections of five Coupled Model Intercomparison Project (CMIP5) GCMs (Global Climate Models) for the 2041-2100 period. The results suggest that due to an increase in the mean annual precipitation, and rainfall of a given return period, the flood quantile is projected to increase by about 7% for the southeastern BC and 29% for southern ON region in the mid- and late 21st century.

Project 1-4: Decision Support Tools for Construction of IDF Relations for Current Climate and for Projected Climate Changes*

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

1. McGill University, Montreal, PQ

In recent years, it has been recognized that society has become more vulnerable to extreme storm events. Many studies have been carried out to investigate the variation of these extreme storms. Of particular interest for water infrastructure design is the investigation of the probability of occurrence of the extreme rainfalls using frequency analysis method. Many probability distributions have been proposed to model the extreme rainfall processes. However, there is no general agreement as to which distribution should be used. Therefore, in practice, a number of popular distributions are often selected and their descriptive and predictive abilities are then investigated and compared. This task requires a significant investment of time due to the availability of an excessive amount of observed data from numerous sites and of different temporal scales and record lengths. This paper presents the development of a decision-support tool for statistical modeling of extreme rainfall processes (SMExRain). The proposed tool can be used in assisting stakeholders and decision-makers to identify the most suitable distribution(s) that could provide accurate extreme rainfall estimates. More specifically, the proposed tool can be utilized to evaluate the descriptive and predictive abilities of ten commonly-used probability models, Beta-K, Beta-P, Generalized Extreme Value, Generalized Logistic, Generalized Normal, Generalized Pareto, Gumbel, Log-Pearson Type III, Pearson Type III, and Wakeby, for their accuracy and robustness in the estimation of annual maximum rainfalls. SMExRain was tested using numerous daily and sub-daily extreme rainfall data available from a wide-range raingage network located in Quebec, Ontario, and British Columbia provinces of Canada.

Project 1-4: Statistical Downscaling of Extreme Rainfall Processes (SDEXRAIN): A Decision Support Tool for Assessing the Climate Change Impacts on Local Rainfall Extremes*

Myeong-Ho Yeo[1] & Van-Thanh-Van Nguyen[1]

1. McGill University, Montreal, PQ

In recent years, climate change has been recognized as having a profound impact on extreme weather events. Many studies have been carried out to investigate this impact using outputs from Global Climate Models (GCMs) and downscaling methods. Of particular interest for water infrastructure design is the investigation of the probability of occurrence of extreme rainfalls in the context of climate change. Hence, in this study a decision support tool for statistical downscaling of extreme rainfall processes (SDEXRAIN) was developed to assess the climate change impact on the extreme rainfalls at a given location. More specifically, the SDEXRAIN consists of two components: (i) SDRain: a spatial statistical downscaling model to describe the linkage between global climate variables and daily annual maximum rainfalls at a given site; and

(ii) SDExtreme: a temporal statistical downscaling model to describe the relations between daily and sub-daily annual maximum rainfalls. The feasibility and accuracy of this tool was assessed based on the NCEP re-analysis and observed daily precipitation data available at two raingages with completely different climatic conditions: Seoul station in South Korea and Dorval Airport station in Montreal (Canada). Results of this assessment have indicated that it is feasible to use the SDEXRAIN for describing accurately the relations between climate predictors provided by GCMs under different climate change scenarios and daily and sub-daily annual maximum rainfalls at a given site. Based on the preliminary results, the proposed assessment tool was then applied to annual maximum precipitations (AMPs) at the selected ten raingages in Ontario (Canada) and four different climate change scenario results for the study region given by the Canadian and UK GCMs for the current period (1961-2000) and future periods (2020s, 2050s, and 2080s). In general, it was found that the AMPs based on both CGCM3 and HadCM3 simulations displayed increasing trends for future periods.

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

Project 1-5: Spatial Changes to Flood Prone Areas in Urban Environments: 2016 Update*

***Andrew Binns*[1, 2] *& Tommy Kokas*[2]**

1. University of Guelph, Guelph, ON
2. Western University, London, ON

Project 1-5 is seeking to evaluate the spatial changes to flood prone areas in urban environments. Research over the past two years has focused on understanding how the effect of floods on the environment has changed as a result of changes in land-use (e.g., urbanization) and investigates measures to reduce the effect of urbanization on occurrences of flooding. Current work has used PCSWMM modeling software to study Black Creek in the greater Toronto as a case study location. Future work starting in 2016 will investigate a site in Hamilton, Ontario.

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

Project 1-6: Study of Generalized Logistic Distribution for Flood Frequency Analysis in Canadian Watersheds

Zhiyang Zhang[1] & Peter Rasmussen[1]

1. University of Manitoba, Winnipeg, MB

The Generalized Logistic Distribution (GLO) for frequency analysis has received wide attention over the past decade, especially after the UK recommended it as their default flood frequency distribution. This project focusses on the development of evaluation methods and examination of the performance of GLO on Canadian annual flood records. The poster presents an outline of the study plan and some of the preliminary findings. As there is no general agreement of the best flood frequency distribution in our country, the evaluation methods developed in this project can be further applied to test other distributions and the most appropriate distribution can be recommended for the Canadian flood estimation manual.

