Assessing baseflow simulation using MESH in Upper Liard Sub-Basin

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Poster Presentation
Session: Modelling and Observations
Poster # 45

Baseflow is an important part of the hydrograph of many rivers. It might contribute a small volume overall, but it maintains flow in streams when other sources are absent. An accurate simulation of the recession part of the hydrograph, which is formed by baseflow, is difficult due to the complexity of several interacting processes, especially in the cold regions that are characterized by snowmelt or glacier melt.
The MESH modelling system of Environment and Climate Change Canada (ECCC) that provides a physically-based hydrologic model is a powerful tool for simulating hydrologic processes in cold regions. However, it had no a mechanism to route the baseflow component of streamflow, as drainage from the bottom of the soil column was added directly to overland and interflow runoff components, reaching the stream quickly. Two conceptual algorithms were added to MESH to route that drainage to introduce the required delayed response. These are based on WATFLOOD and Luo et al., 2012 (Non-Linear Reservoir approach) where two parameters control the process at the scale of river class and Grouped Response Unit (GRU) respectively. The purpose of this study is to assess and compare those algorithms. The parameters of the two existing MESH routing schemes for streamflow were included in the calibration. The baseflow and routing algorithms have been assessed for the 32,000 km2 upper Liard sub-basin. The simulation extends from 2004 to 2012, including a one-year warm-up followed by a 5-year calibration period. A 0.125o grid resolution MESH model is set up with meteorological forcing from the GEM-CaPA dataset. The routing (baseflow and streamflow) component was calibrated using the dynamically dimensioned search technique (DDS) (part of the Ostrich optimization package). A pseudo multi-objective function combining Nash-Sutcliffe “NS”, Nash-Sutcliffe of Logarithm of flow “LNS” and the percentage Bias “PBias” at the outlet flow gauge (in some calibration experiments the metrics of two internal gauges are included in the objective function) was constructed for calibration. The study included sixteen simulation configurations incorporating different baseflow and routing modules and a combination of objective function metrics at either 1 or 3 stations. The results suggest that both baseflow algorithms can provide realistic recession and low flow conditions. Further improvements can be achieved if another storage is added to represent long-term discharge, for example from deeper groundwater. Simulated flows generated by the two routing modules are similar and closely match the observed flow. However, the less lumped routing module (RTE) slightly outperforms the older module (WF_Route) with a difference of 5% for NS and PBias. Incorporating the three metrics of the outlet in the objective function showed an improvement of both of the outlet and the internal station hydrographs compared to using NS only. Including the metrics of internal flow stations in addition to the outlet (nine

metrics) gave a slight improvement in the NS and LNS performance, with a worsening of PBIAS. We conclude that baseflow representation is important, and that the algorithms presented here provide a sound basis for enhanced model performance and regional application.

Agroclimatic Indices Changes over Western Canada by the end of 21st Century in a Convective Permitting Regional Climate Simulation

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Poster Presentation
Session: Climate and Extremes
Poster # 28

Future trends and variability in agroclimatic indices and how patterns of growing season precipitation will change under future climate over Western Canada are investigated. Using simulations from convective permitting scale Weather Research and Forecasting model (WRF) with 4km spatial resolution for 2000-2015 (historical) and 2085-2100 under RCP8.5 using Pseudo Global Warming (PGW) approach, the effect of changing climate on the onset, length and cessation of the growing season are examined together with the constraints or opportunities these changes will present to agriculture. This high-resolution simulation provides better delineation of future changes in climate in the end of century over Western Canada, especially those associated with extreme precipitation and temperature events, which in turn can be translated to better agroclimatic information for the agricultural sector of the economy.

Application of Network Flow Models for Integrated Water Resources Management in Saskatchewan River Basin

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Poster Presentation
Session: Modelling and Observations
Poster # 51

The Saskatchewan River Basin (SaskRB) is a large, multi-jurisdictional river basin that spans the Canadian provinces of Alberta, Saskatchewan, and Manitoba and the US State of Montana, and is a key water resource for these prairie regions. Extensive water developments, primarily irrigation, took place in Alberta prior to the signing of the Master Agreement in Apportionment between the provinces in 1969. The apportionment agreement between different provinces and complex operating policies have resulted in the provinces adopting their own models for water management and decision making, resulting in fragmented water management. However, agricultural land use in the Prairie Provinces continues to evolve, and future increases in the area of irrigated crop land are possible. Increased development, along with increased hydrological variability due to climate change, are likely to further complicate the process of water management in the SaskRB. This increased complexity in water management and possible future shortcomings of the apportionment agreement, particularly under water stress conditions, points to the need for basin-wide integrated water resources management. The aim of this study is to integrate water resources components across the entire SaskRB into one modelling platform, in line with the aims of the Integrated Modelling Program for Prediction and Management of Change in Canada's Major River Basins (IMPC), to facilitate Integrated Water Resources Management (IWRM) in the basin. For this purpose, we use the MODSIM-DSS software package, developed for river basin water management and decision support. We emulate the current physical system within MODSIM model and validate the model by comparing the model results with that of the Water Resources Management Model (WRMM), used by Saskatchewan Water Security Agency (WSA) and Alberta Environment and Parks (AEP).In addition, model performance will be evaluated by reliability, vulnerability, and resiliency of the water management system. A range of future scenarios of hydro-climate change and irrigation expansion will be considered and tested over the 21st century to analyze the vulnerability of the water resources system under different conditions.

Cascade of uncertainty in CMIP5 climate projections for scenario-led water resource impact assessments in major river basins of Canada

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Oral Presentation
Session: Climate and Extremes
14:00–14:15, Wednesday, June 6, 2018
Room 1110

The potential impacts of climate change on hydrology and water resources are now unequivocally recognized as an urgent research issue, with a growing focus on risk assessment, and the identification of appropriate adaptation measures. Global climate models (GCMs) are our major source of knowledge for developing quantitative hydrologic storylines of future change for the water sector. Climate projections have demonstrated the need to adapt to a changing climate, but have been less helpful in guiding how to effectively adapt. Part of the reason is the 'cascade of uncertainty' going from future society, through greenhouse gas emissions, GCM simulations, regional scenarios, impact models and local impacts to an adaptation response. This study focuses on representing the first three layers (future society, emission scenarios, and global climate models) of the uncertainty cascade using quantitative data. This is demonstrated using annual precipitation and air temperature over selected river basins across Canada as projected by 32 GCMs (under four representative concentration pathways—RCPs 2.6, 4.5, 6.0, 8.5) participating in the Coupled Model Intercomparison Project Phase 5 of the Intergovernmental Panel on Climate Change. The analysis is performed for three 20-year future windows (2016–2035, 2046–2055, and 2080–2099), relative to the 1986 – 2005 historical period. Across all basins, results indicate that for the near term (2016–2035), the relative importance of the RCPs is far smaller than the uncertainty in the GCM response. For the mid-term (2046–2055), GCM uncertainty is dominant. However, at the end of the century (2080–2099), the RCP uncertainty tends to dominate more. In terms of climate variables, the uncertainty in basin-wide precipitation due to internal climate variability is found to be larger compared to temperature. These findings have important implications for climate downscaling and water-related impact studies in terms of selection of GCMs, scenarios, realizations and future time windows.

Characterizing ELA Lakes to Predict Safe Drinking Water Sources with Minimal Disinfection By-Products

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 1

Safe drinking water is a universal necessity. Chlorination during the drinking water treatment process removes harmful pathogens, however chlorine reacts with residual organic matter that is recalcitrant to removal and generates potentially carcinogenic disinfection by-products (DBPs). The chemical composition and reactivity of dissolved organic matter (DOM) influences its amenability to removal and subsequently the formation of DBPs during the drinking water treatment process. Research conducted on the physical and environmental factors that govern DOM export from catchments to streams and lakes indicates that the dominant land cover types and hydrology of a system largely drive DOM concentration and composition. Lake water residence time has been shown to be one of the most important factors to influence DOM quantity and quality through its influence on in-situ processes, such as photodegradation, sedimentation, and microbial decomposition. Lakes with longer residence times allow more time for greater in-lake loss and the alteration of DOM. The importance of catchment landscape features and hydrology on controlling the characteristics of DOC in relation to the formation of DBPs is still largely unknown. This research will characterise lakes and catchments at the IISD – Experimental Lakes Area (ELA) in relation to catchment landcover and lake water residence time, and relate this to the formation potential of harmful DBPs in order to predict safe drinking water sources. A subset of eight lakes were chosen through the Lake Variation Climate Change Study in 1993 that have similar lake surface areas with increasing catchment areas over several orders of magnitudes. This creates a unique opportunity to study the influence of an extensive residence time gradient on DOM characteristics in lakes and the formation of DBPs through chlorination. The proposed research aims to develop predictive relationships between landcover, catchment area, and lake residence time with the types of DOM that produce few DBPs. The ultimate goal of this research is to aid in the selection of drinking water sources that produce few DPBs during treatment, thus reducing the cost of water treatment, and the harmful health effects of DBPs.

Northern Canada – regional issues and Global Water Futures' scientific response

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Oral Presentation
Session: Plenary
9:45–10:15, Wednesday, June 6, 2018
Room 1305/7

Canada's north is among the most rapidly warming regions on Earth. The scale and rapidity of recently observed warming-induced changes throughout this region indicate that it is capable of rapid responses to perturbations. Unprecedented changes in snow cover and rates of permafrost thaw are transforming ecosystems (e.g. conversion of forests to wetlands; lakes to thaw lake basins; tundra to shrub vegetation), and changing the distribution and routing of water over the landscape, which confounds the prediction of eco-hydrological responses to combined warming and changes in precipitation regimes. Change or intensification of geomorphic and hydrologic processes have altered flow and sediment regimes and aquatic health of streams, rivers, and lakes, including key waterways used for hydropower, water supply, and transportation. These changes directly affect the health, well-being, safety and livelihoods of northern communities. Resource exploration and production is expected to expand dramatically in the north in the coming years, which will include construction of new highways, pipelines and other infrastructure. Combined with the legacies of past development activities, the security of water resources is of paramount concern. Government and industry decision makers, and local and Aboriginal communities and co-management boards urgently require science-based predictive tools and user-driven mitigation and adaptation strategies. In direct response to these water security challenges, Global Water Futures is supporting Northern Water Futures (NWF), a NWT-focused consortium of knowledge producers, mobilisers and users from university, communities, government, industry and non-governmental organisations. Together, we are working collaboratively to improve the understanding of, and ability to predict and mitigate, the impacts of climate change and industrial expansion on the NWT shared water resources. In this talk, we will review key water resource-related issues in the Northwest Territories and the NWF project.

The Application of MESH Land Surface-Hydrology Model in Sefidrud River Basin, Iran

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Poster Presentation
Session: Modelling and Observations
Poster # 46

The community land surface-hydrology model, MESH, was applied in its standalone mode to a large river basin in Iran. The Sefidrud (Sefidrood) River is the second largest river in the country with a size of more than 65000 square kilometers. The basin elevation ranges from 14 meters below sea level near the Caspian Sea coastline up to 3856 m above sea level in Alborz Mountains in the Northeast and Sahand summit with 3707 m in the Northwest side of the basin. Main part of the study area is semiarid (warm regions in the south and cold regions in the north). The dominant land cover is rangeland, however, variety of land uses such as forests and crops exist in the basin. The basin was discretized into grid cells of around 100 km2. Forcing data are obtained from the Global Environmental Multiscale Model (GEM) dataset available at 25 km resolution. Eighteen hydrometric stations are available for calibration and validation purposes.
Since some dams in the watershed regulate the flow, the initial focus of the work will also be on calibrating to the head-water subbasins with unregulated flows and reproduction of water balance components by the model. The preliminary results show reasonable model performance in this respect. However, simulations are expected to improve in other subbasins as well after implementation of the reservoir operations in the basin. This study is the first application of the MESH model in Iran. Future work can include using MESH for climate and land use change impact studies in this basin.

Examining the base of the food web at the Experimental Lakes Area

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 2

As a direct consequence of concerns about the effects of climate change and land use change on watersheds, there is growing scientific interest as to whether inputs from the terrestrial environment or lake primary productivity drive freshwater ecosystems. Lakes receive organic matter (OM) inputs from their terrestrial surroundings, profoundly shaping these freshwater ecosystems. For instance, inputs of OM from terrestrial systems can shape the function of lakes by darkening water and can subsidize food webs by providing additional nutrients to the system. Primary production can be conducted by phytoplankton communities, macrophytes, or periphyton communities living in the lake. The Experimental Lakes Area (ELA) located in remote Northwestern Ontario, Canada is an ideal location to investigate whether OM of terrestrial origin or in situ primary productivity is more important for aquatic food webs. The ELA allows for the examination of scientific questions at a whole ecosystem level without the limitations of laboratory studies. OM is the main driver of ecosystem function and exists in both particulate and dissolved portions. For boreal systems, key determinants of productivity include the amount of dissolved organic matter (DOM) in the water, and the generation of dissolved inorganic carbon (DIC) used in photosynthesis from dissolved organic carbon (DOC) photolysis and decomposition. By following the stable isotope signature of the OM and DIC in boreal lakes with time across a gradient of DOM, I aim to determine the role of DOM in controlling the isotopic signature of the particulate organic matter (POM) produced in the lake, what terrestrial endmembers contribute to POM, and ultimately the origin of the carbon incorporated into the food web.

Effects of the Scale of Forcing on Winter Albedo and Snowpack Simulation in Boreal Forests Using the Canadian Land Surface Scheme

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Poster Presentation
Session: Modelling and Observations
Poster # 47

Biases in simulated winter albedo and regional climate have been shown to be closely related in global climate and Earth system models (ESMs). Forest albedo measurements from BOREAS (Boreal Ecosystem-Atmosphere Study) in the mid-1990s led to correction of a large overestimation in the albedo of boreal forests in the presence of snow in the ECMWF model, which ameliorated a regional cold bias. However biases in the simulated winter albedo in the boreal forest have persisted in many CMIP5 (Coupled Model Intercomparison Project Phase 5) models, with subsequent effects on regional temperatures and the snow albedo feedback. Inaccurate representation of vegetation distribution (plant functional types) and parameters (e.g. leaf area index, canopy albedo) have been shown to contribute to much of this bias. Recent studies have shown that the rate of unloading of intercepted snow on forest canopies is related to meteorological conditions, and the snow albedo feedback in the Community Climate System Model was found to be sensitive to interception-related albedo errors.
Land surface models (LSMs) are typically developed using site-level measurements followed by regional or global off-line testing forced with a large-scale product [e.g. Earth System Model (ESM) climate, CRUNCEP (Climatic Research Unit National Centers for Environmental Prediction), GSWP3 (Global Soil Wetness Project Phase 3), WATCH (WATer and global CHange)], prior to coupled simulations. Site level experiments can provide a high degree of accuracy, whereas larger-scale forcing offers land surface variability akin to that in a coupled ESM, without the computational expense of an atmospheric model. Given the interdependence of biases in snow-related albedo and surface climate, there is a need for assessments of how large scale products compare with local forcing, and to understand the effects of scale on the simulated surface properties in LSMs, especially albedo and snow properties.
We compare biases in CRUNCEP V8 and GSWP3 relative to site-level forcing and present off-line simulations conducted with the Canadian Land Surface Scheme at Canadian boreal forest sites with forcing at scales from site level to T63 (~2.8°). We show that biases exist in near-surface temperature, incoming longwave radiation, precipitation and wind speed. In CRUNCEP V8, the diurnal range in air temperature was more exaggerated while wind speed was biased high in GSWP3. Precipitation bias varied seasonally and from site to site. As the scale of forcing increases, the number of days with snow on the ground at forest sites increases, the result of a negative temperature bias as the local forest heat island is lost. The average monthly albedo also increases with scale but is less variable compared with

site-level forcing. We examine the effect of these different forcing biases on snowpack properties and the simulated albedo.

Canadian Prairies – regional issues and Global Water Futures' scientific response

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Oral Presentation
Session: Plenary
11:15–11:45, Wednesday, June 6, 2018
Room 1305/7

The prairies represent a unique landscape in Canada, one that features subtle changes in topography and striking variation in climate that contribute to a complex hydrological environment. Extreme cold and heat are commonplace, as are multi-year cycles of wet and dry conditions. Many of Canada's most expensive natural disasters are related to prairie climate. Agriculture is ubiquitous, and while water is critical to the economy of the prairie, the region is far from water secure. Beyond stressors of too little, or too much water, there are ongoing challenges to ecosystem health and drinking water. Water governance remains fragmented, with decisions and policies sometimes lagging key actions on the landscape. Prairie Water is a Global Water Futures research program aimed at enhancing resiliency of prairie communities to water-related stressors. Here, we describe the unique hydrology of the prairies, and the ways in which hydrology, and water-related risks are changing. We discuss key policy challenges and questions, key goals of our research program, and progress towards meeting those goals.

Management options for nutrient control in the northern Great Plains

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 3

The northern Great Plains is a key region to global food production. It is also a region of water stress that includes poor water quality associated with high nutrients. While eutrophication is often considered the primary stressor affecting water quality globally, there are local issues affecting eutrophication risk, and the success of efforts to control eutrophication. Here we review soil and water management beneficial management practices (BMPs) through a regional lens – first understanding key aspects of hydrology and hydrochemistry affecting BMP efficacy, then discussing merits of different BMPs for nutrient control. We recommend continued efforts to support 'keeping water on the land' via wetlands, and reservoirs. Adoption of reduced tillage practices and expansion of perennial forage may have contributed to current nutrient problems, but both practices have other benefits; hence, research is required to identify management changes to minimize nutrient export. Likewise, the expansion of tile and surface drainage raises questions about the magnitude of impact on nutrient export, and options to mitigate drainage impacts. Riparian vegetation is unlikely to significantly aid in nutrient retention, but when viewed against an alternative of extending cultivation and fertilization to the waters' edge, continued support of buffer strip management and refinement of best practices, such as harvesting vegetation for nutrient removal are merited. Implementation of BMPs requires consideration of a complex suite of factors. Here, the low gradient, importance of snowmelt, and high proportion of dissolved nutrients are crucial considerations in identifying BMPs that are most effective in nutrient control.

Carbon and energy exchange of a mature, temperate deciduous forest in Southern Ontario, Canada

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 83

Forest ecosystems store a large amount of carbon and are a major component in the global carbon cycle. In Canada, forests cover 347 million ha of land area, accounting for 9% of global forested area. Many of these forests are plantation or managed forests in different stages of growth. This study investigates how the carbon fluxes of a 90+ year-old temperate deciduous forest, located at a temperate-boreal transition zone, responds to changes in meteorological and phenological conditions in Southern Ontario, Canada. Results from five years (2012-2016) of eddy covariance flux measurements, biometric, and meteorological data show that considerable inter-annual variability exists. The annual mean net ecosystem productivity (NEP), the result of photosynthesis (GEP) and respiration (RE) was found to be 206 g C m-2. The highest annual NEP occurred in 2014 (305 g C m-2), a wet year (991 mm) characterized by a low growing seasons vapor pressure deficit (VPD). Conversely, the lowest NEP was measured in 2015 (90 g C m-2), defined by below average precipitation (750 mm), decreased summer PAR, and a low annual temperature. Both GEP and RE were found to be highly correlated to light (PAR) and temperature (Ta and Ts) controls, while water availability (PPT, VPD, and VWC) was not significant. Ideal conditions for the maximum NEP varied inter-annually, but occurred at temperatures near 22°C, and a VPD around 1kPa. Phenological indicators were not shown to accurately predict net carbon fluxes due to differences in growing season length and cumulative NEP. These finding will help to further the understanding of carbon fluxes in Canadian forests.

The 'Ruisseau des Eaux-Volées' experimental watershed – more than 50 years of data to promote

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 84

To assess the vulnerability of water in boreal forest, the Boreal Water Futures (BWF) team put in place the Pan-Canadian Boreal Observation Network (BON), that cover all Canada's boreal ecozones. The further east (easternmost) site, and the only one in the province of Quebec, is the 'Ruisseau des Eaux-Volées' experimental watershed (REVEW), coordinated by Professor Sylvain Jutras. The purpose of my poster is to describe the REVEW, because of its importance in the study of hydrological processes in boreal forest, and more particularly in my research in progress.
The REVEW is located at Montmorency Forest, the largest territory in the world dedicated to teaching and research in forestry. This site is managed by Université Laval. The objectives of this site are to improve the knowledge of the hydrological processes, to establish the relations between them, to understand the effects of logging, to transfer the knowledge in the regional planning and to contribute in the training of future forest hydrologists. The REVEW was created in 1965. It is a small watershed of approximately 9.2 km2. Several types of hydrological and meteorological data are taken on the site. Between 1965 and 1971, four gauges thresholds were built, as well as three meteorological stations. Through the creation of projects by several students and researchers over the years, it has been possible to improve knowledge about the impact of forest harvesting on watershed hydrology. Some of these studies have even yielded tangible results in support of changes to forest management regulations in Quebec.

Probability of compound extreme precipitation events to inform engineering design

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Oral Presentation
Session: Climate and Extremes
13:30–13:45, Wednesday, June 6, 2018
Room 1110

Providing a credible estimate of high extreme quantiles of weather variables is usually required for environmental risk assessment and engineering practice. The commonly used approach in hydrology and climatology in general, and in particular for precipitation, treats the variable of interest as an univariate process, using univariate asymptotic extreme value models constructed from data without any knowledge about the physical process that had produced them. We describe in this presentation a multivariate extreme value approach for studying rare extreme precipitation events considered as compound events. The proposed approach is general and can be applied to other compound events where the extrapolation outside the range of the available data is the key element. We illustrate this framework by an application to historical 6-hourly total precipitation simulation outputs from the Canadian Regional Climate Model CanRCM4. Main results demonstrate that analysing the precipitation as a compound event, corresponds more directly to the physical process involved, can tell us more about the given phenomenon and offers some measure of credibility when used to estimate high unobserved magnitude of precipitation.

GPM-IMERG Snowfall Estimates in Cold Mountainous Regions

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Oral Presentation
Session: Modelling and Observations - Part I
15:00–15:15, Tuesday, June 5, 2018
Room 1105

Increasing the accuracy of quantitative precipitation estimates, including rate and phase, in cold regions can help improve water resource predictions for downstream users and hydrological forecasts to better prepare downstream communities for extreme streamflow events, such as the flood of June 2013 in the Bow River Basin of the Canadian Rockies. Remotely sensed precipitation estimates are attracting considerable interest due to spatiotemporal consistency of data, but most importantly, by providing quantitative precipitation estimates for data-scarce regions such as mountains. Current advances in the development of new platforms and sensors to estimate precipitation provided by the Global Precipitation Measurement (GPM) constellation, as well as new algorithms such as the Integrated Multi-satellitE Retrievals for GPM (IMERG) have increased the application of remotely sensed precipitation to hydrology. However, the precipitation phase for GPM-IMERG is determined by poor-resolution environmental ancillary data applied to simple temperature threshold phase partitioning. The purpose of this study is to evaluate GPM-IMERG snowfall estimates using recently developed psychrometric phase partitioning techniques in the Bow River Basin of the Canadian Rockies. Snowfall estimates from GPM-IMERG were evaluated using precipitation observations made in the Canadian Rockies Hydrological Observatory (CRHO) and outputs from the runs of Environment and Climate Change Canada's Global Environmental Multiscale Model (GEM) and the Canadian Precipitation Analysis (CaPA) for two consecutive winters (2015 to 2017). Precipitation was partitioned using the Harder-Pomeroy psychrometric approach that models the energy balance of a falling hydrometeor. This method has been proven to be the most successful in the Canadian Rockies at yielding an accurate estimation of snowfall. The method was employed for three datasets: GPM-IMERG precipitation with GEM atmospheric forcings (GPM-GEM), using CaPA precipitation and GEM (CaPA-GEM), and using observations from CRHO as ground truth. GPM-GEM and CaPA-GEM snowfall estimates were also evaluated against measured snowfall accumulation. GPM-IMERG was found to estimate snowfall relatively well at lower elevation; however, it grossly underestimated snowfall at higher elevations. GPM-GEM estimates of precipitation volumes were similar to those from CaPA-GEM, but GPM-GEM precipitation timing varied substantially from CaPA-GEM. Although CaPA-GEM provided better snowfall estimates in this well-instrumented region, CaPA is a data assimilation product, dependent upon station density, which is relatively high in this region compared to the rest of the Western Cordillera in Canada. The next steps in this study will develop and apply new algorithms to adjust GPM precipitation for orographic enhancement of precipitation in mountain regions, as well as to explore new ways to stablish new reflectivity-precipitation relationships for solid precipitation estimates.

Towards a Sustainable Water Future: Shaping the next decade of global water research in the era of Anthropocene

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Oral Presentation
Session: Plenary
9:00–9:45, Wednesday, June 6, 2018
Room 1305/7

There are virtually no places in the world today where a high degree of water security for humans has been achieved without threatening environment and biodiversity. This reflects the 'traditional' management strategy of tolerating degradation of ecosystems and then applying costly remediation strategies (if at all) after the damage has been done.
Competition for water between societal needs and ecosystem demand will intensify in the future, and at the same time securing water for other vital human needs such as food and energy production, as well as safeguarding the quality and quantity of water for ecosystem, should not be neglected in pursuance of water supply and sanitation goals. Thus while framing the SDGs, there is further need for knowledge to understand how to safeguard Earth's life-support system on which the welfare of current and future generations depends. There are still gaps in our knowledge of global environmental change on how to support the economy and the society to move on trajectory which ensures resource-efficiency, sustainability and wellbeing. Unless we address those knowledge gaps, we will bear a high cost of inaction.
Sustainable Water Future Programme, a core programme of Future Earth maximizes the value of water research in the stewardship domain, co-balancing the needs of humankind and nature through the protection of ecosystems and their services provided, offering solutions based on interdisciplinary science with the involvement of all relevant stakeholders. The key note presentation will describe the newly developed programme and focus on the knowledge gaps and the research questions and issues that may be relevant in the next decade to enable human development and set tolerable ranges for the water system to remain in a steady state and within planetary boundaries.

Understanding the role of large-scale physical processes in algal bloom formation in a large shallow lake (Lake St. Clair, U.S.A. – Canada)

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Poster Presentation
Session: Modelling and Observations
Poster # 48

In temperate lakes, the ability of phytoplankton to form blooms, or their elevated concentrations, to a large degree depends on physical processes such as stratification and mixing. While the importance of vertical stratification and mixing processes relevant to deep lakes was investigated in numerous studies and are generally well understood, the importance of horizontal stratification and mixing processes for sediment, nutrient and phytoplankton dynamics has received by far less attention, and yet, not well understood, especially in large, shallow and physically-dominated lakes, such as Lake St. Clair.
Lake St. Clair is a large shallow lake (area >1100 km2; mean depth < 4 m) with a very short flushing time (mean ±SD: 9.1 ±0.4 days), which is expected to limit the lake's primary production and prevent significant accumulation of algal biomass within the lake. However, there are frequent satellite-based observations of localized moderate-sized algal blooms in the south-eastern part of the Lake St Clair. Here, we use a combination of three-dimensional (3D) coupled hydrodynamic and ecological model and remote sensing observations of lake surface temperatures and phytoplankton biomass to delineate the important role of large-scale physical processes, such as horizontal stratification and mixing, in the spatial differences in phytoplankton biomass observed in Lake St. Clair.

Investigating the effects of variable harvesting applications on the regional water balance in a red pine plantation

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Poster Presentation
Session: Climate and Extremes
Poster # 85

Thinning and harvesting in forest ecosystems disrupts water cycle components that may influence the growth response of the forest. This response has implications on forest canopy, understory, and soil carbon storage which may become vulnerable to climate change and extreme weather events that are expected to occur in the future. The variable retention harvesting approach was implemented in a red pine (Pinus resinosa) plantation established in 1931, at the Turkey Point Observatory near Lake Erie, southern Ontario. This system was designed to impart variances in spatial pattern (aggregate and dispersed) and tree density (33% and 55% canopy retention) of residual trees to examine differences in forest evapotranspiration, a key component of the forest water cycle. Evapotranspiration measurements will be collected using eddy covariance, both below the canopy and above (located on flux towers nearby). Components of evapotranspiration will be further partitioned into: stand transpiration, soil evaporation and intercepted rainfall. Sensors are custom-built and installed into trees in each plot to measure sapflow as an indicator of the amount of water transpired by each tree, and then scaled up to the stand level for each treatment. Additionally, soil temperature and moisture will be measured within each plot using a 6000-09TC (LI-COR) and Hydrosense II (Campbell Scientific Inc.), respectively. Finally, drones (Canada Centre for Remote Sensing) will be used to measure relative water content, canopy structure and stand characteristics which are necessary components to determining evapotranspiration for the treatment plots. Findings from this research will support future decision-making in forest management and make recommendations for harvesting initiatives in the region. Additionally, a thorough understanding of the ecosystem water balance is important for predicting and adapting to a changing climate.

Telling the story of a bloom

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 4

Harmful cyanobacterial blooms are a key water quality stressor – increasing in frequency and severity in many regions of the globe. There are multiple factors that may be driving these blooms – and multiple bloom-forming taxa that differ in their ecology, and both toxic and non-toxic taxa, and strains. While biweekly monitoring remains the norm for many lakes – blooms can develop and collapse on much shorter timescales, impeding our understanding of the drivers of onset, and collapse. Here, we follow Buffalo Pound Lake through a bloom season at higher frequency – using process-based measurements of nitrogen fixation, and increased temporal frequency of chemical sampling, and sensor data to understand the onset of bloom, and the capacity of a bloom to support its own nitrogen needs. We report high rates of nitrogen fixation during the peak bloom, and cyanobacterial taxa dominated by nitrogen fixers through much of the bloom season, with the exception of a secondary bloom, which may have been facilitated by nitrogen fixation in the primary bloom. Here we might note the primary bloom is dominated by Anabaena flos-aquae and Aphanizomenon flos-aquae – both potential toxin producers. The secondary bloom is dominated by Planktothrix agardhii, a potentially toxin producer, but one that does not fix atmospheric nitrogen. The onset of the bloom appears to follow increasing water temperatures, and phosphorus concentrations, leading to decreasing N:P ratios. The lake is one where the dominant bloom forming taxa are ones associated with the production of scums, and, potential toxin formation, making cyanobacterial control an important aesthetic, and health-related goal. Unfortunately, with relatively high internal loading, and high potential for nitrogen fixation, internal processes will act against efforts to manage in lake nutrients, creating long-term challenges to mitigating bloom risk in this highly used recreational lake, which serves as a key drinking water supply. Encouraging macrophyte growth, and manipulating turbidity have been proposed as potential tools to manage several of the bloom-forming taxa in other lakes, yet the potential to directly manage this long, narrow water resource is a topic which merits further discussion.

