SEARCH TERM: Climate or Extremes (and synonyms) – 24 projects

Southern Forest Water Futures

- Evaluation of heat and drought impact on carbon exchanges in different age southern temperate managed forest ecosystems. Results indicate that the timing, frequency and concurrent or consecutive occurrence of extreme weather events may have significant implications for growth and carbon sequestration in these forests. Study results will help in developing climate resilient and sustainable forestry practices to offset atmospheric greenhouse gas emissions and converse water resources.
- Development of coupled hydrologic and carbon cycle model (MESH-CTEM) to study coupled water and carbon cycle processes as watershed scales under different climate change scenarios.
- Collaboration with the GWF Co-creation of indigenous water quality tools and ecosystem health group to conduct modelling studies at McKenzie Creek to explore the impacts of climate change on hydrological processes and water resources in the Six Nations Community.
- We also collaborate with members of McMaster Centre for Climate Change for various activities such as Twitter feeds, sponsored public and academic lectures, conference sponsorship to disseminate project results and conduct community outreach.
- Climate adopted forest management strategies for southern forest ecosystems to provide sustainable and clean water resources and enhanced carbon sink capabilities.
- Well tested and improved coupled hydrologic and biogeochemical model (MESH-CLASSIC) for application and research as watershed scale and explore impacts of climate change.
- Community engagement and dissemination of results to enhance awareness about water resources and their security in changing climate.

Agriculture Water Futures

- Improved understanding of interactions between climate, landscape and management drivers on nutrient loss
- Accounted for economic impacts of climate change in the agricultural sector in the Great Lakes Region
- Exploring water use in vineyards in the Great Lakes region and the effects of climate variability
- Exploring interactions between climate, landscape drivers and land management practices on water quality to improve the targeting of conservation practices within and across regions
- Improved understanding of regional differences in nutrient dynamics and the impacts of climate, landscape and management on water quality
- Improved understanding of regional differences in crop water use and the impacts of climate, landscape and management on water use
- Simulations of how future climates may impact crop water use and water quality in the Canadian agricultural sector
- Improved understanding of the costs of climate change to the Canadian agricultural sector

Boreal Water Futures 2

- High impact paper on potential of fuel management in peatlands as nature-based climate solution

Co-Creation of Indigenous Water Quality Tools

- Reality platform that focuses on 'future' tied to results from climate change study (see below).
- Drafting research paper on changes to McKenzie Creek streamflow under climate change
- Developing study on impacts of climate change on McKenzie Creek water quality

Core: Water Resources Management Modelling

- Finalizing climate change scenarios from HYPE and MESH (A Tefs, F Yassin)
- Climate change + renaturalization scenarios in IWRM (L Eamen)
- Production of climate change and renaturalized scenarios of hydrology to assess with/without regulation and climate change impacts

FIShNET

- In collaboration Mushkegowuk Council, Fort Albany First Nation, and consultation with the (FEHNCY) team, we developed a survey to collect data on food behaviour and perceptions of adults (household food insecurity, impact of wild-harvested fish on food security, risk perception, changes to food security and fish health over time and related to climate, relationships between fish health and human consumption).

FORMBLOOM

- Larsen ML, Baulch HM, Schiff SL, Simon D, Sauvé S, Venkiteswaran JJ. 2020. Extreme rainfall drives early onset cyanobacterial bloom. FACETS, 5(1): 899-920, doi: 10.1139/facets-2020-0022.
- Larsen ML, Venkiteswaran JJ. 2019. Data for "Extreme midsummer rainfall event drives early onset cyanobacterial bloom". figshare. Dataset. https://doi.org/10.6084/m9.figshare.7811963.v1

Remotely Sensed Monitoring of Northern Lake Ice

- Comparison of methods for bias correction of climate data (Bayesian approach vs quantile mapping)
- Improve understanding of the processes that regulate the changes in ice cover, extent and thickness in cold regions in a warming climate