Project 1-6: Extreme Rainfall Nonstationary Investigation and Evaluation of Nonstationary-based Intensity-Duration-Frequency (IDF) Curves for Southern Ontario Region in a Changing Climate

Poulomi Ganguli[1], Marc D'Alessandro[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Resilience to nonstationarity in hydroclimatic extremes is prerequisite to accurate assessment of the risk of such events in the changing climate. Even though nonstationarity is often apparent in trends of extremes, in practice, precipitation Intensity-Duration-Frequency (IDF) curves for infrastructure designs are primarily based on stationarity assumptions. Here first we investigate possible nonstationarity in hourly and sub-hourly annual maxima of station-based observed rainfall record in Southern Ontario Region and then explore the potential of nonstationary IDF curves to characterize rainfall extremes. The limited availability of fine-scale temporal resolution of precipitation record prompted us to apply cascade-based disaggregation model based on scale invariance theory to temporally downscale daily precipitation record to a finer resolution. A satisfactory performance is noted between observed and modeled disaggregated annual maxima rainfall intensity. The nonstationary IDF curves are derived using GEV distribution with consideration of time while the associated uncertainties are estimated using Bayesian inference. A range of statistical analysis confirms (i) presence of statistically significant nonstationary signals in hourly and sub-hourly time series of precipitation extremes (ii) the better fit of nonstationary models as compared to the widely used stationary models, and (iii) significant differences in return level estimates in 2-, 50- and 100- year return periods. As a way forward, we will compare projected changes in return level estimates in stationary versus nonstationary frameworks considering climate change scenarios.

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: Forecasting in Madawaska Watershed Considering Parameter Uncertainty*

***Hongli Liu*[1] *& Bryan Tolson*[1]**

1. University of Waterloo, Waterloo, ON

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

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

***François Anctil*[1]**

1. Université Laval, Québec, PQ

Project 2-2: Hydrological evaluation of the Canadian meteorological ensemble reforecast product*

***Mabrouk Abaza*[1] *& François Anctil*[1]**

1. Université Laval, Québec, PQ

This is the first time that the quality of the ensemble hydrological reforecasts obtained using the 18-year ensemble meteorological reforecast dataset available from the Canadian Centre for Meteorological and Environmental Prediction (CCMEP) has been evaluated. This study focuses on four large watersheds of the province of Quebec. A Distribution Based Scaling (DBS) post-processing method has been used to correct the 18-year ensemble precipitation reforecasts. An Ensemble Kalman Filter (EnKF) assimilation technique was also assessed to improve the initial conditions of the hydrologic model. There is a slight improvement of performance and reliability after applying the DBS approach to precipitation reforecasts but this technique induces a reduction of the spread. The impact of the integration of the post-processed precipitations into the hydrologic model is also quite marginal. However, the addition of EnKF provides better ensemble hydrological reforecasts with high performance, reliability, and skill, especially in the first reforecast horizons. Combining DBS and EnKF, hydrological forecasts for the next two weeks are obtained using the CCMEP reforecast, but also the GEFS v2 reforecast, which is considered as a reference. Forecasts of comparable skill and spread are obtained, with CCMEP-based reforecasts showing better spread during the first week, and GEFS v2 based reforecasts showing better skill and spread during the second week. Finally, it is shown that the two meteorological reforecast products assessed in this study have similar economical value for hydrological forecasting applications, based on the cost-loss model.

Project 2-2: Investigating Quality and Value of Dissimilar Streamflow Forecasting Systems*

***Antoine Thiboult*[1]*, François Anctil*[1]*, & Maria-Helena Ramos*[2]**

1. Université Laval, Québec, PQ
2. IRSTEA, Antony, France

Floods are among the most devastating natural hazards, both in terms of human and economic loss. One of the main purposes of the hydrometerological sciences is to build operational and efficient tools, such as Early Warning Systems (EWS), which aim to prevent and mitigate losses that adverse events may cause. In the scientific literature, most streamflow forecasting systems

are assessed according to their quality (bias, accuracy, skill, reliability, etc.). More rarely, their economic value is investigated.

This study assesses the quality and the value of five different ensemble forecasting systems, which differ by the amount of total predictive uncertainty they are expected to decipher and, thus, by their complexity. The forecasting systems rely on tools that quantify and reduce the predictive uncertainty. For this purpose, meteorological ensemble forcing, hydrological multimodel approach and the Ensemble Kalman filter are used to decipher meteorological, structural and parameter, and initial conditions uncertainty, respectively. The EWSs are subsequently assessed with several criteria of forecast quality (Nash Sutcliffe Efficiency, deviation from the rank histogram flatness) and with the Relative Economic Value (REV), in a cost-loss and flood mitigation situation on 20 watersheds.

Results show that every EWS systematically provides an economic gain over the "no warning" case, regardless of the forecasting horizon and the catchment. The different tools applied to quantify uncertainty confer to the forecast a higher quality, which is also reflected in the REV. The most complex EWS, the one that deciphers more sources of uncertainty, also provides hydrological forecasts with the best quality and the highest REV. However, a clear relationship between forecast quality and value could not be detected when considering all EWS investigated. The need for further investigation is discussed.