Current Communications for HABs: Scoping the Literature and Managing Messages

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Poster Presentation
Session: Human-Water Interactions
Poster # 29

Effective communication is a key part of preventing public health threats from harmful algal blooms (HABs). We conducted a scoping review to discover the extent of literature on risk communications and HABS, to summarize current knowledge and practices for both internal communications among research teams and communications from water managers to the public, and to identify testable communication approaches for HABS in the context of freshwater lakes in Canada. We scoped 2473 articles leading to the inclusion of 25 relevant articles and 2 management plans in the sample. Articles used qualitative (14), quantitative (8) and mixed (8) methods, were published between 2002 and 2017, and followed a similar narrative (risk communication for HABS are a problem needing transdisciplinary approaches and culturally-appropriate messaging to solve). Twelve themes emerging from the sample provide direction for how society constructs messages about HABs and how GWF programs can adapt communication strategies internally, and with the public to improve uptake of risk prevention measures for water-related threats like HABs.

Country Food Contaminant Advisories: Assessing Awareness and Preferences of Health and Risk Communication Messages in the Sahtú Region of the Northwest Territories

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Poster Presentation
Session: Human-Water Interactions
Poster # 30

Introduction:
Elevated concentrations of heavy metals in fish and in moose within the Sahtú Region of the Northwest Territories resulted in a series of food consumption advisories that suggested people limit their consumption of country foods in the region. This project has several objectives: to assess the risk perceptions and awareness of current contaminant advisories; to provide baseline data to evaluate the impact of contaminant advisories over time; and to begin to develop more effective health and risk communication dissemination strategies with Dene communities in the Sahtú region.
Methods:
As part of a larger biomonitoring project, this study uses a collaborative and participatory mixed-methods approach with community co-researchers, three terminology workshops, a Health Messages survey, and interviews with community members.
Results:
The terminology workshops with community members (n=27) helped to build important understanding around relevant terms and facilitate more meaningful language use. The Health Messages survey (n=63) gathered information on health behaviours and country food consumption for those who had heard or seen contaminant advisories as well as who community members would trust for information and their health messaging preferences. Interviews (n=12) provided context for the responses to the Health Messages survey.
Conclusions:
Long-term objectives of the study are to help create more effective public health communication strategies to reduce contaminant exposure, maximize nutrient status, while also endorsing country food consumption for Dene communities in the Sahtú region of the Northwest Territories.

The Economic Costs of Eutrophication in the Great Lakes Basin

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Oral Presentation
Session: Human-Water Interactions
14:45–15:00, Tuesday, June 5, 2018
Room 1309

Although the Laurentian Great Lakes are the world's largest fresh surface water ecosystem and contain more than three quarters of North America's available water resources, the seemingly abundance of freshwater is severely constrained by water quality problems. Eutrophication in the Great Lakes has long been a concern. Eutrophication has led to the degradation of the freshwater ecosystem by reducing water quality and altering aquatic ecosystem structure and associated services. With increasing pressures from urbanization, industrialization and climate change, more frequent and severe algal blooms are expected in the future. In both the United States and Canada, agricultural practices, in particular the application of commercial fertilizers and animal manure, are among the primary sources of nutrient pollution in the watersheds draining into the Great Lakes. Environmental protection and conservation programs have been implemented in the Great Lakes basin since the 1970s, such as best management practices on agricultural lands and the upgrading of sewage treatment plants. In order to support sustainable water resources management and justify continued investments in ongoing efforts to reduce nutrient loads into the Great Lakes basin, this study aims to estimate the economic damage costs associated with eutrophication, affecting ecosystem goods and services, including drinking water supply, recreational and commercial fisheries, other water recreation activities such as swimming and boating, public health, property values and aquatic biodiversity. Economic value estimates from existing studies related to the Great Lakes are summarized in a meta-analysis, using a variety of economic valuation methods, including market and non-market valuation techniques. A wide range of values is found, reflecting the uncertainties surrounding the causal relationships underlying eutrophication, algal blooms and economic damage costs. The economic estimates vary between 125 million and 8.6 billion Canadian dollars annually on the Canadian side of the Great Lakes and 3.7 and 38.5 billion Canadian dollars per year on the US side of the Great Lakes (in 2015 price levels). This corresponds to 0.02-1.12 percent of Gross Domestic Product (GDP) in Ontario where the Canadian portion of the Great Lakes are found and 0.06-0.61 percent of GDP in the 8 states that are home to the Great Lakes in the US (Minnesota, Wisconsin, Michigan, Illinois, Indianan, Ohio, Pennsylvania and New York). These values may seem relatively small, but are expected to increase further under future scenarios of economic growth and climate change, affecting especially the further development of tourism and recreation in and around the Great Lakes. They furthermore far outweigh the investment costs in past and current protection and conservation efforts.

Mountain Waters: Change, Vulnerability and Opportunity

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Oral Presentation
Session: Plenary
10:45–11:15, Wednesday, June 6, 2018
Room 1305/7

Mountains are the source water for over half of humanity, and Canada's western mountains are the headwaters of the Saskatchewan, Mackenzie, Yukon, Columbia and Fraser rivers. These river basins support much of Canada's economic activity west of the Great Lakes. However, rapid climate and hydrological changes detrimentally impact Canada's western mountains, and user communities struggle to understand and adapt to this new reality. Critical pressures include rapid population growth, climate change, hydroelectricity, fisheries, mining and agriculture. However, sparse observations, insufficient modelling, and complex terrain impede our ability to quantify and predict hydrological and climatological processes in western Canada. This lack of baseline knowledge is particularly challenging in the face of the region's rapid environmental and land surface changes. To address these challenges, the Mountain Water Futures program's goal is to improve our ability to predict future hydrological regimes and plan appropriate adaptations in Canada's western mountains. In this talk, we will outline critical issues regarding future mountain weather and climate, glacier and cryosphere decline, the role of mountain aquifers on runoff generation, and the impact of changing vegetation including forests and wetlands.

How low can you go? The use of Geotextiles as a Filter for Phosphorus in Overland Flow from Agricultural Croplands in Southern Ontario

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 5

Phosphorus (P) is a key nutrient in agricultural systems but also contributes to eutrophication in waterways. The dominant pathway for P loss in many fields across Ontario is surface overland flow, where P can leave fields in both particulate and dissolved forms. Overland flow may occur during and following heavy rainfall or snowmelt events. To reduce P losses in overland flow, geotextile filters (Filtrexx) were deployed at the edges of two well-managed cropped fields in southern Ontario. Water samples taken before and after the filter material were collected during overland flow events occurring between November 2016 and May 2018. Samples were analyzed for both dissolved and total forms of P, total suspended sediments and anion/cation concentrations. Results show that the filter material has the ability to remove both SRP and TP and reduce TSS loads, but this is not consistent across all runoff events. Temporal variability in the efficacy of the filters with season, flow magnitude and P concentrations will be discussed. The implications of utilizing geotextile filters in combination with commonly used BMP's for P reduction will also be presented.

How competing narratives influence water policy in the Saskatchewan River Basin

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Oral Presentation
Session: Human-Water Interactions
14:00–14:15, Tuesday, June 5, 2018
Room 1309

As global water systems become more complex and deeply uncertain, disagreements between social groups challenge water management decisions. As these decisions will ultimately determine the ability of our water systems to remain resilient and adaptive to conditions beyond our control, it is critical to examine how individuals and organizations go about making decisions, how certain decisions come to prevail over others and the consequences associated with these processes. Representing decision-making as a political struggle over ideas, this research examines the competing narratives stakeholders use as frameworks of interpretation to select strategies in the context of the Saskatchewan River Basin. This basin is a critical water source for the Canadian prairies, and competing stakeholder values and priorities challenge decision-making about water resources. This work explores Saskatchewan water narratives and the impacts they have on the way policy choices and outcomes are perceived. An NVivo-assisted narrative content analysis of stakeholder documents is used to explore the narratives of four key stakeholder groups, Industry, Aboriginal, Irrigation Agriculture and Environment. Results include a collection of references corresponding to key elements of each narrative, such as characters, causal theories and morals. Next, key elements from the Irrigation Agriculture and Aboriginal narratives are entered into a water resources model developed for Saskatchewan (SWAMPsk as per Hassanzadeh et al., 2014) and used as a lens through which to explore three alternative futures in the SRB – a future with present-day conditions, a future with an irrigation expansion and a future with irrigation expansion and climate change impacts. At least four distinct water narratives are shown to exist in Saskatchewan and results suggest that stakeholder perspectives differ on values and priorities in part because each group uses a different interpretive framework to understand the current context, and how that may change into the future. Discussion around desirable policy solutions becomes difficult because advocacy for one policy outcome is associated with the collection of assumptions represented by key narrative elements. Further, each narrative promotes a different perspective on how the future will unfold, exposing decision-makers to real differences in terms of which costs and benefits are highlighted or obscured, and ultimately which groups benefit from the decisions made. Results show there are real costs when one narrative successfully influences the policy outcome but a competing narrative comes to more accurately represent reality. Ultimately, these findings suggest that specific measures to address competing stakeholder priorities around water use are vital to design more transformative and inclusive

policy when planning for a future that is expected to be increasingly challenging for the Saskatchewan River Basin.

Knowledge to Action: Measuring perceptions of credibility, salience and legitimacy in the Integrated Modelling Program for Canada

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Poster Presentation
Session: Human-Water Interactions
Poster # 31

The Integrated Modelling Program for Canada aims to provide an integrated modelling and management platform and identify tipping points and critical trade-offs for decisions analysis. As a Pillar Three project of the Global Water Futures Program, the Integrated Modelling Program for Canada focuses on designing user solutions, including user engagement to inform model development and iterative, two-way sharing of information between scientists and knowledge users.
Both scientists and practitioners have a role to play in making science usable for decision-makers. A large and growing literature in the field of science and technology policy studies reveals how difficult it is to manage the boundary between the production and the use of new knowledge. Ideally, this boundary is characterized by knowledge that is credible (scientifically plausible and trustworthy), salient (useful to stakeholders), and legitimate (respectful of divergent values and beliefs and produced in a fair and unbiased process). Effective knowledge mobilization occurs when science organizations design strategies to effectively and explicitly manage the boundary between science and policy, and ensure that relevant knowledge meets the needs of active decision makers.

GWF's Integrated Modelling Program supports these boundary management functions. This work includes a review of social science studies of best practices for KM in the literature and preliminary results of a survey of user engagement. This survey is informed by Cash et al. (2003)'s conceptualization of boundary knowledge as having characteristics of salience, legitimacy and credibility. We also highlight successes so far resulting from monitoring and evaluating GWF's social networks.
Preliminary results show that investing in mediation and communication is important to managing the science-policy boundary. Results also suggest that boundary organizations play an important role as intermediaries between the production of scientific knowledge and its dissemination to organizations and communities. We will also outline how these preliminary results will inform our program's user engagement work moving forward.

Atmospheric circulation shift in North America since 1980's as an explanation of increasing winter high flows events in southern Ontario

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Oral Presentation
Session: Climate and Extremes
14:30–14:45, Wednesday, June 6, 2018
Room 1110

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

Incorporating the Social Component in Hydrological Modeling to Evaluate the Effectiveness of Agricultural BMPs in a Prairie River Basin

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Poster Presentation
Session: Human-Water Interactions
Poster # 32

There is a growing interest to develop watershed-scaled models that support researchers of physical hydrology and to assist in creating balanced policies for managing watersheds. One drawback of watershed models, however, is that they fail to consider the social dimension of management; such as the perspectives, values, and norms of people that depend on the land, water, and ecosystems for sustenance, economies, and overall wellbeing. Focusing on the impacts of land management practices on ecosystem services can highlight the activities that have a direct influence on water quality and quantity. Research approaches that respond to the needs of stakeholders can deliver information that is salient, credible, and legitimate. This paper discusses how the pilot testing and engagement of the system dynamics model of the Qu'Appelle valley was used to gather insights from local farmers and understand their perceptions of Beneficial Management Practices (BMPs). Mixed-method workshops were held with agricultural producers in the Qu'Appelle watershed to gather direct feedback on the developing model. Qualitative analysis of focus groups and factor analysis of Q-sorts were used to assess the utility of the model, and whether it supports farmers' understanding of the potential effects of BMPs on water quality. We further explore farmers' heuristics about BMPs and the potential of incorporating their decision processes within a model itself. Finally, we discuss the importance of local stakeholder engagement in watershed modeling programs for supporting comprehensive integrated watershed management.

PRELIMINARY ASSESSMENT OF LANDSAT-8 AND SENTINEL-2 DATA FOR THE ESTIMATION OF CHLOROPHYLL-A CONCENTRATION IN BUFFALO POUND LAKE, SASKATCHEWAN, CANADA

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Poster Presentation
Session: Modelling and Observations
Poster # 49

Although there is an urgent need for the monitoring of water quality parameters in small inland waters, currently, there is no satellite sensor specifically designed for this purpose. Ocean-color satellites such as MODIS-Aqua and Sentinel-3 are only applicable to large water bodies due to their relatively coarse spatial resolution (250-300 m). As a result, Landsat-8 (L8) and Sentinel-2 (S2) seem to be the best options for the monitoring of water quality of small systems from space. Using in-situ observations collected by a buoy and a cruise during summer season 2017 in Buffalo Pound Lake, Saskatchewan, Canada, the present study assesses the performance of L8 and S2 to estimate chlorophyll-a (chl-a) concentration during an algae bloom season. Although previous studies have shown a good agreement between actual water-leaving reflectance and satellite-derived one for both L8 and S2, our preliminary results indicate a better performance for S2 in terms of the estimation of chl-a concentration. The assessment is based on the results of five common empirical algorithms which are applied on the surface reflectance data. Amongst all different indices, the SLH (Scattering Line Height) provides the highest R2 and the lowest RMSE with values of 0.82 and 2.84 mg/m3, respectively. For L8, the OC3 algorithm outperforms other algorithms (R2=0.71, RMSE = 13.56 mg/m3); however, it indicates a saturation in high amount of productivity in water. In addition to the lack of essential spectral bands, especially 407 nm, the more adverse effect of sun glint in L8 images is another reason for the poorer performance of L8 in comparison to S2.

Towards co-creation: youth engagement in monitoring stream health in indigenous communities

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Oral Presentation
Session: Human-Water Interactions
13:45–14:00, Tuesday, June 5, 2018
Room 1309

Surface water, whether from streams or lakes, is an important source of drinking water. Those who live near these sources have the most stake in ensuring their continued health. In 2013-2014, through funding from the RBC Blue Water Initiative, I developed a stream monitoring program for indigenous youth of the Saugeen Ojibway Nations of the Bruce Peninsula. This program was modeled after a successful citizen-science program called URBAN (Urban-Rural Biomonitoring and Assessment Network), which allowed Hamilton residents, especially students from primary and secondary schools, to participate in stream health assessments using well established scientific protocols. Students. After gaining the support of chiefs and elders of the two indigenous communities (took over 3 months of emails and phone calls and site visit), we gave an interactive seminar about the program to students in several high schools and met with parents of potential students. The Environment office of the SON played a pivotal role in recruiting and retaining the interest of 10 students, ranging from Grade 8 to Grade 12. Through consultations, we chose 2 creeks for the sampling that took place from May to July in 2013 and 2014. The aboriginal students worked side by side with my undergraduate and graduate students, learning how to collect and process water samples, operate field equipment , and to sort and identify benthic invertebrates in streams (the most fun part). The informal interactions between the First Nations youth and the McMaster students helped them feel at ease when they returned to the McMaster campus in August for a 3.5-day workshop. The final workshop was a celebration that included the students, their parents/chaperones, elders from the Cape Croker Band, and included both a water and fire ceremony. I want to use this as a model to co-create a program to engage youth in monitoring stream health on the Six Nations reserve that would also include creation of an indigenous key to identify the benthic invertebrates in the language of one of the nations.

Pursuing reliable hourly nutrient predictions in cold regions through the coupling of CRHM to an extended version of WINTRA

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Oral Presentation
Session: Modelling and Observations - Part II
14:00–14:15, Wednesday, June 6, 2018
Room 1105

There is great interest in modelling the export of nitrogen (N) and phosphorus (P) from agricultural fields in Canada and other cold regions because of ongoing challenges of eutrophication. However, the use of existing hydrochemistry models can be problematic in cold regions because models frequently employ incomplete or conceptually incorrect representations of the dominant cold regions hydrological processes and are over-parameterized, often with insufficient data for validation. Here, a nutrient catchment model (N and P) for cold regions, WINTRA (WInter Nutrient TRAnsport model), was extended to simulate biogeochemical cycling in soils, streams and lakes, and fully coupled to the Cold Regions Hydrological Model (CRHM). The CHRM-WINTRA simulation platform has been specially designed for cold regions and accounts for the effect of processes such as (1) snowmelt, (2) blowing snow and heterogeneous snowcover depletion, (3) frozen soils and its effect on runoff-soil contact for nutrient release, (4) soil erodibility, (5) rain-on-snow events, (6) biochemical processes in cold climates, (7) freeze-thaw cycles and its effect on nutrient leaching from plants, (8) agricultural practices, and (9) snow metamorphosis and ion exclusion on nutrient transport. Previous applications of WNTRA have demonstrated the model improvements that are possible if these processes are included. The model is currently being tested in an intensively monitored agricultural basin in Manitoba, Canada, to help to identify the main climate, soil and anthropogenic controls on nutrient export.

Microwave Sensing in a Microfluidic Device for Water Quality Monitoring

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Poster Presentation
Session: Modelling and Observations
Poster # 50

Microfluidic devices are portable instruments that can precisely control sub-microlitre volumes of fluid. Combining these devices with microwave systems can provide further manipulation and analysis of the fluid. For example, microfluidic devices can be integrated with a microwave resonator through standard microfabrication processes to enable rapid heating and mixing of fluids. Furthermore, the resonance frequency of the resonator is dependent on the electrical properties of a fluid and its contents (i.e. permittivity, conductivity), and therefore it can act as a sensor. Portable microwave circuitry has been developed to measure resonance frequency and enable point-of-care, label-free microwave sensing for different fluids. Consequently, such a device has the potential to monitor contaminants within drinking water. Another area of water quality management to explore would be during sample preparation, as microwave heating could be used as a technique for cell lysis prior to sensing.

Patterned cotton threads for nitrite detection

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 19

Monitoring nitrite levels in water is essential as its presence in aquatic environments increases the likelihood of algal blooms and consequently decreases the oxygen concentration available for native aquatic life. Further, it inhibits haemoglobin's oxygen binding capacity, reduces respiration efficiency of aquatic life and increases the burden on already fragile freshwater ecosystems, even at concentrations less than 1µg/ml. Nitrite has been known to cross the placental barrier which reduces the available oxygen in the blood stream i.e. particularly debilitating to babies. While adult humans are relatively insensitive to nitrite contamination in water, ingestion of 0.4mg/Kg of the weight of the baby can lead to the formation of methemoglobinemia, which reduces the efficiency of respiration. WHO guidelines recommends a maximum of 3µg/ml concentration in drinking water for human consumption. Moreover, existing testing methods require skilled technicians to manually measure testing reagents' volume. This prevents use of current methods for continuous on-line nitrite detection. The emerging trend towards low cost detection has led to the development of colorimetric sensing kits. These kits provide quantitative measuring capabilities by analyzing the color change of the testing reagent in the presence of 5-10ml solutions of contaminated water, with detection limits as low as 1 µg/ml.
The present study proposes a method to store and transport reagents using a cotton thread patterned into discrete compartments with known volumes of the colorimetric reagent trapped within them. Imaging is then done using a regular DSLR camera, and colorimetric analysis is used to identify nitrite concentrations as low as 0.4µg/ml in 40µl of water as the sample. We also present a low-cost device with an embedded patterned thread for continuous online monitoring of nitrite concentration in water as an alternative to the expensive current methods.

The MESH Model: Past, Present and Future

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Oral Presentation
Session: Modelling and Observations - Part I
13:15–13:30, Tuesday, June 5, 2018
Room 1105

The Hydrologic-Land Surface Scheme (H-LSS) “Modélisation Environnementale communautaire - Surface Hydrology” (MESH) has a long history that dates back 20 years. Originating by merging the Canadian Land Surface Scheme (CLASS) with the WATFLOOD Hydrological model as WATCLASS at the University of Waterloo in the previous millennium, the newly formed H-LSS was cutting-edge in its approach to land-surface modelling for hydrological prediction. As the model evolved into a community-based platform, a larger group of users and developers began to contribute to its growth. The community grew to include significant contributors from Environment Canada, the University of Saskatchewan, and other partnering institutions, most notably through involvement in the Mackenzie GEWEX Study (MAGS), the International Polar Year, and IP3 research networks. MESH was given a particularly important boost with the formation of the Global Institute for Water Security (GIWS) and the Changing Cold Regions Network (CCRN). During this time, considerable improvements were coded into the model and significant applications were developed, most notably in the development of algorithms and methods for accounting for prairie depressional storage, frozen soil infiltration, permafrost, irrigation, water management, blowing snow, slope and aspect in mountains and glaciers, ice jams and water quality parameters. Other improvements include faster code to speed-up MESH on small computers and allow massive scaling on High Performance Clusters; a new modularized code-base to facilitate rapid progression of scientific understanding into the model platform; a forecasting prototype system created for partner organizations; the large Mackenzie and Saskatchewan watershed models developed to maturity; and alignment of MESH with land-surface representation in both climate and weather forecasting systems being used at Environment and Climate Change Canada (ECCC). Most exciting, with the development of Global Water Futures (GWF), MESH is the principal component of the Core Modelling Strategy and will be deployed to 7 drainage basins across Canada with a cumulative area the size of the European Union.

Drivers of land cover change after large fire disturbance in boreal forests

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Oral Presentation
Session: Watershed Management and Disturbance
14:00–14:15, Tuesday, June 5, 2018
Room 1110

Fire is the dominant disturbance in boreal forests but climate change is causing increased wildfire activity in the North. Evidence shows these altered fire regimes could lead to shifts in forest structure and changes in land cover. For example, there have been sustained shifts from conifer to deciduous dominance after severe fires in Alaska, which has implications for ecosystem functions such as wildlife habitat, nutrient cycling, and ecosystem-protected permafrost. The generalities of these patterns to other regions of the boreal forest after large fire events is unclear. Our overall aim was to investigate forest regeneration after a large fire event in high latitude boreal forests to understand drivers of land cover change across the Taiga Shield and Taiga Plains. The Northwest Territories (NWT) of Canada experienced a large fire year in 2014, with 3.4 Mha burning. We established 221 permanent sites across seven burn scars and assessed regeneration of canopy species by counting seedlings. We assessed regeneration of understory plants and recorded their regeneration modes: from seed or from underground structures that survived the fires (rhizomes). We also undertook DNA sequencing and culturing of the post-fire fungal communities to relate them to vegetation regeneration. Our results showed that jack pine increased post-fire across the landscape post-fire, even in sites that were previously dominated by black spruce. This is in contrast with the shift to deciduous dominance in Alaska. Further, we found that most of the understory plants survived the fires through underground structures, enabling plants to rapidly regenerate post-fire. This was particularly apparent in areas with thick organic soil layers and poor drainage. There were more seedlings and plants regenerating from seed in areas of exposed mineral soil or mosses growing on mineral soil, supporting previous work that these are important seed beds. The composition of regenerating understory communities were weakly but significantly correlated with soil fungal community composition suggesting that there are important relationships between above and belowground communities post-fire. This study shows the importance of seed beds in determining post-fire regeneration and ecological legacies that promote resilience of boreal forests, even after large disturbance events. Overall, this suggests that landscape-level hydrology helps to predict the resilience of forest vegetation to wildfire. It further suggests the need to investigate regionally-specific drivers of land cover change to better predict impacts of a changing fire regime on forest structure.

Boots on the Ground: Wolf Creek Research Basin

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Oral Presentation
Session: Watershed Management and Disturbance
13:30–13:45, Tuesday, June 5, 2018
Room 1110

The Wolf Creek Research Basin in southern Yukon has been a highly researched basin with global recognition for over 25 continuous years. As a result, the basin is data rich and heavily instrumented, yet remains an intact representative watershed in close proximity to the city of Whitehorse. Global Water Futures funding has allowed an increase in monitoring and research support in the Wolf Creek watershed enabling consistent field data collection, which include, but are not limited to, stream flow measurements, water quality sampling, snow surveys, and meteorological towers measurements. In collaboration with the Government of Yukon, GWF researchers have the available infrastructure and support to conduct high levels of research. Field data from Wolf Creek Basin is ultimately used to develop enhanced northern hydrological models and help improve the understanding of hydrometeorological processes.

Sensor Biofouling: Impact and Solutions

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Oral Presentation
Session: Aquatic Environment and Ecosystems
14:45–15:00, Wednesday, June 6, 2018
Room 1309

Long term monitoring of fresh water resources is significantly limited by the ability of the monitoring hardware to effectively function under real environmental conditions. Sensors perform differently under the idealized conditions of the lab than when exposed to environmental conditions in the field. Foreign surfaces exposed to aqueous environments will foul due to adsorption of organic and inorganic matter, and the formation of biofilms due to bacterial attachment and colony growth. Biofilms are the most detrimental forms of fouling that sensors will experience in aquatic environments. Biofilm formation on sensors surfaces will inhibit sensor sensitivity, reliability, and accuracy. Our proposed approach is to evaluate new lab-developed sensors under environmental fouling conditions and to correlated their signal as a function of fouling. Further, sensor surfaces will be developed to resist biofouling and strategies, including applied electric field modulation, will be developed to limit the onset of surface fouling, to optimize their sensitivity and signal generation, and thereby to improve their environmental robustness and longevity. The preliminary steps to initiate this research require protocols for aquatic sampling, biofilm growth, and standardized sensor signal measurement. We have develope protocols for water collection from First Nations' peoples' taps, open cisterns, and local natural aquatic environments. We present standardized biofilm growth protocols using these collected samples. Finally, we demonstrate signal characterization of off-the-shelf sensors to standardize reliability testing under environmental conditions.

Linking Water Governance in Lake Erie to External Economic, Social and Political Drivers

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Oral Presentation
Session: Human-Water Interactions
13:30–13:45, Tuesday, June 5, 2018
Room 1309

Lake Erie is the shallowest, warmest and most biologically productive of the five bi-national Great Lakes shared by Canada and the United States. Approximately 11 million people receive their drinking water from the lake, including the citizens of Toledo, Ohio, who in 2014 experienced the shutdown of their drinking water system due to the presence of microcystin, a toxin produced by harmful algae blooms (or HABs) in the western basin of the lake. The causes of these blooms are complex, and are thought to include increasing amounts of phosphorous (P) and dissolved reactive phosphorous (DRP) entering the lakes, internal phosphorous loadings, climate change, the supply of nitrogen (N), and increasing colonization of dressenid mussels and other invasives. However, P loads from the Maumee, Detroit, Sandusky and Cuyahoga rivers are thought to be the main drivers of the re-eutrophication of the lake. Agricultural production is a key source of P and DRP.

A coordinated response to eutrophication in Lake Erie is ongoing, with major actors including the federal governments of Canada and the United States; state and provincial (Ontario) governments in the United States and Canada; the International Joint Commission; Indigenous peoples and governments; municipal governments; industry; and the agriculture sector. The main policy response being pursued is a 40% reduction in total P load by 2025. Many measures are being pursued to achieve these targets, including best management practices for reducing DRP loadings, cover crops and buffer zones, bloom treatment, and constructed wetlands. Scavia and colleagues, in their 2017 multi-model evaluation of current strategies, suggest that reaching the targets will require a concerted, coordinated and resource intensive effort. Importantly, they also suggest that policy and behavioural changes may also be needed in the food and energy sectors – which are not well integrated with water sector.

In our GWF-funded research, we analyze the extent to which the current problem definition for the re-eutrophication of Lake Erie can account for external actors and drivers in adjacent action situations such as food, energy and trade. Determining whether or not and how the current water governance system can be adapted to account for external drivers and actors from adjacent action situations is the long-term goal of the project.

In this paper, we establish the governance challenge in the Lake Erie basin, and provide an overview of a diagnostic framework grounded in social-ecological systems thinking that will be used during the research. The role of biofuels policies in Canada and the United States provides a concrete example of an adjacent action situation where decisions are being made that may be contributing to the re-eutrophication of the lake. Drawing on this example, we highlight opportunities for others engaged in water management and governance to account for the role of external actors and drivers.

Robust Global Sensitivity Analysis and its application to the water management model of Lake Diefenbaker-Saskatchewan river basin

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Poster Presentation
Session: Modelling and Observations
Poster # 52

Mathematical modeling and its accuracy are fundamental for the management and risk assessment of any environmental systems. One of the main components that directly affects the model accuracy is the knowledge of model input parameters. Global sensitivity analysis (GSA) methods can assist to identify which parameters have a strong impact on the model outputs as well as provide both modelers and system managers an insight into the simulation model.
Among various available sensitivity analysis methods, the VARS framework, which estimates the sensitivity of model outputs to each input parameter based on a variogram analysis, has proven to be effective, comprehensive, and robust. However, the current VARS method can only be applied to models with uniform input parameters. In this work, the VARS method is extended to accommodate models that contain non-uniform input parameters. By computing the Euclidean distances between randomly sampled data along each non-uniform parameter range and clustering them into different scaled intervals, the variogram of the parameter can be estimated. This allows the sensitivity of the model parameters to be evaluated.
The case study is a water management model simulating the operation of South Saskatchewan River system including the Lake Diefenbaker within the boarder of the province of Saskatchewan. We assess the sensitivity of the vulnerability and resilience of the water resources system to the variation of different factors such as inflows, demands by different users, and operation policies. Preliminary results show that the method is able to provide reliable sensitivity measures across the full range of the model input parameters. We identify the dominant controls of the vulnerability and resilience of the system.

