FloodNet Annual General Meeting 2017 Scientific Program

NSERC Canadian FloodNet 3rd Annual General Meeting: DAY 1 - 27 June 2017 Agenda	
Registration and Breakfast D1: 8:00-8:30 AM	**Breakfast and Registration** 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 4 – RISK ANALYSIS OF PHYSICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF FLOODS **Chairs: Bharath Raja & Ceara Talbot**	
Project 4-1 M. Xenopoulos D1: 8:50-9:10 AM	**Role of Floods on Aquatic Ecosystem Condition** Environmental Effects of Flooding Project Update *M. Xenopoulos*
Project 4-3 A. Elshorbagy D1: 9:10-9:30 AM	**Modelling-based Integrated Assessment on Flood Impacts on Urban and Rural Water Resources Systems** Project Update *A. Elshorbagy*
Project 4-4 A. Elshorbagy D1: 9:30-9:50 AM	**Flood Risk Analysis and its Utility for Management Decisions** Framework for National Flood Risk Assessment for Canada Project Update *A. Elshorbagy*
Project 4-5 N. Yiannakoulias D1: 9:50-10:10 AM	**Assessing and Planning for the Socio-Economic Effects of Floods** Using Experimental Games to Understand Flood Decision Making Project Update *N. Yiannakoulias & D. Scott*
D1: 10:10-10:30 AM	**Coffee Break**
SESSION 2: THEME 2- QUANTIFYING AND REDUCING THE PREDICTIVE UNCERTAINTY OF FLOODS **Chairs: Antione Thiboult & Amine Bessar**	
Project 2-1 B. Tolson D1: 10:30-10:50 AM	**Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on a Single Model** Project Update *Bryan Tolson*
Project 2-2 F. Anctil D1: 10:50-11:10 AM	**Comparison of Ensemble Forecast Methods for Operational Streamflow Forecasting Based on Multiple Models** Project Update *F. Anctil*

Project 2-4 F. Anctil D1: 11:10-11:30 AM	**Evaluation of Flood Warning Based on Hydraulic Model with Assimilation and Hydrological Ensemble Forecasts** Project Update *F. Anctil*
Project 2-5 A. Tilmant D1: 11:30-11:50 AM	**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: THEME 3 - DEVELOPMENT OF CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) **Chairs: Jongho Keum & Tara Razavi**	
Project 3-1 P. Coulibaly & T. Stadnyk D1: 11:50-12:10 PM	**Evaluation of Flood Forecasting and Warning Systems Across Canada** Project Update *T. Stadnyk*
Project 3-2 A. Berg D1: 12:10-12:30 PM	**Real-time Spatial Information Evaluation and Processing** Project Update *A. Berg*
D1: 12:30-1:30 PM	**Lunch**
D1: 1:30-1:35 PM	**Group Photo**
D1: 1:35-2:20 PM	**KEYNOTE ADDRESS** **Flood alert and runoff thresholds in some European warning systems and estimation in ungauged basins with asymmetric error functions** ***Dr. Elena Toth***
SESSION 3b: THEME 3 - DEVELOPMENT OF CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) **Chairs: Jongho Keum & Tara Razavi**	
Project 3-3 W. Zhuang D1: 2:20-2:40 PM	**Enhanced Information Communication Systems** Project Update *W. Song*
D1: 2:40-3:00 PM	**Coffee Break**
Project 3-4 P. Coulibaly D1: 3:00-3:20 PM	**Development of Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS)** Project Update *P. Coulibaly*
SESSION 4a: THEME 1 - FLOOD REGIMES IN CANADA: LEARNING FROM THE PAST AND PREPARING FOR THE FUTURE **Chairs: Martin Durocher & Hussein Wazneh**	
Project 1-1 D.H. Burn D1: 3:20-3:40 PM	**Update of Current Flood and Storm Quantiles** Project Update *D. H. Burn*
Project 1-2 F. Ashkar D1: 3:40-4:00 PM	**Examination of Spatial and Temporal Variation of Extreme Events** Project Update *F. Ashkar & D.H. Burn*

Project 1-3 A. Arain D1: 4:00-4:20 PM	**Analysis and Applicability of Future Extreme Events in Regional and Local Context** Project Update *A. Arain*
SESSION 5: NSERC CANADIAN FLOODNET POSTERS **Chairs: Hussein Wazneh, Frezer Seid Awol & James Leach**	
D1: 4:20 – 5:00 PM	**Poster Pitch**
D1: 5:00-6:30 PM	**Poster Session and Networking**
D1: 6:30-9:00 PM	**Networking Dinner**

To save trees the Book of Abstracts is ONLY available online.

If can be accessed on
www.nsercfloodnet.ca/annual-meeting-2017
or by scanning the QR code below.

FloodNet
NSERC

NSERC Canadian FloodNet 3rd Annual General Meeting: DAY 2 – 28 June 2017 Agenda	
Breakfast D2: 8:00-9:00 AM	**Breakfast and Networking (All Participants)** **Board of Directors Meeting** **Partner Advisory Committee Meeting**
SESSION 4b: THEME 1 - FLOOD REGIMES IN CANADA: LEARNING FROM THE PAST AND PREPARING FOR THE FUTURE **Chairs: Martin Durocher & Hussein Wazneh**	
Project 1-4 V. Nguyen D2: 9:00-9:20 AM	**Development of New Methods for Updating IDF Curves in Canada** Project Update *V.T.V. Nguyen*
Project 1-5 A. Binns D2: 9:20-9:40 AM	**Spatial Changes to Flood Prone Areas in Urban Environments** Project Update *A. Binns*
Project 1-6 D. Burn D2: 9:40-10:00 AM	**Development of a New Flood Estimation Manual for Canada** Project Update *D.H. Burn*
D2: 10:00-10:20AM	**Coffee Break**
SESSION 6: WORKING GROUP PANEL DISCUSSIONS	
D2: 10:20-11:05 AM	**Working Group # 1 Panel Discussion**
D2: 11:05-11:50 AM	**Working Group # 2 & 3 Panel Discussion**
D2: 11:50-12:50 PM	**Lunch**
D2: 12:50-1:50 PM	**Working Group #4 Panel Discussion**
SESSION 7: PARTNER & COLLABORATOR INVITED PRESENTATIONS **Chairs: Christina Fasching & Qiang Ye**	
D2: 1:50-2:05 PM	**Quantification of Predictive Uncertainty in Flood Forecasting using Bayesian Approaches** *D. Biondi*
D2: 2:05-2:20 PM	**Evaluation of Streamflow and Lake Inflow Forecasts from ECCC's Water Cycle Prediction System for the Great Lakes and St. Lawrence** *V. Fortin, D. Durnford, Y.-L. Shin, M. Dimitrijevic, L. Benyaha*
D2: 2:20-2:35 PM	**The 2013 Billion Dollar Flash Flood in Toronto – Challenges for Operational Forecasting and Nowcasting** *D. Sills*
D2: 2:35-2:55 PM	**Coffee Break**
D2: 2:55-3:15 PM	**ISAP & PAC Feedback**
D2: 3:15-3:30 PM	**Closing Remarks** *Dr. Pietroniro & Dr. Coulibaly*

FloodNet Annual General Meeting 2017 Book of Abstracts

KEYNOTE PRESENTATION **5**

FLOOD ALERT RUNOFF THRESHOLDS IN SOME EUROPEAN WARNING SYSTEMS AND ESTIMATION IN UNGAUGED BASINS WITH ASYMMETRIC ERROR FUNCTIONS* 5

THEME 1: FLOOD REGIMES IN CANADA: LEARNING FROM THE PAST AND PREPARING FOR THE FUTURE **7**

PROJECT 1-1: UPDATE OF CURRENT FLOOD AND STORM QUANTILES **7**
PROJECT 1-1: UPDATE OF CURRENT FLOOD AND STORM QUANTILES* 7
PROJECT 1-1: EVALUATION OF SEASONALITY BASED POOLED FREQUENCY ANALYSIS IN A SUPER REGION CONTEXT* 7
PROJECT 1-1: IMPROVED HOMOGENEOUS GROUP FORMATION FOR REGIONAL IDF ESTIMATION 8
PROJECT 1-1: CONFIDENCE INTERVALS FOR FLOOD QUANTILES 8
PROJECT 1-1: EXTRACTING PEAKS OVER THRESHOLD (POT) DATA FROM DAILY DISCHARGE RECORDS AND PRESENTING THEM IN AN INFORMATIVE MANNER 9
PROJECT 1-2: EXAMINATION OF SPATIAL AND TEMPORAL VARIATION OF EXTREME EVENTS **10**
PROJECT 1-2: EXAMINATION OF SPATIAL AND TEMPORAL VARIATION OF EXTREME EVENTS: RESEARCH UPDATE* 10
PROJECT 1-2: NEW RESULTS ON THE DISCRIMINATION BETWEEN THREE-PARAMETER DISTRIBUTIONS FOR HYDROLOGICAL FREQUENCY ANALYSIS* 10
PROJECT 1-2: SEASONAL FREQUENCY ANALYSIS OF FLOODS IN CANADA 10
PROJECT 1-3: ANALYSIS AND APPLICABILITY OF FUTURE EXTREME EVENTS IN REGIONAL AND LOCAL CONTEXT **11**
PROJECT 1-3: ANALYSIS AND APPLICABILITY OF FUTURE EXTREME EVENTS IN REGIONAL AND LOCAL CONTEXT* 11
PROJECT 1-3: IMPACT OF CLIMATE CHANGE ON CLIMATE INDICES IN LATITUDES ACROSS CANADA* 11
PROJECT 1-3: PAST AND FUTURE EVOLUTION OF STREAMFLOW IN THREE WATERSHEDS IN SOUTHERN ONTARIO* 11
PROJECT 1-4: DEVELOPMENT OF NEW METHODS FOR UPDATED IDF CURVES IN CANADA **13**
PROJECT 1-4: DEVELOPMENT OF NEW METHODS FOR UPDATING IDF CURVES IN CANADA 13
PROJECT 1-5: SPATIAL CHANGES TO FLOOD PRONE AREAS IN URBAN ENVIRONMENTS **14**
PROJECT 1-5: SPATIAL CHANGES TO FLOOD PRONE AREAS IN URBAN ENVIRONMENTS: 2016 UPDATE* 14
PROJECT 1-5: SPATIAL CHANGES TO FLOOD PRONE AREAS IN URBAN ENVIRONMENTS* 14
PROJECT 1-6: DEVELOPMENT OF NEW FLOOD ESTIMATION MANUAL FOR CANADA **15**
PROJECT 1-6: TOWARDS A FLOOD ESTIMATION MANUAL FOR CANADA* 15
PROJECT 1-6: PREDICTION OF FLOOD QUANTILES AT UNGAUGED SITES IN CANADA USING REGIONS OF INFLUENCE AND GENERALIZED LEAST-SQUARES* 15
PROJECT 1-6: STATISTICAL DISTRIBUTION AND REGIONALIZATION TECHNIQUE FOR FLOOD FREQUENCY ANALYSIS IN CANADA 16