Climate related precipitation extremes

- Illustrated the role of topography in shaping the occurrence and intensity of freezing precipitation in current and historical climate conditions over Manitoba and NB
- Evaluated the downscaling performance for both the CTRL and PGW periods, focusing on extremes, and whether the downscaling scheme calibration determined for the historical period remains valid for the future period.
- Assessed water budget over western Canada in the current and future climate using convection permitting WRF simulations
- Analysis of factors affecting hail formation using CONUS I in the present and future climate including local terrain's effects on wind shear as well as synoptic and mesoscale processes
- Evaluation of whether statistical downscaling schemes such as BCCAQv2 can be used to leverage high cost, and thus limited availability, convection permitting simulations as training data for downscaling lower cost, more plentiful, climate change simulations with conventionally parameterized climate models.
- Examination of Canadian Prairies warm season extreme precipitation events and their associated atmospheric circulations in the current and future climate

Integrated Modelling Program for Canada

- **Improved hydrological land-surface modelling** (Dr. Pomeroy's team w/Core Modelling): developed and evaluated a 2-D water flow through snow model to advance both the physical understanding of and ability to simulate water flow through snowpacks as well as a 3-D blowing snow model that reduces the computational costs of accounting for the impact of blowing snow on snow water equivalent and snowmelt. The team also used the Cold Regions Hydrological Model to evaluate the response of snow and hydrological regimes to climate warming, with results showing a generalized decoupling of mountain river hydrology from headwater snowpack regimes.
- **Analysis of extremes** (Dr. Elshorbagy's team): defined seven flood indicators to describe the key hydro-climatic components that could contribute to the generation of spring floods in the Canadian prairies, characterized the generation mechanisms of more than 2000 spring-flood events, and identified spring-flood generation mechanisms.
- **Integrated Water Management modelling** (Drs. Razavi & Brouwers' teams): Model integration efforts successfully completed so far combine the MODSIM Water Resource Management framework with the Inter-Regional Supply-side Input-Output (ISIO) economic model to evaluate relative economic impacts in the SRB under changing climate conditions, socioeconomic development, and policy interventions, to identify opportunities for building resilience into the SRB water system. Several python scripts have been developed to link ecological metrics to the modelling framework.
- **Ecological modelling** (Drs. Jardine & Strickerts' teams): naturalized daily and future flows from MESH (15 climate scenarios, 3 time periods) were used to produce naturalized flow presumptive standards (sustainable boundaries) for 28 sites in Alberta, five sites in Saskatchewan, and two sites in Manitoba. Ecological performance indicators were developed, including percent deviation from natural flow and Indicators of Hydrologic Alteration (IHA) variables.
- **Improving Modelling and forecasting capacity:** Dr. Li's team has recently been evaluating the impacts of surface coupling strength on regional climate simulation using Fluxnet site observations and the

continental scale 4-km WRF CONUS simulations, along with assessment of the uncertainty for the coupled simulations of future climate. Dr. Papalexiou's team is actively performing detailed statistical analysis of gridded products based on the available in situ and gridded observation data over Canada and all available CMIP6 simulations (both historical and future for four SSPs) for precipitation, max and min temperature.

- **Model intercomparison:** now underway for the Nelson-Churchill by Dr. Stadnyk's team to produce scenarios under i) no regulation, ii) with regulation, and iii) under climate change. The team has attracted contributions from many stakeholders, employed a project manager, meets now on a monthly basis, and is receiving results from the first stage of the work.

Integration of next-generation hydrological and land surface models to address changing cold region processes:

- Detailed statistical analysis based on the available in situ and gridded observation data, as well as CMIP6 projections; comparison between observation and projections. Downscaled CMIP6 precipitation projections for target regions alone with quality assessment of the downscaled products.
- Complete pan-Canadian high resolution (4-km) atmospheric modelling of historical climate and future warming, the CONUS II simulation; post-processed WRF output; sensitivity test of land–atmosphere feedbacks using existing coupled atmosphere - land surface model. Conduct inter-model comparisons with the ECCC MESH/CLASS modelling system for cold region land surface schemes by collaborating with the core modeling and the ECCC MESH groups. Conduct scenario runs for the assessment of land–atmosphere feedbacks using WRF-MESH/CLASS coupled modeling system to provide additional context of model and scenario uncertainty.