Envisioning Polycentric Water Governance in a Canadian Context

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Poster Presentation
Session: Human-Water Interactions
Poster # 33

The challenges of understanding the social-cultural-ecological (SES) requirements for polycentric governance and the very real prospects for innovation in design and implementation of multi-level polycentric governance in a Canadian context are unique in a global context. This paper considers constitutional issues, Indigenous Rights, global change, bioregionalism and local authorities as drivers for fresh modelling, relevant to the objectives of Global Water Futures, and to longer-term stewardship,and sustainability.

Dialogue That Flows: The role of narrative in supporting watershed governance

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Poster Presentation
Session: Human-Water Interactions
Poster # 34

The Saskatchewan River Basin's (SRB) network of rivers and streams flows west over the vast Canadian Prairies. It crosses three provinces, Alberta, Saskatchewan, and Manitoba. Water allocation in the SRB is prioritized separately by jurisdiction, industry, and culture in a dynamic network of water governance. This diverse social setting faces increasing stress from climate change and intensifying land use. To identify stakeholder interests, attempts have been made to understand different perspectives of water security. Less work has been done however, to understand how Prairie residents communicate about water day to day. To help Prairie water governance evolve, policy must consider how local knowledge influences collaboration in a watershed. All residents who live and work within a watershed possess unique understandings of local hydrology, including agricultural, municipal, and particularly Indigenous groups. When collaboration supports responsible watershed management (water stewardship) effective and meaningful communication is key. A common method of communicating local knowledge is by sharing stories and personal experiences (narratives). I am exploring how narratives about water support collaboration in watershed stewardship. Fieldwork will begin in the North Saskatchewan River Basin where Indigenous groups are particularly involved in watershed governance. The Red Deer River Watershed may be included for additional data, if resources allow. I explore how/if narratives have influenced collaboration when solving or preparing for water challenges by interviewing watershed residents who are experienced in water stewardship.

Impact of climate and associated land cover changes on the hydrology of the Mackenzie River Basin

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Poster Presentation
Session: Modelling and Observations
Poster # 53

The Mackenzie River basin (MRB) covers a large area of North-Western Canada (about 1.8 million square kilometers) and discharges 300 cubic kilometers of water into the Arctic Ocean on an average annual basis. As such, it has a tremendous influence on ocean circulation through its large freshwater input and represents the fifth largest discharge source into the Arctic globally. The basin itself has a highly variable climate due to its large range in latitude (52-70 degrees N) and altitude (from sea level at the north outlet to over 4000 m in the western cordillera headwaters). The western part of the basin is dominated by mountainous terrain, overlain by glaciers and high snowpack that generate much of the flow. The interior plains further east are dominated largely by boreal forest and wetland complexes, underlain by continuous and discontinuous permafrost layers. The eastern part of the basin has a more undulating topography dominated by pre-Cambrian shield features and to the south the basin has agricultural and parkland regions with little or no permafrost. Large lakes dominate parts of the system, especially to the east, with a major wetland complex at the convergence of the Peace and Athabasca rivers, and a very large delta, the Mackenzie delta, at the mouth. As a whole, the hydrology of this basin is exceedingly complex both hydrologically and hydraulically.
High rates of warming have been observed at high latitudes and Earth System Models (ESMs) project that these trends will continue, accompanied with enhanced precipitation. More than half of the MRB area is underlain by permafrost and such rapid warming is resulting in permafrost thaw with implications for soil moisture, hydraulic connectivity, streamflow seasonality, land subsidence, and vegetation. A detailed hydrological model for the MRB has been developed and calibrated using MESH (Modélisation Environmentale Communautaire - Surface and Hydrology) at 0.125° spatial resolution and is giving good performance in reproducing the current hydrology. The model is used to explore the impacts of climate change and associated changes in land cover and glaciers on the basin hydrology and permafrost thaw. Two 30-year periods are selected for analysing the changes, centered around 2040 and 2085, to show the impacts in the near and far future respectively compared to a baseline period centered around 2000. The simulation is continuous from 1950-2100 to correctly account for permafrost evolution. Climate scenarios are constructed from CanESM2 simulations dynamically downscaled by CanRCM4 and bias corrected to reflect current climate. Associated land cover scenarios are introduced as static changes for each period based on analysis of the drivers (climate, fire, soil suitability) and expert judgement. Changes to glacier extent are analysed from a set of compatible projections. Preliminary results show strong spatial heterogeneity of response, but overall increases in river flows, especially during the spring freshet, and reduced permafrost coverage, by the end of the 21st century.

Towards improved subsurface representation in Land Surface Models

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Poster Presentation
Session: Modelling and Observations
Poster # 54

Land surface models (LSMs) are becoming a key component in hydrologic, atmospheric, and ecologic models to study water and other environmental resources. Proper configuration and parametrization of these complex models are critical for improved model application and performance, and thus outcomes. In this work, we aim to highlight the importance of representing shallow subsurface in LSMs, which can be often neglected. In particular, we illustrate individual and interactive impact of three important factors in LSMs, namely soil permeable (active) depth (sometimes known as depth to "bedrock"), soil vertical discretization, and vegetation rooting depth.
For this purpose, we conducted local (manual) and global sensitivity analysis (GSA) experiments of a complex land surface–hydrology model, Modélisation Environmentale–Surface et Hydrologie (MESH). MESH couples the Canadian land surface scheme (CLASS) with the hydrological routing component of WATFLOOD, WATROUTE. GSA experiments were carried out using a new variogram-based sensitivity analysis technique, called Variogram Analysis of Response Surfaces (VARS).
Results reveal that shallow subsurface representation can have a large impact on LSMs' outputs, which is often overlooked. Individual and relative values of soil permeable depth, rooting depth, and soil vertical discretization are very influential on CLASS/MESH response. In particular, it is observed that the default 3-layer soil profile of CLASS/MESH (with a very thick layer of nearly 4m at the bottom) is susceptible to ET overestimation. As a simple cure to alleviate this issue, it is recommended to at least add an extra soil layer at rooting depth in CLASS/MESH. Future works should carefully consider subsurface representation in LSMs including efficient ways to also represent ground water, another key and often-overlooked component not discussed here.

An Evaluation of Current and Future Water Allocation Strategies in the Saskatchewan River Basin

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Oral Presentation
Session: Human-Water Interactions
15:00–15:15, Tuesday, June 5, 2018
Room 1309

Competition among water users for limited water resources has been intensified due to growing water demands and decreasing available water in many regions. Under these circumstances, allocating water among competing users efficiently becomes more controversial, particularly in large and multi-jurisdictional basins like the Saskatchewan River Basin (SaskRB). In the SaskRB, licenses have been issued to allocate water on the "first in time, first in right" basis. In this study, we focus on Alberta and Saskatchewan as the two main provinces that share the Saskatchewan River Basin. Upstream Alberta is facing a challenge of water over-allocation due to extensive developments. Meanwhile, downstream Saskatchewan has not yet used the total amount of water it has claimed and is entitled to. Thus, the Saskatchewan province is planning for new developments that demand more water from the South Saskatchewan River.
Therefore, in this presentation, we aim to evaluate the existing water allocation system and assess the economic impacts of alternative water allocation strategies in the Saskatchewan River Basin. Within this context, first, we analyze water allocation and actual withdrawal data in different sectors for period 2005 to 2016 in the SaskRB to examine the current status of water use in the basin. A GIS data-frame is also developed by employing the ArcGIS platform to study the spatial distribution of different water users in sub-basins of the SaskRB. Second, we employ an Input-Output hydro-economic model to study the economic impacts of the existing and alternative future water allocation strategies on the economy of the SaskRB. The Input-Output model is an analytical framework developed based on the Leontief Input-Output model and the Canadian Input-Output tables for year 2014. This model uses inter-industry relationships in each province to estimate the changes caused by different water allocation strategies. We couple this model with a water resources system model already developed within the MODSIM-DSS framework for the SaskRB that provides us with alternative future water allocation scenarios.
Results of our study show that from 2005 to 2016, total annual water withdrawals from the surface water resources in Alberta and Saskatchewan did not exceed 51 and 30 percent of the allocated amount through the licenses, respectively. This study also demonstrates that the amount of agricultural water withdrawal from the surface water resources in Alberta and Saskatchewan provinces had more fluctuations (as expected), compared with the other sectors. Moreover, results indicate that in some of the sub-basins, the ratio of water withdrawals to the entitled water has changed considerably over time. With the existing water allocation strategy, agriculture is the third and 17th biggest contributor to the

provincial gross domestic product in Saskatchewan and Alberta provinces, respectively. We evaluate and report how the economy of the region might change under different future water allocation scenarios.

Water Risk Assessment in Mine and Site Decommissioning: An SES framework

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Poster Presentation
Session: Human-Water Interactions
Poster # 35

In this paper, we aim to develop the foundations for a socio-ecological framework for water risk assessment in mine and site decommissioning. As explained by Völker, C. et al (2017), SES frameworks of risks assessment are more sensitive to the interactions between society and nature than traditional approaches, and they consider non-intended side-effects, system interdependencies, and uncertainty. In applying this model to mine and site decommissioning, we hope to illuminate how water resilience and governance models impact the community industry community interface.

A Comparison of Time Series Databases for Storing Water Quality Data

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Poster Presentation
Session: Modelling and Observations
Poster # 55

Data persistence for time series is an old and in many cases traditional task for databases. Time series data, i.e., data consisting of a series of timestamps and corresponding values, is a special type of data occurring in water quality data. In this paper, we provide a survey of data persistence solutions for water quality time series data. The paper analyzes the effectiveness of various Time Series Databases (TSDB) based off relational and NoSQL-based databases. We make sure to distinguish between open source and commercial solutions as well. Furthermore, solutions are analyzed based on security, speed, ease of use and storage. Lastly, we provide installation and usage instructions for a handful of selected TSDB technologies, as well as a demonstration on utilizing Arduino boards to interact with TSDBs through a REST API.

Impact of meteorological forcing data on snowpack and streamflow simulations in the Canadian Rockies

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Poster Presentation
Session: Modelling and Observations
Poster # 56

This study evaluates hydrological simulations of streamflow and snowpack regimes in the Canadian Rockies using various sources of meteorological forcing data. Hydrological models were created using the Cold Regions Hydrological Modelling platform (CRHM) for two mountain forest headwater basins: Marmot Creek Research Basin (~9.4 km^2) and Fortress Mountain Basin (~5.9 km^2). These models were parameterized from local field research findings to represent the relevant streamflow generation processes: wind redistribution of alpine snow, snow avalanching on steep alpine slopes, snow interception, sublimation, drip and unloading from forest canopies, infiltration to frozen and unfrozen soils, overland and detention flow, hillslope sub-surface water redistribution, and evapotranspiration from forests, clearings and alpine tundra. In-situ hourly observations from 14 high altitude weather stations, near-surface output from Environment and Climate Change Canada's 2.5-km Global Environmental Multiscale (GEM) atmospheric model in forecast mode (no bias correction), and bias corrected near-surface outputs from the 4-km Weather Research and Forecasting (WRF) model were used to drive the hydrological models. Air temperature, relative humidity, wind speed, incoming shortwave radiation, and precipitation were extracted from stations and atmospheric models over each basin, and then interpolated by elevation to hydrological response units within each basin to drive the hydrological models over November 2014 to August 2017. Simulations of snowpack and streamflow using station data were acceptably good without calibration of model parameters. The snowpack simulations using GEM showed errors as modelled wind fields did not reflect the high wind speeds measured over ridges and GEM misrepresented winter precipitation dynamics. Streamflow simulation using GEM output for Marmot Creek was impacted by overestimation of late-lying snowcovers in the alpine due to overestimation of precipitation, while underestimation of precipitation from GEM output caused poor streamflow simulation for Fortress Mountain Basin. GEM-driven models therefore missed both the timing and magnitude of seasonal streamflow. WRF outputs were bias corrected using the quantile delta mapping (QDM) method with respect to station data during October 2005-September 2013 at Marmot Creek. Snowpack and streamflow simulations using the bias-corrected WRF outputs were much better than these using uncorrected outputs and achieved comparable predictability to simulations driven by station data.

Groundwater Protection - Looking Deeper

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Oral Presentation
Session: Watershed Management and Disturbance
13:15–13:30, Tuesday, June 5, 2018
Room 1110

Groundwater protection requires an understanding of the connectivity of hydrogeological systems. Aquitards are commonly thought to form effective barriers to contaminant migration from both surface and subsurface sources. Such units have been mapped in many areas as part of source water protection plans but significant gaps remain. Recent work has suggested modern water has been found in many deep aquifers that host fossil water supplies. There has also been growing concern about migration of contaminants from deeper strata due to drilling, stimulation and fluid disposal activities by the oil and gas industry. The pathways through for the contaminants could be geological in nature (faults, non-deposition, erosion, etc.) or the result of pathways introduced by well completion, operation and abandonment practices. Current efforts are focused on characterizing the nature of such pathways and improving our understanding of groundwater chemistry to enable identification of deep fluid sources.

Modeling of agricultural system impact on phosphorus loads in the Thames River watershed: research methods overview

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Poster Presentation
Session: Human-Water Interactions
Poster # 36

Agricultural system has three major human interconnected components that continuously interact with natural systems. We identified them as: individual relations, economic relations and governance. All components influence each other on diverse time and spatial scales while at the same time are greatly dependant on environmental circumstances, quality and availability of resources.
In this paper we present identified research problems such as the coupling of an agent based model and a hydrological model, understanding impact of government driven economic measures and programs on phosphorus reduction in the Thames River Watershed in the 1972-2017 period, and determination of grain sector domain and drivers that influence changes within food-water-energy nexus, and present scientific methods applied in our analyses.
Scientific methods presented are: systematic review, comprehensive hydrological model selection and complex integrated environmental – economic analyses.
Instead of a conclusion we give our present understanding of the link between different human components, their dependability and natural drivers.
Presented research is part of the first year of the Work Package Three Agricultural Water Future project. Full results of the research will be presented in later stages of the project.

Experimental Characterization of Membrane Fouling under Intermittent Operation and Its Consideration for the Design Optimization of Solar Photovoltaic Powered Reverse Osmosis Drinking Water Treatment Systems for Remote Communities

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Poster Presentation
Session: Modelling and Observations
Poster # 57

This work presents a novel experimental characterization of reverse osmosis membrane fouling from the intermittent operation of solar powered water treatment systems. This research also depicts the development of an analytical membrane fouling model and a design framework to configure location-customized solar photovoltaic reverse osmosis systems.

The World Health Organization estimates that 760 million people worldwide lack access to clean drinking water. The regions with the highest water scarcity are usually off-grid, remote and have high solar insolation. Therefore, the use of solar powered reverse osmosis water treatment systems is a viable solution. However, to minimize the costs, these systems are configured with minimal battery storage and operated intermittently with extended shutdown periods. Literature lacks an experimental characterization of the effect of this intermittent operation on membrane fouling and an associated design optimization framework.

This research work on reverse osmosis water treatment systems is divided into two main parts: (1) the experimental characterization of membrane fouling under intermittent operation, and (2) the development of an analytical membrane fouling model and a design optimization framework for these systems.

A new fully-instrumented experimental lab-scale system was designed, built, commissioned and operated with triplicate measurements of membrane permeability and membrane salt rejection for the experimental characterization. A new pilot-scale experimental system was also designed, built and operated. The membrane fouling was characterized experimentally for intermittent and continuous operation. The effect of anti-scalant and rinsing was also investigated. Two types of experimental water was tested: an experimental MilliQ-based matrix and an experimental groundwater-based matrix. The groundwater was from Nobleton, Ontario. In addition, membrane autopsy was performed using scanning electron microscopy.

An analytical membrane fouling model was developed based on the experimental results. Furthermore, a novel design framework was developed using this new analytical membrane fouling model. This design optimization framework can be used for the configuration of community-specific solar photovoltaic reverse osmosis systems that are reliable throughout the system life at a minimal cost. The design optimization framework can be adapted for other modular systems such as renewable power systems for off-grid communities, remote First Nations, Métis, and Inuit communities, or remote mining sites.

Internal and External Exposure Analysis of Mercury Amongst the Dene and Métis Communities of Northwest Territories.

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 6

Background: Fish is an important dietary source for the Indigenous communities in the Dehcho and Sahtu regions of the Northwest Territories (NWT). However, mercury (Hg), an environmental contaminant, is often found present in traditional foods, such as fish, which can present public health concerns. As such, it is paramount to elucidate the potential link between dietary and demographic determinants with respect to an individual's internal Hg exposure. Additionally, culinary preparation methods may also influence Hg bioaccessibility and Hg exposure levels amongst individuals.
Objectives: This research will provide greater understanding about Hg exposure characterization from biomonitoring the Indigenous communities of Northwest Territories. Furthermore, this study will also address how fish preparation methods, particularly drying, may potentially have an effect on the bioaccessibility of Hg by using a static in vitro bioaccessibility (IVBA) model.
Methods: Hg biomonitoring component - 150 Dene and Métis participants, between the ages of 6-79, were recruited from Deline, Fort Providence, Hay River Reserve, Kakisa, West Point First Nation and Jean Marie Reserve of NWT. Biological samples such as hair and blood were collected for internal Hg exposure assessments. Participants were also asked to provide demographic information and complete a food frequency questionnaire (FFQ), in order to obtain external Hg exposure information. Multiple linear regression modelling was used to relate FFQ findings to Hg blood and hair biomarkers. Log transformation were applied to multiple regression linear models, in order to improve model's capability to capture output's variability.
Hg bioaccessibility component – 5 whole store-bought lake whitefish (Coregonus clupeaformis) were used. Subsections of each samples were either prepared dried or left uncooked. All dried and uncooked fish samples underwent a single phase, gastric only, IVBA model treatment. Hg concentrations were determined using a mercury analyzer and pyrolyzer.
Results: Both multiple log-linear regression models were statistically significant at predicting Hg levels in blood and hair ($p< 0.001$ and $p<0.001$ respectively) and explain the following levels of variability ($R2 = 0.3497$ and adjusted $R2 = 0.4055$ respectively). For blood log-linear model, age was the only statistically significant determinant (β-coefficient = 0.0225 and $p<0.001$). For hair log-linear model, age and frequency consumption of lake trout were statistically significant (β-coefficient = 0.0106 and $p<0.001$; β-coefficient = 0.0544 and $p<0.05$).

Dried and uncooked whitefish samples had initial concentrations of 0.194 mg/kg and 0.080 mg/kg respectively. Differences between concentrations is due to moisture loss as dried whitefish samples only retained 46% ± 7 % of the original mass, after culinary treatment. Dried whitefish had higher levels of Hg in both pre and post-digestion phases compared to uncooked fish ($p<0.002$ and $p<0.001$). The single phase, gastric only, IVBA model shows that the bioaccessibility of dried whitefish (53%± 5%) was statistically lower ($p< 0.001$) compared to uncooked whitefish (102%± 6%).
Conclusion: Multiple regression models show that dietary and demographic determinants may provide greater understanding about human Hg exposure. Compared to uncooked, drying fish may reduce the bioaccessibility of Hg. Although it is still unclear whether or not differences in bioaccessibility will result in differences in human exposure.

Regional modelling with a simple land surface model: the strengths, weaknesses and a novel implementation of the Variable Infiltration Capacity (VIC) model

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Oral Presentation
Session: Modelling and Observations - Part I
13:30–13:45, Tuesday, June 5, 2018
Room 1105

The Variable Infiltration Capacity (VIC) model is a well-known and widely applied simple hydrological land-surface model. Over the years of its development, more processes have been added to the model. Although the model developments were undertaken to satisfy different scientific and practical purposes, the true validation of the model, due to its large scale of applications, remains rather unexplored.
In this presentation, VIC formulations and theirs rationale are presented, and the weaknesses and strengths of the VIC model are discussed. A computationally efficient VIC model configuration that explicitly accommodates all the information on soil, vegetation, elevation and forcing data is presented. The new implementation of VIC for Group Response Units (GRUs) with unique land cover, soil type, elevation and forcing data, which are not necessarily based on regular grids, is elaborated and its various benefits are discussed.
This presentation is meant to provide material for wider discussion regarding large scale modeling at Global Water Futures annual science meeting in general and VIC modelers of GWF in particular.

Analyzing News Media Coverage in Extreme Environmental Events: The Key Role of Media in Human Adaptive behaviors toward water use

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Oral Presentation
Session: Human-Water Interactions
14:30–14:45, Tuesday, June 5, 2018
Room 1309

In today's world, media plays a crucial role in shaping public opinions and changing public beliefs. There are examples in the literature that indicate a decrease in water use in response to widespread media coverage about droughts, and also adaptive behaviors in response to flood media coverage. Socio-hydrological models can be used to simulate the coupled human-hydrology systems and evaluate how much public awareness can affect human responses to environmental events, such as droughts and floods. However, the important role of media in changing human behavior has often been overlooked in socio-hydrological models. This is complicated because the quantification of such media coverage and the relationship with human behavior is non-trivial. In this work, we address the quantification of media coverage challenge and conduct an empirical analysis to understand and quantify this factor in extreme environmental events in the Saskatchewan River Basin, located in Western Canada. This basin has been threatened by drought and flood several times in the last century, leading to widespread socio-economic damages. In this study, we analyze news media coverage in extreme events that include drought and flood, using an open-source software called Articulate, which can be further incorporated in socio-hydrological models. The results provide a vision on how the media can potentially influence human adaptive behaviors toward water use.

Environmental Forensics: What is it and what can it do?

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Oral Presentation
Session: Plenary
11:45–12:15, Wednesday, June 6, 2018
Room 1305/7

Regulators, scientists and local communities face significant challenges in their mandate to protect aquatic ecosystems and predict future trajectories for these ecosystems in a rapidly changing world. Key to successfully accomplishing these mandates is the ability to reliably and rapidly detect subtle changes in environments within the context of natural variability and to predict future trends to be able to act as an early warning system. There are many stressors, chemical, physical and biological that can affect the structure and function of ecosystems. Environmental Forensics is a field of science that monitors the status and trends in ecosystems and then determines causality for observed changes. The work I have been conductions over the past 40 years had involved research in the laboratory and in the field and from molecular to ecosystem scales. Studies are bottom-up and top down. Sometimes we observe effects in the environment and, not unlike a Crime Scene Investigator (CSI), we determine the cause or causes of the observed effects. Alternatively we observe chemicals in the environment and then decipher what effects they might cause through assessments of hazard and risk. Specifically, environmental 'omics, (including eDNA) and advanced environmental fingerprinting technologies, such as next generation sequencing (NGS) and ultra-high resolution mass spectrometry (UHRMS), will be developed and applied to monitoring of status and predicting future trends of ecosystem structure and function in rapidly changing environments. By applying these tools my team at the University of Saskatchewan has discovered thousands of novel chemicals in the environment, some of which were synthetic chemicals that are now banned globally. Others were determined to be natural products, which begs the question: What produces them and why? In this lecture I will tell several stories of discover and the significances of those discoveries for environmental policy.

Quantifying the bioavailable Ni2+ through the development and comparison of two methods: a nickel ion selective electrode compared to a DNA aptamer sensor

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Poster Presentation
Session: Modelling and Observations
Poster # 58

The purpose of this project is to develop a sensing system that is specific for the divalent cation Ni2+. Nickel can enter ecosystems both anthropogenically and non-anthropogenically, having profound effects on water quality criteria. With Ni2+ being the most bioavailable fraction and thus the most toxic, having a reliable means of quantifying the bioavailable Ni is critical for the development of appropriate water quality criteria. This research will focus on the development and comparison of two different sensing methods that can measure and quantify bioavailable Ni. First, we propose to develop an in-house nickel ion selective electrode (ISE) based on a published method. The nickel ion selective electrode will utilize a pvc-based membrane of 1,5-diphenylthiocarbazone and is expected to reveal a Nernstian response over a concentration range of 5.0x10-6 to 1.0x10-2 M. The proposed electrode is expected to detect the bioavailable fraction Ni2+ at high selectivity in the presence of a wide range of metals. The ion selective electrode will be simple to use, highly selective and fast, thus, providing a solution for monitoring water quality. A second method we propose to develop in comparison to the Ni ISE is a DNA aptamer sensor specific for the bioavailable Ni2+. This research will study the effects of dissolved organic carbon (DOC) on aptamer-based sensors. DOC is likely to chelate a fraction of the metals, leaving free metals such as Ni2+ available for DNA binding. Metals bound to dissolved organic matter tend to not be toxic, thus, we propose that an aptamer-based sensor should respond to the bioavailable Ni2+ of the total metal (NiT). These two methods will be compared on the parameters of speed, simplicity, selectivity and portability. Monitoring and quantifying the bioavailable fraction Ni2+ is critically relevant in establishing water quality criteria based on bioavailability-based approaches such as the biotic ligand model (BLM). By implementing these values into the BLM, appropriate water quality criteria parameters can be established.

Use of Remote Geophysical Imagery for the Analysis of Hydrogeological Processes in the Central Mackenzie Valley

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 86

The Central Mackenzie Valley (CMV) is a region of the Northwest Territories which is undergoing baseline environmental and groundwater monitoring in anticipation of both shale oil development and climatic changes associated with permafrost thawing. This particular research, contributing to the larger goals set by the Northern Water Futures project, aimed to remotely establish priority groundwater monitoring locations by detecting and analyzing surface features which have an association with hydrogeological processes.

Two process chains were developed and used to extract information from optical and infrared Landsat-4/5 and RapidEye imagery. The first of these, adapted from the works of Wolfe & Morse (2015), automatically detects the presence of icings (or aufeis) on the ground surface during the late spring. Icings are frozen lenses of ice which form on the ground surface during winter as a result of discharging groundwater. They may be attributed to permanent or intermittent groundwater springs, but nonetheless represent: a) definitive points of groundwater-surface water interactions, and b) regions which are underlain by unfrozen ground. As GW-SW interaction points represent potential pathways for subsurface contaminants to reach the surface, an understanding of the distribution and evolution of these interaction points is of vital importance. It was determined that in the study area of interest within the CMV, approximately 12.5% of icings recurred in years 2004, 2009, and 2016. It is also found that these recurring icings are strongly correlated with either sandy material or bedrock as a primary surficial geology type. The association of these icings with bedrock suggests that groundwater springs may be formed through fractured shale. Though further field studies are required to better understand the interaction between groundwater and icings, the remote imagery utilized in this work provided an inexpensive method of detecting priority field monitoring locations.

The second process chain developed for this work aimed to locate regions of continually degrading forest cover. The works of Dr. Quinton and colleagues have demonstrated that in a watershed south of the CMV, degraded forest cover is resultant of permafrost thaw creating bog-like conditions in which trees cannot thrive. It was hypothesised that this phenomenon may also be occurring within the CMV. High-resolution RapidEye-3 imagery accessed from Planet Labs was successful in pinpointing regions which have continually lower vegetation indices over a consecutive 4-year period. This work was performed specifically for the Bog Creek Watershed – the region of future field campaigns within the CMV – in order to establish field monitoring locations which may be beginning to experience the effects of permafrost thaw.

Subsurface flow paths and risk of P transport in no-till agricultural soils

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 7

Phosphorus (P) from agricultural tile drains can elevate P loss, particularly when P fertilizers are applied and left on the soil surface. However, if and to what extent this may vary with soil texture is poorly understood. This study investigated (1) interactions between soil texture, antecedent moisture conditions, and the relative contributions of matrix and preferential flow and (2) the associated P movement through the soil profile when fertilizers are applied to the surface or placed in subsurface bands. Brilliant blue dye was used to stain subsurface flow paths in 8 1 x 1 m plots, (4 clay, 4 silt loam), under wet and dry antecedent conditions (2 plots each per site). Fertilizer P was applied to the surface of 2 plots (one wet, one dry) per site, and in the subsurface to the remaining two plots. Plots were excavated to a depth of 1 m and stain patterns were photographed for 8 slices throughout each pit. Images were processed and classified based on flow patterns. Soils surrounding the plots were sampled and analyzed for P sorption capacity, while soils within plots were sampled and analyzed for water extractable P. Results showcasing risk of P transport based on links between subsurface hydrology and fertilizer placement, under different soil textures and moisture conditions will be presented. This work will provide an improved understanding of the hydrological mechanisms driving P mobilization in the vadose zone, and will shed light on when, why and where subsurface P placement may be advantageous over surface broadcasting.

Developing crop growth model in Raven

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 59

Modelling of crop growth and agriculture practice is essential to understand the eco-hydrological processes in a watershed. Response of crop growth and nutrient uptake and losses to different agriculture management scenarios is critical basic information for sustainable watershed land management. Currently, crop growth procedures from the Aquacrop model and the nitrogen (N) uptake procedure from soil and water assessment tool (SWAT) were added into Raven hydrologic modelling framework software. Sensitivity analyses of model parameters were carried out. And response of crop growth to different water and N stress at different growth stage was studied. The developed crop growth model will be further evaluated with real measurement data, compared with other crop growth models, and incorporated with more complex crop growth modelling routines if needed. Once validated, these routines can then be included in other hydrologic models.

Land-Atmosphere Implications of Crops, Wetlands and Hydrology on the Canadian Prairies

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Poster Presentation
Session: Modelling and Observations
Poster # 60

The Canadian Prairie land surface is a dynamic mosaic of large scale annual cropping, intermixed with perennial pastures and forages, and ephemeral wetlands. The heterogeneity of these dynamic surface features complicates the expression of interactions between the land surface, agriculture practices, hydrology, and the atmosphere. To quantify the land-atmosphere interactions and agricultural management implications of this region an extensive field campaign is currently being implemented to gather the necessary observations to drive land-surface and hydrological model development and validation efforts. This extensive field campaign is currently gathering energy balance, meteorological, soil, and vegetation data over a selection of agricultural surfaces (perennial forage, pasture, wheat, canola, peas) at sites near Saskatoon, Saskatchewan. Buoy mounted eddy covariance and scintillometer observations over a wetland complex, are also being gathered to estimate the energy and mass exchanges of the ephemeral wetland landscape features. The objective of this work will be improved estimates and models of land-atmosphere interactions over the Canadian Prairies which will provide improved lower boundary conditions for large scale modeling efforts. These advances will improve our ability to understand and predict land-atmosphere response to changes in agricultural practice and climate on the Canadian Prairies.