THEME 2: QUANTIFYING AND REDUCING THE PREDICTIVE UNCERTAINTY OF FLOODS 17

PROJECT 2-1: COMPARISON OF ENSEMBLE FORECAST METHODS FOR OPERATIONAL STREAMFLOW FORECASTING BASED ON A SINGLE MODEL 17
PROJECT 2-1: COMPARISON OF ENSEMBLE FORECAST METHODS FOR OPERATIONAL STREAMFLOW FORECASTING BASED ON A SINGLE MODEL: PROJECT UPDATE* 17
PROJECT 2-1: THE CANADIAN SURFACE PREDICTION ARCHIVE CASPAR: OVERVIEW & STATUS QUO* 17
PROJECT 2-1: AN IMPROVED MODEL CALIBRATION FRAMEWORK BASED ON INCORPORATING DATA UNCERTAINTY 18
PROJECT 2-2: COMPARISON OF ENSEMBLE FORECAST METHODS FOR OPERATIONAL STREAMFLOW FORECASTING BASED ON MULTIPLE MODEL 19
PROJECT 2-2: COMPARISON OF ENSEMBLE FORECAST METHODS FOR OPERATIONAL STREAMFLOW FORECASTING BASED ON MULTIPLE MODELS* 19
PROJECT 2-2: MULTIMODEL HYDROLOGICAL ENSEMBLE FORECASTS FOR THE ENGLISH RIVER CATCHMENT. 19
PROJECT 2-2: A MULTIMODEL DATA ASSIMILATION FRAMEWORK FOR HYDROLOGY* 19
PROJECT 2-2: HYDROLOGICAL POST-PROCESSING OF STREAMFLOW FORECASTS ISSUED FROM MULTIMODEL ENSEMBLE PREDICTION SYSTEMS* 20
PROJECT 2-4: EVALUATION OF FLOOD WARNING BASED ON A HYDRAULIC MODEL WITH ASSIMILATION AND HYDROLOGICAL ENSEMBLE FORECASTS 21
PROJECT 2-4: EVALUATION OF FLOOD WARNING BASED ON HYDRAULIC MODEL WITH ASSIMILATION AND HYDROLOGICAL ENSEMBLE FORECASTS* 21
PROJECT 2-4: ENSEMBLE FORECASTING OF WATER LEVELS IN RIVERS WITH DATA ASSIMILATION: APPLICATION TO CHAUDIÈRE RIVER IN QUEBEC* 21
PROJECT 2-5: REAL-TIME RESERVOIR OPERATION BASED ON A COMBINATION OF LONG-TERM AND SHORT-TERM OPTIMIZATION AND HYDROLOGICAL ENSEMBLE FORECASTS 22
PROJECT 2-5: REAL-TIME RESERVOIR OPERATION BASED ON A COMBINATION OF LONG-TERM AND SHORT-TERM OPTIMIZATION AND HYDROLOGICAL ENSEMBLE FORECASTS 22
PROJECT 2-5: OPTIMAL MULTIRESERVOIR OPERATION BASED ON A COMBINATION OF SHORT-TERM AND MID-TERM FORECASTS* 22

THEME 3: DEVELOPMENT OF THE CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) 23

PROJECT 3-1: EVALUATION OF FLOOD FORECASTING AND WARNING SYSTEMS ACROSS CANADA 23
PROJECT 3-1: EVALUATION OF SNODAS SNOW DEPTH AND SNOW WATER EQUIVALENT ESTIMATES FOR EASTERN CANADIAN WATERSHEDS: ONTARIO 23
PROJECT 3-1: IMPACT OF MODEL STRUCTURE ON THE ACCURACY OF HYDROLOGICAL MODELING OF A CANADIAN PRAIRIE WATERSHED* 24
PROJECT 3-2: REAL-TIME SPATIAL INFORMATION EVALUATION AND PROCESSING 25
PROJECT 3-2: REAL-TIME SPATIAL INFORMATION EVALUATION AND PROCESSING* 25
PROJECT 3-2: CHARACTERIZING THE SMOS SOIL MOISTURE-RUNOFF RELATIONSHIP OVER CANADIAN CATCHMENTS* 25
PROJECT 3-2: TRENDS AND VARIABILITY OF SNOW WATER EQUIVALENT IN THE NORTHERN HEMISPHERE 25
PROJECT 3-3: ENHANCED INFORMATION COMMUNICATION SYSTEMS 27
PROJECT 3-3: ENHANCED INFORMATION COMMUNICATION SYSTEMS* 27

PROJECT 3-3: DEVICE-TO-DEVICE (D2D) DATA DISSEMINATION WITH POWER BUDGET CONSTRAINTS 27
PROJECT 3-3: COLLABORATIVE MESSAGE DISTRIBUTION VIA DEVICE-TO-DEVICE COMMUNICATIONS 27
PROJECT 3-3: TOKEN-BASED ADAPTIVE MEDIUM ACCESS CONTROL FOR DEVICE-TO-DEVICE COMMUNICATIONS* 27
PROJECT 3-3: MASSIVE ACCESS MANAGEMENT IN IOT-ENABLED QOS CONSTRAINED APPLICATIONS 28
PROJECT 3-4: DEVELOPMENT OF THE CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS) 29
PROJECT 3-4: DEVELOPMENT OF THE CANADIAN ADAPTIVE FLOOD FORECASTING AND EARLY WARNING SYSTEM (CAFFEWS)* 29
PROJECT 3-4: DEVELOPMENT OF CAFFEWS: PRELIMINARY CONFIGURATION AND APPLICATION TO DON RIVER WATERSHED* 29
PROJECT 3-4: APPLICATION OF PRECIPITATION-DEPENDENT HYDROLOGIC UNCERTAINTY PROCESSOR TO A CANADIAN SEMI-URBAN WATERSHED 29
PROJECT 3-4: SENSITIVITY AND PARAMETER VARIABILITY OF SWMM5 MODEL IN SEMI-URBAN DISTRIBUTED WATERSHED 30
PROJECT 3-4: DATA ASSIMILATION OF SOIL MOISTURE AND SNOW WATER EQUIVALENT DATA INTO HYDROLOGIC MODEL OF AN URBAN BASIN. 30
PROJECT 3-4: AN EVALUATION OF TWO SNOWMELT ESTIMATION TECHNIQUES WITHIN MAC-HBV MODEL FOR DAILY MEAN AND PEAK FLOW 31
PROJECT 3-4: INTERDEPENDENCE OF HYDROLOGICAL MODEL PARAMETERS AND PRECIPITATION 31
PROJECT 3-4: MULTI-OBJECTIVE OPTIMIZATION OF DON RIVER PCSWMM/SWMM5 MODEL 32
PROJECT 3-4: GEO-STATISTICAL APPROACH TO COMPARE RADAR ESTIMATED PRECIPITATION DATA AND CONVENTIONAL SURFACE RAIN GAUGE MEASUREMENTS – A CASE STUDY FOR HUMBER WATERHSED 32
PROJECT 3-4: ASSESSING RELIABILITY OF 6-HOURLY AND DISAGGREGATED 1-HOURLY CANADIAN PRECIPITATION ANALYSIS (CAPA) DATA 32

THEME 4: RISK ANALYSIS OF PHYSICAL, SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF FLOODS 34

PROJECT 4-1: ROLE OF FLOODS ON AQUATIC ECOSYSTEM CONDITION 34
PROJECT 4-1: ENVIRONMENTAL EFFECTS OF FLOODING* 34
PROJECT 4-1: THE IMPORTANCE OF HYDROGRAPHIC EVENT ON NUTRIENT CONCENTRATIONS IN STREAMS* 34
PROJECT 4-1: NUTRIENT BUDGETS CALCULATED IN FLOODWATERS USING A WHOLE-ECOSYSTEM EXPERIMENTAL MANIPULATION 34
PROJECT 4-1: HYDROLOGY AND LAND USE CONTROL DOM AND NUTRIENT PATTERNS IN STREAMS 35
PROJECT 4-3: MODELLING-BASED INTEGRATED ASSESSMENT OF FLOOD IMPACTS ON URBAN AND RURAL WATER RESOURCES SYSTEMS 36
PROJECT 4-3: MODELLING-BASED INTEGRATED ASSESSMENT OF FLOOD IMPACTS ON URBAN AND RURAL WATER RESOURCES SYSTEMS: PROJECT UPDATE 36
PROJECT 4-3: MODELLING-BASED INTEGRATED ASSESSMENT OF FLOOD IMPACTS ON URBAN AND RURAL WATER RESOURCES SYSTEMS* 36
PROJECT 4-3: IMPACTS OF LAND USE AND CLIMATE CHANGE ON THE DRAINAGE OF THE DAVIS CREEK SUBWATERSHED 37
PROJECT 4-4: FLOOD RISK ANALYSIS AND ITS UTILITY FOR MANAGEMENT DECISIONS 38
PROJECT 4-4: FRAMEWORK FOR NATIONAL FLOOD RISK ASSESSMENT FOR CANADA* 38
PROJECT 4-4: FLOOD RISK ASSESSMENT UNDER UNCERTAINTY – A CASE STUDY OF THE QU'APPELLE RIVER BASIN* 38

PROJECT 4-4: A TOPOGRAPHY- AND RULE-BASED APPROACH TO INUNDATION MAPPING IN THE PRAIRIES 39
PROJECT 4-5: ASSESSING AND PLANNING FOR THE SOCIO-ECONOMIC EFFECTS OF FLOODS 40
PROJECT 4-5: A MICROSIMULATION MODEL OF WILLINGNESS TO PAY* 40
PROJECT 4-5: A METHOD TO ASSESS THE IMPACT OF FLOODING ON TRAFFIC FLOWS IN HAMILTON 40

PARTNER AND COLLABORATOR INVITED PRESENTATIONS 41

QUANTIFICATION OF PREDICTIVE UNCERTAINTY IN FLOOD FORECASTING USING BAYESIAN APPROACHES* 42
DAILY STREAMFLOW AND WATER TEMPERATURE SIMULATION: CASE STUDY OF PACIFIC COAST (CANADA) 43
DAILY STREAMFLOW AND WATER TEMPERATURE SIMULATION: CASE STUDY OF PACIFIC COAST (CANADA) 43
FLOOD FORECASTING WITH WATFLOOD®/CHARM™ 44

Note: Asterisk indicates oral presentation

Keynote Presentation

Flood alert runoff thresholds in some European warning systems and estimation in ungauged basins with asymmetric error functions*

***Elena Toth*[1]**

1. University of Bologna, Italy

The talk will first present a brief overview of some of the national and regional European flood warning systems and of the operational pan-European flood warning system developed by JRC-European Commission, EFAS (European Flood Awareness System), in particular in reference to the flood warning threshold identification.