Project 2-2: Hydrologic Post-Processing of Streamflow Simulations using Multi-Model Ensemble Strategy

***Jing Xu*[1] *& François Anctil*[1]**

1. Université Laval, Québec, PQ

Forecasts have long been used and developed in to remain people about the ignorance of future event. And forecasts are made in various fields, such as climate and hydrological forecasting, medical epidemics forecasting and economic and financial forecasting, etc. With the growing concern over the forecast of hydrologic extreme events (e.g., floods, droughts and heavy rainfall, etc.), the multi-model ensemble forecast plays an increasingly important role in predicting hydrologic events. Therefore, it is important to test the multi-model ensemble approach and to explore the post-processing of hydrologic ensemble forecasts issued from multiple hydrologic models. In this study, firstly, explore the best way to apply the Bayesian model averaging (BMA) scheme to develop more skillful and reliable probabilistic hydrologic predictions from multiple models; Secondly, decipher the specific role of each model based on the BMA estimates and exploit an ensemble with fewest models that could outperform the best of 20 hydrologic models; Thirdly, evaluate the capacity of BMA to improve hydrologic forecasts from biased and unreliable meteorological forecasts; Fourthly, explore various post-processing methods for hydrologic ensemble forecasts issued from a single model.

Project 2-4: Evaluation of Flood Warning Based on a Hydraulic Model with Assimilation and Hydrological Ensemble Forecasts

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

***François Anctil*[1]**

1. Université Laval, Québec, PQ

Project 2-4: Ensemble Forecasting of Water Levels in Rivers with Data Assimilation: Application to Chaudière River in Quebec*

***Mohammed Amine Bessar*[1] *& François Anctil*[1]**

1. Université Laval, Québec City, PQ

Hydraulic forecasting has an important role in damage prevention related to flood events. To make a good water levels forecast in rivers, it is important to achieve a suitable hydraulic model and explore the various sources of uncertainty in order to understand their influence on the modeling results. Ensemble forecasting will allow us to study the effects of these different sources. Also introducing data assimilation techniques, where data allow, will help us improve our forecasts. This overall approach will be applied to the “Chaudière” River in the province of Quebec.

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*

***Amaury Tilmant*[1]**

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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: Overview of River Flood Forecasting Practices in Canada*

Sanjeev Jha[1], Zahra Zahmatkesh Aliabadi[1] & Peter Rasmussen[1]

1. University of Manitoba, Winnipeg, MB

River floods in Canada have severely affected lives, economy, and infrastructure. Theme 3 of the FloodNet project is targeted towards developing advanced tools and methodologies which will help enhance existing flood forecasting systems across the country. Project 3.1 has the specific objective of reviewing currently implemented flood forecasting procedures in each province and identify areas in which FloodNet can contribute. As a first step, site visits were organised in the beginning of spring 2016. Dr. Sanjeev Jha was responsible for the collaboration with the Flood Forecasting Centres (FFCs) in Alberta, British Columbia, Manitoba, and Saskatchewan. Dr. Zahra Zahmatkesh Aliabadi visited FFCs in New Brunswick, Newfoundland and Labrador, Quebec, and three FFCs in Ontario. We prepared a set of questions, mainly inquiring about the role of the FFC, the main tasks of the forecasters throughout the year, details of data and hydrologic models used in the forecasting, the evaluation of forecast products, and the communication with the public and emergency response teams during major flood events. The various FFCs were extremely helpful and happily shared available documentations (reports, manuals, databases, presentations, etc.) and gave us a demonstration of their forecasting tools and procedures. We found that after each major flood event, a detailed report was often prepared by provinces or consultants to summarize what occurred, including how forecasts were produced and used and what aspects of the forecast procedure could be improved. Some of the reports prepared by the consultants for the Alberta FFC had goals similar to ours, namely to compare flood forecasting procedures at the FFCs in Canada as well as in other countries. However, we noticed that those reports did not cover all the FFCs in Canada, and the findings from those reports need to be updated with the latest details on data, models, communications, etc. We are in the process of preparing a report summarizing the information collected during our visits to the FFCs across the country. The report is expected to be available by the FloodNet AGM in 2016.

The next step in FloodNet Project 3.1 is to identify, in collaboration with the FFCs, specific tasks where FloodNet can make a useful contribution within the given time constraints of the project. This will be beneficial not only for Project 3.1 but also for other research groups in FloodNet who may have relevant expertise to work on the challenges faced by the FFCs. Some of the challenges in terms of data collection and processing include relying on data from multiple sources to determine antecedent soil moisture, estimating snow-water equivalent, uncertainty in the precipitation forecast, and relying on the accuracy of streamflow forecast at upstream locations in neighbouring provinces or US states. In terms of hydrologic and hydraulic modelling, some FFCs use in-house developed models, while others use commercial off-the-

shelf models. The hydrologic modelling of the Prairie region, characterized by a high percentage of non-contributing areas due to potholes, and the presence of urban and rural areas in the same watershed are some examples of challenges for the modellers at the FFCs. Most of the FFCs are still developing in-house tools for the automated and integrated real-time forecast system.
Two major challenges faced by the FFCs in the Western Canada are already being investigated under Project 3.1. In collaboration with Australian experts, Dr. Sanjeev Jha is looking into reducing the uncertainty in the precipitation forecast data. Mr. Ameer Mohammed, a Ph.D student at the University of Manitoba, is developing methods for better representation of geographically isolated wetlands in the hydrologic models of the Prairie region in Saskatchewan and Manitoba.