Integration of water quality metrics, ecological metrics, and climate change scenarios into the water management modelling framework:

- Couple flows and fluxes between MODSIM and WASP; calibrate/validate MODSIM-WASP modelling system; complete development of MESH-WASP modelling system. Run water-management and climate-change scenarios with MESH-WASP and MODSIM-WASP modelling systems.
- Deriving a target range of river flows for people and wildlife to thrive in the Saskatchewan River Delta (based on 'presumptive standard method' that estimates sustainable boundaries for flow) and using integrated models to understand how these targets may be met or not.
- Including future climate change scenarios (possible collaboration with Core modelling on use of climate change scenarios) in combination with policy scenarios as described in section above.
- Definition and testing flow-ecology relationships and coupling validated flow-ecology metrics with the MODSIM model.

Warming Estuaries, Closing Gates

- **Invited talks at international conferences (*denotes HQP): (1)** Kurylyk BL,*Smith KA, *KarisAllen J. 2021. Thermal heterogeneity and climate change sensitivity of transitional, coastal waters. American Fisheries Society Meeting, virtual and Baltimore, Maryland (Nov. 2021) **and (2)** Kurylyk BL,*KarisAllen J, *Smith K, *Cantelon JA, *Zeighami A. 2020. (American Geophysical Union Fall Meeting, Virtual.

- **Other talks: (1)** *Smith KA, Kurylyk BL, O'Sullivan A, Kennedy G. 2020. Seasonal, interannual, and spatial patterns of groundwater temperature change in Nova Scotia, Canada. Geological Society of America Conference (GSA Connects), virtual. **(2)** *KarisAllen J, Jamieson RC, *Mohammed AM, Kurylyk BL. 2020. Groundwater-derived thermal buffering of coastal habitat in the context of climate change, Canadian Geophysical Union (online webinar series)

- **Five journal manuscripts/publications** – 1 on inter-tidal spring temperature dynamics (already published in *HP*), 1 on coastal groundwater warming and impacts to groundwater-dependent coastal ecosystems (in prep, led by MASc student J. KarisAllen – to be submitted to *HESS*), one on groundwater temperature patterns in coastal regions as measured in provincial observation well networks (in prep, led by PhD student K. Smith – to be submitted to *HESS*), 1 on estuary temperature modeling under climate change scenarios (in prep, led by PhD student A. Zeighami – to be submitted to *WRR*), 1 on drone vs. fiber-optic DTS vs. loggers ("what do we miss from the air", led by PhD student K. Smith – to be submitted to a hydrology like *HP* or environmental technology journal like *ES&T*). We are also considering a sixth paper on coastal storms and the impacts to thermally stratified lagoons.

Lake Futures

- Developed a process-based model ELEMeNT that predicts N and P concentrations and loads as a function of current land use and climate and past nutrient legacies. ELEMeNT is the first ever process-based model that can describe legacy accumulation and time lags to water quality improvement. We have developed ELEMeNT-N and ELEMeNT-P models for the Grand River Basin (Liu et al. 2021, Van Meter et al. 2021).

- Developed a new hydro-economic model for the GLB which analyzes the direct and indirect impacts of possible future water use restrictions due to climate change on economic activities

Managing Urban Eutrophication Risks

WP1: watershed hydrology and water quality modeling

- Complete the PCSWMM of the two Ajax sewersheds in PCSWMM and predict trends in P loadings to WLO under different climate change scenarios. A manuscript will be submitted comparing the sources, fate and transport of P in these two urban sewersheds.

WP4: integration of WP1-3

- Integrate the knowledge base and modeling tools of WP1-3 into a decision-support framework for adaptive urban stormwater management under climate change and urban development.