In the operation of real-time flood forecasting systems, it is in fact necessary to determine the values of threshold runoff that trigger the issuance of flood watches and warnings. The runoff threshold should correspond to a 'flooding flow', that is to a value that may produce flood damages, and it is very difficult to determine for all the cross-sections of interest on a regional or national scale, since detailed local information on each cross-section would be needed: many operational systems all around the world therefore adopt statistically-based thresholds, corresponding to the flood peaks with a given return period.

For locations where the series of past streamflow are absent or very limited, the peak flow of given frequency to be associated with the watch/warning threshold can be estimated with regionally-derived empirical relationships, such as those that are applied for the estimation of the index flood at ungauged sites. Such regression-like methods consist in a relation between a set of catchment descriptors that may be obtained also for ungauged sites and the desired flood quantile.

Whatever is the function form, such models are generally parameterised by minimising the mean square error, that assigns equal weight to overprediction and underprediction errors, whereas, instead, the consequences of such errors are extremely different when the estimates are to be used as warning threshold. In fact, false alarms (due to an underprediction of the warning threshold) generally have a much higher level of acceptance than misses (that would derive from an overestimated threshold).

For this reason, it is proposed (see Toth, HESS, 20(6), 2016) to parameterise the regression model through an asymmetric error function, that penalizes more the overestimation than the underestimation discrepancies. The predictions of models with increasing degree of asymmetry are compared with those obtained with a traditional training based on the mean-square error, in a cross-validation experiment referred to a database of catchments covering the Italian country.

The appropriate degree of asymmetry might be identified depending on the risk-averseness of the specific flood-prone context. The quantification of risk aversion is extremely difficult and case-specific: it should keep into account that the perception of society may be very different from a technical appraisal of the involved costs and it should include also indirect, intangible and long-term impacts. More research on the societal perception in different contexts would greatly improve the process of risk-based decision-making, including the choices concerning flood-

warning thresholds. Hopefully, in the next years, a more close collaboration between the hydrologic research communities and the policy-makers and stake-holders, as auspicated in the new Panta Rhei science initiative (http://iahs.info/Commissions--W-Groups/Working-Groups/Panta-Rhei.do), and in particular as far as data-driven modelling is concerned (see Mount et al., Hydr. Sci. J., 61(7), 2016), will provide a progress in this direction.

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

Flood events continue to cause property damage and social and economic disruption in many locations across Canada. Research in this FloodNet project explores ways to better estimate the probability of occurrence of extreme flood and rainfall 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: Evaluation of seasonality based pooled frequency analysis in a super region context*

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

1. University of Waterloo, Waterloo, ON

Accurately estimating flood magnitude and frequencies is essential for effective design of hydraulic structures, flood mitigation measures, reservoir management, and pollution control. Ideally, estimation of these frequencies would be obtained by hydrologic analysis of local long-term flood records. However, such records are seldom available at the location of interest and extreme events are by definition rare. In such situations, techniques are needed to combine extreme flow information from a number of similar sites to augment the available, but generally limited, at-site information. Thus, identification of pooling groups (regions) that will provide effective spatial transfer of extreme flow information is important in this analysis. The objective of the pooling process is the identification of sufficiently similar groupings of catchments to justify the combination of extreme flow information from sites within the region. This work aims to explore approaches for obtaining improved pooled flood frequency estimates. In this study, the Region of Influence (ROI) approach was employed to identify a potential set of stations for each catchment. Traditional physiographic and climatic catchment characteristics and also statistics representing the timing and variability of flood events were utilized and compared to construct homogeneous pooling groups for Canadian catchments. The present work also addresses the effect of major grouping of gauges based on catchment scale and climate on the pooled flood frequency analysis. Mean annual precipitation (MAP) and catchment area were employed as surrogates for catchment descriptors to identify super regions in Canada. Gauges associated with each super region were later employed in a regionalization technique based on seasonality measures to identify homogeneous pooling groups. The effectiveness of the

described pooling techniques in estimating extreme flow quantiles were explored for a set of Canadian catchments.

Project 1-1: Improved homogeneous group formation for regional IDF estimation

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

1. University of Waterloo, Waterloo, ON

Extreme rainfall events can have devastating impacts on society, in the form of extensive property damage, through flooding in urban areas. However, recent changes in rainfall climatology caused by climate change and urbanization have made estimates provided by the traditional IDF approach become increasingly inaccurate. In the stationary environment, three major problems exist in the traditional IDF estimation: the ineffective choice of attributes in the formation of a homogeneous group, an inadequate number of stations in the pooling group for quantile estimation and the negative impacts from pooling group's cross-correlation on the homogeneity test. For the first issue, an automatic feature selection and weighting algorithm, specifically the hybrid searching algorithm of Tabu search and supervised clustering, was used to select the relevant features for homogeneous group formation at a specific region. During the process, the impacts of urbanization and climate change on rainfall climatology were considered. For the second issue, the two sample Kolmogorov-Smirnov test-based sample ranking process is used to compare the confidence interval widths generated from the potential groups, during which the method of linear programming is used to rank these groups. To generate the cross-correlated random number for the last issue, the mean absolute difference matrix is used in the eigen decomposition to obtain the relationship among the input stations and the Gaussian random datasets from this representation are transformed into a non-Gaussian distribution. During the process, the comparison of L- skewness and L- kurtosis between the generated groups and original groups is used as the performance indicator to scale the generated series. All of the proposed procedures were used for the stationary rainfall quantile estimation in the Ontario region. The results demonstrate the effectiveness of the approaches for extreme rainfall quantile estimation in the catchments under study.

Project 1-1: Confidence Intervals for Flood Quantiles

Mounada Gbadamassi[1] & Fahim Ashkar[1]

1. Université de Moncton, Moncton, NB

We will present results on methods of improving the accuracy of confidence intervals for quantiles of the generalized Pareto distribution and the Kappa distribution, which are used in flood frequency modeling by the Peaks over threshold approach. We will also outline a plan to apply the same process to the Gumbel distribution.

Project 1-1: Extracting peaks over threshold (POT) data from daily discharge records and presenting them in an informative manner

Babacar Dieng[1] & Fahim Ashkar[1]

1. Université de Moncton, Moncton, NB

We will suggest methods of extracting Peaks over threshold (POT) data from daily discharge records and presenting them in an informative manner; how to make goodness-of-fit tests for distributions such as the generalized Pareto, and how to construct confidence intervals for flood quantiles calculated by the POT approach.

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]**

2. 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. A study of hydrometric stations across Canada has identified significant regional or local increasing or decreasing trends. Rates of change during the period of record were also 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. When necessary, seasonal models will be proposed which would be more appropriate than non-seasonal ones. We will also propose homogeneity tests for statistically confirming whether or not seasonal modelling is needed at a specific hydrological site.

Project 1-2: New results on the discrimination between three-parameter 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 between three-parameter distributions for hydrolgical frequency analysis. We had presented in 2016 some results on the discrimination tests aimed at correctly choosing between the Gumbel distribution and a group of alternative frequency distributions. We will update these results by including new research on the Generalized extreme value, Generalized logistic and Pearson type 3 distributions. Our updated results will show more clearly the advantages of the (modified) Shapiro-Wilk statistic and the (modified) Probability Plot Correlation Coefficient Test as a model discrimination tools.

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

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

1. Université de Moncton, Moncton, NB

Our study is based on the use of the POT method in order to divide the year into different seasons at 188 hydrometric stations across Canada, with a test to ensure that the seasons are significant and distinct at each of the stations. This will help us regroup stations with the same seasonal characteristics, in order to classify the obtained groups into geographical regions with regard to seasonality.

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: Impact of climate change on climate indices in latitudes across Canada*

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

1. McMaster University, Hamilton, ON

Extreme events such as floods, droughts, heat waves and freezing rains have serious impacts on communities and vulnerable populations. In recent years many indices have been developed to describe and characterize extreme weather events. In this study, we analyze the impacts of the past and future climate change on extreme weather events for southern parts of Canada. A set of precipitation and temperature based indices has been computed using the downscaled CMIP5 multimodel ensemble projections (Coupled Model Intercomparison Project Phase 5) at 8km resolution over the 21st century for two Representative Concentration Pathways scenarios (RCP 4.5 and 8.5). Results showed that this region is projected to experience stronger warming and higher increase in precipitation extremes. Generally, projected changes in indices based on minimum temperature were greater than changes in indices based on maximum temperature. We also expect a decrease in frost days and an increase in warm nights. By the year 2100 and relative to the reference period 1981-2000, global mean changes in annual minimum of daily minimum temperature and annual maximum of daily maximum temperature are respectively 12°C and 7°C, under RCP 8.5 scenario. For the same time frame and scenario, there will be no cold nights or days. In term of precipitation indices, annual total precipitation is expected to increase by about 16% and heavy precipitation by 5 days. Overall, changes and variability in temperature and precipitation indices are most pronounced under RCP8.5 than RCP 4.5.

Project 1-3: Past and future evolution of streamflow in three watersheds 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 General climate models (GCM) for two IPCC greenhouse gases emissions scenarios (RCP4.5 and 8.5), are used as input in the model. The results 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.

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

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

1. McGill University, Montreal, PQ

The presentation will provide a summary of the achievements and research progress to date for the Project 1-4.

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]**

1. University of Guelph, Guelph, ON

The investigators and HQP involved in Project 1-5 will provide a project update on the progress of this research. Project 1-5 seeks to investigate the spatial changes to flood prone areas in urban environments in response to changing environmental and hydrologic conditions. Research to date has included the completion of one Master's thesis that examined the effect of land-use and stormwater management measures on urban flood hazard in the Black Creek subwatershed in Toronto, Ontario. Other ongoing research is investigating flood hazard due to changing environmental conditions in the City of Edmonton, Alberta and the City of Hamilton, Ontario. Results from this research will assist in updating urban development guidelines to minimize flood hazard and evaluate the effectiveness of various stormwater management features (e.g., low impact development measures).aim to assist in guiding future land use management and the design of storwmater management infrastructure.