Project 3-1: Aggregate Effect of Prairie Potholes on Downstream Hydrology: Case Study of the Upper Assiniboine River Basin at Kamsack

Ammer Mohammed[1] & Peter Rasumussen[1]

1. University of Manitoba, Winnipeg, MB

One of the objectives of Theme 3 of the NSERC Canadian FloodNet is to evaluate the flood forecasting procedures adopted at Forecast Centres across Canada. This study falls under Project 3.1, which is led by Dr. Coulibaly, and has the specific objective to assess the existing modelling tools and techniques used at the Forecast Centres. My PhD research directly addresses modelling issues faced at the Hydrologic Forecasting Centre (HFC) of Manitoba. The HFC is in the process of developing and comparing several hydrologic models. One of the main challenges is the representation of potholes in the Prairie region of Manitoba and Saskatchewan. The current models do not possess the capability of representing potholes and the dynamics of contributing and non-contributing area. In collaboration with the HFC, we are working towards developing a modified Soil Water Assessment Tool (SWAT) that will not only capture the fill-and-spill hydrology but also the dynamics of the contributing and non-contributing areas. At present, the model calibration is done and verification is underway. The ultimate objective of my research is to quantify parameter uncertainty in streamflow simulations of the prairie watershed.

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

***Aaron Berg*[1]**

1. University of Guelph, Guelph, ON

Project 3-2: A Relationship Between Satellite Derived Soil Moisture Anomalies and Watershed Runoff Ratios over Canadian Watersheds*

***Elené Ueckermann*[1] *& Aaron Berg*[1]**

1. University of Guelph, Guelph, ON

Soil moisture plays an integral role in the hydrological cycle by controlling the partitioning of rainfall into infiltration or overland flow. With improved access to remotely sensed data, it is possible to establish the strength of the relationship between remotely sensed soil moisture and the runoff ratio over watersheds to improve predictions of peak runoff. This has many applications for improved flood forecasting, and will also lead to a better understanding of the physical controls on the basin's hydrologic response.The objective of this research is to develop an approach for extracting soil moisture data over several Canadian watersheds, and establishing the strength of its relationship to the basin's runoff ratio. This research uses the soil moisture product from the Soil Moisture and Ocean Salinity Mission (SMOS) L-band radar, which is able to estimate volumetric soil moisture data within the top 5cm of soil. Using warm season data (April-October) from 2010 to 2015, a GIS tool was developed to extract a time series of the soil moisture anomaly (difference from 6 year average), which was compared to the calculated to runoff ratio from local discharge and precipitation data. The results are used to classify basins according to strength of the correlation between soil moisture and runoff, and to isolate the different landscape controls on this relationship.

Project 3-2: Trend and Self Organizing Map Analysis of Snow Data of Northern Hemisphere for 1979-2014

***Hester Scheepers*[1] *& Thian Yew Gan*[1]**

1. University of Alberta, Edmonton, AB

The 1979-2014, 25km-resolution snow water equivalent (SWE) monthly dataset of the Globsnow project of the European Space Agency prepared from combining Nimbus-7 SMMR, DMSP SSM/I-SSMIS SWE data with observations of ground-based synoptic weather stations was analyzed. The dataset covers the terrestrial non-mountainous regions of Northern Hemisphere except the Greenland. The monthly SWE dataset of October-May was analyzed for monotonic trends using the non-parametric Mann-Kendall test at 0.05 significant levels. Based on the total number of pixels analyzed, up to 15.5% (7.7%) of the pixels show statistically significant decreasing (increasing) trends. December has the largest snow cover extent and the greatest percentage of statistically significant decreasing trends, of which the majority are located north of 55° latitude which may reflect the effect of polar warming. April exhibits the

greatest percentage of statistically significant positive trends and most of these are located in Asia. The mean trend magnitudes detected for October–May range from 0.18 to 1.42 mm/yr. Principle component analyses was performed on the SWE dataset and the leading components were correlated with temperature, precipitation, and climate indices such as El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO), and others. The method of self-organizing map and k-means clustering were also applied to delineate 20 regions in the Northern Hemisphere that exhibit similar SWE patterns.

Project 3-2: Investigating the Relationship Between Precipitation Input and Model Parameter Distribution during Calibration: Initial Results from 72 Canadian Basins

Kurt C. Kornelsen[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Model calibration is an important step in any hydrological forecasting system and is an important potential source of structural model errors. To investigate the impact of precipitation forcing on model parameter calibration and parameter distributions, the Mac-HBV model was calibrated using a Markov Chain Monte Carlo algorithm known as MT-DREAM(ZS) with three different precipitation products in 72 Canadian reference hydrometric basins. Precipitation was derived from a classic inverse-distance weighting (IDW) approach, from the ANUSPLIN derived CanGRD daily precipitation product and from the Canadian Precipitation Analysis (CaPA). The median Nash-Sutcliffe Efficiencies (NSE) were 0.79, 0.82 and 0.38 for CaPA, CanGRD and IDW respectively during the calibration period. The difference in model performance (NSE) when calibrated with CaPA or CanGRD was less than 10% in 50 basins, 5% in 39 basins and 1% in 13 basins. Despite the similar performance during the calibration period, in all cases the similar performance (within 1%) was achieved with markedly different distributions of most parameters.