Mountain Water Futures

Cryosphere

- Completed modelling of the effect of climate change along with deglaciation on Canadian Rockies. Using WRF-PGW for climate change in non-glaciated basins we predict a substantial decrease in snowfall, sublimation and peak snowpack, advance in melt timing, and an increase in rainfall, ET and annual streamflow. Using the same climate forcing for glaciated basins, predicted a decrease in snowfall, blowing snow sublimation, peak snowpack and annual streamflow volume, advance in melt timing, loss of ice and firn melt contributions, and an increase in rainfall.

Climate

- Development of a climatology of landfalling atmospheric rivers along the BC and southeastern Alaska coast and quantification of their contributions to annual precipitation and streamflow in the region.
- Examined the occurrence of precipitation transition regions in the current and future climate using CONUS I information and found that occurrences and average elevations increase more in interior regions than near the coast under PGW conditions.
- Carrying out additional studies on atmospheric rivers including the extreme mid-November 2021 event in BC.

Surface/Groundwater Interactions

- Methodology to estimate the probability of alpine permafrost in the Canadian Rockies based on climate, topography, and surficial covers.

Cryosphere

- Improved understanding of cryosphere change on coupled climate-hydrological systems

Climate

- Better understanding of changes in rain-snow transitions across western Canada in warmer climate conditions.
- Better understanding of AR contributions to hydrological extremes, floods and other hazards in BC including the fall 2021 active storm season.

Northern Water Futures

- *Understanding patterns of terrestrial landscape change caused by climate-induced hazards*
  - Integrate spatial datasets to create hazard probability maps for key climate-related land hazards (thermokarst, severe burning)

Old Meets New

- Planning for geochemical sampling in spring 2021 (in combination with GWF project **Groundwater, Climate Change and Water Security in the Canadian Prairies**)

Assessing Soil Moisture and Streamflow Relative to Tree-ring Reconstruction

- Forcing a calibrated MESH model of the Athabasca River basin with various climate model simulations: pre-industrial, historical and RCP8.5
- Conclusions and recommendations regarding the extent to which climate models, and thus the climate forcing of hydrological models, is lacking certain modes of natural variability that are evident in longer (proxy) hydrological records

- In collaboration with technical experts in the energy, mining and agricultural sectors, apply the new knowledge to an assessment of climate risks to industrial water supplies.

Prairie Groundwater

- Preliminary correlation to climate indices (temperature, antecedent wetness, precipitation)
- Identifying potential climate and land/water use scenarios for the model
- Finalizing GAMLSS results for correlation between baseflow and climate indices
- Development of integrated hydrologic model for Dalmeny basin & other representative aquifer systems
  - Model scenarios to demonstrate potential changes to surface and groundwater availability due to changes in climate, land use and water use
- Baseflow and hydrograph trend analysis to identify regions susceptible to streamflow depletion
  - Correlation to climate indices to indicate susceptibility to climate change

Sub-Arctic Metal Mobility Study

- Climate-induced changes to dissolved organic matter quality in the Northwest Territories, Canada, will affect disinfection by-product formation in freshwaters (mid-2022 submission.)

Saskatchewan Private Wells

- Exploration of potential impacts of climate change on water quality in private wells

Paradigm Shift in Downscaling Climate Model Projections

- Bias-corrected climate model maximum and minimum temperature simulations using EMDNA dataset for Canada. A total of 652 simulations each (maximum and minimum temperature) are bias-corrected at daily scale for the time period 2021-2100 at spatial resolution.
- Projected changes in average, maximum and minimum temperature over Canada and for different climate regions in Canada are evaluated. Both Spatial and temporal changes (till 2100) for different Shared Socio-economic Pathways (SSPs) are calculated.
- Evaluated changes in the risk of extreme temperatures in terms of ETCCDI, heat and cold wave indices in the 11 major Canadian cities and 199 megacities worldwide.
- Bias-correcting climate model precipitation simulations using EMDNA dataset for Canada. The Semi-Parametric Quantile Mapping (SPQM) method is developed to bias-correct the simulations at daily scale for the time period 2021-2100 and tested for a couple of grids across Canada. A total of 759 simulations are used for bias-correcting.
- Obtaining projected changes in precipitation over Canada and for different climate regions in Canada is under process. Both Spatial and temporal changes (till 2100) for different Shared Socio-economic Pathways (SSPs) will be evaluated.
- A database of climate model simulations for precipitation, average minimum and maximum temperature at monthly and daily scales, and several observation datasets.