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

***Zihao Zhang*[1] *& Yiping Guo*[1]**

1. McMaster University, Hamilton, ON

The number of flooding events in Canadian urban environments continue to increase, causing major environmental, economic and social consequences. This research is aimed at assessing the effect of intensifying urban development on spatial changes to flood prone lands and improving decrease flood hazard in urban environments. Previous work has used SWMM to study Davis Creek in Hamilton as a case study. Current research uses the East River Basin, located in the City of Edmonton, to investigate the impacts of urbanization on flood hazard and evaluate the effectiveness of various storm water management facilities at reducing this hazard by conducting hydrological modeling. GIS mapping techniques will be used to assess how changes in land use, and the associated changes to the amount of impervious area. Storm water management measures will be simulated in various scenarios to investigate their effects at reducing flood hazard.

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

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

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

Canada, unlike many other countries, does not have a unified approach for the estimation of extreme event quantiles. This FloodNet project integrates the results from other work in Theme 1 and aims to provide a flood estimation manual for Canada along with associated software. This presentation provides an overview of the progress on this project to date including work on selecting an appropriate frequency distribution, approaches for developing pooling groups for pooled frequency analysis, and approaches for the analysis of flood events at ungauged locations. Input is sought from potential users of the manual with regard to the capabilities of the system.

Project 1-6: Prediction of flood quantiles at ungauged sites in Canada using regions of influence and generalized least-squares*

Martin Durocher[1] and Donald H. Burn[1]

3. University of Waterloo, Waterloo, ON

One of the objectives of Theme 1-6 is to propose a methodology for predicting flood quantiles at ungauged sites across Canada. The method consists of fittting multiple regression models in the neighborhoods of target sites, or regions of influence (ROI), to describe the relation between flood quantiles and site characteristics. A particularity of this problem is that flood quantiles are not directly observed, but are outputs of a previous analysis conducted on gauged sites. Therefore, to correctly account for the sampling and model error, estimation based on the generalized least squares (GLS) approach are preferred. First, a covariance matrix must be obtained to reflect the sampling uncertainty of the gauged flood quantiles. The possibility of easily mixing different families of distributions inside the gauged analysis motivates the decision of using Monte-Carlo simulations to approximate the covariance matrix. Copula models were explored on a few paired observations to identify the nature of the spatial dependence and a non-parametric model was used to estimate the strength of the association between each paired site. In a preliminary analysis, the performance of the ROI-GLS approach was evaluated for a set of 918 sites, where the variables of interest are the flood quantiles of return periods 10 and 100 years. The response variable is obtained from at-site frequency analysis using L-moments and generalized extreme value distributions. In general, very good prediction performances are found based on cross validation. Comparisons between different methods for forming the ROI are also explored.

Project 1-6: Statistical distribution and regionalization technique for flood frequency analysis in Canada

Zhiyang Zhang[1], Donald H. Burn[2] & Tricia Stadnyk[1]

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

Having reliable flood quantile estimation provides essential hydrological information for infrastructure design and flood mitigation. One mandate of Theme 1-6 is to establish a Flood Estimation Manual for Canada, which recommends statistical model and regionalization techniques for flood quantile estimation. The research presented here first investigates the best-fit statistical distribution for at-site flood frequency estimation in Canadian climates. Two statistical Goodness-of-fit measurements, namely the Modified Anderson-Darling test and Hosking and Wallis z-test, are employed to assess and discriminate between four three-parameter statistical distributions for reliable flood quantile estimation. The results show the Generalized Extreme Value distribution was the best candidate for flood quantile estimation using the Canadian Reference Hydrometric Basin Network (RHBN) annual maximum and instantaneous peak flow records. Second, we investigate techniques to delineate homogeneous pooling groups for regional flood frequency analysis. The framework of investigation is based on the region of influence method. Six different approaches are compared by assessing their effectiveness to develop homogeneous pooling groups and their accuracy of flood quantile estimation. Each approach uses a type of basin characteristics to measure station similarity. The six types of basin characteristics are: (i) flood seasonality; (ii) physiographic attributes; (iii) station proximity; (iv) monthly average precipitation; (v) monthly average temperature; and (vi) monthly average precipitation and temperature. Our findings reveal that the key factor that effectively develops homogeneous pooling groups is less dependent on the characteristics used to measure flood similarity, but relies more on the regionalization process; particularly the procedure to revise a heterogeneous pooling group. Our results show that the six approaches yielded similarly good predictive performance and that all of them were capable of developing homogeneous pooling groups for up to 90% of 186 RHBN stations with reliable regional flood quantile estimation. Flood seasonality and station proximity measures are recommended for regional flood frequency analysis in Canada primarily because their attribute values are convenient to obtain compared to others.

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: The CAnadian Surface Prediction ARchive CASPAR: Overview & Status Quo*

***Juliane Mai*[1], *Kurt Kornelsen*[2], *Bryan Tolson*[1], *Paulin Coulibaly*[2], *Francois Anctil*[3], *Vincent Fortin*[4], *Michael Leahy*[5], *and Brent Hall*[5]**

1. University of Waterloo, Waterloo, ON
2. McMaster University, Hamilton, ON
3. Université Laval, Québec City, QC
4. Meteorological Research Division, Environment and Climate Change Canada, Dorval, QC
5. ESRI Canada Inc., Toronto, ON

Environmental models are tools for the modern society 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. These environmental models differ in the processes they incorporate. For example land surface models (LSMs) focus on the energy, water, and carbon cycle of the land but not the atmosphere while hydrological models (HMs) concentrate mainly on the water cycle only. 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.

These data are provided by the Meteorological Service of Canada (MSC) on a daily basis. MSC provides multiple products ranging from large scale global models (~ 33km/grid cell) to high resolution pan-Canadian models (~ 2.5km/grid cell). Operational products providing forecasts in real-time are made publicly available through various means with new forecasts issued 2-4 times per day. The data, however, are stored as a short term rolling archive (~ weeks) on MSC systems prior to being committed to a 6 year rolling tape archive. The recovery costs for retrieving data from that tape archive are prohibitive and hence makes these data practically inaccessible for research purposes.

The vision of the new Canadian Surface Prediction Archive (CASPAR) platform is (A) to archive 10 of MSC's NWP products, (B) to extract for the user a specific time period, region and variables of interest and (C) provide post-processing scripts and tools such that the users, for example, can interpolate the data due to their needs. We will present the outline of CASPAR and provide some insights in the current development of the web-based user interface (frontend)

and implementations used to retrieve MSC's data and provide the data to the user in the inquired shape (backend).

Project 2-1: An improved model calibration framework based on incorporating data uncertainty

Hongli Liu[1] & Bryan Tolson[1]

1. University of Waterloo, Waterloo, ON

This study proposes an improved model calibration framework that can explicitly account for data uncertainty. Compared with traditional model calibration approaches, this framework has two key aspects. First, it uses multiple realizations of forcing and response data instead of a deterministic data series. Second, it modifies the goodness-of-fit indicator to account for response data uncertainty in the process of model performance evaluation. In our synthetic case study, the true forcing and response data as well as model parameters are known; precipitation uncertainty is represented by gridded ensemble precipitation estimates; flow uncertainty is derived from the rating curve uncertainty estimation. Our approach to validation is validated in open-loop forecasting mode. Case study results show that, by incorporating data uncertainty, the forecast flow uncertainty interval becomes wider and more reliable (covering a higher proportion of the true flow series) than the interval without considering calibration period data uncertainty.

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: Multimodel hydrological ensemble forecasts for the English River catchment.

***Emixi Stefany Valdez Medina*[1] *& François Anctil*[1]**

1. Université Laval, Québec, PQ

According to the Global Risks Report, published by the World Economic Forum in 2015, the water crisis is one of the global greatest concerns nowadays, because of its impact level. In addition to, the severe weather changes we are facing, has increase human´s awareness about the fact of global warming. In the last few years, climate variations have resulted in extreme phenomena such as more pronounced floods and droughts. These types of events have been registered on the English river basin, like the flooding occurred in 1992 and the dry year of 1981. This watershed is located in northwestern Ontario and is regulated through a set of dams distributed in its area. In a system like this, where it is necessary to satisfy different users, hydrological forecasting is essential, which plays an important role for the efficient operation of water infrastructures, the mitigation of natural disasters and their increasingly importance in supporting integrated water resources management. However, all forecasts contain uncertainty and one of the most successful ways of dealing with them is the use of ensembles. The main objective of this project is to compare different methods to combine ensemble forecasts from different numerical weather prediction forecasting models in order to produce a grand ensemble with optimal forecasting performance, and in this way to be able, to produce ensembles for real-time reservoir operation to support the generation of electricity. The used model takes into account the three main sources of uncertainty: meteorological forcing, the initial condition of the watershed and the structure of the hydrological model whose meteorological inputs consist in max and min temperature, rainfall and snow height equivalent.

Project 2-2: A multimodel data assimilation framework for hydrology*

***Antoine Thiboult*[1]*, François Anctil*[1]**

1. Université Laval, Québec, PQ

Hydrological model states often drift away from the values that best describe the catchment state. These errors mainly arise because of the uncertainty that lies in the model structure and the forcings. Data assimilation (DA) techniques can be used to correct such erroneous model states. By combining adequately model simulations and the observations, DA allows reinitializing the model in such way that it enhances the quality of the simulation.

Many algorithms have been developed for such purpose. The particle filter (PF) is among the most popular as it proved to be efficient for reducing the error in the initial conditions in a wide variety of cases. Nonetheless, the uncertainty in the model structure remains unaddressed with the traditional PF. A possible way to explicitly account for the structural uncertainty is to resort to a multimodel approach, i.e. using collectively several dissimilar hydrological models to issue a probabilistic predictive density function.

We suggest here a framework based on the PF to update simultaneously every model composing the multimodel ensemble. Instead of attempting to minimize the difference between the simulation and the observation for each model, model states are updated to ensure that they form together a predictive function with an appropriate shape, spread, and mode. Models are allowed to perform a specific role in the multimodel ensemble and possibly to compensate for the errors which are made by the other models.

The suggested methodology is assessed on several catchments in the Province of Québec. Preliminary results show that the suggested approach yields to similar accuracy but provides a gain in reliability over the traditional PF approach.