During validation 49, 53, and 21 basins were within 80% of the calibration NSE for CaPA, CanGRD and IDW respectively and 41 basins had NSE values below zero. An investigation of basin characteristics and parameter distributions will be used to elucidate the strengths and weaknesses of the precipitation products. Since each of these precipitation products are only available as an analysis, a forecast experiment with each parameter set and NWP precipitation forecasts during the validation period will also be used to examine operational forecast skill.

Project 3-2: Surface Soil Moisture Downscaling Using Microwave Data: Application and Comparison

Kim Huong Hoang[1], Kurt C. Kornelsen[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Microwave remote sensing has become a useful tool for near-surface soil moisture estimation based on the contrast in dielectric properties between dry soil and water derived from backscatter data and microwave emissions. In hydrologic studies, soil moisture is a critical component as it control the partitioning between infiltration and run-off and in partitioning the incoming radiation between latent and sensible heat fluxes. The hydrological and climatological process influenced by soil moisture can impact many environmental phenomena from extreme events like droughts and flooding to state patterns such as ecological distribution of homogenous vegetation zones.

Satellite-based microwave remote sensing is the most promising technique for providing key elements of the near-surface soil moisture. However, the spatio-temporal resolution of the recent microwave remote sensing data is a drawback for near-surface soil moisture retrieval. Their use in hydrological and agricultural predictions is limited because of the discrepancy in scale between the satellite products a (> 25 km) and that of hydrological processes (< 1 km). In the case of flood prediction and flood forecasting application, this research focuses on downscaling soil moisture, while also improving the hydrological simulation accurately.

An adapted method of disaggregation and Ensemble Kalman Filter (EnKF) will be applied for soil moisture downscaling on a field site near Kenaston area, Saskatchewan. The Moderate Resolution Imaging Spectroradiometer (MODIS), RADARSAT-2, Soil Moisture Active Passive (SMAP) and Soil Moisture and Ocean Salinity (SMOS) soil moisture data will be used in this research.

Project 3-3: Enhanced Information Communication Systems

Project 3-3: Enhanced Information Communication Systems*

***Wei Song*[1]**

1. University of New Brunswick, Fredericton, NB

In this presentation, we will introduce the work progress of Project 3-3 in the past year. In particular, we will introduce some promising wireless communication approaches we proposed to collect and disseminate data efficiently and reliably.

Project 3-3: Joint Scheduling and Transmission Power Control in Wireless Ad Hoc Networks*

***Kamal Rahimi Malekshan*[1] *& Weihua Zhuang*[1]**

1. University of Waterloo, Waterloo, ON

Project 3-3: Channel-Aware Device-to-Device Pairing for Collaborative Content Distribution

***Jianguo Xie*[1] *& Wei Song*[1]**

1. University of New Brunswick, Fredericton, NB

With the increasing penetration of smart devices, device-to-device (D2D) communications offer a promising paradigm to accommodate the ever-growing mobile traffic and unremitting demands for fast message distribution. Particularly, D2D communications can facilitate disaster alerts and event notifications. In this work, we study the D2D pairing problem, which appropriately pairs a device requesting a message with a nearly device which caches the requested message. In general, it is preferable to satisfy as many D2D requesters as possible without consuming much time on pairing. We propose to use distance information and channel information in a minimum-distance pairing algorithm and a best-channel algorithm, respectively. In addition, we consider two priority rules that order the message requests to be considered in the pairing: First-come, first-served (FCFS) or last-come, first-served (LCFS). We conducted computer simulations to compare the pairing algorithms for both a static scenario and a dynamic scenario. The simulation results demonstrate that our algorithms outperform a random strategy in terms of the total number of served D2D pairs and the average latency of served pairs. We also investigated the effects of various system parameters on the performance.

Project 3-3: Cooperative Communication in Wireless Device-to-Device Networks

***Yong Zhou*[1] *& Weihua Zhuang*[1]**

1. University of Waterloo, Waterloo, ON

Wireless device-to-device networks have been attracting more and more attentions in recent years from both academia and industry, because of their low deployment costs and broad applications. Due to the scarcity of the radio spectrum, enabling concurrent cooperative

transmissions can achieve both spatial frequency reuse gain and spatial diversity gain to enhance spectrum utilization. The concurrent cooperative transmissions redistribute the interference over the network. Accurate characterization of interference is a fundamental step towards understanding the performance of cooperative communication. In this presentation, we evaluate the effectiveness of cooperative communication from a perspective of overall network performance, while taking into account the interference redistribution due to relay transmissions.