A Multi-Spectral Fluorescence Imaging System for Water Quality (e.g. HAB) Monitoring.

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Poster Presentation
Session: Modelling and Observations
Poster # 61

To increase the monitoring capabilities of water quality, there is a need for new, affordable, sensitive and portable instruments that could be operated in the field easily. In this report, we describe a portable, and low-cost fluorescence imaging platform containing multispectral light illumination for use in remote detection of water quality (e.g. Harmful Algal Bloom) monitoring. The system consists of readily available LED of specific wavelength as light sources, image sensor as detector, optical filters to sense desired wavelength, and driver circuit. The goal of this multi-wavelength illumination system, which currently covers three wavelengths (465 nm, 535 nm, and 630 nm), is to selectively excite and detect the algae that contains two primary algal group (green and blue-green algae). Environmental parameters, which can have significant effect on fluorescence cross-section, needs to be kept in mind. The system's ability to detect fluorescence has been verified using Fluorescein with various concentration. To demonstrate the potential application of this system, we are in progress to test it on different algae cultures.

Public, Private and Partnership and Public Utilities

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Poster Presentation
Session: Human-Water Interactions
Poster # 37

Somaliland is categorized as semi-arid land and is situated in natural disaster prone region and is regularly faced with droughts, floods and water points conflict driven emergencies. This paper compares and contrasts public utility management versus recently established PPP arrangements. The Ministry of Water Development (MWD) and UNICEF under a 5 year EU funded project "Improving Urban Water Service Delivery in Somaliland" has worked with municipal authorities to establish a PPP arrangement for the town of Tog-Wajaale. In contrast, MWD and the African Development Bank (AfDB) have worked with Berbera Water Utility to strengthen the public utility. The underlining issues of both projects are management, operational issues, resilience, equity and pro poor services. Because there are different types of private sector and public arrangements emerging in Somaliland, this means their performance can be compared and the best practices identified and adopted more broadly.

Permafrost thaw induced drying of wetlands at Scotty Creek, NWT, Canada

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 87

Northwestern Canada is one of the most rapidly warming regions on Earth. The scale and rapidity of recently observed warming-induced changes throughout this region indicate that it is particularly sensitive to climate warming and capable of rapid responses to perturbations. Unprecedented rates of permafrost thaw in the zone of discontinuous permafrost are transforming forests to wetlands, and changing the distribution and routing of water over the landscape as evidenced by recent increases in basin discharge. However, the impact of increasing basin discharge on basin water storage is not well understood. Water levels on a permafrost plateau, channel fen, and isolated and connected bogs were monitored from 2003 to 2017 in the Scotty Creek watershed, Northwest Territories. The water level in the channel fen did not significantly change over the 2003 to 2017 period of study, sustained by inputs from the increasingly connected network of bogs as permafrost barriers thawed. Bogs with varying levels of connection to the drainage network, released from storage between 40 and 53 mm of water over the study period. The water level in the monitored isolated bog did not significantly change over this period. Estimates of contributions from thawing permafrost and from the expansion of contributing areas account for 90% of the observed cumulative increase in basin runoff of 1043 mm between 1998 and 2012, leaving 109 mm of this increase unaccounted for. Increasing connectivity to the drainage network and transient wetland drainage at the landscape scale resulted from permafrost thaw-induced talik development. The similarity between the magnitude of wetland drainage and that of enhanced runoff suggests that increased connectivity of wetlands to the drainage network may contribute to increasing runoff from the Scotty Creek watershed. Permafrost thaw-induced land cover transition was found to have both short and long-term effects on runoff generation.

Evapotranspiration of deciduous- and evergreen-dominated peatlands in the Hudson Bay Lowlands

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 88

Evapotranspiration (ET) in boreal peatlands has the potential to increase in a warmer climate. A detailed understanding of ET dynamics in boreal peatlands is thus crucial to reliably assess future water resources in the boreal zone. Evapotranspiration is controlled by both abiotic (e.g., water table, vapour pressure deficit) and biotic (e.g., stomatal control of transpiration) drivers. These drivers are expected to vary in their importance between different peatland ecosystems. For example, ET in fens with higher water tables and greater proportion of deciduous species may respond differently to warmer weather than ET in bogs with lower water tables and more evergreen tree and shrub species.

To better constrain difference in ET dynamics between peatland ecosystem types, we analyse five years of eddy-covariance ET measurements in a deciduous-dominated fen and an evergreen-dominated bog in the Hudson Bay Lowlands. Initial results show that growing season (May to September) ET of the fen (344+-36 mm, n = 5) and bog (340+-30 mm, n = 5) are not significantly different. However, seasonal dynamics of ET differ between fen and bog. During the growing season, maximum daily ET (>90th percentile) is higher at the fen (3.9 mm day-1) than at the bog (3.7 mm day-1). In contrast, during vegetation senescence in September, ET is higher at the bog (42+-7 mm vs 36+-7 mm at the fen, n = 5) balancing the lower peak growing season ET. These differences in ET seasonality highlight the need for seasonally resolved climate projections when predicting future boreal water resources.

Future work will combine ET measurements with ecohydrological modelling to explain underlying differences in ecosystem processes between fens and bogs in the Hudson Bay Lowlands. Additionally, model simulations will be used to explore potential climate change impacts on boreal peatland ET.

The affect of variable snow cover on mineralization rates for soluble reactive phosphorus during winter

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 8

In southern Ontario, snowmelt contributes a sizeable amount to annual hydrological and nutrient regimes, resulting in increased phosphorus loads that can produce eutrophic conditions in surface freshwater ecosystems. Many areas of Ontario do not experience substantial freezing in soils due to the presence of deep snow cover; however, under a warmer climate, it is anticipated that there will more frequent freeze-thaw cycling and less continuous snow cover, leading to more ground frost. It is unclear if and how this may impact soil P dynamics, which may in turn affect P loads in runoff. This field study quantifies soil net P mineralization rates in winter in an agricultural silt loam field under conservation tillage management, and investigates whether net mineralization rates differ between surface soils with and without snow cover. Shallow soil cores (0-5 cm and 5-10 cm) were collected and net P mineralization rates were determined using the buried-bag technique on three occasions between January and April 2018, from a snow covered plot and from a plot from which snow cover was continuously removed, leaving the surface bare. Temperature and moisture differences were apparent between the two plots, where the snow-free plot experienced higher sensitivity to air temperatures, and largely had drier soil moisture conditions. Although there is more moisture at depth in the no snow plot during snowmelt events compared to higher soil moisture conditions near the surface in the snow plot during these events. Soil water-extractable P pools and net P mineralization rates will be presented and related to environmental conditions, preliminary results reveal net P mineralization under snow cover conditions and net P immobilization with no snow conditions. This work will improve models, which currently do not adequately account for winter processes, and will provide insight for future nutrient regimes in agricultural systems, which will create better-informed policy decisions.

The Importance of Better Predicting Short- and Long-Term Water Quality Changes to Ensure Robust Drinking Water Treatment

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Oral Presentation
Session: Aquatic Environment and Ecosystems
13:45–14:00, Wednesday, June 6, 2018
Room 1309

Drinking water providers, which are primarily municipalities, must provide a safe and reliable supply that meets regulatory requirements. Providers can increasingly expect to face new challenges related to climate change. These include both short-term raw water quality degradation due to extreme weather events, and long-term shifts in baseline water quality. In addition, blooms of cyanobacteria, which are being experienced more frequently, can lead to levels of raw water cyanotoxins that would exceed a treatment plant's ability to cope.

Information of the type generated by a number of GWF projects has the potential to be of considerable assistance to drinking water providers in planning for these challenges. This presentation will outline the scope of the problem being faced by drinking water providers. This could assist GWF researchers in scoping and shaping future work, and can inform dissemination activities.

The basic functions of drinking water treatment are to remove microbial and chemical contaminants. Treatment plants typically use a 'train' of different processes that individually or in combination deal with specific contaminants. In general, more complex treatment trains are required for surface water than for groundwater sources.

Extreme weather events have the potential to overwhelm a treatment train that has been designed based on historical raw water quality. One major problem could be turbidity (suspended solids) levels that exceed a plant's capability to handle. A second significant issue could be increased total organic carbon (TOC) concentrations or a shift in TOC composition. TOC impacts many treatment processes, including affecting the level of chemical addition required for effective turbidity removal. Elevated TOC can interfere with disinfection, can lead to unacceptable levels of harmful disinfection by-products, and can increase membrane fouling. If raw water cyanotoxin levels are elevated, a plant may have to modify treatment. A plant needs to develop a paradigm to identify operational changes that could be implemented quickly with little or no capital expenditure. The optimum solution may involve a combination of responses, and will be different for each plant

In addition to handling extreme events, treatment plants must have the capability to deal with long-term water quality changes that may occur. This may involve long-term modifications, including additional treatment processes, that would involve considerable capital expenditures.

Our research objective is to develop a robust paradigm for identifying the most promising options for a treatment plant to successfully manage long-term water quality changes and recurring periods of

shorter-term adverse water quality. This work will benefit greatly by having a better understanding of the types of water quality changes that may be expected in a given location or region.

Can microRNA Secreted from Trout Be Used to Detect Their Response to Stress?

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 9

Measurements of waterborne environmental DNA are currently being employed to identify both invasive and endangered species in Canadian waterways. However, little research has examined the potential of environmental RNA within the water as a marker of health of a given population. MicroRNA (miRNA) are stable, targeted, post-transcriptional regulators of mRNA, and are therefore useful markers that can be linked to phenotypic responses. Changes in miRNA in tissues and circulation have previously been measured in fish in response to acute and chronic stress. This study examines the potential sources of waterborne miRNA from rainbow trout following an acute stressor to demonstrate the utility of miRNA as an environmental marker of stress. Following a three-minute air exposure, adult rainbow trout epithelial mucous and gills were collected. Gills were processed by the removal of blood followed by immersion in saline, in order to collect miRNA that would be released into water. From these samples, stress-predicted miRNA (let-7a, miR-21, miR-29a, miR-143, miR-146) were quantified via RT-qPCR. Ultimately, measurement of miRNA isolated from skin mucosa and gills leads to the potential use of waterborne miRNA as non-invasive biomarkers of stress in fish.

Understanding and Rehabilitating Damaged Riverine Ecosystems

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Oral Presentation
Session: Aquatic Environment and Ecosystems
13:15–13:30, Wednesday, June 6, 2018
Room 1309

We face a challenge in our research and management: the reintegration of our understanding of watershed and riverine form and function. This reintegration is essential if we wish to rehabilitate our watersheds and their rivers, lakes and streams to some level of relative health and function compared to current states. In this presentation I explore the relationships at several scales of watershed biophysical processes and functions and how they manifest and drive more local riverine processes, forms and functions. This understanding is essential if we wish to restore physical, chemical and biological habitats for organisms that live in and adjacent to rivers. The presentation also provides an example of how several scales of biophysical processes are important to understand, manage and rehabilitate habitat for aquatic life in rivers.

Assessing drivers of human-induced change in Lake Erie using fuzzy cognitive mapping

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Poster Presentation
Session: Human-Water Interactions
Poster # 38

Organic pollution as a source of eutrophication on Lake Erie has been a concern since the 1920s. Research to identify candidate causes has led to management activities that have repeatedly solved acute issues. However, the relative importance of main drivers changes, and the effects of their interactions remain unclear. As part of the Lake Futures project at the University of Waterloo, we are using fuzzy cognitive maps (FCMs) to identify putative relationships between drivers (e.g., phosphorus loading, human population, precipitation), intermediate variables, and ecosystem indicators (e.g., cyanobacteria biomass, botulism animal kills, phytoplankton biomass) of eutrophication. FCMs are semi-quantitative models that consist of concepts (nodes), joined by directional edges (arcs) representing purported causal relationships among concepts identified through best professional judgement. We combine results from three sets of expert workshops addressing proximal and ultimate causes of eutrophication to obtain a consensual FCM representing the current understanding of causes of Lake Erie eutrophication. We use the resulting consensual FCM to propose recommendations for continuing research to understand current concerns of human-induced changes in Lake Erie.

SAMMS: Sub-Arctic Metal Mobility Study

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 11

The Sub-Arctic Metal Mobility Study (SAMMS) will characterize effects of mining on legacy pollution in the Northwest Territories, evaluate the role of dissolved organic matter as a mobilizer of both natural and legacy metals, and examine how a warming climate may exacerbate these transport processes to aquatic systems. The first phase of SAMMS focuses on lakes and their catchments in the downwind airshed of Giant Mine, given prior evidence for previously unrecognized far-field atmospheric pollution from the mine. Work plans include to identify metal depositional history, pathways, and processes in lake sediments. Reconnaissance fieldwork at lakes along Highway 3 northwest of Yellowknife has included retrieval and analysis of lake sediment cores. At 'Lake 10', located approximately 60 km northwest of Yellowknife, sediment core results reveal an increase in arsenic and antimony concentrations between 10 and 3 cm core depth, likely associated with former emissions from Giant Mine. 'Lake 10' and its catchment will serve as a key site to launch additional SAMMS research. Other fieldwork plans for 2018 include to obtain lake sediment cores from headwater lakes at 10 km increments along a 80 km transect northwest of Yellowknife. The systematic collection and analysis of lake sediment cores is critical to assess for evidence of far-field atmospheric deposition of arsenic and other pollutants from Giant Mine. Overall, findings will inform improved decision-making by multiple stakeholders in the NWT, including Indigenous peoples, about the legacy of mining activities and implications of new mining developments on water quality in a changing environment.

Use of Decision Support Tools to Address Emerging Issues in the Great Lakes

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 89

Canada possesses huge number of small and large lakes that play a crucial role in production of clean drinking water, transportation of goods, recreational opportunities, biodiversity and climate regulation. Despite having enormous amount of water, Canadian lakes are under the direct threat from climate change, agricultural intensification, urbanization as these are exerting huge pressures on the ecosystem services of the lakes, and their associated social and economic benefits.

Over the past decade, Lake Erie, the smallest and shallowest Great Lake, is struggling with the algal blooms issue and this is compounded by climate change. In August 2014, an algal bloom contaminated with toxic bacteria shocked Toledo, poisoning the city's Lake Erie drinking water and forcing the city of 400,000 people to drink bottled water for three days.

Many practitioners are now working together to better manage and address the algal bloom issue in the Lake Erie. However, decision-making in the face of uncertainty and involvement of multiple stakeholders with different interests and objectives which keep changing over time, is a challenging element in environmental management with significant economic implications. This work package 5.3 of Lake Future Project will integrate knowledge obtained from work packages 1 to 4 in the creation of a decision support system (DSS) to improve the quality of decision-making that targets the management of algal blooms in Lake Erie. The main essence behind DSSs is that they are intended to facilitate reproducible, robust and transparent decision-making. This will helps practitioners to use data, documents, knowledge, and models to solve simple or complex problems alike and make decisions regarding the future of Canadian Lakes in a timely manner.

Integrated Water Resources Management of the Saskatchewan River Basin using WEAP

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Oral Presentation
Session: Modelling and Observations - Part II
15:00–15:15, Wednesday, June 6, 2018
Room 1105

Canada's water resources are facing multiple threats including water quality degradation, water scarcity and an increasing frequency of extreme events such as floods and droughts. The drivers mainly relate to climate change, increasing socio-economic development and population growth. Within this context, the water governance paradigm chosen can also play a significant role as it can either mitigate or exacerbate the evolving challenges. Governance of the transboundary Saskatchewan River Basin (SaskRB), located in Western Canada, is fragmented between the three Canadian provinces of Alberta, Saskatchewan and Manitoba as well as part of Montana in the USA. This fragmented water management approach fails to consider the integrated social, political and economic values of water across the entire basin. The solution is integrated basin-wide water resources management of the SaskRB. To this end, the Integrated Modelling Program for Canada (IMPC) under the Global Water Futures (GWF) programme has been designed to provide appropriate water management and decision-making tools for major Canadian river basins. Therefore, this research aims to develop an integrated water resources model of the SaskRB by applying the Water Evaluation and Planning (WEAP) modelling software. WEAP has been chosen mainly because of its easy-to-use interface and flexibility in defining complex water management policies. The SaskRB operating policy will be represented in WEAP by reference to that implemented within the Water Resources Management Model (WRMM), which has been applied to some individual parts of the SaskRB. Water allocation policies will be based on licensed allotment rules and allocations set by the respective administration districts. The WEAP model results will be validated against that of the WRMM. To solve the water allocation problem efficiently at each time step, two different linear programming solvers, LPSolve and Gurobi, will be used. This integrated water resources model will facilitate the assessment of different water management scenarios and operation policies at a basin scale. The model will also allow the assessment of the potential effects of hydrological variability resulting from climate change on water management by appropriately coupling WEAP with a hydrological model. The study will help to assess the viability of the current inter-provincial and international agreements established within the SaskRB under future climatic scenarios and provide guidance for further investigation.

Seasonal Patterns of Chlorophyll and Temperature in Lakes: Detection and Attribution of Climate Change Signal

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Poster Presentation
Session: Modelling and Observations
Poster # 12

The abundance and productivity of phytoplankton in lakes are subject to a complex set of pressures. Because climatic drivers – temperature, wind speed and direction, precipitation, and ice cover – impact the physical environment in which algae live, climate change imparts long-term changes in phytoplankton dynamics. Human activities in a lake's catchment further modulate temporal and spatial trends of algal growth by changing the inflow of water and the delivery of limiting nutrients. Climate warming not only translates into higher surface water temperatures of the lake, but also in physical changes, including water column stratification and turbidity, and biogeochemical changes, including bottom water oxygenation and internal nutrient loading. In addition, the Intergovernmental Panel on Climate Change (IPCC 2014) predicts that changes in the hydrological cycle will increase the frequency of extreme events, such as severe rainfall events, which in turn modify the yearly distribution of runoff to lakes.

To assess and unravel the changes that affect lentic ecosystems, long-term data-series are of paramount importance. The need for more effective environmental monitoring has led to notable advances in satellite technology and algorithm development, including enhanced ocean color sensor data acquisition capabilities to detect and map phytoplankton blooms with adequate spatial and temporal resolution. The concentration of chlorophyll-a (Chl-a) remains one of the most widespread and informative parameters to monitor algal biomass and trophic conditions in lakes. The availability of sunlight and nutrients, especially phosphorus, nitrogen, silicon and iron, are essential for the growth of phytoplankton. The short-term variations in the supply of nutrients to a lake's surface water are mainly controlled by the circulation regime and mixed layer dynamics. Therefore, much attention has been devoted on relating variations of Chl-a distributions to in-lake physical properties, in particular the lake surface temperature and thermal structure of the water column. However, far fewer efforts have attempted to relate long-term changes in Chl-a distributions to long-term. In this study, lake- and basin-wide phytoplankton chlorophyll-a concentrations (Chl-a), Lake Water Surface Temperature (LWST), and watershed Land Surface Temperature (LST) for Lake Erie are assembled and analyzed for Lake Erie, Lake St. Clair and Lake Ontario. We leverage 16 years of data (2002-2017) using consistent, well-calibrated remotely-sensed observations, which are particularly suitable to identify temporal patterns of variability. Our preliminary results also show that lake Erie's water surface temperature exhibits an increasing trend during winter season (December to February) for the 2002 to 2017 period. Similar trends, however, are not found for summer and autumn. To our knowledge, the observed winter

warming trend has not yet been reported. We believe this is a very significant finding and could help explain the temporal changes in Chl-a concentration.

Approaches to understanding the fate of mercury in aquatic ecosystems

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Oral Presentation
Session: Aquatic Environment and Ecosystems
13:30–13:45, Wednesday, June 6, 2018
Room 1309

Methylmercury (MeHg) is of global concern due to its toxicity to fish-eating wildlife and humans and to the fish themselves, and the use and release of mercury from human activities is under increasing scrutiny and monitoring due to the recent ratification of the Minamata Convention. In Canada, the presence of elevated levels of MeHg in fishes has led to a number of consumption advisories and increasing focus on understanding and reducing its impacts. MeHg concentrations in aquatic food webs increase with trophic level (TL) but this process of biomagnification varies among lakes and rivers, thereby changing exposures of top predators to this metal. The trophic transfer of MeHg can be contrasted across gradients of latitude, physicochemical characteristics, and diversity using trophic magnification factors (TMFs), a metric based on the slope between log MeHg (or total Hg) concentrations and TL (measured with stable nitrogen isotopes; delta15N). In a large review, TMF values were higher for MeHg (7.5 fold increase per TL) than for total Hg (a measure of both MeHg and inorganic Hg; 4.8 fold increase per TL) across diverse freshwater and marine food webs. Some of this wide variation was related to latitude, with Arctic food webs having higher MeHg TMFs (~10 times/TL) than those from the tropics (~4 times/TL), likely because of slower growth rates of organisms in colder climates. In freshwater systems, MeHg TMF values were higher in riverine than lake food webs. This presentation will review our understanding of MeHg fate in aquatic systems and approaches for contrasting both its trophic transfer and its effects across species. Understanding how Hg behaviour in food webs is affected by system characteristics can help identify areas at greatest risk from legacy inputs or those that may respond more quickly to global reductions in Hg emissions through the Minamata Convention.

Improving estimates of phosphorus loads from tile-drained landscapes using Kriging techniques

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Oral Presentation
Session: Aquatic Environment and Ecosystems
14:00–14:15, Wednesday, June 6, 2018
Room 1309

Excessive transport of phosphorus from agricultural lands to downstream water bodies and lakes has led to proliferation of algal blooms in the Great Lakes region. Efficient management of phosphorus transport needs accurate assessment of the amount and timing of phosphorus loads in surface runoff and subsurface tile drainage. Nutrient loads are the function of both water flow rates and nutrient concentrations. Given that continuous measurement of nutrient concentrations over time is not practically and economically possible, calculation of nutrient loads is always accompanied with some uncertainty. Assessment of uncertainties and their temporal variation are important for reliable estimates of nutrient loading and to identify high-risk periods and pathways of nutrient loss. In this study, we used the Ordinary Kriging method to interpolate soluble reactive phosphorus (SRP) concentrations in tile drainage for a time series over 6 years (2012-2017), at 15 minute intervals, from croplands in southern Ontario. SRP concentrations were divided into deterministic and stochastic components. The deterministic part was estimated by fitting a Log-Log linear relationship between measured tile flow rates and instantaneous SRP concentrations, and was subsequently estimated as a time series using continuous flow rates and Log-Log relationships. Residuals between the observed and deterministic SRP concentrations were used in the stochastic component, where Kriging was applied to interpolate residuals from the sampling times to a continuous time series. Through Kriging, we determined the mean and standard errors as a continuous time series for the entire study period. By adding the deterministic SRP concentrations to the time series with the residual mean time series and its standard errors, we determined the loads and their standard deviations for each 15min interval. These results, and implications for reliable estimates of nutrient loadings to evaluate water quality from tile-drain landscapes will be discussed.

the role of practitioners in DSS formulation

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Oral Presentation
Session: Human-Water Interactions
14:15–14:30, Tuesday, June 5, 2018
Room 1309

Collaborative water resources governance requires that planning and management activities consider a broad set of sectors such as environment, energy, industry, transportation, agriculture, recreation, and tourism. The process is complex due to the required involvement of numerous stakeholders and decision makers with conflicting preferences and different value preferences. Methodologies to support such management conundrums benefit from having science and research central, in support of policy development and implementation. As such, this task focuses on developing a decision support framework at the scale of the Great Lakes basins to explicitly improve the quality of decision making to achieve better manage eutrophication and nuisance algal growth.
Building on advances in eutrophication challenges in the Baltic Sea, the decision support system aims at a finding cost-effective nutrient reductions necessary to improve the state of Lake Erie and other Great Lakes in Canada. We will relate inputs to the system and ecosystem responses in a manner that is interactive, reliable based on current science, and plausible enough for modeling scenarios.

To account for uncertainties regarding future scenarios, the portfolios will include a range of choices for short-term action as well a framework to guide future actions, allowing dynamic adaptation over time to meet changing circumstances. All developments will benefit from early practitioner input on the design of decision-support tools, to better address objectives from multiple stakeholders and improve likelihood of agencies to implement monitoring systems to gauge the success of the actions and need for adjustments

Past and future Arctic treeline hydrology under changing climate and vegetation

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Poster Presentation
Session: Modelling and Observations
Poster # 62

The rapidly warming Arctic is also experiencing increasing shrub cover and density, and permafrost thaw. Understanding, quantifying and predicting the impact of these environmental changes on the hydrological regime of Arctic basins represents a great challenge, particularly due to the sparse monitoring network, limited understanding of governing physical processes and their interaction, and the uncertainty in future climate projections. This study investigated the past and future hydrology of Havikpak Creek, a small Arctic basin located near the treeline in the Northwest Territories. A hydrological model suitable for application in the Arctic was developed using the Cold Regions Hydrological Model Platform (CRHM), including the key physical processes found in this environment: flow through snowpack, organic terrain and mineral soil, evapotranspiration, infiltration into frozen and unfrozen soils, blowing snow redistribution and sublimation, snowpack energy balance, evaporation/sublimation from canopy interception of rain/snow, ground freeze and thaw and streamflow routing. Validation showed the model's capabilities representing daily streamflow, snow accumulation and melt, and active layer thickness.
Mean water balance for the last 30 years showed that snowfall is the largest water input (58%), whereas the water losses have been dominated by evapotranspiration (47%), streamflow (39%) and sublimation (14%). Great variability was found between different landcover for most mass fluxes, demonstrating the need to include detailed vegetation characterizations in the model. Historical change analysis between 1960 and 2016, including observed changes in climate and vegetation, showed that precipitation has dropped (13%) and temperature has increased (3.7°C), decreasing streamflow discharge (21%), sublimation (14%), evapotranspiration (10%), and increasing active layer thickness (10 - 23 cm), among other changes. Future climate using a high resolution (4 km) regional climate model and expected changes in vegetation revealed large changes in climate and water cycling. Substantial increase in mean air temperature (6.1°C), annual precipitation (117 mm) and incoming longwave radiation (21 W/m2) are projected. The hydrological regime is projected to respond rapidly under such changes. For example, spring streamflow will double and occur earlier, fall runoff is delayed and peakflow increases (30%). Other changes, such as larger snow accumulation (45%), shorter snow cover season (1 month), greater runoff ratio and active layer thickness, and increase ET are projected. The overall changes in climate from 1960 to 2100 at Havikpak Creek are profound, almost 10°C of warming and a substantial increase in precipitation. Although relatively small historical changes were found, under a high-end concentration scenario, hydrological changes are expected to be much larger, with significant hydrological and ecological consequences.

Investigating alpine forest water use under variable growing season and climate conditions in the Canadian Rocky Mountains, Kananaskis, Alberta

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 91

Fresh water supplies in mountainous regions are at risk as snow and ice stores continue to decline under rising global temperatures, earlier winter snowmelt and changing climate regimes. Alpine forests are of particular importance due to their hydrological connectivity within watersheds such as controlling groundwater base flow, influencing evapotranspiration and snow storage dynamics. A change in the water availability to alpine vegetation could have a drastic effect on the health of these forests, making it imperative to understand the hydrological connectivity of high alpine forests. Study sites located at Fortress Mountain in Kananaskis, Alberta are composed of coniferous tree stands of Abies lasiocarpa and Picea engelmannii. Little is known about water use dynamics of these species at high elevations, specifically the quantity and when they intake their water during the shoulder and growing seasons. In addition, climate model projections show a rapidly declining tree population in mountain valley bottoms of the Kananaskis area within 100 years due to historical climate variations and differing snow pack regimes. With a potentially limited future tree population at lower alpine elevations, the hydrologic services of trees at higher elevations become more important to the watershed. This study used a combination of hydrological and meteorological tools to address coniferous tree water use behaviour before, during and after the alpine growing season (June-September). Methodologies focussed on determining seasonal transpiration (T) patterns using the non-invasive stem-heat balance method to determine sap flow and eddy covariance to capture stand evapotranspiration (ET). Groundwater monitoring wells, soil tensiometers, precipitation gauges and two meteorological stations measuring net radiation, air temp, relative humidity, variable depth soil temperature and soil moisture were used to determine environmental conditions. Understanding tree response to precipitation and drying events was the main objective addressed, yielding stark differences between the growing seasons of 2016 and 2017. Stand T was higher in 2017 (165mm) than 2016 (118mm) despite a much drier and warmer season (213mm of rain compared to 283mm). A deeper, sustained snowpack in 2017 coupled with higher net radiation allowed for higher T rates, helping to address the second objective: which hydrological sources are most important to tree productivity. Well draining soils and shallow depth to bedrock determine a lack of groundwater accessibility for studied trees, thus soil moisture appeared to supply a majority of water to the tree population. Dry conditions in 2017 showed a clear trend between soil moisture levels and tree water use, with 2016 having almost double the soil moisture and tree productivity in the tail end of the growing season. For 2017, 7% of the season's total T occurred with average volumetric water content (VWC) of 0.15 compared to 2016's 14.5% and VWC of .30. By closely examining the patterns of alpine tree water use, we can begin to clarify how these important ecosystems services will be impacted under a changing climate in addition to helping us better manage our forestry and freshwater resources.