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

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

1. Université Laval, Québec, PQ

Forecasting is the process of making predictions of the future based on past and present data and most commonly by analysis of trends. They are commonly issued in various fields such as meteorology, hydrology, epidemiology, economics, finance, and so on. With the growing concern over the forecast of hydrological extreme events (e.g., floods, droughts, heavy rainfalls, etc.), multimodel ensemble prediction systems plays an increasingly important role (Duan Q et al., 2007; Fowler et al., 2009; Vavrus et al., 2015). Therefore, it is important to explore methods for post-processing ensembles issued from multiple hydrological models based on an adapted ensemble strategy. The focus of this work is to set up a multimodel ensemble strategy to explore the post-processing of hydrological ensemble forecasts issued from multiple hydrological models. The main objectives of the research are: 1) Explore the best way to apply the Bayesian model averaging (BMA) scheme to develop more skillful and reliable probabilistic hydrological predictions from multiple models; 2) Decipher the specific role of each model based on the BMA estimates and construct an ensemble, based on fewer models, which could maintain the forecast performance as using all 20 hydrological models jointly; 3) Evaluate the capacity of BMA to improve hydrological forecasts from biased and unreliable meteorological forecasts; 4) Explore various post-processing methods for hydrological 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. In order to make reliable water level forecasts 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]**

1. Université Laval, Québec, PQ

Project 2-5: Optimal Multireservoir Operation Based on a Combination of Short-term and Mid-term Forecasts*

***Hajar Ashouri*$_1$ *& Amaury Tilmant*[1]**

1. Université Laval, Québec, PQ

Hydrologic forecasts are critical for the operation of water resource systems. When dealing with a multireservoir system, long-term, seasonal, forecasts are needed for planning reservoir operation while short-term forecasts drive the real-time operation. In many agencies, planning and operation of the system evolves side by side with varying degrees of coordination. When an optimization framework is developed, the complexity of the reservoir operation problem requires that a temporal decomposition approach be implemented: the results of the long-term planning model must be used as a boundary condition of the short-term model. In this talk, we will present the building blocks of an optimization framework that simultaneously processes seasonal and short-term hydrologic forecasts.

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 SNODAS snow depth and snow water equivalent estimates for Eastern Canadian watersheds: Ontario

Zahra Zahmatkesh Aliabadi[1], James Leach[1], Paulin Coulibaly[1] & Tricia Stadnyk[2]

1. McMaster University, Hamilton, ON
2. University of Manitoba, Winnipeg, MB

The National Weather Service's SNOw Data Assimilation (SNODAS) modelling and data assimilation system provides daily, gridded estimates of snow products such as snow depth, and snow water equivalent (SWE), at a 1-km^2 resolution for conterminous USA since October 2003, and for Southern Canada since December 2009. These products could be used to support hydrologic modelling and analysis. Here, snow depth (SD) and snow water equivalent (SWE) simulations of SNODAS are compared with the observed ground-measured snow data for sample study locations in Eastern Canada. Two watersheds with different land-use in Ontario are selected: Don River watershed (representative of urban areas), and Madawaska River watershed (representative of forest areas). To do the comparison, several stations over the watersheds are considered. Data for these stations are obtained from Environment Canada and Global Historical Climatology Network. Observed recorded snow related data for these watersheds is snow depth. To fairly estimate SWE in mm, observed SD in mm is divided by 10. The results showed that no significant correlation exist between SNODAS SD and observed SD. However, there exist correlation between estimated observed SWE and SNODAS SWE. Based on the considered watersheds and stations, no comment can be made on the accuracy of SNODAS products depending on the watershed land-use. Moreover, a statistical analysis is performed on the SNODAS products for several grids all over the watershed to check how diverse/similar these products are. The results for this analysis indicated that the mean for the timeseries of SNODAS data for the considered grids is different. To validate SWE accuracy modeled by SNODAS, in addition to do comparing the system outputs with independent, ground-based snow survey data, it can be investigated if SNODAS SWE can be used for estimation of the watershed runoff (based on water balance calculation relationships). For these purpose, more SNODAS products representative of the wind effect and temperature are needed. We are still working on downloading those SNODAS products. When these products are available, statistical relationships/regression equations can also be developed for best estimation of SWE from the SNODAS products. This would be of particular use for the regions where stations are not available to record snow depth.

Project 3-1: Impact of model structure on the accuracy of hydrological modeling of a Canadian Prairie Watershed*

Ammer Mohammed[1], Paulin Coulibaly[2] & Tricia Stadnyk[1]

1. University of Manitoba, Winnipeg, MB
2. McMaster University, Hamilton, ON

Floods are recognized as the most common, largely distributed natural disaster in Canada. In close collaboration with the Flood Forecasting Centres (FFC), the NSERC Canadian FloodNet project aims at developing advanced tools and technologies that will allow Canada to better face the reality of floods. Under Theme 3-1 of FloodNet, an article discussing the current flood forecast systems across Canada was published in Vol. 1 of Flash FloodNet, where some challenges were highlighted including those in the Canadian Prairie Region. A common problem of Prairie hydrology is how to improve representation of potholes in hydrologic models. This study, in the context of FloodNet, evaluates the hydrology of the Canadian Prairies. The specific objective is to assess multiple methods of pothole wetland representation within a singular watershed-scale hydrologic model to provide guidance for future modeling efforts in the PPR. The Soil Water Assessment Tool (SWAT) is utilized to assess the accuracy of model structure in replicating streamflow. Three variant of the model is constructed; 1) lumped, 2) distributed with no modification, 3) and distributed with modification to the potholes representation for the Upper Assiniboine River Basin at Kamsack. Improvements were observed in the case of the modified model, and we foresee that it will improve the predictive power of SWAT model thus, enhancing our understanding of the aggregate effect of potholes in this complex yet important watershed.

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

***Aaron Berg*[1]**

1. University of Guelph, Guelph, ON

Project 3-2: Characterizing the SMOS Soil Moisture-Runoff Relationship over Canadian Catchments*

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

1. University of Guelph, Guelph, ON

Soil moisture plays a key role in runoff generation through its control on rainfall partitioning over a catchment. While many studies have shown the value of assimilating soil moisture into hydrological forecasting models on small scales, a large-scale analysis of the strength and controls on the catchment soil moisture-runoff relationship has not been conducted in a Canadian context. The objective of this research was to evaluate the strength of this relationship over a series of variable Canadian watersheds using macroscale estimates of soil moisture obtained with the Soil Moisture and Ocean Salinity Mission (SMOS) satellite. Data from the satellite, which is able to estimate volumetric soil moisture data within the top <5cm of soil using an L-band radar, was used to derive average daily and weekly absolute and anomaly soil moisture data over a subset of 80 watersheds across Canada. Warm season data from 2011 to 2014 was compared to the calculated to runoff ratio from local discharge and climate data through a regression analysis at various thresholds and lag times. To determine the relative importance of the antecedent soil moisture for runoff generation, the basins were further characterized according to a series of climate and topographical parameters used for a predictive model development. Preliminary results show a significant ($P>0.05$) positive correlation between soil moisture and runoff ratio over 25% of the catchments studied, as well distinct spatial trends in these correlations. The presence of soil moisture and precipitation thresholds offer some explanatory power for these results, while climate variables such as average annual precipitation and number of precipitation events are more important than topographic variables in determining the strength of the soil moisture-runoff link. This method shows promise as a large-scale tool to offer new insight on large-scale controls on runoff over remote landscapes in Canada.

Project 3-2: Trends and Variability of Snow Water Equivalent in the Northern Hemisphere

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

1. University of Alberta, Edmonton, AB

It is important to track snow accumulation because snowpacks store water that is later released into soil and rivers. Satellite measurements enables research into global snow accumulation patterns. Trends and variability of snowpacks of the Northern Hemisphere for November to March between 1988 and 2016 were investigated using snow water equivalent (SWE), that is, the depth liquid water that would result if the snowpack melted, from the Globsnow SWE dataset. Based on the Mann-Kendall test for monotonic trends, about 16% of grids with SWE averaged over the first five days in January have statistically significant decreasing trends. The maximum

percentage of grids with increasing trends (4.85%) are for SWE averaged between 16-20 March. Most of the significant decreasing SWE trends are located in the subarctic region of Canada and in European Russia. Significant increasing SWE trends are located in Siberia. ERA-Interim reanalysis was used to analyze surface temperature and snowfall of the Northern Hemisphere. Increasing temperature trends and accumulated snowfall trends are evident in the Arctic. The geographic location of these trends do not correspond to the SWE trend locations, however both temperature and SWE correlated well with SWE pentads. Principal Component Analysis and Self-Organizing Map analyses was applied to the SWE pentad data. The results from the two analysis methods were similar. SWE was negatively correlated to the Pacific North American pattern for large parts of Canada. The Arctic Oscillation was positively correlated to SWE in Siberia and negatively correlated SWE in Eastern Russia.

Project 3-3: Enhanced Information Communication Systems*

***Wei Song*[1]**

1. University of New Brunswick, Fredericton, NB

Project 3-3: Device-to-Device (D2D) Data Dissemination with Power Budget Constraints

***Yiming Zhao*[1] *& Wei Song*[1]**

1. University of New Brunswick, Fredericton, NB

With the evolution of wireless networks and pervasive mobile devices, device-to-device (D2D) communications have been envisioned as an effective means for data dissemination, e.g., in disaster alerts and event notifications. As mobile devices are battery-powered, it is essential to save power during data dissemination. Also, users are generally more willing to forward data to others with social connections. In this paper, we take into account two important aspects, i.e., D2D users' social incentive constraint and power budget constraint, to enable more practical data dissemination. We propose a coalitional graph game based approach, which iteratively derives a transmission graph to reach every interested user. Simulation results demonstrate the high performance of our approach in various scenarios with different network scales and social connections.

Project 3-3: Collaborative Message Distribution via Device-to-Device Communications

***Xi Tao*[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 an important problem for D2D-assisted content distribution, which allocates the message requests to be served by the cache devices via D2D multicast. Aiming to minimize the total transmission cost or maximize the gain in cost saving for the base station, this message allocation problem is formulated and solved from different perspectives. We conducted computer simulations to compare the three algorithms in static and dynamic scenarios, focusing on four performance metrics including D2D offload ratio, total cost, unit cost per message request, and service latency.