Project 3-3: Adaptive Medium Access Control for Internet-of-Things Enabled Mobile Ad Hoc Networks

Qiang Ye[1] & Weihua Zhuang[1]

1. University of Waterloo, Waterloo, ON

An Internet-of-Things (IoT) enabled mobile ad hoc network (MANET) is a self- organized distributed wireless network, in which nodes can randomly move making the network traffic load vary with time. A medium access control (MAC) protocol, as a most important mechanism of radio resource management, is required in MANETs to coordinate nodes' access to the wireless channel in a distributed way to satisfy their quality of service (QoS) requirements. However, the distinctive characteristics of IoT-enabled MANETs, i.e., distributed network operation, varying network traffic load, heterogeneous QoS demands, and increased interference level with a large number of nodes and extended communication distances, pose technical challenges on MAC. An efficient MAC solution should achieve consistently maximal QoS performance by adapting to the network traffic load variations, and be scalable to an increasing number of nodes in a multi-hop communication environment. In this presentation, we discuss the proposed comprehensive adaptive MAC solutions for an IoT-enabled MANET with the consideration of different network characteristics.

First, an adaptive MAC solution is proposed for a fully-connected network, supporting homogeneous best-effort data traffic. Based on the detection of current network traffic load condition, nodes can make a switching decision between IEEE 802.11 distributed coordination function (DCF) and dynamic time division multiple access (D-TDMA), when the network traffic load reaches a threshold, referred to as MAC switching point. The adaptive MAC solution determines the MAC switching point in an analytically tractable way to achieve consistently high network performance by adapting to the varying network traffic load.

Second, when heterogeneous services are supported in the network, we propose an adaptive hybrid MAC scheme, in which a hybrid superframe structure is designed to accommodate the channel access from delay-sensitive voice traffic using time division multiple access (TDMA) and from best-effort data traffic using truncated carrier sense multiple access with collision avoidance (T-CSMA/CA). According to instantaneous voice and data traffic load conditions, the MAC exploits voice traffic multiplexing to increase the voice capacity by adaptively allocating TDMA time slots to active voice nodes, and maximizes the aggregate data throughput by adjusting the optimal contention window size for each data node.

Lastly, we develop a scalable token-based adaptive MAC scheme for a two-hop MANET with an increasing number of nodes. In the network, nodes are partitioned into different one-hop

node groups, and a TDMA-based superframe structure is proposed to allocate different TDMA time durations to different node groups to overcome the hidden terminal problem. A probabilistic token passing scheme is adopted for packet transmissions within different node groups, forming different token rings. An average end-to-end delay optimization framework is established to derive the set of optimal MAC parameters for a varying network load condition. With the optimal MAC design, the proposed adaptive MAC scheme achieves consistently minimal average end-to-end delay in an IoT-based two-hop environment with a high network traffic load.

This research on adaptive MAC provides some insights in MAC design for performance improvement in different IoT-based network environments with different QoS requirements.

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: Uncertainty Estimation through Bayesian Forecasting System (BFS): An Application to Humber River Watershed in Southern Ontario, Canada*

***Shasha Han*[1] *& Paulin Coulibaly*[1]**

1. McMaster University, Hamilton, ON

Accurate site specific forecast of flood events with uncertainty estimate remains a challenging task faced by hydrologists worldwide. As deterministic forecasting models are unable to provide information about the uncertainty associated with the flood forecasts, probabilistic forecast models appear promising complement. The latter not only predicts the point forecast but also expresses the associated degree of confidence of the flood forecast. This work presents preliminary application of the Bayesian forecasting system (BFS) to Humber river watershed in Southern Ontario, to assess and reduce the flood forecast uncertainty. BFS is a robust theoretic framework for developing probabilistic forecasting through any deterministic hydrologic model. It considers all major sources of uncertainties and provides a reliable estimate of flood flow. The preliminary application results demonstrate that hydrologic uncertainty and precipitation uncertainty are two significant sources of uncertainty in flood forecast. The experiment results indicate that predictive uncertainty grows with higher precipitation and increasing lead time. If the hydrologic model has a good performance, the predictive density and posterior density generated by BFS can reduce the total uncertainty and give a more accurate estimation than prior density. Under the condition that hydrologic model do not have a good forecast ability, the posterior distribution automatically converges to prior distribution to guard against poor forecast. A particular advantage of the BFS is that it can be used with any available deterministic forecast model.

Project 3-4: Hydrologic Models Identification for Adaptive Ensemble Flood Forecasting in Canada

***Frezer Seid Awol*[1] *& Paulin Coulibaly*[1]**

1. McMaster University, Hamilton, ON

Operational and semi-operational flood forecasting centers are increasingly shifting from deterministic forecast to probabilistic flood forecasts using Ensemble Prediction Systems (EPS). The use of ensemble flood forecasting is a great achievement for researchers and scientists in estimating flood risks under uncertainties. This study will address the recent developments in ensemble flood fore-casting with enhanced and adaptive application of multiple models and verification methods in the Canadian context. It aims to generate several thousands of ensembles

from each source of uncertainties and cascading through multiple hydrological and hydraulic models to produce ensemble streamflow forecasts at several lead times and quantifying their probability distribution function. The ensemble verification and performance metrics will be able to identify which model and combination of models perform well for which hydro-meteorological region in Canada. Multiple models will be compared with well calibrated benchmark or reference models by basic criteria, categorical forecast verification and probabilistic forecast verification. The study areas are selected from Eastern, Western and the Prairie regions.