- A novel method, Semi-Parametric Quantile Mapping, for bias-correcting the simulations at any temporal scale.
- A suite of bias-corrected fine resolution climate model simulations for precipitation, minimum and maximum temperature at daily scale for Canada.
- Projected changes in the extreme precipitation and temperature and associated risks in terms of magnitude, frequency and duration of extreme events such as droughts, heat and cold waves.
- Projected changes in the compound extremes considering both precipitation and temperature.

Transformative Sensor Technologies and Smart Watersheds

- Increased accuracy and precision when quantifying snow resources and climate change.

Winter Soil Processes

- We developed machine-learning model and synthesis data-driven approaches to determine that changes in soil moisture, temperature, and photosynthesis are the primary drivers of changes in net C flux during the non-growing season (NGS). We projected a 103 per cent increase in Mer Bleue peatland C loss by 2100 under a high radiative forcing scenario, highlighting that the peatland C loss will therefore constitute a strong positive climate feedback loop.
- Using CO_2 production rates measurements in laboratory incubations with soils from seven Canadian peatland sites in the boreal and temperate bioclimatic vegetation zones (or 'ecoclimates'), we found that the statistically significant variations in the temperature sensitivity of peat soil CO_2 production rates between the cold-temperate and boreal ecoclimate zones. The finding highlights that the variable temperature sensitivities under different climate conditions need to be accounted for when assessing future global trajectories of peatland carbon pool stability.
- We used climate-related parameters to define the start and end dates of the NGS and our results supported defining NGS based on readily available climatic parameters that account for the interannual variability of regional climate and ecosystem response.

Short-duration extreme precipitation

- FZ: Compared intra-annual and long-term trend scaling of extreme precipitation with temperature in a large-ensemble regional climate simulation. (**Sun, Q., F.W. Zwiers, X. Zhang** and G. Li, 2020: A comparison of intra-annual and long-term trend scaling of extreme precipitation with temperature in a large-ensemble regional climate simulation. *Journal of Climate*, 33, 9233-9245, doi:10.1175/JCLI-D-19-0920.1)
- FZ: Analyzed the of changes in extreme precipitation at global, continental and regional scale. (**Sun, Q**., **X. Zhang**, **F.W. Zwiers**, S. Westra and L.V. Alexander, 2021: A global, continental and regional analysis of changes in extreme precipitation. *Journal of Climate*, 34, 243-258, doi:10.1175/JCLI-D-19-0892.1)
- YL: Applied the object-based tracking of precipitation systems in western Canada and discovered the importance of temporal resolution of source data in determining the statistics characteristics of the

MCSs. (**Lintao Li, Yanping Li*, Zhenhua Li**, 2020: Object-based tracking of precipitation systems in western Canada: the importance of temporal resolution of source data. *Climate Dynamics*, DOI:10.1007/s00382-020-05388-y)

- FZ: Quantify the human influence on the intensity of extreme 1- and 5-day precipitation amounts at global, continental, and regional scales. (**Sun, Q**., **F.W. Zwiers**, **X. Zhang**, J. Yan, 2021: Quantifying the human influence on the intensity of extreme 1- and 5-day precipitation amounts at global, continental, and regional scales. Submitted, *Journal of Climate)*
- YL: examine the change of extreme precipitation events and atmospheric circulation under current and future climate for the Canadian Prairies.