Project 3-3: Token-Based Adaptive Medium Access Control for Device-to-Device Communications*

***Qiang Ye*[1] *& Weihua Zhuang*[1]**

1. University of Waterloo, Waterloo, ON

In this work, we propose a distributed token-based adaptive medium access control (TA-MAC) scheme for a two-hop D2D communication network. Specifically, D2D communications can facilitate timely data dissemination in flood-affected areas. In the proposed MAC scheme, devices are partitioned into different one-hop groups, and a time division multiple access

(TDMA)-based superframe structure is proposed to allocate different TDMA time durations to different device groups to overcome the hidden terminal problem. A probabilistic token passing scheme is devised to distributedly allocate time slots to devices in each group for packet transmissions, forming different token rings. The distributed time slot allocation is adaptive to variations of the number of devices in each token ring due to device movement. To optimize the MAC design, performance analytical models are presented in closed-form functions of both the MAC parameters and the network traffic load. Then, an average end-to-end delay minimization framework is established to derive the optimal MAC parameters under a certain network load condition. Analytical and simulation results demonstrate that, by adapting the MAC parameters to the varying network condition, the TA-MAC achieves consistently minimal average end-to-end delay, bounded delay for local transmissions, and high aggregate throughput. Further, the performance comparison with other MAC schemes shows the scalability of the proposed MAC in a two-hop disaster environment with an increasing number of devices.

Project 3-3: Massive Access Management in IoT-Enabled QoS Constrained Applications

Hesham Moussa[1] & Weihua Zhuang[1]

1. University of Waterloo, Waterloo, ON

With the emergence of the concept of Internet-of-Things (IoT), it is projected that the number of connected devices will be in the order of billions. Those devices will be scattered throughout the globe creating an enormous network that requires ubiquitous connectivity. Furthermore, due to the heterogeneity of the applications, the generated traffic will span a large spectrum of QoS requirements that needs to be attended to. In this work, we focus on providing ubiquitous and uninterrupted connectivity to critical applications such as early warning systems and eHealth systems. Those applications are characterized by their large number of simple, power and computationally constrained nodes that are spread densely and randomly across a large surface area. The data generated from the nodes are delay and fault intolerant, and they are generated randomly in response to changes in the surrounding environment. Access technologies from the field of cellular M2M are the most adopted for the applications of interest, however, the massive number of devices poses many challenges that need to be studied. In this work, we study the problem of massive access management using cellular network while observing QoS requirements of the generated traffic as well as energy efficiency. We further study the problem in a more realistic scenario under the assumption of the coexistence of the IoT applications and the traditional cellular human-to-human applications. We also investigate the potential of employing recent technologies such as small cells and D2D underlayed cellular networks to support the massive number of devices. We will then investigate the advantage of applying this network in a real life scenario. We will develop an early warning system for flood monitoring where a large number of sensor nodes are distributed over the area of interest and the data is gathered regularly for early detection of floods to avoid damage and minimize losses.

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: Development of CAFFEWS: Preliminary configuration and application to Don River Watershed*

***Jongho Keum*[1], *Tara Razavi*[1], *Paulin Coulibaly*[1] & *Edwin Welles*[2]**

1. McMaster University, Hamilton, ON
2. Deltares USA, Silversprings, MA

The development of the Canadian Adaptive Flood Forecasting and Early Warning System (CAFFEWS) involves many steps, modules, and models at work. CAFFEWS is being built on the Community Hydrologic Prediction System (CHPS) of the US National Weather Service (NWS), which is based on Delft-FEWS platform. As an initial step, CHPS was adapted and applied to Don River Watershed in Ontario. In specific, this includes a semi-distributed SAC-SMA model with SNOW17 as a snowmelt estimation routine, a unit hydrograph as a catchment routing, and Lag-K as a channel routing which were configured to calibrate model parameters by adapting CHPS templates. Next step will involve the addition of data assimilation algorithms and other hydrologic models.

Project 3-4: Application of Precipitation-Dependent Hydrologic Uncertainty Processor to a Canadian Semi-Urban Watershed

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

1. McMaster University, Hamilton, ON

It is widely recognized that uncertainty assessment in flood forecasting provides better information to decision makers, however, challenges remain for accurate quantification of uncertainties. Among all the predictive uncertainty assessment approaches, Bayesian Forecasting System (BFS) provides a robust theoretical framework that could be used for probabilistic forecasting via any deterministic hydrologic model, and it has the ability to quantify the total uncertainty associated with flood forecast. BFS includes three components: Hydrologic Uncertainty processor (HUP), Precipitation Uncertainty Processor (PUP), and integrator (INT). This work mainly focuses on the application of a Precipitation-Dependent HUP to a semi-urban watershed in Canada to assess hydrologic uncertainty. Results show that HUP is a reliable analytic-numerical method for hydrologic uncertainty quantification, the actual values are well captured by the uncertainty bounds produced by HUP, and the relative small continuous ranked probability score (CRPS) indicates good performance of this Bayesian processor. Hydrologic uncertainty increases with the increase of lead time and grows with increasing discharge, which lead to deterioration of the forecast. In the context of extreme high flow, in order to generate

improved probabilistic forecast, a well performed deterministic model is required to work with HUP. Future work will focus on PUP to analyze precipitation input uncertainty, and then combine precipitation uncertainty and hydrologic uncertainty in INT to accurately assess the total uncertainty.

Project 3-4: Sensitivity and parameter variability of SWMM5 model in semi-urban distributed watershed

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

1. McMaster University, Hamilton, ON

The nature of spatial parameter variability among calibration events is not well discussed in the literature. The objective of the study is to assess the sensitivity and Spatio-temporal parameter variability of SWMM5 model in the semi-urban watershed. The scope involves addressing the uncertainty in event-based parametrizations in a semi-urban area and proposing methods of minimizing. The study is conducted in Humber River Wateshed, located in Southern Ontario and covers 911km^2 drainage area. The sensitivity analysis was performed by using two methods: Regionalized Sensitivity Analysis and Cumulative Sum of the Normalized Reordered Output. The results of both sensitivity analysis indicate that Imperviousness followed by Drying time (DT) are the most sensitive SWMM5 parameters against NSE, Peak flow error and Volume error. The variability of calibrated model parameters sets was assessed in terms of peak flow response and the discrepancy of two sensitive parameters. The result indicates a presence of high uncertainty in representing the most impervious areas of sub-catchments and pervious areas with rapid recovery time to become dry. The spatial and temporal variability implied the need to verify potential model parameters sets with robust validation methods.

Project 3-4: Data assimilation of soil moisture and snow water equivalent data into hydrologic model of an urban basin.

James Leach[1], Kurt C. Kornelsen[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

This work examines the impact assimilation of soil moisture and snow water equivalent has on modeling an urban basin. The Sacramento Soil Moisture accounting (SAC-SMA) model was used for the analysis. The commonly used Ensemble Kalman Filter (EnKF) data assimilation method was chosen for its relative ease of implementation. Various assimilation schemes were tested with the EnKF to determine which provide the most improvement to the model. This includes performing state updating with soil moisture, snow water equivalent, and a combination of the two, as well as dual state and parameter updating doing the same while also using streamflow to update the parameters. Results showed that the dual state parameter updating with soil moisture and soil moisture with snow water equivalent had similar improvements over the open loop simulation.

Project 3-4: An evaluation of two snowmelt estimation techniques within MAC-HBV model for daily mean and peak flow

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

1. McMaster University, Hamilton, ON

Snowmelt plays an important role in the hydrology of snow-dominant areas such as North America, especially during spring snow melt period. Accurate simulations of spring snowmelt obtained by employing different snowmelt components are critical to water resource managers and flood forecasters. The focus of present study is on spring peak flows which are caused by a combination of sudden snowmelt and heavy rains and can lead to floods. Current research aims at identifying robust technique to replace existing snowmelt routine in MAC-HBV hydrological model. MAC-HBV a lumped conceptual rainfall-runoff model developed following HBV model, is currently equipped with simple temperature index method i.e. degree-day snowmelt routine. Temperature index method is based upon empirical relationship between air temperature and snowmelt where a threshold temperature is set above which melt occurs and is referred to as positive degree day. SNOW-17, a single layer conceptual snow model, represents energy exchange explicitly at snow-air interface. The current temperature index method and SNOW-17 model were adapted and their performance was evaluated for daily streamflow as well as spring peak flow estimation using MAC-HBV model. The study uses 36 years of data across 4 sub-watersheds of La-Grande River Basin located in North –Central Quebec.

Project 3-4: Interdependence of Hydrological Model Parameters and Precipitation

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

1. McMaster University, Hamilton, ON

Conceptual hydrological models are the backbone of operational hydrology for applications such as streamflow/flood forecasting and climate change impact studies. In a typical application a model is calibrated using high quality precipitation data and then used in an operational setting with a different precipitation data set, either from numerical weather prediction, radar, or downscaled climate models. We will demonstrate the strong inter-dependence between model parameters and forcing leading to large model uncertainty, particularly for high flows. Three gauge based high quality forcing data sets were used to calibrate the MAC-HBV model in 72 basins across Canada. The results will be presented from an uncertainty analysis and cross validation experiment to demonstrate the importance of the interaction between the particular characteristics of the chosen precipitation product and model parameters to the simulated flow uncertainty. Hydrological model parameters resulted in the largest source of uncertainty for low flows, whereas precipitation uncertainty and model parameter uncertainty were approximately equal contributors to the overall uncertainty of high flows. Interestingly, when considering total model performance, as expressed by the Nash Sutcliffe Efficiency, the largest source of uncertainty in simulated streamflow was the interaction between model parameters and precipitation forcing. The importance of the interaction term will be discussed as well as its implications for hydrological applications such as streamflow forecasting, climate change impact studies and hydrological stationarity.

Project 3-4: Multi-objective optimization of Don River PCSWMM/SWMM5 model

Tara Razavi[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

In this study, two automatic single and multi-objective optimization frameworks for Don river PCSWMM/SWMM5 model are investigated. A single-objective genetic algorithm and Non-dominated Sorted Genetic AlgorithmII (NSGAII) are adapted for optimizing the peak flow sensitive model parameters. Both approaches exploit observed rainfall data from several storm events simultaneously. For the single-objective optimization approach, the discharge data of the downstream gauge (Todmorden) are used; for the multi-objective optimization, the discharge data of several stream gauges are used simultaneously. Four model performance metrics, including Nash Sutcliff Efficiency (NSE), Volume error (VE), Kling-Gupta Efficiency (KGE), and percent of peak flow error are applied for both model optimization and evaluation.