Project 3-4: Potential Improvement of Don River PCSWMM Model with Hydrologic Data Assimilation

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

1. McMaster University, Hamilton, ON

Data assimilation (DA) optimally merges information from model simulations and observations with appropriate uncertainty modeling. It accounts for various types of uncertainty such as errors in model state, variables, and hydrometeorologic forcing data. Numerous research studies have shown that DA can be used to improve prediction accuracy while also quantifying uncertainty. The application of DA with a distributed hydrologic model with the purpose of improving flood forecasting and shortening lead times, as well as application in improved operational forecast systems have been challenging in this context.

In this study we demonstrate the performance of the Don River watershed PCSWMM model for calibration and different validation periods. We then evaluate the potential of Ensemble Kalman Filtering in updating SWMM5 state variables and improving its performance in predicting peak flows.

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*

***Marguerite Xenopoulos*[1]**

1. Trent University, Peterborough, ON

Project 4-1: Factors Influencing Stream Nutrient Concentration-Discharge Relationships in Ontario and Manitoba Streams*

***Sarah C. D'Amario*[1], *Henry F. Wilson*[2], *Robert Metcalfe*[3], *Marguerite A. Xenopoulos*[1]**

1. Trent University, Peterborough, ON
2. Agriculture and Agri-Food Canada, Winnipeg, MB
3. Ontario Ministry of Natural Resources and Forestry, Peterborough, ON

Climate change is predicted to alter the magnitude and frequency of flooding, potentially increasing nutrient export from terrestrial to aquatic ecosystems. Concomitant with flooding, many other variables may play a role in how these nutrients are transported, such as agricultural land use and local climate. We compared concentration-discharge relationships between streams in intensively agricultural ecoregions in Ontario and Manitoba using ANCOVAs. Both total nitrogen (TN) and total phosphorus (TP) were lower in Ontario than in Manitoba, even at the same proportion of agriculture, with C-Q relationships similar between provinces. Only TP showed a significant relationship with discharge, and only in the spring. The reason for the lower Ontario concentrations may be that Manitoba catchments are generally drier, colder, flatter, and have less tile drainage than Ontario catchments; we are currently exploring the influence of these factors on stream nutrient levels.

Project 4-1: Quantifying Changes in Nutrient Concentration in Floodwaters

***Ceara Talbot*[1], *Michael J. Paterson*[2] *and Marguerite A. Xenopoulos*[1]**

1. Trent University, Peterborough, ON
2. IISD-ELA, Winnipeg, MB

Flooding provides pathways for nutrients to move into surface waters and alter nutrient concentrations, therefore influencing downstream ecosystems and increasing events of eutrophication. Nutrient enrichment will likely affect water quality, primary production, and overall ecosystem function. Quantifying the amount of nutrients released into and moving through surface waters after flooding will help evaluate the risks or advantages flooding will have on ecosystem processes. Here we constructed nutrient budgets using data that was collected as part of the Flooded Upland Dynamics Experiment (FLUDEX) at the Experimental Lakes Area (ELA) in northwestern Ontario. Three experimental reservoirs were created by flooding forested

land from May through August annually in 1999, 2000, 2001, 2002, and 2003. Water samples were collected at the inflows, outflows, and within each reservoir. Nutrient budgets are currently being constructed to quantify the relative amounts of nitrogen and phosphorus entering and exiting surface waters after flooding. This data presented a unique opportunity to evaluate how flooding alters nutrient dynamics in freshwaters and ultimately how flooding changes water quality.

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

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

***Amin Elshorbagy*[1]**

1. University of Saskatchewan, Saskatoon, SK

Project 4-3: Development of a Suitable Hydrological Model for Streamflow Simulation in Canadian Prairie Watershed*

***Md. Kamrul Hussein*[1] *& Amin Elshorbagy*[1]**

1. University of Saskatchewan, Saskatoon, SK

Worldwide, floods have been identified as a standout amongst the most widely recognized catastrophic events, resulting in the loss of life and property. These natural hazards cannot be avoided, but their consequences can certainly be reduced by having prior knowledge of their occurrence and impact. In the context of floods, the terms occurrence and impact are substituted by flood hazard and flood vulnerability, respectively, which collectively define the flood risk. There is a high need for identifying the flood-prone areas and to quantify the risk associated with them. The present study aims at delivering flood risk maps, which prioritize the potential flood risk areas in Canada. The methodology adopted in this study involves integrating various available spatial datasets such as nightlights satellite imagery, land use, population and the digital elevation model, to build a flexible framework for national flood risk assessment for Canada. The flood risk framework assists in identifying the flood-prone areas and evaluating the associated risk. All these spatial datasets were brought to a common GIS platform for flood risk analysis. The spatial datasets deliver the socioeconomic and topographical information that is required for evaluating the flood vulnerability and flood hazard, respectively. Nightlights have been investigated as a tool to be used as a proxy for the human activities to identify areas with regard to economic investment. However, other datasets, including existing flood protection measures, we added to identify a realistic flood assessment framework. Furthermore, the city of Calgary was used as an example to investigate the effect of using Digital Elevation Models (DEMs) of varying resolutions on risk maps. Along with this, the risk map for the city was further enhanced by including the population data to give a social dimension to the risk map. Flood protection measures play a major role by significantly reducing the flood risk of events with a specific return period. An analysis to update the risk maps when information on protection measures is available was carried out for the city of Winnipeg, Canada. The proposed framework is a promising approach to identify and prioritize flood-prone areas, which are in need of intervention or detailed studies.