Longer summers drive multiple cyanobacterial blooms on lake 227

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Oral Presentation
Session: Aquatic Environment and Ecosystems
14:15–14:30, Wednesday, June 6, 2018
Room 1309

Cyanobacteria-dominated blooms are an increasing threat to freshwater systems across the globe. As the incidence of nuisance blooms increases, there is a pressing need to better understand, predict, and manage the drivers of bloom onset/cessation, duration, and composition. In this study, we focussed on the environmental and climatic factors controlling cyanobacteria bloom formation in Lake 227, a small, soft water, experimentally eutrophied lake at the IISD Experimental Lakes Area in northwestern Ontario. Using data associated with the period of constant phosphorus addition, but following the cessation of nitrogen addition, we observed a gradual transition from a single, long mid-season cyanobacterial bloom to two, shorter bloom peaks in the early and late season. This pattern is likely due, in part, to a nearly two-week increase in the number of ice-free days, which has subsequently increased the open-water stratification period in the lake. Interestingly, although the total cyanobacterial biomass was dominated by the genus Aphanizomenon in both early and late blooms, the rates of N-fixation are significantly different. Together, these findings indicate that even under a constant nutrient-loading regime, bloom onset and duration will change. Management goals and mitigation strategies and must be responsive to the complexity of drivers affecting blooms.

Cyanobacterial bloom composition and duration within Contestogo reservoir: An investigation into the drivers of bloom formation

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 13

Cyanobacteria-dominated blooms are an increasing threat to freshwater systems across the globe. As the incidence of nuisance blooms increases, there is a pressing need to better understand, predict, and manage the drivers of bloom onset/cessation, duration, and composition. In this study, we focussed on bloom onset, duration, and the taxonomic and toxin composition in Conestogo Lake, a flood control reservoir managed by the Grand River Conservation Authority in southwestern Ontario. An Aphanizomenon flos-aquae dominated bloom began in the eastern arm of the reservoir in mid July 2017 following a heavy rainfall event. A secondary bloom, also dominated by A. flos-aquae was detected in the western arm a week after the bloom in the east arm, with cyanobacteria and its toxins spreading into downstream locations within a week. Three microcystin variants, including microcystin-LR, -YR, and -RR, were detected in samples during the bloom period, which lasted between 2 - 4 weeks depending on the location within the reservoir. Together, these findings indicate that water movement through the reservoir system, combined with temperature and oxygenation, are key drivers for cyanobacterial blooms in Conestogo Lake. Management goals and mitigation strategies must be responsive to the complexity of drivers affecting blooms. For reservoirs with large watersheds, flow management may be one of the few options available for short-term bloom mitigation.

Projected changes over western Canada using convection-permitting regional climate model

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Oral Presentation
Session: Climate and Extremes
13:45–14:00, Wednesday, June 6, 2018
Room 1110

Results from the General Circulation Models (GCMs) suggest more frequent and more severe extreme rain events in a climate warmer than the present. However, current GCMs cannot accurately simulate extreme rainfall events of short duration due to their coarse model resolutions and parameterizations. This limitation makes it difficult to provide the detailed quantitative information for the development of regional adaptation and mitigation strategies. Dynamical downscaling using nested Regional Climate Models (RCMs) are able to capture key regional and local climate processes with an affordable computational cost.

Recent studies have demonstrated that the downscaling of GCM results with weather-permitting mesoscale models, such as the pseudo-global warming (PGW) technique, could be a viable and economical approach of obtaining valuable climate change information on regional scales. We have conducted a regional climate 4-km Weather Research and Forecast Model (WRF) simulation with one domain covering the whole western Canada, for a historic run (2000-2015) and a 15-year future run to 2100 and beyond with the PGW forcing. The 4-km resolution allows direct use of microphysics and resolves the convection explicitly, thus providing very convincing spatial detail. With this high-resolution simulation, we are able to study the convective mechanisms, specifically the control of convections over the Prairies, the projected changes of rainfall regimes, and the shift of the convective mechanisms in a warming climate, which has never been examined before numerically at such large scale with such high resolution.

Combined Effects of ENSO and MJO on the Growing Season Precipitation over the Canadian Prairies

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Oral Presentation
Session: Climate and Extremes
15:15–15:30, Wednesday, June 6, 2018
Room 1110

Warm-season precipitation over the Canadian Prairies plays a crucial role in activities in environment and society and has particular importance to agricultural production over the region. This research investigates how a warm season precipitation deficit¬ over the Canadian Prairies is related to tropical Pacific forcing in the early summer 2015 drought. The significant deficit of precipitation in May and June of 2015 were coincident with a warm phase of El Nino-Southern Oscillation (ENSO) and a negative phase of Madden-Julian Oscillation (MJO)-4 index as they both favor a positive geopotential height anomaly in western Canada. Further investigation during the instrumental record period (1979-2015) shows that the warm-season precipitation in the Canadian Prairies and the corresponding atmospheric circulation anomalies over western Canada teleconnected with the lower boundary conditions in the tropical western Pacific. MJO may play a crucial role in determining the summer precipitation anomaly in the western Canadian Prairie when equatorial central Pacific is warmer than normal (NINO4 > 0) and MJO is more active. The mechanism of this teleconnection may be due to the propagation of stationary Rossby wave that is generated in the MJO-4 index region. When the tropical convection around MJO-4 index regions (western tropical Pacific, centered over 140 E) is more active than normal when NINO4 >0, a Rossby wave train originates from western Pacific and propagates into the midlatitude North America causing an anomalous ridge in the upper level over western Canada.

Monitoring river ice cover development using the Freeman-Durden decomposition of quad-pol Radarsat-2 images

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Poster Presentation
Session: Modelling and Observations
Poster # 63

The monitoring of river ice development and measurement of ice thicknesses are crucial guidance indicators to establish safe crossings along river ice covers. This is the first study, based on our knowledge, to understand the interactions between ice cover structures and radar signals and to further monitor ice development using C-band synthetic aperture radar (SAR) images. The study was applied to the Slave River, Canada, using Freeman-Durden decomposition of quad-pol C-band Radarsat-2 FQ14W images and ice core crystallography analysis. The decomposed components, mainly including surface scattering and volume scattering, were also used to retrieve ice thickness. Results demonstrate that the combination of volume and surface scattering can be used to monitor ice cover development that cannot be interpreted from single polarization images, such as Radarsat-2 Spotlight images used in this study. Surface scattering also show potential for ice thickness estimations. These results indicate that the decomposed quad-pol Radarsat-2 images can provide a more effective guide than the single-pol Radarsat-2 SLA images to select safe ice transportation routes. This decomposition approach can be extended to other snow and ice covered rivers.

Model couplings to include river water temperature, overland and instream water-quality and river ice processes in the MESH modelling system

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Oral Presentation
Session: Modelling and Observations - Part II
13:45–14:00, Wednesday, June 6, 2018
Room 1105

MESH is a semi-distributed physically based land surface-hydrological modelling system developed by Environment & Climate Change Canada for hydrological applications. It uses the Canadian Land Surface Scheme (CLASS) for vertical exchanges and generation of lateral fluxes of energy and water balance for vegetation, soil and snow, WATROF or PDMROF for lateral movement of soil and surface water to the drainage system and the WATFLOOD for streamflow routing through river channels. It also uses the Group Response Unit (GRU) approach, i.e. combining areas of similar hydrological behaviour, to address the complexity and heterogeneity in the drainage basin for computational efficiency. This is a more suitable approach for large scale drainage basins due to its operational simplicity while retaining the basic physics and behaviour of a distributed model. In order to extend MESH's simulation capabilities to include overland sediment and nutrient transport, river ice processes and fish habitat, the following dynamic models have been successfully coupled to the MESH modelling system:
-RBM – to simulate river water temperature, ice-cover duration and fish habitat
-RIVICE – to mimic river ice process such as frazil-generated ice covers, ice jamming, hanging-dam formation and ice-cover ablation
-MESH-SED – to calculate sediment transport from land surfaces into receiving waters.
Application examples of each will be presented in this talk. Next steps are to couple the following models:
-WASP – to simulate instream water quality processes to reflect phytoplankton/nutrient cycles within receiving waters
-MESH-NUT – incorporate transport of nutrients, nitrogen and phosphorus, in the MESH-SED algorithm

DNA-based biosensors for metal detection

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Oral Presentation
Session: Aquatic Environment and Ecosystems
15:00–15:15, Wednesday, June 6, 2018
Room 1309

Metal ions are critically important analytes for biomedical and environmental analysis. Biosensors for metal ions are needed to provide on-site and real-time analytical information. DNAzymes are DNA-based catalysts, and they require metal ions for their catalytic activity. Therefore, it is possible to intentionally select DNA sequences that can selectively recognize target metal ions. In the last few years, we have isolated a suite of new metal-specific RNA-cleaving DNAzymes using in vitro selection. Some representative examples will be presented for the detection of monovalent Ag+ and Na+, divalent Cd2+, Cu2+, and Ca2+, and trivalent lanthanides. These DNAzymes have been converted to catalytic beacon sensors by labelling fluorophore/quencher pairs. Cleavage in the presence of target metal ions induces a fluorescence enhancement. Most of these sensors can detect the target metal ion down to low parts-per-billion level with thousands to millions fold of selectivity against competing metals. The detection in environmental water samples was also demonstrated.

Temporal and spatial controls of nitrogen to phosphorus ratios in a Canadian prairie watershed

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Oral Presentation
Session: Watershed Management and Disturbance
15:00–15:15, Tuesday, June 5, 2018
Room 1110

On the Canadian prairies, eutrophication of aquatic ecosystems is frequently attributed to the transport of phosphorus (P) from upstream agricultural watersheds. Nitrogen (N) is also an important nutrient in fueling algal growth and the relative supply of P relative to N may be an important factor in defining algal species composition. This study attempts to analyze the temporal and spatial impacts of climate, land use, and management practices on the runoff N:P ratios in the 76-km2 South Tobacco Creek (STC) Watershed located in southern Manitoba, Canada and within the larger watershed of Lake Winnipeg. In the study watershed, N and P in runoff were monitored from 2005 to 2015 at three spatial scales: 1) the edge of 8 fields (with various land uses and management practices), 2) the outlet of a sub-watershed containing these 8 fields (the 206-ha Steppler Watershed), and 3) the outlet of the overall STC watershed. Relationships between climate, land use or management practice, and the N:P ratio in runoff will be developed at the field scale, and consistency or change in these relationships across spatial scales will be evaluated based on patterns observed at the sub-watershed and the watershed scales. Interaction with climatic drivers will be evaluated through separate characterization of patterns for snowmelt, rain on snow, and summer runoff, respectively.

Past, Present, and Future: Quantification of Long-Term Phosphorus Legacies in the Grand River Watershed

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 14

Phosphorus (P) inputs into human-impacted watersheds more than doubled within the last century. In the Great Lakes basin, high P loading over the past few decades is the main chemical driver of the severe algal blooms that occur in Lake Erie annually. Outcomes from management practices to alleviate eutrophication have not met targets, and P accumulation in the landscape may be the cause. In addition, the forms and relative magnitudes of legacy P accumulation are still not well understood. In the present work, we have developed a parsimonious, process-based model, ELEMeNT-P, that pairs soil P dynamics with both erosion processes for simulation of surface P transport and a travel time-based approach for simulation of transport and retention along subsurface pathways. Using a more than 100-year trajectory of watershed P inputs to the biggest watershed draining into Lake Erie, we were able to reconstruct total phosphorus yields at the watershed outlet, as well as estimate the magnitudes of P accumulation along surface and subsurface pathways. As Lake Erie and other inland lakes continue to be impacted by eutrophication events, such estimates of legacy P accumulation will be crucial to developing more effective management plans, and setting realistic targets for reducing P loading. These estimates will also give us a better understanding of the contribution of P legacies to current and future watershed nutrient dynamics.

Setting the background for water prediction in the Yukon River Basin using MESH modeling system

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Poster Presentation
Session: Modelling and Observations
Poster # 64

The Yukon River Basin, fifth largest basin in North America, comprises a headwaters area of the Coastal Range mountains of northern British Columbia and a vast area of Southern Yukon Territory and central Alaska totaling more than 850,000 km2, about 324,000 km2 of which lies in Canada. The river originates from the Llewellyn Glacier and flows northwest along a 3,185 km arc shaped course to discharge into the Bering Sea. Global Water Futures has committed to developing a model to forecast streamflow on a daily basis over the short term and to predict the impact of climate, land cover, water management and glacier change on future hydrological cycling in the basin over decadal periods. Of special interest is the hydrological interaction between rivers and glaciers, lakes, wetlands, permafrost and groundwater. This work focusses on preparing the MESH land surface hydrology model for these purposes in the predominantly Canadian river basin draining west into Eagle Alaska, which encompasses six sub-basins: Yukon Headwaters, Teslin River, Pelly River, Stewart River, White River and Upper Yukon. To prepare MESH for this basin required compilation of comprehensive GIS, hydrometric and hydro-meteorological data from different sources including ECCC and USGS. Drainage basin land surface features such as the river network, water bodies and soil types were combined with existing topography and vegetation cover to create a seamless basin characterization across the international boundary. Parameterisation in MESH required delineating and specifying parameters for model calculations within and between Grouped Hydrological Response Units, which were based initially on land cover, slope and aspect, and will be adjusted in the future to include soil type and terrestrial ecology features. The results of 25 years of scientific investigations at Wolf Creek Research Basin near Whitehorse will inform parameterisation. The model was driven using hourly 2002-2017 GEM-CaPA weather forcing data. The results from these initial model runs, are being compared to observations and assessed for crucial corrections and fixes. This provides the first Canadian modelling of the Yukon River Basin in Canada and so is an important step for forecasting and prediction in Yukon Territory.

The influence of snow data assimilation on the performance of a coupled numerical weather forecast and physically based cold regions hydrological model

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Poster Presentation
Session: Modelling and Observations
Poster # 65

Accurate estimation of snowpacks and streamflow in snow dominated regions is crucial for local water management. Data assimilation (DA) can be used to improve simulations through merging the uncertainty of model forcing data and observed snowpack information. This research assimilated ground observed snow depth and density as snow water equivalent (SWE, once or twice a month) and snow depth (ds, daily) from snow surveys and sonic ranging sensor measurements, respectively, into the Cold Regions Hydrological Modelling platform (CRHM) forced by Global Environmental Multiscale (GEM) model 2.5 km output using an ensemble Kalman filter (EnKF) in a headwater basin in the Canadian Rockies – Marmot Creek Research Basin (MCRB). To evaluate the influence of various DA methods on snowpack main properties, several parallel DA experiments were conducted by assimilating SWE and ds separately, or combining SWE or ds or including historical snowpack density (ρ) data with ds to estimate SWE. The SWE from several snow survey sites was interpolated into the whole MCRB based on the relationship between local snow accumulation and topography, vegetation, and wind effect. This interpolated SWE was then assimilated into CRHM to evaluate the impact of SWE DA on streamflow simulation. The DA simulated snow conditions and streamflow were evaluated by using ground based observation data. The results indicated that, although ds measurement and assimilation had high frequency, assimilating ds alone had limited improvement on SWE due to the poor simulation of ρ by CRHM. Assimilation SWE alone improved the SWE simulation accuracy, but due to sparse SWE data availability, this improvement was limited in the early accumulation and late melt periods. This improvement was small in dry years. A combined DA using both SWE and ds provided the best results among all designed DA experiments as it showed dramatic improvement estimating SWE for the whole snow season. Assimilation of ds and historical snowpack density together was close to the performance of this approach, suggesting an alternative when SWE measurements are not available. Assimilation of interpolated SWE in the basin scale improved the simulated stream flow in the early melt period of each year while the improvement in later melt season was much smaller except dry years with low rain fall precipitation.

Groundwater Flow and Permafrost Distribution in a Subarctic Watershed

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Oral Presentation
Session: Watershed Management and Disturbance
13:45–14:00, Tuesday, June 5, 2018
Room 1110

Groundwater processes across subarctic Canada have exhibited sensitivity to climate warming through changes in the thickness and distribution of perennially frozen ground, otherwise known as permafrost. New hydrogeologic pathways, previously blocked by impermeable permafrost, may create positive feedbacks that accelerate thawing. The objective of this study is to develop a conceptual understanding of the processes that control groundwater flow in northern mountain environments, and to assess the long term impacts of climate change on these systems using a combination of field data and numerical modelling.

The study site, Granger Basin in the Wolf Creek Research Basin, Yukon Territory, is representative of the interior subarctic cordilleran landscape where climate change is already altering freeze-thaw patterns of the active layer and underlying permafrost. Our study transect covers both north and south facing slopes, which have different permafrost distribution patterns due to differing amounts of solar radiation received on each slope. A capacitive-coupled resistivity survey was used to map vertical permafrost distribution across our transect in March 2018. Using preliminary results, we identified locations to install monitoring wells, each with two piezometers to monitor shallow and deep groundwater movement. With historic stream discharge data as a constraint, we will create a two dimensional model simulating groundwater flow and heat transport that will be calibrated against data from wells and soil resistivity surveys.

Water and Agriculture in Canada

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Oral Presentation
Session: Plenary
16:15–17:00, Tuesday, June 5, 2018
Room 1305/7

The fate of Canadian agriculture depends strongly on water availability, patterns of water use, and water quality. Water quality and availability are threatened by growing global populations and the impacts of climate change. These pressures have serious implications for water sustainability in general, and, for agriculture in particular. The essential roles that agriculture and food production systems provide for all Canadians are being challenged by current and emerging future issues of water access, use and quality. The Canadian landscape is heterogeneous, with significant regional differences in climate, hydrology, geomorphic factors, agricultural activities as well as economic, governance and socioeconomic drivers. Furthermore, the climate is changing, but these changes differ regionally across Canada. To maintain food security in Canada, knowledge is needed on how agriculture in Canada can change and possibly adapt over the next several decades in response to climate change, and if/how this may vary regionally across the country. The Agricultural Water Futures project is working with Global Water Futures to evaluate contemporary water availability, use and quality in a Pan-Canadian context with the goal of improving current and future agricultural water sustainability.

Status report on the Great Lakes Runoff Inter-comparison Project for Lake Erie (GRIP-E)

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Oral Presentation
Session: Modelling and Observations - Part I
13:45–14:00, Tuesday, June 5, 2018
Room 1105

The Great Lakes Runoff Inter-comparison Project (GRIP) includes a wide range of lumped and distributed models that are used operationally and/or for scientific purposes across Canada and the United States. The models participating to date are GEM-Hydro, WRF-Hydro, MESH, VIC, HYPE, and LBRM. The project is aiming to run all these models over the entire Great Lakes domain with Lake Erie chosen as the initial domain (GRIP-E). Inter-comparison studies were however already conducted for Lake Michigan (GRIP-M) and Lake Ontario (GRIP-O) with various models including a subset of the aforementioned models.
One of the main contributions of the project is to identify a default, consistent dataset for model building that all participants in the inter-comparison project can access and then process to generate their model-specific required input variables. This presentation will give an update of the datasets all collaborators agreed on and the various scripts converting these datasets into model-specific setup files. The results of this project will not only serve as a classical framework for model inter-comparison demonstrating the differences in model capabilities, but will also develop strategies to handle cross-border inconsistencies of available data and develop unifying approaches. During development, the project team will share all codes and data on a private GitHub repository. In the final stage of the project all scripts and datasets will be transferred to a public GitHub repository such that the entire community can benefit from it. Some datasets, however, might be excluded due to non-disclosure agreements among the partners.
The inter-comparison project will furthermore test the operational applicability of participating models and identify respective model strengths, i.e., learning which models perform best under certain conditions. The generated multi-model ensembles will help to quantify the uncertainty of hydrologic processes including states and fluxes. All model outputs will be shared with the public as far as non-disclosure agreements allow.

Occurrence and distribution of pesticides in the Prairie Pothole Region

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 15

Recent studies in the Canadian Prairie Pothole Region (PPR) have demonstrated that neonicotinoid pesticides occur frequently in wetlands. However, the distribution and occurrence of the complete suite of pesticides and the risk that these pesticides pose to the aquatic ecosystems remains largely unknown. Therefore, the aim of this study is to identify the distribution of pesticide use and priority areas which will aid in evaluating the cumulative ecological risk of pesticides in wetland ecosystems.
To identify priority areas, we complied information from recent remote sensing crop inventory maps, and pesticide use data. Based on risk maps, we designed two monitoring campaigns throughout the Prairies. Results from the pesticide distribution models suggest high pesticides use in areas around the province of Saskatchewan. Insecticide such as chlorpyrifos were found up to 22 times higher in Saskatchewan compared to other prairie provinces. Based on these results, two monitoring campaigns were designed with the ultimate goal of estimating the ecological risk of pesticides.

Dynamic modelling of geochemical (C, N, P, Fe, O, S) fluxes in lakes using a coupled water-column and sediment diagenesis model

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Poster Presentation
Session: Modelling and Observations
Poster # 66

We updated the 1D physical model of lake and coupled it to a vertically resolved sediment diagenesis module. Also, we built biogeochemical reaction network seamlessly coupling water column and sediment processes. The application of the model to a boreal lake shows the capacity of the model to simulate daily water quality and sediment-water exchange fluxes dynamically over a long historical period.
In our prognostic scenarios, we studied the importance of sediment as well as we tested the effects of various climatic and anthropogenic driving forces on biogeochemical cycles in lakes. First, coupled Lake-Sediment model was used to study the effect of increasing air temperature on water quality. Secondly, given the chief role of ice cover in controlling water column and biogeochemical cycles, we also examined extreme scenarios of presence and total absence of ice cover. Thirdly, in the artificial scenario with a complete cut-off of the phosphorus loading from the watershed to the lake, we assessed an internal capacity of the lake to preserve phosphorus in water over time. Finally, due to many efforts to improve water quality have relied on the addition of reactive material to the water column, we investigated the influence of iron addition on the DIP flux from the sediment and, consequently, phytoplankton in the lake.

Incorporation and tillage practices to mitigate phosphorus loss through tile drains following fall application of dairy manure

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 16

Increased loads of phosphorus (P) from agriculture into the Great Lakes can lead to eutrophication resulting in an increase in the size and level of harmful algal blooms as well as hypoxic conditions. In recent years, many studies have highlighted the important role of tile drains in contributing to the total P loads from agricultural runoff. However, the findings have been mixed as to whether tillage and incorporation help to mitigate subsurface total P loads. The uncertainty in the efficacy of these management practices is exacerbated by a lack of field data with year-round monitoring. The goal of this study was to determine if different management practices including reduced till, conventional till, and incorporation mitigate P loss through tile drains following fall application of dairy manure. This study had 3 specific objectives: 1) to quantify annual runoff, P loss, and P speciation from tiles located within a silt loam soil; 2) to determine if incorporation of dairy manure impacts P loss or speciation in tile runoff; and 3) to investigate if tillage depth contributes to P loss or speciation in tile runoff following fall surface applied dairy manure. This study used a field approach with water samples being collected on an event basis from 3 adjacent tile drains with different treatments. Two plots received shallow tillage (3”), whereas the third plot received deeper tillage (7”) to simulate conventional tilling methods. All plots received the same rate of liquid dairy manure application in a surface application. However, following application, one of the shallow tilled plots received a second shallow disk till (3”) to incorporate the manure. Differences in soluble reactive P (SRP) concentrations throughout the non-growing season (Oct – May) will be presented and discussed. This study will provide important insight into fall manure management for farmers and policy makers.

Indigenous Knowledge and Western science co-creation of Indigenous Water quality tools

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Oral Presentation
Session: Plenary
14:15-14:45 Monday, June 4, 2018
The Gathering Place on the Grand, Ohsweken

IK and Western science can lead to innovative strategies to resolve critical water futures facing Indigenous people globally. In Canada, a 2017 federal budget underscores the priority of IK inclusion of all scientific endeavors in Canada to "develop and implement a plan to integrate traditional Indigenous knowledge" to build a better understanding of climate change. An overview of how to engage both systems to advance knowledge of the ecosystems all humans depend.

The Problem: An analysis of water security and climate change in Indigenous communities shows that up to 72,000 people could have been affected by drinking water advisories (DWAs) in First Nations at the start of 2017. In 2016 alone, 133 boil water advisories in 90 indigenous communities were issued that affected over 50,000 people across the country.

The Plan: This project will work with two distinct communities, Six Nations of the Grand River (Ontario) and Lubicon Cree Nation of Little Buffalo (northern Alberta), to capture the range of water challenges in Indigenous communities. The project will use an innovative research framework informed by the Indigenous partners to facilitate sharing and integration of contemporary science and Indigenous and Local Knowledge.

The Outcome: The co-creation of sensors, data analysis and culturally relevant tools will build long-term and sustained community capacity to address current and future uncertainties in water quality. Many other Indigenous communities across Canada will stand to benefit from the collaborative methodologies and pedagogies of integrating western and Indigenous knowledge, experience, tools and expertise gained from this project.

Risk assessment; reducing toxin exposure during Harmful Algal Blooms

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 17

Harmful algal blooms (HABs) are a water quality issue in lakes across Canada, as excessive growth of cyanobacteria can lead to ecological degradation, including hypoxia and anoxia, and potential toxicity, impacting human and animal health. Warmer weather, high nutrient levels, and decreased mixing of water are some factors known to increase the risk of a bloom. Identifying the most important factors in managing blooms and drivers of toxin production are questions addressed by the FORMBLOOM (Forecasting Tools and Mitigation Options for Diverse Bloom-Affected Lakes) team in partnership with the ATRAPP (Algal Blooms, Treatment, Risk Assessment, Prediction and Prevention through Genomics) group. Here we use intensive sampling to understand temporal changes in toxin risk using taxonomic approaches, 16 S amplicon sequencing, and toxin analyses using HRMS and ELISA, and applying metagenomic and metatranscriptomic sequencing to determine gene content and expression when toxins are present in-lake. We aim to understand the meaning of point measurements in assessing risk, and options to help reduce risk of toxin exposure via forecasting and warnings.

Precipitation intensity and type distribution during the January 2017 Ice Storm in the Maritime Provinces

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Poster Presentation
Session: Climate and Extremes
Poster # 26

The ice storm that affected the Maritime Provinces on 24-26 January 2017 led to major ice build-up on trees and power lines, resulting to a major power outage across the area. In New Brunswick, approximately 133 000 customers were affected over a period of 2 weeks in some area. Many types of precipitation such as freezing rain and snow were observed at the surface during the storm. The total amount of precipitation reported was up to 100 mm near the center of the province. Up to 50 mm of freezing rain was measured in some area near the east coast and the Acadian Peninsula. The goal of this study is to investigate weather conditions and precipitation during the ice storm in January 2017. A complete atmospheric model coupled with a sophisticated microphysical scheme is used to simulate the storm. An analysis of the weather conditions and synoptic scale pattern that produced the ice storm was conducted. The distributions of precipitation amounts and types at the surface and aloft were evaluated with respect to the atmospheric conditions and observations. Overall, the occurrence of this type of storms may increase with climate change and it is critical to improve our understanding of the mechanisms leading to freezing rain versus other types of precipitation at the surface.

Stable Isotope and Dendroclimatological Methods to Evaluate Water Use in Forest Ecosystems

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 92

Stable isotope ratios of carbon and oxygen in tree-ring and other plant material carry signals of past climate and environmental conditions because these isotope ratios are controlled by the plant's water and CO2 exchange rates. The carbon isotope composition (δ13C) of plant matter is a long-term indicator of intrinsic water use efficiency as a record of the balance between stomatal conductance and photosynthetic rate. The stable oxygen isotope composition (δ18O) of plant material records source water as an inference of air temperature, and leaf transpiration through vapour pressure deficit. Dendrochronological and stable isotope methods have been successfully implemented in an age sequence of plantation forests at the Turkey Point Observatory to examine climate and environmental controls on radial growth and tree physiology over their life history. Radial growth and δ13C values from tree-rings were highly correlated to air temperature, suggesting heat stress may hinder the resilience of these planted to extreme weather events that are likely to occur as a result of increased warming in the region. The stable isotope composition of plant matter, alongside dendrochronological and climate records, were also examined for water budget changes brought upon by climate and stand thinning treatments. Here we demonstrate the progress that has been made at the Turkey Point Observatory and show stable isotope dendroclimatology's unique strengths, and how it will make further novel and specific contributions in the GWF Southern Forests network.

Airborne Measurement of Seasonal Snow in Western Canada

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Oral Presentation
Session: Modelling and Observations - Part I
14:45–15:00, Tuesday, June 5, 2018
Room 1105

As part of the Mountain Water Futures Program, we are developing a mountain snow measurement methodology that ranges from seasonal airborne laser altimetry measurements made over many hundreds of square km to more frequent surveys over small catchments using unmanned air vehicles (UAVs) equipped with cameras permitting structure from motion estimation of the surface. Our presentation presents one component of this research, namely our airborne laser altimetry surveys. We describe our methods and strategies to acquire seasonal changes in snow depth using laser altimetry across the main mountains of western Canada. We also present first results from our Spring, 2018 snow measurement campaign.

GWF Knowledge mobilization highlights: Examples of good KM process from GWF year 1

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Oral Presentation
Session: Knowledge Mobilization
11:55–12:15, Tuesday, June 5, 2018
Room 1305/7

Over the first year of GWF-funded projects there have been many great examples of knowledge mobilization (KM) planning and initiation, engagement activities, network and relationship building, and increasing team capacity. In this session, the KM Core Team will highlight tangible KM processes and outputs that project teams have co-created with key partners and user communities toward their shared goal of developing innovative solutions to Canada's water and climate change challenges. We will highlight examples from GWF projects to demonstrate how the flow of engagement between researchers and partners and user communities is informing the research methods and outputs. We will emphasize KM definitions and concepts and communicate to the GWF network how the KM Core Team can assist with KM moving forward.