Project 3-4: Geo-statistical approach to compare radar estimated precipitation data and conventional surface rain gauge measurements – A case study for Humber Waterhsed

Dayal Wijayarathne[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Radar produces real time, spatially and temporally continuous precipitation data over a large area. There is a considerable interest in real time precipitation information derived from radar over the conventional rainfall gauges in operational forecasting. In the current study, rain gauge measurements and radar estimated precipitation along with model simulations were compared to provide optimal precipitation data for real time flood forecasting. Preliminary results indicate that there is a significant difference between means of gauge and radar estimated precipitation measurements. After removing the mean bias the reported average difference is reduced from 32%to 20.5%. Even though the model simulations using both gauge measured and radar simulated precipitations do not show a good match with observed discharge at the outlet of the watershed, the correlation is relatively higher for gauge estimated precipitation than the radar estimated precipitation. This study shows that the radar adjustment techniques should be used to adjust the radar data to match with gauge measurements before using radar data as precipitation input for hydrological models to predict real time flash floods.

Project 3-4: Assessing reliability of 6-hourly and disaggregated 1-hourly Canadian Precipitation Analysis (CaPA) data

Pedram Darbandsari[1] Tara Razavi[1] & Paulin Coulibaly[1]

1. McMaster University, Hamilton, ON

Canadian Precipitation Analysis (CaPA) system is designed by Environment Canada to combine various sources of precipitation data to produce a near real-time gridded accumulated 6-hourly precipitation estimates. In order to use the 6 -hourly CaPA data for flood forecasting in areas where rain gauges are sparse or have poor quality records, reliable 1-hour disaggregated form of CaPA data is really crucial. In this study, first the original 6-hourly CaPA Precipitation data are compared with the available gauge data in Don River and Humber River watersheds, then a combination of quantile mapping bias correction and cascade-based disaggregation technique is

applied to generate a more reliable and proper hourly continuous precipitation time series for the aim of flood forecasting.

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: The Importance of Hydrographic Event on Nutrient Concentrations in 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

As high discharge events are predicted to increase in Canada, it is important to understand how these events will influence the levels of nutrients in our streams to help predict and mitigate potential contamination of our waterways. While stream discharge measurements are often collected daily, nutrient levels are measured far less frequently, thus the concentration of nutrients must be estimated for missing days. Typical estimation methods primarily take discharge into account, however nutrient concentrations vary at the same discharge level depending on whether the stream water is rising or falling. We examined long term data for 79 sites across Ontario to assess the factors that influence the differences between average nutrient levels and those on the rising and falling limbs of the hydrograph. Using nutrients binned by discharge exceedance levels, ANCOVA analysis showed that 10-20% of had significant total phosphorus, phosphate, total kjeldahl nitrogen, and/or nitrate concentration differences between rising and falling hydrograph limbs. Using BIC model selection, we found that the catchment parameters explaining these differences varied depending on the discharge exceedance level. We plan to use this information to assess whether a hydrographic limb adjustment improves nutrient estimation of commonly used models.

Project 4-1: Nutrient budgets calculated in floodwaters using a whole-ecosystem experimental manipulation

***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 through 2003. This whole ecosystem experiment data presented a unique opportunity to evaluate how flooding alters nutrient dynamics in freshwaters and ultimately how flooding affects water quality. Total nitrogen and total phosphorus fluxes were positive in all reservoirs in all years of flooding, indicating internal nitrogen and phosphorus production occurred. Phosphorus fluxes decreased after each flooding season, but nitrogen fluxes remained high during all flooding seasons. These results indicate that substantial amounts of nitrogen and phosphorus can be released after one flood, but nitrogen continues to be released at similar levels with repeated flooding.

Project 4-1: Hydrology and land use control DOM and nutrient patterns in streams

Christina Fasching[1], Henry F. Wilson[2], Sarah C. D'Amario[1] & Marguerite A. Xenopoulos[1]

1. Trent University, Peterborough, ON
2. Agriculture and Agri-Food Canada, Winnipeg, MB

Streams and rivers play a major role in carbon cycling at the reach to global scale, controlling the input, transport and transformation of both terrigenous and autochthonous organic matter, and nutrients along the river continuum, regulating the stream nutrient and organic matter budget. Thus, the natural flow regime influences in-situ stream production and nutrient and organic matter inputs from the surrounding catchment, as well as the degree of biogeochemical processing within the stream. The frequency and amplitude of floods and high flow events significantly alter these inputs and the ability of streams to effectively process received nutrients and dissolved organic matter (DOM). In the light of ongoing climatic and anthropogenic induced changes, affecting stream hydrology as well as land use patterns, it is crucial to understand the effects of extreme hydrological events on nutrient and DOM dynamics within ecosystems. Here we present event-based data from 21 predominantly agriculture based catchments in Manitoba, Ontario. We studied the effect of extreme hydrological events on stream phosphorus and nitrogen concentrations and DOM composition and bioavailability, monitoring streamwater dissolved organic carbon (DOC) and a suite of optical properties of DOM across varying hydrological and climatic conditions over four years. Preliminary results suggest the flow regime controls stream DOM dynamics, modulated by seasonal processes and land use properties. We used DOM, an important intermediary in carbon cycling, as a tracer of solute source, allowing us to link the terrestrial catchment inputs to the stream during flooding events. Flood events initially led to the export of more bioavailable DOM, possibly from autochthonous production during low flow, while continuing high flows resulted in the downstream export of more refractory DOM fractions. DOC concentration during high discharge events coincided with increased total nitrogen levels and specific ultraviolet absorbance (SUVA) index, indicating the export of relatively more refractory DOM originating from soils into the stream. Our study highlights the relevance of the flow regime and land use patterns on the dynamics and composition of DOM and nutrients in streams. We discuss these findings in the context of environmental impacts of extreme hydrological events.

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

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

1. University of Saskatchewan, Saskatoon, SK

Integrated flood risk assessment requires developing suitable methods to quantify and predict impact of floods on the physical environment. Developing hydrological models to quantify these floods is one of the main objectives of project 4-3. In the present study, we develop a hybrid systems modeling approach to predict streamflow in the Qu'Appelle river basin (QRB), which is dominated by the prairie hydrological processes. Unique topography with dynamic hydrological contributing area, in association with multiple lake system operations and interactions, increase complexities in applying conventional hydrological systems models for specific purposes in such areas. The hybrid modeling approach is intended to consider both natural processes and lake system management, where a hydrological model (Modelisation Environmentale Communautaire (MEC)—Surface and Hydrology (MESH)) is intended to handle natural processes, and the lake system model is designed to address lake operations and interactions. The performance of a hydrological model in the prairies is mostly dependent on the runoff generation process. In this direction, we proposed an improvement to existing runoff generation algorithms within MESH, which was presented in the previous FloodNet workshop. A separate lake systems model is also developed using System Dynamics (SD) approach to handle the system of multiple lakes in the Qu'Appelle River Basin. Hybridization of models is done by using MESH to feed outflows of the natural tributaries to the lake system model and predict streamflow at the outlet considering the effects of multiple lakes system. The effect of lakes is analysed by observing the differences between estimated flows of a naturalized MESH model and SD model to understand the benefit of model hybridization. Key challenges associated with the hybrid modelling including sensitivity analysis, calibration and validation, hybridization, and quantification of error propagation will be discussed.

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 134.80% 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. An 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 risk assessment under uncertainty – A case study of the Qu'Appelle river basin*

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

1. University of Saskatchewan, Saskatoon, SK

Developing a systematic approach for food risk analysis that quantifies the risk along with its uncertainty, and utilize the quantification for management and planning purposes forms the basis of project 4-4. In the direction of addressing the objectives of the project, we present the progress in two parts. In the first part, a combined 1D/2D model using HEC-RAS, is setup for the Moose Jaw river and a reach of the Qu'Appelle river in Saskatchewan to simulate water depth in the channel, as well as inundation extents and depths in the floodplain along the river reaches. The model is setup by dividing the study area into reaches defined by 1D elements and reaches completely defined by 2D elements, depending on dominant flow patterns at those locations. A one-at-a-time sensitivity analysis is carried out to determine the effect of boundary conditions, model parameters, and choice of DEM on the output, i.e. inundation depths. Model simulations are conducted based on perturbing these parameters within expected ranges of uncertainties to rank the sensitive parameters in the hydraulic model. We propose replacing the conventional approach of defining the flooding extent by a single line, with a probabilistic inundation extent. Inundation probability is defined as the number of times a pixel in the floodplain is inundated divided by the total number of simulations. Such a probabilistic flood hazard map (PFHM) will help visualize uncertainty in the boundary of flood extents. A product of PFHM and exposure map can result in a probabilistic flood risk map (PFRM) with uncertainty bounds that would be useful for more informed decision making. The second part of the study presents the development of a hydraulic model for the entire reach of the Qu'Appelle river up to Welby, SK. The purpose of this study is to identify and propose best practices for flood modeling in a river system dominated by controlled and uncontrolled lakes. Insights into the effects of lake management strategies and utilizing hydrological model outputs as boundary conditions for hydraulic models are also discussed.

Project 4-4: A topography- and rule-based approach to inundation mapping in the prairies

***Mohamed Ismaiel Ahmed*[1] *& Amin Elshorbagy*[1]**

1. University of Saskatchewan, Saskatoon, SK

Canadian prairies are characterized by flat and undulating terrain with millions of depressions of glacial origin, known as prairie potholes. The prairie depressions can retain a significant portion of the surface runoff during snowmelt or rainfall events, and flow propagation follows a unique fill and spill mechanism. Flooding patterns over the potholes cover large areas and cannot be modeled using conventional hydraulic models. Existing approaches to represent pothole connectivity and storage dynamics use either probability distributions or utilize very fine resolution terrain models to extract their actual properties. A drawback with the former approach is its inability to represent the actual spatial distribution of the pothole connectivity, whereas the latter approach is computationally expensive or unaffordable. There is a need to develop a model that can predict flooding patterns and surface water connectivity using available digital elevation models (DEMs). In this study, we introduce an approach that utilizes topography and rule-based method to model the connectivity of water in potholes and determine the path of surface runoff. The direction and amount of flow is determined using a minimization algorithm that attempts to minimize the differences of water elevation in contiguous cells, whereas the travel time is governed by the Manning's equation. The proposed approach is tested over a pothole dominated area within the Moose Jaw watershed using hypothetical and observed rainfall events. The model provides promising results in predicting the spatial pattern of flooding with time, and in representing the actual connectivity between potholes over different DEM resolutions. The proposed approach can be extended by considering other hydrological processes (e.g. infiltration, evaporation) in conjunction with overland flow.