Project 4-3: The Effect of Extreme Rainfall on Urban Drainage Infrastructure

Jun Wang[1] & Yiping Guo[1]

1. McMaster University, Hamilton, ON

Research Plan: 1.Collect data for the Davis Creek watershed in Hamilton; 2.Construct a SWMM model to model hydrologically the Davis Creek watershed; 3.Calibrate the SWMM model using observed flow data; 4. Obtaining observed or predicted representative extreme rainfall data; 5.Run the SWMM model using the obtained rainfall data; 6. Analyze SWMM results to quantify the effects of various types of extreme rainfalls on the various components of urban drainage infrastructures.

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

Modeling flood disaster and developing mitigation strategies require assessing flood risk and risk level zonation within river basins. One of the objectives of project 4-4 focuses on developing a systematic approach for analyzing and quantifying flood risk along with its uncertainty. Flood risk can be defined as the product of flood hazard and flood vulnerability wherein hazard is represented by the probability of a flood event and vulnerability is represented by value of the properties exposed to floods. To address the objective, this study presents an approach to assess flood risk and identify potential flooding areas along a reach of the Moose Jaw River within the Qu'Appelle river basin. 1-D and 2D Hydrodynamic models were developed for a reach of Moose Jaw River to simulate flood flows of different high return periods (greater than 100 years) using HEC-RAS. To assess flood hazard within the floodplains along the river, a flood hazard classification scheme, indicating hazard based on increasing levels of severity (flooding extents and depths), has been proposed using these parameters. A similar vulnerability classification scheme for the watershed is also proposed using indicators such as land value and population. The flood risk is also calculated, classified into different levels, and further represented in the form of flood risk maps. Sensitivity of the flood risk maps to the type of model used and the resolution of the digital elevation models are also assessed to determine variation in the resulting maps. Such maps can be used to identify risk zones within the watershed, and in turn propose measures to minimize potential flood damage.

Project 4-4: Hydraulic Modeling of Moose Jaw River for Flood Risk Assessment*

***Raja Bharath*[1] *& Amin Elshorbagy*[1]**

1. University of Saskatchewan, Saskatoon, SK

Modeling flood disaster and developing mitigation strategies require assessing flood risk and risk level zonation within river basins. One of the objectives of project 4-4 focuses on developing a systematic approach for analyzing and quantifying flood risk along with its uncertainty. Flood risk can be defined as the product of flood hazard and flood vulnerability wherein hazard is represented by the probability of a flood event and vulnerability is represented by value of the properties exposed to floods. To address the objective, this study presents an approach to assess flood risk and identify potential flooding areas along a reach of the Moose Jaw River within the Qu'Appelle river basin. 1-D and 2D Hydrodynamic models were developed for a reach of Moose Jaw River to simulate flood flows of different high return periods (greater than 100 years) using HEC-RAS. To assess flood hazard within the floodplains along the river, a flood hazard classification scheme, indicating hazard based on increasing levels of severity (flooding extents and depths), has been proposed using these parameters. A similar vulnerability classification scheme for the watershed is also proposed using indicators such as land value and population.

The flood risk is also calculated, classified into different levels, and further represented in the form of flood risk maps. Sensitivity of the flood risk maps to the type of model used and the resolution of the digital elevation models are also assessed to determine variation in the resulting maps. Such maps can be used to identify risk zones within the watershed, and in turn propose measures to minimize potential flood damage.

Project 4-5: Using Experimental Games to Understand Flood Decision Making*

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There is considerable evidence that populations at risk of floods are inadequately prepared. This is likely because floods are Low-Probability High-Consequence (LPHC) events. These types of risk events are not easily understood by non-experts, which presents a challenge for policy makers and industry. Research that improves our understanding of decisions in the context of flood-risk is an essential part of understanding the short and long term impact of floods on society. In our project we use economic games to understand decisions making related to risk-reward levels of living in flood-prone areas.

In our first iteration, we developed a game played on a map of a fictional city with zones of varying flood risk and exposure. Players made housing location decisions, choices about private insurance, and public investments in mitigation. Within the game, flood events occurred with a low probability. Subjects were undergraduate students in an environmental policy course. Decisions were recorded in an online spreadsheet for analysis purposes. Our preliminary results found that the recent experience of a flood resulted in a tendency to make more conservative choices, with players generally choosing to expose themselves to less risk over time. However, there were too many instances of "winning" dominant strategies that had more to do with game theory and the simplicity of the game implementation, and which did not reflect players' real risk-preferences.

Our second iteration has been to develop a web-based version of the game. The advantages of switching to a digital version include increasing the complexity of the game while simultaneously speeding up the pace by eliminating manual calculations and reporting. Moreover, it eliminates reporting errors and more easily allows altering the game's risk-reward parameters. Our vision for this game includes becoming both a research instrument and a policy and business education tool. As a web-based tool, we can use crowdsourcing to easily (and inexpensively) increase participation in the experiment. Results from this crowdsourced data will be used to calibrate agent-based-models which investigate the interactions of large populations of people making decisions. Moreover, the act of playing the game could help people involved in flood policy or insurance to better understand LPHC disasters in a tactile and interactive environment, providing insight to which they might not otherwise have access.