Multi-Fibre Optode Microsensors: affordable designs for monitoring oxygen in soils under varying environmental conditions

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Poster Presentation
Session: Modelling and Observations
Poster # 67

The biogeochemical functioning of natural and engineered environments is closely linked to spatial and temporal variations in molecular oxygen (O2) concentrations. As such, O2 measurement in field and laboratory soils provides useful insight into the soil system. However, monitoring soil O2 is often challenging due to high costs and limited customizability and durability of existing O2 sensors. To meet this challenge, a luminescence-based, Multi Fibre Optode (MuFO) microsensor technique was developed in-house to measure O2 concentrations in variably water-saturated soil systems under changing temperature regimes. The design is simplified by the use of a basic DSLR camera, LED light, and fibre optic cables. The technique relies on the conversion of high-resolution digital images of sensor-emitted light into O2 concentrations using the classical Stern-Volmer (SV) and Lehrer equations. The method was successfully tested in two artificial soil (20% peat, 80% sand) column experiments designed to simulate freeze-thaw cycles (FTC), with temperature cycling from -10°C to 25°C, and water table fluctuations (WT) under controlled conditions. Depth distributions of O2 levels were monitored without interruption for 20 (WT experiment) and 39 days (FTC experiment). No degradation of optode performance or O2 signals were observed over the entire duration of the column experiments, hence supporting the long-term deployment of the microsensors for continuous O2 monitoring in field and laboratory settings. The technical specifications of the system are fair, with a detection limit of 0.2% O2 saturation and Ksv' = 0.006. The main advantage of the MuFO over commercial applications is the low cost ($2,350 CAD), and ease of customizability. The system has been further developed for near real-time monitoring in the field, where the imaged data is transmitted remotely. The MuFO sensor is deployed in a field site where it will be left for testing over winter and spring. Preliminary results of the field test are presented here together with the lab results.

A synthetic inverse modeling study to detect karst conduit patterns via hydraulic tomography

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Poster Presentation
Session: Modelling and Observations
Poster # 68

Karst aquifers are geologic media that consist of enlarged solution conduits. The geometry of such conduits are very difficult to delineate and its hydraulic parameters are difficult to estimate. Although entering karst caves and mapping of conduits are the most direct approaches in karst aquifer characterization, it may fail due to the existence of unknown and/or inaccessible conduits. Conventional indirect methods such as tracer tests, geophysical surveys and pumping/pressure tests have also been extensively used, but have been unsuccessful in mapping conduit geometry. Therefore, there is a critical need to develop alternative approaches for improved mapping of karst aquifers.

Hydraulic tomography (HT) has been shown to successfully map the hydraulic heterogeneity of porous and fractured rocks aquifers. In this study, we utilize a set of synthetic karst models to explore the ability of HT to detect conduit patterns and their hydraulic parameters. This research attempts to assess the ability of HT: (1) to detect the conduit locations; (2) to differentiate between the network and branchwork conduit patterns; (3) to estimate their hydraulic parameters, connectivity, and uncertainties through the use of head and flux data collected during water injection tests.

In particular, two synthetic forward models, network and branchwork, are designed using VSAFT2 (Yeh et al., 1993) to produce the necessary data for inverse modeling. The response of the synthetic models (e.g., time variation of flux at the outlet and the map of groundwater flow direction) to the injection wells under steady condition are obtained for both models. Forward modeling results show that in general, water fluxes at the outlet of the branchwork model is higher than the network model even when the same water injection rates are applied at the wells. In addition, location of the injection well has a significant impact on the flux at the outlet. Therefore, it is expected that flux variation at the outlet is related to the distance between the injection well and the outlet as well as the pattern of conduit connectivity. The results also reveal that the flow lines mainly follow the conduit pattern, thus is highly dependent on the pattern. Groundwater flows at higher velocities through the conduits and focuses toward the model outlets.

We then conducted the HT analysis of these data using a set of six models (branchwork and network) to map the heterogeneity of different conduit systems through the activation of one or more of the injection wells under steady conditions. Our results reveal that the estimated hydraulic conductivity (K) maps become more reliable as the number of injection tests and the corresponding monitoring data are increased in inverse model. However, the results of the branchwork model is closer to the original conduit pattern in comparison to the network model. Overall, we find that our results confirm the feasibility of applying HT in detecting major conduits as well as being able to differentiate between branchwork and network conduit patterns.

Water governance in Indigenous territories in Canada

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Poster Presentation
Session: Human-Water Interactions
Poster # 39

Water threats represent pivotal points of discussion and concern for state and non-state actors in modern societies. The inherent complexity of these threats necessitates reflections, discussions, and actions on water governance. In Canada collaborative water governance approaches promoting the participation of local Indigenous people, their expertise and knowledge are exercised. Indigenous governance processes have not been understood by key stakeholder groups and therefore collaborative water governance has not always been successful. The lack of inclusion of core Indigenous governance principles such as self-determination and Indigenous worldview incorporation represent critical 'blind spots' in Canada's water governance. Indigenous peoples strongly advocate for the recognition of their inherent rights as self-determined nations with their own principles, rules, practices, and knowledge exercised and adapted in time. Indigenous governance systems allow them to adjust to their physical environment from a sacred kinship position rather than the owners of water. The recognition of Indigenous self-determination is essential for sustainable water governance that will benefit Indigenous peoples but also contribute to holistic benefits for non-Indigenous people in Canada.

A Software Platform for Integrated Monitoring, Modelling and Testing of Environmental Information Systems

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Poster Presentation
Session: Modelling and Observations
Poster # 69

This poster describes the iEnvironment system which is being developed in a partnership between the University of Waterloo's Computer Systems Group (UW/CSG), the University of Saskatchewan's Global Water Futures initiative, CANARIE (a national organization responsible for the advancement of Canada's knowledge and innovation infrastructure), several leading environmental researchers and a variety of other data providers and users. UW/CSG uses innovative techniques and technologies to make data and technology more accessible to researchers and other data providers and users that are authorized to use it. We describe aspects of these approaches that help to address concerns such as keeping data current, and ensuring existing applications still work as the underlying databases change to accommodate new approaches to modelling and monitoring.

KM lessons learned from 15-years of Canadian Water Network and the future through GWF

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Oral Presentation
Session: Knowledge Mobilization
10:50–11:05, Tuesday, June 5, 2018
Room 1305/7

Effective knowledge mobilization requires ongoing and continual engagement of researchers, decision makers and research partners throughout the course of a research program to improve the relevance, uptake and application of research knowledge for environmental, economic, social or public health benefit. It is a real challenge to develop a common vocabulary and shared expectations as research outcomes evolve during the course of a study. Often the outcome expectations and success markers of researchers and end users do not align, and there are valuable lessons to learn from previous attempts to improve the relevance and actionability of research efforts for end users.

2030 Water Secure- Fostering Global Cooperation for Water Security Capacity Needs

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Poster Presentation
Session: Human-Water Interactions
Poster # 40

The talk with launch and present a global scale collaborative initiative of Water Future programme and the United Nations University, '2030WaterSecure'. This capacity initiative is conceptualized to secure the 21st Century Water Risk through the building of an innovative vision for water secure futures and to strengthen the capacity of actors, agents, agencies and institutions in realizing the water security agenda promulgated by UN-Water to tackle the 21st-century water challenges. The initiative will also support efficient implementation of water-related sustainable goals and targets- mainly, but not limited to SDG 6. The modus operandi are to unite the state-of-the-art data, information and knowledge with current, custom-made communication tools and methods, and –to develop the capacity of water professionals, community leaders, managers and young professionals to transform them as stewards addressing the science-policy interactions in the water sector. The key focus on youth, women in the water sector and mentoring the 'next generation' of water experts and practitioners is clear embedded in the action planning. Global Water Future (GWF) annual meeting will provide '2030WaterSecure'a platform to engage with experts from Canada and to map avenues of collective agenda towards planning, adopting and implementing reforms towards sustainable water futures. Acknowledging that knowledge capitalizing from science, technology, assessment tools and local and indigenous knowledge and value systems can promote an extended use of integrated tactics towards strategies for water security- the interaction and exchange with the large spread of GWF projects can aptly feed into development of a global thinking to create capabilities in developing and emerging economies via exchange of technical and scientific know-how, interdisciplinary research and knowledge communication with the Canada's water stakeholder's diaspora. '2030WaterSecure' further aims to facilitate and co-create training and building knowledge and skills of professionals in developing countries, executed via a regional network of training institutions and universities. Holding hands with GWF towards this goal could add value to the development of targeted and tailored outputs towards capacity needs.
In addition, the presentation will also discuss 'The UN-Water Learning Centre' a dedicated program of UNU INWEH to capacity needs of water professionals and practitioners worldwide. In operation for more than 10 years through network of regional units- this collective action program provides training and diploma opportunity in Integrated Water Resources Management (IWRM), Water and Health (launching soon) and Water Security, work in progress- a pioneering effort, to address the crucial need of unpacking the water security conceptual framework- the thematic spread of this exercise captures relatively under investigated dimensions in conventional water management viz., water related conflicts, water, and peace, addressing pluralism in managing shared water systems- to name a few. Details available at http://wlc.unu.edu/wp-content/uploads/2017/09/Water-Security-e-Course.pdf. This

presentation will also include discussion on rationale (gaps and needs) structure, design and summary for 5 modules, of the ten in total [trans-boundary water management; conflict and peace issues; resilience to water-related disaster and extremes; economic activities & development and financing for water security]- explaining mechanisms that makes this global scale collaborative exercise both challenging and an opportunity for collective action.

Widespread photosynthetically-induced CO2 invasion in numerous lakes across the Peace-Athabasca Delta (Alberta, Canada)

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 18

The Peace-Athabasca Delta (PAD), located in northern Alberta, Canada, is recognized as a Ramsar Wetland of International Importance and UNESCO World Heritage Site for its ecological, cultural, and historical value. The PAD supports numerous dynamic ecosystems, including shallow lakes, marshes and wetlands that are strongly regulated by periodic river floodwater to maintain water levels and aquatic habitats. Concerns have been mounting over lake level drawdown and the potential consequences on lake carbon balance. To explore the utility of carbon isotope composition of dissolved inorganic carbon as a tracer of carbon balance, water samples were collected in July 2017, the period of peak aquatic productivity, from ~60 lakes and ~10 river sites in the PAD. Additional measurements of nutrients (N, P) and chlorophyll a were performed on water samples and in situ measurements of pH and specific conductivity were determined using a YSI multi-parameter sondes. The lake water δ13C-DIC ranges broadly from -21.50‰ to -3.83‰, suggesting there are different sources and processes influencing individual lake carbon balances. Exploration of the results show that highly productive, closed-drainage lakes possess high pH and low δ13C-DIC values, which are patterns consistent with strong kinetic carbon isotope fractionation that occurs during chemically-enhanced (photosynthetically-induced) CO2 invasion. Closed-drainage lakes are thus serving as a carbon sink, but they are most vulnerable to desiccation which would likely convert them to carbon sources.

Climate change and source water protection planning with First Nations in the prairie region

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Oral Presentation
Session: Human-Water Interactions
13:15–13:30, Tuesday, June 5, 2018
Room 1309

In Canada, access to safe drinking water in many First Nation communities remains a challenge. Today, approximately one in five First Nation communities is on a boil water advisory with some advisories lasting a decade or longer. There are many factors contributing to this problem including poor raw water quality, insufficient water treatment technology, inadequate water distribution systems as well as local and regional water contamination by land users. Institutional factors also contribute to the drinking water quality problem including inadequate design standards for wastewater disposal, difficulty with retention of qualified water treatment plant operators, as well as insufficient federal funding for water system upgrades. Notwithstanding these contributing factors, climate change is now poised to exacerbate the current drinking water quality problem. The prevalence of extreme weather, unpredictable weather patterns as well as fluctuation in climate trends is now contributing to unanticipated levels of community risk including both flood and drought with variable impacts on water quality and quantity. Research has shown that extreme weather will continue to produce not only seasonal fluctuations but also annual extremes in weather cycles across the prairie region.

This paper explores the impact of climate change on drinking water quality within First Nation communities and the role of source water protection planning as community adaptation. The principle of source water protection is prevention of contamination at the source of a drinking water supply, either groundwater or surface water. Source water protection is operationalized through a planning process that first identifies land use activities and natural processes that pose a risk to a drinking water source. Next, specific management are assigned to each identified risk with the intent of reducing, or eliminating, each risk. Implementation of the management actions and periodic review of the plan complete the plan-making process.

Unanticipated benefits of this planning activity is the empowerment of First Nations to engage in plan-making, building local capacity for action, sharing in decision-making and re-connecting community members to their land and water. Data for this paper has emerged from a cross-sectional analysis of six recently completed source water protection plans in Alberta and Saskatchewan across Treaty 4, 5, 6 and 7. While source water protection planning has been supported at the Nation to Nation level, a lack of institutional capacity to implement many of the developed plans is a challenge.

Environment and Climate Change Canada's water cycle prediction program and Global Water Futures

Presenting Author:
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Oral Presentation
Session: Plenary
11:15–12:00 Monday, June 4, 2018
Room 1305/7

Water availability, security and water futures are critical issue in Canada. While Canada has a significant portion of the world's fresh water supply the distribution and timing of surface water can result in threats to life, property and economic viability through either flooding or drought. Recent events include the southern Alberta floods of 2013 that claimed four lives, caused $6 billion in damages and displaced 100,000 people. In contrast, the summer of 2015 saw severe drought in western Canada and though no comprehensive cost estimate is available at this time, the event impacted agricultural production, power generation and forest fire frequency. In 2017, we saw unprecedented and record levels in Lake Ontario, and significant flooding along the Ottawa River. Climate change implies changes to the water cycle, therefore the timing and distribution of water availability will also change. For a large country such as Canada, with a range of regional climates, these changes are complex and attribution of possible futures difficult. Consensus suggests that the frequency and magnitude of extreme events, such as droughts and floods, will increase, mandating governments and academia to find solutions. Practitioners are being asked to meet the upcoming challenges of water management and we are increasingly looking at robust modelling systems to help answer societal questions around water futures. However, in many cases these modelling systems are not sufficient to truly address some of the important questions. The problem is particularly acute in places like Canada where we are dealing with extremely large and complex basins, limited forcing data, complex landscapes and hydrological processes that are either poorly represented, or not represented at all in most hydrology or land-surface modelling systems.

Within ECCC, advances in Numerical Weather and Environmental Prediction (NWEP) have led to the new systems at increasing spatial resolution where the representation of hydrological fluxes is an integral part of the forecast models. This work has leveraged significantly from year of collaboration with the university sector through programmes like GEWEX, IP3, CCRN, FloodNet and now GWF. As a result ECCC is now able to contribute and develop new products and services to support flood guidance and hydrological analysis, through improved knowledge of forecasting hydrological events. As part of ECCC efforts and in conjunction with the Global Water Futures programme, we have developed a modelling framework that we determine is needed to deliver new modeling tools, in conjunction with new monitoring systems for Canada and the cold regions of the world. The GWF community is taking a very systematic approach to model development through the core modelling team. The framework we have been developing has consistently focused on blending a bottom-up and top-down approach to achieve, as best possible scale-independence in the parametrization, sufficient granularity on the forcing and initial conditions while maintaining a computationally efficient framework. We are evaluating a series of models from the experimental catchment scale at numerous representative sites across the country while simultaneously applying large scale hydrology-land-surface systems in both forecasting and continuous simulation mode. These open-source platforms are focused around hydrological models and land-surface schemes that can resolve the coupled energy and water budget of the land surface at

multiple scales, including features pertinent to cold regions such as lakes, wetlands, snow, frozen ground and glaciers.

Dominant glacial landforms in the lower Great Lakes region exhibit differences in soil chemistry and potential risk of phosphorus loss

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Oral Presentation
Session: Watershed Management and Disturbance
14:45–15:00, Tuesday, June 5, 2018
Room 1110

Phosphorus (P) loadings in river tributaries vary considerably around the Lake Erie basin. Although some of this variability has been attributed to a build of P in soils and legacy P, it does not seem to be the only factor controlling P loss patterns across the lower Great Lakes region. Establishing potential natural and geographical differences in soil physical and biogeochemical properties influencing the mobility of soil P to runoff is essential to provide insight for farmers into more effective and customized P management strategies based on soil type and according to risk of soil P loss. The objectives of this field-based study were to comparatively assess soil storage of inorganic P (Pi) and the sensitivity of soils to Pi loss in contrasting glacial landscapes (hummocky coarse-textured till versus lacustrine and fine-textured till-plain) in the lower Great Lakes region. Surficial, subsurface and deep soils (tile drain depth) from 8 agricultural fields in Ontario, Canada, and Indiana and Ohio, USA, were analyzed for particle size, composition, total Pi concentrations (legacy Pi), Pi sorption capacity, and solid-phase Pi partitioning. Results show distinct soil Pi partitioning as well as potential subsurface water transport pathways in soils developed from contrasting glacial deposits across the region. Further research will expand into croplands of the Canadian prairies to delineate potential broader linkages between soil geochemistry and associated Pi partitioning. Characterizing soil biogeochemistry linked to soil Pi availability, and the implications for predicting risk of Pi movement from agricultural fields to downstream surface waters will be presented.

The Global Energy and Water Exchanges (GEWEX) Project of the World Climate Research Programme

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Oral Presentation
Session: Plenary
9:00–9:45, Tuesday, June 5, 2018
Room 1305/7

The Global Energy and Water Exchanges (GEWEX) project, as part of the World Climate Research Programme (WCRP), is dedicated to understanding Earth's water cycle and energy fluxes at the surface and in the atmosphere. We are a network of scientists gathering information on and researching the global water and energy cycles, which will help to predict changes in the world's climate. The project is structured in 4 panels which foster international activities in i) land surface model development and evaluation, ii) contribute to atmospheric model development, iii) development of global atmospheric, surface water and energy budget products and iv.) predict continental scale hydroclimates for hydrological applications. GEWEX also coordinates the WCRP grand challenges on extremes and water for the food baskets of the world.
This presentation will give an overview of these activities and show how the Global Water Futures can contribute and benefits from the progress made by other groups through GEWEX.

Quantifying Phosphorus Inputs from Bunker Silo Effluent to a Riparian Wetland in Maryhill, Ontario

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 20

Agricultural phosphorus (P) has been the focus of many studies, as it is a large contributor to eutrophication in freshwater ecosystems. Livestock farming persists to contribute substantial loads of P to surface and groundwater, and has proven difficult to mitigate. The chronic leaching of effluent from bunker silos contributes to the degradation of surface waters, as its acidity, and nutrient concentrations are extremely high. This study aims to characterize nutrient dynamics on a dairy farm in Maryhill, ON. The objectives of the study are to 1) quantify the inputs of P from the bunker silos effluent and farmyard runoff into loads, and 2) to determine if the riparian wetland (which lies just down gradient from the bunker silos) is acting as a source of legacy P to the stream. ISCO automatic water samplers were placed up and downstream of the farmyard under a range of flow conditions. Furthermore, a series of nested wells and piezometers were installed across the riparian zone at depths of 25, 50, 75, 100, and 150 cm, with wells that were at a depth of 75 cm. Preliminary results demonstrate that there are substantial increases of P concentrations downstream of the farmyard and bunker silos. Although these data show that some P is supplied directly from the bunker silo in surface runoff, considerable amounts of P are present in the groundwater of the riparian wetland. These preliminary data provide an insight into the significance of critical source areas, and the importance of researching point sources in the landscape that contribute substantial P loads to freshwater ecosystems.

Present and future of Water quality monitoring system on IoT platform

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Poster Presentation
Session: Modelling and Observations
Poster # 70

Many watersheds and water sources both in Canada and across the world are under stress due to human activity as well as climate change. Population growth in urban areas as well as agricultural practices and resource extraction tend to introduce pollutants such as nutrients, metals, microorganisms, pharmaceuticals, industrial waste products and other emerging contaminants into watersheds. These water quality issues are further exacerbated by climate change and other environmental changes in watersheds. There is a critical need to gain a detailed understanding of the effect of human activities on the ecosystem and water in particular. A crucial part of that strategy involves the use of sensors and sensing systems that can be deployed in the environment to monitor for the presence of contaminants and their variation over the short and long time scales. Although sensors and sensing systems for long term monitoring exist, they are not sufficiently low in cost and require technical expertise for operation and maintenance. The developments of specific low cost sensors that are capable of integrate them with the sensing system. This sensing system is basically a combination of wireless sensor network and IoT (Internet of Things). Besides the sensor itself, there is a huge scope of technological development in the field of embedded internet, energy harvesting, low-power system design and communication protocols for seamless communication among the devices, servers and end-users. As a whole, besides working with the sensor development we have to work on the development of the computing architecture. This poster depicts the present computing architecture involved with the sensing system of the water quality monitoring and the future scope of development in the same.

An Overview of VARS-TOOL and it New Features for Comprehensive, Efficient, and Robust Sensitivity and Uncertainty Analysis of Earth and Environmental Systems Models

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Oral Presentation
Session: Modelling and Observations - Part II
13:15–13:30, Wednesday, June 6, 2018
Room 1105

This presentation provides an overview of VARS-TOOL and its new features developed recently. VARS-TOOL is a software toolbox for sensitivity and uncertainty analysis of Earth and environmental systems models. Developed originally around the VARS (Variogram Analysis of Response Surfaces) framework, it expands to embed a suite of algorithms and tools for global sensitivity analysis (GSA), including the commonly used Morris and Sobol' algorithms. VARS-TOOL is enabled with the most efficient sampling techniques, including Progressive Latin Hypercube Sampling (PLHS) to maximize efficiency, robustness, and convergence rate of the GSA. Other new features of VARS-TOOL include (1) analytical tools for dynamical systems models, (2) factor grouping for handling high-dimensional problems, (3) online visualization for monitoring stability and convergence, (4) model emulation for handling model failures, and (5) an interface for working with any model in any programming language and operating system. As a test bed for training and research, VARS-TOOL provides a set of mathematical test functions, and a series of example case studies with the HBV-SASK hydrologic model and MESH land surface-hydrology model. For updates and software download, please visit http://vars-tool.com/.

Winter Soil Processes in Transition

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 21

In an uncertain future climate, both the quantity and quality of water supplied by headwater wetland source areas in cold regions are expected to change significantly. However, our knowledge of how climate change will impact the biogeochemical functioning and hydrochemistry of these source areas remains limited. We propose to elucidate the role of winter soil processes on the export of carbon (C) and nutrients (N, P, S, Fe) to the river network under changing climate conditions. The project builds on the hypothesis that spring pulses of dissolved organic and inorganic C and nutrients by these headwaters reflect the cumulative effects of microbial and geochemical processing of redox sensitive elements during the non-growing season. The project will advance the predictive understanding of C and nutrient cycling in soils of headwater source areas under seasonal snow and ice cover. The project specifically aims to improve our conceptual and quantitative understanding of changes in C and nutrient stocks, speciation and fluxes driven by variations in snow cover and freeze-thaw cycles. The data collected in laboratory experiments will be integrated into reactive transport and bioenergetic modeling to simulate the biogeochemical transformations of C and nutrients in winter soils under changing climate conditions. The data and insights gained through the proposed laboratory-controlled experimental and modeling activities will yield a better conceptual understanding of shallow subsurface biogeochemical processes and strengthen their representation in coupled biogeochemical-hydrological catchment models. Overall, the proposed project will enhance our ability to evaluate the impact of different potential climatic scenarios on C and nutrient export and speciation along the aquatic continuum.

Streamflow forecasting for the Yukon River and Liard River basins using a coupled atmospheric hydrological model.

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Poster Presentation
Session: Modelling and Observations
Poster # 71

An operational streamflow forecasting system was developed to assist the Water Resources Branch of Yukon Environment with forecasts for the Stewart, Pelly, Ross, and Yukon rivers of the Yukon River Basin and the Liard River Basin. The forecasting system consists of calculating modelled streamflow values using the modelling system MESH (Modélisation Environnementale communautaire - Surface Hydrology), which is a Community Hydrology – Land Surface scheme configured to operate in this case with a grid of 10 x 10 km cells. The current setup includes seven possible land cover types for each cell, which are needleleaf vegetation, broadleaf vegetation, mixed forest, wetland, grass, urban/exposed soil and water/ice. There are three soil layers of thickness 0.10, 0.25 and 3.75 m. The calibration and validation periods from 2002 to 2012 resulted in Nash-Sutcliffe (NS) values between 0.83 and 0.916, and between 0.63 and 0.915, respectively. The NS values for the Yukon River at Whitehorse and Marsh Lake are significantly lower than these ranges. A calibration of 116 parameters was performed using the Dynamically Dimensioned Search (DDS) optimization algorithm. Challenges associated with the current setup include the uncertainty in the snow distribution and accumulation, and the absence of slope and aspect, alpine, shrubs and glaciers in the representation of the land surface.
The forecasting system is setup to first produce a 24-hour hindcast using precipitation data at a 10 km resolution for 6-hour intervals from the Canadian Precipitation Analysis reanalysis system (CaPA) and other atmospheric forcings from the +18h forecast at a 10 km resolution from the Regional Deterministic Prediction System (RDPS) of the Global Environmental Multiscale (GEM) model. The system subsequently produces a 2-day forecast by incorporating data from the next day's RDPS GEM +18h forecast with a resolution of 10 km, and a 10-day forecast by incorporating data from the next day's Global Deterministic Prediction System (GDPS) GEM +12h forecast with a 25 km resolution. The 25 km GDPS data are interpolated using 'nearest neighbor' to the 10 km MESH grid resolution. Future developments are planned to redefine the land cover types to better represent the land surface, implement ensemble forecasts from parameter ensembles and examine uncertainty using different hydrological land-surface schemes. In time, the forecast coverage will extend to include most of the Yukon River Basin in Canada.

Evaluating evaporative fluxes in complex mountain terrain

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Poster Presentation
Session: Modelling and Observations
Poster # 72

In mountains, the role of diurnal wind (i.e. valley, slope winds) due to differential heating and radiation and topography in controlling evaporative fluxes is not well understood. The Weather Research and Forecasting (WRF) model was applied in the complex terrain of the Kananaskis valley, Canadian Rockies, Alberta, to investigate the performance of the model for creating the surface driving data needed to calculate evaporative fluxes for fair-weather summer days. The model results were validated against measurements made using atmospheric sounding by SODAR and Wind-RASS profilers, and several micrometeorological stations located in both high altitude ridge top and valley bottom locations, providing regular measurements of the main atmospheric variables, such as air temperature, humidity, atmospheric pressure, solar irradiance, wind speed and direction. The use of PBL schemes and Large Eddy Simulations (LES) in WRF was examined by applying local filtering to alleviate the problems with steep terrain in the terrain-following vertical coordinate of WRF. The model was used to examine the temporal and spatial evolution of wind and fluxes with variability in topography and how this influences evaporation fluxes.

Interactive Visualization of Geospatial Water Datasets

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Poster Presentation
Session: Modelling and Observations
Poster # 73

Interactive visualization of complex datasets is a common technique in today's world to explore big data. We examine the scope of visualization in the exploration of water datasets. Our results show how such interactive visual exploration can be effectively used for the knowledge discovery in water datasets.

Standardized remote-sensing strategy to study post-fire health recovery of boreal forests in Alberta

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 82

The Boreal Forest biome encompasses the largest forest regions in Canada, representing ~77% of woodlands. These forests provide many services such as fishing, hunting, leisure or spiritual pursuits, and economic opportunities to many rural communities as well as indigenous people. Fire is considered one of the most widespread, natural disturbances in boreal forests and can shape its structure, composition and function, as well as influence the rates and processes of ecological succession and encroachment. Climate change, however, can increase the area burned, the duration of the fire season, and the intensity as well as severity of the fire. One way to detect changes with respect to natural fire occurrences is to map and quantify burn severity. By linking burn severity to recovery trajectory of forests, we may be able to model long-term changes in successional dynamics. Remote sensing provides the best means of analyzing forest changes over large spatial scales. We propose to investigate the burn severity and recovery patterns of selected watersheds in Alberta that have experienced multiple fire outbreaks since 2004 using remote sensing and Geographic Information Systems (GIS) techniques. We will analyze the burn severity for selected fire events and develop a severity classification system for each occasion. We will use a time series of satellite images to study how the forests recover after each fire event in relation to the standardized fire severity classes. Finally, we will evaluate the effect of past fire events on vulnerability of the watershed to future fire. These data will be used by collaborators on the Social-Ecological Systems (SES) team of the Boreal Water Futures project to investigate the human dimensions affected by the temporal and spatial patterns of fire outbreaks. The overall objective of this study is to investigate the effect of the natural disturbance on the health of the boreal forests and to identify possible effects of forest fires on the nearby human populations.

Urban Metabolism of the Greater Toronto Area: A Study of Nitrogen and Phosphorus Across an Urban, Suburban, and Rural Continuum

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 10

It has been predicted that approximately 65% of the developing world and 85% of the developed world will be living in cities by 2050. Toronto, the largest city in Canada and the fourth largest in North America, is expected to double in population in the next 50 years. Although such rapid urbanization can lead to enormous social, economic, and environmental change, little is understood about how population growth in Greater Toronto Area will impact the ecological systems of Southern Ontario. In our study, we are particularly interested in the ways in which increasing population densities in the Greater Toronto Area are impacting nutrient flows across Southern Ontario's urban/rural continuum and how changing nutrient dynamics may lead to increasingly impaired water quality in Lake Ontario and beyond. In this work, we utilize a mass balance approach to quantify the flow of nutrients through urban, suburban, and agricultural areas of the Greater Toronto Area. A wide range of factors are considered, including human behaviour, domestic animals, and wastewater treatment processes. The present results suggest that any study of urban metabolism must take into account not only nutrient flows within urban boundaries, but must also identify externalities of urban development associated with a range of processes, from global trade to regional waste management.

Integration of a Slope-Based Lateral Soil Water Algorithm into a Coupled Land Surface and Dynamic Vegetation Model

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Oral Presentation
Session: Modelling and Observations - Part I
14:00–14:15, Tuesday, June 5, 2018
Room 1105

Changes in the hydrological cycle have long been known to affect carbon cycles in vegetation ecosystems. However, land surface models have traditionally not focused on these interactions between an ecosystem's carbon cycling and hydrology. This research aims to implement contemporary advancements in hydrological processes into a land surface-terrestrial ecosystem model to evaluate the effects on the accuracy of the water and carbon cycle simulations. Specifically, a slope-based hydrological algorithm was introduced into the coupled Canadian Land Surface Scheme and the Canadian Terrestrial Ecosystem Model (CLASS-CTEM) for site-specific simulations that include lateral movement of soil water or interflow. The introduction of a slope gives rise to changes in the surface water budget, which in turn leads to changes in ecosystem productivity. For instance, volumetric water content near the surface for two evergreen coniferous forests with slopes of 1.8\% and 12\%, saw noticeable but variable decreases after rainfall events of up to 4% and 5% respectively. This reduction in soil water has led to modelled annual net ecosystem productivity decreasing by 1.2% and 3.5% for both sites respectively. Additionally, the accuracy of CLASS-CTEM to estimate multiple components in the carbon and water cycles was increased, with significant improvements at sites located in steeper terrain. This work is part of the Global Water Futures and will help to improve the capabilities of the Canadian Earth System (CanESM) model used for future climate predictions.