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

Project 4-5: A microsimulation model of willingness to pay*

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

1. McMaster University, Hamilton, ON

We use a microsimulation model to understand the dynamics of population vulnerability to flood risk. Our model serves as a 'virtual lab' for testing 1) the assumptions of previous research on willingness to pay for insurance and risk mitigation and 2) the effects of different policy instruments on the distribution and level of future flood risk. Our model is parameterized based on the effects found in previous research, and uses data from a combination of sources, including the 2011 National Household Survey and environmental data. Our results suggest there are important differences in population vulnerability to floods across a variety of policy options. Future work will parameterize the model with experimental and survey data from the community.

Project 4-5: A Method to Assess the Impact of Flooding on Traffic Flows in Hamilton

Nosheen Alamgir[1]& Darren Scott[1]

1. McMaster University, Hamilton, ON

This research presents an approach for assessing the traffic flow impacts of flooding events on urban road networks. The approach, known as the Network Robustness Index (NRI), measures the change in system-wide congested travel time associated with the partial or full closure of a road segment. The approach is demonstrated for Hamilton's road network.

Evaluation of Streamflow and Lake Inflow Forecasts from ECCC's Water Cycle Prediction System for the Great Lakes and St. Lawrence*

V. Fortin[1], D. Durnford[1], Y.-L. Shin[1], M. Dimitrijevic[1], L. Benyahya[1]

1. Meteorological Research Division, Environment and Climate Change Canada, Dorval, Canada

Since June 2016, the Water Cycle Prediction System (WCPS) provides short-term forecasts of various components of the water cycle for the Great Lakes and St. Lawrence watershed. These include streamflow forecasts on a 1-km grid as well as lake inflow forecasts for each of the Great Lakes. The system is completely automated and provides forecasts for three days into the future. In this presentation, we present an evaluation of the performance of this system by comparing forecasts to observations but also to operational forecasts issued by the Government of Quebec. It is shown that the system displays a persistent bias which changes from season to season. Once this bias is accounted for, these automated forecasts are shown to have skill comparable to that of forecasts issued by the Government of Quebec after careful quality control by a forecaster. The WCPS is particularly skillful at predicting rises in streamflow. Since the WCPS currently does not assimilate any streamflow observations in the Province of Quebec, it is expected that the trend forecasted by the WCPS can be useful to identify locations where flooding might occur due to rainfall or snowmelt at both gauged and ungauged locations.

The 2013 Billion Dollar Flash Flood in Toronto – Challenges for Operational Forecasting and Nowcasting*

David Sills[1]

1. Environment and Climate Change Canada, Toronto, ON

July 8th 2013 seemed like a typical summer day in southern Ontario – warm and humid with a chance of thunderstorms in the afternoon. Forecasters expected storms to be accompanied by heavy rain and gusty winds with only a 'slight risk' of storms becoming severe. Despite the lack of typical meteorological ingredients for a significant flash flood event, copious amounts of rain fell over the Greater Toronto Area (GTA) over a period of several hours with up to 138 mm observed. While only minor injuries were reported with the event, there were approximately $850M CDN in insured losses and at least $150M CDN more in uninsured losses, making it a 'billion dollar storm'.

The interaction between the Lake Ontario lake-breeze front and an outflow boundary generated by an initial area of storms north of the GTA appeared to play a critical role in the event, causing unexpected storm development along the lake-breeze front toward the Lake and directly over the GTA. Large and rapid increases in total lightning preceded the flash flooding by more than 20 minutes, and occurred more than an hour before a warning was issued.

Real-time NWP output and post-event, very high-resolution simulations both significantly under-predicted precipitation amounts. Rainfall accumulations from Canadian

radars were significantly underestimated as well. However, algorithms using dual-polarization products from the King City radar post event were able to mostly correct for attenuation problems and gave accumulations exceeding 150 mm. Social media provided some of the first and only real-time indications that an historic flash flooding event might be underway.

The evolution of what is now Ontario's costliest natural disaster, the operational challenges associated with forecasting and nowcasting for this event, and key indicators that could help improve prediction for this type of flash flooding will be discussed.

Quantification of Predictive Uncertainty in Flood Forecasting Using Bayesian Approaches*

***Daniela Biondi*[1]**

1. Università della Calabria, Calabria, Italy

An explicit recognition and a proper quantification of uncertainties associated with deterministic hydrological models output are essential for purposes of both research and operational modelling (e.g. for flood risk management and water resources management). Predictive uncertainty (PU) is defined as the probability of occurrence of a future value of a predictand of interest (such as water level, discharge or water volume) conditional on all the information available on the future value. In hydrological forecasting, the knowledge about future discharges or water levels are typically embodied in a single or multiple model forecasts derived from meteorological-hydrological forecasting chain, that typically are affected by several sources of uncertainty. Formal statistical analysis, mainly based on Bayesian statistics provide the foundations and the tools to handle the problem of decision making under uncertainty and lead to the development of model post-processors for PU estimation based on a number of alternative approaches, that were firstly thought to work in conjunction with a single deterministic model, while recently increasing interest has been devoted to estimate PU associated to hydro-meteorological ensembles forecasts. The performance of a Bayesian Forecasting System (BFS), with the aim of evaluating total uncertainty in real-time flood forecasting from a single model prediction will be presented for a small basin in Southern Italy. The predictive uncertainty of future streamflow is estimated through the Bayesian integration of two separate processors. The former evaluates the propagation of input uncertainty on simulated river discharge, the latter computes the hydrological uncertainty of actual river discharge associated with all other possible sources of error.

The first outcomes of a new approach aimed at obtaining a correct predictive probability density that also take into account the uncertainty of the forecast models expressed by the spreads of hydrological ensembles, will be also outlined. The results emphasize the importance of performing a comprehensive analysis on predictive distributions by using different diagnostic approaches, in order to have a multifaceted view of the attributes of the prediction.

Daily streamflow and water temperature simulation: Case study of Pacific Coast (Canada)

Loubna Benyahya[1], Milena Dimitrijevic[1], Dominique Bourdin[2], Vincent Fortin[1]

1. Meteorological Research Division, Environment and Climate Change Canada, Dorval, Canada

Streamflow and water temperature are among the most important parameters that characterize the physical conditions of freshwater ecosystems. Although water temperature is generally most sensitive to the heat exchange processes at the air–water surface interface, changes in streamflow significantly affect water temperatures due to changes in thermal capacity, travel time, and dilution capacity for thermal effluents. Among river temperature models, forecasting models remain relatively unused compared to water temperature simulation models. However, water temperature forecasting is extremely important for in-season management of fisheries, especially when short-term forecasts (a few days) are required. Moreover, to forecast fate and transport of oil in coastal waters, ocean models require freshwater boundary conditions as inputs. In order to provide realistic estimatesof daily streamflow and water temperature, the performance of a cascade of numerical models (the ISBA land-surface scheme, the WATROUTE river routing model and the RBM river temperature model) forced offline by the GEM atmospheric model, was evaluated for various simulation periods between 2013 and 2015. During this period, GEM outputs were available from three configurations: RDPS (10-km resolution over North America for the whole period); LAM-WEST (2.5-km resolution over southern BC and Alberta until November 2014); and HRDPS (2.5-km resolution, national coverage since October 2014). The performance of the GEM (ISBA)-WATROUTE-RBM system was evaluated by comparing output to observed daily streamflow and water temperature at three streamflow gauging stations. The impact of using a gridded snow depth analysis was also evaluated in order to constrain the land-surface model. The results indicate that the most accurate estimates of streamflow were obtained when using the higher resolution HRDPS configuration of GEM and using the snow analysis to constrain the surface model. For small river basins, the modelling approach has the potential to be used for water resource management to provide forecasted streamflow and water temperature for management decisions (e.g. thermal pollution) and climate change impacts.

Daily streamflow and water temperature simulation: Case study of Pacific Coast (Canada)

É. Gaborit[1], V. Fortin[1], D. Durnford[1]

1. Meteorological Research Division, Environment and Climate Change Canada, Dorval, Canada

This work describes the implementation of the distributed GEM-Hydro runoff modeling platform, developed at Environment and Climate Change Canada (ECCC), for the tributaries of the Hudson Bay and the Mackenzie River. The latest version of GEM-Hydro combines the SVS (Soil, Vegetation and Snow) land-surface scheme and the WATROUTE routing scheme. The implemented simulation platform can have many environmental applications such as short-term operational flood forecasts or climate-change impact assessment, and can generally serve as a useful tool to promote an integrated and optimized freshwater resource management. It was implemented here at a very-low spatial resolution (0.5˚) over the Hudson Bay watershed, but also at a higher resolution (≈0.17˚) for the Nelson and Churchill Rivers, two tributaries of the Hudson Bay. GEM-Hydro was implemented with a 0.125˚ resolution for the Mackenzie River. As regulation significantly influences the hydrological regime in these areas, its effect was represented in the model using lakes with a natural behavior, i.e.,

with storage-discharge relationships. Finally, the higher-resolution GEM-Hydro model implemented over the Mackenzie and Churchill Rivers was calibrated using a global calibration framework allowing to increase model performances at different sites in a simultaneous manner. As global calibration generally leads to robust parameter sets, some of the calibrated parameters obtained this way were then transferred to the rest of the Hudson Bay tributaries and the Mackenzie watershed, resulting in a significant gain in performances compared to default ones.

Flood forecasting with WATFLOOD®/CHARM™

***Nicholas Kouwen*[1]**

1. University of Waterloo, Waterloo, ON

WATFLOOD® is a set of computer programs designed specifically for flow and flood forecasting. Its architecture is designed to make optimal use of various gridded data including numerical weather forecasts, remotely sensed watershed land cover and digital elevation data without any loss of the spatially relevant features of each data set.

The main component is the Canadian Hydrological And Routing Model (CHARM™). There are a number of associated pre & post processing programs to convert historical and predicted weather data for modelling with CHARM. In addition, NRC's Green Kenue graphical interface is used for visualization of model inputs and forecasts. It allows animation of all variables in the model.

Three variations of the WATFLOOD forecasting system are currently available for real-time forecasting based on CMC Regional and Global Numerical weather forecasts. One is a brute-force method, the second is a semi-automatic approach using Python scripting and Green Kenue while the third is a fully automated web-based approach where the forecast is ready in the morning and the user merely has to open a website to view the anticipated flows.

The poster will show an application of the WATFLOOD system to flow forecasting