Convective precipitation initiation over the leeside of the Canadian Rockies

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Oral Presentation
Session: Climate and Extremes
15:00–15:15, Wednesday, June 6, 2018
Room 1110

Convective precipitation is a significant source of intense short-duration precipitation events, providing a key water input to the hydrological cycle in summer over North America. However, the atmospheric processes that modulate convective precipitation are not fully understood. Convection-permitting regional climate models (CPM) can significantly improve simulation of summer precipitation, and thus the representation of convective storms. Field experiments have shown that the presence of convergence lines, particularly the dryline characterized by a strong horizontal gradient of specific humidity, are critical to initiate convective cells over the lee side of the Canadian Rockies. However, field experiments are limited in time and space. This study uses output from a 13-year (2001-2013) historical and end-of-century CPM simulation to improve our understanding of dryline convection on the lee side of the Canadian Rocky and their potential changes in a warmer climate.
37% of the most severe storms are initiated by drylines. In general, drylines induce low-level horizontal wind convergence with a favored initiation of precipitation right on the eastern side of the dryline. The initiation of convection due to the dryline usually occurs around 5 pm local time, which also coincides with the development of the boundary layer and the uplifting branch of the mountain-plain circulation. Results show that the amplitude of the diurnal cycle of precipitation increases significantly during May and June under warmer condition in this region. In a warmer climate the dryline is more intense and shifted to the north, along with a more frequent convective initiation, following the northern displacement.
These simulations of dryline convection improve our understanding of warm season rainfall on the leeside of the Canadian Rockies and provide insight into climate change impacts on server convection in this region.

Modeling the response of fish to major infrastructure upgrades in wastewater treatment plants.

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Oral Presentation
Session: Aquatic Environment and Ecosystems
14:30–14:45, Wednesday, June 6, 2018
Room 1309

Municipal wastewater represents one of the largest sources of effluent to Canadian aquatic ecosystems. These effluents contain a diversity of contaminants, including those than can alter endocrine function and reduce reproductive performance of fish. Recent studies in the central Grand River, Ontario, Canada, have demonstrated that a wide variety of endocrine active compounds (e.g. natural estrogens, ethinylestradiol, triclosan) are released into the environment from municipal wastewater outfalls. Fish populations, including rainbow darter (Etheostoma caeruleum), associated with these outfalls have shown a variety of biological changes including altered gene expression (i.e. transcriptomes), physiology (e.g. steroid production), energy storage and reproductive success (e.g. egg survival). Of particular note has been the extremely high incidence and severity of intersex (developing eggs in testes tissue) below the outfalls. The local municipality is currently investing hundreds of millions of dollars to upgrade several treatment plants in the watershed. More efficient aeration of secondary clarifiers, increased retention time, and a switch from chlorine to UV disinfection in the Kitchener treatment plant in 2012 led to an increase in nitrification and decreased estrogenicity of the effluent. In the three years since these changes a recovery of several biological endpoints in fish, including in vitro steroid production and intersex, has been observed. Some effects, such as gene expression and low incidence of intersex remain evident and are likely due to residual chemicals, upstream urbanization and other wastewater effluent outfalls A mechanistic fate and effects model was developed and used to predict the distribution of estrogens in the wastewaters and the river and predicts that until the upstream treatment plant is fully upgraded there will be detectable intersex in fish downstream of both outfalls. Further model development is planned to better predict changes in fish health related to wastewater and how these complex mixtures interact with multiple stressors in the watershed (cumulative effects).

Characterization of nutrient budget in a large prairie reservoir

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 22

We examined and quantified the most important nutrient pathways of the Lake Diefenbaker (LD) and its nutrient retention to assess inter-annual variation in its nutrient budget which are likely to be greatly affected by hydrological forces. This provide an understanding of the sensitivity of LD to changes in nutrient loads as affected by extreme flows (climate related events). Extreme flows entered the reservoir from the South Saskatchewan River in early summer (June to early July) in all four years which resulted in highest nutrient load and export in early summer. Large loads of total P (TP), total dissolved P (TDP), total dissolved N (TDN) and total N (TN) were significantly correlated with peak flows in early summer (2011-2014). Annual water retention was lowest (-16%) in 2011, but highest (-3%) in 2013. The reservoir acted as sink of nutrient with 92% of TP, 38% of TDP and 19% of TN retained; while, it acted as a source of TDN (-3%). 2011 was the only year in which the reservoir acted as a source of TN (-18%) and TDN (-39%). Overall, the result shows the important role of hydrological forces and their inter-annual variations in characterization of nutrient budget in LD.

Spatio-temporal variations of landscape nitrate fluxes in agricultural catchments driven by flow pathways and nutrient transport mechanisms

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Oral Presentation
Session: Modelling and Observations - Part II
14:15–14:30, Wednesday, June 6, 2018
Room 1105

Due to intensive agricultural activities, the inputs of reactive nitrogen (N) to terrestrial systems have dramatically increased in the past decades, resulting in a cascade of undesirable environmental outcomes in receiving waters. Constraining soil N losses by conservation practices, as a priority for N pollution reduction, requires a predictive understanding about the fate and transport of N in ecosystems. Proper representation of flow routes from the landscape to the surface water system is a key for reliable modeling of solute transport, because individual flow paths may yield unique chemical signatures. This research focuses on watershed-scale analyses of N export through different flow pathways in two nested watersheds in Ontario. We develop a parsimonious conceptual coupled hydrological-nitrogen model for quantifying flow pathways and nitrate export, and employ it for predicting nitrate fluxes at different spatial and temporal scales. We also utilize tile flow measurements for constraining flow partitioning generated by our model, and demonstrate the importance of proper characterization of flow paths and transport mechanism in capturing hydro-chemical dynamics at the watershed scale. Results show that, consistent with previously reported plot-scale field studies, seasonal variations of nitrate fluxes is explained mostly by the export via shallow sub-surface pathways (including near-surface lateral flow and tile flow). It is therefore recommended that conservation practices focus on areas with high likelihood of forming such transport pathways including tile-drained agricultural sub-watersheds and areas where soil properties facilitate significant lateral flows.

An Automated Parameter Grouping Strategy for Efficient Sensitivity Analysis of Large-scale Hydrological Models

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Oral Presentation
Session: Modelling and Observations - Part II
13:30–13:45, Wednesday, June 6, 2018
Room 1105

Hydrological models are becoming increasingly more complex to address the ever-growing endeavor of hydrologists to predict the hydrologic effects of the land use and climatic changes in large-scale watersheds over long time periods. These models are essential tools for providing sustainable water management plans to improve the resilience of the large-scale watersheds. However, such models typically include many uncertain parameters and are computationally demanding. As a result, effective implementation of any model analysis tool such as global sensitivity analysis (GSA) becomes challenging because a comprehensive model analysis usually requires a prohibitively large number of model runs. On the other hand, the importance of advanced GSA techniques in the development and application of hydrological models cannot be downplayed.
To break down this barrier, we developed an automated “parameter grouping” strategy that can be integrated into any GSA framework. The proposed grouping strategy is designed to robustly categorize model parameters into an optimal number of groups of different sizes using information gained throughout the GSA. We also introduced a measure of reliability based on parameter grouping, which expedites the execution of GSA with a limited number of model runs. In this study, we evaluated the performance of this methodology with a variogram-based GSA technique, known as Variogram Analysis of Response Surfaces (VARS). The highly parametrized, semi-distributed, land surface-hydrology modeling framework developed by Environment and Climate Change Canada, known as MESH, has been used as a case study. Our results confirm that grouping of model parameters in terms of their sensitivity can considerably reduce the computational cost required to perform GSA on MESH. Furthermore, it can help reduce the complexity of the problem in the follow-up experiments (e.g. model calibration) by identifying dominant groups of parameters that significantly contribute to the variability of the model outputs.

Challenges in modelling Prairie hydrology under future climates

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Oral Presentation
Session: Modelling and Observations - Part I
14:15–14:30, Tuesday, June 5, 2018
Room 1105

Historically, modelling the hydrology of the Canadian Prairies has been challenging because of the difficulties in representing the complex hydrological processes of the region, which is very cold and relatively dry. However, it is demonstrated that although the physical processes of cold regions are complex, involving coupled heat and mass transfers, the spatial and temporal scaling of these processes are fairly simple, and are amenable to physically-based models, allowing them to function well without calibration. In contrast, rainfall runoff has simpler physics, as it is rarely influenced by phase changes, but more demanding scaling.

Recent research has demonstrated statistically-significant trends over the 20th Century in the phase of precipitation (from snow to rain) in many locations in the Prairies in the fall and spring. It has also been demonstrated that multiple-day rain events have also increased. As a result of these changes, many of the old rules which have governed Prairie hydrology, and therefore its modelling, are changing. Instead of being based entirely on snowmelt, peak streamflows are becoming more due to rainfall runoff.

It is argued that the changes in air temperature under future climates will require the use of algorithms for processes not often seen in the region under historical conditions, such as for the infiltration to partially-frozen soils, and the simulation of discontinuous snowpacks. In addition, changes in the spatial and temporal scaling of precipitation may reduce the certainty of hydrological forecasts under changed climates.

Water resources management modelling for Integrated Water Resources Management within Canada's large river basins

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Oral Presentation
Session: Modelling and Observations - Part II
14:45–15:00, Wednesday, June 6, 2018
Room 1105

Management of water within Canada falls primarily under provincial administration; therefore, water has traditionally been managed according to provincial rather than catchment boundaries. However, some large river basins transcend multiple provinces. This has resulted in fragmented management of water within these large river basins, with sometimes complex operational rules implemented in individual provinces, and sharing of water between provinces being achieved through simplistic apportionment agreements. Increased hydrological variability due to climate change and increasing development is likely to place increasing stress on Canada's water resources, and traditional approaches to water resources management will likely be inadequate. The paradigm of Integrated Water Resources Management recognises the need for coordinated development and management of water, and the Integrated Modelling Program for Prediction and Management of Change in Canada's Major River Basins (IMPC) under the Global Water Futures (GWF) programme aims to deliver decision-making tools and solutions for achieving IWRM within Canada's major river basins. Appropriate tools for integrated water management modelling must be sufficiently complex to represent the existing and possible future operating policies of large basins in Canada. In addition, to achieve true IWRM, they must be flexible enough to be incorporated into modelling frameworks representing the entire hydrological cycle. The aim of this study is to assess one possible water management model, the Water Resources Integrated Modelling System 2 (WRIMS2). WRIMS 2 is the generalised water management model that was used to develop the CALSIM model that is applied in California, and is free and open source. An initial investigation suggests that the model has sufficient flexibility to represent complex operating policies, and the open source nature of the model suggests model flexibility for future adaptation and extension. WRIMS 2 will be applied to the Saskatchewan River Basin (SaskRB; ~400,000 km2) transcending the three Canadian Provinces of Alberta, Saskatchewan and Manitoba as well as a portion of the American State of Montana. Management of the SaskRB is shared between the provincial administrations, with little co-operation between the provinces, and simplistically sharing is achieved through the Master Agreement in Apportionment (1969). The results of the WRIMS 2 model will be assessed against that of the Water Resources Management Model (WRMM), which has traditionally been applied by individual provinces for management of their portions of the basin. WRIM 2 will be assessed against whether it can sufficiently represent the existing and possible future complex operation policies implemented in the

basin. The study will also discuss the potential for integrating WRIMS 2 within a larger modelling framework that includes hydrology and water quality.

Global Sustainability Processes and a UN Water Decade: 2018-2028

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Oral Presentation
Session: Plenary
10:10–10:55, Monday, June 4, 2018
Room 1305/7

The Presentation will summarise the objectives and status of some major global processes and initiatives related to Sustainable Water Resources Development, including Sustainable Development Agenda 2030, the outcomes of the work of the High-Level Panel on Water (HLPW), and the recently launched, at UN Headquarters in New York, new Decade for Action "Water for Sustainable Development". It will describe the Water Decade objectives and proposed work streams, overview of the UN Secretary General Action Plan for the Decade, with main action areas and example activities, reflect on the launch of the Decade, discuss how UN-Water (the network of some 60 UN-agencies and partners working on various aspect of water management) plans to support the Decade implementation, and propose how individual UN member States can contribute to the Decade process and progress. The Presentation will also touch upon the effectiveness of the previous and ongoing global water initiatives, explore a role that Canada may play at the global water stage, and how Global Water Futures Program can contribute to the new UN Decade and to resolution of global burning water problems overall.

Forest growth dynamics in northwestern North America

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Oral Presentation
Session: Watershed Management and Disturbance
14:15–14:30, Tuesday, June 5, 2018
Room 1110

Recent, rapid warming in the boreal forest has led to changes in the growth dynamics of these high-latitude trees. Many species have demonstrated shifts in the climatic drivers of growth patterns documented through tree-ring studies. One species of particular interest is black spruce (Picea mariana) – the most widespread tree species in the North American boreal forest. This iconic species dominates the forest canopy in the cold, wet soils that are experiencing some of the most dramatic changes as a result of rapid warming and thawing of permafrost. In this study, we used tree-ring studies to compare patterns and climatic drivers of black spruce growth across four sites, effectively capturing this species' 15° latitudinal extent in western Canada. In addition to performing traditional climate-growth analyses, we used stable carbon isotope analysis to investigate moisture stress signals and provide a mechanistic understanding of the growth patterns observed.

We found that three of the study sites showed significant increases in growth over time, while in contrast our mid-latitude site has shown decreases in annual growth. At our two northern sites, increases in growth were driven largely by increasing temperatures and reduced snowfall. Neither of these sites demonstrated a significant trend in stable carbon isotope signatures. At the mid-latitude site, tree growth responded positively to increased precipitation and negatively to warmer temperatures over the growing season, which is indicative of drought stress. Trends in carbon isotope signatures also point toward increased moisture stress at this site. At the southernmost site, there were no significant climatic drivers of growth identified through our analysis. However, carbon isotope trends revealed that growth may be driven by carbon fertilization. To put the growth trends that we observed in our study into the context of black spruce growth trends across northwestern North America, we acquired black spruce tree-ring data from the International Tree-Ring Data Bank. We found in the northern regions of the boreal forest growth trends over time were largely positive, consistent with our results. In the mid-latitude and southern extent of the boreal growth trends were inconsistent at the regional scale, indicating that there are environmental influences on growth in addition to climate that result in this variability.

Our next step is to investigate environmental drivers of the variability in growth dynamics that we observe within the discontinuous permafrost landscape. We are now working a network of 134 Canadian Forest Inventory permanent sample plots across the Taiga Plains region of the NWT. In addition to tree-ring and climate data from each site, this dataset has a suite of environmental variables on soil characteristics, tree stand characteristics, and known forest disturbances that we will use to predict the growth patterns of forests in the Taiga Plains.

Connecting with Communities: Adventures in Community Engaged Scholarship

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Poster Presentation
Session: Human-Water Interactions
Poster # 41

Drawing on collaborative projects, we will demonstrate how art and science are complimentary within transdisciplinary, community-engaged scholarship. Five projects will be described each using visual strategies to connect art and science in ways that immersed people into human environmental systems. Faculty and student artists, and scientists, together with traditional and local knowledge holders, sought co-production of embodied experiences of environmental change associated with water. Those involved in the projects were encouraged to think about and sense the environmental impacts that have befallen Canada's large in-land freshwater deltas: the Peace-Athabasca, the Slave, and the Saskatchewan. These three inland deltas are home to traditional cultures that have witnessed a precipitous decline in the productivity of their socio-ecological systems. The five projects examined are 1) Downstream – performing perspectives of water security using forum theatre; 2) Delta Dialogue Network Display – an interactive exhibit that used sculpture and multi-media materials to convey scientific and Indigenous knowledge in multiple languages and formats and was displayed in nine community venues; 3) the Becoming Water course and documentary film - a studio fine arts class that permitted students to interact with artists, scientists and traditional knowledge holders about the challenges of managing freshwater systems in the Anthropocene; and 4) The Qu'Appelle Valley Participatory Water Quality Modelling project. Each will be described drawing on principles of co-design, community-engaged art practices and social-learning. Two principles of art, science and traditional knowledge that are put forward include 1) developing goals for collaboration that serve communities' expressed needs and move beyond instrumentality and 2) learning to see through different disciplinary perspectives and world views.

A Comparison of Time Series Databases for Storing Water Quality Data

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Poster Presentation
Session: Modelling and Observations
Poster # 74

"Data persistence for time series is an old and in many cases traditional task for databases. Time series data, i.e., data consisting of a series of timestamps and corresponding values, is a special type of data occurring in water quality data. In this paper, we provide a survey of data persistence solutions for water quality time series data. The paper analyzes the effectiveness of various Time Series Databases (TSDB) based off relational and NoSQL-based databases. We make sure to distinguish between open source and commercial solutions as well. Furthermore, solutions are analyzed based on security, speed, ease of use and storage. Lastly, we provide installation and usage instructions for a handful of selected TSDB technologies, as well as a demonstration on utilizing Arduino boards to interact with TSDBs through a REST API."

Detection of shifting flow regimes at watersheds in western North America using Deep Learning techniques

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Poster Presentation
Session: Modelling and Observations
Poster # 75

Detecting shifts in streamflow regimes driven by climate change is a major scientific challenge as changes may be subtle, appear during different times of the year, and must be detected from data with limited length and considerable inter-annual variability. Warming temperature and changing precipitation patterns strongly influence flow regimes, through altering and redefining fundamental hydrologic processes (i.e. partitioning, storage, and releasing). Flow regimes in cold-region watersheds are particularly sensitive to climate change as the cryosphere (snowpack, permafrost, and glaciers) is ephemeral over short and long time scales and shrinking in a warming climate. Considerable effort has been devoted to identifying and quantifying the changes in flow regimes, with Mann-Kendall techniques the most common approach to detect trends from a given time series. The Mann-Kendall test is typically applied to one or a combination of hydrological indices that represent various facets of flow regime, as opposed to a single measure of change. While highly informative, identifying a combination of indices that are fully capable of illustrating shifts of flow regimes requires considerable hydrological knowledge and a-priori expertise. Deep Learning (DL), a state-of-art technology, is able to self-learn and design a set of features from raw flow data that characterize, differentiate, and classify flow regimes. In this study, Annual Daily Hydrographs (ADHs) for watersheds in western North America are classified using DL, and the class membership of ADHs are arranged in yearly order for each watershed. Class transition of ADHs explicitly indicate a shift in flow regimes. This new approach provides an alternative method to identify changes in watershed hydrology that require less a-priori knowledge of hydrological processes, yet are also subject to considerable uncertainty.

Reservoir Nutrient Dynamics as a Function of Watershed and Management Controls

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 23

River damming provides a range of services to human populations, including hydropower production, irrigation, and flood control. Damming, also, however, increases the residence times of river waters, effectively changing flowing rivers to a series of standing lakes and thus fundamentally altering the conditions driving biogeochemical processes. In particular, within the reservoirs created behind river dams, we see increases in temperature, increased stratification, decreases in water turbulence, and, often, increases in primary production. In recent decades, as human populations have grown and as agricultural management practices have intensified, nutrient loading to reservoirs has increased, thus increasing the incidence of eutrophication events within the river network. At the same time, the increased residence times within reservoirs also create the potential for more nutrient removal, providing additional time for denitrification and more opportunities for settling of particulate phosphorus—thus reducing loads to downstream water bodies. Accordingly, much remains to be understood regarding the overall impacts of reservoirs on riverine nutrient processing. In the present work, we are pairing sediment core analysis with long-term watershed N and P mass balance data to assess multi-decadal trends in water quality within two major reservoirs within the southern Ontario's Grand River Watershed, the largest Canadian watershed draining to Lake Erie. Our preliminary results show that while sedimentation rates have remained relatively constant, algal production has nearly doubled since the mid-1990s and continues on an increasing trend. Our results also suggest that while primary production within the reservoirs is only weakly correlated with watershed nutrient inputs, it may be more strongly correlated with changes in reservoir water management. In future work, we will be using ground penetrating radar together with sediment core data to provide long-term estimates of P retention within these reservoirs and to quantify the potential contributions of reservoir P legacies to current and future water quality in watersheds around the Great Lakes.

Improving mountain hydrological predictions by better representing mountain topography in a hydrological land surface model

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Poster Presentation
Session: Modelling and Observations
Poster # 76

Realistic simulation of streamflow derived from mountains is crucial for mitigation of flood damage and better water resources management for community and irrigation under a changing climate. Simulating the mountain hydrological cycle including cryospheric change is also critical for predicting climate impacts on these world heritage ecosystems. However, most hydrological land surface models lack sufficient representation of complex terrain topography and cold regions processes to accurately simulate streamflow from and hydrology in high mountain basins. Problems include poor representation of cold regions physical processes in models, lack of high resolution atmospheric inputs, and sparse or inaccurate land surface data for model parametrization. This study aims to make improvements to the GWF-ECCC hydrological land surface model, MESH (Modélisation Environmentale Communautaire - Surface and Hydrology), driven by the atmospheric Global Environmental Multi- scale model (GEM), in order to make the coupled GEM-MESH more suitable for mountain predictions. MESH has previously treated all land surfaces within a grid cell as flat and at the same elevation, a reasonable assumption for plains, but not for the mountains. Here, incoming solar radiation was calculated as a function of terrain slope and aspect, and temperature, pressure, humidity and longwave radiation were corrected for elevation. The elevation corrected for the differences in elevation between the high resolution elevation used in MESH and the low resolution elevation used in GEM. GEM-MESH was setup at 0.125° spatial resolution at which the Canadian Precipitation Analysis (CaPA) combined with GEM outputs are available. Sensitive model parameters were calibrated for the period October, 2003 to October, 2012 using measured streamflow on the Bow River at Banff, representing the headwater catchment. MESH with and without the improved representation of slope, aspect and topography was validated at the same stream gauging station for the period October, 2012 to September, 2017 and another stream gauging station located upstream. Model performance criteria covered includes high flows, volume bias and low flows in a multi-criteria optimization framework. The modelling experiment showed improved predictive performance with more realistic representation of mountain topography in GEM-MESH. The improved Bow River GEM-MESH model can be used for forecasts and predictions for mountain river basins where rigorous consideration of topography heterogeneity, slope and aspect is necessary to forecast floods and assess the impact of future climate change on water resources availability.

Building knowledge and capacity through watershed modeling in indigenous community

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Poster Presentation
Session: Human-Water Interactions
Poster # 42

Advances in science and technology have made watershed modeling more powerful, but, the model results are often inaccessible to the lay public, hindering information flow and collaborative learning opportunities. The proposed research intends to evaluate the utility of a watershed model in social learning and building capacity in an indigenous community. The research will use a mixed-method approach consisting of a quantitative model in the form of the Wetland DEM Ponding Model (WDPM) and a qualitative approach using focus group discussion (FGD). The WDPM, which was developed specifically for the Canadian prairies, will be used to generate simulated spatial extents of water in the community. The community members will be engaged from the initial modeling process, including establishing objectives and selecting modelling scenarios. The water depths computed by the model, will then be used in creating flood hazard maps using GIS . The model output will be taken back to the community and be evaluated based on the perspectives of participants in group discussion. The data from the discussion will then be analyzed for the social learning with the model to understand the existing knowledge and perceptions that drive decisions in the community around flood events. The second part of the research will focus on building capacity within the community by providing training on using the WDPM and associated GIS software, to a community member. The usefulness and accessibility of the model will be evaluated from the perspective of the end user. Overall, the proposed research will not only assist in understanding the value of watershed models in water governance but also provide an opportunity for knowledge sharing and learning, as well as feedback to the model developers.
Keywords: Watershed modeling, Flood, WDPM, Focus group discussion, social learning, capacity-building

Meteorological conditions, precipitation intensity and type distributions associated with icing on structures

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Oral Presentation
Session: Climate and Extremes
14:15–14:30, Wednesday, June 6, 2018
Room 1110

Extreme winter storms can impact many sectors of society as well as ecosystems. One such impact is on electricity distribution, which can cause interruptions of power up to several days. In winter, snow is the most common type of precipitation. Although snow can be hazardous, most catastrophic episodes of precipitation occur when temperatures are near 0°C when freezing rain and wet snow can accumulate on power lines, infrastructure and vegetation. When combined with strong winds, this can lead to even more damages. In collaboration with Manitoba Hydro and NB Power, specific meteorological events that led to significant power outages and damages to infrastructure have been identified. One of these events is the recent ice storm in the Maritime Provinces on 22-24 January 2017, which led to one third of the population of New Brunswick being without electricity for days. Although freezing rain events are less common in Manitoba, when they occur, they can also lead to substantial impacts. An overview of the similar and unique meteorological conditions associated with such events as well as their precipitation types and intensity distributions will be discussed.

Freezing Precipitation and Wet Snow Events Affecting Manitoba Hydro

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Poster Presentation
Session: Climate and Extremes
Poster # 27

Freezing precipitation and wet snow events are a major hazard across much of Canada. These events can cause significant damage to transportation networks, infrastructure, and vegetation. Under future warming climatic conditions, there is concern that the spatial, temporal, and intensity characteristics of precipitation will change, freezing precipitation and wet snow included. However there is considerable uncertainty regarding exactly how these changes will manifest.

The changes in freezing precipitation that may occur within the province of Manitoba is the focus of this study. One of the primary concerns is the potential damage to the extensive network of electricity transmission and distribution lines operated by Manitoba Hydro. To examine this issue, four freezing precipitation or wet snow events were identified that impacted Manitoba Hydro. These occurred on April 27, 1984; November 6-12, 2000; October 4/5, 2012; and March 8, 2017. These were characterized using data from the Japanese 55-year Reanalysis (JRA-55), surface observations, as well as high resolution 4 km Weather Research and Forecasting (WRF) output.

Several factors are typically associated with these events. These include large scale factors such as appropriate synoptic flows and dynamics, and the presence of atmospheric rivers bringing moisture. Local factors include topography, such as the Manitoba Escarpment and the large Manitoba lakes; the climatological areas of severe ice loading are collocated closely with these local features.

The four events were similar in several ways. They all featured a strong 500 hPa trough to the west/southwest of the province, strong baroclinicity with a surface low pressure centre nearby, and an atmospheric river flowing into the province. Three of the four events featured a jet streak at the 500 hPa level, with the left exit of the jet aligned over the province. There were differences between the hydrometeors in these events, with one being a freezing rain event, and the others largely producing wet snow, ice pellets, or a mixture of types.

Future analyses will include a comparison to pseudo global warming WRF output. This will assess whether these events would be more intense under warmer, more moist conditions.

The Impacts of Extreme Precipitation Events on the Insurance Industry

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Oral Presentation
Session: Climate and Extremes
13:15–13:30, Wednesday, June 6, 2018
Room 1110

Extreme precipitation, especially those in the form of hail, heavy rain and freezing rain, causes the insurance industry significant property losses every year. In the past, large hail in Alberta was the main driver for insurance catastrophes in the summer months, or what the industry calls “CAT” season. However, since companies now offer forms of flood insurance, heavy rain catastrophes are becoming increasingly common since the exposure has increased. Heavy rain events that lead to flooding having become more frequent and the need to understand them is more important than ever. The insurance industry has a wealth of data from past events, however, a clearer picture of the future of extreme precipitation events is required to understand where we are headed.

Nutrient Cycling in a Fen Peatland One-Year Post-Wildfire

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 94

Peatlands are nutrient limited wetland systems, that store a significant amount of nitrogen (N) and phosphorus (P), even with low availability, due to dominant anoxic conditions that slows decomposition,allowing organic matter to be stored in peat for thousands of years. Wildfire disturbance in boreal peatlands is expected to increase, causing the organic matter in peat to combust, releasing organically bound nutrients to bioavailable forms, and consequently changes ecosystem nutrient cycling. Poplar Creek Fen (PCF), a moderately-rich fen in Fort McMurray was burned during the Horse River Wildfire in early May of 2016 is being studied to address the effects of burn severity on N and P cycling within the nexus of soil, plant and water.. Our results revealed a shift in ratio of soil available N (NO_3^- and NH_4^+) from 1:4 in undisturbed portions of the peatland to 1:1 in burned portions, suggesting an increased oxidation of NH_4^+ to NO_3^- under post-fire conditions.. The mobility of NO_3^- within the ecosystem was exacerbated by the inflow of dissolved ash-infused water during spring melt. The excess nutrients in surface water reflected in groundwater once hydrologic connectivity was established between surface and subsurface water after water table was raised to the surface by spring snowmelt water. Vegetation regrowth in moderately burned portions played a key role in fixing the excess nutrients in bioavailable pools. However, due to the complete loss of microbial biomass and minimal vegetation regrowth, the severely burned portions experienced an increase in nutrient availability relative to the unburned. Between microforms, hollows burned more severely than the hummocks and had higher concentration of bioavailable nutrients and mineralization rates. Nutrient cycling processes in the unburned and in hummocks within burned portions of the fen are similar to those of undisturbed fens in the region. These post-fire nutrient feedbacks observed between burned and unburned portions of the fen can help determine the trajectory of recovery for the ecosystem and provide insight on the potential effect of future wildfire to alter the highly conserved nutrient cycling process of boreal peatlands.

Great Lakes and Water Quality: A Regional Perspective

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Oral Presentation
Session: Plenary
9:45–10:15, Tuesday, June 5, 2018
Room 1305/7

Canada has an abundance of fresh surface water resources, and most of this water is stored in over 2 million lakes that cover around 7.6% of the country's land mass. These lakes, both large and small, play a crucial role in the country's water supply, food production, resource extraction, hydropower generation, transportation, recreation, biodiversity, and climate regulation. However, despite such water wealth, climate change, agricultural intensification, shoreline development and urbanization are exerting mounting pressures on the health and ecosystem services of lakes, and their associated social and economic benefits. Because many of the environmental stressors affecting lake ecosystems originate in the surrounding watersheds, long-term management strategies and governance models must embrace the lake basin in its entirety. This is the focus of the Lake Futures project that brings together watershed and lake scientists, with economists and ecologists, as well as various stakeholder agencies to develop adaptive watershed and lake management solutions in the Great Lake Watersheds that minimize trade-offs between lake ecosystems, water uses, and economic growth. We focus on the Laurentian Great Lakes (LGL), a transboundary body of water comprised of a series of very large, interconnected freshwater lakes located in the upper Mideast region of North America, on the Canada-US border. The LGL, especially Lakes Erie and Ontario, are subject to considerable pressures from activities in the watersheds, including agricultural intensification and urbanization. In this presentation, we discuss the impacts of climate change, land use and land management versus those of internal lake cycling processes on the water quality of the LGL. First, we explore nutrient inputs and stream monitoring data across the watersheds of the LGL to address two questions: (1) What are the impacts of climate, land use and land management on stream nutrient loads?, (2) If we make changes in the landscape how long will it take for the water quality in our streams to improve? Second, we link the nutrient inputs delivered from the watersheds to biogeochemical lake models to determine the relative importance of external versus internal nutrient loadings (with a focus on phosphorus). We further analyze existing time data series to uncover changes in climate forcing on the biogeochemical dynamics of the LGL This is illustrated using surface water temperature and ice cover data for Lake Erie. We conclude by discussing the various modeling strategies currently being pursued to advance the predictive capabilities for water quality in the lower LGL.

Comparing methods of determining seasonal ground ice position in a boreal peatland

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 95

Seasonal Ground Ice (SGI) is an important hydrological component in boreal peatlands particularly during the spring season. The timing of SGI melt and its position relative to the peatland surface influences the water table position, potential evapotransporation losses, and surface runoff from peatlands. The degree of SGI influence on these ecohydrological processes will vary with its position relative to the surface. SGI close to the surface elevates water table positions by blocking the infiltration of spring precipitation and snowmelt which can then runoff to downgradient systems. The melting of SGI aids in decreasing early growing season potential evapotransporative losses by reducing the available energy at the surface. Therefore, in order to determine the timing of these various influences, it is important to accurately describe the position of SGI during the melting period. Methods for this include field observations such as ice probes and direct measuring, modelling using the Stefan equation, spatial interpolation, and using ground temperature profiles. This poster will show a comparison between the various methods using field data from a poor fen located approximately 40 km south of Fort McMurray. Each method will be used to determine the position of SGI as it melts during the month of May, 2017. Results will facilitate a discussion on the advantages and disadvantages of each method, and conclude with an assessment of the validity of using each method in a boreal peatland.

Landscape Legacies: Long-Term Nutrient Trajectories in Great Lakes watersheds and Beyond

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Oral Presentation
Session: Watershed Management and Disturbance
14:30–14:45, Tuesday, June 5, 2018
Room 1110

Global nutrient flows have increased significantly over the last century in response to land-use change, population growth, and agricultural intensification. Despite widespread implementation of a range of conservation measures to mitigate the impacts of intensive agriculture, nitrogen (N) and phosphorus (P) concentrations in surface waters are in many cases remaining steady or continuing to increase. It is increasingly understood that this lack of response may be in part due to legacy nutrient stores within the landscape, from nitrate accumulation in groundwater to phosphorus legacies in soils and sediments. It has remained unclear, however, what the magnitudes of such stores might be, and how they are partitioned among various "pools" across the landscape. In recent work, we have developed the ELEMeNT model - which pairs a simulation of soil nutrient dynamics with a groundwater travel time-based approach - to reconstruct historic N and P yields at the watershed outlet and to model future nutrient loading under a range of scenarios. Our analysis of long-term nitrogen trajectories in the Mississippi River basin shows that even if agricultural N use were to become 100% efficient, it would take on the order of decades to meet policy goals for improving water quality. In the Great Lakes region, we have used a more than 100-year trajectory of watershed P inputs to the Grand River watersheds not only to reconstruct total P loads at the watershed outlet, but also to estimate the magnitudes of P accumulation along surface and subsurface pathways. Such estimates of both N and P accumulation are crucial to setting realistic targets for nutrient loading and for better understanding the contribution of nutrient legacies to current and future water quality.

Targeting Phosphorus Legacies in the Laurentian Great Lakes Watersheds

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 24

Anthropogenic phosphorus (P) inputs into agricultural soils have exceeded crop demand for decades. The resulting release of the excess P to surface water contributes to eutrophication, including the occurrence of harmful algal blooms (HABs), with severe threats to drinking water security and aquatic ecosystems. Efforts to reduce the inputs of P to Canadian agricultural soils started in the late 1970s-early 1980s, and was initially successful, but the decrease in P loading to surface water did not continue into the 2000s. HABs are still an issue in the Laurentian Great Lakes (LGL), and this is likely result of legacy P that has accumulated in soils and groundwater in agricultural watersheds due to historical nutrient management. Thus, even after reducing P inputs, legacy P continues to be exported from the soils after several decades. Agricultural P soil legacies are therefore a major concern for decision makers and stakeholders. This project aims to locate and quantify agricultural legacy P in the watersheds that drain into the LGL by using a long-term (1961 – 2016) large-scale mass balance. The mass balance model will be implemented into a Geographical Information System (GIS) platform to create maps that delineate the accumulation and depletion of legacy P within the landscape. These maps will inform nutrient management and abatement strategies.

High-resolution hydrological modelling of the June 2013 flood in the Canadian Rockies

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Oral Presentation
Session: Modelling and Observations - Part I
14:30–14:45, Tuesday, June 5, 2018
Room 1105

During 19-22 June 2013, intense rainfall and concurrent snowmelt led to devastating floods in the Canadian Rockies, foothills and downstream areas including the city of Calgary, Alberta. The complexity of the topography in the upper catchments and the presence of snow at high elevations made, among other factors, hydrological forecasting challenging for this extreme event. In this study, the ability of the distributed hydrology platform GEM-Hydro to forecast hydro-meteorological conditions during this event is assessed. GEM-Hydro couples the SVS (Soil, Vegetation and Snow) land-surface scheme and the WATROUTE routing scheme. A configuration of GEM-Hydro at 1-km grid spacing over Southern Alberta is used in this study. Meteorological forecasts for this event were produced at 10 km, 2.5 km and 1 km with the GEM (Global Environmental Multi-scale) numerical weather prediction system. The Canadian Precipitation Analysis (CaPA) was then used to generate precipitation analysis at these different resolutions. These forecast and analysis products were finally used to drive GEM-Hydro to quantify the impact of the resolution of the atmospheric forcing on the hydrological response simulated by GEM-Hydro. Ssensitivity to horizontal resolution and benefits of dynamical downscaling to generate atmospheric forcing are especially discussed for the different mountainous catchments of Southern Alberta. Additional simulations with a version of SVS including the multi-layer snowpack scheme Explicit Snow (SVS-ES) have also been carried out and compared to results obtained with the default version of SVS featuring a single layer snow scheme. In particular, the impact of the initial snowpack conditions on simulated runoff is discussed. Observations of precipitation, snow depth, snow water equivalent, radiation, temperature, humidity, wind speed and streamflow taken at multiple stations of the Canadian Rockies Hydrological Observatory were used for model evaluation. The results guide the development of GEM-Hydro as a hydrological forecasting system over the Canadian Rockies.

Boreal Water Futures: The Burning Issues

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Oral Presentation
Session: Plenary
16:15–17:00, Tuesday, June 5, 2018
Room 1305/7

The boreal is a mosaic of forests and peatlands shaped by wildfire. Fire drives boreal vegetation and organic soil dynamics and is a vital component of this biome that plays a globally important role in climate regulation. However, boreal wildfire severity and area burned are expected to double by the end of this century as forest and peat fuels become drier. An increase in high severity 'mega fires' can lead to catastrophic ecosystem collapse and the loss of valuable ecosystem services such as water regulation and quality to downstream communities. This increase in wildfire risk is taking place at the same time as more people are working, living and playing in the boreal. Recent wildfire disasters such as Slave Lake in 2011 and Fort McMurray in 2016 have increased the awareness of the importance of boreal forest land cover and management challenges and issues. "How can the boreal wildland-societal interface be managed to reduce the risk of catastrophic ecosystem collapse while protecting human health, water quality, property and economic activity from wildfire?". In this talk, the scientific and societal water and wildfire issues for Canada's boreal region and how they are being addressed in the Boreal Water Futures project will be discussed.

Hydroclimatic controls on runoff generation in an artificially drained, near-level vertisolic clay landscape

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 90

The expansion of agricultural tile drainage in the Northern Great Plains of North America is controversial due to persistent water quality problems such as eutrophication. While those water quality problems are undoubtedly influenced by hydrological processes, runoff-generating mechanisms in tile-drained landscapes have seldom been investigated, especially in the presence of vertisolic soils. This study evaluated the role of climate drivers on the activation of overland (OF) and tile (TF) flow and groundwater flow responses (GWT) on tiled and non-tiled working farm fields in Southern Manitoba, Canada. Focus was on the Red River Valley which exemplifies near-level, clay-rich landscapes in the Northern Great Plains. Twenty-three hydrological events were monitored during the 2015 and 2016 open water periods (April-October). The time delays between rainfall inputs and the activation of various flow pathways (OF, TF, GWT) were determined and compared to infer dominant runoff generation processes. Results show that more rapid responses occurred with greater rainfall intensity; however, TF and GWT activation in spring was also hastened under wetter antecedent conditions. Most often, OF was activated prior to TF and GWT in the tiled field, and the soil profile wetted up from the top down. Patterns in the activation of OF did not differ between the tiled and non-tiled field, suggesting that tile drains do little to reduce the rapid activation of OF in this landscape. Although vertisolic soils are often prone to vertical preferential flow via desiccation cracks, such patterns were uncommon at our site. These conclusions bear significant implications for the potential expansion of tile drainage and the impact of such an expansion on hydrological and biogeochemical processes in agricultural landscapes.

Tall shrubs mediate soil conditions and plant communities at the treeline-arctic tundra ecotone

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 93

The productivity and areal extent of shrubby vegetation is increasing across the circumpolar arctic tundra driven primarily by regional increases in summer air temperatures. The resulting changes in physical structure of tundra vegetation have been found to have important consequences on ecosystem processes. For example, the snow-shrub hypothesis, first proposed by Sturm et al. 2001, suggests that increased snow capture by tundra shrubs could lead to warmer soils beneath shrub patches, potentially leading to a localized region of greater nutrient availability and further increase productivity. Since its proposal many studies have added to our understanding of how tundra shrub patches may interact with their environment in such a way that the biotic and abiotic conditions of the patch are distinct from those of the surrounding open tundra. Shrubs have been shown to alter processes such as snow capture, soil moisture dynamics, active layer development, and patterns of nutrient cycling such as decomposition rates, organic matter accumulation, and plant nutrient availability. Such changes in growing conditions may have important implications on the understory vegetation community living in shrub patches and so the potential for distinct vegetation communities to exist in shrub patch and open tundra habitats is strong. Green alder (Alnus viridis) may have a particularly important role to play in altering biotic and abiotic conditions of the tundra due to both its stature relative to other tall shrubs and its capacity to form symbiotic relationships with nitrogen fixing Frankia bacteria.
In this study we test whether: 1) alder patches support distinct vegetation communities 2) alder patches differ from surrounding tundra in key environmental variables such as soil moisture and nutrient availability and 3) whether these environmental variables can explain variation in vegetation community composition. To do this we established ten sites at Trail Valley Research Camp on the low-arctic tundra north of Inuvik, NT. At each site we ran transects through alder shrub patches and adjacent open tundra locations and quantified vegetation community composition as well as soil moisture, thaw depth, organic matter depth, relative decomposition rates, plant available nutrients, and snow depth. Environmental variables did differ between habitats, particularly snow depth, soil moisture and nutrient availability, confirming that alder patches modify the growing conditions experienced by understory plants. While the two habitats had a large degree of overlap in their vegetation composition we found that differences in relative abundances resulted in two distinct plant communities. In particular the abundance of evergreen shrubs was greater in shrub patches, which we suspect is driven by greater spring snow cover. In addition to general community composition we found evidence that greater tall shrub cover is associated with decreased richness of tundra specialist species. Our results confirm that alder patches do alter niche availability in low arctic tundra systems and raise the possibility that future expansion of alder patches in this region may lead to important hydrological changes as well as shifts in biodiversity at this important arctic ecotone.

Sahtu Hydrologic Observatory: Hydrogeologic Conceptual Model and Baseline Conditions

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Poster Presentation
Session: Modelling and Observations
Poster # 77

Northern Canadian water resources face unprecedented impacts from shale oil and gas resource extraction and the looming threat of climate change. Potential effects on groundwater and surface water quality and quantity remain uncertain, and data acquisition for baseline monitoring remains difficult due to lack of infrastructure and site access, short field seasons, and prohibitive costs. This project is a part of a larger study which aims to explore methods for establishing baseline monitoring in the Sahtu Settlement Area in Northwest Territories, Canada. Objectives for this particular work includes creation of a conceptual hydrogeological model and characterization of the groundwater flow system of the region through interactions with surface water. Data collected from papers and reports will guide targeted fieldwork within a small watershed near the Mackenzie River. This site is characterized by a bedrock-controlled stream drainage pattern within a regional syncline of folded sedimentary rocks, with a thin discontinuous blanket of Quaternary and modern alluvial sediments. Regional aquifers are confined from shallow aquifers by the presence of permafrost and thick shale sequences. Discontinuous permafrost underlies much of the region and its extent and thickness is unknown but crucial to understanding the groundwater flow system and interactions with surface water. Groundwater comes to the surface through open taliks which act as windows in the permafrost, and planned fieldwork aims to identify, instrument and sample several key sites of groundwater discharge. Physical measurements of the groundwater system will be supplemented by geochemical and isotopic analysis.

A Watershed Classification for the Canadian Prairies

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Poster Presentation
Session: Modelling and Observations
Poster # 78

Much of our understanding of prairie watershed response to environmental change is based on a few research sites. The representativeness these responses to other regions within the Prairies is unknown, however, which impedes extrapolation to other, potentially comparable basin. Our objective is to develop a typological framework for prairie watersheds that will identify areas of similar physio-geographic characteristics and thus potential hydrologic behaviour with changes in climate and land management. We compiled a dataset comprising climatic, geographical, hydrological, and land cover data for watersheds of approximately 100 km2 (n=4127) in the Canadian Prairies. The multivariate dataset was first decomposed into principal components and then analyzed using an agglomerative hierarchical clustering algorithm. This approach yielded six watershed classes, with the most influential classifying variables including climate, soil zone, fractional noncontributing area, number of wetlands, and land cover. Two classes were characteristic of grasslands in southeastern Alberta, while three classes followed the black soil zone in central Alberta and Saskatchewan. The final class was characteristic of southern Manitoba's highly drained landscape. This framework provides a flexible assessment of prairie watershed typology to generate multilevel classifications based on a variety of variable types. Our future work will characterize hydrologic response of each class and assess this response under changing environmental conditions, such as changing climate and altered land-use practices.

Assessment of the reliability of various remotely sensed and data assimilation based products in characterizing the water balances for cold region river basins in Canada

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Poster Presentation
Session: Modelling and Observations
Poster # 79

The availability of various remotely sensed and data assimilation based products for different water budget components makes it possible to better evaluate the water balance and its uncertainty. This is especially relevant given the scarcity of direct in-situ measurements of various water budget component. This study characterizes the water balance closure of 15 major Canadian river basins of size ranging from 90,900 to 1,679,100km2 during 2003-2010 associated with the application of various remotely sensed and data assimilation based products. Multiple sources of data for each water budget component, including two precipitation products (the global product WATCH Forcing Data ERA-Interim (WFDEI), and the Canadian Precipitation Analysis (CaPA)), two evapotranspiration products (MODerate Resolution Imaging Spectroradiometer (MODIS), and Global Land-surface Evaporation: the Amsterdam Methodology (GLEAM)), three sources of different attributes of water storage data (the Gravity Recovery And Climate Experiment (GRACE), the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E), and the CanSISE Observation-Based Ensemble of Northern Hemisphere Terrestrial Snow Water Equivalent (CanSISE)) are combined through a water balance equation to estimate monthly and annual streamflow, which is compared with observed streamflow by using bias, absolute error and correlation coefficient to assess water balance performances. The results will provide an assessment of the reliability of different products in undertaking water balance characterization at regional and continental scales, and in particular for improving the understanding of cold region hydrological processes in Canada.

Hydrophobicity of Peat Soils: Characterization of organic compounds associated with water repellency

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Poster Presentation
Session: Aquatic Environment and Ecosystems
Poster # 25

The chemical composition of compounds responsible for peatland water repellency has not been fully understood. In this study, we evaluated the chemical characteristics of soils and their impact on water repellency under saturated and dried conditions. To this end, we characterized the extracted organic compounds from peat soil (feather moss) samples obtained from Pelican Mountain, Alberta, Canada with an isopropanol/15.7M ammonia mixture (v:v, 7:3). Extracted organic compounds were methylated or silylated and characterized by gas chromatography-mass spectrometry (GC-MS). Fatty acids (C14-C30), saccharides (C5-C7, C12), and complex ring-structured compounds (cholesterol derivatives) were detected in all samples. Supporting measurements by Fourier Transform Infrared Spectra (FTIR) identified specific functional groups present in the soil organic matter. FTIR results indicated the presence of aliphatic hydrocarbon, carboxyl group, hydroxyl group and carbohydrates in peat soils. Peat soil hydrophobicity was correlated to compounds identified through GC-MS and FTIR analyses. Peat soil hydrophobicity was determined through Molarity of Ethanol Droplet (MED) tests. Initial findings indicate that soil hydrophobicity is related not only to the organic composition of soils, but also to the water content of the soils. Natural peat soils were hydrophilic, but laboratory air drying under 20℃ for 24hr increased the water repellency. Further drying in an oven under 105℃ for 24hr caused a marked increase in the soil hydrophobicity. Hydrophobicity was associated with the organic compounds rather than changes in soil structural properties, as BET N2 adsorption surface area of peat soil samples was small. This finding suggested that coating of hydrophobic compounds on soil particle surfaces during the drying process may be primarily responsible for the peat soil water repellency.

Synthesis of carbon fluxes to heart and drought impacts in North America forests.

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Oral Presentation
Session: Climate and Extremes
14:45–15:00, Wednesday, June 6, 2018
Room 1110

Climate extremes such as heat and drought are projected to occur more frequently with future increasing temperature and intensified hydrological cycle. It is important to quantitatively understand how forest carbon fluxes response to heat and drought stresses, particularly in North American where forest carbon dynamics are controlled by the climatic variables, and an increase in both frequency and severity of climate extremes is expected. However, the sensitivity of forest carbon fluxes to climate extremes vary with the timing of the events. The FLUXNET provides continually measured meteorological data and estimates of net ecosystem productivity (NEP), gross ecosystem productivity (GPP) and ecosystem respiration (RE) in many sites representing the North American forests. In this study, we developed a series of monthly indexes of sensitivity to heat and drought stress as indicated by air temperature (Ta) and evaporative fraction (EF) estimated by latent heat and sensible heat. Using relatively normalized daily data from 28 forest sites (324 site/year) in North American in the FLUXNET2015 dataset, the seasonal pattern of sensitivities of NEP, GPP and RE responding to Ta , EF and soil water content (SWC) anomalies were compared among different forest types, stand ages, management strategies, and climate condition. The results shew that seasonal variations have a strong impact on forests sensitivity to heat and drought stress. The sensitivity of GPP and RE to temperature anomalies increased with mean annual temperature (MAT) in summer but decreased with MAT in spring. The higher temperature in spring led to increasing NEP in evergreen forests but decreasing NEP in most of the deciduous forests. The drought-induced decrease of NEP, mostly occurred during late summer in the subtropical and continental areas, were driven by the reduction of GEP in most of the sites, while in subarctic area drought limited RE, therefore had a positive impact on NEP through the growing season. The sensitivity of NEP and GEP to drought stress in summer month increased with mean annual precipitation. Sites with greater annual GEP were more sensitive to heat and drought condition, but less sensitive to changes in SWC. The sensitivity of NEP to SWC decrease with increasing water use efficiency in the early growing season. Our results implied that phenological dynamics of forests and timing of the climate extreme events should be considered in studies and modeling of the impact of climate extreme events on forest carbon cycle.

Resilience of socio-hydrological systems in Canadian prairies to agricultural drainage: Policy analysis and modelling approach

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Poster Presentation
Session: Human-Water Interactions
Poster # 43

The goal of the research is to explore trade-offs between agricultural management and ecosystem services in the Canadian prairies, and specifically to model the economic costs and benefits associated with wetland drainage policies of the Saskatchewan Water Security Agency's Agricultural Management Strategy. The study area is the Smith Creek Research Basin in south-eastern Saskatchewan in western Canada. The proposed methodology links the Cold Regions Hydrological Model (CRHM) for hydrological simulations with the Inclusive Wealth approach for modelling cost-benefit analysis. We will use shadow price, defined as the marginal change in social value for a marginal change in the current stock quantity, and CRHM to evaluate changes in hydrological conditions and in social value of all capital asset stocks that contribute to social welfare. CRHM simulates major alterations of the hydrological regime including increased peak flows, discharge volumes and duration of streamflow under different policy conditions. Changes in wetland storage and function will be used to estimate the changes in social welfare associated with agricultural production over a 30-year period for different policy scenarios.

Development of Real-time Cyanobacteria Sensors

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Poster Presentation
Session: Modelling and Observations
Poster # 80

The need for real-time monitoring biological indicators of water quality is a growing priority in Canada and around the world. More nutrients produced by growing populations are discharged to rivers and lakes, which causes eutrophication in water. Early warning of harmful algal blooms (HABs) and real-time monitor the cyanobacteria and other algae is the best solution to prevent the outbreak of HABs. There is a strong demand to forecast and prevent the outbreak of the HABs and reduce public health risks caused by possible toxins produced by the harmful algae.
Based on the established micro-flow cytometer sensing platform developed in Xu's group at McMaster, we will develop an advanced real-time cyanobacteria sensor. Initially, the focus will be on proof-of-principle and prototype development to demonstrate the feasibility of this technology. The cyanobacteria sensor is based on micro-flow cytometry, which is an individual optical interrogation and detection method via hydro-dynamically induced single particle flow. By detecting the unique scattering and auto-fluorescence characteristics of cyanobacteria (e.g., phycocyanin), it is possible to distinguish cyanobacteria from other particles and cells. Phycocyanin is a pigment unique to freshwater cyanobacteria that can be used to determine cyanobacterial biomass. The detection approach pursued here will have a lower detection limit than commercially available units and will thus be more suitable for early HABs warning.

Long-term Evapotranspiration Trends in Upper Stream of Heilongjiang (Amur) River in northeastern Asia

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Poster Presentation
Session: Watershed Management and Disturbance
Poster # 96

In cold and arid region of upper Heilongjiang (Amur) river basin (UHAR), the variations of precipitation and actual evapotranspiration (ET) have pronounced impact on the regional hydrological balance. In this study, long term (1982-2013) climatic and vegetation dynamic datasets from the Climatic Research Unit (CRU) and Global Inventory Monitoring and Modeling System (GIMMS) initiatives were utilized to estimate temporal and spatial dynamics of ET in the region, using three models (i.e. Brutsaert-Strickler, Szilagyi-Jozsa and Granger-Gray model) in order to analyze and explore changes in regional hydrologic cycle and their possible causes. Observed ET values from Kherlenbayan Ulaan (KBU) site of the Asia Flux from 2004 to 2009 were used to validate simulated ET values. We found a persistent decreasing trend in precipitation and increasing trend in ET in the region, resulting in the shrinkage of lake water levels over the study period (1982-2013). Mean annual ET values (prediction of randomforest tree model) for the region increased from 132.7 mm in 1980s to 155.9 mm in 2010s (9.0 mm/decade, p=0.00), while observed precipitation values deceased from 262.8 mm to 203.9 mm (25.1 mm/decade, p=0.04). Over the same period, mean annual values of air temperature increased from -1.9 oC to -1.0 oC. All three models overestimated the ET 2.4-2.8 times when compared to observation, possibly due to the negligence of spatial vegetation dynamics across the regions or watershed. Disagreement between simulated and observed ET values was found to be more pronounced during the periods when ET values were either extremely high or low. By classification tree analysis, we found that ET could be characterized by minimum temperature (TMIN) of 5.9 oC (primary control), and by the Normalized Difference Vegetation Index (NDVI) of 0.1 (secondary control), implying different controls in growing and non-growing seasons. This study has helped to investigate the variations in hydrologic cycle and its components in the background of regional climate change. Further investigations on the impact of land use change and human disturbances are needed to fully understand the trends in regional hydrologic budgets.

Integrating Flow Measurements, Flood-hazard Maps, and DEMs for flood mapping in Ungauged Large Scale Basins

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Poster Presentation
Session: Human-Water Interactions
Poster # 44

The determination of inundation extents that result from potential flooding events, using minimum data requirements, is essential for many purposes, such as development planning and mitigating flood damages. The regular mapping of floods involves hydraulic and hydrologic modeling. The accuracy of these models depends on data availability, and is usually computationally expensive. Therefore, flood mapping in large areas, and at locations where no historical measurements are available is challenging. Recently, methods were developed to create Canada-wide flood hazard maps, with graded hazard classes, and based on topography only. However, a drawback of such maps is the lack of relation between the flood hazard classes and flood frequencies or magnitudes.
This work proposes a methodology to overcome data scarcity at ungauged sites and to map potential floods over large areas in relation to pre-selected flood quantiles of various return periods. The methodology integrates three components: streamflow and stage measurements at gauged locations, an already established flood-hazard map for Canada with flooding hazard classes ranging from severe to very low, and digital elevation terrain data (DEM). First, frequency analysis is conducted with the streamflow measurements to determine the flood quantiles that correspond to various return periods (50-, 100-, 500-, and 1000-year) at all available gauged locations. Second, the water levels, corresponding to the flood quantiles, are estimated from the available flow-stage rating curves at the same gauging locations. Interpolated water surface profiles are constructed for different flood quantiles using the estimated water elevations. Third, Geographic Information Systems (GIS) are then employed to map flood inundation extents based on the available DEM and the interpolated water surface profile. Finally, the determined flood extents are related to the severity classes of the flood-hazard map of Canada based on the topographic slopes of the floodplains, and consequently, flooding extents over ungauged basins are determined for the various return periods. The proposed methodology, when completed, will solve the data scarcity problem at ungauged basins, and provide fast and reliable estimates of flood extents due to significant flood quantiles at small and large scale basins. In the first stage, this method will be applied and verified over the Canadian prairies, then, it will be extended over Canada. This method is intended to provide a baseline flood mapping over large areas, and will be further improved and verified in the future using more detailed hydrodynamic modeling.

A comparison of laboratory and field-based measurements of chlorophyll-a, turbidity, and dissolved organic carbon for agricultural surface waters in Ontario and British Columbia, Canada

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Oral Presentation
Session: Modelling and Observations - Part II
14:30–14:45, Wednesday, June 6, 2018
Room 1105

In situ measurements using a sonde instrument\probe in the field are often relied upon for rapid water quality assessment locally and nationally, including for use in remote sensing of surface water quality. National scale investigations require an understanding of the behaviour of sonde measurements made by differing users, in differing environments, and amongst differing instruments for watershed comparison. We describe herein an assessment of sonde performance to measure water quality for use in national scale investigations. Multiple Yellow Spring Instrument (YSI EXO2) sondes were used to measure chlorophyll-a (chl-a), turbidity, and fluorescence dissolved organic matter (fDOM) within 4 watersheds in North America (i.e., the South Nation River, SNR; Grand River, GR; Ausable-Bayfield River, ABR; and the Fraser River, FR, watersheds of Canada) in year 2015. Water samples were collected in tandem with sonde measurements at each site (n=20, 8, 32, and 25 samples collected in SNR, GR, ABR, and FR watersheds, respectively (n=85 total)) and were sent for laboratory analysis for comparison. Sonde measures demonstrated a near 1:1 relationship with laboratory-measured chl-a using logarithmically-transformed data collected from all regions. The relationship between laboratory measured dissolved organic carbon (DOC) and field-measured fDOM improved when the regression models were developed based on the dynamics of water optical properties, changing in both space and time (i.e., site and season). Results of this study demonstrate that the performance of sonde fluorometric sensors which measure chl-a and DOC differ spatially and temporally, relative to laboratory results. The optical probes have great potential to provide near real-time information and contribute to producing long-term trends of water quality for aquatic environments. Post field collection comparison of sonde data against laboratory results is suggested prior to using them further amongst and within regions of comparison.

Chemiresistive sensors for monitoring the concentration of metal cations in water

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Poster Presentation
Session: Modelling and Observations
Poster # 81

Access to safe drinking water has been recognised as a human right for almost two decades, and the monitoring and analysis of water are crucial environmental management practices. There are many parameters that must be controlled in the quest to clean water, one of them being the presence of metal cations. Thus, there is a growing demand for methods that are able to easily and reliably measure their concentrations, with an emphasis on real-time data acquisition and portability. However, the commercially available instrumentation for in-situ monitoring is very limited. With that in mind, we have been working to develop chemiresistive sensors for the quantification of different metal cations in water samples. Functionalized nanocarbon films serve as the transductive element, showing noticeable doping as a result of charge transfer between the functionalized film and the analyte. This causes a change in sheet resistance, which can be quantified by probing the sensor with a small voltage. The resulting change in conductance has been found to be proportional to the concentration of the metal over a wide dynamic range. The selective nature of the functionalities decreases interferences from other common cations present in water. All in all, our sensors demonstrate a potential as a cheap, reproducible and sensitive approach to the continuous measurement of free metal cations.